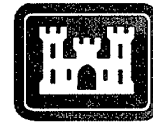ERDC/EL TR-02-28

US Army Corps
of Engineers®
Engineer Research and
Development Center

Geospatial Technology Research and Development Program

GIS-Assisted Spatial Data Management for Corps of Engineers Real Estate Activities: Spatial Data Conversion Options

Linda Peyman Dove   September 2002

Environmental Laboratory

20030109 111

GIS-Assisted Spatial Data Management for Corps of Engineers Real Estate Activities: Spatial Data Conversion Options

by   Linda Peyman Dove

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Final report

Contents

Preface

This report was prepared as part of the Geospatial Technology Research and Development Program Work Unit 33181, "GIS-Assisted Spatial Data Management for CE Real Estate Activities." Research was conducted by the Environmental Laboratory (EL), U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS. The research was sponsored by Headquarters, U.S. Army Corps of Engineers (HQUSACE), and was carried out during the period October 1998 to September 2002.

This report was prepared by Dr. Linda Peyman Dove, Environmental Systems Branch (ESB), EL. The case study for the U.S. Army Engineer District, Walla Walla, was developed by Mr. Robert Meyer and Mr. Blaise Grden, Walla Walla District. The case study for the Fort Worth District was developed by Mr. Bruce Hunter and Mr. Robert Ayensu, University of North Texas. Mr. Bryon Haney, Fort Worth District, supplied the cost data. Mr. Randall Mayne, Fort Worth District, was the project manager for the Lewisville Lake, TX, project presented in the case study. The case study for the New England District was provided by Mr. Matthew Walsh, New England District. The case study information for the Rock Island District was supplied by Mr. John Kincaid and Mr. Kirk Sundermand, Rock Island District. Dr. Rose Kress, EL, was principal investigator for this project.

The study was under the general supervision of Mr. Harold W. West, Chief, ESB; Dr. Dave Tazik, Chief, Ecosystem Evaluation and Engineering Division, EL; and Dr. Edwin A. Theriot, Director, EL. The HQUSACE technical monitors were Mr. M. K. Miles and Ms. Nancy Blyler. Reviews were provided by Mr. West, Dr. Kress, and Mr. Mark Graves, ESB.

At the time of publication of this report, Director of ERDC was Dr. James R. Houston. Commander and Executive Director was COL John W. Morris III, EN.

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1 Introduction

Currently, the U.S. Army Corps of Engineers (CE) relies primarily on hard-copy paper maps and documents to manage real estate assets. The majority of the real estate spatial data, such as tract boundaries, are in hard-copy format, with a small amount of the data in computer-aided drafting (CAD) and geographic information system (GIS) files. The nonspatial or tabular data that describe the spatial data are typically in hard-copy format or in the digital Real Estate Management Information System (REMIS) database. REMIS, which is a non-spatial database, is the primary digital database for the Corps' real estate data.

It is now widely understood that real estate data are fundamentally geospatial and that there is a great advantage to managing and maintaining cadastral information in a GIS. Such a shift in data management would increase efficiency for storing, retrieving, processing, and editing information by all users and would make cadastral real estate data more readily available throughout the Corps and to the public. In order to provide the data in a geographic format, the existing hard-copy and digital data must be converted into an appropriate format.

Research funded under the Corps' Civil Works Geospatial Technology Research and Development Program was initiated to avoid the development of numerous incompatible real estate GIS solutions within the Corps. A part of the research resulted in this report. This report discusses issues related to data conversion, such as converting hard-copy paper maps and digital real estate data to a compatible GIS format. The report includes:

a. Real estate data sources.

b. Spatial data conversion options.

c. Case studies from U.S. Army Engineer Districts, Fort Worth, New England, Walla Walla, and Rock Island.

2 Real Estate Data Sources

For input into a GIS, digital polygons and attributes describing the polygons are needed for the Corps' tracts, project footprint, disposals, outgrants, and encroachments. This report discusses spatial data conversion options to develop the digital polygons from existing data sources. A separate report discusses the tables and attributes needed to describe the digital polygons (Peyman Dove, Graves, and Lopez 2001). The data conversion options discussed in this report are: using coordinate geometry (COGO), digitizing hard-copy maps, and scanning hard-copy maps and then using heads-up digitizing or automated conversion.

The Corps' Real Estate offices maintain a wealth of maps and text-based documents of the Corps' real estate land holdings. The spatial data are typically in the form of hard-copy maps, such as tract maps, segment maps, and land acquisition maps, but can also be found in text documents such as warranty deeds that have descriptions of tract acquisitions. This report does not address the conversion issues associated with real estate text-based documents that need to be converted for a document management system. The real estate GIS is not a document management system, rather a system in which the Corps' real estate land holdings can be stored, accessed, and utilized for business practices. Text-based documents can nevertheless be attached to the real estate GIS files.

The primary hard-copy and digital sources of data available for conversion to a GIS are described in the following sections.

Segment Maps

Segment maps show the land acquired for a project or part of a project, such as Lake of the Pines, TX, in the Fort Worth District or the Missouri River Project in the Rock Island District. The maps are typically at a scale of about 1:24,000. Figure 1 is a segment map for the Saylorville Reservoir Project, Rock Island District. Segment maps show the outline of fee acquisitions and less-than-fee acquisitions, such as flowage easement tracts. The maps may also show other features such as roads, railroads, the conservation pool or water's edge, generalized contours, and township, range, and section lines. Some of the maps show longitude and latitude tics along the map border. A tract register in columnar form is usually included on the segment map. It typically shows the tract numbers, name of landowners, and acreage of each tract that has been acquired or where there are plans for it to be acquired (Engineer Regulation (ER) 405-1-12,
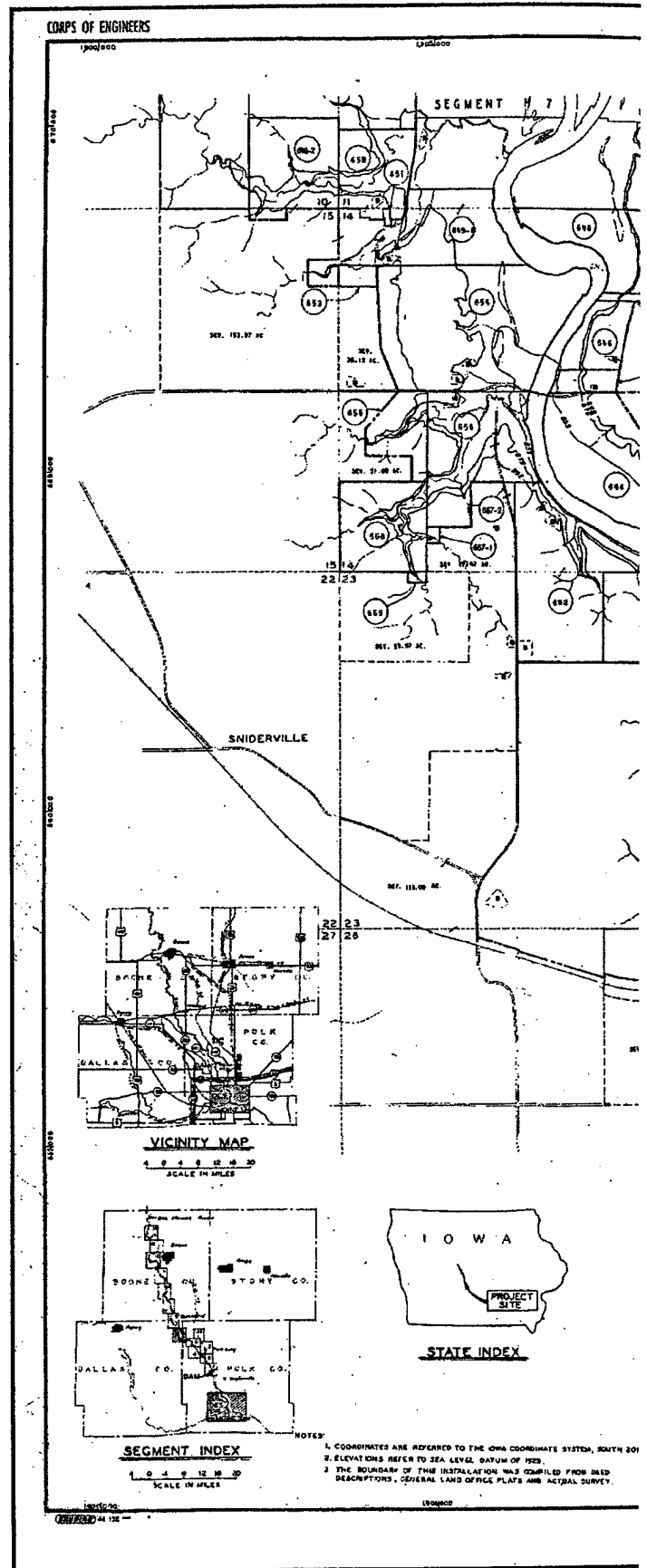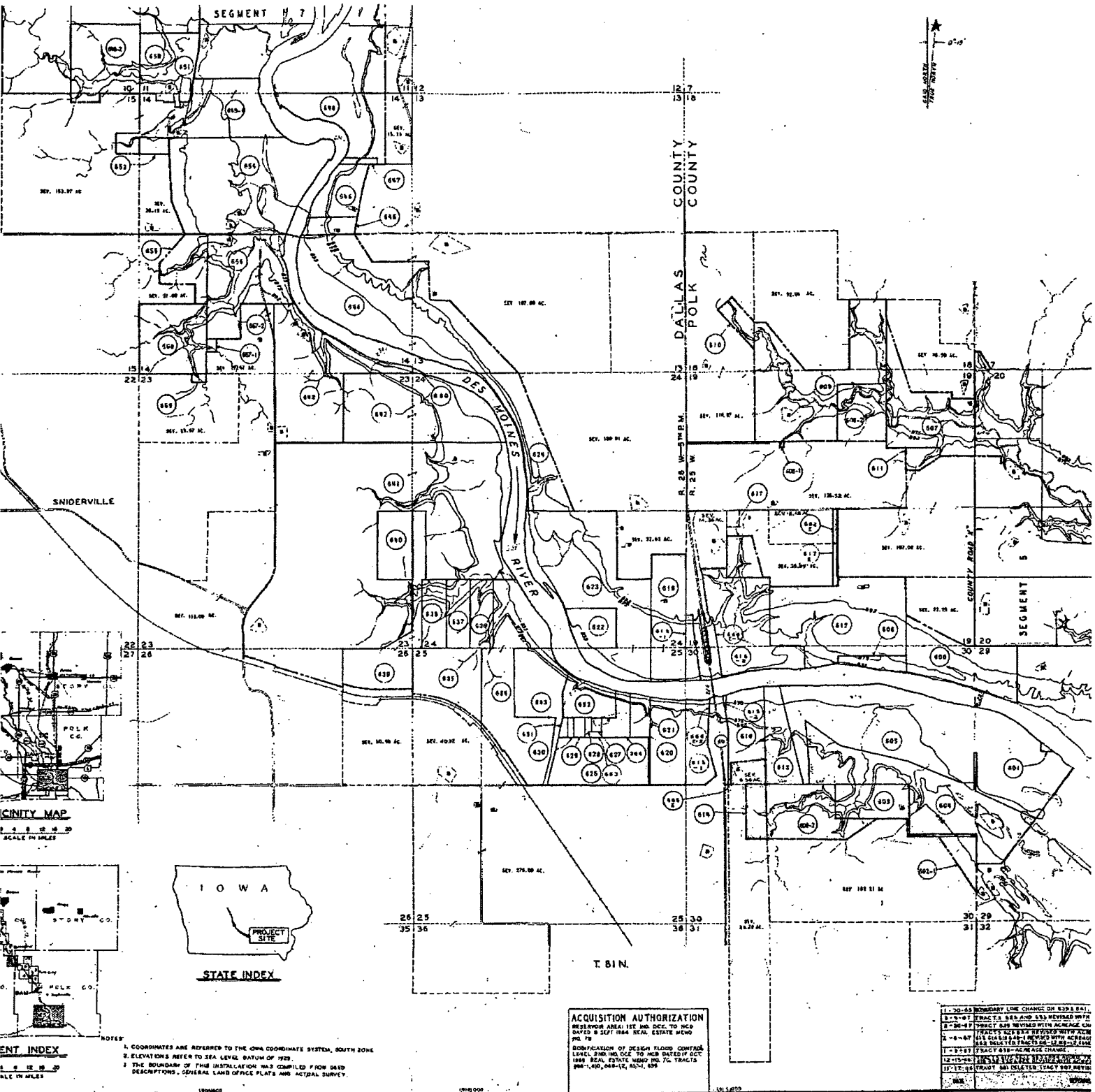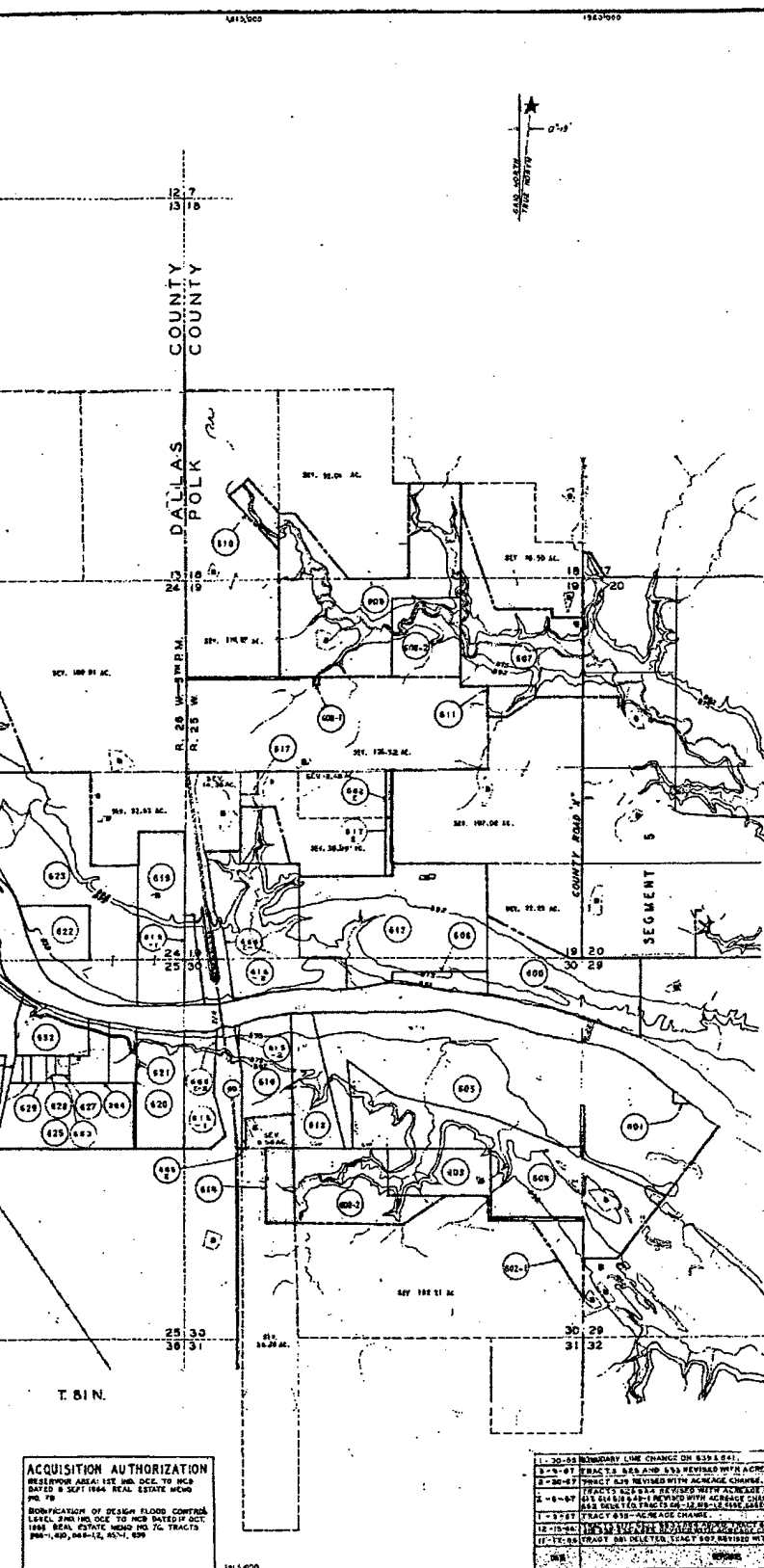
Figure 1. Example of segment map for Saylorville Reservoir

Sample of segment map for Saylorville Reservoir Project, Rock Island District

TRACT REGISTER OF ACQUISITION AFTER 1 JAN. 1943

TRACT NO.	LAND OWNER	ACREAGE FEE	ACREAGE EAS'MT	REMARKS
600	JESSE CROUSE	45.70		
601	ROBERT JAMES	0.50		
602-1	FRANK L. NIZZI, ET UX	8.85		
602-2	FRANK L. NIZZI ET UX	33.44		
603	OAK W. SATEMAN	22.92		
604	B. L. PETERS ET AL	91.98		
605	HAZEL B. SCHROEDER	165.08		
606	POLK COUNTY IOWA	8.08		
607	RALPH E. WYLIE ET UX	54.50		
608-1	MARLOWE CARLSON, ET UX	8.17		
608-2	"	22.68		
609	FANNIE M. JAGERSON	90.24		
610	IVYL CARLSON, ET UX	6.47		
611	EDWARD C. LAMAY	5.48		
612	FRANK BOGARDRIGHT, ET UX	88.71		
613	S. W. MILLER	81.30		
614	RAYMOND C. LAVALLEY, ET UX	9.64		
616	RONALD E. MASON	26.60		
617	JOHN D. WEBSTER, ET UX	11.02		
619	AMOS PINHERO ET UX	36.00		
620	HAZEL E. LYTLE	26.10		
621	PAUL VANDYK, ET AL	7.30		
622	MILWAUKEE LAND CO	13.15		
623	A. P. OTTO, ET UX	85.90		
624	D. E. SCHAAL	91.00		
625	LOE A. NIZZI	40.30		
617C	JOHN D. WEBSTER		1.50	PERPETUAL ROADWAY R/W EASE.
627	GEORGE L. ERVIN	1.17		
628	EMIL GALETICH ET AL	0.91		
629	STEPAN KUDE, ET UX	1.91		
630	NELIA PAGE	0.93		
631	HERICO NIZZI	1.18		
632	LOE NIZZI, ET AL	14.10		
633	LOE A. NIZZI, ET AL	36.90		
634	ETTA SNIDER LIFE EST	75.00		
635	MARION S. SNIDER	95.00		
636	MARY EDNA ELIFRITS	14.00		
637	BEULAH JEAN CINCHELOE ET AL	14.00		
638	GEORGE ELVIN	16.00		
639	RICHARD E. CONNOLLY,	44.40		
640	H. J. SIGLIN	26.00		
641	HAROLD J. SIGLIN, ET UX	355.00		
642	JAMES AARON CROUCH	80.20		
643	BRUNO LENGINI, ET UX	79.70		
644	MORRIS O. PENQUITE	120.00		
645	MAE LEE SWISHER	7.30		
646	HARRY AUSTIN ET UX	18.30		
647	ESTATE OF W.R. SCHNEITHUM	1.72		
648	CHARLES H. WILLIAMS, ET UX	34.00		
649-1	WILLIAM NEWLAND	68.41		
649-2	WILLIAM NEWLAND	81.85		
650	RONALD N. BOLLE	30.80		
651	DALLAS COUNTY IOWA	0.58		
653	HORACE MCFARLAND, ET UX	3.88		
654	ROBERT D. SIGLIN, ET UX	121.50		
655	BEN NORDINE, ET UX	21.80		
656	GEORGE VEGNOVITCH	56.00		
657-1	WILLIAM MIKE MORAN	1.15		
657-2	WILLIAM MIKE MORAN	1.58		
658	EDITH W. NEWELL	40.00		
659	LESLIE O. NEWELL	1.02		
660	DALLAS COUNTY, IOWA	0.33		
662C	FLOYD GATES, ET UX		1.21	PERPETUAL ROADWAY R/W EASE.
663	W. OLIVER DONATI	0.78		
664	CHALE NIZZI, ET AL	6.00		
615-1	MARNELIOUS SCHUTTINGA	19.50		
615-2		0.46		
618-1	ROSE T. HENDERSON, ET AL	6.50		
618-2		92.00		
666C	HELEN M. MOORE ET VIR		0.07	PERPETUAL ROADWAY R/W EASE.
666C-?	STATE OF IOWA			PERPETUAL FLOWAGE EASEMENT
666E-?	" "		2.95	

PROJECT MAP (CONTINUATION SHEET)

DEPT. OF THE ARMY — CORPS OF ENGINEERS

LOCATION OF PROJECT — TRANSPORTATION FACILITIES

STATE IOWA — RAILROADS C., M., ST. P. & P., C.G.W.

COUNTY DALLAS, POLK — STATE ROADS US. 301, 415, 141, 210, 69

DIV. NORTH CENTRAL — FEDERAL ROADS 30, 69, 169

DIST. ROCK ISLAND — AIRLINES

MOST AREA 5TH

6 MILES N.W. OF DES MOINES

27 MILES S.E. OF BOONE

SEGMENT 6

DEPARTMENT OF THE ARMY
OFFICE OF THE ROCK ISLAND DISTRICT ENGINEER
NORTH CENTRAL DIVISION

REAL ESTATE

DES MOINES RIVER, IOWA

SAYLORVILLE RESERVOIR

DRAWN BY: N.J.

TRACED BY: N.J.

CHECKED BY: W.R.

OFFICE, CHIEF OF ENGINEERS, WASHINGTON, D.C. 20315

DATE 30 SEPT. 1966

SCALE IN FEET

ENG FORM 3456-C

ACQUISITION AUTHORIZATION
RESERVOIR AREA: 1ST IND. OCE. TO NCB DATED 8 SEPT 1964 REAL ESTATE MEMO NO. 7B

MODIFICATION OF DESIGN FLOOD CONTROL LEVEL, 3RD IND. OCE TO NCB DATED IF OCT. 1966 REAL ESTATE MEMO NO. 7C. TRACTS 608-1, 610, 648-12, 657-2, 639

T. 81 N.

Headquarters, U.S. Army Corps of Engineers 1985). These maps usually do not provide the bearings and distance information that can be used to create an accurate digital tract file through the use of COGO. If the bearing and distance information is included, it is only for exterior fee and less-than-fee tract boundaries (ER 405-1-12).

These maps are used frequently by the Corps' Real Estate offices. A separate set of these maps is frequently used by Districts to record outgrants and encroachments.

Tract Maps

Unlike segment maps, tract maps typically show only a few tracts per drawing and are at a scale of about 1:12,000. The maps typically provide a detailed tract boundary, with bearings and distances and turning points. They may also contain township, range, section, and quarter section lines; longitude and latitude as margin tics; and other features such as roads, railroads, and water's edge. These maps provide the bearings and distance information that can be used to create an accurate digital tract file through the use of COGO. However, these maps do not necessarily provide a geographically referenced point of beginning that can be used to geographically reference the tract boundary. Figure 2 is an example of a tract map from the Mississippi River Project, Rock Island District.

Outgrant Maps

The Corps has fee title land in which the Corps outgrants areas for use by other entities. The Real Estate offices typically record outgrants on a special set of segment maps. The outgrants are noted through color outlines and shading of outgrant areas.

Acquisition Maps

Acquisition maps primarily show land acquisition with topography, at a scale of about 1:2,400. The maps have bearings and distances for the tract boundaries as well as physical features such as railroads (Stanley Consultants 1999). Figure 3 is an example of a Mississippi River real estate acquisition map, Rock Island District, that depicts 0.3-m (1-ft) interval land contours as they existed in the 1930's when the map was created.

Text Documents

Text documents include various legal documents, such as warranty deeds and appraisals, that are kept within the Corps' Real Estate offices. The survey data from the warranty deed can be used to develop the tract boundary using COGO.

Photographs

Photographs, such as those taken during the acquisition process, are documented and stored for historical record. The photos may be currently useful as documentation of preproject conditions. These files can be attached to the corresponding tract in the GIS file.
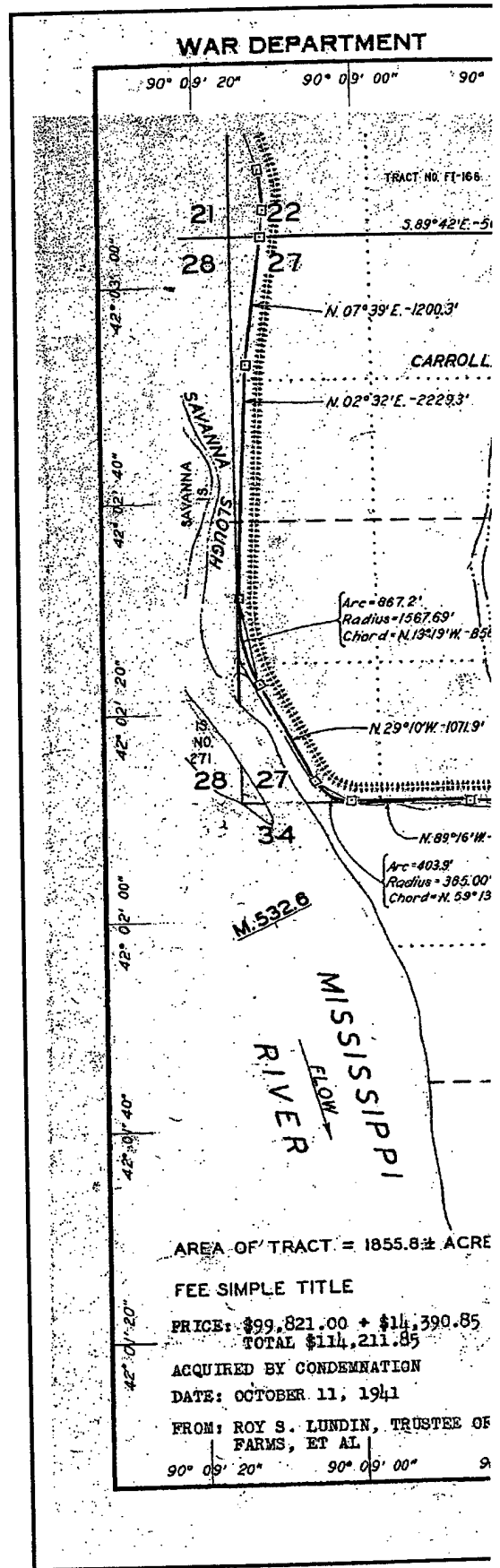
Figure 2. Example of tract map for Mississi

TRACT NO. FI-166

TRACT NO. FI-167

TRACT NO. FI-168.

Point of Beginning
S.89°41'E.-4925.5'

N.89°42'E.-5015.3'

N.89°38'E.-164.5'

N.60°17'E.-450.4'

Arc = 80.1'
Radius = 2297'
Chord = S.07°
S.06°32'E.-3

S.13°59'E.

Highway

S.06°24'

TRACT

CARROLL   COUNTY   DRAINAGE   AND   LEVEE   DISTRICT   NO.   1

N.07°39'E.-1200.3'

N.02°32'E.-2229.3'

SAVANNA SLOUGHS

N.89°5

Arc = 867.2'
Radius = 1567.69'
Chord = N.13°19'W.-856.2'

ILLIN
HIGHWAY

S.06°

N.29°10'W.-1071.9'

S.89°39
60.3'

N.89°18'W.-3095.2'

N.89°16'W.-1168.3'

TRACT
NO. FI-165

Arc = 403.9'
Radius = 385.00'
Chord = N.59°13'W.-385.6'

M.532.6

MISSISSIPPI RIVER
FLOW

N.00°00'E.-5890.7'

S.00°14'E.-1977.1'

CHICAGO BURLINGTON & QUINCY RAILROAD

S.06°20'E.-2688.5'

S.89°59'W.
662.2'
S.89°26'W.
665.5'

S.16°14'W.
31.3'
S.89°25'W.-675.7'
S.00°15'W.-661.9'

Pipe

S.89°24'W.-1321.3'

TRACT NO. FI-163

TRACT
NO. FI-162

Highway Right of Way Line

Highway Right of Way Line
S.89°48'W.
2682.0'

AREA OF TRACT = 1855.8± ACRES

FEE SIMPLE TITLE

PRICE: $99,821.00 + $14,390.85 INTEREST,
    TOTAL $114,211.85

ACQUIRED BY CONDEMNATION

DATE: OCTOBER 11, 1941

FROM: ROY S. LUNDIN, TRUSTEE OF CARROLL
    FARMS, ET AL

TWP 24 N
TWP 23 N

GOVT. LOT 3   GOVT. LOT 4   GOVT. LOT 3   GOVT. LOT 5   GOVT. LOT 6   GOVT. LOT 3

2. Example of tract map for Mississippi River Project, Pool 13, Rock Island District

78° 00" 90° 07' 40" 90° 07' 20" 90° 07' 00" 90° 06' 40" 90° 06' 20" 90° 06' 00" 90° 05' 40"

TRACT NO. FI-168.

Point of Beginning

3

6

N.88°38'E.-164.5'
N.00°17'E.-4504'
S.89°41"E.-4925.5'

Arc = 80.1'
Radius = 2297.93'
Chord = S.07°32'E.-80.1'
S.06°32'E.-378.5'
S.13°59'E.-1825'

23 | 24

26 | 25

Highway Right of Way

LEVEE DISTRICT NO. 1

S.06°24'E.-2529.0'

TRACT NO. FI-164

N.89°59'E.-251'

ILLINOIS
HIGHWAY NO. 80

S.06°28'E.-2681.8'

APPROXIMATE DECLINATION
1938

TRUE NORTH
MAGNETIC NORTH
5°00'

6

5

S.89°39'W
80.3'

26 | 25

35 | 36

Highway
Right of Way Line

PART OF
SE¼ SE¼ SECTION 23
PART OF
W½ SECTION 25
PART OF
SECTIONS 26, 35 AND FRACTIONAL SEC. 27
AND PART OF
W½ NW¼ SECTION 36
TWP. 24 N., R. 3 E. OF THE 4TH PRIN. MER.

CARROLL COUNTY, ILLINOIS

S.06°28'E.-2688.5'

CHICAGO BURLINGTON & QUINCY RAILROAD

Highway Right of Way Line

S.89°59'W
662.2'

S.89°25'W
665.5'

Pipe

S.16°14'W.
31.3'

S.89°25'W.-675.7'
S.00°15'W.-661.9'

S.89°24'W.-1321.3'

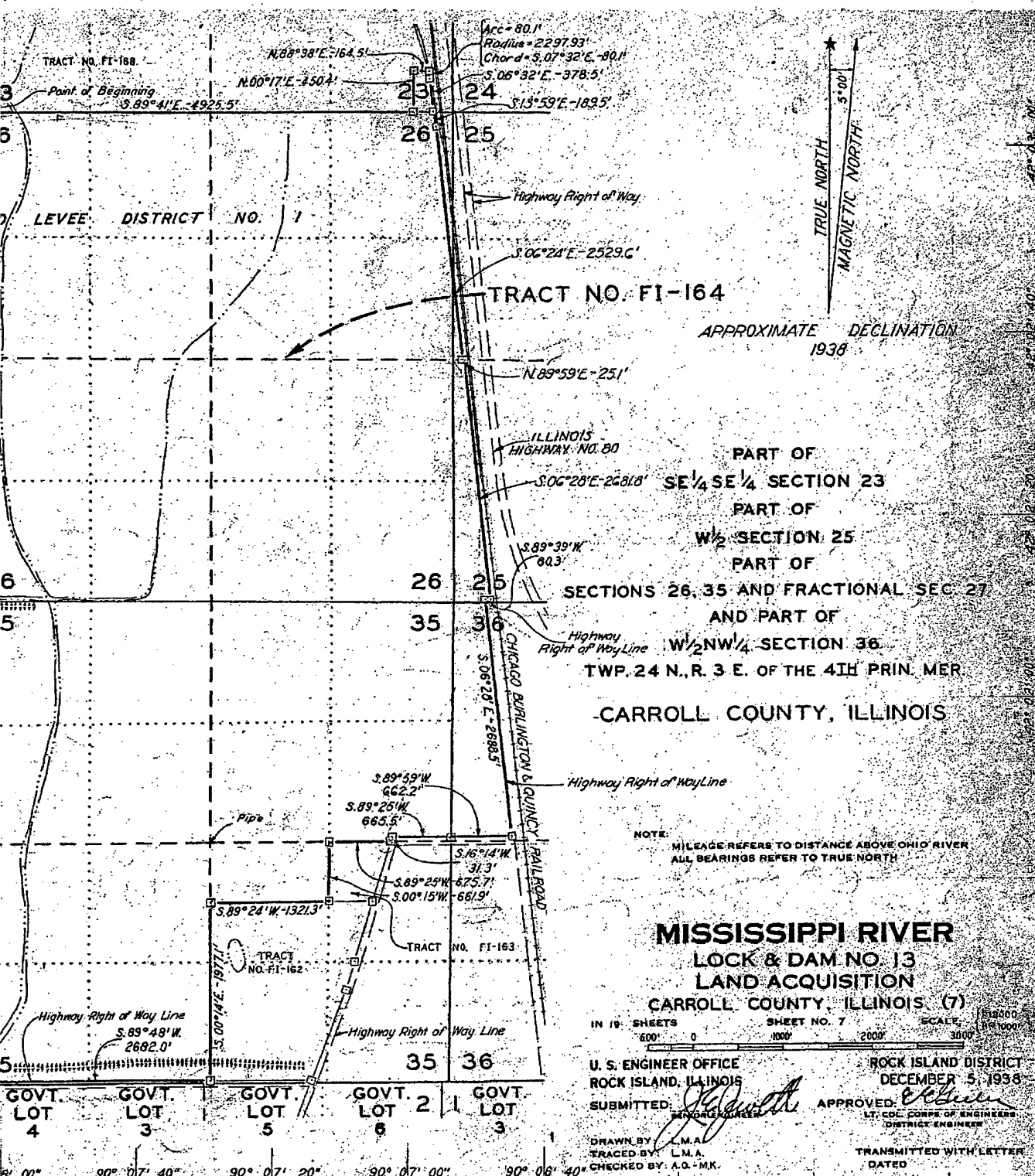S.00°14'E.-1977.1'

TRACT
NO. FI-162

TRACT NO. FI-163

Highway Right of Way Line
S.89°48'W.
2682.0'

Highway Right of Way Line

5

35 | 36

MISSISSIPPI RIVER
LOCK & DAM NO. 13
LAND ACQUISITION
CARROLL COUNTY, ILLINOIS (7)

IN 19 SHEETS   SHEET NO. 7   SCALE

600'   0   1000   2000   3000

U. S. ENGINEER OFFICE
ROCK ISLAND, ILLINOIS
SUBMITTED:

ROCK ISLAND DISTRICT
DECEMBER 5, 1938
APPROVED:
LT. COL. CORPS OF ENGINEERS
DISTRICT ENGINEER

DRAWN BY: L.M.A.
TRACED BY: L.M.A.
CHECKED BY: A.Q.- M.K.

TRANSMITTED WITH LETTER
DATED

GOVT.
LOT
4

GOVT.
LOT
3

GOVT.
LOT
5

GOVT.
LOT
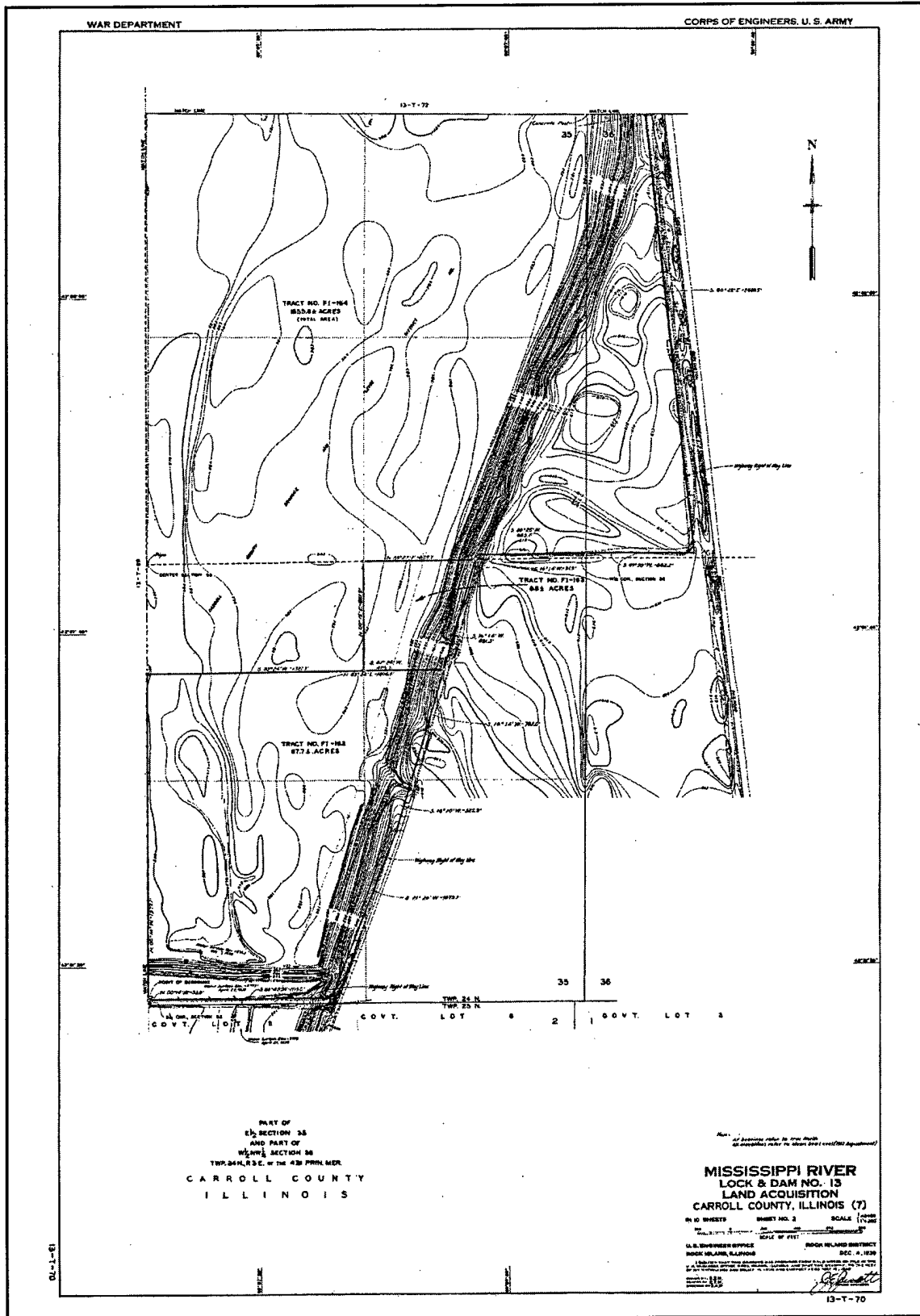6

2 | 1

GOVT.
LOT
3

1

13-FIT-190

sland District

3

Figure 3. Example of real estate acquisition map, Rock Island District

3 Spatial Data Conversion Options

There is a need within the Corps to convert the Real Estate maps, such as the project boundary footprint and tract boundaries, to a GIS. This report refers primarily to tract data conversion, although the methods to convert tract data to a GIS are pertinent to other conversion issues, such as for project boundaries, outgrants, encroachments, and disposals.

There are various conversion options available. The options depend on the source and content of the existing data and the desired accuracy of the GIS database. As the accuracy requirements are increased, the cost also rises. It has been said that 95 percent of the cost of data conversion can be incurred in ensuring the accuracy of the data from 95 to 100 percent (Hohl 1998). There must be a balance between available funds and accuracy requirements.

There are two tiers of geographic data collection in a GIS, primary and secondary. Primary data include data compiled directly from field measurements using methods such as traditional surveying or data resulting from the use of global positioning system (GPS) technology. COGO can be used to convert primary data, such as surveying points, to a digital GIS format. Secondary data are derived from such products as existing maps. Most common methods of converting existing tract data to a GIS, such as digitizing and scanning existing maps, rely on secondary data sources. The quality of secondary data sources depends on the original field measurements but also on the scale of the map, the drafting accuracy, map medium, digitizing accuracy, as well as other factors (Parrish 1999). In contrast, the accuracy of a primary data source depends on the accuracy of the field measurements used to collect the data (Parrish 1999).

Using primary and/or secondary data sources, the most common methods to convert the spatial and attribute tract data to a GIS include:

a. Using COGO.

b. Digitizing hard-copy maps.

c. Scanning hard-copy maps.

(1) Heads-up digitizing.

(2) Automated vectorization.

d. Using an attribute data linking tool.

Each of these methods is discussed in the following paragraphs.

COGO

COGO software transforms field measurements into accurate geographic positions and spatial relationships using mathematical calculations (Parrish 1999). Entering numerical data from a survey plan into a GIS provides the greatest consistency and least distortion, resulting in greater tract integrity. It is the most accurate and most expensive method for converting cadastral data. Costs are four to twenty times more expensive than manual digitizing (Hohl 1998).

Since the more accurate the conversion method the more expensive the cost, decisions must be made on how accurate the tract GIS needs to be. For example, in a report that documented the parcel conversion efforts of counties in New Jersey, COGO was dismissed by several counties because of the cost and the fact that it produces a higher level of accuracy than that required for the majority of the county GIS users. In many of the counties the users are employing the data for planning level work, rather than for efforts which require pinpoint positional accuracy. For their purposes, a tract lot line with an error of 9.1 to 12.2 m (30 to 40 ft) was accurate enough (Parrish 1999). However, in this same study, other counties were willing to pay the cost for a higher accuracy tract GIS database that would be consistent with the level of accuracy of the accompanying data. It should be noted that if the other geographic data that will be used in conjunction with the Real Estate tracts are not very accurate, fit problems between the COGO-placed features and other data may result. The better the land base accuracy, the better the fit of the COGO data (Montgomery 1993).

For many Corps lake projects, an alternative approach to using COGO for every tract is to precisely enter only the outside project boundary using COGO. The interior tracts can be developed through means other than COGO, such as scanning the hard-copy segment maps and then heads-up digitizing, and then using a best-fit adjustment for these interior tracts. This method is far more economical and still provides a solid spatial solution for the project boundaries (Montgomery and Schuch 1993).

Another consideration before selecting COGO is whether the survey data are georeferenced (real world coordinates). If the survey data do not have a geo-referenced point of beginning, the shape of the tracts will be highly accurate, but the horizontal location of the tracts may be compromised. The majority of the existing field data collected by land surveyors are not geographically referenced. They are computed and processed in a local assumed coordinate system, meaning each survey is computed by using an arbitrary origin X and Y and an approximate north direction (Hohl 1998). This means that the coordinates of two adjacent surveys will likely be different depending on the survey from which the coordinates were computed. At the time that much of the existing Real Estate survey data were developed, there were no GIS considerations or a need to use a

geographically referenced coordinate system. So, descriptions of the point of beginning, such as "the large oak tree" or "a point ten feet west of the corner of the stone wall of Mr. Jones' front yard," were adequate for the time of the survey, but present conversion problems today. These surveys are still of great value because of the accuracy of their internal relative geometry. However, to make them compatible with a GIS, the COGO-computed coordinates for the individual tracts must be transformed into a uniform geographic coordinate system in order to make the tract mapping seamless.

Also, if the tracts are generated from individual maps or deeds, the COGO process will depict discrepancies between adjacent tracts. The maps and legal documents are not error-free and adjacent tracts are not edge-matched. Incorrect edge matching between tract maps creates gaps and overlaps between tracts. These conflicts will have to be resolved by qualified individuals so that the tracts fit together seamlessly. Sometimes, noting in the metadata that the tracts have been modified is all that many offices can realistically do to address this problem.

COGO using hard-copy maps/records

One of the most common data items for use with COGO is the hard-copy tract map. The records that were initially used to make the tract maps, such as deed information, are also used in COGO. As stated above, the original survey documents are either geographically referenced or not tied to a geographic reference system.

Typically, there is a point of beginning on survey documents that is geo-referenced to real world coordinates or referenced to a local assumed coordinate system. The following discussion documents options to follow, depending on whether or not the data are georeferenced.

Georeferenced. If the map or record is georeferenced, the process of using COGO with a hard-copy map or record is relatively straightforward. Survey data are entered into a COGO software program as a sequential set of bearing, dis-tance, and curve parameters. Both CAD and GIS packages typically have COGO capabilities. The ordered data of bearing and distances are referred to as a "traverse" (Parrish 1999). Entering traversed survey data in COGO is a process in which the boundary of the property is traced mathematically in a sequential order. First, the geographically referenced coordinate of a point of beginning is keyed in, followed by the bearings and distances of each side of the tract, ending the tract back at the point of beginning. COGO provides a check on the geo-metric closure of each tract. If the computed ending point and point of beginning coordinates are not equal, this should be addressed before they are converted to a GIS file. COGO can perform a mathematical adjustment to all traverse points to ensure the closure. This creates a closed tract or polygon, which is necessary in a GIS. This process provides a quality check where the area for each tract, as calculated by the COGO software, can be compared to the area calculations on the survey documents.

Once the COGO data are converted to a GIS file, the data should not be edited or "cleaned." Cleaning can compromise the accuracy of the shape of the

tract. The fundamental identifying attributes for each tract, such as the tract number and project identification number, should also be attached to each polygon. This provides the opportunity of linking each tract to other databases, such as REMIS.

Not georeferenced. If the map or record is not georeferenced, the same process as above should be followed; however, the data also need to be geo-referenced. There are various ways to georeference the survey points from a map or record that is not georeferenced. In selecting the method, it is important to remember that, if the accuracy of the georeferencing points is lower than the accuracy of the survey data, then the resulting accuracy of the georeferenced GIS data will also be lower.

One approach to assign a geographic coordinate system to the survey points is to use digital georeferenced orthophotos. An orthophoto is a digital photo-graph derived from aerial photography and corrected to depict features in their true geographic positions (Hohl 1998). The orthophoto is displayed on the computer screen, and the tract is moved around until it matches existing tract boundaries, roads, fence lines, or other information that helps identify its true location. Fitting tract information to orthophoto features is a common geo-referencing practice (Parrish 1999). If COGO data are georeferenced to ortho-photos, the positional accuracy of the COGO points will be decreased if the positional accuracy of the orthophoto is lower than the accuracy of the COGO points. For example, if COGO data are georeferenced to quarterquad ortho-photos, the high accuracy of the COGO points is decreased since the positional accuracy of the orthophoto is less than that of the field survey points. Quarter-quad orthophotos have a positional accuracy of ±9.1 m (±30 ft) while the posi-tional accuracy of surveying data are better than ±0.03 m (±0.1 ft) (Parrish 1999). Rubber sheeting, which is the adjustment of features on a digital map to compel them to fit with other data, should not be used to fit the COGO data to the ortho-photo since the accuracy of the shape of the tract could be compromised (Hohl 1998). Once in the GIS, the COGO data should not be edited or cleaned since this would compromise the shape of the tracts or polygons.

Another way to georeference the tract data are to use COGO to form the tract and then place the tract into a georeferenced position based upon a "best-fit" of the tract to identifiable physical features, such as road intersections, fence lines, and building edges. The physical features can be identified and surveyed with GPS to establish their coordinates. The same features must be identifiable both on the survey drawing and with the GPS. When numerous reference points are surveyed with GPS, a coordinate transformation can be used to compute the best fit of the COGO coordinates to the selected geographic coordinate system.

COGO using a CAD drawing

CAD drawings typically show tract bearing and distance information and are often drawn and certified by a professional land surveyor (Parrish 1999). Most GIS softwares include CAD-to-GIS data conversion options. If the CAD data are developed with the CAD-to-GIS conversion in mind, the conversion is relatively simple. But, most often, the CAD file was not created with this conversion

consideration. Several of the most common problems with the CAD files result from the fact that CAD systems allow open polygons and disjointed lines. So, for easy data conversion, the tract boundaries, as created in the CAD software, should be polygons rather than lines. Also, labeling, such as the tract number in the CAD file, should be placed within the tract boundary. Often, the tract attributes are placed as annotation outside the tract boundary with an arrow pointing to the tract. Because of these fundamental problems, the majority of existing CAD files must be edited with GIS editing tools before the derived data can be used. The CAD files, which could be a highly accurate source of tract data, are often compromised due to the fact that the data has to be edited to create a usable GIS database. These factors are important to consider when developing new CAD files that will eventually be converted to a GIS.

As with hard-copy maps or records, CAD files are also either georeferenced or not georeferenced.

Georeferenced. Most GIS softwares have CAD-to-GIS data conversion options. If the CAD data are georeferenced, the conversion is relatively simple, as long as the data meet certain criteria, such as closed polygons and attribute data inserted inside the tract boundary.

Not georeferenced. If a CAD file is not georeferenced, the coordinates of the CAD file will have to be transformed to a geographically referenced coordinate system using GPS, orthophotos, or other means to obtain geographic coordinate values for the same features that are identifiable on both the CAD drawing and the real world orthophoto or GPS coordinates. If the accuracy of the georeferencing points is lower than the accuracy of the CAD data, than the resulting accuracy of the georeferenced CAD data will be decreased.

Summary

In summary, advantages and disadvantages of using COGO for data conversion are:

Advantages

- Horizontally accurate tract base if the point of beginning is georeferenced

- Shape of tracts is very accurate

- CAD files, if in the correct format, provide fast and easy conversion

- Can develop precise outside project boundary using COGO and then use less expensive method for the interior tracts

Disadvantages

- If the data are not georeferenced, the horizontal accuracy may be decreased

- Discrepancies must be manually resolved (adjacent tracts entered with COGO are not edge-matched and require substantial time to resolve)

- Cannot be rubbersheeted because the accuracy of the data would be destroyed

- Time-consuming

- Four to twenty times more expensive than manual digitizing (Hohl 1998)

- Require detailed source data

Digitized Hard-Copy Maps

To digitize a hard-copy map, the digitizing operator follows tract boundaries on the screen and clicks with a puck on points that define the shape of the tract boundary. The file created from the tablet digitizing is a digital file of numbers representing the coordinates of points with the computerized instructions to connect the points. This file is comprised of vectors or lines defining the shape of the tract. It is not a polygon but can be processed to create polygons from the vector line work. It is necessary to create a polygon for the tracts in order to fully utilize the data in the GIS. The data entry should also consist of the operator attaching the uniquely identifying attributes to each polygon, such as the tract number and project identification number. Digitized data must normally be edited to remove minor topologic errors such as undershoots and overshoots.

The accuracy of paper maps being digitized (such as segment maps) is indeterminate in many cases since they were usually developed many years earlier and have had error and distortion introduced through repeated revisions, copying, and the shrinking and swelling of paper. Many times though, mylar maps present a more stable medium that does not have the amount of shrinking and swelling as paper maps. Digitizing GIS tract data from segment maps is often one of the easiest methods to pursue for creating a digital GIS file of the tracts. The segment maps were not originally developed for the rigorous accuracy of being converted into GIS data. The data are not spatially accurate enough for site-specific GIS analyses. For example, the GIS area developed for each tract is in most instances not going to match the tract area as calculated on the original individual tract maps or the deed information. Although the GIS data obviously should not be considered a substitute for site-specific data or legal documentation, they can provide an acceptable representation if relative accuracy for visual display is what is primarily needed (Parrish 1999).

When digitizing segment maps, there are usually many segment maps that make up an entire project. Each segment map must be digitized individually, and the separate maps must be edge-matched. If the maps are georeferenced, the registration points can be used from the map. Otherwise, the registration points will have to be obtained from another source, such as known road intersections that were collected with GPS technology, digital orthophotos, or other methods. Four or more locations on the source map are matched to the coordinate system,

and the root mean square error is calculated and evaluated (Parrish 1999). As many control points as possible should be used on each map.

As an example, in New Jersey's tax mapping program, Morris County digitized hard-copy tax maps and utilized coordinates from visible road intersections on U.S. Geological Survey (USGS) quad sheets or records of surveyed monumentation. After the coordinates were transferred to their corresponding location on the tax maps and all the maps were stitched together, the municipality had shifted more than 91 m (300 ft) to the north from its real world position. Obviously, more features than could be obtained from monumentation and coordinates from large intersections were needed. They used a planimetric map of the county at a National Map Accuracy Standard of 2.4 to 3.0 m (8 to 10 ft) locational accuracy. They captured features such as streets, railroad tracks, visible rights-of-way such as gas pipelines and electric transmission lines, large building footprints, and small building centroids (Parrish 1999).

In summary, advantages and disadvantages of digitizing hard-copy maps are:

Advantages

- Inexpensive (lower costs are primarily from lower equipment costs and less stringent requirements for operator training)

- Easy to learn

- Source maps can be captured at same accuracy (Hohl 1998)

Disadvantages

- Accuracy limited by the stability of the source media and drafting quality of the source

- Tedious and error-prone

- Cleanup or editing step required

Scanned Hard-Copy Maps

Hard-copy maps can be scanned in order to make a digital file. Scanning is the process of converting paper maps and documents into a digital raster format. Scanners have two basic types of operation: reflective and transmissive. Reflective scanners have the light source and sensor on the same side of the document, while the transmissive scanners shine the light through the document to the sensor which is located on the other side. Reflective scanners are necessary for opaque maps and documents. Since segment maps are usually in paper format, reflective scanners must be used. Transmissive scanners generally produce higher quality images since there is less light scattering. They are used for transparent documents such as mylar maps (Montgomery and Schuch 1993).

Digital data developed through scanning are in a raster format, or a row-and-column grid of picture elements or pixels, each with a numeric value. Pixel values can be on/off binary values, or more typically they are recorded as an

eight-bit value from 0 to 255. This is referred to as a pixel's brightness value (Montgomery and Schuch 1993).

When the scanning procedure is complete, the scanned image can be displayed on a graphics screen. The map is now in a raster digital format. It is not registered to any geographic location. It also does not have any vector linework that forms polygons for each tract and does not have any attributes attached to the tracts. These maps are often referred to as "dumb maps" since they cannot be displayed geographically and because the tracts cannot be selected and queried for descriptive or attribute information. The scanned maps do, however, provide a digital historic record of the hard-copy maps and can be further refined to generate a GIS coverage that can be used in conjunction with other GIS data.

To fully utilize the scanned maps in a GIS, the scanned maps need to be registered, converted to a vector format, and unique identifying attributes attached to each tract polygon. The scanned image can be registered to a geographic coordinate system using digital orthophotography or known reference points. Alternatively, the tract boundaries in the raster image can first be converted to vectors, and then the vectors can be translated into the geographic coordinate system using such means as digital orthophotography, GPS technology, or known reference points.

If funding is not available to convert the scanned image to vectors, the registered scanned map can be used as a raster image with very limited capabilities. For example, in New Jersey's pilot study of converting their tax maps to a GIS, Monmouth County had over 2,000 tax sheets which they scanned and registered to the state's digital aerial orthophotograph. Since funds did not allow them to create vector polygons for each tract from the raster image, they attached a centroid in each tract and attached their real estate database to the whole map. This enabled tract map queries based on the database. The staff could query the database on all homes assessed at greater than $175,000, and the resulting graphic would display dots over the aerial orthophoto for all such homes (Parrish 1999). Even though this method limits the use of the data, it can be used, particularly as a stepping stone until the raster data are vectorized.

Vectorizing is the method to convert raster images into editable line data. This process changes a series of raster dots in a scanned image into a vector. The vector has a beginning and an ending point as well as vertices along the line, each represented by a coordinate value. The vectors can be built into polygons, with attribute data attached to each polygon. The two methods to vectorize scanned tract lines are heads-up digitizing or automated vectorization (Parrish 1999).

Heads-up digitizing

Heads-up or on-screen digitizing is a method in which the user displays an image on the monitor, such as a scanned segment map, and adds lines into the GIS by tracing features on the segment map. This converts the scanned image to vectors or lines that represent the boundary of the tract. The vectors then have to be converted to polygons. Each polygon or tract would then be attributed with

those attributes that create a unique identifier for each tract, such as the tract number and the project identification number.

Automated vectorization

Automated vectorization consists of creating vector graphics from raster data. Automated vectorization computer programs process the file by turning black dots into lines (Parrish 1999). The line work on the hard-copy originals must be of sufficient quality for automated vectorization. Map line work is the simplest of map data to recognize and vectorize. This area is by far the most advanced. Line work in a raster image is a connected group of pixels. These are recognized by the software and converted to lines, arcs, or curves. These techniques are continually being refined, but this method still requires a human quality check to assess the conformity to the real image condition. Manual cleanup functions, such as line snapping and the elimination of overshoots and undershoots, are usually required (Montgomery and Schuch 1993). Common problems that arise include:

   a. Falsely recognizing different line types and styles, such as railroads, roads, and water bodies, as tract boundaries.

   b. Recognizing text and boxes around text as tract boundary vectors.

   c. Division of arcs into too many line segments.

Automated vectorization has not yet replaced manual conversion as the preferred and most practical method of data conversion. Currently, most conversion contractors agree that the most effective method of conversion is not fully automated, but rather, interactive, operator-assisted vectorization (Montgomery and Schuch 1993). Even though the previous reference is dated, the technology still does not seem to have advanced to the point that it has overtaken the operator-assisted method. However, there are examples of entities successfully using this method. Morris County, New Jersey, utilized automated vectorization software to convert more than 58,000 tracts into digital format. Within a year the tracts were converted to a digital format, checked and corrected, and then merged together (Parrish 1999). Morris County viewed automated conversion software as a method to scan a map and convert both the lines and text, such as tract numbers, into accurate digital information at relatively little cost (Parrish 1999).

Summary

In summary, disadvantages and advantages to scanning and heads-up digitizing or automated conversion are:

Advantages

- Potential for higher accuracy

Disadvantages

- Inaccuracies present in the original tract map will be reproduced

- Falsely recognizing railroad, roads, water bodies, and text boxes as tract boundaries

- Tract boundary divided into too many line segments with automated vectorization

Attribute Data Linking Tool

The previous data conversion options referred primarily to spatial data conversion. Because it is often more expensive to capture attribute data than spatial features associated with the attributes, every effort should be made to procure attribute data from existing digital sources and minimize the amount that must be entered manually. As stated in the previous section, it is often necessary to manually add the attributes into each polygon that provide a unique identification for the polygon, and thus the capability of linking to other existing digital attribute sources. Some of the tabular data are stored in hard-copy format, but over the past few years, the Corps' Real Estate offices have entered a large amount of attribute data into REMIS.

The tabular data in REMIS must be matched with tracts or polygons in the GIS file. This is done by using unique identifiers to match the tract polygon to the same tabular data in a database such as REMIS. For example, for a tract, the tract number and project identification number must both be used to uniquely identify tracts in REMIS. Therefore, these two attributes can be combined or concatenated to develop a unique identifier in the GIS tract file and the REMIS database.

As part of the same work unit that this report was developed under, a report and software tool were developed to assist in the development of the needed attributes for the various real estate spatial data, and the process of linking to the REMIS database to obtain the tabular data. The report and software tool can be found at *http://www.wes.army.mil/el/gdaf/realestate/realestate.html*.

The software tool was written to automate the generation of a cadastre real estate GIS. This tool utilizes the ArcGIS 8 software (Environmental Systems Research Institute, Inc. 2002). Along with the spatial data standard (SDS) (Information Technology Laboratory 2002) generator, the tool performs the following tasks:

a. Generates an SDS-compliant personal cadastre real estate geodatabase.

b. Generates SDS-compliant cadastre real estate tables, relationships between tables, and domain values within the geodatabase.

c. Adds the geographic features (e.g., tracts, outgrant boundaries, disposal boundaries, encroachment boundaries, and fee boundaries) from existing ArcInfo shapefiles or coverages to the geodatabase.

d. Links the geodatabase to the REMIS Oracle database to retrieve the appropriate records to populate the SDS-compliant cadastre real estate tables in the personal geodatabase. This tool provides a one-way link to REMIS; it does not make changes, updates, or deletions to the REMIS database. REMIS users will continue to enter and modify data using the existing REMIS interface.

e. Allows the user to manually input attribute data into the tables (e.g., for attributes that are not in the REMIS database or are not populated in the REMIS database).

f. Populates the area and perimeter attributes based on the geospatial data.

4   Case Studies

Four case studies are presented in this report: Fort Worth, New England, Walla Walla, and Rock Island Districts. These Districts applied data conversion techniques to develop a real estate GIS database primarily for tract acquisitions and project boundaries, and to a much lesser degree for outgrants and disposals. The case studies served as learning tools, allowing Districts to refine the process before applying it to other sites. The four case studies represent diverse conversion methods and techniques.

Fort Worth District Case Study

The case study for the Fort Worth District includes converting the Lewisville Lake, Texas, project boundary and tracts to a GIS format. The Fort Worth District contracted the work to the Center for Watershed and Reservoir Assessment and Management, University of North Texas (UNT). The data conversion involved using a combination of technologies such as scanning segment maps, using GPS technology, COGO, and tablet and heads-up digitizing. The following discussion provides a summary of the data conversion methodology. For more information on the conversion methods, e-mail hunter@unt.edu.

Project boundary

Scanning segment maps. Initial conversion consisted of scanning segment maps and registering the scanned segment maps to match digital ortho photoquad coordinates projected to UTM, NAD 83, Zone 14. The following procedure was used:

a. The individual scanned images were imported into Photoshop where they were converted from bitmap to grayscale and then rotated to approximate north. Unnecessary map information was deleted.

b. The images were saved as bitmaps and exported back into tif format and taken into ArcView for warping. Warping is the process by which one set of spatial data is forced to fit another set (Montgomery and Schuch 1993). (The Spatial Analysis extension must be running in ArcView 3.x for the warp to work.)

c. Warp Environment (sample) was downloaded from the ArcScripts site at *www.esri.com*.

d. Pertinent digital ortho quarter quadrangles (DOQQs) were loaded (in this case, Mr. SID format was used) for the basis of registration.

e. The images were warped. This process includes these steps:

(1) Load a segment tif in one view and the corresponding DOQQ in another.

(2) From the Warp menu, specify the From View (segment) and To View (DOQQ).

(3) Create a new link file (this houses the ground control point coordinates).

(4) Identify points on the segment map that correspond to locations on the DOQQ.

(5) After gathering numerous points scattered across the segment map, use Calculate Fit from the Warp menu. You want to get as low a root mean square (RMS) value as possible. More than likely you will need to delete some links that have high RMS contributions, or add some more points, in order to get a lower RMS.

(6) Once the desired RMS has been obtained, warp the segment image to the DOQQ.

(7) Once the segment map has been warped, overlay the new file on top of the DOQQ and check for accuracy.

(8) The tif can be converted to a grid.

(9) All of the warped segment maps can be mosaiced into one large segment map for the area. (In the case of Lewisville Lake, there were five segment maps that were compressed in Mr. SID format for ease of storage and use.)

Using GPS to locate monuments around Project Fee Boundary. Corps of Engineers Fee Boundary monument locations were recorded for Lewisville Lake during a 9-day period in April 2001. The perimeter of the boundary is approximately 374 km (232 miles) and contains over 3,000 monuments. This project required eight to nine crews per day (two persons minimal) for a 9-day period.

The GPS crews were given training in the use of Trimble ProXRS units. Each crew checked its unit to a benchmark monument at the project office prior to beginning fieldwork. At the end of each day, GPS files were downloaded to a PC and backed up to disk. File names were assigned each day with the initials of the GPS operator and the date, e.g., BAH040801A (A representing the first file of the day).

GPS points were postprocessed by Corps personnel at the project office. The postprocessing was optional since personnel were using ProXRS units with an expected accuracy of 0.30 to 0.61 m (1 to 2 ft) on-the-fly. Raw data were collected in longitude latitude format. Raw GPS points were then converted to ArcView 3.x shapefiles (UTM, NAD 83, Zone 14).

Of the approximately 2,500 points that were collected in the field, approximately 1,700 were found to be usable. Although points were collected, they were often attributed as "Not Found" and might have been fence corners or other obvious landmarks that were assumed to be boundary monuments. Any point that was not attributed as "Found" was deleted from the dataset used in the creation of the boundary file. Verified monument locations were connected to produce sections of the Lewisville Lake Fee Boundary.

Since approximately only half of the total monuments for Lewisville Lake were found by GPS, it was necessary to devise other methods to complete the project boundary. These methods are described in the following section.

Digitizing tract maps to develop Project Fee Boundary. Individual tract maps within the Lewisville Lake segments were digitized into ArcInfo. A total of more than 400 maps were digitized. When possible, all features were digitized including Fee Boundary, Flood Easement, roads, etc. The digitized maps were then transformed into real world coordinates using monuments with GPS coordinates as tics. Digitized Fee Boundary sections, which could be transformed into UTM, NAD 83, Zone 14 with an RMS value lower than 5.0, were then integrated into the Fee Boundary file produced from GPS points. This method was successful in producing sections of the Fee Boundary that researchers were unable to obtain where there were missing monuments.

Using COGO to locate monuments around Project Fee Boundary. For many of the digitized map sheets researchers were unable to gather sufficient GPS points (a minimum of four) to transform the data. COGO was chosen to reproduce the location of missing monuments. There were several steps taken in the COGO process. Initially, the COGO ArcView extension was tried. When this process was found to be unsatisfactory, COGO was then processed using a simple formulae written in an Excel spreadsheet based on the first geodetic problem, which calculates coordinates from bearings, distances, and a known coordinate system.

There were several issues in the COGO process. The first was that all the paper maps were drawn using the State Plane NAD 27 coordinate system with distance in feet. Therefore, all COGO coordinates were generated in State Plane NAD 27 feet. Very few of the paper maps had coordinate values for monuments. Therefore, starting points for the COGO process had to be taken from GPS points converted from UTM NAD 83 to State Plane NAD 27. The major issue with the COGO process was that bearings were recorded in degrees and minutes but did not include seconds. The surveyed maps were produced in the 1960's and for some reason only degrees and minutes were recorded. Without having seconds in the COGO process, the generated points were located at a lower accuracy than if they had been generated using seconds, particularly on boundary sections with long distances between monuments.

Numerous coordinates representing missing GPS monuments were computed in COGO using the cadastral maps. These coordinates were generated as points in ArcView GIS using the Add Event Theme command and were then reprojected to UTM, NAD 83, Zone 14 meters.

Using monuments recorded by GPS and generated through digitizing and COGO, the Fee Boundary was created by "connecting the dots." All line sections produced through this method were attributed with a Value of "1" to signify relative confidence of their accuracy. However, there remained numerous sections of the Fee Boundary that could not be obtained because of missing monuments. Digitizing of the scanned segment maps was used to fill in the gap.

Heads-up digitizing scanned segment maps to develop Project Fee Boundary. Mr. SID format scanned segment maps (produced by Texas A&M University) had been provided to UNT by the Lewisville Lake project office. The Fee Boundary produced through GPS, digitizing, and COGO was overlaid onto the segment maps to show gaps in the coverage. Missing sections were then heads-up digitized using the segment maps as a guide. The heads-up digitized sections were attributed with a value of "2" to signify the lower confidence in accuracy. In this manner, the Fee Boundary for Lewisville Lake was completed, allowing a calculation of area for the Corps of Engineers property (polygon format). The attributing of the boundary also allows the use of different color symbolization for easy identification of boundary sections that will require survey work to confirm locations.

Tracts

The 1,491 tracts for Lewisville Lake were heads-up digitized from scanned segment maps. The purpose was to produce a polygon coverage of tracts within the project area. The boundary of each tract was digitized from the scanned segment maps, and the tract identification number was assigned to each polygon. A polygon shapefile with all identifiable tracts was produced. It cost approximately $48/tract to convert the tracts and project boundary for Lewisville Lake to a GIS format.

New England District Case Study

The New England District has converted project boundary and/or tracts to a GIS format for 30 flood-control projects. The procedure for the conversion is discussed below, and costs are detailed in Table 1.

Project boundary

The process to convert the project boundaries to a GIS format is documented below:

a. Key in monument numbers, northings, eastings, elevations, and descriptions listed on boundary survey sheets into an Excel file.

Table 1
Conversion Costs, Number of Tracts, and Miles of Project Boundary in New England District Converted to a GIS Format

Project	Project Boundary	Tracts	No. of Tracts	Miles of Boundary	Cost to Automate Tracts	Cost to Automate Boundary
Barre Falls Dam	X	X	15	8.0	$47	$293
Birch Hill Dam			n/a	n/a		
Knightville Dam		X	76	n/a	$237	
Littleville Lake	X		n/a	10.3		$378
Tully Lake	X	X	101	14.6	$315	$535
Blackwater Dam	X		n/a	27.5		$1,008
Edward MacDowell Lake	X	X	52	19.3	$162	$708
Franklin Falls Dam	X		n/a	33.6		$1,232
Hopkinton/Everett Lakes	X		n/a	70.9		$2,600
Black Rock Lake	X		n/a	6.6		$242
Colebrook River Lake	X		n/a	9.7		$356
Hancock Brook Lake	X		n/a	10.0		$367
Hop Brook Lake	X	X	101	6.7	$315	$246
Northfield Brook Lake	X	X	36	5.6	$112	$205
Thomaston Dam	X	X	234	19.5	$730	$715
Buffumville Lake	X		n/a	9.2		$337
Conant Brook	X		n/a	5.9		$216
East Brimfield Lake	X		n/a	33.2		$1,217
Hodges Village Dam	X		n/a	11.3		$414
Mansfield Hollow Lake	X	X	226	32.2	$705	$1,181
West Hill Dam	X	X	133	10.5	$415	$385
West Thompson Lake	X	X	156	20.9	$487	$766
Westville Lake	X		n/a	20.2		$741
Ball Mountain Lake	X	X	97	19.4	$303	$711
North Hartland Lake	X	X	91	18.1	$284	$664
North Springfield Lake	X	X	131	17.4	$409	$638
Otter Brook Lake	X	X	50	21.1	$156	$774
Surry Mountain Lake	X	X	90	40.2	$281	$1,474
Townshend Lake	X	X	98	10.8	$306	$396
Union Village Dam	X	X	75	14.5	$234	$532

b. Export the data to a text file in ArcInfo point generate and line generate format.

c. Use the ArcInfo generate command to generate a boundary monument point coverage and a boundary line coverage.

d. Scan and register the boundary survey sheets, using either the State Plane grid, if shown, or boundary monuments.

e. Use the registered boundary survey sheets to heads-up digitize the property boundary where it did not connect directly from monument to monument, e.g., where it followed a road or river.

f. Build the line coverage for polygon topology to create a property boundary polygon.

Tracts

The process to convert the tracts to a GIS format is documented below:

a. Scan and register the real estate tract maps using boundary monuments. The coordinates of the boundary monuments were known from the boundary survey sheets.

b. Use the registered real estate tract maps to heads-up digitize the real estate tracts.

c. Link tracts to REMIS database using cadastre real estate software tool (Peyman Dove, Graves, and Lopez 2001).

Walla Walla District Case Study

The need to place real estate data into the District GIS was established in the Walla Walla District's GIS Implementation Plan approved in 1988. Since that time, the work has taken place as funding allowed.

Project boundary, tract, outgrant, and disposal GIS files have been completed for several projects. The process for converting the existing real estate data to a GIS format is discussed below and is based on the method used for the Dworshak project.

Project boundary

Key in project boundary monument coordinates to develop point file of monuments. Project boundary monuments were precision placed by X-Y coordinates (State Plane coordinate system) into Microstation design files using existing coordinate tables shown on the monumented project boundary map sheets (Table 2). Each boundary monument was depicted as a point cell placed at its proper X-Y locations and sized relative to the scale of the source map. The monument name was placed on a separate level/layer as a text feature. A design

Table 2
Example of Boundary Monument Coordinate Table, Walla Walla District

RIGHT BANK (CONT.)			
DESCRIPTION	WASH. COORDINATES SOUTH		DISTANCE AND BEARING
	NORTHING	EASTING	
404=407	425,101.64	2,831,158.51	263.77' S03°20'50.2"E
407-4A	424,838.32	2,831,173.86	140.92' S03°20'50.2"E
407-4B	424,697.64	2,831,182.05	69.53' S03°20'50.2"E
407-4C	424,628.23	2,831,186.09	116.81' S03°20'50.2"E
407-4D	424,511.62	2,831,192.88	666.30' S03°20'50.2"E
407-4E	423,846.45	2,831,231.67	61.03' S03°20'50.2"E
407-405	423,785.53	2,831,235.31	

file containing the monumented boundary points was created for each individual project (***surv.dgn). The boundary monument point cells were automatically placed in each design file by using a script file to bulk place each point cell, based on its X-Y coordinate value.

The Survey and Mapping Section developed the attribute data structure and the element feature naming convention after consulting with the GIS group within the District. What evolved was a structure that followed the existing GIS standards for the District (1994/95), while also including attributes that would be helpful to Survey and Mapping in managing its project boundary monuments. The data structure used for the project boundary monument attribute table is shown in Table A1, Appendix A.

Upon completion of placing the boundary monument cells at their proper X-Y position, the design file was brought into Intergraph's Modular GIS Environment (MGE) for attaching attributes (feature code/entity name), symbology verification, and database table linkage to the point cells. This was accomplished using the Feature Maker and Blank Loader tools within MGE. Once the database linkage to the boundary monument cells had been established, Bulk Update utility was run for those attribute fields that were consistent for all boundary monuments (i.e., project_name, state_d, etc.). The rest of the attribute data were manually keyed in using the Feature/Attribute Manager utility, referencing the monumented boundary map sheets, as well as Survey and Mapping Section boundary records, for all the required information.

Key in project boundary monuments and heads-up digitizing scanned project maps to develop project boundary. A separate design file was created containing the actual project boundary lines (***bound.dgn) for each project. The monumented boundary segments were drawn utilizing the same tabular coordinate data used to place the project boundary monuments. The non-monumented boundary segments were digitized onto a separate level/layer, with a different symbology from the monumented segments. Depending on the boundary maps, some nonmonumented segments were drawn using bearing-distance call-outs, while others segments were converted using heads-up digitizing from scanned project boundary map sheets. Prior to digitizing, the

existing hand-drawn monumented project boundary map sheets (mylar or paper copies) were scanned to a binary (black and white) raster format (Intergraph's .cit) at 200 to 300 dpi. The scanned maps were projected to State Plane coordinate system using the affine-1 method within Intergraph's Rasbatch Utility (IRASB) environment, utilizing the existing boundary monument points and/or the plotted coordinate grid tics as reference points (as shown on the source maps). No attribute feature information has been attached to the line work at this time.

Tracts and outgrants

The tracts for the Lower Snake River Projects (Ice Harbor, Lower Monumental, Little Goose, and Lower Granite), McNary, and Dworshak were placed into a GIS in 2000 and 2001. This was done due to a request from the Payos Kuus Cuukwe, a cooperating group made up of cultural resource professionals from affected tribes of the Lower Snake River Projects, McNary, and Dworshak. This group also provided the funding for the project. The tract map for Mill Creek Bennington Lake was mapped during the Master Plan update approved in 1995.

Outgrants for the Lower Snake River Projects were mapped on mylar monumented sheets by in-house personal in the early 1980's. The outgrants were researched from legal descriptions. The maps were published as part of a contract for the Lower Snake River Fish and Wildlife Compensation Plan. The maps were periodically updated and served to speed the process for entering the data into a GIS.

Scanning segment maps. To create GIS tract and outgrant files, black and white copies of segment map sheets for six projects (109 total map sheets) were scanned to a binary raster format (Intergraph's .cit) at 200 to 300 dpi prior to using heads-up digitizing. In some instances, reservoir maps and/or legal descriptions with sketches/exhibits were also scanned since the original outgrants were delineated on these maps. The scanned source maps were projected to the State Plane coordinate system, using the affine-1 method within the IRASB environment utilizing existing boundary lines, known section corner information, and/or coordinate grid tics as reference points (as depicted on the source maps). Legal descriptions were provided for any new outgrants not previously delineated on a map sheet.

Heads-up digitizing scanned segment maps to develop tracts and outgrants. Heads-up digitizing of the tracts and outgrants was to a Microstation design file (named ***tracts.dgn and ***outgr.dgn, respectively) set up for each project. Where the tract line and the project boundary line were the same, care was taken to copy the project boundary line into the tracts design file rather than redraw the line and introduce potential error in analysis. Approximately 4,037 tracts have been digitized. Any existing project boundary line, tract line, or any other map features that served to define an outgrant area was also utilized (copied) rather than redrawing the line segment and introducing potential errors in analysis later on in the process. A total of 1,063 outgrants on six projects have been digitized and have attributions attached (included in this number are

multiple locations of outgrants under the same contract number, such as the navigation aids permit).

Attaching attributes to tract and outgrant GIS files. The attribute data structure for tracts and outgrants was developed by looking at what was currently shown in the SDS data structure (version 1.75/1.80), and by what data fields were requested by the Real Estate offices. The existing SDS attribute table, "cdrelpar," for property parcels, although very helpful, did not quite fit project requirements for the tract GIS file. After consulting with U.S. Army Engineer Research and Development Center personnel, an attribute table called "cdreltract" was developed which borrowed several of the attribute names found in the SDS attribute table plus ones created specific to project needs. The data structure used for the attribute table "cdreltract" is shown in Table A2, Appendix A.

Also, in reference to tracts, initial work has been implemented on disposals. In cases where the whole tract was disposed of, it was simply noted as a disposal in the actions attribute field within the tracts database. For those occurrences where only partial tracts were disposed of, additional line work was digitized, feature coded, and a database linkage established for the portion being disposed. For this new area, the tract_id attribute was kept the same as the original, but the actions attribute was changed to signify the disposal. When the disposal data were completely entered, a basic query of the database was conducted to verify that all the disposal actions were correctly digitized and entered into the database, and a report file was generated. This was checked against the legal descriptions supplied, with the results forwarded to the Real Estate office.

At the time of conversion, attributes specific to outgrants were not included in the SDS format. Therefore, researchers developed an attribute structure that tried to follow, as much as possible, the SDS format plus included those items in REMIS that were important to the Real Estate office. Table A3, Appendix A, lists the attribute data structure used for outgrants.

Upon completion of heads-up digitizing, the design file containing the tract or outgrant features was brought into MGE for attaching attributes (feature code/entity name) and verification of clean line work, as well as to link the database table to the graphics (via a node/centroid). This was accomplished using the following tools within MGE: Feature Maker, Free-Endpoint Processor, Duplicate Line Processor, and Centroid Placer (with blank records option). Once database linkages had been established with the tract or outgrant areas, Area Loader was run to update the calculated area attribute within the database for each tract or outgrant. Also, Bulk Update was run for those attribute fields that were consistent for all the tracts (i.e., project_id, state_id). The rest of the attribute data was manually keyed in using the Feature/Attribute Manager utility referencing the source maps for all the required information. A topology file (.top) of the finished tract and outgrant files was generated referencing the line work and the centroid/node, using the Topo Builder tool in MGA. A basic query of the topology file/database was conducted, and a report file was generated for each source sheet to verify the accuracy of the data conversion. A copy of this report was furnished to Real Estate office.

Converting MGE tract and outgrant GIS files to ArcView format. An ArcView version of the real estate tract and outgrant data set was created from the finished MGE tract and outgrant files. Prior to import into ArcView, the dgn file was converted into complex shapes using the Complexer tool within MGE. This tool converts the tract and outgrant boundary line work and area centroid into complex shapes, transferring all the area centroid database linkages to the complex shape and outputting the information to a new design file. The number of records output to complex shapes was noted for future reference (possible duplicate records/shapes during ArcView conversion).

Rock Island District Case Study

A pilot project was initiated by the Rock Island District for the development of tract GIS files, metadata, and related data files for Corps tracts along eight pools of the Illinois Waterway. COGO was used to convert the existing data for approximately 360 tracts. The average cost was about $235 per tract (Table 3). It should be noted that even though the project boundary file for these eight pools was not included in this pilot study, the cost inherently includes the cost of developing project boundary files for the eight pools since the project boundary could be developed by simply dissolving the interior tract lines.

Table 3 Costs of Converting Existing Tracts to GIS Format for Eight Pools Along the Illinois Waterway, Rock Island District	
Pool	Number of Mapped Tracts
Brandon Road	19
Dresden	71
Marseilles	30
O'Brien	75
Peoria	17
Starved Rock	65
LaGrange	78
Peoria Boatyard	5
Total No. of Tracts	360
Total Cost	$84,500
Average Cost per Tract	$235

Existing real estate information used included scanned paper maps in tif format and legal descriptions in pdf format. The legal descriptions were entered by hand into surveying software to develop coordinates for each point. The coordinate information was translated into ArcInfo polygon GIS coverages in the Illinois State Plane coordinate system, making adjustments to bearings and distances as required for the State Plane grid. Federal Geographic Data Committee (FGDC) format metadata describing the process was prepared using Spatial Meta-Data Management System (SMMS) software. A text file describing the distance and bearing of each leg of the boundary was developed for each parcel. Data files from intermediate processing steps and pdf files of any hand computations were also generated.

The Rock Island District developed a comprehensive scope of work that was used to accomplish the pilot project. The scope of work provides useful information for those involved in the development of similar work. It is attached as Appendix B.

5 Summary

Real estate data are fundamentally geospatial and the Corps of Engineers realizes that there is great advantage to managing and maintaining cadastral information in a GIS. Various Districts within the Corps are transitioning from the hard-copy real estate data environment to a digital environment. The Districts are utilizing data conversion methods that vary in their methodology, price, and accuracy. There is no one best method for converting existing real estate data to a GIS environment, rather there are many methods and combinations of methods. An overall comparison of the conversion methods presented in this report is listed in Table 4.

Table 4
Comparison of Conversion Methods

Tablet Digitizing	Scanning & Heads-Up Digitizing or Automated Vectorization	COGO
Accuracy limited by the stability of the source media and drafting quality of the source media	Inaccuracies present in the original tract map will be reproduced	Real world coordinates - Horizontally accurate - Shape of tracts precise
Low cost method	Using automated vectorization, falsely recognizing railroad, roads, water bodies, text boxes, as tract boundaries	No real world coordinates - Shape of tracts precise but horizontal accuracy may be decreased
Tedious and error-prone	Using automated vectorization, polygon lines divided into too many line segments	Discrepancies between tracts must be resolved
Cleanup or editing step required	Low cost method	4 to 20 times more expensive than manual digitizing (Hohl 1998)

The conversion methods discussed in this report are pertinent to converting existing real estate data to a GIS format, such as tracts, project boundaries, outgrants, encroachments, and disposals. Data conversion efforts can be prioritized to address the data most needed in the Corps' business practices. For example, converting project boundaries to a GIS format has been a top priority at some Districts since this information is fundamental to many business practices, such as assessing encroachments. The interior tract boundaries are pertinent to many business practices and are an important historical record. The conversion of project boundaries and tracts to a GIS format represents the majority of real estate data conversion efforts in the Corps. A limited number of outgrants and disposals have also been converted.

The most accurate data conversion method is through COGO. However, the expense of this method may be cost-prohibitive. If geographically referenced (real world) points of beginning are not available on the documents or maps used for the COGO conversion, the process may not be justified since the horizontal location of the real estate data will be only as accurate as the data used to geo-reference the survey data. Having precisely shaped polygons may not be as useful if the horizontal location of the polygons is not precise. Nevertheless, if the real estate data can be georeferenced with accurate digital photography, then the process may be justified, especially for projects where the most accurate boundaries are needed.

If COGO is used to develop a GIS file of tracts, time must be factored in to address possible discrepancies between tract borders that may arise when individual tracts are pieced together. One compromise to using COGO for every tract is to use COGO to create a precise project boundary and then use a less expensive method to convert the interior tracts to a digital GIS. Nevertheless, some Corps offices need the accuracy that COGO can offer and are willing to expend the funds to use COGO in developing the tract-level GIS database.

One of the least costly by methods of converting real estate data to a GIS is through scanning maps (e.g., segment, tract, project boundary survey sheets) and then using heads-up digitizing, or tablet digitizing, to convert the tracts, project boundary, disposals, and outgrants on the scanned image to vector polygons. The scanned maps must be georeferenced, and the method and cost to achieve this will vary depending on the available survey data.

Attribute data must also be incorporated into the GIS files. For example, each tract can be uniquely identified through the concatenation of the tract number and project identification number. Unique identifying attributes provide the opportunity to link to other databases that have useful spatial and nonspatial information. Linking to the REMIS database provides a wealth of information about each tract, project boundary, outgrant, encroachment, and disposal. A software tool has been developed that provides the ability to link from the real estate GIS to REMIS (Peyman Dove, Graves, and Lopez 2001).

Four case studies have been presented in this report. Specifics of their conversion efforts can be found in Chapter 4 of this report. Conversion methods have varied as well as the cost (Table 5). It is evident from the case studies that it often requires a combination of methods to convert existing data to a GIS format. These Districts have shared their methods so that other Districts can benefit.

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Table 5
Conversion Methods and Costs for Four Case Studies

District	Method to Convert Project Boundary	Number of Tracts Converted to GIS	Method to Convert Tracts	Contracted or In-House	Cost to Convert ($/tract, includes project boundary)
Fort Worth (based on Lewisville Lake)	Combination of GPS technology and COGO to locate monuments for project boundary, digitizing tract maps, and heads-up digitizing of segment maps	1,491	Heads-up digitizing scanned segment maps	In-house and contracted (Univ. of Texas)	$48
Walla Walla	Keyed in project boundary monument coordinates, heads-up digitizing scanned segment maps	4,037	Heads-up digitizing scanned segment maps	In-house	$49
Rock Island (based on 8 pools on Illinois Waterway)	To be developed by dissolving interior tract lines	360	COGO	Contracted (Stanley Consultants)	$235
New England (based on 16 projects where both project boundary and tracts have been converted)	Keyed in and connected project boundary monument coordinates, heads-up digitizing of scanned property boundary survey sheets	1,686	Heads-up digitizing scanned project boundary survey sheets	In-house and student labor	$11

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Appendix A
Walla Walla District Attribute Tables

These attribute tables were developed by the Walla Walla District for use with the digital Intergraph design files of the project boundary monuments, tracts, and outgrants for the Dworshak Project. This appendix is referenced in the Walla Walla District Case Study, Chapter 4 of this report.

Table A1. Walla Walla District Project Boundary Monument Attribute Table

Category - Entity Class: Cadastral_Monumentation
Attribute Table Name: cadastral_monument (lwr snake river projects)

Attribute Name	Data Type	Nulls	Domain/Description
Mslink	Integer	No	
Mapid	Integer	yes	
monument_name	Char(30)	yes	
project_name	Char (8)	yes	projects_npw
Date_established	Char(8)	yes	
established_by_d	Char(30)	yes	cadastral_firm_company_ageny
City	Char(20)	yes	
County	Char(20)	yes	
state_d	Char(5)	yes	government_state_code
Latitude	Char(20)	yes	
Longitude	Char(20)	yes	
coord_easting_x	double	yes	
coord_northing_y	double	yes	
coord_elevation_z	double	yes	
coord_local_east	double	yes	
coord_local_north	double	yes	
local_coord_system_d	Char(8)	yes	projects_npw
Horizontal_datum_d	Char(20)	yes	cadastral_horizontal_datum
vertical_datum_d	Char(20)	yes	cadastral_vertical_datum
Geoid_height	double	yes	
geoid_year_d	Char(8)	yes	cadastral_geoid_year
Projection_d	Char(32)	yes	cadastral_projection
unit_of_measurement_d	Char(3)	yes	unit_of measure_length
monument_type_d	Char(2)	yes	cadastral_monument_type
Monument_purpose_d	Char(25)	yes	cadastral_monument_purpose
monument_quality_d	Char(10)	yes	cadastral_monument_quality
mon_qual_comments	Char(150)	yes	
Horizontal_accuracy_d	Char(6)	yes	coordinate_distance_accuracy_st
vertical_accuracy_d	Char(6)	yes	coordinate_elevation_accuracy_st
mon_discrim_d	Char(20)	yes	monument_discriminator
gps_suitability	Char(3)	yes	gps_suitability
Usgs_24k_quad_d	Char(30)	yes	
Fieldbook	Char(30)	yes	
rec_of_survey_num	double	yes	
pls_corner	Char(10)	yes	
general_comments	Char(200)	yes	

(Feature Code/Entity naming Structure)
Spatial Data Layers

Feature Category: Cadastral_Monumentation
Lower Granite Project Boundary – llasurv.dgn

Theme	Lv	Wt	LC	CO	Element Type	Feature Code	Feature Name	Attr.Table
monument cell								
(s00033)	3	1	0	3	point cell	150300103	usace_project_boundary_mon_p	cadastral_monument
label/text	4	1	0	3	Text	150300104	usace_project_boundary_mon_t	

Table A2. Walla Walla District Attribute Table (cdreltract) for Dworshak Project Tracts

Category - Entity Class: Cadastre_Real_Estate_Tracts
Attribute Table Name: cdreltract

Attribute Name	Data Type	Nulls	Domain/Description
Mslink	integer	No	
Mapid	integer	Yes	
project_id	char (20)	Yes	default to "Dworshak"
tract_no	char (20)	Yes	
owner_id	char (40)	Yes	
tract_type	char (20)	Yes	tract_type (fee, license, lease, etc)
calc_area	double	Yes	
listed_area	char (20)	Yes	
Acq_authority	char (99)	Yes	acq_authority (r.e. directives)
Remarks	char (150)	Yes	
Actions	char (20)	Yes	action_type (terminated, excessed, etc)
action_date	char (10)	Yes	format yyyymmdd
instln_id	char (20)	Yes	Default value "WAWA-2-0006"
segment_mapsht_no	char (20)	Yes	1 of ---
map_file_no	char (15)	Yes	default to "WW-RE-297"
townshp_id	char (15)	Yes	
plssrng_id	char (15)	Yes	
Plss_section_no	char (10)	Yes	
county_id	char (20)	Yes	county name (list table)
state_id	char (15)	Yes	state name (list table)
change_date	char(10)	Yes	format yyyymmdd
mod_user_id	char(10)	Yes	LAN User-id
meta_id	char (20)	Yes	metadata filename & location

Level assignment, element symbology, and element feature code/entity name were developed in-house, with all effort made to follow the format of SDS naming conventions, while still incorporating current District GIS data structure. The format used is shown below:

(Feature Code/Entity Naming Structure)
Spatial Data Layers
Cadastral - Real Estate – Tracts
Dworshak Tracts - dwatracts.dgn

Theme	Level	Wt	LC	CO	Element Type	Feature Code	Feature Name	Attr.Table
Real Estate Tract	3	1	0	194	linestring	cdreltractb	Cdrel_tract_line_b	
Centroid	4	5	0	7	Point	cdreltractc	Cdrel_tract_line_c	cdreltract
Text	5	1	0	194	Text			
FYI Lot lines, *etc.*	6	1	1	9	linestring			

Table A3. Walla Walla District Attribute Data Structure for Outgrants

Category - Entity Class: Cadastre_Real_Estate_Outgrants
Attribute Table Name: cdreloutgr

Attribute Name	Data Type	Nulls	Domain
Mslink	Integer	No	
Mapid	Integer	Yes	
Project_id	char (20)	Yes	
Contract_no	char (25)	Yes	
grantee_id	char (60)	Yes	
Outgrant_type	char (20)	Yes	outgrant type (list table)
Outgrant_descriptn	char (60)	Yes	
Outgrant_authority	char (20)	Yes	
outgrant_wi_code	char (10)	Yes	
effective_date	char (10)	Yes	format yyyymmdd
expiration_date	char (10)	Yes	format yyyymmdd
Outgrant_status	char (10)	Yes	outgrant status (list table)
purpose_category	char (10)	Yes	
rental_amount	char (20)	Yes	
rental_freq_cat	char (20)	Yes	
Calc_area	Double	Yes	
listed_area	char (20)	Yes	
State_id	char (15)	Yes	state_code (list table)
County_id	char (20)	Yes	county name (list table)
Tract_no	char (15)	Yes	
township_id	char (15)	Yes	
Plssrng_id	char (15)	Yes	
Plss_section_no	char (15)	Yes	
segment_mapsht_no	char (20)	Yes	
Change_date	char (10)	Yes	format yyyymmdd
mod_user_id	char (10)	Yes	
digitize_record	char (200)	Yes	
Meta_id	Char(20)	Yes	metadata filename & location

Level assignment, element symbology, and element feature code/entity name were developed in-house, with all effort made to follow the format of the SDS naming convention, while still incorporating current District GIS data structure. Example of format used is shown below.

Spatial Data Layers
Cadastral - Real Estate - Outgrants
  Dworshak Outgrants - dwaoutgr.dgn

Theme	Level	Wt	LC	CO	Element Type	Feature Code	Feature Name	Attr.Table
Easement Road R/W	3	1	0	211	linestring	outgrerdrwb	cdrel_outgr_easement_road_rw_b	
Centroid	4	5	0	7	point	outgrerdrwc	cdrel_outgr_easement_road_rw_c	cdreloutgr
Text	5	1	0	211	text			
point r/w	6	1	0	211	point cell	outgrerdrwp	cdrel_outgr_easement_road_rw_p	cdreloutgr
Easement Electrical line	7	1	0	5	linestring	Outgreelb	cdrel_outgr_easement_elec_line_b	
Centroid	8	5	0	7	point	Outgreelc	cdrel_outgr_easement_elec_line_c	cdreloutgr
Text	9	1	0	5	text			
Point	10	1	0	5	point cell	Outgreelp	cdrel_outgr_easement_elec_line_p	cdreloutgr
Easement U/G Elec.	11	1	0	132	linestring	outgreuglb	cdrel_outgr_easement_ug_line_b	
Centroid	12	5	0	7	point	outgreuglc	cdrel_outgr_easement_ug_line_c	cdreloutgr
Text	13	1	0	132	text			
Easement Pipeline	15	1	0	254	linestring	outgreplb	cdrel_outgr_easement_pipeline_b	
Centroid	16	5	0	7	point	outgreplc	cdrel_outgr_easement_pipeline_c	cdreloutgr
Text	17	1	0	254	text			
Point	18	1	0	254	point cell	outgreplp	cdrel_outgr_easement_pipeline_p	cdreloutgr
Easement Pump Station	19	1	0	8	linestring	outgrepstb	cdrel_outgr_easement_pumpsta_b	
Centroid	20	5	0	7	point	outgrepstc	cdrel_outgr_easement_pumpsta_c	cdreloutgr
Text	21	1	0	8	text			
Point								
Easement Sewer Line	27	1	0	195	linestring	outgreswlb	cdrel_outgr_easement_sewerline_b	
Centroid	28	5	0	7	point	outgreswlc	cdrel_outgr_easement_sewerline_c	cdreloutgr
Text	29	1	0	195	text			
Point	30	1	0	195	point cell	outgreswlp	cdrel_outgr_easement_sewerline_p	cdreloutgr
Easement Communication	35	1	0	2	linestring	outgrecomb	cdrel_outgr_easement_com_line_b	
Centroid	36	5	0	7	point	outgrecomc	cdrel_outgr_easement_com_line_c	cdreloutgr
Text	37	1	0	2	text			
Point	38	1	0	2	point cell	outgrecomp	cdrel_outgr_easement_com_line_p	cdreloutgr
Lease	43	1	0	4	linestring	Outgrlseb	cdrel_outgr_lease_b	
Centroid	44	5	0	7	point	Outgrlsec	cdrel_outgr_lease_c	cdreloutgr
Text	45	1	0	4	text			
Point	46	1	0	4	point cell	Outgrlsep	cdrel_outgr_lease_p	cdreloutgr
License	47	1	0	57	linestring	Outgrlicb	cdrel_outgr_license_b	
Centroid	48	5	0	7	point	outgrlicc	cdrel_outgr_license_c	cdreloutgr
Text	49	1	0	57	text			
Point	50	1	0	57	point cell	outgrlicp	cdrel_outgr_license_p	cdreloutgr
Permit	51	1	0	153	linestring	outgrpermb	cdrel_outgr_permit_b	
Centroid	52	5	0	7	point	outgrpermc	cdrel_outgr_permit_c	cdreloutgr
Text	53	1	0	153	text			
Point	54	1	0	153	point/cell	outgrpermp	cdrel_outgr_permit_p	cdreloutgr

Appendix B
Rock Island District Scope of Work for Development of Real Estate Tract Files Using COGO

This scope of work was developed by the Rock Island District and used with the contractor to accomplish a pilot project for the development of digital tract GIS files, metadata, and related data files for Corps tracts along eight pools of the Illinois Waterway. This appendix is referenced in the Rock Island District Case Study, Chapter 4 of this report.

SCOPE OF WORK
ARCHITECT/ENGINEER SERVICES
Creation of Coverages from
Real Estate Tracts
Illinois Waterway

1. GENERAL DESCRIPTION OF WORK:

    a) The A/E shall provide all necessary design services required in producing attributed ESRI coverages for the Real Estate boundary tracts as described herein. The work will consist of the development and attribution of the tract boundaries as described herein.

    b) Boundary Tracts: The work will consist of featuring and attributing the tracts as specified in the Spatial Data Standards 2.0. All work will be done through using either ArcView 3.2a or greater, or ArcInfo V8.02 or greater. The delivered product will be an attributed ArcInfo coverage for each Illinois Waterway pool containing the tract boundaries as provided by the Government.

2. PROJECT LOCATION:

    The project will be completed using available information provided by the Government and other public resources that are readily available to the Contractor. All meetings will be held at the Rock Island District HQ in Rock Island, Illinois.

3. PROJECT PARTNERING MEETING:

    A project partnering meeting will be held within three working days after the contract award. The intent of this meeting is to review the scope of work and introduce POC's for the project. The Government will also identify in writing to the contractor those 10 tracts that are to be used for the 10% submittal at this meeting.

4. WORK TO BE PERFORMED:

    a) The Contractor shall convert all the tract information contained on the delivered section maps, descriptions and deeds into ArcInfo coverages. All tract boundaries will be developed as outlined below. These tracts shall be imported into or developed in ArcInfo v8.02 or greater to create polygons within the guidelines prescribed in Section 7, QUALITY ASSURANCE. Each tract polygon will be attributed to the Info database. One coverage will be created for each pool. The attribution table shall consist of four entries; PROJECT_ID , PARCEL_NO, CAPTURE_METHOD and PLACE_STAT. Each of these attribute fields will be a 20 character text field. All the attribute data will be provided by the Government, except the CAPTURE_METHOD. This field will be determined by the methodology used to determine the point of origin of each tract (survey or graphical).

    b) All intermediate files used to create the final coverage will be included in the final submittal. This would include COGO data files and intermediate graphics files (such as shapefiles and MicroStation design files).

c) Tract data will be obtained from Tract Descriptions, Deeds, and/or other applicable documents and maps, copies of which will be furnished by the Government.

d) The tract descriptions contained in the furnished documents will be carefully read to ascertain the Points of Commencement, Points of Beginning and closing lines or points, to note the relationship between all elements of the tract described and the relationship of that tract to the adjoining tracts. Reference to existing maps may be necessary to ascertain the relationship of the tracts and other features called for in the tract descriptions. Knowledge of the intricacies of the Public Land Survey System is required for interpreting the descriptions.

e) The mathematical data from the descriptions will be entered into a surveying, traversing or coordinate geometry program, as appropriate, to produce a closed traverse/polygon that represents the tract described. Closure of the traverse/polygon must be reviewed. The unadjusted linear error of closure must be greater than 1:5000. Because these documents relate to work already accepted and filed for record, we believe the closures have been previously checked and adjusted as necessary. If closure adjustments have not been previously done, the prescribed Corps of Engineers method for traverses of that era is the Compass Rule (the Bowditch method) after the angles have been adjusted in equal increments. Minor closure problems due to rounding-off of angular values may exist.

f) Courses in descriptions that have calls for adjoiners may require careful review of other tracts and/or Real Estate Segment Maps or other maps furnished by the Government.

g) Resolution of problems with closure and interpreting calls for adjoiners or other non-geometric calls may be referred to the Contracting Officer's Representative.

h) The bearings in all descriptions are thought to be referred to true (astronomic) north. Since no coordinate system is apparent in the descriptions, careful selection of coordinate system origin is important to tie all the tracts together and fit in the system GIS. Individual tracts may be computed on a local assumed system and then rotated, scaled, and otherwise transformed to fit the system-wide scheme.

i) Product deliverables will also include all data files created in the GIS conversion process along with a stand alone point coordinate file for all tract boundary corners/angle points for non-GIS users.

j) A text file will also be created for each tract to preserve the dual description call system (words and numbers) for appropriate use in the final GIS as evidence of the intent of the mathematical data plotted for resulting maps.

k) Complete FGDC compliant metadata will be developed using the SMMS utility. Particular attention shall be given to the process description section of the metadata.

l) Each ArcInfo coverage will contain complete projection information provided by using the ArcInfo command PROJECTDEFINE.

m) The Contractor shall notify the Government in writing if the point of origin of a particular tract cannot be determined from the available information using approved mathematical techniques. The Corps will provide the Contractor with a point of origin for these tracts within 10 working days of the receipt of such notification. The Contractor shall, where practical, make these submissions in groups of not less than 10 tracts.

5. ATTRIBUTION:

a) All tracts shall be attributed with the following items:

   1) PROJECT_ID
   2) PARCEL_NO
   3) PLACE_STAT
   4) CAPTURE_METHOD

b) All attribution will be done in upper case. The data required to attribute these tracts will be provide in Microsoft Access format by the Government.

6. MATERIAL PROVIDED BY THE GOVERNMENT:

a) Digital othophotos in TIF world format of the Illinois Waterway. These orthophotos were developed in Illinois East and West State Plane Coordinate Systems, NAD 1983 US survey foot. The orthos were produced at two different resolutions for some pools. Use the highest resolution for your work in all cases.

b) Approximately 400 tracts on section maps and property descriptions delivered in PDF format.

c) The contractor will be responsible for obtaining the Spatial Data Standards and AEC CADD Standards information required for this project from the CADD\GIS Technology Center in Vicksburg, Mississippi (http://tsc.wes.army.mil).

7. QUALITY ASSURANCE:

a) GENERAL. Clean line work is generally understood as essential for quality GIS production. This level of quality consists of creating correctly closed graphic shapes or boundary features, placement of all centroids for area features, removal of overlapping or dangling linear features, edge-matching of graphic tiles, correct feature coincidence, and correct performance all graphic-to-database associations. The following paragraphs outline quality assurance steps and reporting requirements. The contractor shall provide the process report for all of the following QA steps on one of the CD-ROM disks in a directory called \QA.

b) QUALITY ASSURANCE TOOLS. Specific quality assurance tools are described by product name in the following sections. The contractor may prefer to use other COTS quality assurance tools which are compatible with their own GIS data development software tools. In this case, the contractor, at the pre-work conference, will correlate their software's functionality against the referenced tools' capabilities and demonstrate how they will report performance of these quality assurance checks using their own preferred tools.

c) TOPOLOGICAL ACCURACY. All digital map products should be topologically clean and free of errors. The topology of all required map products must be verified and free of overshoots, undershoots, slivers, open polygons (boundaries), unlabeled polygons, and unresolved line segment intersections. The digital representation of all coincident, common boundaries must be exactly the same. Coincident features are those which are in common between two or more data layers.

d) FEATURE CHECKING. All files shall be processed to flag and to correct any invalid features, attribution, and graphics symbology.

e) DATABASE RECORD CHECKING. All database records in the GIS shall be validated for meeting a series of validity checks. There shall be no orphaned records that have no associated graphics, have a NULL mapid value, have an invalid mapid value, or refer to an associated map file that cannot be opened.

f) POLYGON DEVELOPMENT: These polygons shall:

1) Be input using double precision;
2) By definition, all close;
3) The ArcInfo utility build will be run on each coverage;
4) Be fully attributed in accordance with Section 5.
5) In addition:
   i. Polygons with common borders shall share a common line.
   ii. No sliver polygons or other artifacts shall be formed as a result of adjacent polygons.
   iii. The shape files will contain only polygon feature types.

6) At the 10% review (see Appendix A, pg B8), the contractor shall specify in writing the methodology used to create and QC the coverages. This methodology shall include at a minimum:
   i. A detailed listing of the major steps involved with creating the coverages.
   ii. The assumptions made, if any, in their creation.

8. DELIVERABLES:

a) Store all finalized GIS data on CD-ROM format disks in directories named after the pool to which they represent. Each directory shall contain separate sub directories for GIS coverages, and survey data and calculations. Directories will also be made for intermediate products as defined in Section 4. An index in MicroSoft Excel of all the files in the CD shall be included with each CD. This index will include the file name, its location on the CD and a brief description of that file's contents. These CDs, upon completion of work, shall become the property of the Government.

b) All items provided by the Corps are considered non-expendable and shall be returned upon completion of this delivery order.

c) All submittals shall be accomplished in accordance with Appendix B (pg B9).

9.   QUALITY CONTROL PLAN:

The A/E shall submit a plan outlining the measures to ensure quality throughout the contract period. The quality control plan is to be submitted prior to the Partnering Meeting. The plan shall include as a minimum:

a) Project description.

b) Names and disciplines of all project team members.

c) Data development criteria and assumptions.

d) Review process procedures.

e) Complete schedule from concept design through construction contract award.

f) Responsibilities of the A/E and the Corps.

10.   COMMUNICATIONS AND DOCUMENTATION:

a) A free flow of communications is essential between the A/E and the Corps. The A/E and the Corps shall each assign a single point of contact. The Corps single point of contact through the design phase will be Roger Perk. Other points of contact will be established during the Design Partnering Conference. The A/E is responsible for appointing a project engineer/architect to act in a similar capacity. Mr. Perk's title and phone number:

  Roger Perk, PE
  Civil Engineer, Project Engineering Section
  309-794-5475

b) The A/E shall communicate regularly by E-mail, phone, and FAX. Mr. Perk's e-mail address and FAX number:

  Roger.A.Perk@usace.army.mil
  309-794-5698

c) The A/E shall document all meetings and records of pertinent conversations, beginning with the pre-proposal meeting and continuing throughout the design process.

d) The A/E shall provide minutes of all meetings within five business days to the Corps via E-mail.

11.   INFORMATION MEETINGS AND REVIEW CONFERENCES:

All meetings will be held at the Rock Island District Headquarters in Rock Island, Illinois. The following is the anticipated schedule:

12.   SCHEDULE:

The following schedule begins with the A/E contract award date. The 400 tracts on this project are

equally divided (as reasonably possible) amongst the submittals.

a) Project Partnering Meeting – Fifteen working days after contract award. Discussion of Contract issues. The Government will provide all information as required by this work order.

b) 10% Review – 30 working days after contract award. This review shall include a CD submission of the first ten tracts in final format. The information and materials to be provided at this submission is outlined in Appendix A.

c) 10% Review Meeting– 35 working days after contract award. This meeting will take place by teleconference/or at the Rock Island District HQ as determined by the nature of the comments.

d) 90% of T. J O'Brien and LockPort submitted – 50 working days after contract award.

e) Review Comments Returned on T. J O'Brien and LockPort submittal - 55 working days after contract award.

f) Final of T. J O'Brien and LockPort submitted – 60 working days after contract awarded.

g) 90% of Dresden, Marseilles, Starved Rock and Brandon Road submitted – 75 working days after contract award.

h) Review Comments Returned on Dresden, Marseilles, Starved Rock and Brandon Road Submittal - 80 working days after contract award.

i) Final of Dresden, Marseilles, Starved Rock and Brandon Road submitted – 85 working days after contract awarded.

j) 90% of Lockport, Peoria and LaGrange submitted – 100 working days after contract award.

k) Review Comments Returned on Lockport, Peoria and LaGrange #1 Submittal - 105 working days after contract award.

l) Final of Lockport, Peoria and LaGrange submitted – 110 working days after contract awarded.

m) Completion - The completed work shall be delivered to the COR by 110 working days after the contract is awarded.

n) Packaging of each final submission shall be accomplished such that the materials will be protected from handling damage. Each package shall contain a transmittal letter of shipping form, in duplicate, listing the materials being transmitted.

Appendix A
Requirements for 10% Submittal

The following items shall be submitted for review at the 10% submittal.

1. 3 Sets of CD'S for the first 10 tracts identified to the contractor at the project partnering meeting.
2. These CD's shall be named "Creation of Coverages from Real Estate Tracts, Illinois Waterway, 10% Submittal."
3. The CD's shall contain the directory structures, information and file formats as described for each final submission.
4. The submittal shall be in accordance with Appendix B.

A. GENERAL.

All design work, coverages, maps, computations, spreadsheets, text documents, project schedules, sketches and other miscellaneous documents to be provided under this task order shall be accomplished and developed using micro-computer based software and procedures conforming to the following criteria.

B. DOCUMENT FORMATS.

CADD data for all drawings shall be supplied in Bentley Corporation, three-dimensional or two-dimensional as appropriate, MicroStation J or later version native electronic digital format (i.e., .dgn, .cel, .i), Windows NT, and version currently used, operating system. The target platform is an Intel based computer using the Windows NT, version 4.x or later, operating system. The contractor shall ensure that all digital files and data (e.g., base files, reference files, cell libraries) are compatible with the Government's target CADD system (i.e., basic and advanced CADD software, platform, database software), and adhere to the standards and requirements specified herein. The term "compatible" means that data can be accessed directly by the target CADD system without translation, preprocessing, or postprocessing of the electronic digital data files. It is the responsibility of the A-E to ensure this level of compatibility.

GIS coverages shall be submitted in ArcInfo v 8.02 or greater format. Shape files shall be delivered in ArcView 3.2a or greater format. The non-graphical database delivered with prepared drawings shall be in Info format. All linkages of non-graphical data with graphic elements, relationships between database tables, and report formats shall be maintained. All database tables shall conform to the structure and field-naming guidance provided by the Government.

Text documents and spreadsheets shall be provided in Microsoft Office Suite 97 or later format. All scheduling should be accomplished using Microsoft Project 98 or later. All documents shall follow a standard naming convention that shall be submitted and approved in writing prior to the initiation of work. All documents that are to be submitted, but are not initially completed in electronic format, shall be scanned and converted to Adobe PDF format version 4.x or later. These documents shall also follow the approved naming convention. All other text or graphics output that is to be submitted that is not addressed in the above paragraphs shall be submitted in Adobe PDF format.

C. DOCUMENT STANDARDS.

All text documents, calculations, computer output as indicated herein and other non-CADD documents should be prepared on 8-1/2"x11" letter size paper and electronic equivalent. Where a letter sized paper is not appropriate sheet, sizes should be maintained at 8-1/2"x14" legal size and "11x17" report size. All units of weight and measure shall be in English units.

D. DELIVERY MEDIA AND FORMAT.

A copy of all GIS data, CADD data, CADD or GIS related files, and all project related submission documents developed under this contract shall be delivered to the Government on electronic digital media with each progress submission. All submittals shall be provided in their native electronic digital format and shall be provided on read-only memory (CD-ROM). The electronic digital media shall be in the format that can be read and processed by the Government's target Intel based computer system. Each

CD-ROM shall have an index file created in Microsoft Excel placed in its root directory named "index.xls" that shall contain as a minimum a list of the filenames, their directory location on the CD-ROM, and a brief description of their content. (i.e. CADD file would have the drawing title listed, a letter would have the subject listed):

The external label for each electronic digital media shall contain, as a minimum, the following information:

    (1) The Contract Number (and Delivery Order Number if applicable) and date.

    (2) The format and version of operating system software.

    (3) The name and version of utility software used for preparation (e.g., compression/decompression) and copying files to the media.

    (4) The sequence number of the digital media.

The files shall be copied to the delivery media using standard DOS copy or xcopy commands, or other methodology approved in writing by the Government, in an orderly directory structure approved by the Government. This directory structure shall be approved at least 5 working days prior to each submittal.

E. SCANNING AND PDF REQUIREMENTS.

All documents, including hand calculations, which are not created in those standard formats as described above, need to be printed or scanned to Adobe PDF format. The PDF file generation settings need to be submitted in writing and approved by the Government. Where necessary, documents shall be scanned at a resolution of 150 dots per inch (dpi) or greater. Files printed from scanned documents shall be as legible as the originals. Care shall be taken to optimize the scanning settings to ensure to avoid excessive PDF file size. All scanned documents shall be assembled into the fewest number of individual files as appropriate and grouped according to project task. All PDF files shall contain indexes that are hot linked to the appropriate sections of the document to facilitate its use. The PDF documents shall open to display a full sheet view of the first page of the document and the necessary bookmarks.

F. HARD COPY TRANSMITTALS.

A transmittal letter containing, as a minimum, the following information shall accompany each submittal to the Government. The transmittal letter shall be dated and signed by the appropriate A-E's representative. The transmittal letter shall be provided to the Government on 8-1/2-inch by 11-inch paper. An electronic copy of the transmittal letter in a Microsoft Word 97 or later format shall also be provided on the electronic digital media submitted to the Government.

    (1) The information included on the external label of each media unit (e.g., disk, tape), along with the total number being delivered, and a list of the names and descriptions of the files on each one.

    (2) Brief instructions for transferring the files from the media to a server or computer.

    (3) A signed certification document, attachment, that all delivery media are free of known computer viruses. A statement including the name(s) and release date(s) of the virus-scanning software used to analyze the delivery media, the date the virus scan was performed, and the operator's

name shall also be included with the certification. The release or version date of the virus-scanning software shall be the current version that has detected the latest known viruses at the time of delivery of the digital media.

(4) A statement indicating that the A-E will retain a copy of all delivered electronic digital media (with all files included) for at least one year and, during this period of time, will provide up to two additional copies of each to the Government, if requested, at no additional cost.

G. OWNERSHIP.

The Government, for itself and such others as it deems appropriate, will have unlimited rights under this contract to all information and materials developed under this contract and furnished to the Government and documentation thereof, reports, and listings, and all other items pertaining to the work and services pursuant to this agreement including any copyright. Unlimited rights under this contract are rights to use, duplicate, or disclose text, data, drawings, and information, in whole or in part in any manner and for any purpose whatsoever without compensation to or approval from the A-E. The Government will at all reasonable times have the right to inspect the work and will have access to and the right to make copies of the above-mentioned items. All text, electronic digital files, data, and other products generated under this contract shall become the property of the Government. By reference, the following DFAR clauses are included in this contract as a part of the requirements herein:

a. DFAR 252.227-7013, "Rights in Technical Data and Computer Software."

b. DFAR 252.227-7018, "Restrictive Markings on Technical Data."

c. DFAR 252.227-7019, "Identification of Restricted Rights Computer Software."

d. DFAR 252.227-7028, "Requirement for Technical Data Representation."

e. DFAR 252.227-7037, "Validation of Restrictive Markings on Technical Data."

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13. SUPPLEMENTARY NOTES

14. ABSTRACT

Currently, the U.S. Army Corps of Engineers relies primarily on hard-copy paper maps and documents to manage real estate assets. It is now widely understood that real estate data are fundamentally geospatial and that there is great advantage to managing and maintaining cadastral information in a geographic information system (GIS). In order to provide the data in a geographic format, the existing spatial hard copy and digital data must be converted into an appropriate format.

The most common methods to convert existing spatial data to a GIS include using Coordinate Geometry (COGO) with paper maps and survey documents, converting computer-aided drafting drawings; digitizing hard-copy maps; and scanning hardcopy maps and then using heads up digitizing or automated vectorization. These methods are discussed in this report. Four Corps District Offices have provided examples of their spatial data conversion methods.

15. SUBJECT TERMS
See reverse.

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15. (Concluded)

Cadastral
Cadastre
COGO
Geographical information system
GIS
Real Estate
Real estate management information system
REMIS
Spatial data conversion