Midwest Geological Sequestration Consortium

Assess Carbon Dioxide Transportation Options in the Illinois Basin

Topical Report

October 1, 2003–September 30, 2005

Douglas J. Nyman
D.J. Nyman & Associates

J. Steve Dracos
Universal Ensco, Inc.

Preparer Contact: Robert Finley
Illinois State Geological Survey
(217) 244-8389
finley@isgs.uiuc.edu

Report Issued: December 31, 2005

U.S. DOE Contract: DE-FC26-03NT41994

The Board of Trustees of the University of Illinois
K.L. Williams, Associate Director
c/o Grants & Contracts Office
1901 S. Research Park, Suite A
Champaign, IL 61820

Illinois State Geological Survey
with Team Members:
Kentucky Geological Survey
Indiana Geological Survey
Southern Illinois University
Brigham Young University
D.J. Nyman & Associates

Disclaimer

Contents

Scenarios and Outcomes for a Specific Carbon Dioxide Transportation Option, Pekin to Edwards County, Illinois: 7,700,000 Tons of CO_2 per Year, Pipeline Route, Size Calculation, and Cost Based on Task 3 (M 4-12)

Introduction

The team of Dr. D.J. Nyman and Associates and Universal Ensco, Inc. (UEI) was commissioned to prepare this report on a specific carbon dioxide (CO_2) pipeline transportation option in support of the Midwest Geological Sequestration Consortium's (MGSC) assessment of opportunities for geological sequestration of CO_2 in the Illinois Basin.

This report was prepared by J. Steve Dracos of UEI, under the general direction of Douglas J. Nyman of D.J. Nyman & Associates. Mr. Dracos was assisted by UEI's engineering and Geographic Information Systems (GIS) staff in the assessment of pipeline hydraulics and routing of the pipeline. This report presents a specific pipeline route, a range of pipeline diameter, and cost for each diameter in response to a specific transportation scenario between a main CO_2 source and a storage site as defined by the Illinois State Geological Survey (ISGS). The presentation is based on the 2004 MGSC report to the U.S. Department of Energy (DOE) (Phase I, year 1) *Assessing CO_2 Pipeline Transportation Options in the Illinois Basin* by Nyman and Dracos. Initially, the ISGS provided two possible options but ultimately selected a scenario for transportation of 10.3 million m^3/day (362 million standard cubic feet (scf)/day) or 6,985,322 tonnes/year (7,700,000 tons/year) of CO_2 from the Pekin, Illinois, area (Pekin) to a terminal point in Edwards County, Illinois. The selected conceptual route originated in the Pekin area central to an existing power plant. The route runs generally southward to a point slightly east of Springfield and then turns south-southeasterly toward the Illinois-Indiana border. The terminal point in Edwards County was selected by ISGS as an approximate geographic central point for the MGSC's estimate for CO_2 storage in the Illinois Basin.

The 2004 report was based on a conceptual route with beginning and ending points that are very similar to the specific scenario requested for this study by ISGS. Because of this similarity, the data and discussions of the previous route are applicable to this report. As such, it is recommended that the reader review the previous report prior to reading this report.

Even though a specific route has been selected, this analysis remains in the conceptual stage. Sufficient data have been obtained and analyzed to provide a basis for making the key determinations necessary to move the project to the basic design stage.

Preliminary Route Selection

Route selection was based on origination and termination points provided by the ISGS. The origination point was a large power plant near Pekin, Illinois (Lat 40° 32’ 23.84” N, Long 89° 40’ 42.98” W). The termination point was the geographic central point of an oil production area in Edwards County, Illinois (Lat 38° 24’ 52.54” N, Long 88° 6’ 5.40” W), which potentially could use CO_2 for enhanced oil recovery operations in the future. The straight line distance between these points is 273.4 km (169.9 miles).

As discussed in the 2004 report, pipeline routes are selected in two stages, preliminary route selection and detailed route selection. The preliminary route is used as a basis for the planning and budgeting phases of the project. Once the project receives funding for permitting and right-of-way acquisition, detailed route selection and design are initiated. The work developed and presented in this report pertains to the preliminary route selection.

The objective of the preliminary route selection is to identify a viable pipeline route that will minimize impact to the public, landowners, and the environment pursuant to commercial constraints. This objective was accomplished based on UEI’s existing general knowledge of the area and also on information relative to land acquisition, environmental requirements, and construction methods compiled in the previous report. These data and knowledge were then applied to specific site data acquired by UEI’s GIS department. The GIS group obtained data from various Internet resources to support the “in-office” route selection process. Due to the abundance of detailed information relevant to routing a pipeline through Illinois, the preliminary route selection defined herein is thought to be valid and unlikely to change significantly during a subsequently detailed route selection phase. If the project receives further funding, ground or aerial reconnaissance should be used to confirm the route. In addition, high resolution aerial photography should be purchased and the route refined before the start of planning for survey, land acquisition, environmental review, permitting, construction, and detailed route selection.

Route Selection Process

Data Acquisition.

Land use data in GIS form were obtained from Web sites maintained by the U.S. Census Bureau, ESRI, the Illinois Department of Agriculture, ISGS, and the U.S. Department of Agriculture (Table 1).

GIS Data Compilation.

Land use data were imported into an ArcView GIS database.

Table 1. Illinois mapped data used for pipeline routing.

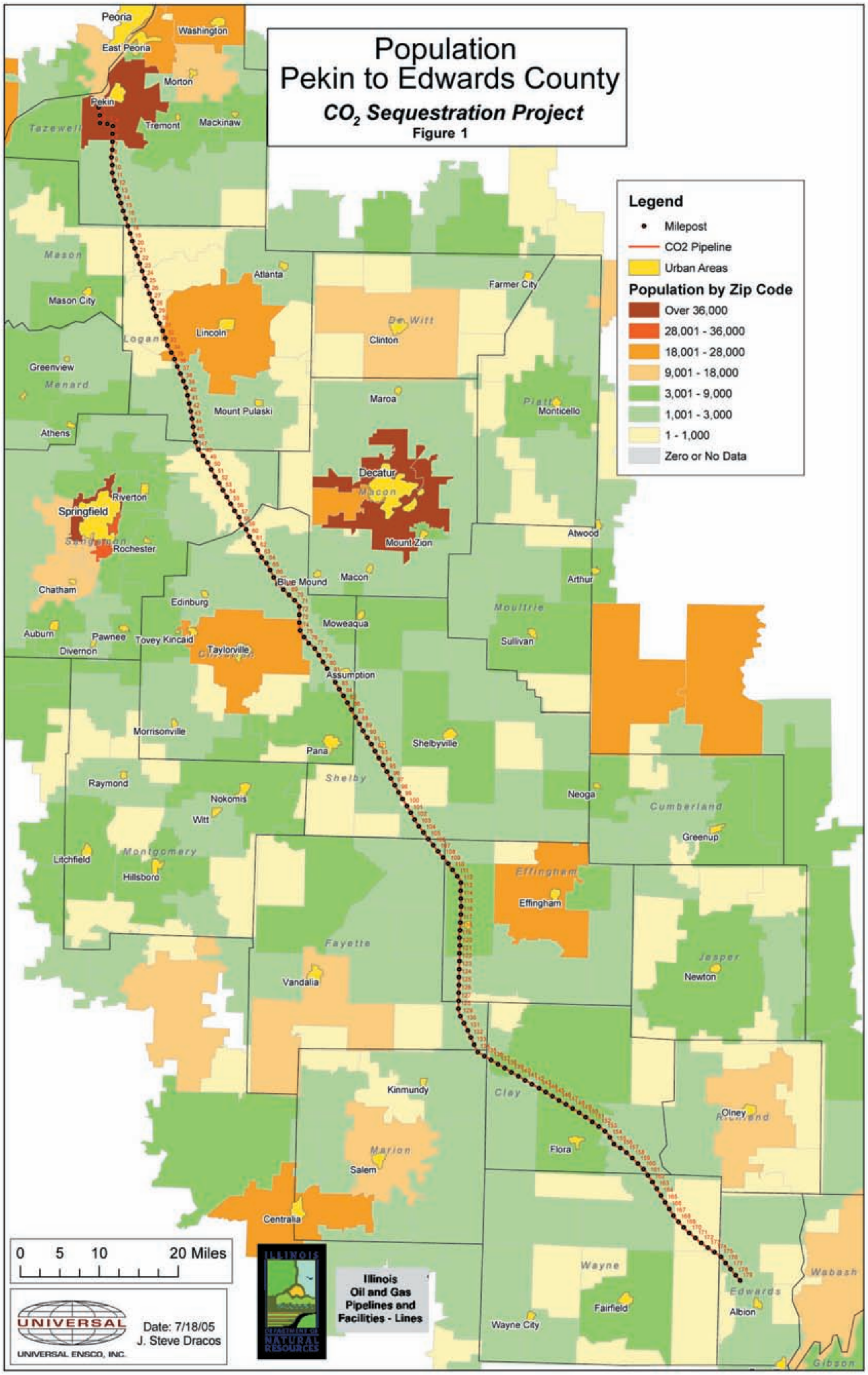
Source	Description	Review attributes
U.S. Census Bureau	Topologically Integrated Geographic Encoding and Referencing system (TIGER) Data. Web site - http://www.census.gov/geo/www/tiger/	• Roads • Railroads • Rivers • County lines • Water bodies • Urban areas • Population by zip code
Digital Chart of the World (DCW)	ESRI product developed for the US Defense Mapping Agency. Web site www.geocomm.com	• Power lines • Parks • Federal lands • Landmarks
Illinois Department of Agriculture	Web site http://www.agr.state.il.us/gis/landcover.html	• Land use
Illinois State Geological Survey	Web site http://www.isgs.uiuc.edu/nsdihome/browse/statewide/pipelineb.gif	• Pipelines
U.S. Department of Agriculture	Web site http://datagateway.nrcs.usda.gov/	• Land use a) 1:24,000 Digital Raster Graphics b) 1-m grayscale imagery

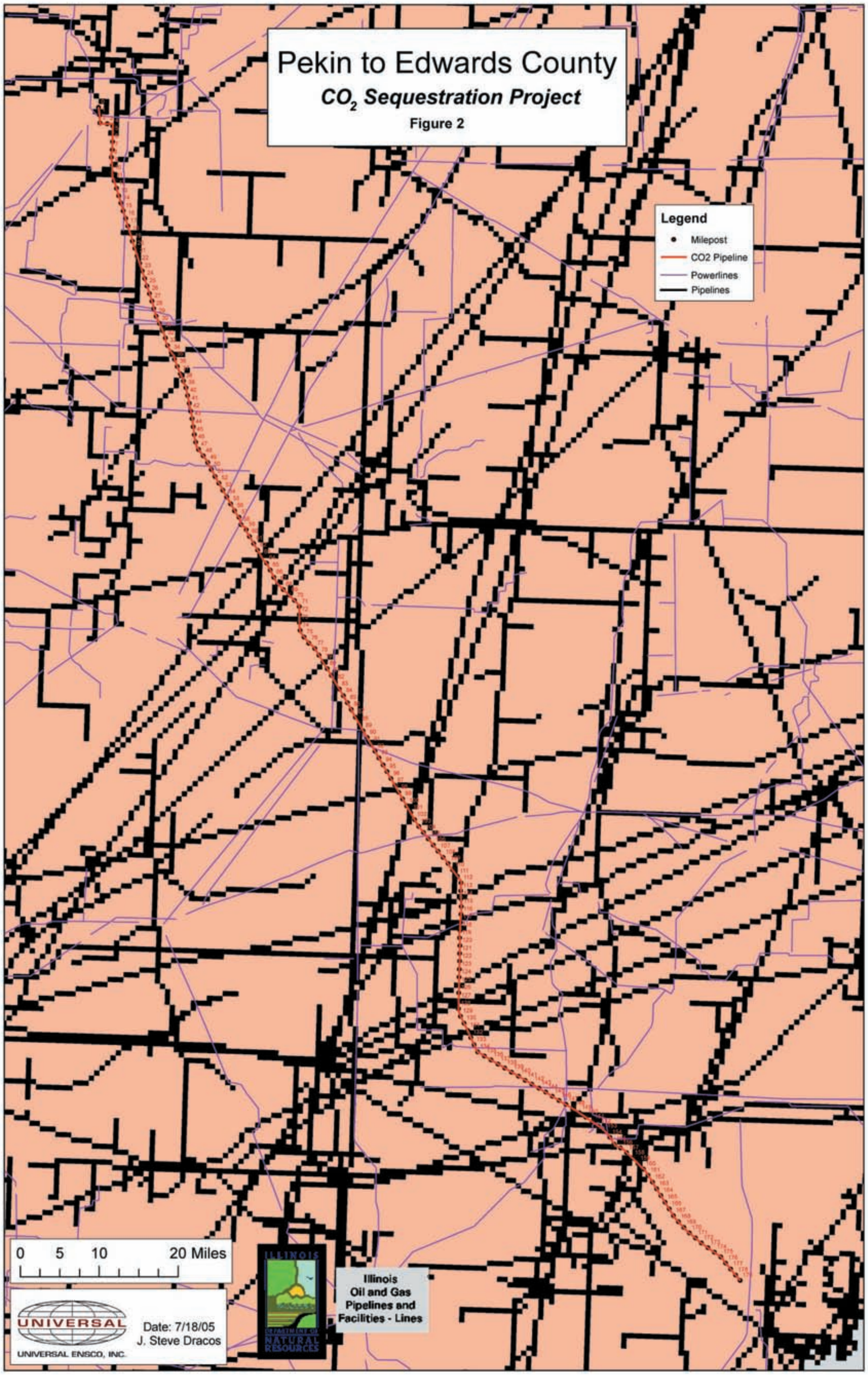
Route Review.

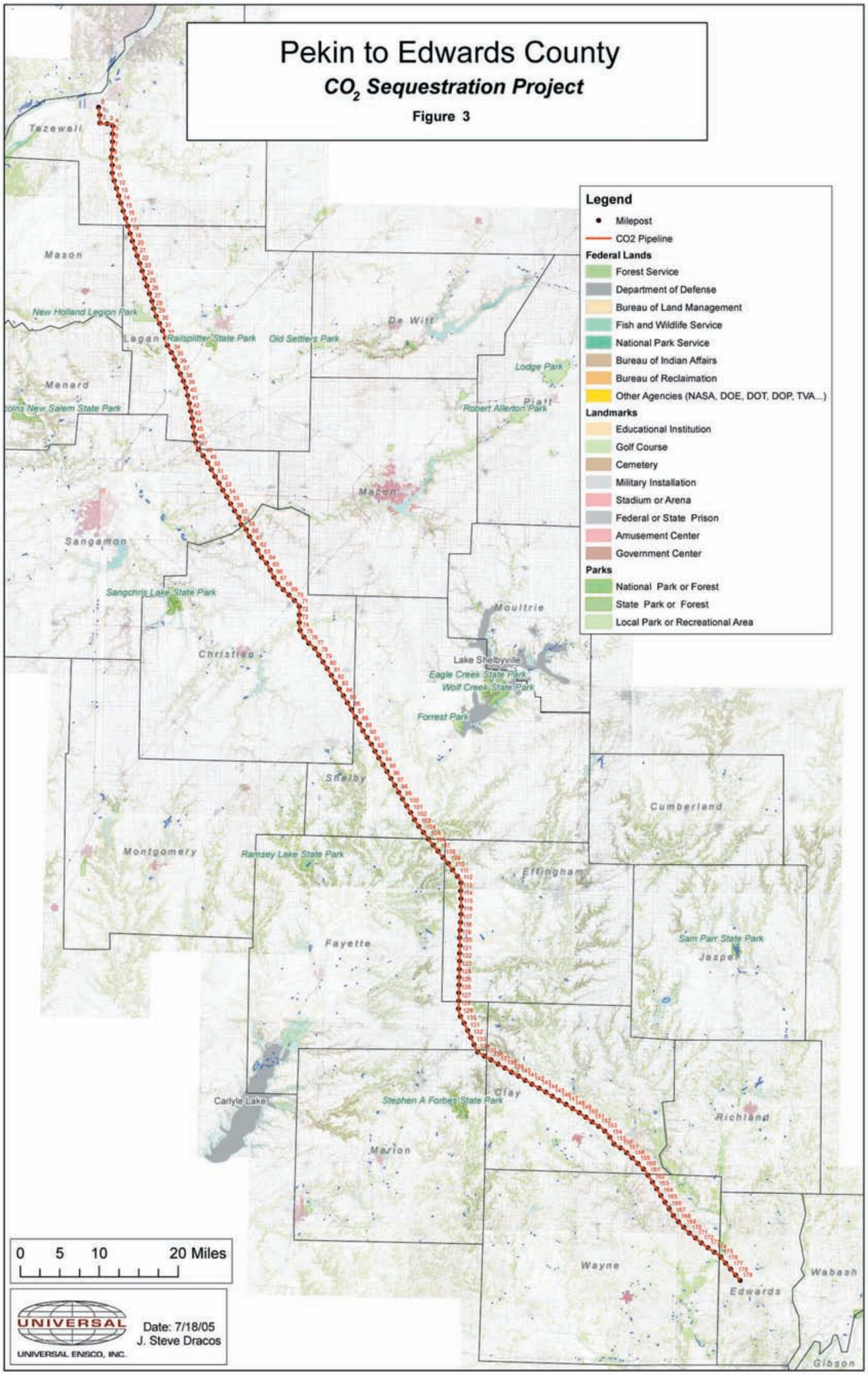
The general pipeline route was reviewed by reference to commonly available maps and general knowledge of the central Illinois landscape. The route passes through prime farmland, generally without major terrain or environmental features. Thus, the main parameters that governed route location reverted to avoidance of population centers, utilities, parks, and rivers. By including these factors, the route was optimized for land use by GIS data and GIS aerial photography.

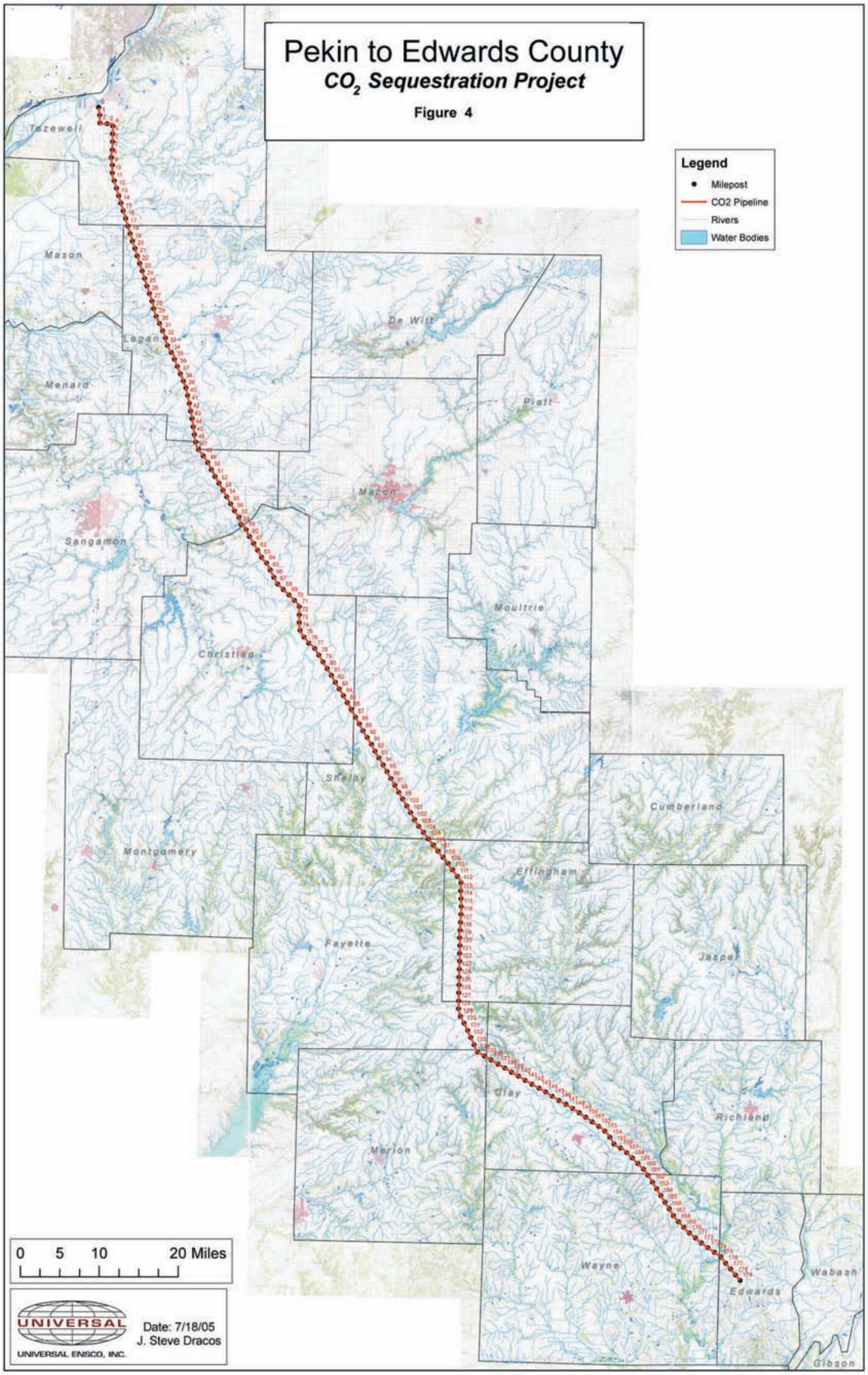
1. ***Population*** The 273.4-km (169.9-mile) direct route was examined while viewing the urban areas and population by zip code data (Figure 1). The reviews indicated a direct route would pass through the following urban areas: Lincoln, West Decatur, and Shelbyville. The best possible routing to avoid these areas would be to the west. Therefore, the direct route was segmented by adding vertices or points of intersection (PI) midway between Springfield and Decatur.

2. ***Utility corridors*** The newly segmented route was reviewed against utility, pipeline, and railroad data (Figure 2). Most cross-country pipelines in Illinois are oriented in a southwest to northeast direction and, thus, are of little use as a possible corridor for the proposed CO_2 pipeline, which would run generally in a south-southeast orientation. The data also show that most utilities are east-to-west or north-to-south with no significant existing corridor near the proposed route. Therefore, existing utility corridors appear to be of limited use in the preliminary design. Existing utility corridors should be examined more carefully during the detailed route selection process, but it is doubtful that the prospects for using existing utility corridors would improve.

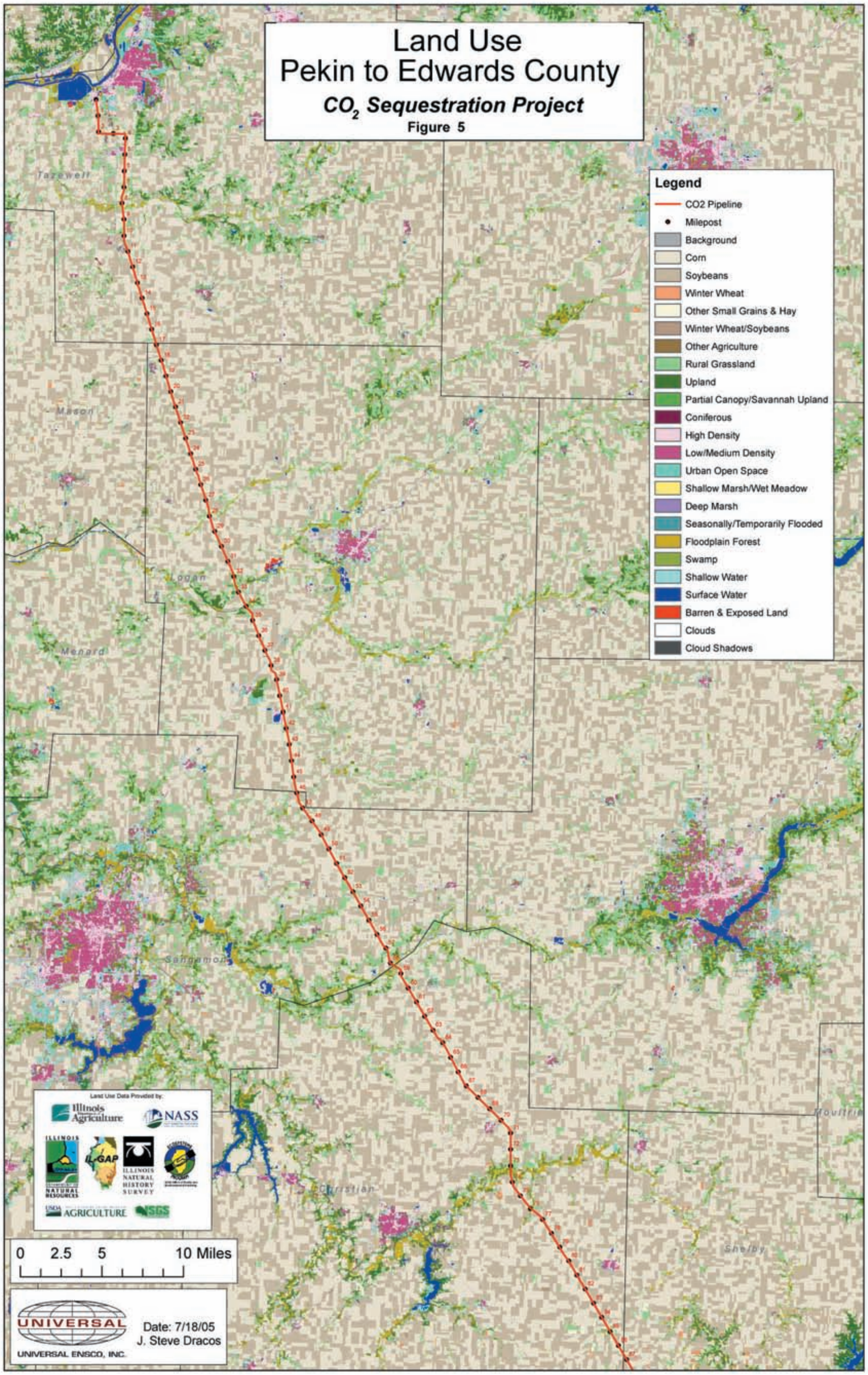

Population
Pekin to Edwards County
CO_2 Sequestration Project
Figure 1
Legend
Milepost
CO2 Pipeline
Urban Areas
Population by Zip Code
Over 36,000
28,001 - 36,000
18,001 - 28,000
9,001 - 18,000
3,001 - 9,000
1,001 - 3,000
1 - 1,000
Zero or No Data
Peoria
Washington
East Peoria
Morton
Pekin
Tremont
Mackinaw
Tazewell
Mason
Mason City
Atlanta
Farmer City
De Witt
Clinton
Logan
Lincoln
Greenview
Menard
Mount Pulaski
Maroa
Piatt
Monticello
Athens
Decatur
Macon
Riverton
Springfield
Sangamon
Rochester
Mount Zion
Atwood
Chatham
Blue Mound
Macon
Arthur
Edinburg
Moultrie
Auburn
Pawnee
Tovey
Kincaid
Taylorville
Christian
Moweaqua
Sullivan
Divernon
Assumption
Morrisonville
Pana
Shelbyville
Shelby
Raymond
Nokomis
Witt
Neoga
Cumberland
Greenup
Litchfield
Montgomery
Hillsboro
Effingham
Effingham
Fayette
Jasper
Newton
Vandalia
Kinmundy
Clay
Olney
Richland
Marion
Salem
Flora
Centralia
Wayne
Wabash
Edwards
Albion
Fairfield
Wayne City
Gibson
0 5 10 20 Miles
UNIVERSAL
UNIVERSAL ENSCO, INC.
Date: 7/18/05
J. Steve Dracos
Illinois
Oil and Gas
Pipelines and
Facilities - Lines


Pekin to Edwards County
CO2 Sequestration Project
Figure 2
Legend
Milepost
CO2 Pipeline
Powerlines
Pipelines
0 5 10 20 Miles
UNIVERSAL
UNIVERSAL ENSCO, INC.
Date: 7/18/05
J. Steve Dracos
Illinois
Oil and Gas
Pipelines and
Facilities - Lines

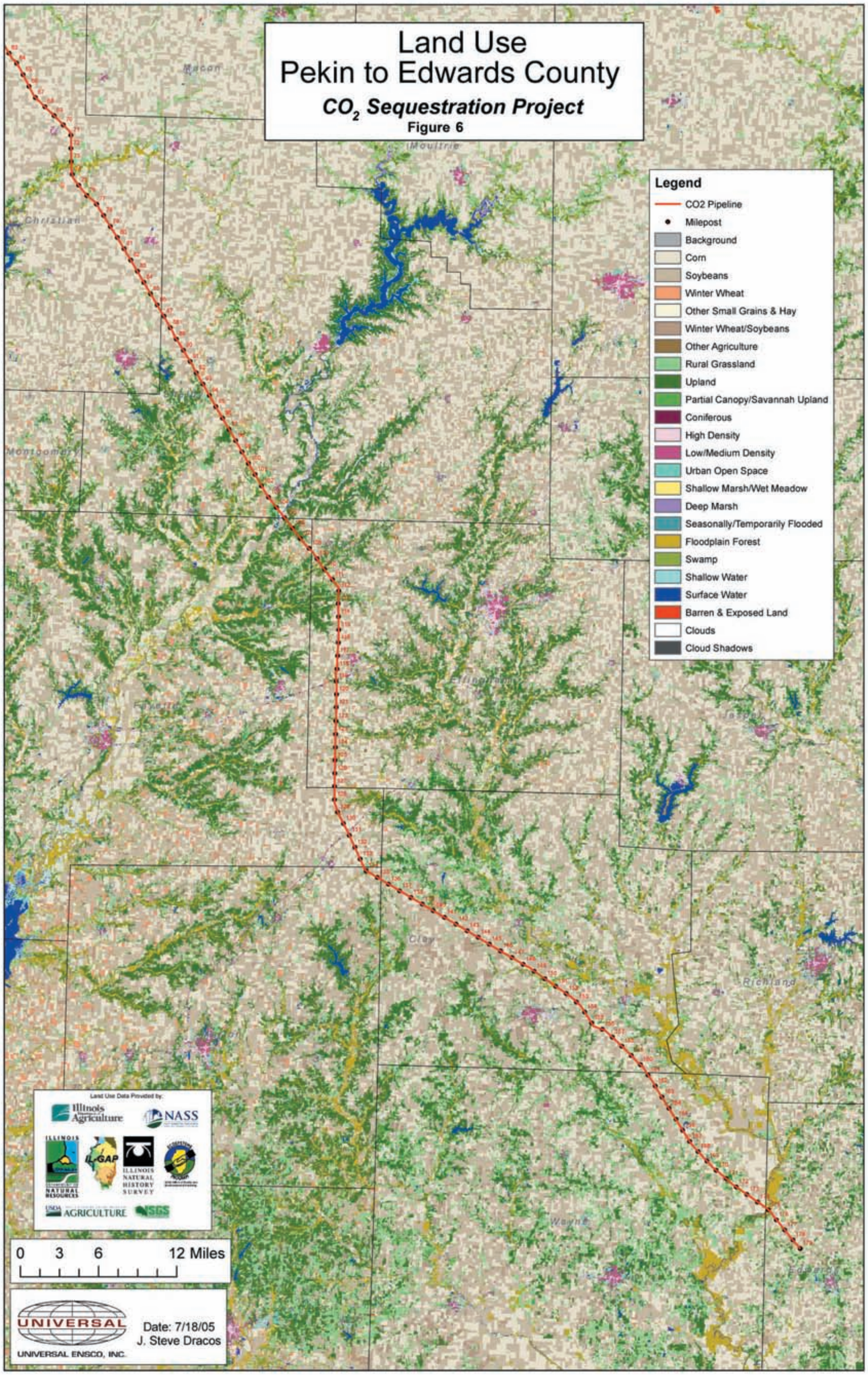

Pekin to Edwards County
CO_2 Sequestration Project
Figure 3
Legend
Milepost
CO2 Pipeline
Federal Lands
Forest Service
Department of Defense
Bureau of Land Management
Fish and Wildlife Service
National Park Service
Bureau of Indian Affairs
Bureau of Reclamation
Other Agencies (NASA, DOE, DOT, DOP, TVA...)
Landmarks
Educational Institution
Golf Course
Cemetery
Military Installation
Stadium or Arena
Federal or State Prison
Amusement Center
Government Center
Parks
National Park or Forest
State Park or Forest
Local Park or Recreational Area
Tazewell
Mason
New Holland Legion Park
Logan
Railsplitter State Park
Old Settlers Park
De Witt
Lodge Park
Menard
Piatt
Robert Allerton Park
Lincolns New Salem State Park
Macon
Sangamon
Sangchris Lake State Park
Moultrie
Christian
Lake Shelbyville
Eagle Creek State Park
Wolf Creek State Park
Forrest Park
Shelby
Cumberland
Montgomery
Ramsey Lake State Park
Effingham
Sam Parr State Park
Jasper
Fayette
Carlyle Lake
Stephen A Forbes State Park
Clay
Richland
Marion
Wayne
Wabash
Edwards
Gibson
0 5 10 20 Miles
UNIVERSAL
UNIVERSAL ENSCO, INC.
Date: 7/18/05
J. Steve Dracos



Pekin to Edwards County
CO_2 Sequestration Project
Figure 4
Legend
Milepost
CO2 Pipeline
Rivers
Water Bodies
Tazewell
Mason
Logan
De Witt
Menard
Piatt
Macon
Sangamon
Moultrie
Christian
Shelby
Cumberland
Montgomery
Effingham
Fayette
Jasper
Clay
Richland
Marion
Wayne
Wabash
Edwards
Gibson
0 5 10 20 Miles
UNIVERSAL
UNIVERSAL ENSCO, INC.
Date: 7/18/05
J. Steve Dracos



Land Use
Pekin to Edwards County
CO_2 Sequestration Project
Figure 5
Legend
CO2 Pipeline
Milepost
Background
Corn
Soybeans
Winter Wheat
Other Small Grains & Hay
Winter Wheat/Soybeans
Other Agriculture
Rural Grassland
Upland
Partial Canopy/Savannah Upland
Coniferous
High Density
Low/Medium Density
Urban Open Space
Shallow Marsh/Wet Meadow
Deep Marsh
Seasonally/Temporarily Flooded
Floodplain Forest
Swamp
Shallow Water
Surface Water
Barren & Exposed Land
Clouds
Cloud Shadows
Tazewell
Mason
Logan
Menard
Sangamon
Christian
Shelby
Land Use Data Provided by:
Illinois Agriculture
NASS
IL-GAP
Illinois Natural History Survey
USDA Agriculture
0 2.5 5 10 Miles
UNIVERSAL
UNIVERSAL ENSCO, INC.
Date: 7/18/05
J. Steve Dracos



Land Use
Pekin to Edwards County
CO_2 Sequestration Project
Figure 6
Legend
CO2 Pipeline
Milepost
Background
Corn
Soybeans
Winter Wheat
Other Small Grains & Hay
Winter Wheat/Soybeans
Other Agriculture
Rural Grassland
Upland
Partial Canopy/Savannah Upland
Coniferous
High Density
Low/Medium Density
Urban Open Space
Shallow Marsh/Wet Meadow
Deep Marsh
Seasonally/Temporarily Flooded
Floodplain Forest
Swamp
Shallow Water
Surface Water
Barren & Exposed Land
Clouds
Cloud Shadows
Macon
Moultrie
Christian
Montgomery
Clay
Richland
Wayne
Land Use Data Provided by:
Illinois Agriculture
NASS
IL-GAP
Illinois Natural History Survey
USDA Agriculture
0 3 6 12 Miles
UNIVERSAL
UNIVERSAL ENSCO, INC.
Date: 7/18/05
J. Steve Dracos

3. ***Parks, preserves, and landmarks*** The route was reviewed with federal lands, landmarks, and park data (Figure 3). Only one area of interference was located at the New Holland Legion State Park. A few PIs were added to move the pipeline route to the east of the park.

4. ***Rivers, wetlands, and water bodies*** Route review with the river, wetlands and waterbodies (Figure 4) indicated a possible problem at the lower one-third of it where the route did not cross the watersheds but actually followed them. Using the GIS system, a count and listing of the water crossings were for the lower third of the route showed multiple crossings of the tributaries of the Little Wabash River. As a result, a more detailed view of the route was analyzed, and a significant number of PIs were added. The route at the lower end was moved to the west so that it crossed the Little Wabash River only once and did not run along the river valley. Using the more detailed view, PIs were also added on the rest of the pipeline route to cross streams in as short a deep burial segment as possible (essentially perpendicular to stream channels) and to avoid running parallel to streams.

5. ***Land use*** Land use data from the Illinois Department of Agriculture for 1999 through 2000 was reviewed relative to the pipeline route (Figures 5 and 6). These data indicated that additional rerouting (more PIs) was necessary in the lower third of the route to minimize impact on the floodplain forests. These were avoided due to the probability of encountering old growth forest, the Indiana bat habitat, and archeological sites.

6. ***Photography*** The route was viewed using 1-m pixel, orthorectified photography available from Terra-Server. The route was reviewed from south to north in an iterative process to minimize/optimize the crossing of other pipelines, roads, railroads and streams. Some effort was made to avoid routing the pipeline near farm residences. During the session, the route from the originating point near Pekin was revised to be southerly to a point where it turned east until encountering a railroad, which it could then follow to the south out of the Pekin area. A series of route maps (1 inch on the map represents 2,000 ft on the ground surface) are included in the Appendix.

After the route was set, the GIS system added the mileposts to each of the maps in the report. The route modifications increased the length of the preliminary route from a 273.4-km (169.9-mile) straight line distance to a total length of 287.9 km (178.9 miles).

A summary of land use along the pipeline route is provided by county in Table 2. The land use along the route is agricultural; the mix of crops is primarily corn and soybeans.

Table 2. Land use summary along pipline route.

	Land use by county (%)[1]											
Land use description	**Tazewell**	**Logan**	**Sangamon**	**Christian**	**Shelby**	**Fayette**	**Effingham**	**Marion**	**Clay**	**Wayne**	**Edwards**	**Total**
Agricultural	90.6	93.7	94.6	93.9	81.6	78.7	85.6	90.8	91.9	89.9	79.0	90
Pasture	7.3	5.2	4.4	3.9	6.8	2.9	5.2	2.2	5.2	4.6	9.0	5
Marsh and streams	0.0	0.1	0.0	0.2	1.1	1.4	0.8	0.4	0.0	0.0	0.7	0
Floodplain forest	0.0	0.2	0.0	1.0	1.1	0.8	0.3	0.0	0.3	0.0	5.1	1
Timber	0.0	0.0	0.1	0.5	1.5	0.3	1.1	4.0	1.0	3.9	4.5	1
Scrub	0.0	0.3	0.0	0.4	7.7	15.7	6.3	2.6	1.5	1.3	1.7	3
Light urban	2.1	0.6	0.9	0.2	0.1	0.2	0.5	0.0	0.1	0.3	0.0	0
	100	100	100	100	100	100	100	100	100	100	100	100
	Agricultural makeup by county (%)[1]											
Crop type	**Tazewell**	**Logan**	**Sangamon**	**Christian**	**Shelby**	**Fayette**	**Effingham**	**Marion**	**Clay**	**Wayne**	**Edwards**	**Total**
Corn	63.1	59.1	48.2	55.7	27.7	42.7	35.3	31.2	24.9	43.1	40.1	45.1
Soybeans	36.9	40.9	50.0	41.8	59.6	48.0	43.9	45.2	60.6	47.1	40.9	47.1
Winter wheat	0.0	0.0	1.8	0.3	7.6	0.8	7.0	5.8	0.0	1.8	0.0	1.8
Winter wheat/soybeans	0.0	0.0	0.0	0.4	2.6	5.0	11.6	17.8	13.5	5.6	14.8	4.6
Other small grains & hay	0.0	0.0	0.0	1.7	2.3	0.3	2.3	0.0	1.1	2.4	4.1	1.2
Other agriculture	0.0	0.0	0.0	0.1	0.3	3.1	0.0	0.0	0.0	0.0	0.0	0.2
	100	100	100	100	100	100	100	100	100	100	100	100

[1]Illinois Department of Agriculture (1999–2000).

Design Elements

A preliminary diameter or ranges of diameters were selected based on the planned flow rate and the route selected. The preliminary route indicates that 10.3 million m^3/day (362 million scf/day) of CO_2 will be transported over a distance of 287.9 km (178.9 miles) from Pekin, Illinois, to Edwards County, Illinois. Due to the conceptual status of the project and the limited scope of services for Task 9, the diameter selection process is limited to the methods for sizing described in Section 3 of the 2004 Task 3 report. Although these methods are approximate they will provide a valid range of diameters so that the costing phase of the scope of work can be accomplished.

If the project proceeds to the basic engineering phase, the hydraulics and costing will be developed with greater specificity and accuracy. During the basic engineering phase, the pipeline diameter should be optimized for multiple cases using hydraulic calculations for a range of diameters, wall thicknesses, pipe grades, pumping configurations, and delivery pressures. For each case, an accurate capital cost, power cost, and operating cost will be prepared. In addition, the economic impact of multiple phase flow pattern will be investigated. All of these variables will be assessed based on the owners' economic guidelines (such as the minimum acceptable internal rate of return for capital) to develop the pipeline diameter.

Because this is a conceptual report, attempting to optimize any single item from this list will not add value to the end results. Within a given range of diameters, however, some operational considerations are presented that demonstrate potential impact on flow rate and cost.

Pipeline Diameter

Referring to the discussion in Section 3 of the 2004 MGSC pipeline report, CO_2 pipelines normally operate in the supercritical region, which is above 7,433 kPa (1,078 psia). Most CO_2 pipelines operate with an upstream pressure of 17,237 kPa (2,500 psig) or higher and have a delivery pressure near 10,342 kPa (1,500 psig). The meter and regulator stations at each end require a pressure drop of approximately 345 kPa (50 psi) each, which gives a pipeline differential pressure of about 6,895 kPa (1,000 psi) to achieve the flow rate. For the purpose of this preliminary design, the maximum and minimum operating pressures in the pipeline are approximated as 17,237 kPa (2,500 psig) and 10,342 kPa (1,500 psig), respectively, in this report. Graphs from Section 3 of the 2004 report for pressure drop and horsepower versus flow rate for pipeline diameters ranging from 4.5 to 24 inches are duplicated as Figures 7 and 8 respectively. These figures were used to determine a range of diameters for further hydraulic analysis.

Three pipeline diameters, 40.64, 45.72, and 50.8 cm (16, 18, and 20 inches), were selected for hydraulic calculations using the formula in Section 3 of the 2004 report. The calculations were made using

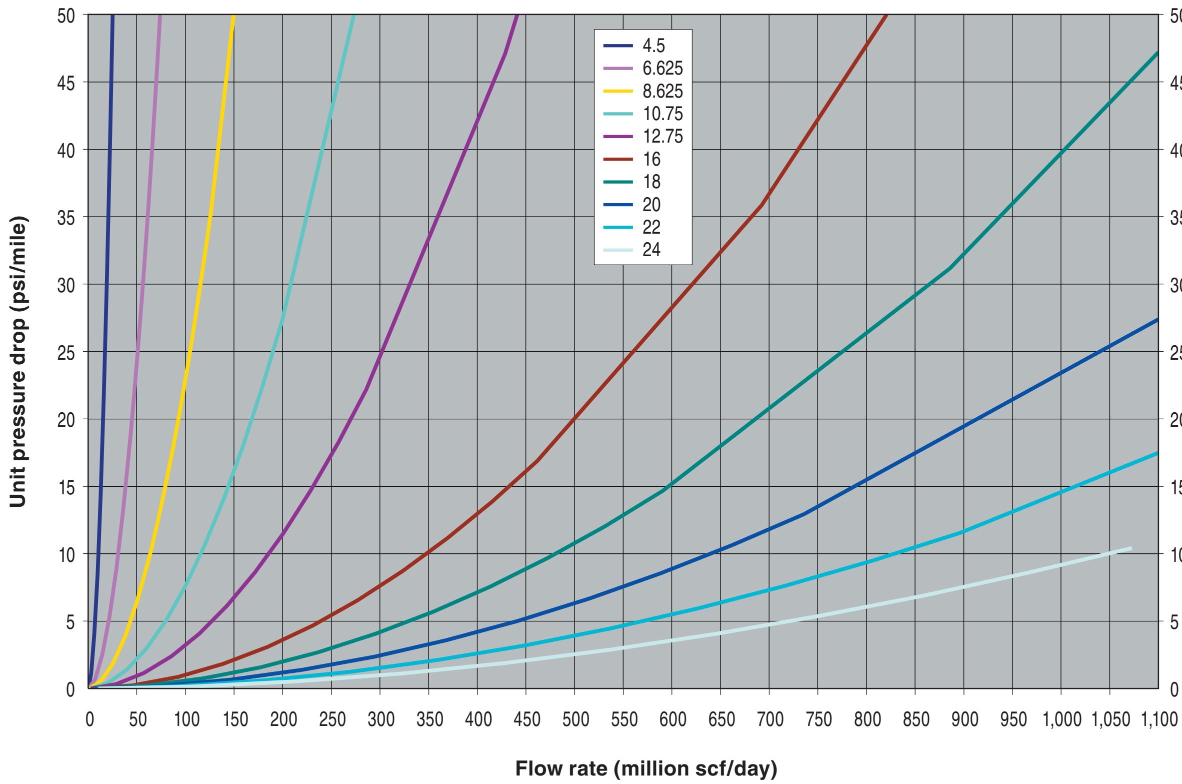


Figure 7 *Unit pressure drop versus flow rate as a function of pipe outside diameter.*

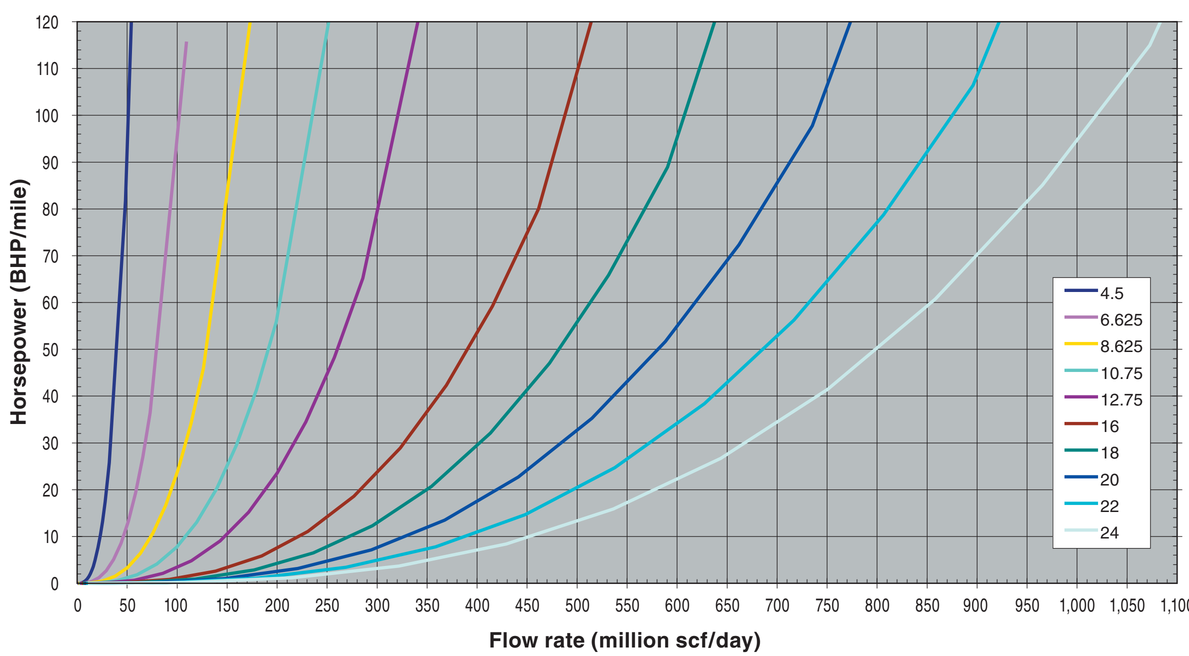


Figure 8 *Horsepower versus flow rate as a function of pipe outside diameter.*

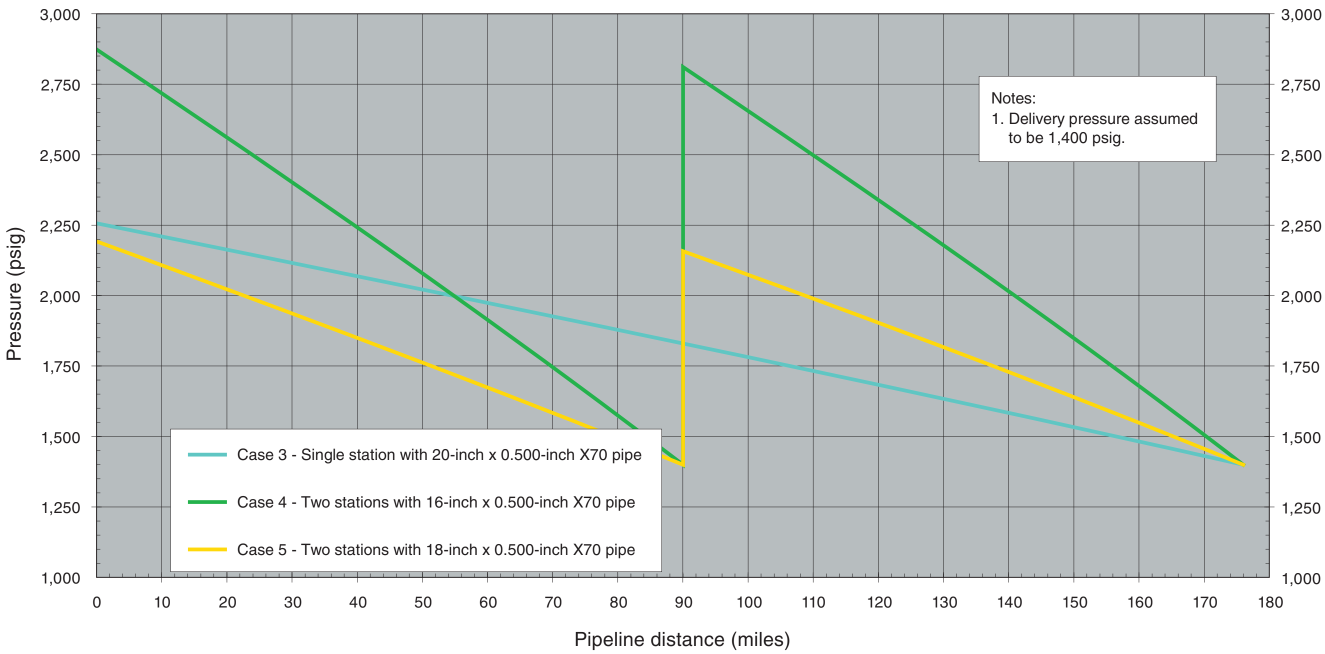


Figure 9 *Specific transportation option, Pekin to Edwards County, Illinois: 7.7 million tons per year,* CO_2 *sequestration pipeline.*

8.0-km (5-mile) segments to calculate the CO_2 properties, assuming no elevation change along the route, a booster station location (if required) at Milepost (MP) 90, and an assumed pipeline length of 287.9 km (178.9 miles) based on the route analysis. The cases calculated were for a 40.64-cm (16-inch) pipeline with origin station and booster station, an 45.72-cm (18-inch) pipeline with origin station and booster station, and a 50.8-cm (20-inch) pipeline with origin station only. After a number of calculations were made it was decided to use a lower delivery pressure from 10,342 to 9,653 kPa (1,500 psi to 1,400 psi). The results of the calculations are displayed for the three cases as a plot of pressure versus distance in Figure 9, and the specific pressure and horsepower are summarized in Table 3.

These three cases demonstrate the typical cases that are presented in the scoping phase of the basic engineering sizing of a pipeline. The first case is the smallest diameter pipeline with booster stations that meet the initial flow rate but lacks expansion capability. This case has the lowest construction cost but consumes the most power and for this report is represented by the 40.64-cm (16-inch) pipeline with origin and booster station. The second case is usually represented by the diameter that does not require booster stations. By definition, this case always has significant expansion capability augmented by the addition of booster stations (50.8-cm (20-inch) pipeline in this report). The final case that is usually presented is a diameter and boosting configuration that is a compromise between the first and second case (45.72-cm (18-inch) pipeline in this report). Detailed costs are then prepared for each case to determine which should be optimized. The cost of the 16-, 18-, and 20-inch pipeline cases are presented next.

Table 3. CO_2 pipeline design for flow rate of 362 million scf/day and distance of 180 miles.[1]

Pipe diameter (inch)	Pressure (psi)		BHP required per mile (Figure 8)	BHP required (HP)		Required
	Origin station	Booster station MP 90		Origin station at Pekin	Two booster stations MP90	Station total (psi)
16	2,870	2,810	40	3,600	3,560	7,160
18	2,190	2,160	22	1,980	1,960	3,940
20	2,250		12.5	2,240	N/A	2,230

[1]Assumptions: pipeline length is 178.9 miles; flow rate is 362 million scf/day; minimum pressure is approximately 1,400 psi per Figure 8; maximum pressure is approximately vary psi as per the 2004 Task 3 report; single station operation is desired if maximum pressure will not exceed 2,500 psi; if two stations are required, assume section station at pipeline midpoint at Milepoint (MP) 90 and operate both stations at equal discharge pressure.

Operational Considerations

As discussed herein and in the previous report, many variables impact the design of the pipeline for each case and for the system in general. Considerations related to variations in operating pressure, the addition of booster station(s) and the reduction of delivery pressure are presented.

16-inch case

As shown in Figure 7, the 16-inch pipeline will require a booster station. At the stated capacity of 10.3 million m^3/day (362 million scf/day) of CO_2 over a distance of 287.9 km (178.9 miles), the 16-inch pipeline is at full capacity. The operation of a remote unmanned booster station at a pressure of 20,684 kPa (3,000 psig) at the design flow rate should be thoroughly investigated in the next stage of the project as the required pumps could be at or near the limit of practical design. Alternate designs using multiple smaller units operating in parallel could be a solution to the size limit, but they will increase the complexity of operation.

18-inch case

The 18-inch pipeline in the current hydraulic design also requires a booster station. However, the pump units are operating at 15,168 kPa (2,200 psig), which is well below the normal range (17,236 kPa (2,500 psi)) of CO_2 projects. If the operating pressure is increased to 17,236 kPa (2,500 psi), the capacity of the 18-inch pipeline could increase by 1.7 to 2.0 million m^3/day (60 to 70 million scf/day). The extra cost of pipe and construction would be approximately $2 million over the 18-inch pipeline with a single booster.

20-inch case

The 20-inch pipeline provides considerable spare capacity either by increasing the operating pressure or by adding a booster station. If the pressure increased to 17,236 kPa (2,500 psig), the capacity of the 20-inch would be increased by 2.83 to 3.40 million m^3/day (100 to 120 million scf/day). The cost of the additional pipe and construction would be around $2.5 million. Adding a booster station would increase the capacity by 5.66 to 6.23 million m^3/day (200 to 220 million scf/day) over the 20-inch pipeline.

Delivery Pressure Reduction

The delivery pressure for hydraulic analysis was reduced from 10,243 to 9,652 kPa (1,500 psig to 1,400 psig) because the 18-inch case and the 20-inch case were approaching an equipment pressure classification break point. By lowering the delivery pressure, the operating pressure of the 20- and 18-inch pipelines are within the limits for ANSI 900 fittings and valves. If the delivery pressure is not lowered, the next higher rating of ANSI 1500 would be required, which would result in significant cost increases for the valves and fittings at the diameters under consideration. In Phase II of the DOE project, the delivery pressure at Edwards County should be optimized, if feasible, to keep the pipeline operating pressure at a level that would not require the ANSI 1500 fittings.

Costs

The methods and data used for the development of the costing information in Section 8 of the 2004 Task 3 report were used for determining the conceptual cost of the proposed project. Based on the length of the route, the range of pipeline diameters, and pump station configuration, the tables and data from the previous report are used to calculate the approximate cost for the three cases presented in of this report. The summary of unit costs were originally presented in Table 8-7 of the 2004 Task 3 report.

Table 4. Unit costs for pipeline construction per mile.

Diameter (inches)	Cost per mile, U.S. Dollars				
	Right-of-way	Materials	Construction	Services	Total
4	36,713	24,303	85,071	29,217	175,304
6	36,713	47,630	115,915	38,049	238,307
8	44,500	79,370	141,753	47,812	313,435
10	44,500	115,424	173,476	56,678	390,078
12	51,731	159,084	210,730	67,447	488,992
16	66,750	247,199	275,533	88,422	677,905
18	66,750	310,766	306,206	95,721	779,444
20	66,750	381,893	336,354	102,050	887,047
22	66,750	460,465	365,978	107,183	1,000,375
24	66,750	546,136	395,601	121,018	1,129,505

For each of the three cases (40.64-cm (16-inch) pipeline origin and booster station, 45.72-cm (18-inch) pipeline origin and booster station, and 50.8-cm (20-inch) pipeline origin):

1. The pipeline cost was calculated extending the unit prices in Table 4 by length of the route. (The measured distance of 287.9 km (178.9 miles) was rounded to 290 km (180 miles) to allow for some minor reroutes.)
2. The cost of pumping facilities for each case was calculated by extending the horsepower amounts in Table 3 of this report by $1.34/W ($1,000/hp) as presented in Section 8 of the 2004 Task 3 report.
3. Pipeline operating costs were extended for the length and diameter using the $16.317/meter diameter/km/year ($667/inch diameter/miles/year) as presented in Section 8 of the 2004 Task 3 report.
4. Pump station operating costs were extended for the horsepower amounts shown in Table 3 of this report by $0.067/W/year ($50/horsepower/year) presented in Section 8 of the 2004 Task 3 report.
5. Power costs were extended for the horsepower amounts in Table 3 of this report by $0.48/W/year ($360/horsepower/year) presented in Section 8 of the 2004 Task 3 report.

These costs for the three cases are summarized in Table 5. As expected, the 16-inch case, which has no additional capacity, also has the least capital cost and highest operating cost. The 20-inch case, which has the greatest flexibility for expansion, has the highest capital cost and lowest operating cost. The 18-inch case is a compromise between the 16-inch and the 20-inch case.

Table 5. Comparison of costs for 16-, 18- and 20-inch diameter pipeline options, 180-mile pipeline from Pekin to Edwards County, Illinois.

Installation unit costs, pipeline, and stations (from Table 8-7 of 2004 Task 3 Report)			
Component cost	**16 inches**	**18 inches**	**20 inches**
	Unit costs per mile of pipeline, $		
Pipeline right-of-way	66,750	66,750	66,750
Pipeline materials	247,199	310,766	381,893
Pipeline construction	275,533	306,206	336,354
Support services	88,422	95,721	102,050
Midpoint station, $/HP	Station unit cost $/BHP		
	1,000	1,000	N/A
Total installation costs, pipeline and stations for a 180-mile pipeline			
Component cost	**16 inches**	**18 inches**	**20 inches**
Pipeline right-of-way	12	12	12
Pipeline materials	45	56	69
Pipeline construction	50	55	60
Support services	16	17	18
Midpoint station, 3,600 BHP	3.6	2.0	0.0
Total cost ($1,000,000)	127	142	159
Annual operating costs			
Component cost	**16 inches**	**18 inches**	**20 inches**
Pipeline operating cost ($667/inch-diameter/mile/year for 180 miles (2004 Task 3 report, Table 8-8)	1.9	2.2	2.4
Station operating costs ($50/hp/year for maintenance and $360/hp/year for power), $1,000,000	7,200 hp	3,960 hp	2,250 hp
	3.0	1.6	0.9

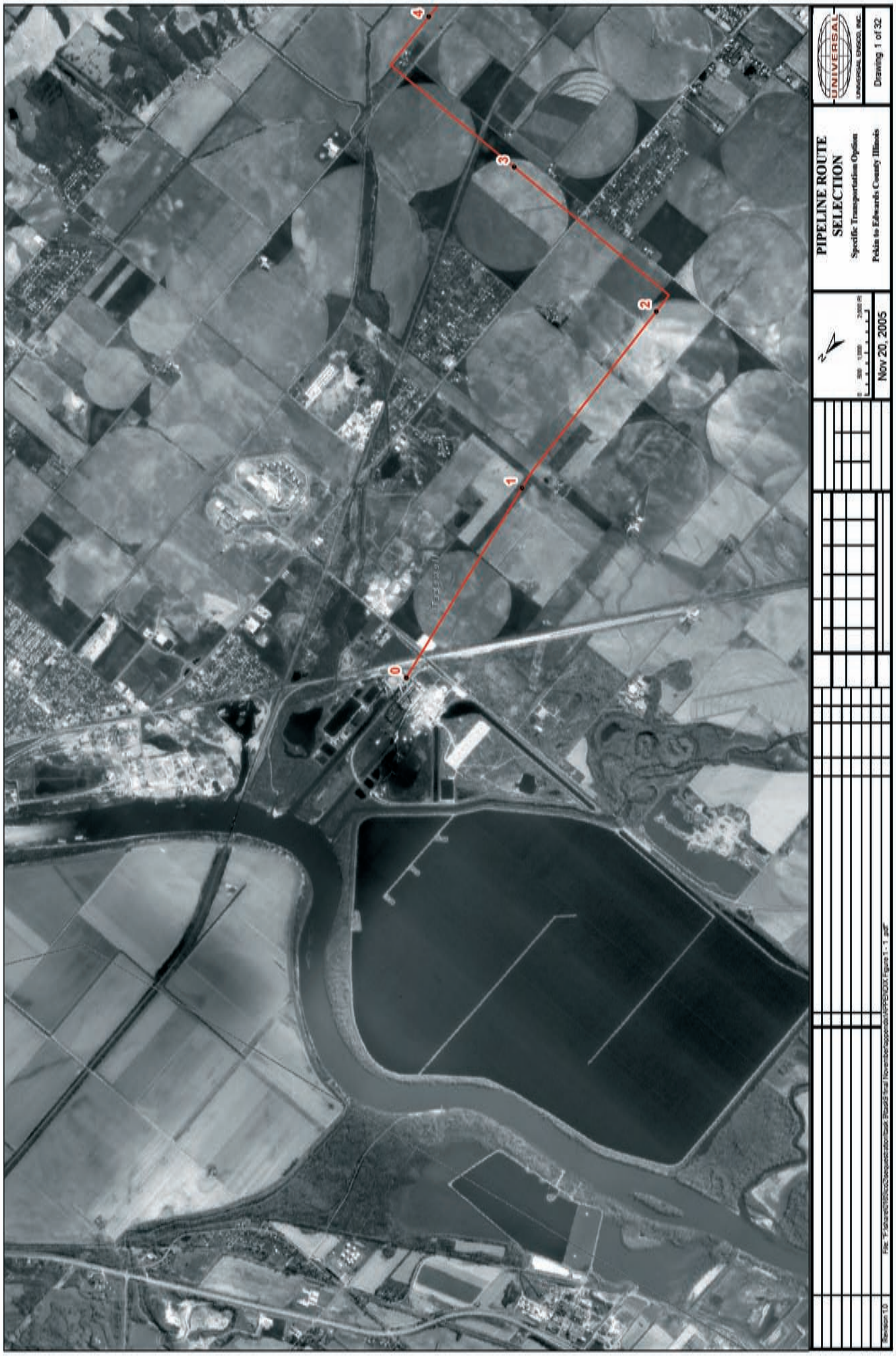
If the project implementation is delayed for several years or more, it would be advisable to update the conceptual cost estimate for inflation/deflation in pipe and land values and inflation in construction and service. The cost of steel is expected to be highly variable over the next few years, and construction costs are expected to increase due to the large number of planned oil and gas pipeline projects.

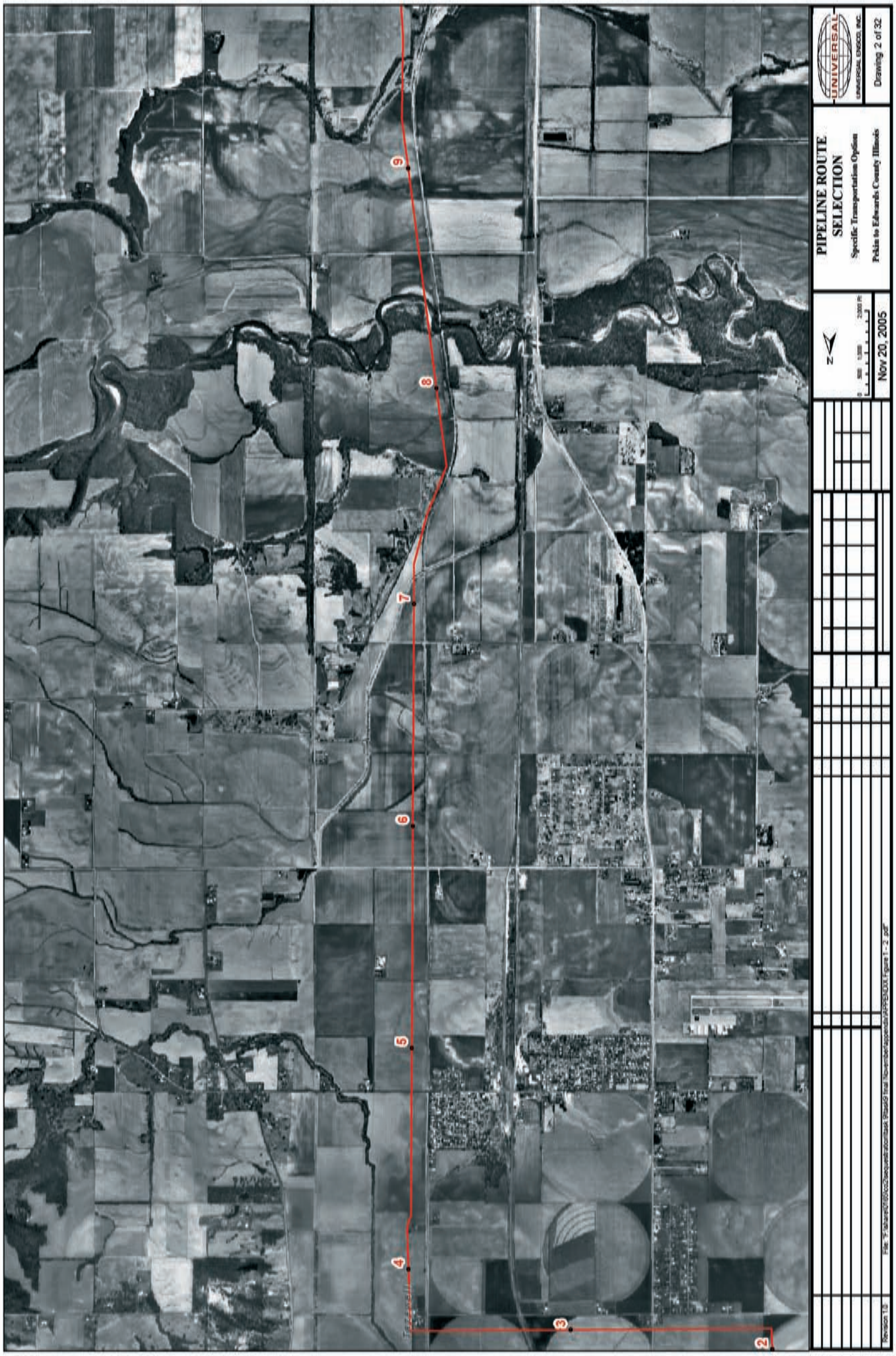
A more detailed cost estimate for the proposed pipeline can be prepared in a future project phase, once a final pipeline diameter and route have been selected. This detailed estimate would include material quantities and prices based on drawings and vendor prices; construction costs based on route review by contractors and engineers, right-of-way costs based on detailed work space estimates combined with spot values appraised for the route; and a detailed estimate of all services required.

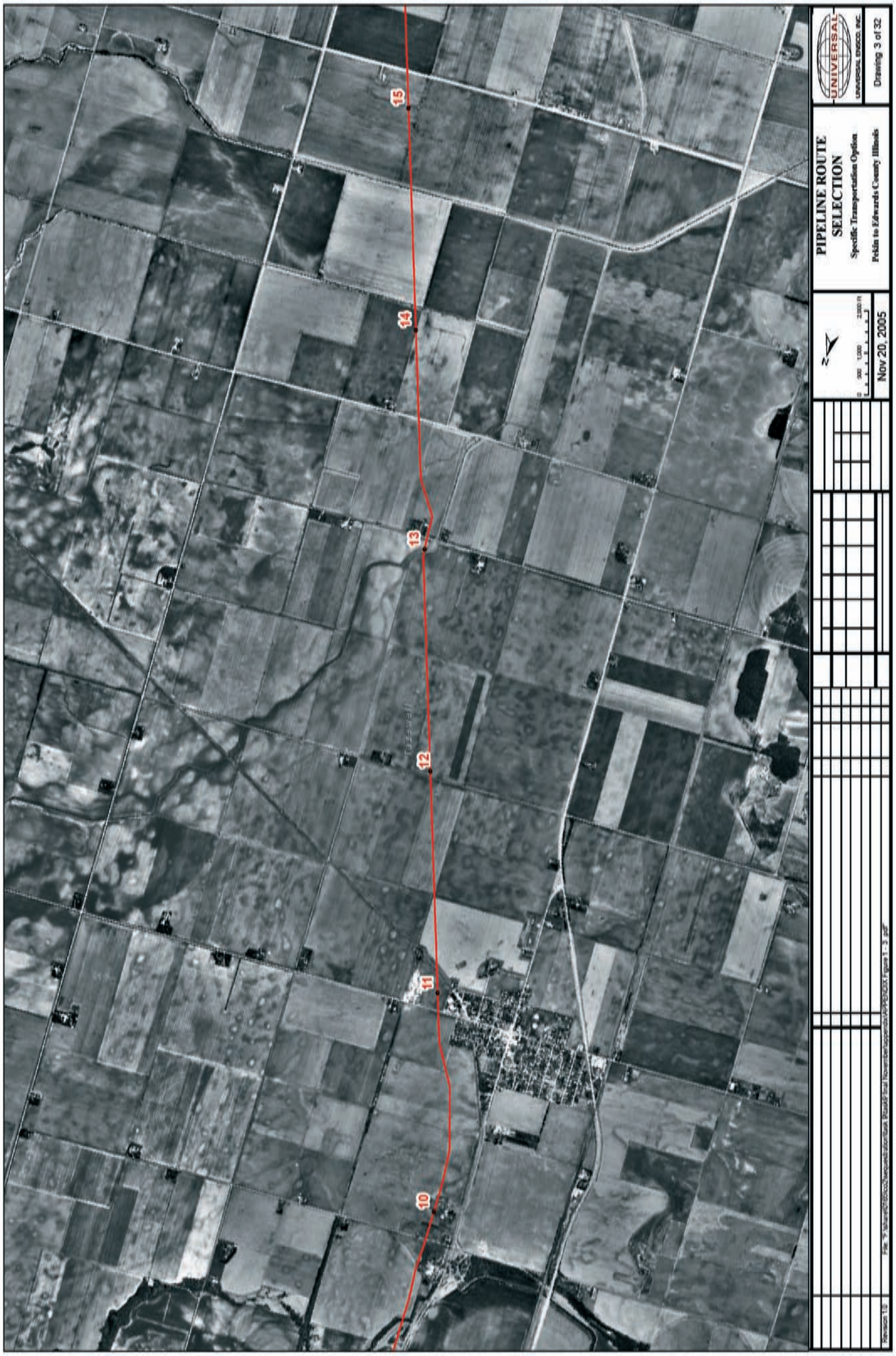
In the future, potential savings should be available through the use of higher tensile strength pipe. CO_2 pipelines have been limited to X70 grade pipe; however, X80 grade pipe was recently installed on a CO_2 pipeline project in Mississippi and Alabama. For the same pressure rating, the weight of the X80 pipe will be approximately 7/8 of the X70 pipe weight. It is reported that, even though the price per ton of the X80 pipe and the associated construction costs for X80 are higher, the net effect was a reduction in overall cost. Because X80 pipe requires welding procedures that are not well established, the construction contractor includes contingency into their commercial bids. As procedures for X80 pipe manufacture and construction become standard practice, it should be possible to achieve the full 1/8 savings in pipe costs. Until that time, net cost savings are anticipated to be approximately 50% of the 1/8 weight savings.

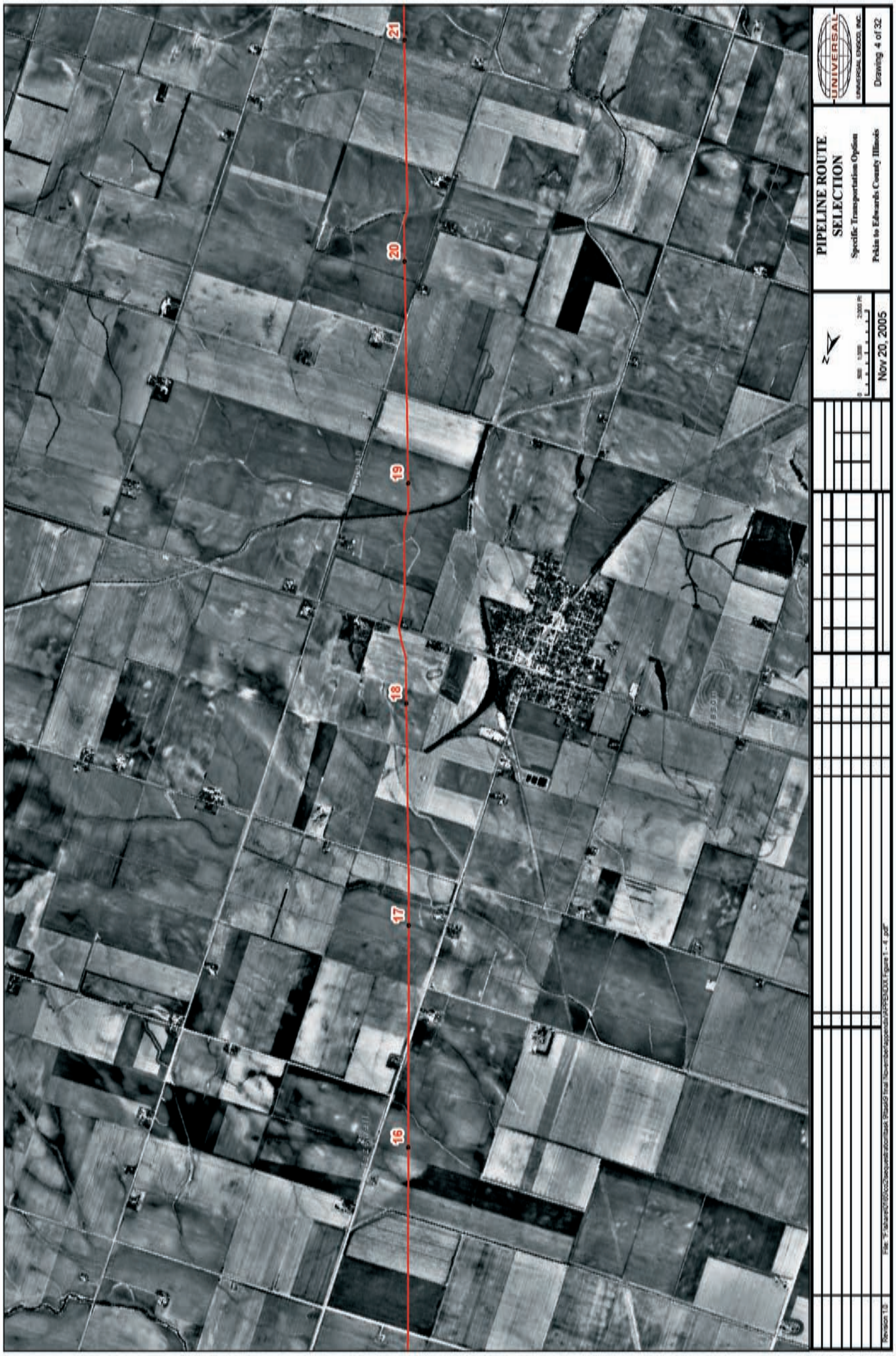
Appendix

The digital version of this appendix contains 32 route aerial photograph maps at a detailed scale (1 inch on the map represents 2,000 ft on the ground surface). (The maps that follow in the printed version have been reduced to page size.) The maps together show the area of pipeline route selection, specific transportation option, Pekin to Edwards County, Illinois.

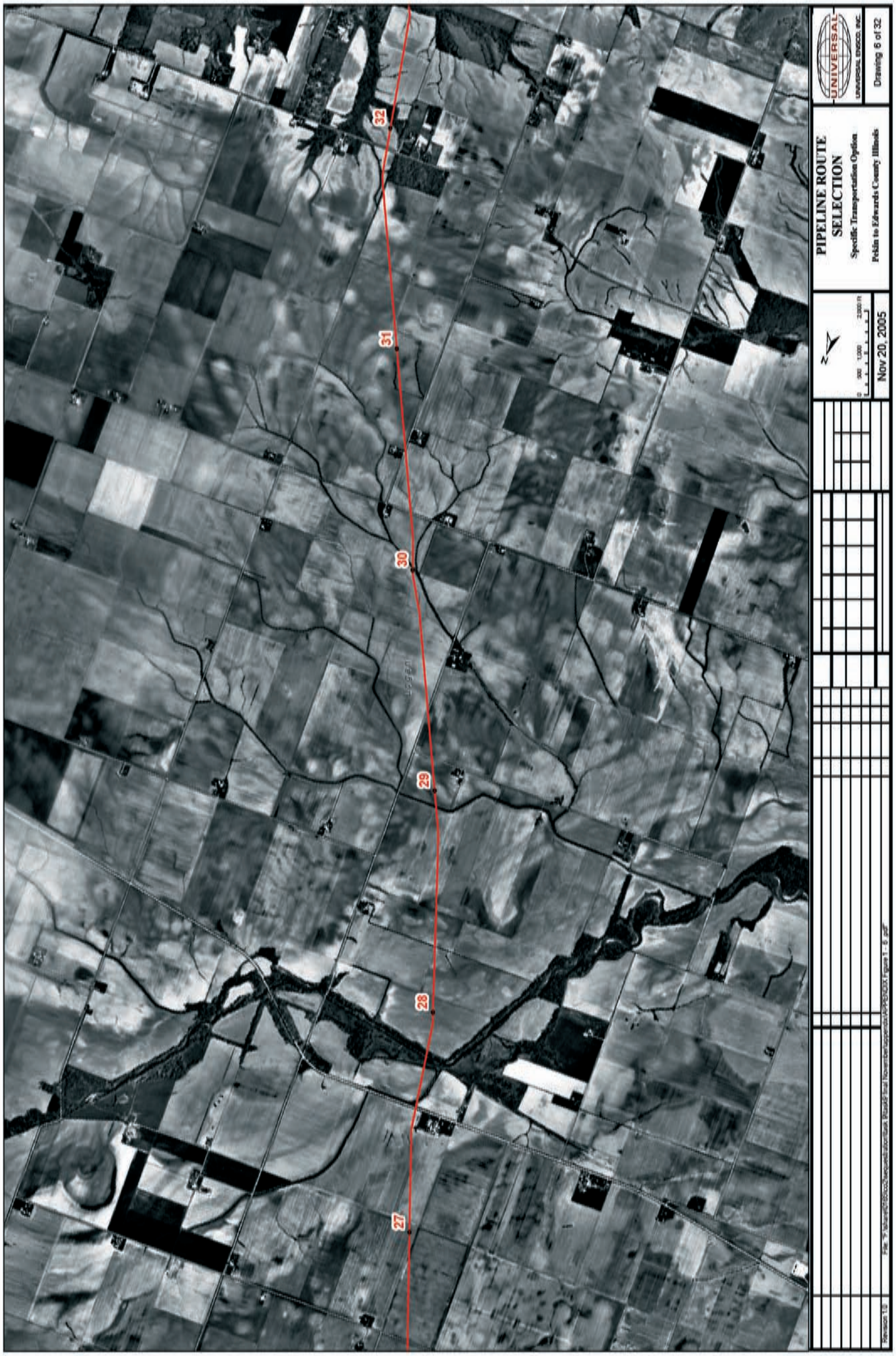

PIPELINE ROUTE SELECTION
Specific Transportation Option
Pekin to Edwards County Illinois
Nov 20, 2005
UNIVERSAL
UNIVERSAL ENSCO, INC.
Drawing 1 of 32
0
1
2
3
4

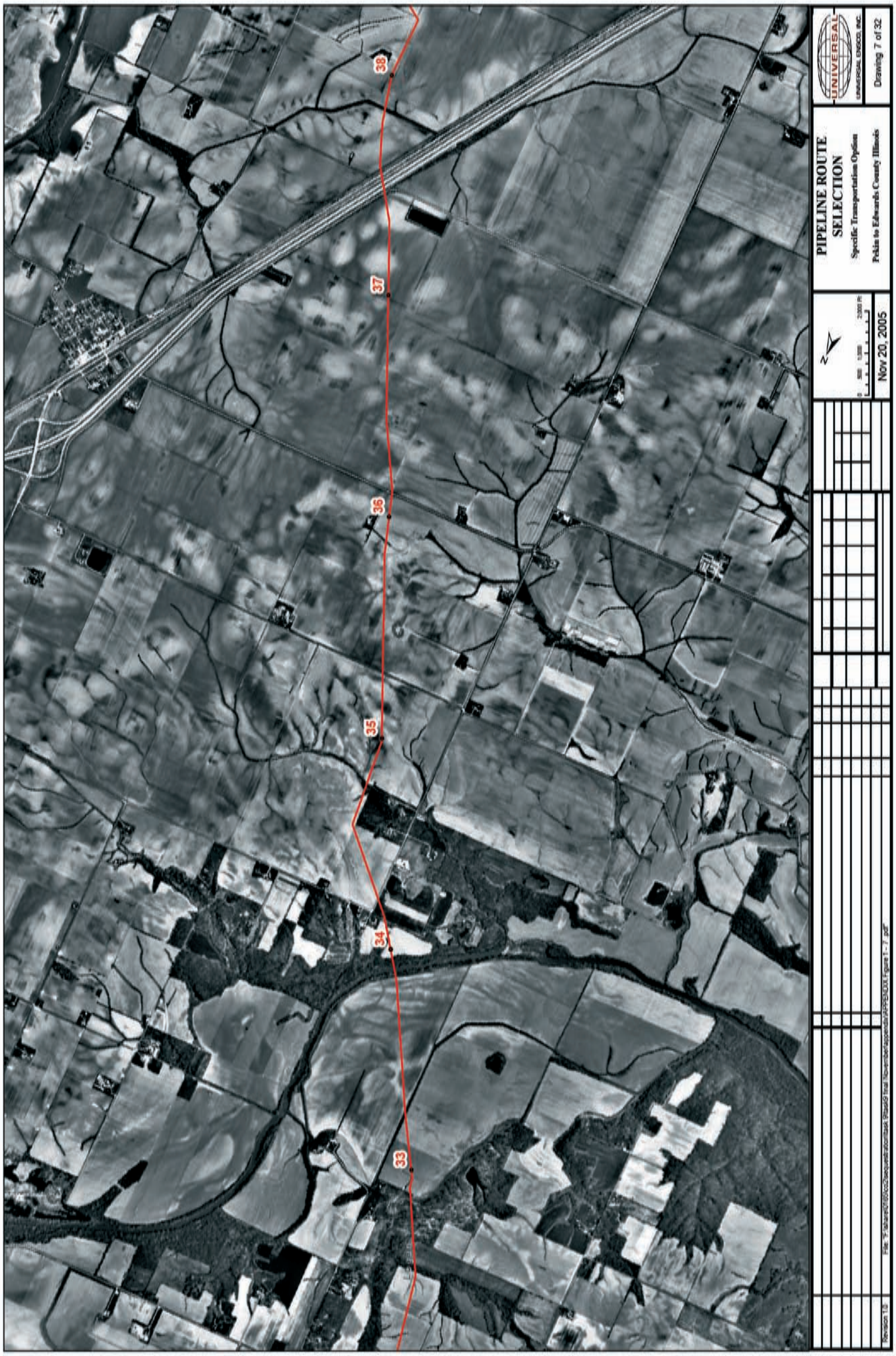

PIPELINE ROUTE SELECTION
Specific Transportation Option
Pekin to Edwards County Illinois
Nov 20, 2005
UNIVERSAL
Drawing 2 of 32
2
3
4
5
6
7
8
9

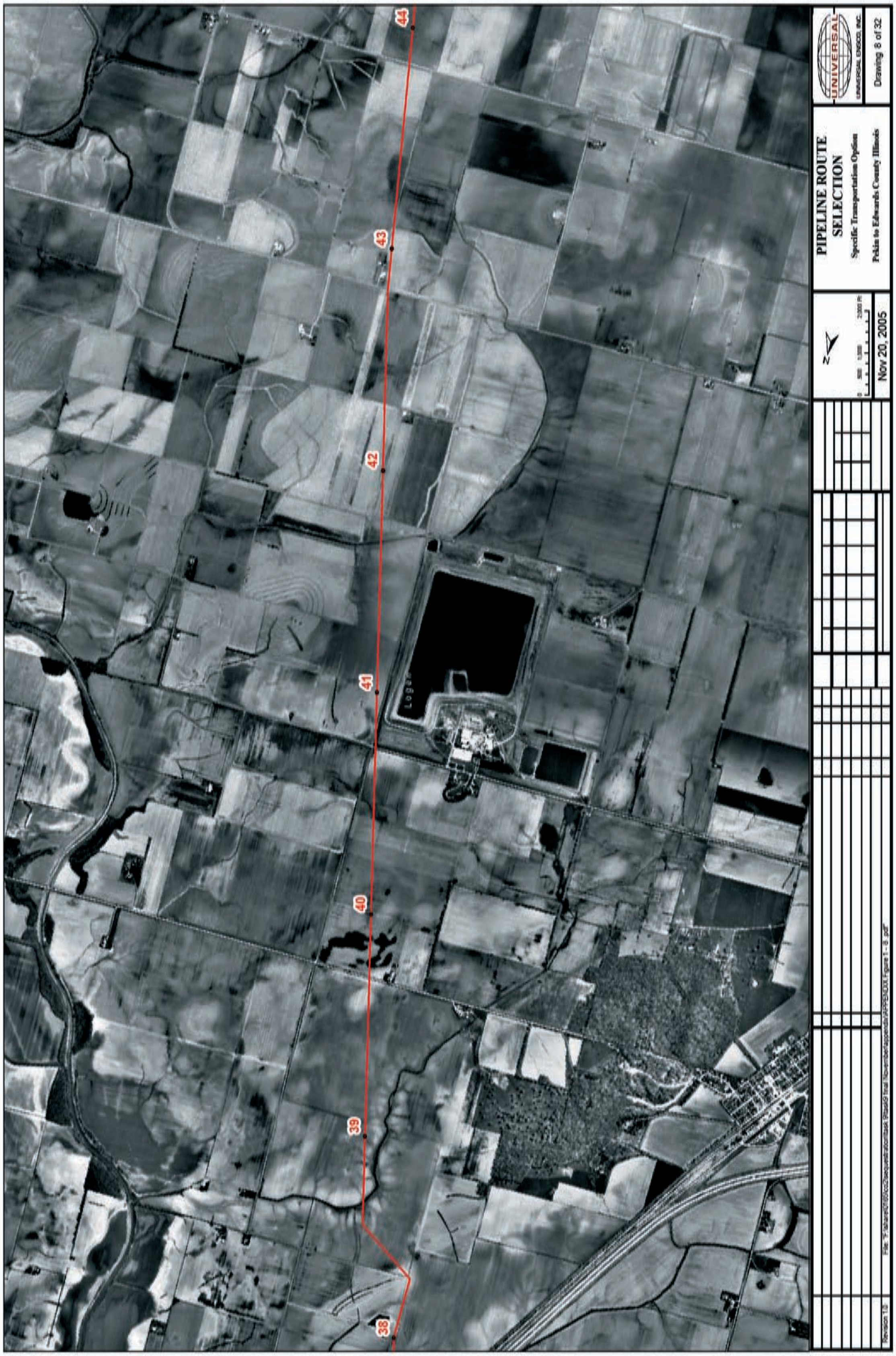

PIPELINE ROUTE SELECTION
Specific Transportation Option
Pekin to Edwards County Illinois
Nov 20, 2005
UNIVERSAL
Drawing 3 of 32
10
11
12
13
14
15

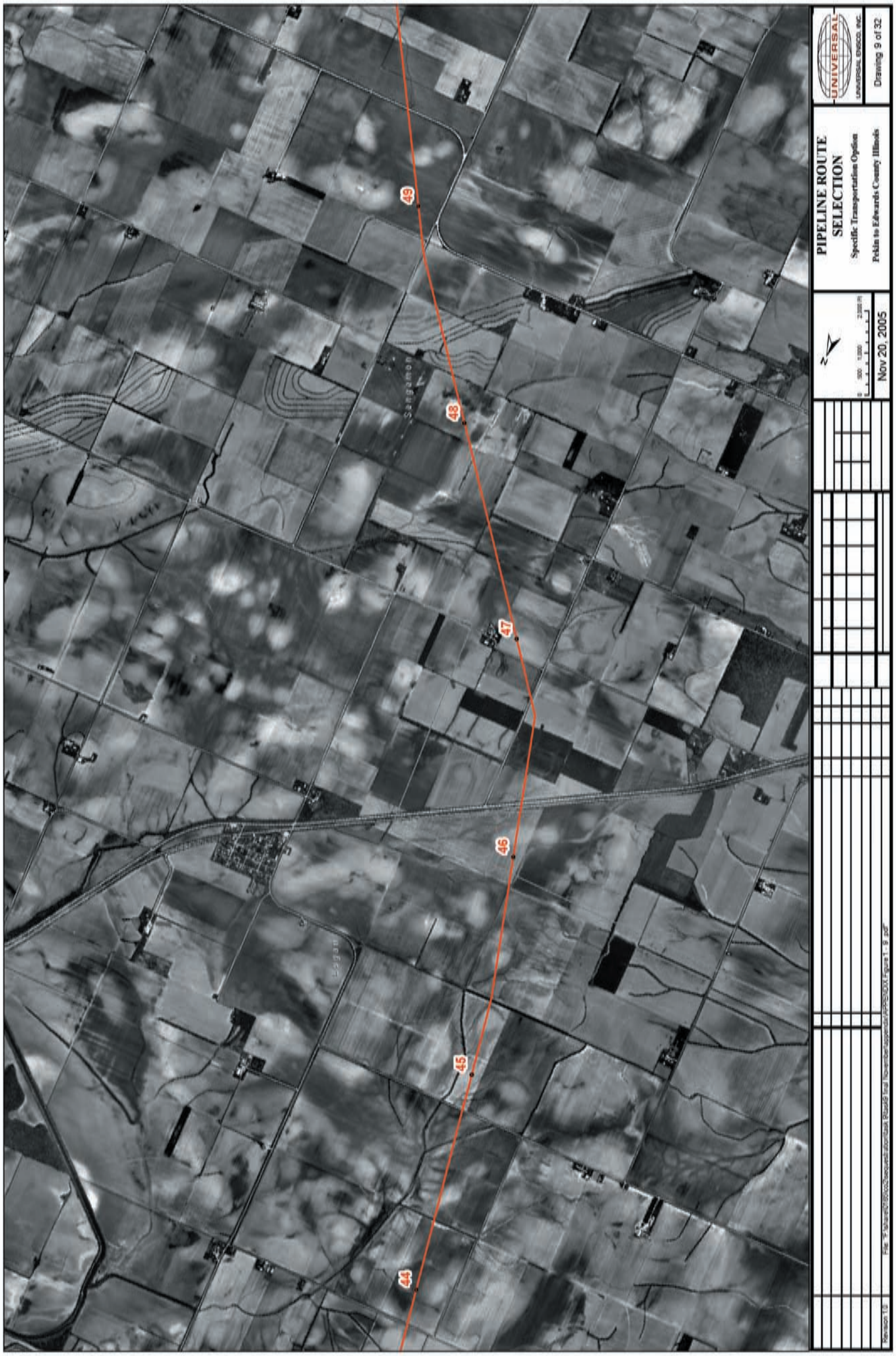

21
20
19
18
17
16
PIPELINE ROUTE SELECTION
Specific Transportation Option
Pekin to Edwards County Illinois
UNIVERSAL
Drawing 4 of 32
Nov 20, 2005

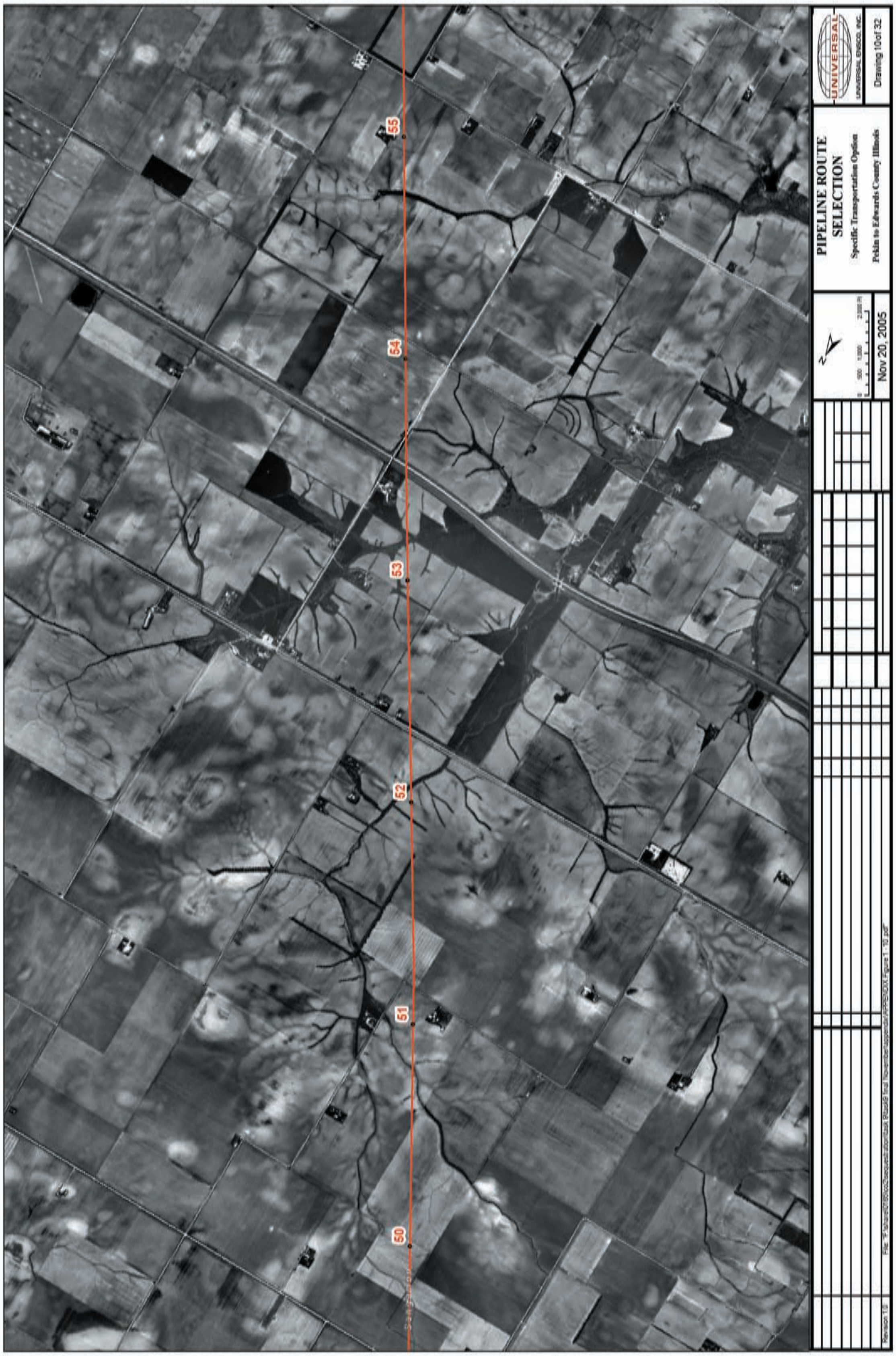

PIPELINE ROUTE SELECTION
Specific Transportation Option
Pekin to Edwards County Illinois
Nov 20, 2005
UNIVERSAL
Drawing 5 of 32
21
22
23
24
25
26

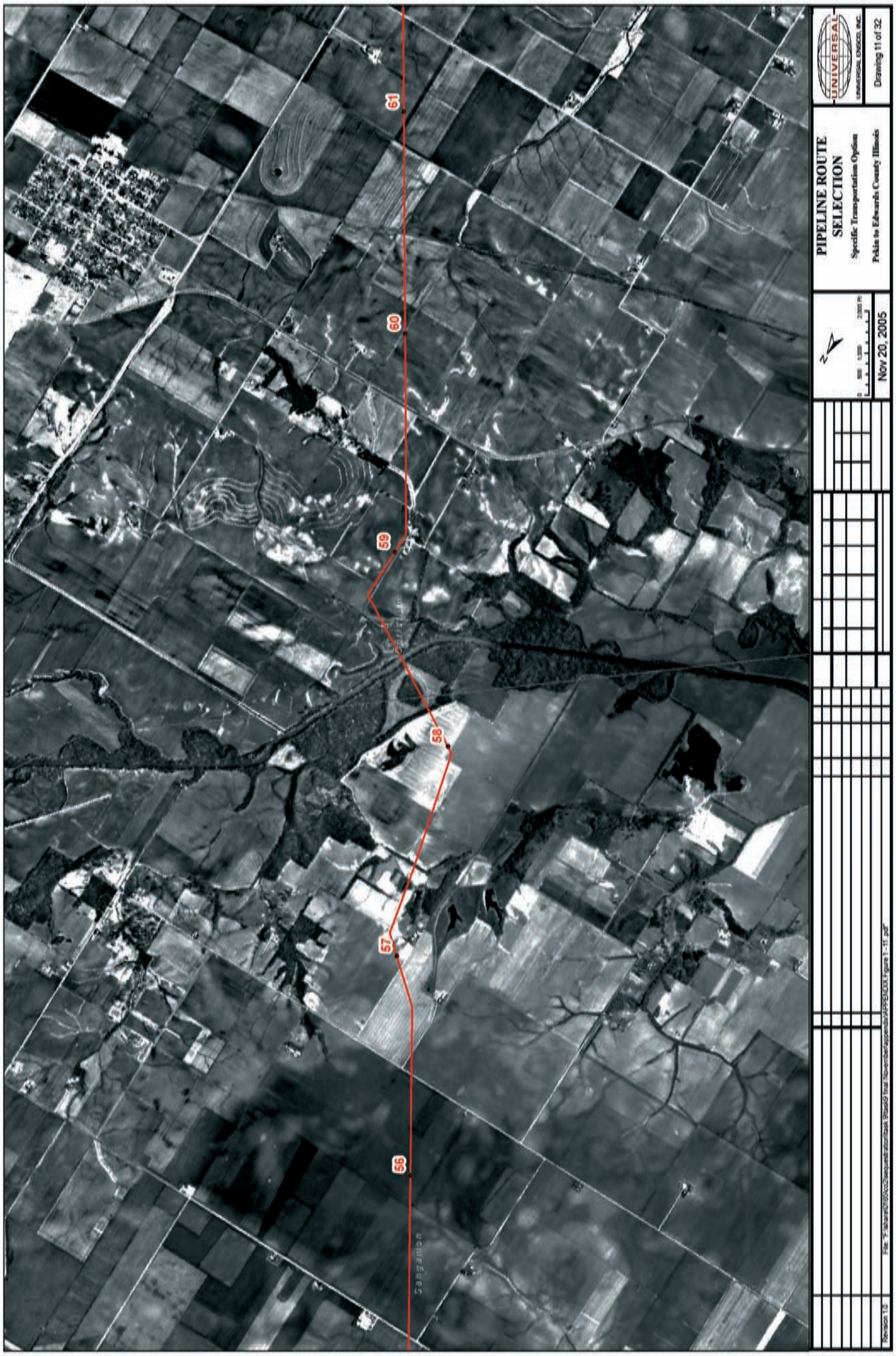

PIPELINE ROUTE SELECTION
Specific Transportation Option
Pekin to Edwards County Illinois
Nov 20, 2005
UNIVERSAL
Drawing 6 of 32
27
28
29
30
31
32

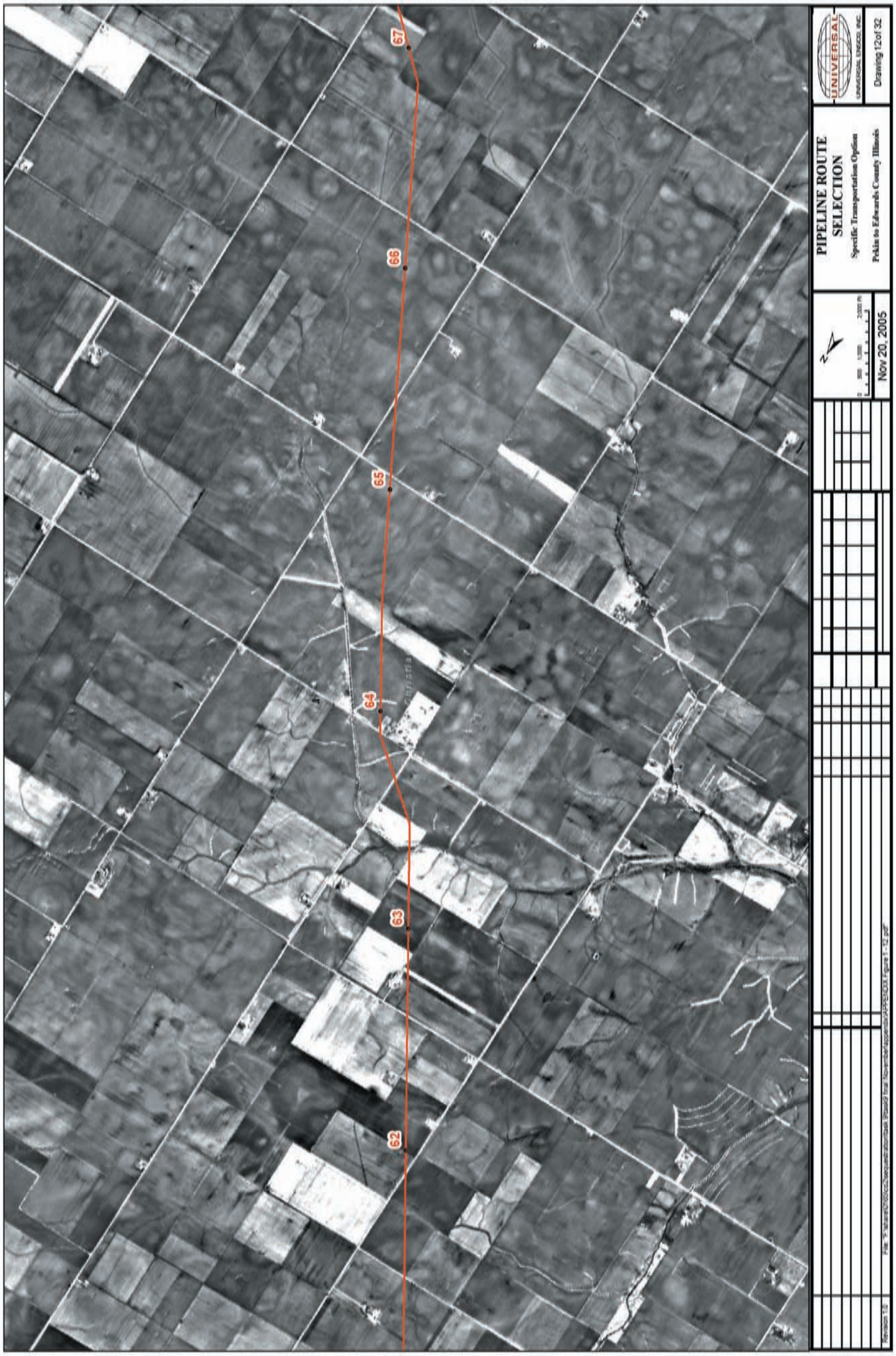

PIPELINE ROUTE SELECTION
Specific Transportation Option
Pekin to Edwards County Illinois
UNIVERSAL
Drawing 7 of 32
Nov 20, 2005
33
34
35
36
37
38


PIPELINE ROUTE SELECTION
Specific Transportation Option
Pekin to Edwards County Illinois
Nov 20, 2005
Drawing 8 of 32
UNIVERSAL
38
39
40
41
42
43
44

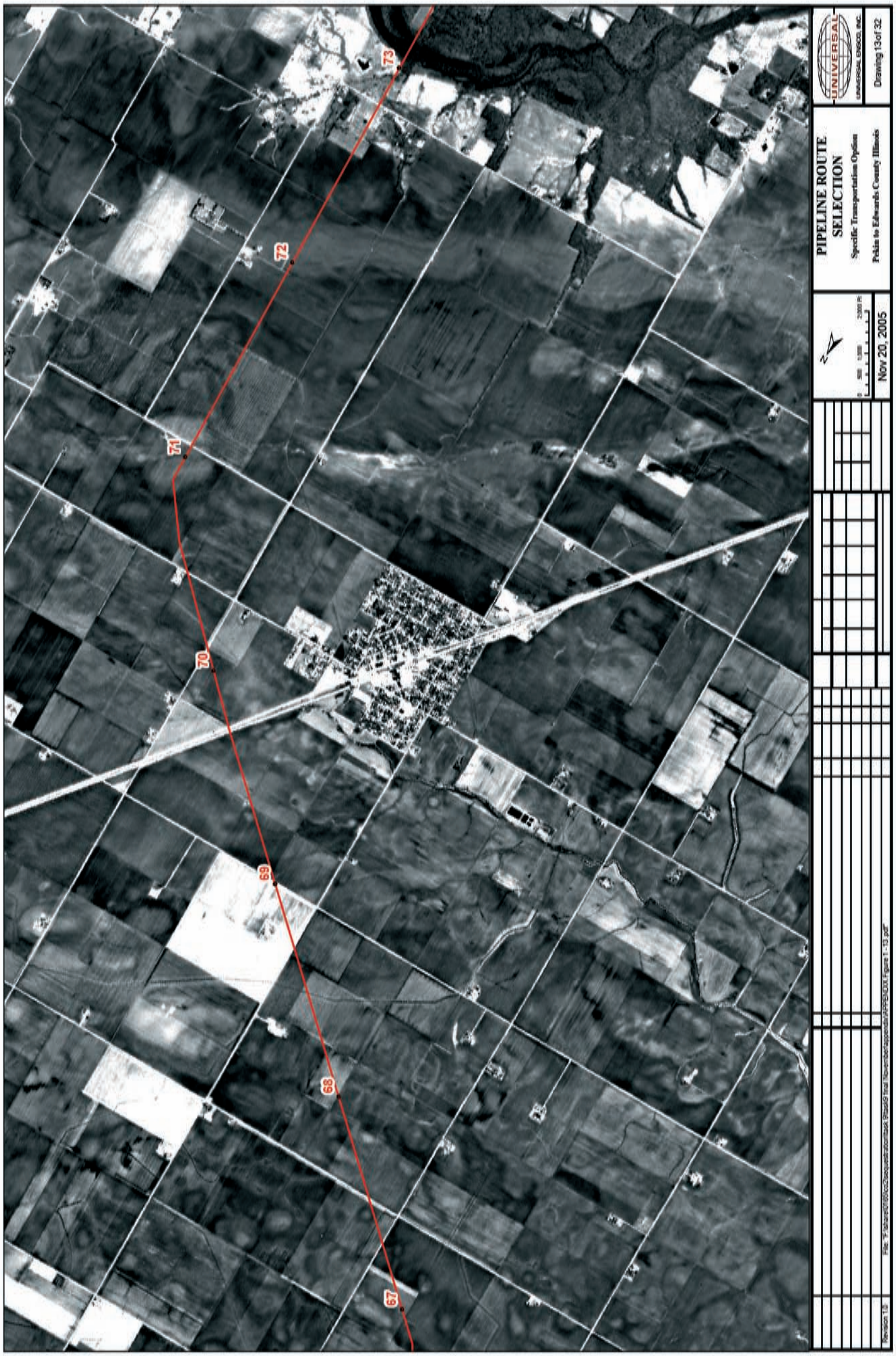

PIPELINE ROUTE SELECTION
Specific Transportation Option
Pekin to Edwards County Illinois
Nov 20, 2005
UNIVERSAL
Drawing 9 of 32
44
45
46
47
48
49


55
54
53
52
51
50
UNIVERSAL
UNIVERSAL ENSCO, INC.
Drawing 10 of 32
PIPELINE ROUTE SELECTION
Specific Transportation Option
Pekin to Edwards County Illinois
Nov 20, 2005


PIPELINE ROUTE SELECTION
Specific Transportation Option
Pekin to Edwards County Illinois
Nov 20, 2005
UNIVERSAL
Drawing 11 of 32
56
57
58
59
60
61
Sangamon



67
66
65
64
63
62
Nov 20, 2005
PIPELINE ROUTE SELECTION
Specific Transportation Option
Pekin to Edwards County Illinois
UNIVERSAL
Drawing 12 of 32


PIPELINE ROUTE SELECTION
Specific Transportation Option
Pekin to Edwards County Illinois
Nov 20, 2005
UNIVERSAL
Drawing 13 of 32
67
68
69
70
71
72
73

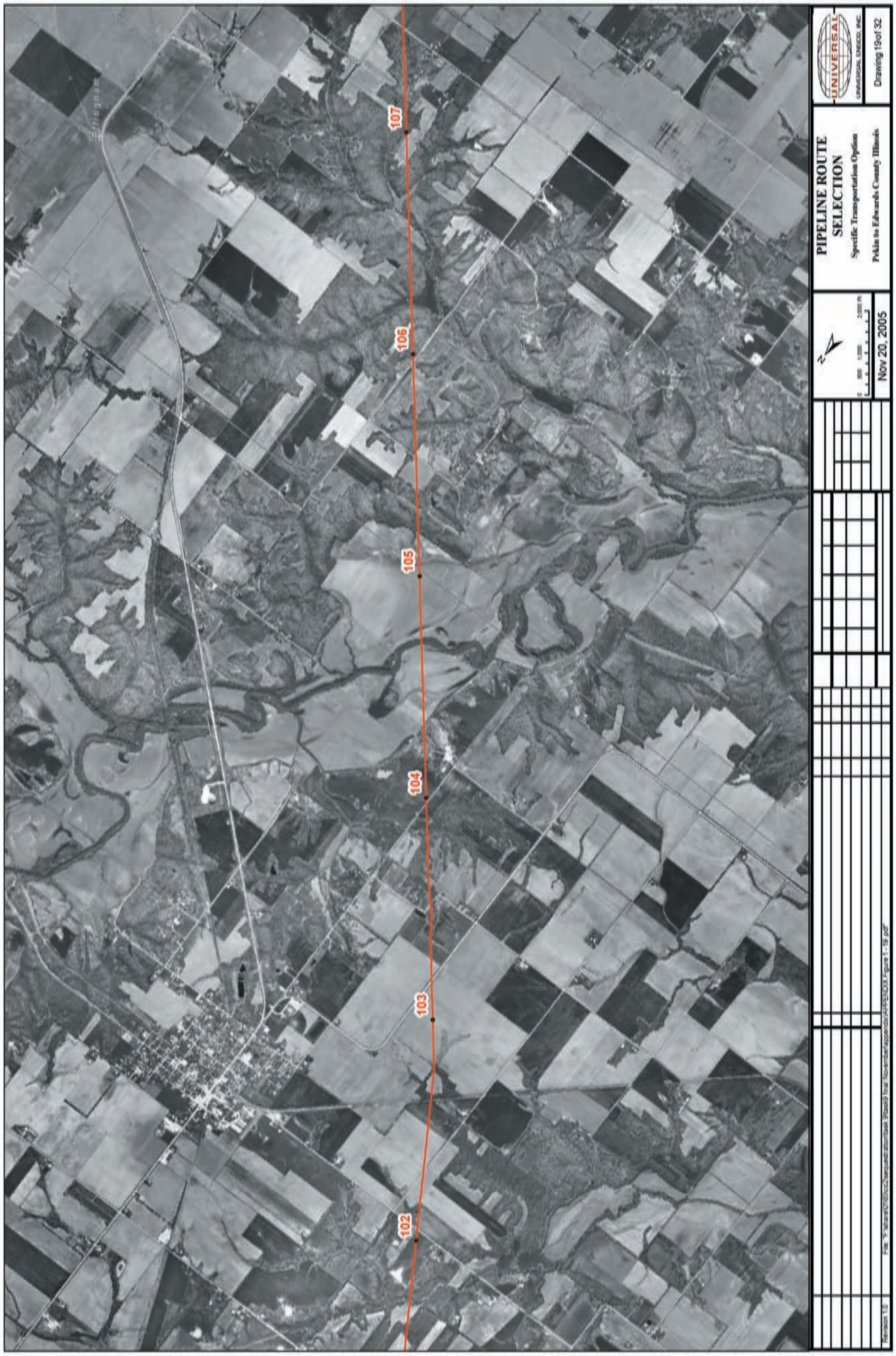

PIPELINE ROUTE SELECTION
Specific Transportation Option
Pekin to Edwards County Illinois
UNIVERSAL
Drawing 14 of 32
Nov 20, 2005
73
74
75
76
77
78
79

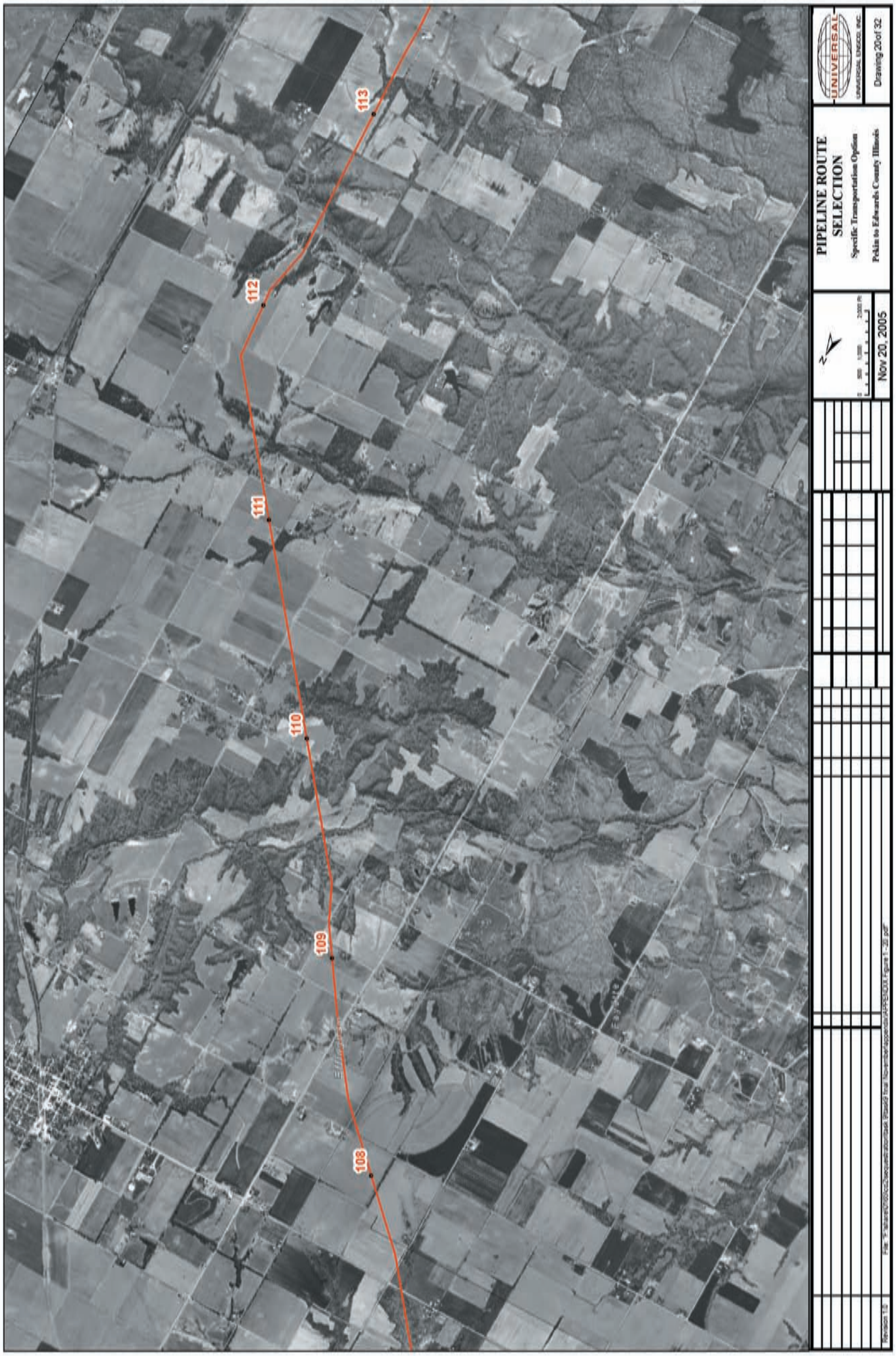

84
83
82
81
80
79
PIPELINE ROUTE SELECTION
Specific Transportation Option
Pekin to Edwards County Illinois
Nov 20, 2005
UNIVERSAL
Drawing 15of 32


90
89
88
87
86
85
PIPELINE ROUTE SELECTION
Specific Transportation Option
Pekin to Edwards County Illinois
Nov 20, 2005
UNIVERSAL
Drawing 16 of 32


PIPELINE ROUTE SELECTION
Specific Transportation Option
Pekin to Edwards County Illinois
Nov 20, 2005
UNIVERSAL
Drawing 17 of 32
91
92
93
94
95
96

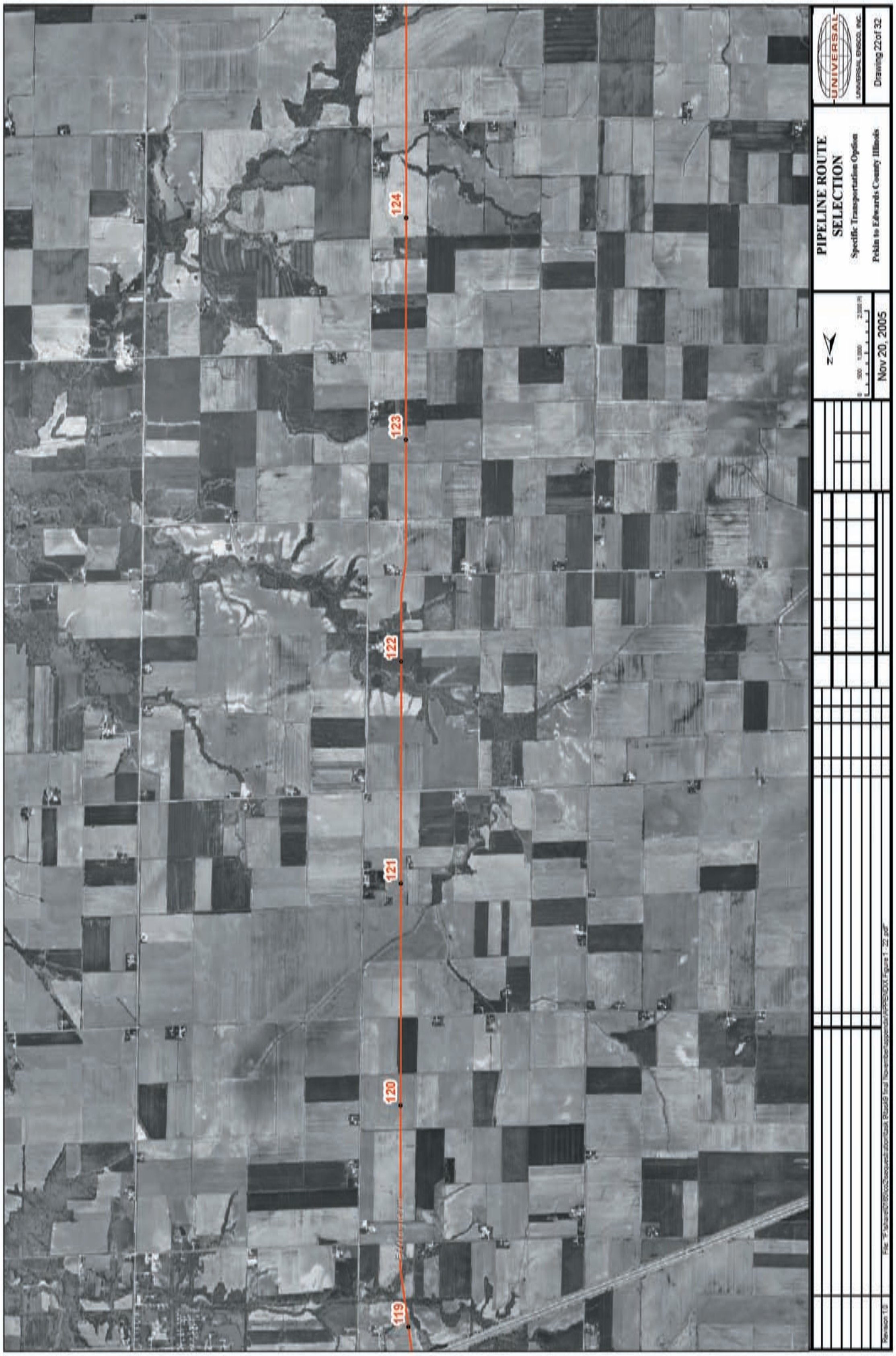

PIPELINE ROUTE SELECTION
Specific Transportation Option
Pekin to Edwards County Illinois
Nov 20, 2005
Drawing 18 of 32
UNIVERSAL
96
97
98
99
100
101

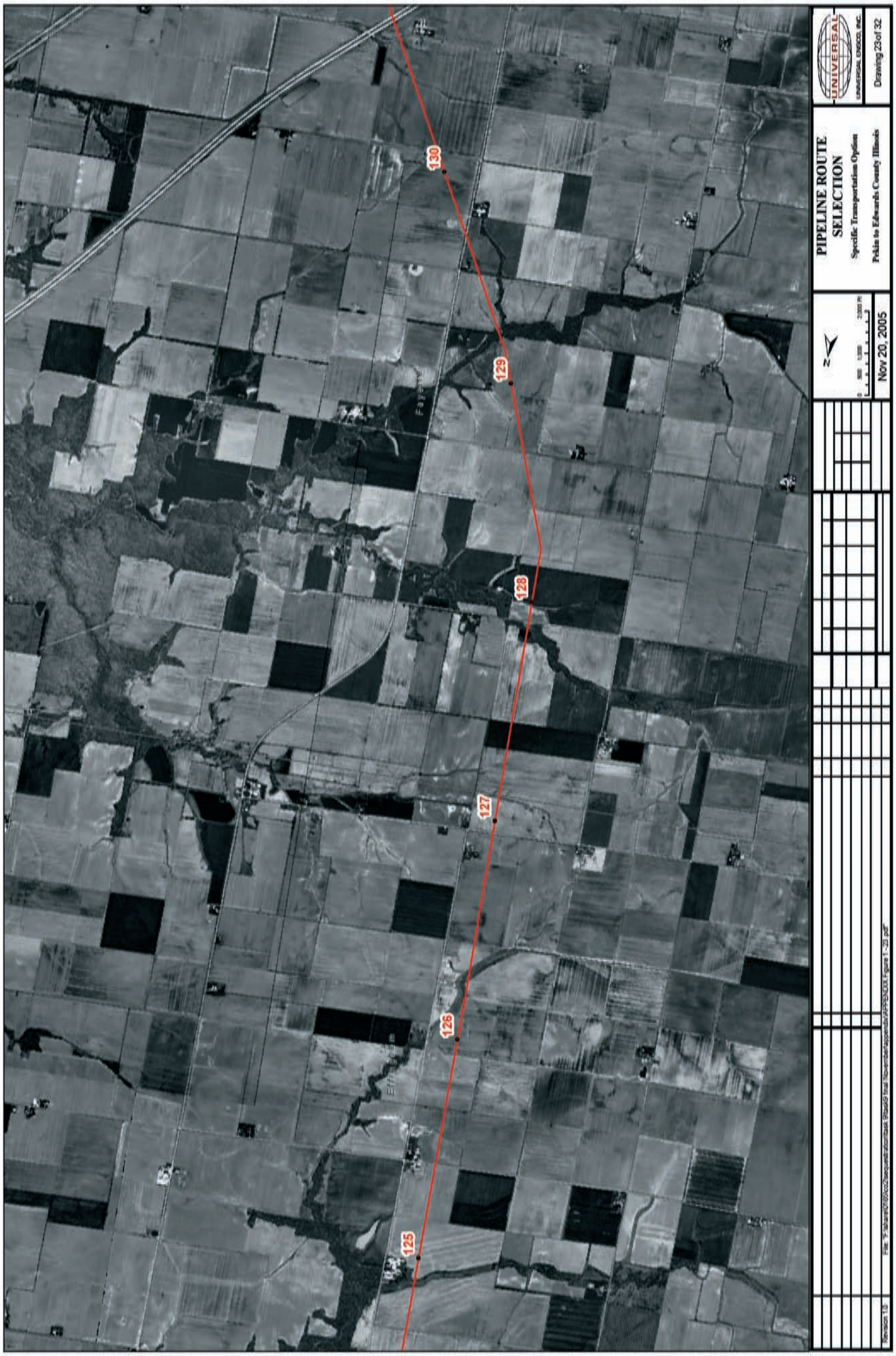

107
106
105
104
103
102
PIPELINE ROUTE SELECTION
Specific Transportation Option
Pekin to Edwards County Illinois
UNIVERSAL
Drawing 19 of 32
N
Nov 20, 2005

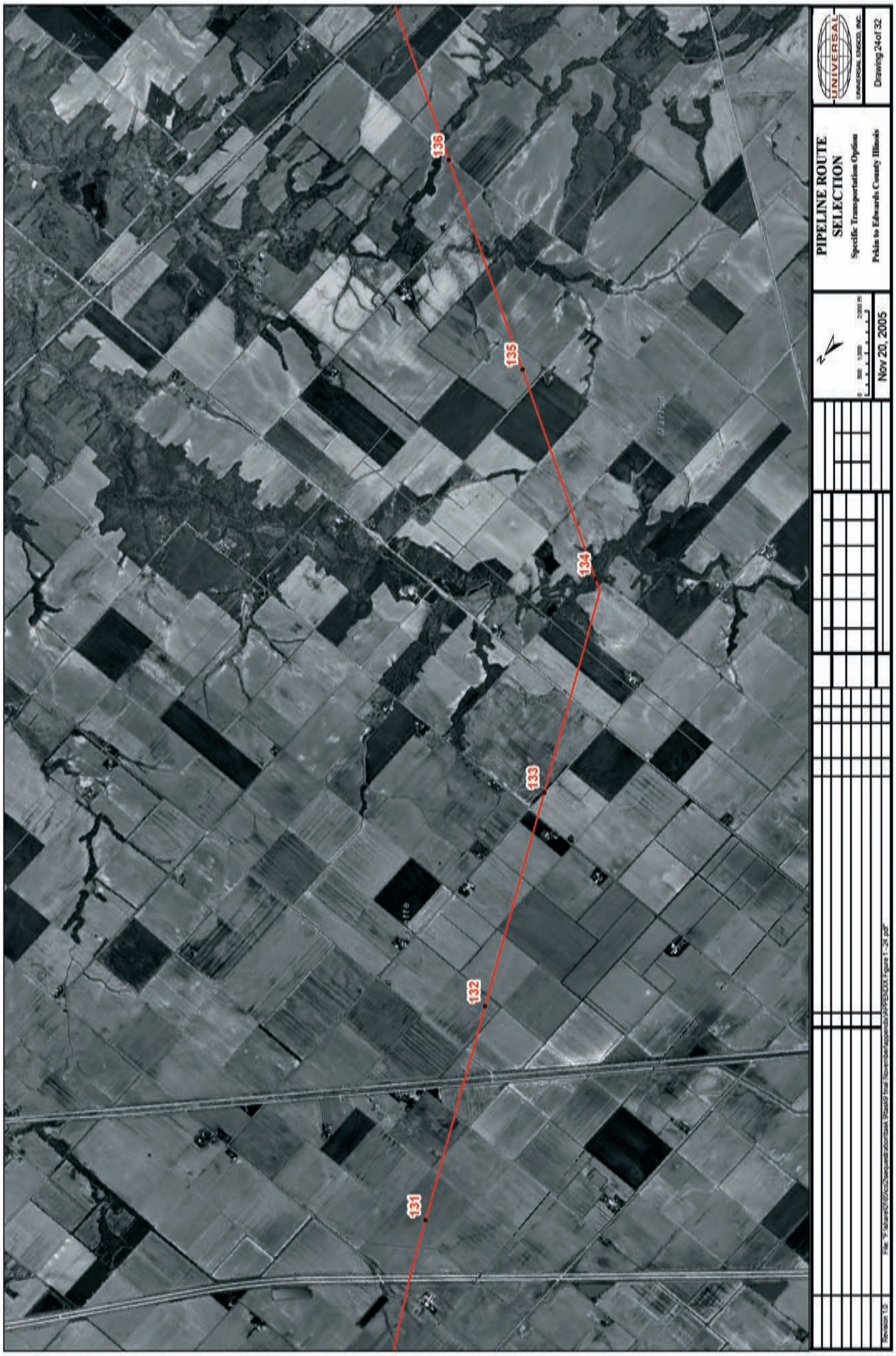


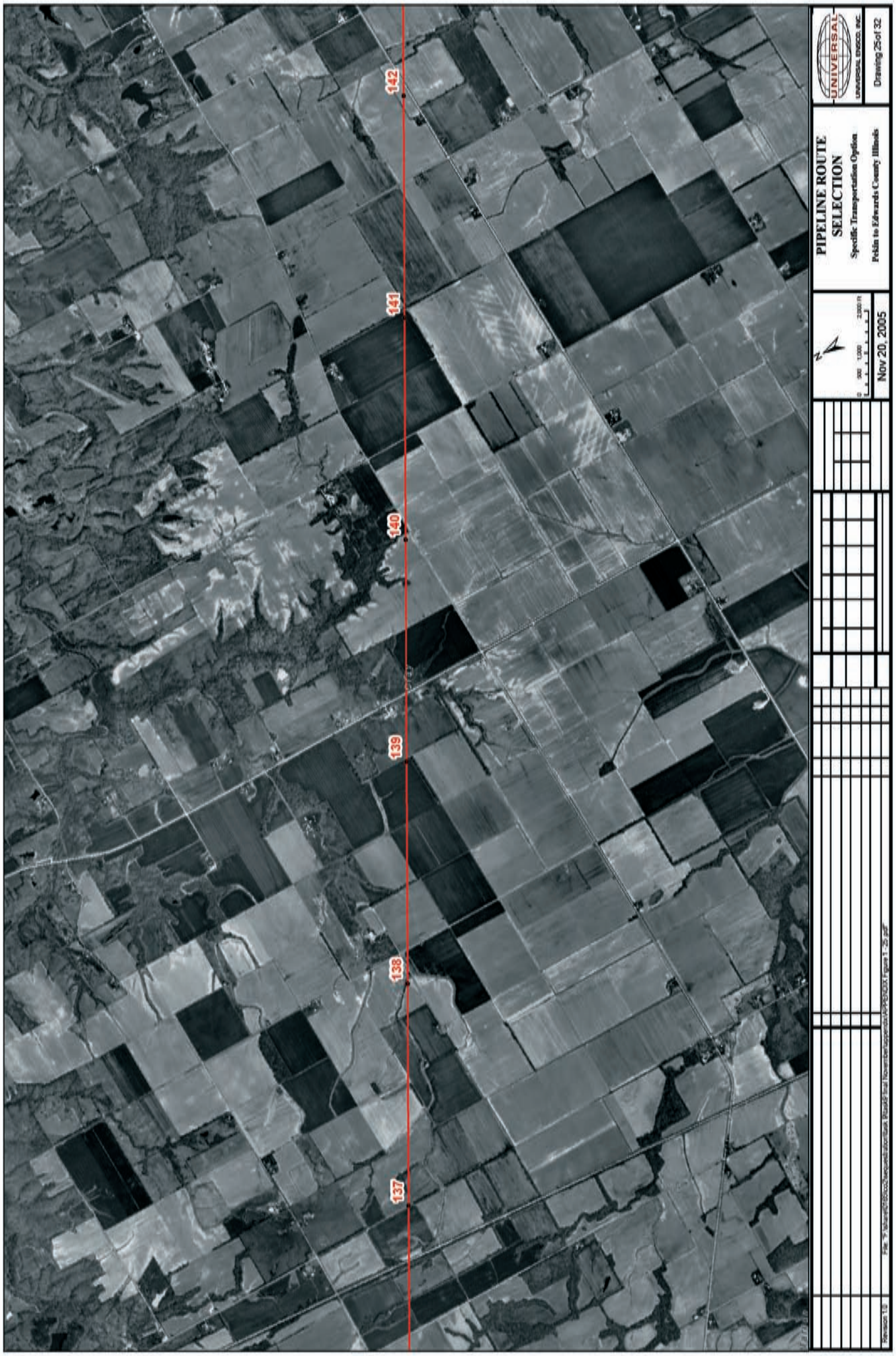
113
112
111
110
109
108
PIPELINE ROUTE SELECTION
Specific Transportation Option
Pekin to Edwards County Illinois
Nov 20, 2005
UNIVERSAL
Drawing 20 of 32

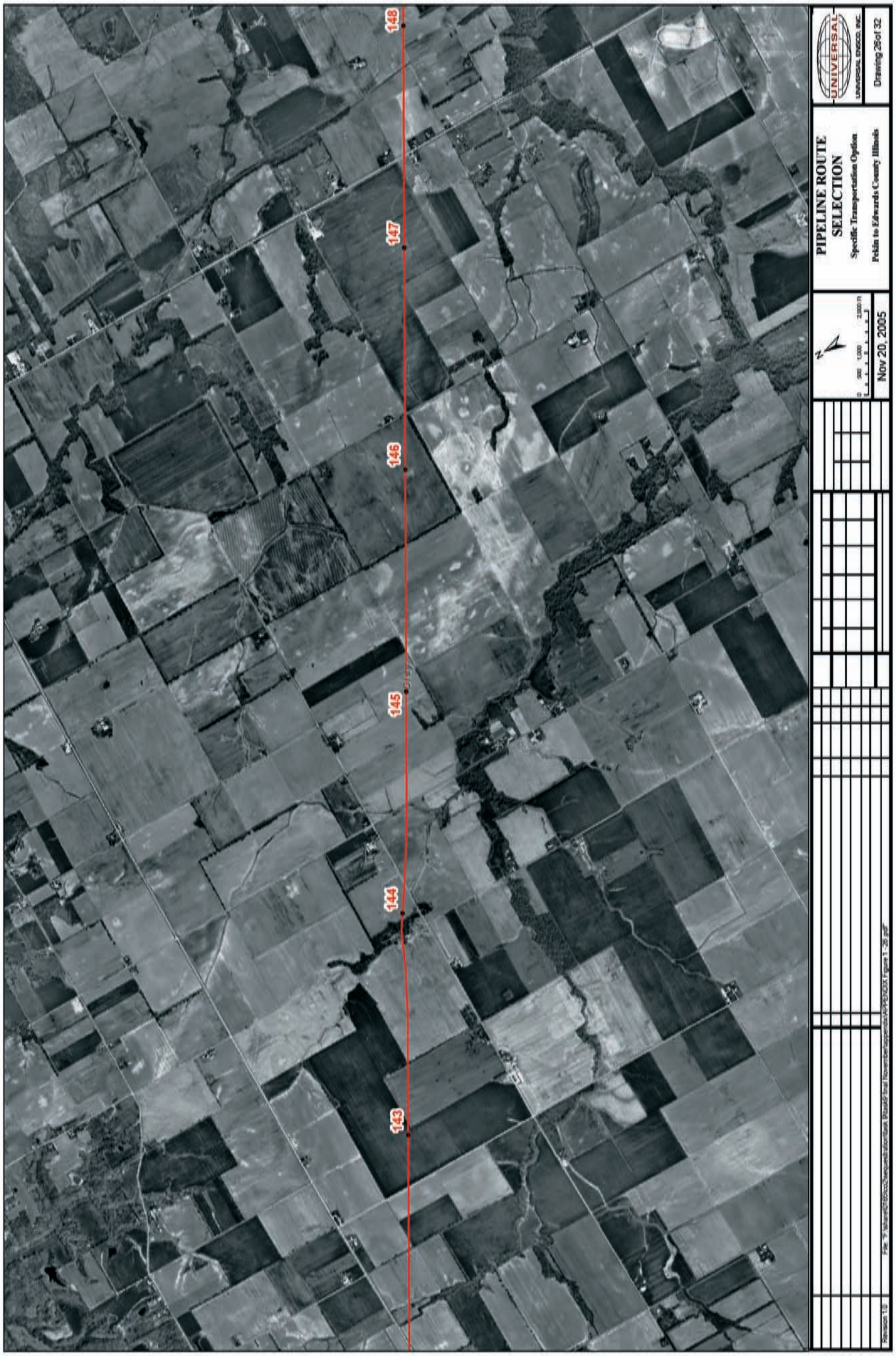

PIPELINE ROUTE SELECTION
Specific Transportation Option
Pekin to Edwards County Illinois
Nov 20, 2005
UNIVERSAL
Drawing 21 of 32
114
115
116
117
118
119
Effingham

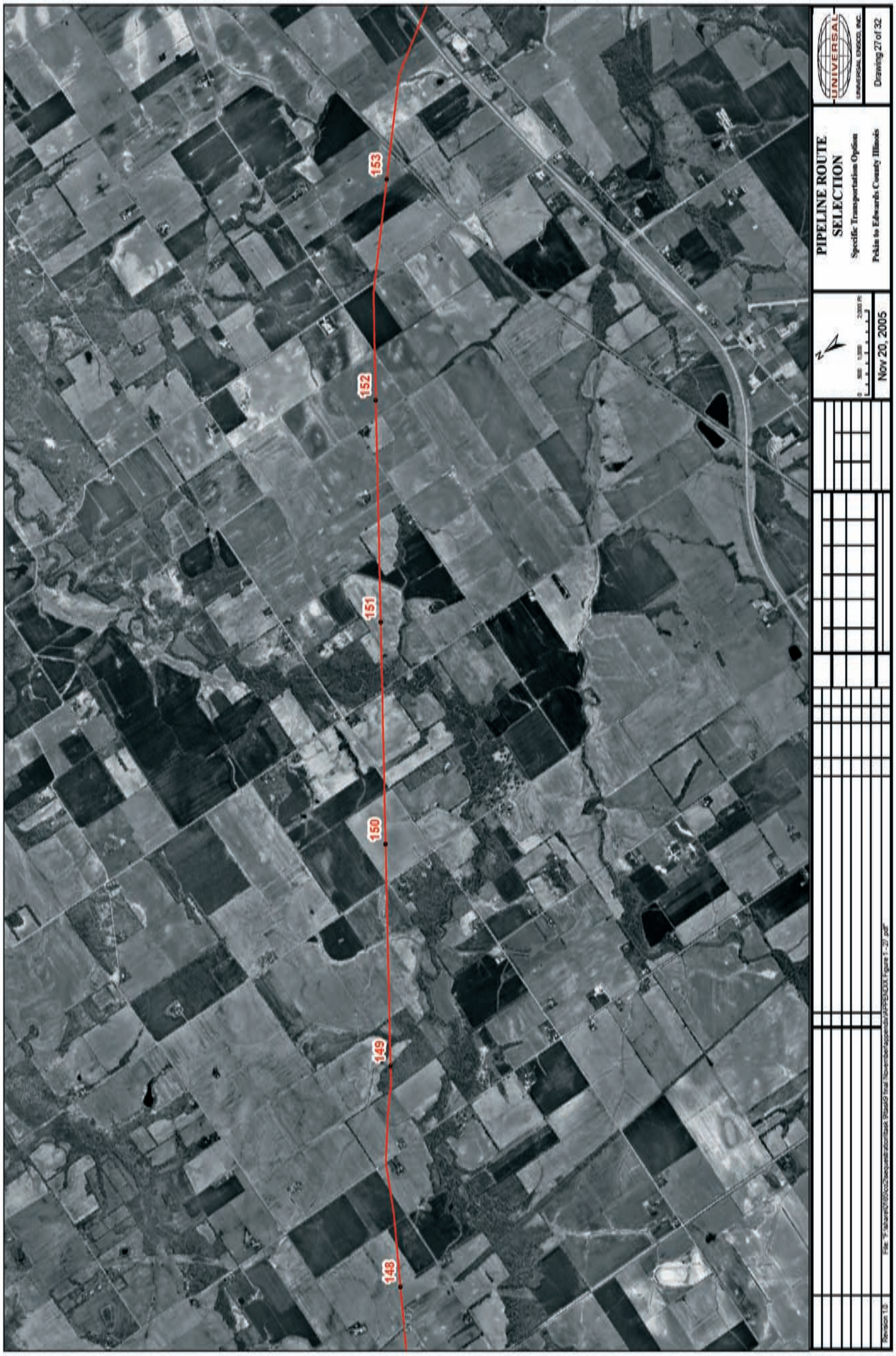

124
123
122
121
120
119
PIPELINE ROUTE SELECTION
Specific Transportation Option
Pekin to Edwards County Illinois
Nov 20, 2005
UNIVERSAL
Drawing 22 of 32


PIPELINE ROUTE SELECTION
Specific Transportation Option
Pekin to Edwards County Illinois
UNIVERSAL
Nov 20, 2005
Drawing 23 of 32
125
126
127
128
129
130

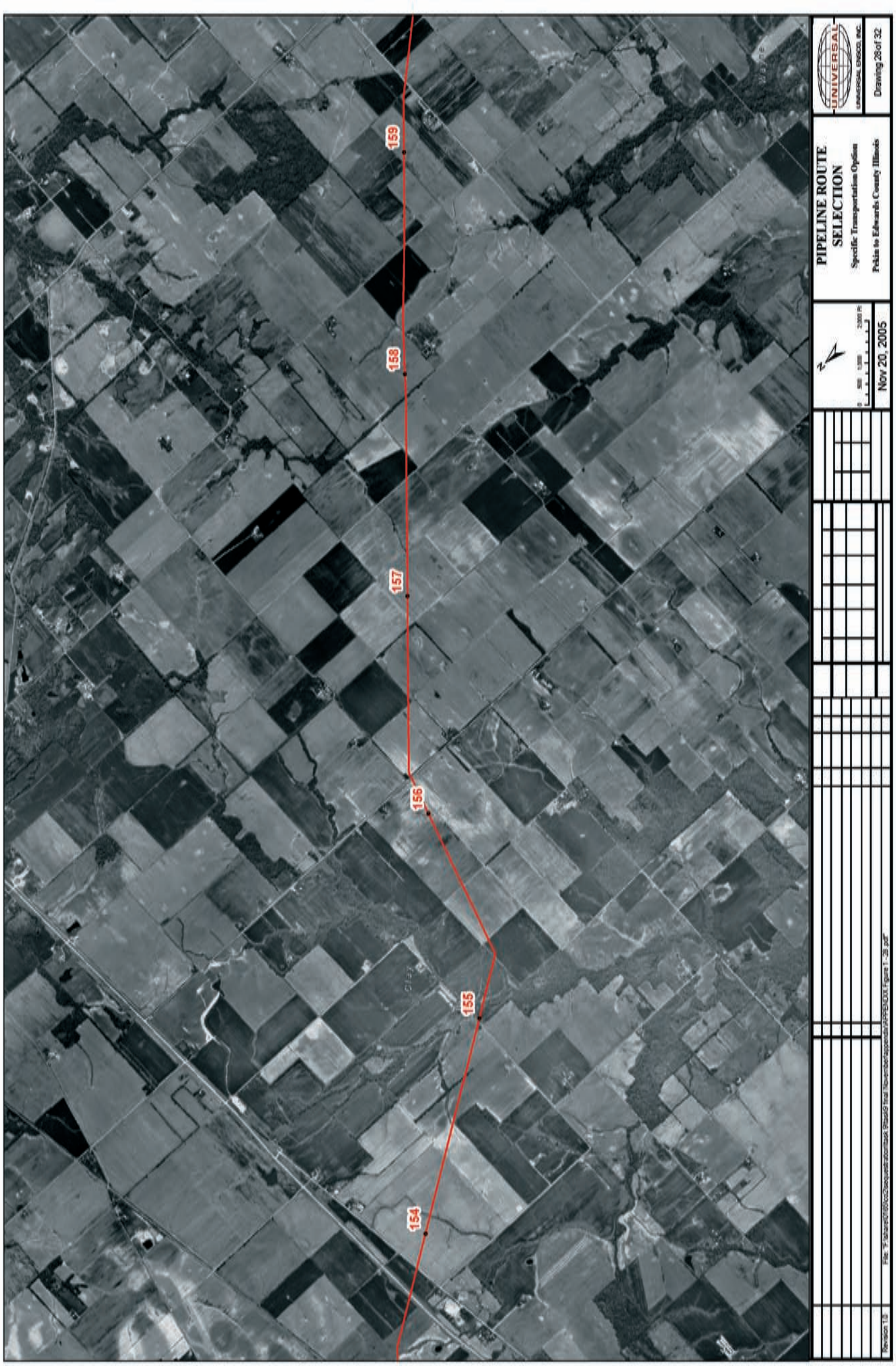

PIPELINE ROUTE SELECTION
Specific Transportation Option
Pekin to Edwards County Illinois
Nov 20, 2005
Drawing 24 of 32
UNIVERSAL
131
132
133
134
135
136

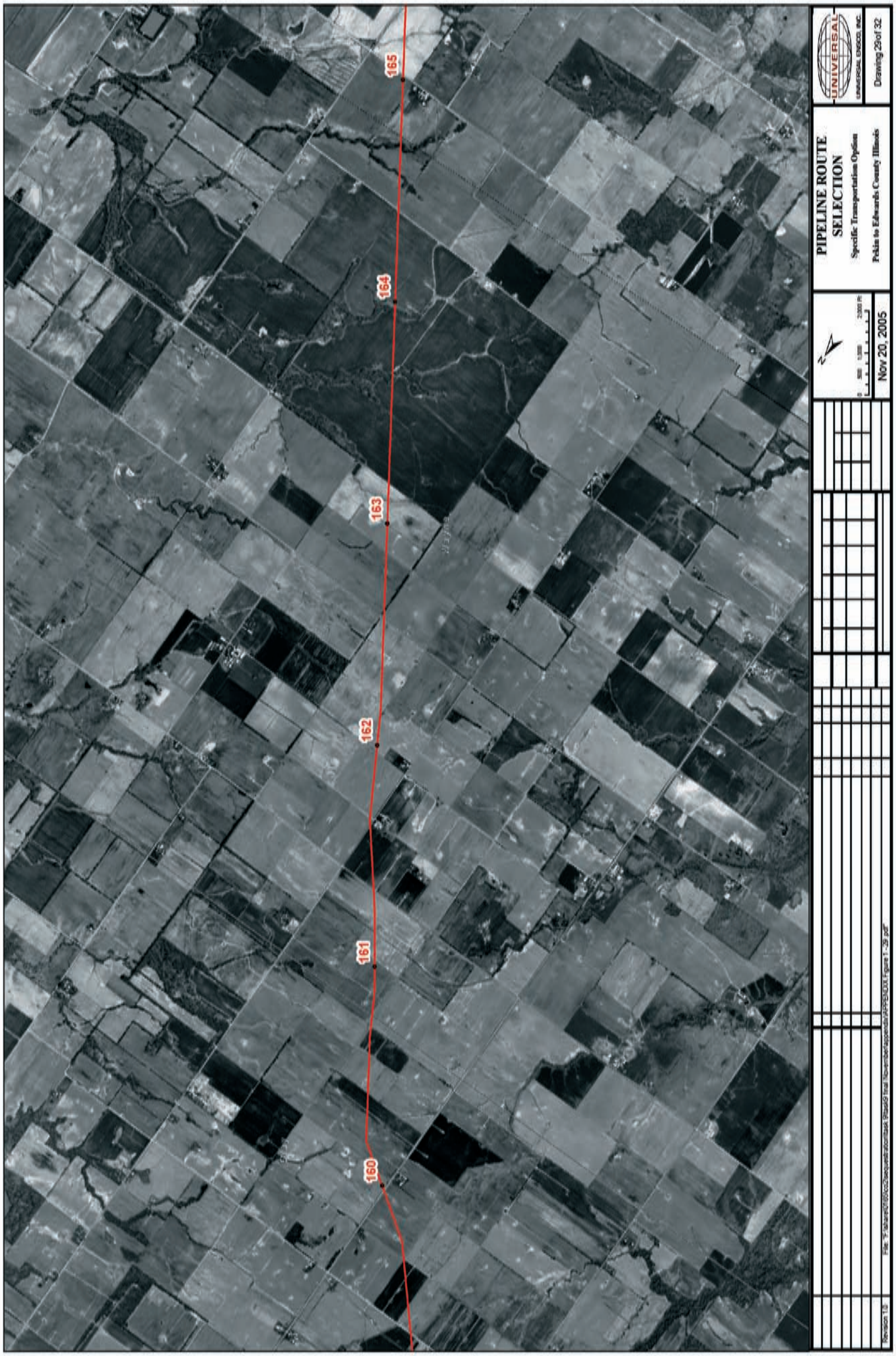

142
141
140
139
138
137
PIPELINE ROUTE SELECTION
Specific Transportation Option
Pekin to Edwards County Illinois
Nov 20, 2005
UNIVERSAL
UNIVERSAL ENSCO, INC.
Drawing 25 of 32

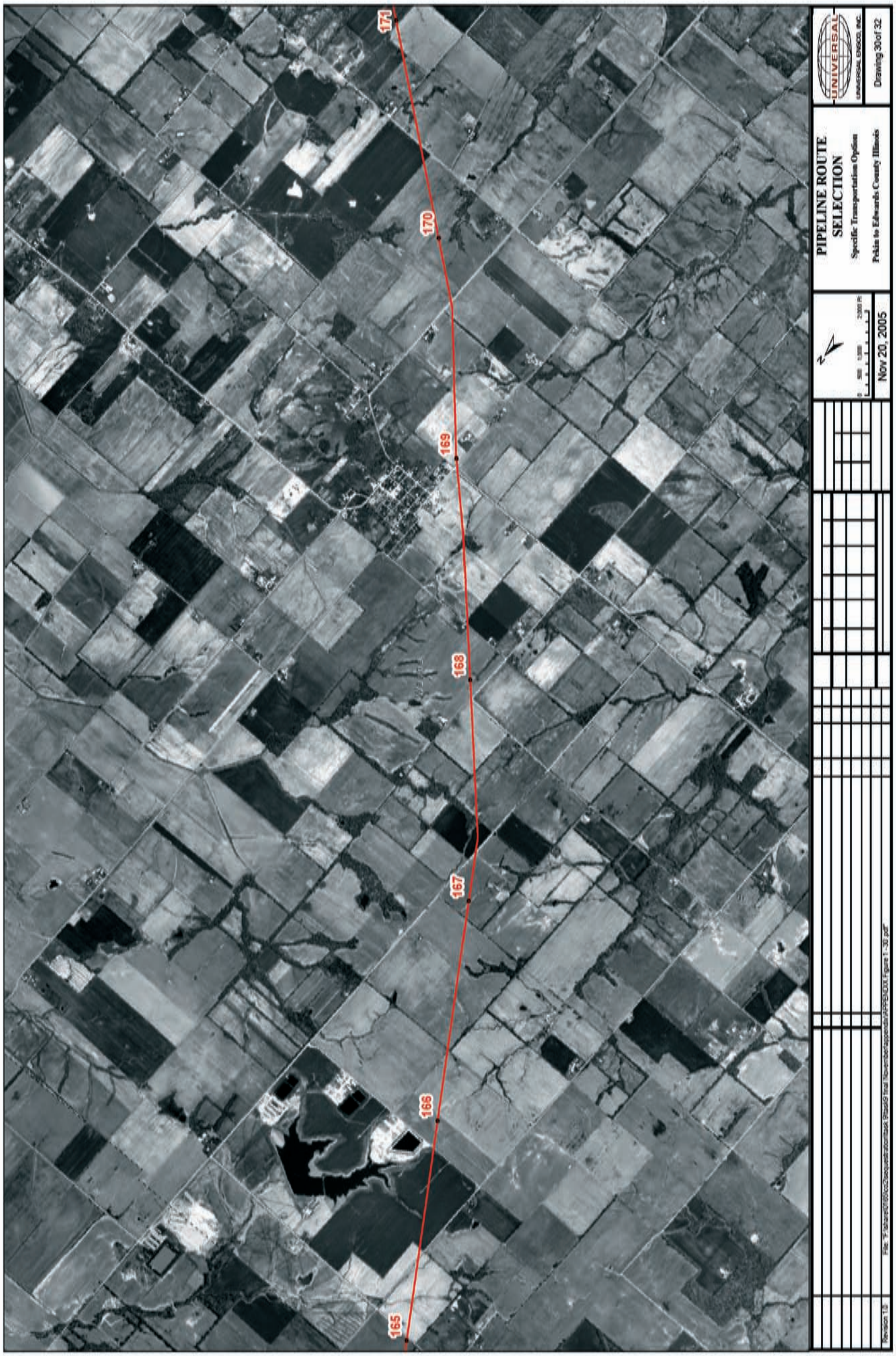

148
147
146
145
144
143
PIPELINE ROUTE SELECTION
Specific Transportation Option
Pekin to Edwards County Illinois
UNIVERSAL
UNIVERSAL ENSCO, INC.
Drawing 26 of 32
N
0 500 1,000 2,000 ft
Nov 20, 2005

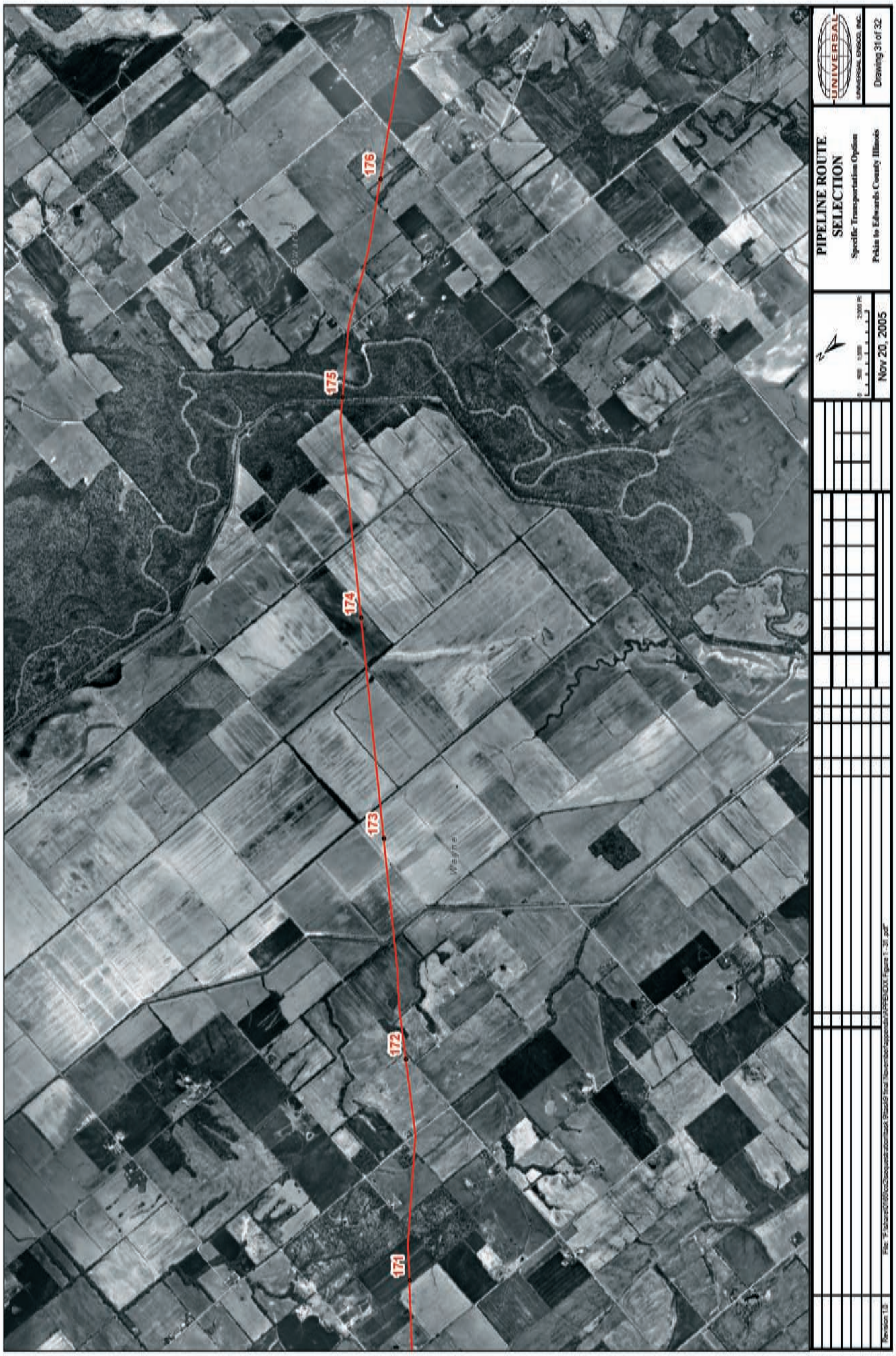


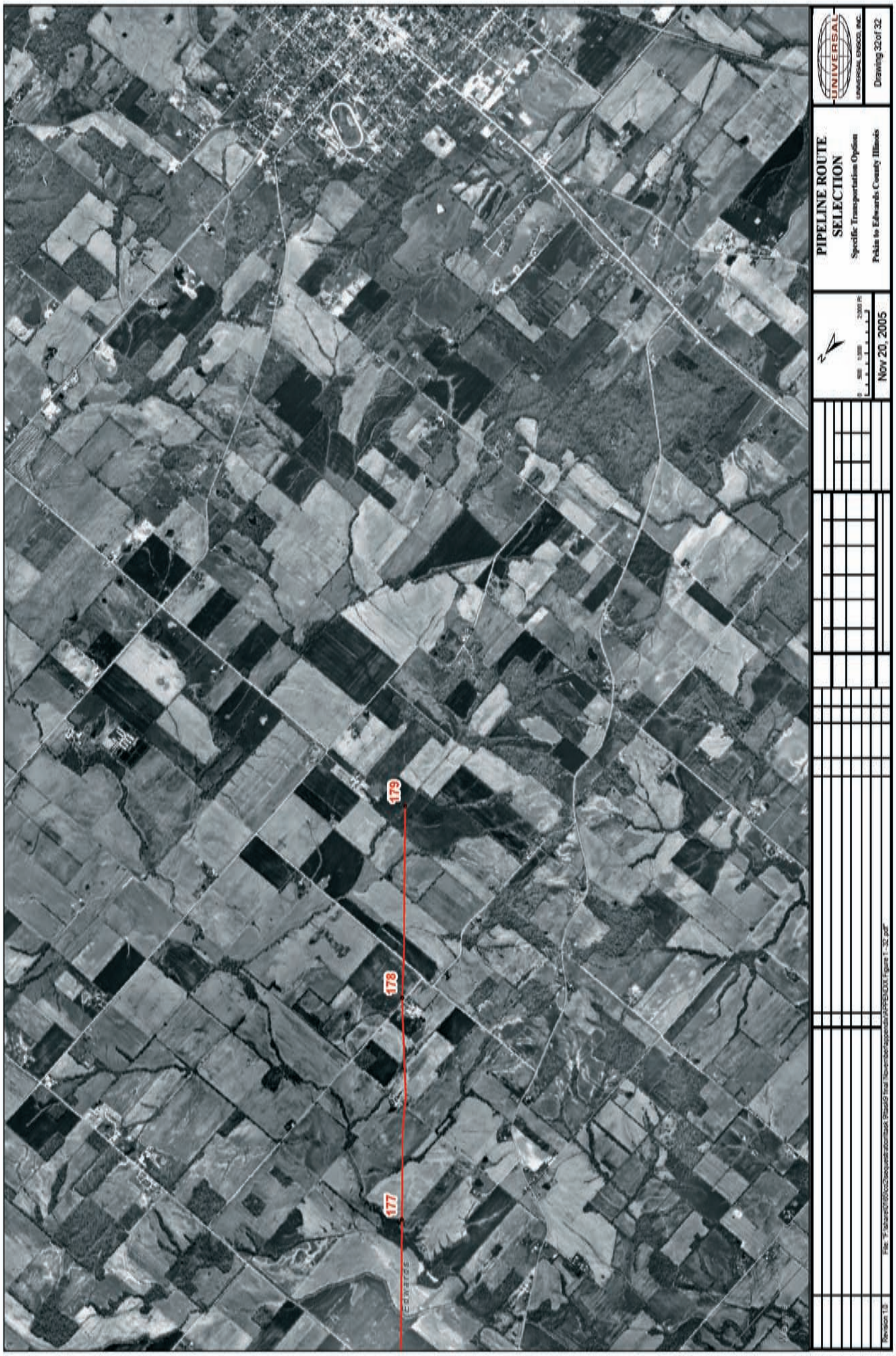
153
152
151
150
149
148
PIPELINE ROUTE SELECTION
Specific Transportation Option
Pekin to Edwards County Illinois
UNIVERSAL
Drawing 27 of 32
Nov 20, 2005
N


159
158
157
156
155
154
PIPELINE ROUTE SELECTION
Specific Transportation Option
Pekin to Edwards County Illinois
UNIVERSAL
Drawing 28 of 32
Nov 20, 2005
N


165
164
163
162
161
160
PIPELINE ROUTE SELECTION
Specific Transportation Option
Pekin to Edwards County Illinois
Nov 20, 2005
UNIVERSAL
Drawing 29 of 32


171
170
169
168
167
166
165
PIPELINE ROUTE SELECTION
Specific Transportation Option
Pekin to Edwards County Illinois
UNIVERSAL
Drawing 30 of 32
Nov 20, 2005


PIPELINE ROUTE SELECTION
Specific Transportation Option
Pekin to Edwards County Illinois
Nov 20, 2005
UNIVERSAL
Drawing 31 of 32
171
172
173
174
175
176
Wayne


PIPELINE ROUTE SELECTION
Specific Transportation Option
Pekin to Edwards County Illinois
Nov 20, 2005
UNIVERSAL
Drawing 32 of 32
177
178
179