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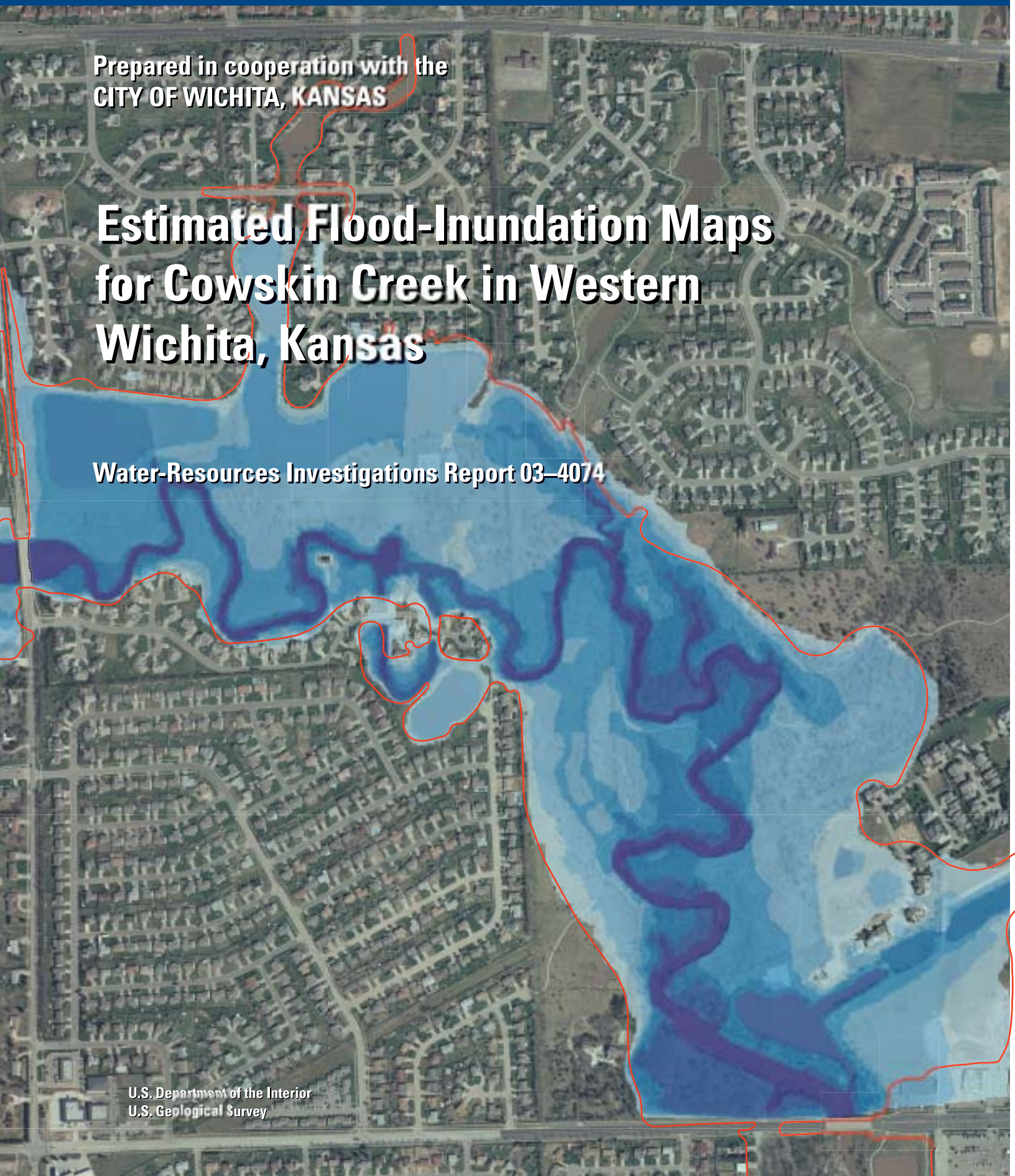

Prepared in cooperation with the
CITY OF WICHITA, KANSAS

Estimated Flood-Inundation Maps for Cowskin Creek in Western Wichita, Kansas

Water-Resources Investigations Report 03–4074

U.S. Department of the Interior
U.S. Geological Survey

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By SETH E. STUDLEY

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Lawrence, Kansas
2003

U.S. Department of the Interior

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CONVERSION FACTORS, ABBREVIATIONS, AND DATUMS

Multiply	By	To obtain
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
foot (ft)	0.3048	meter (m)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
inch (in.)	25.4	millimeter (mm)
inch per hour (in/hr)	25.4	millimeter per hour (mm/hr)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Estimated Flood-Inundation Maps for Cowskin Creek in Western Wichita, Kansas

By S.E. Studley

Abstract

The October 31, 1998, flood on Cowskin Creek in western Wichita, Kansas, caused millions of dollars in damages. Emergency management personnel and flood mitigation teams had difficulty in efficiently identifying areas affected by the flooding, and no warning was given to residents because flood-inundation information was not available.

To provide detailed information about future flooding on Cowskin Creek, high-resolution estimated flood-inundation maps were developed using geographic information system technology and advanced hydraulic analysis. Two-foot-interval land-surface elevation data from a 1996 flood insurance study were used to create a three-dimensional topographic representation of the study area for hydraulic analysis. The data computed from the hydraulic analyses were converted into geographic information system format with software from the U.S. Army Corps of Engineers' Hydrologic Engineering Center. The results were overlaid on the three-dimensional topographic representation of the study area to produce maps of estimated flood-inundation areas and estimated depths of water in the inundated areas for 1-foot increments on the basis of stream stage at an index streamflow-gaging station.

A Web site (http://ks.water.usgs.gov/Kansas/cowskin.floodwatch) was developed to provide the public with information pertaining to flooding in the study area. The Web site shows graphs of the real-time streamflow data for U.S. Geological Survey gaging stations in the area and monitors the National Weather Service Arkansas-Red Basin River Forecast Center for Cowskin Creek flood-forecast information. When a flood is forecast for the Cowskin Creek Basin, an estimated flood-inundation map is displayed for the stream stage closest to the National Weather Service's forecasted peak stage. Users of the Web site are able to view the estimated flood-inundation maps for selected stages at any time and to access information about this report and about flooding in general. Flood recovery teams also have the ability to view the estimated flood-inundation map pertaining to the most recent flood. The availability of these maps and the ability to monitor the real-time stream stage through the U.S. Geological Survey Web site provide emergency management personnel and residents with information that is critical for evacuation and rescue efforts in the event of a flood as well as for post-flood recovery efforts.

INTRODUCTION

Flooding is the principal natural hazard in the United States, accounting for more damages and loss of life than any other hazards according to data from 1974 to 1994 (Mileti, 1999). In October and November 1998, major flooding in south-central Kansas and the Kansas City and Wichita areas caused millions of dollars in damages and the loss of several lives. One notable occurrence of flooding was in the Cowskin Creek area of western Wichita, Kansas. Nearly 170 homes and businesses along Cowskin Creek and its tributaries reported about $4 million in flood

damage from the October 31, 1998, flood (Schminke and Wolf, 2001).

Since that time, the U.S. Geological Survey (USGS) in cooperation with the city of Wichita with assistance from the National Weather Service (NWS) conducted a study to develop management tools to improve flood-warning and flood-recovery efforts. These tools can provide estimated flood-inundation maps to city management and residents before, during, and immediately after flooding.

The current (2003) local flood-warning system (ALERT) for the Cowskin Creek Basin uses data from a streamflow-gaging station operated by USGS and several rainfall and river-stage gages operated by NWS to develop a forecasted peak stage for one location (Cowskin Creek at 119th Street West, station 07144480, fig. 1) in the basin. Stage is the water-surface elevation of the stream, in feet above a specified gage datum. The ALERT system was designed to improve the accuracy and timeliness of flood forecasts and to increase the safety of residents and businesses in the Cowskin Creek Basin when flooding is imminent (National Weather Service, 2002). Although this information is particularly useful for residents in the immediate area of the flood-forecast location, it is of limited use to residents upstream or downstream because the water-surface elevation is not constant through the entire reach of the stream. Also, Federal Emergency Management Agency (FEMA) and State emergency management mitigation teams typically lack information related to where and how deep the water is at locations other than near USGS gaging stations or NWS flood-forecast points.

In the past, measured flood-inundation mapping frequently has been done after major events like the 1993 floods in Kansas (Perry and others, 1997). This mapping typically is done well after flooding has subsided and often is of marginal use for rescue and recovery efforts.

The current (2003) availability of more accurate (1- or 2-ft interval) digital elevation data for communities and advanced hydraulic analysis computer programs make the production of estimated flood-inundation maps more accurate than in the past. Estimated flood-inundation maps can be produced using remote-sensing information, accurate topographic elevation data, field surveys, real-time streamflow-gaging station data, hydraulic analysis, and geographic information system (GIS) technology. The estimated flood-inundation maps can show an estimate of the extent of flooding, the depth of floodwaters, and could greatly assist recovery and possibly rescue efforts before, during, and after floods.

Purpose and Scope

The purpose of this report is to describe the development of a series of estimated flood-inundation maps for various stream stages of Cowskin Creek near Wichita, Kansas. The maps and other useful flood information are available on the USGS Kansas World Wide Web site (http://ks.water.usgs.gov/Kansas/cowskin.floodwatch). Users of the USGS Web site can view current real-time gaging-station information and select estimated inundation maps for current flood conditions, for the NWS forecasted peak stage, or for other selected stream stages.

Tasks specific to the development of the estimated flood-inundation maps and the Web site were: (1) installation of two gaging stations on Cowskin Creek—a continuous-discharge record station at 119th Street West (station 07144480, fig. 1) and a stage-only station at 29th Street North (station 07144470, fig. 1), (2) collection of geometric data and steady-flow data, (3) performance of a hydraulic analysis of the Cowskin Creek Basin and computation of water-surface profiles using the U.S. Army Corps of Engineer's HEC-RAS computer program, (4) production of estimated flood-inundation maps at various stream stages using the U.S. Army Corps of Engineer's HEC-GeoRas computer program and GIS, and (5) development of a Web interface that uses real-time gaging-station information and NWS forecasted peak stage to display appropriate estimated flood-inundation maps on the World Wide Web during floods.

The scope of this study was limited to the Cowskin Creek area between Central Avenue and 21st Street North (fig. 2) due to the availability of hydraulic information and ongoing construction to the south of this area. Future data-collection and hydraulic analyses are needed to provide estimated flood-inundation maps for Cowskin and Calfskin Creeks between the study area and U.S. Highway 54 (fig. 1), which was undergoing construction activities related to flood mitigation at the time of this study.

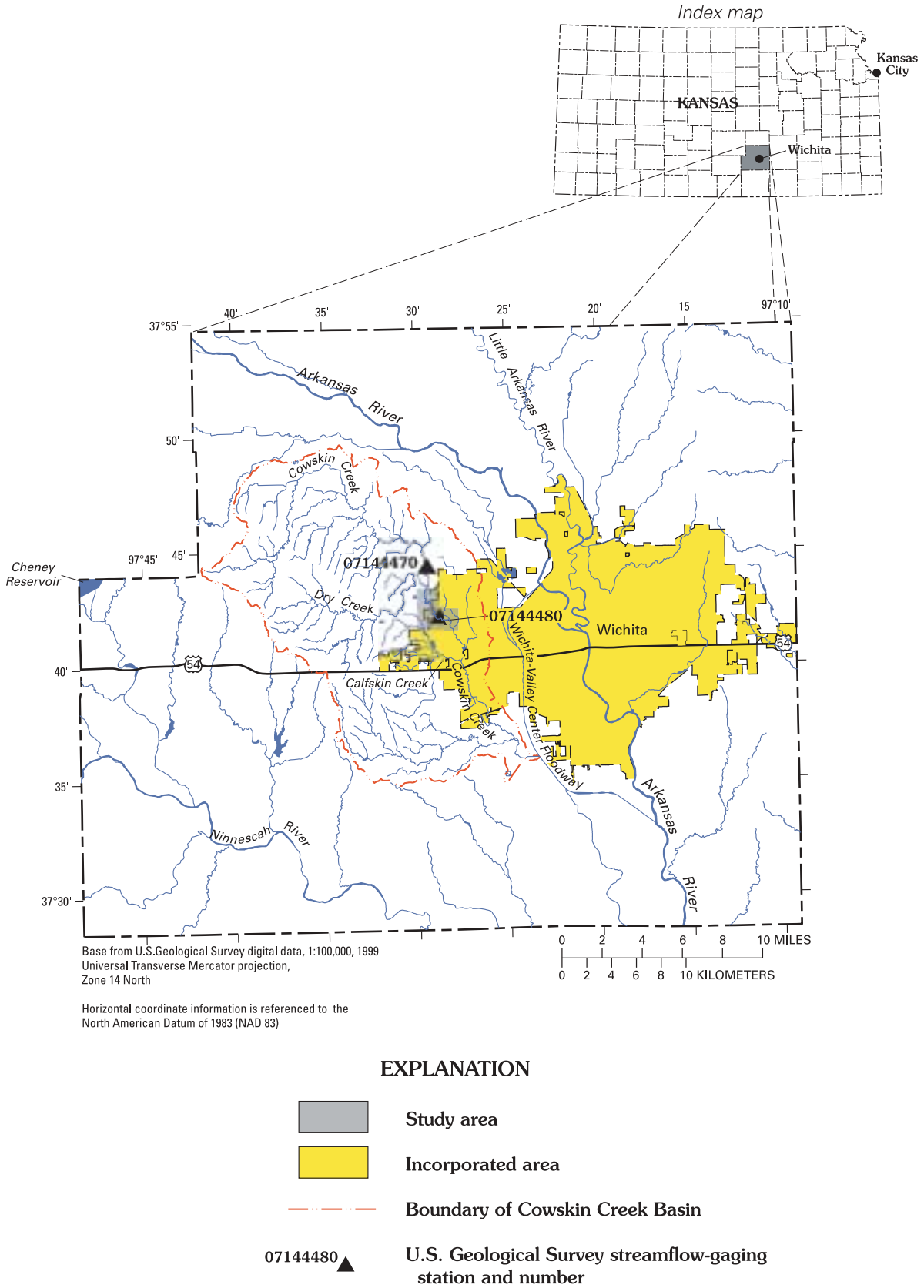

Figure 1. Location of Cowskin Creek Basin and study area in western Wichita, Sedgwick County, south-central Kansas.

Figure 2. Location of U.S. Geological Survey streamflow-gaging station (07144480) used as index site and October 31, 1998, flood-inundation boundary determined by field survey (Wichita Public Works Stormwater Division, written commun., 2001).

Benefits

Local emergency management personnel could use the estimated flood-inundation maps prior to a flood to identify potentially threatened areas and take appropriate actions to warn property owners. The maps also could help business owners and the public identify property that is potentially threatened by floodwaters. A better inundation mapping system in place prior to flooding would provide more accurate information that could greatly improve rescue and recovery efforts, prevent loss of life, and provide warning to property owners.

During flooding, time is critical to rescue crews, and logistical decisions need to be made quickly. If rescue efforts become necessary, knowledge of where and how deep the water is will help rescue crews decide what type of equipment and boats to move into the area. Knowing conditions at NWS forecasted peak stage will help rescue crews plan recovery efforts before conditions worsen.

The results presented in this report will supplement the information collected as part of the city of Wichita's flood-alert system. After viewing the estimated inundation maps on the Web site, people will have a better idea where conditions are unsafe for driving. The information can be shared with neighbors who do not have access to the World Wide Web. The maps could be helpful in rescue operations during a flood and in saving lives. Local and county road and street crews or the Kansas Department of Transportation could use the flood-inundation maps to help identify where road closures may be needed.

After flooding, Federal and State mitigation teams move into flood-affected areas and are responsible for collecting information on damages and for informing the public on issues related to flood insurance, acquisition of property, applications for hazard mitigation grants for projects to reduce future flood damages and loses, and flood mapping. Information from the estimated inundation maps for the flood would help the mitigation teams more efficiently conclude these recovery efforts.

DESCRIPTION OF STUDY AREA

Cowskin Creek is located on the western edge of Wichita in Sedgwick County, south-central Kansas (fig. 1), and has a total drainage area of 221 mi^2. The stream reach detailed in this report extends from near 21st Street North at the upstream end to Central Avenue at the downstream end (fig. 2).

The stream channel slopes gently at approximately 5.5 ft/mi with a total length of about 5.2 mi through the study reach. The channel banks are generally tree lined with brushy undergrowth. The flood plain beyond the channel banks consists mostly of low grasses and lawns with a few small agricultural plots in the northern end of the study area. The study area is still under development with new houses and some commercial businesses.

The climate of western Sedgwick County varies both seasonally and daily. The average annual precipitation for Sedgwick County is about 30 in., with most occurring in April and May. The county has an average of about 55 thunderstorms per year, mainly in the spring and summer. Typically, rainfall rates for the thunderstorms are 1.0 to 1.5 in/hr with durations of several minutes to several hours. The record rainfall intensity for Sedgwick County occurred on June 15, 1982, when nearly an inch of rain fell in 5 minutes. The most intense 24-hour rainfall total of 7.99 in. was recorded in September 1911. The storm that caused the 1998 Cowskin Creek flood had a 24-hour rainfall total of 5.84 in. on October 30–31 (National Weather Service, 2003).

Two USGS streamflow-gaging stations were installed in April 2001 as part of the study described in this report. The first gaging station is located on Cowskin Creek at 119th Street West (fig. 3*A*) (station 07144480) and is a real-time streamflow-gaging station that is used as the index site for the hydraulic analysis described in this report, and it also serves as the "trigger" to determine which estimated flood-inundation map is displayed on the USGS Web site during flooding. The second gaging station (fig. 3*B*) is located upstream from the study area at 29th Street North (station 07144470). This gaging station collects stream stage data in real time and serves as an early warning site for possible flooding in the study area. Both of these stream gages also collect real-time precipitation data.

HYDRAULIC ANALYSIS

The hydraulic analysis for the Cowskin Creek study area was performed using the Hydrologic Engineering Center's River Analysis System (HEC-RAS) computer program to develop a hydraulic model (U.S. Army Corps of Engineers, 1998) to simulate estimated

(A)

(B)

Figure 3. U.S. Geological Survey streamflow-gaging stations on Cowskin Creek at *(A)* 119th Street West (station 07144480, figs. 1 and 2) and at *(B)* 29th Street North (station 07144470, fig. 1).

flood-inundation areas. The HEC-RAS program was designed specifically for application in flood-plain management and flood-insurance studies to evaluate floodway encroachment (U.S. Army Corps of Engineers, 1998) and to simulate estimated flood inundation. The program is designed to compute one-dimensional, steady-flow, water-surface profiles on the basis of the solution of the one-dimensional energy equation:

$$Y_2 + Z_2 + (a_2 V_2^2)/2g = Y_1 + Z_1 + (a_1 V_1^2)/2g + h_e, \quad (1)$$

where

Y_1, Y_2 = depth of water at cross section;
Z_1, Z_2 = elevation of the main channel inverts;
V_1, V_2 = average velocities (total discharge/total cross-sectional area);
a_1, a_2 = velocity weighting coefficients;
g = gravitational acceleration; and
h_e = energy head loss.

The input data for the HEC-RAS program were divided into three categories—topographic, geometric, and steady-flow data. Topographic data for Cowskin Creek between Central Avenue and 21st Street North were obtained from the Sedgwick County GIS Department (Wichita, Kansas). The 2-ft-interval land-surface elevations were mapped at a scale of 1 in. = 200 ft based on February 1994 aerial photography. Mylar copies of the maps for the area between Maize Road and 21st Street North were scanned and converted to a digital format and entered into the HEC-GeoRAS computer program. The HEC-GeoRAS (U.S. Army Corps of Engineers, 1999) computer program is a package of ARC/INFO (Environmental Systems Research Institute, Inc., 1991) macros specifically designed to view and manipulate geospatial data for use in the HEC-RAS computer program.

Geometric data consisted of establishing the connectivity of the river system (cross-sectional data, reach lengths, friction losses, and losses due to expansion and contraction) and hydraulic structures (information on bridges, culverts, weirs, and so forth). The geometric data for the study area was obtained from 2-ft-interval land-surface elevation maps, field observations, and high-resolution aerial photographs. Stream cross sections were extracted graphically from the 2-ft interval data coverage using HEC-GeoRAS. This process allowed the location of cross sections anywhere in the study area without performing difficult and time-consuming field surveys. Field observations and high-resolution aerial photographs were used to select Manning's roughness coefficients for friction loss calculations. The selected Manning's roughness coefficients ranged from 0.045 to 0.060 for this analysis. The hydraulic structures in the study area consisted of three bridges located at 13th Street North, 119th Street West, and Central Avenue. Field surveys were performed to obtain the bridge geometry and embankment and abutment data.

Steady-flow data consisted of flow regime, boundary conditions (known water-surface elevation, critical depth, normal depth, or rating curve), and peak discharge information. The steady flow data for the study reach were obtained from previous studies and field measurements of streamflow at the Cowskin Creek gaging station made at 119th Street West. Normal-depth boundary conditions were used in all computations using discharge values with known stages from actual streamflow measurements made at the 119th Street West gaging station and estimates of stage and discharge from previous studies to calibrate the hydraulic model (Ellis and others, 1963; Black and Veatch Corporation, 2001).

CALIBRATION AND RESULTS OF HYDRAULIC ANALYSIS

The resulting hydraulic model was calibrated using the estimated discharge and stage from the October 31, 1998, flood at 119th Street West, a GIS coverage of the extent of flooding for October 31, 1998, from the Wichita Public Works Stormwater Division (written commun., 2001), and the measured stage and discharge from the 119th Street West gaging station that was made during the October 4, 2002, flood.

The estimated peak discharge for the October 31, 1998, flood was 14,700 ft^3/s (estimated 100- to 200-year flood) at an estimated stage of about 22.1 ft at the 119th Street West gaging station (Black and Veatch Corporation, 2001), and the measured discharge and stage for the October 4, 2002, flood were 1,080 ft^3/s and 17.01 ft, respectively. Calibration of the hydraulic model was achieved by making small adjustments to the roughness coefficients until the results of the hydraulic computations closely agreed with the two known flood discharge and stage values. The simulated estimated flood-inundation extent for the

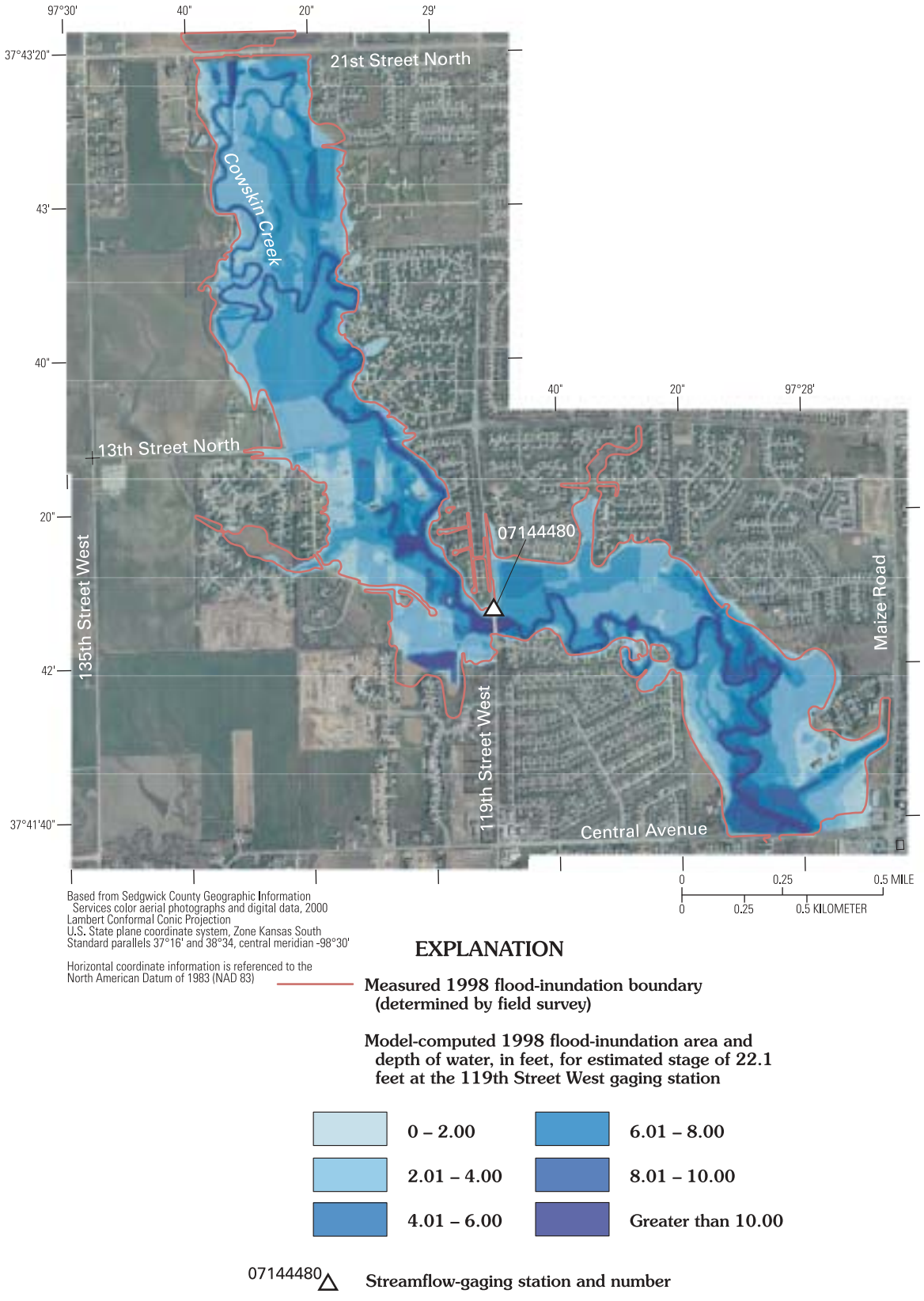

Figure 4. Comparison of measured flood-inundation boundary and estimated flood-inundation areas for the October 31, 1998, flood on Cowskin Creek in Wichita (measured flood-inundation boundary from field survey by the Wichita Public Works Stormwater Division, written commun., 2001).

October 31, 1998, flood discharge compared to the GIS flood coverage for the study area showed close agreement (fig. 4). Differences between the two coverages most likely can be attributed to the lack of detail of 2-ft-interval contour lines in very flat parts of the study area and to changes in the land surface caused by new construction since the 2-ft-interval elevation data were produced in 1994.

After the model was calibrated, discharge values were entered by trial and error until the desired stages of 17, 18, 19, 20, 21, 22, and 23 ft were simulated at the 119th Street West gaging station to compute estimates of discharge. These stages represent flow from bankfull to just above the October 31, 1998, flood peak. One-foot increments were selected because they match the uncertainty of the topographic information. The computed estimates of discharge are listed in table 1 with the water-surface elevation and the estimated flood recurrence interval for each estimate.

DEVELOPMENT OF FLOOD-INUNDATION MAPS

Flood-inundation maps have been developed in the past by hand-plotting inundation boundaries on topographic maps using known water-surface elevation points and interpolating the boundary lines between the points while taking into account the land-surface elevations. In this report, high-definition digital topographic data and computer software are used, and the water-surface profiles from hydraulic analyses can be overlayed on digital maps with greater efficiency and accuracy than in the past. As a result, real-time inundation mapping (Jones and others, 1998) or estimated flood mapping (for areas where precipitation variation can be assumed to be modest, such as in small drainage basins like Cowskin Creek) can be very useful.

The simulated estimated flood-inundation maps in this report were developed using the U.S. Army Corps of Engineer's HEC-GeoRAS software and high-definition, georeferenced, aerial photographs obtained from Sedgwick County, Kansas. Water-surface profiles from HEC-RAS simulations were imported to HEC-GeoRAS, and the flood-inundation areas then were computed and overlaid on the topographic representation of the study area. Then, using ARC/INFO, the estimated flood-inundation areas were overlaid on georeferenced digital photographs of the study area to create a map that represents an aerial view of the estimated flood-inundation areas.

The resulting estimated flood-inundation maps for stream stages of 17 to 23 ft in 1-ft increments are displayed in the Appendix (figs. 5–11). The estimated inundated areas are shown in graduated colors of blue to indicate the depth of the water. Darker areas have a greater water depth than the lighter areas.

COWSKIN CREEK FLOOD-INUNDATION MAPS ON THE WORLD WIDE WEB

A World Wide Web site was developed to provide Cowskin Creek estimated flood-inundation information to the public, especially during times of impending flooding. The Web site URL is http://ks.water.usgs.gov/Kansas/cowskin.floodwatch and also can be accessed by a link through the USGS Kansas Web site at http://ks.water.usgs.gov

The main page of the Cowskin Creek Web site displays graphs of the current streamflow and stage at the 119th Street West gaging station (07144480) and also

Table 1. Water-surface elevations for selected stream stages and estimated discharges and flood-recurrence intervals at U.S. Geological Survey streamflow-gaging station on Cowskin Creek at 119th Street West, Wichita, Kansas (station 07144480, fig. 1)

[NAVD 88, North American Vertical Datum of 1988; <, less than; >, greater than]

Stream stage (feet)	Water-surface elevation (feet above NAVD 88)	Estimated discharge (cubic feet per second)	Estimated flood-recurrence interval (years)
17.0	1,329.4	1,160	<2
18.0	1,330.4	1,720	2–5
19.0	1,331.4	3,080	5–10
20.0	1,332.4	5,700	10–25
21.0	1,333.4	9,600	50–100
22.0	1,334.4	14,200	100–200
23.0	1,335.4	19,100	>200

the current stage at the 29th Street North gaging station (07144470). If the stream stage at 119th Street West gaging station is above 16.5 ft, an image of the estimated flood-inundation map closest to the current stage is displayed. When a National Weather Service (NWS) Arkansas-Red Basin River Forecast Center (ARBFC) flood forecast has been issued for Cowskin Creek, a link is available from the USGS Kansas Web site to the estimated flood-inundation map closest to the NWS forecasted peak stage. Also, the peak stage and corresponding estimated flood-inundation map for past floods are stored in an archive and can be displayed. This report is provided as a reference. The estimated flood-inundation maps are displayed in sufficient detail to note the extent of flooding with respect to individual structures. This real-time information is available to the public and emergency management personnel so that preparation for flooding can be done in an efficient manner.

Other useful links provided on the USGS Kansas Web site allow users to view current weather data, watches and warnings, and safety information from the National Weather Service. There also are links to Web sites that contain more information on flooding and related subjects provided by the USGS and the city of Wichita, Kansas.

SUMMARY

A series of estimated flood-inundation maps were developed in cooperation with the city of Wichita, Kansas, for Cowskin Creek between 21st Street North and Central Avenue. These maps, in conjunction with the real-time stage data from the USGS gaging station at 119th Street West (station 07144480) and National Weather Service flood-stage forecasts, will help the city to efficiently manage emergency flood operations and flood mitigation efforts. A USGS Web site also was developed to allow public access to the real-time flood information so that they may take safety precautions prior to emergency conditions.

The maps were developed using the U.S. Army Corps of Engineers' HEC-RAS and HEC-GeoRAS programs to compute water-surface profiles and to delineate estimated flood-inundation areas for selected stream stages. The maps show estimated flood-inundation areas overlaid on high-resolution, georeferenced, aerial photographs of the study area for stream stages of 17, 18, 19, 20, 21, 22, and 23 ft at the 119th Street gaging station. The estimated inundation areas are shaded to give a general indication of the depth of water at any point; lighter shaded areas have shallower depths of water than the darker shaded areas.

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APPENDIX—Estimated Flood-Inundation Areas for Selected Stages of Cowskin Creek in Western Wichita, Kansas

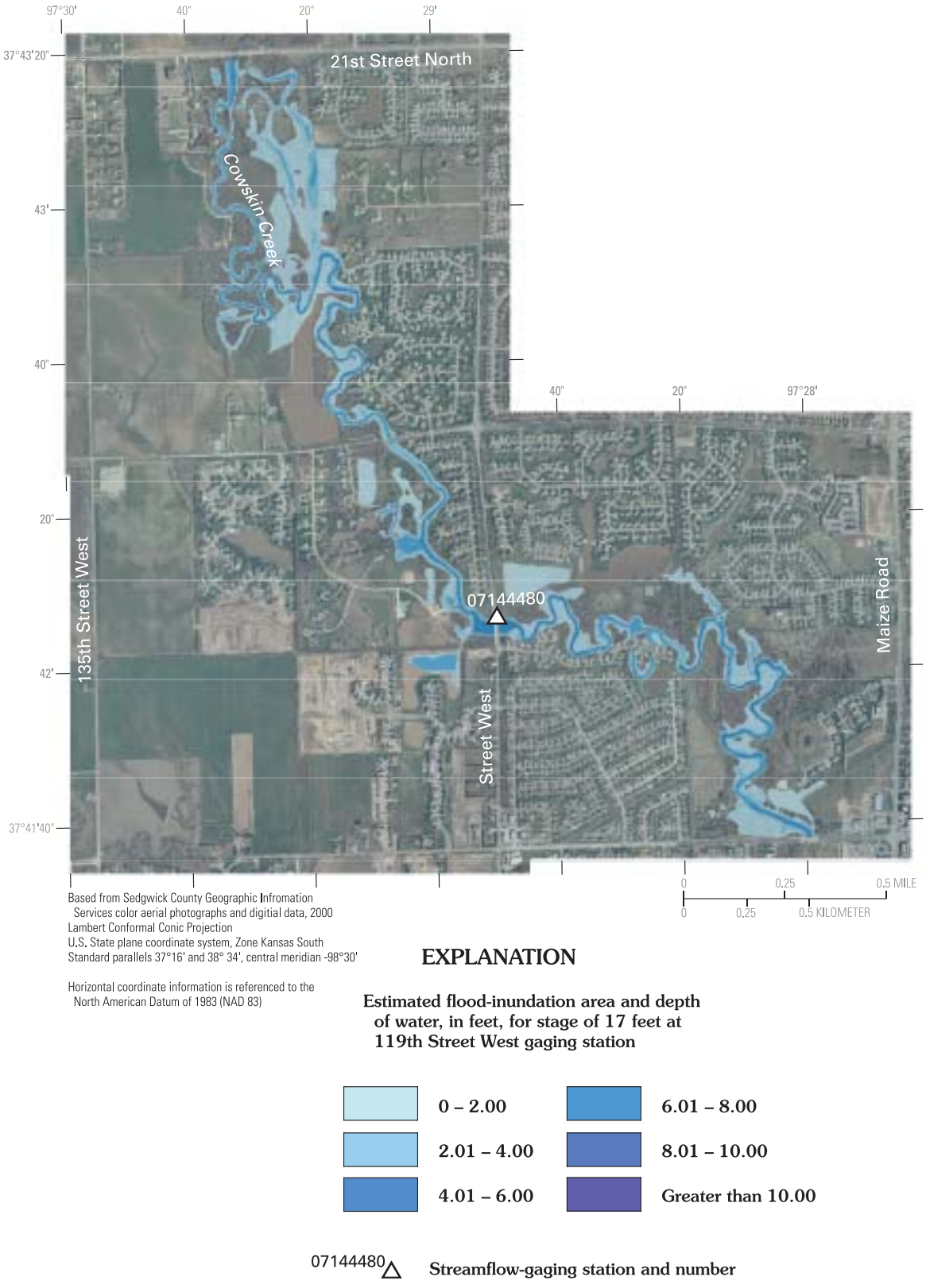

Figure 5. Estimated flood-inundation areas and estimated depths of water at Cowskin Creek at 119th Street West gaging station for stream stage of 17 feet.

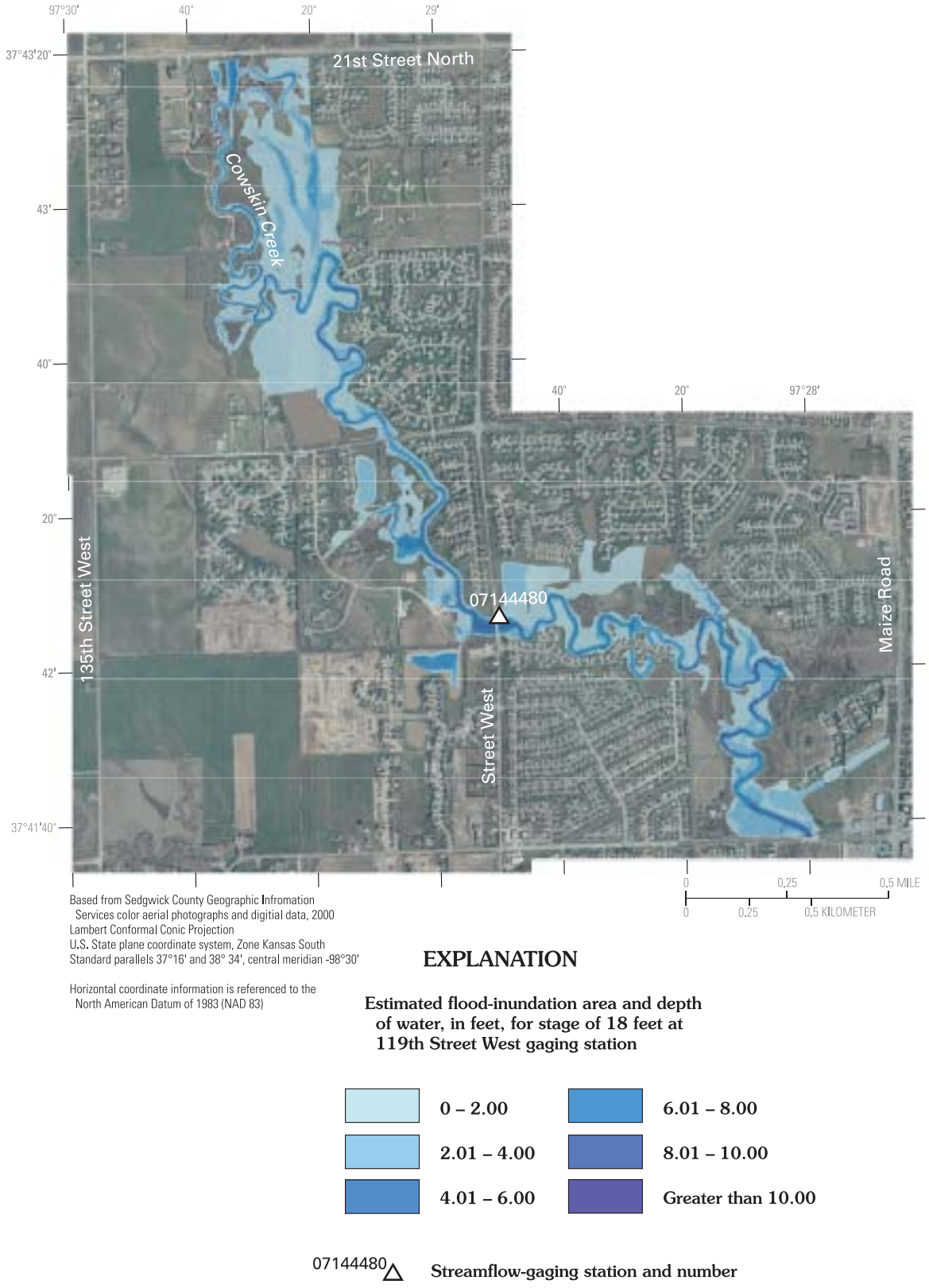

Figure 6. Estimated flood-inundation areas and estimated depths of water at Cowskin Creek at 119th Street West gaging station for stream stage of 18 feet.

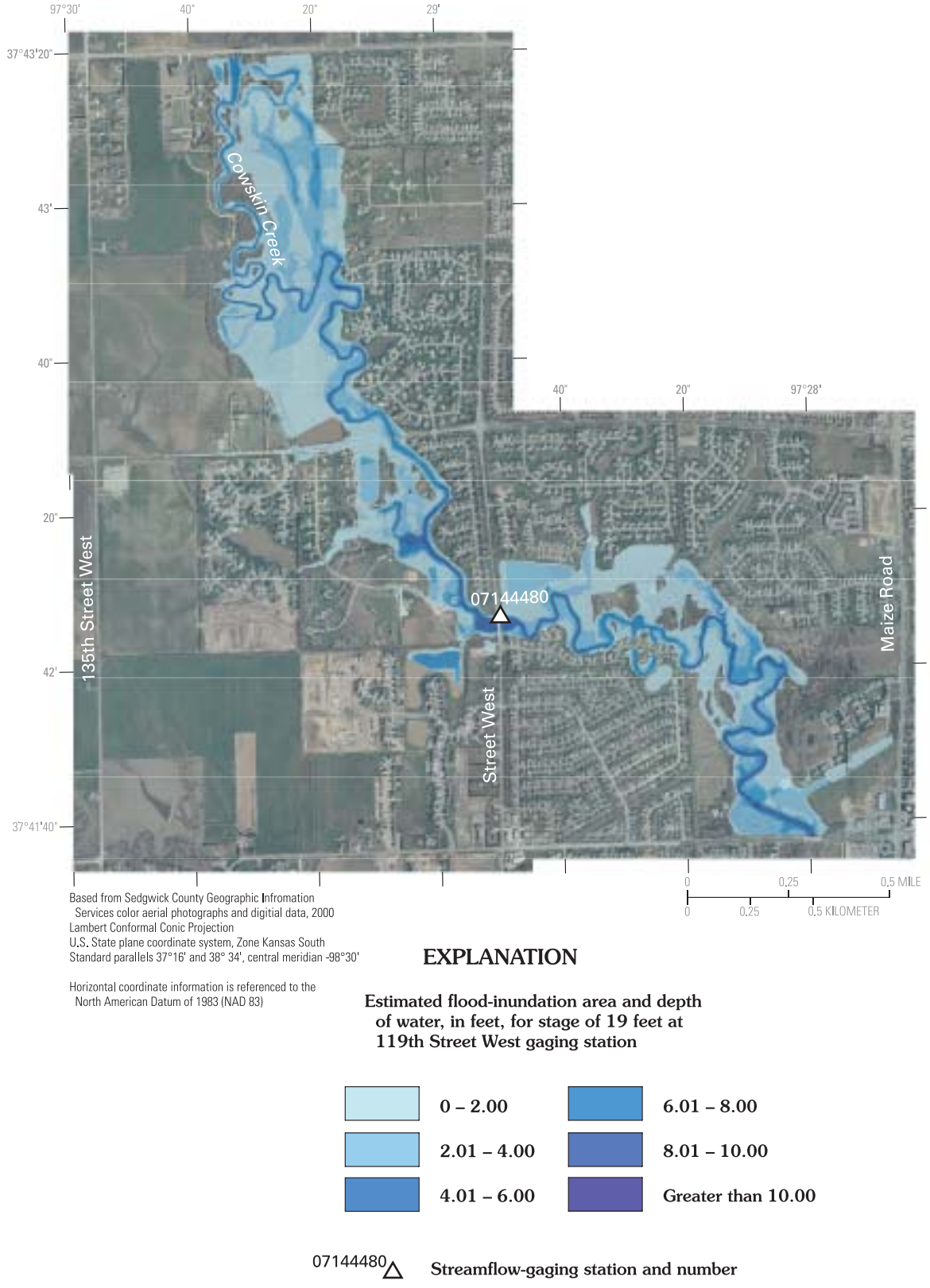

Figure 7. Estimated flood-inundation areas and estimated depths of water at Cowskin Creek at 119th Street West gaging station for stream stage of 19 feet.

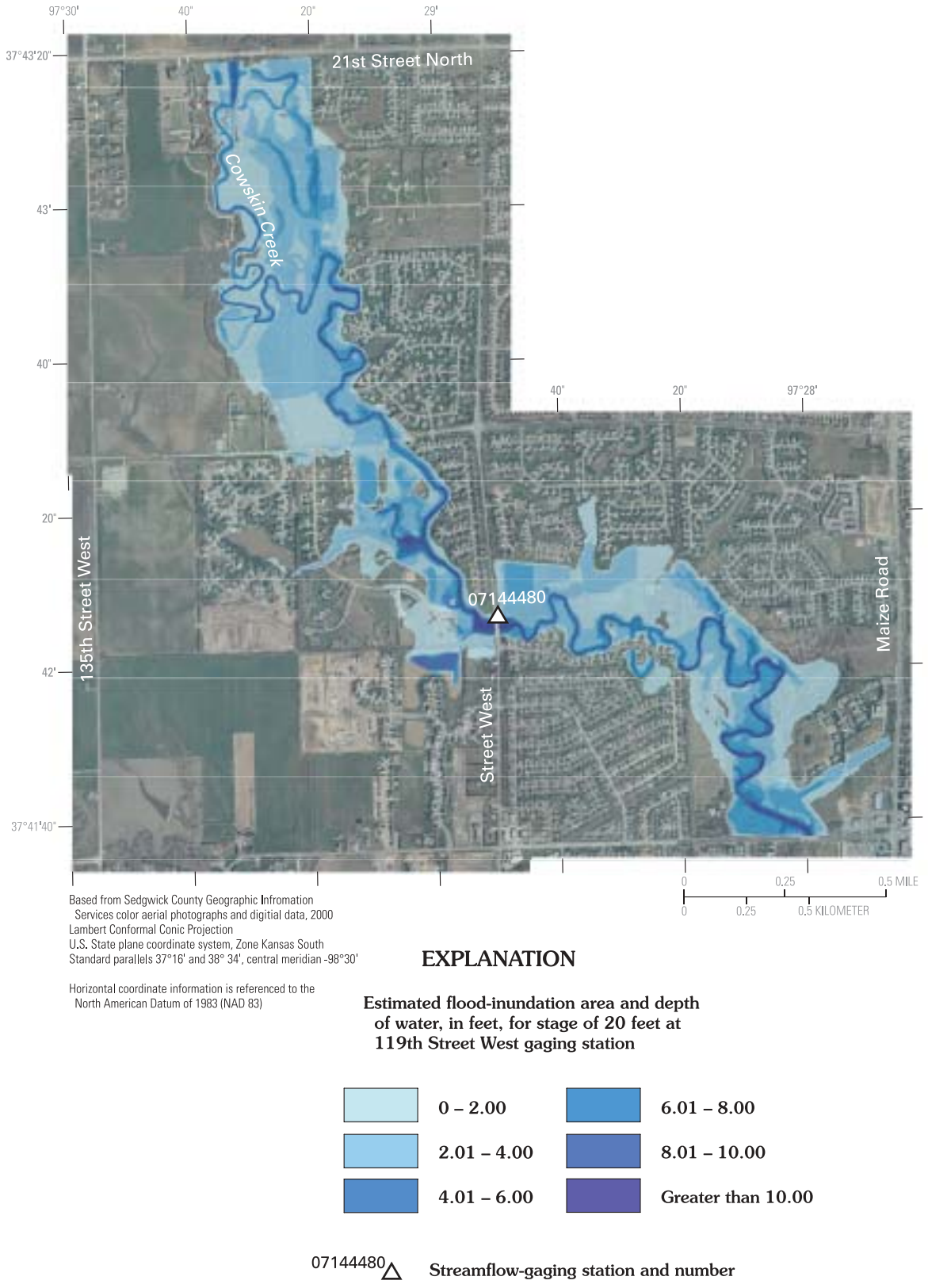

Figure 8. Estimated flood-inundation areas and estimated depths of water at Cowskin Creek at 119th Street West gaging station for stream stage of 20 feet.

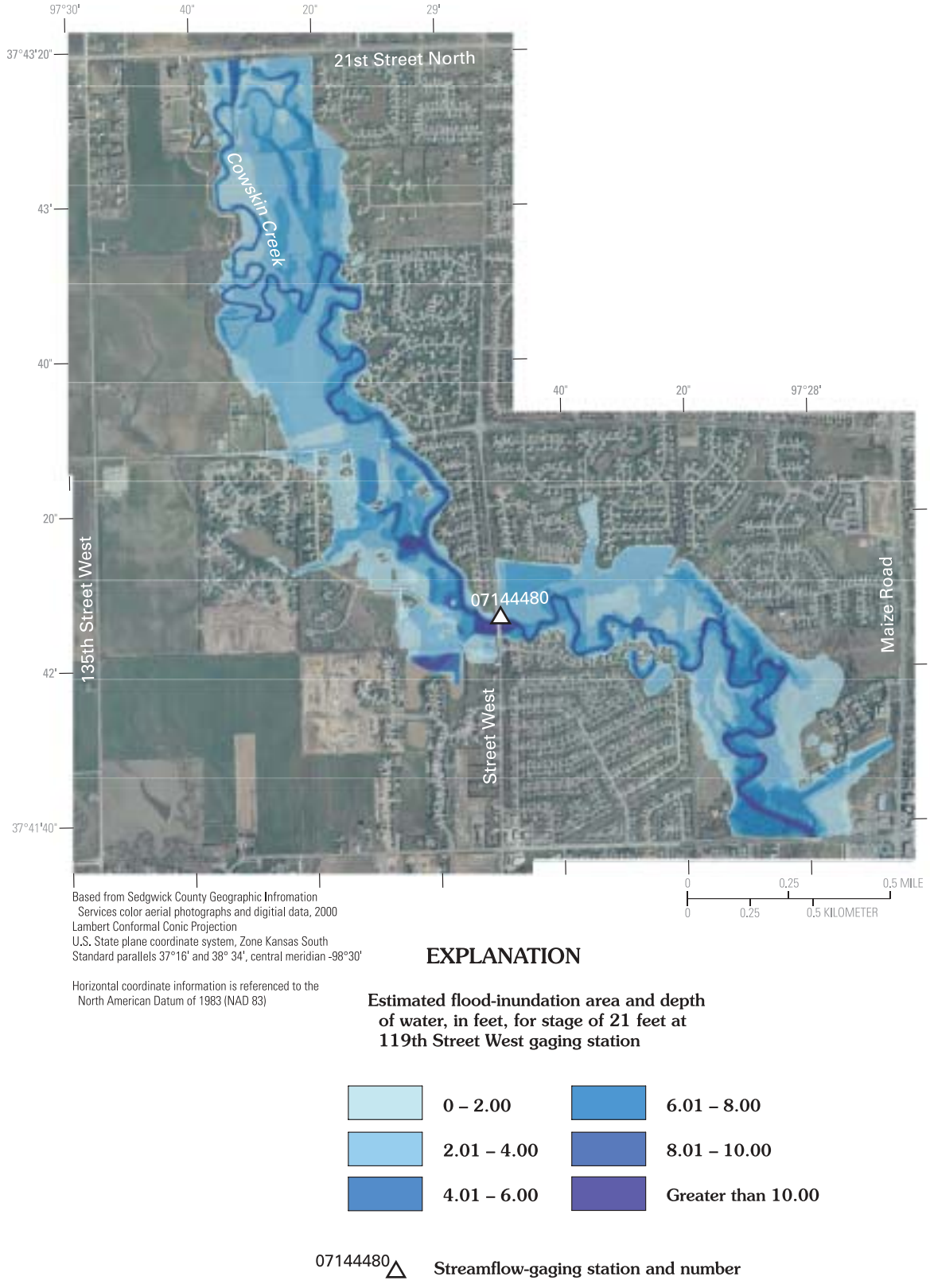

Figure 9. Estimated flood-inundation areas and estimated depths of water at Cowskin Creek at 119th Street West gaging station for stream stage of 21 feet.

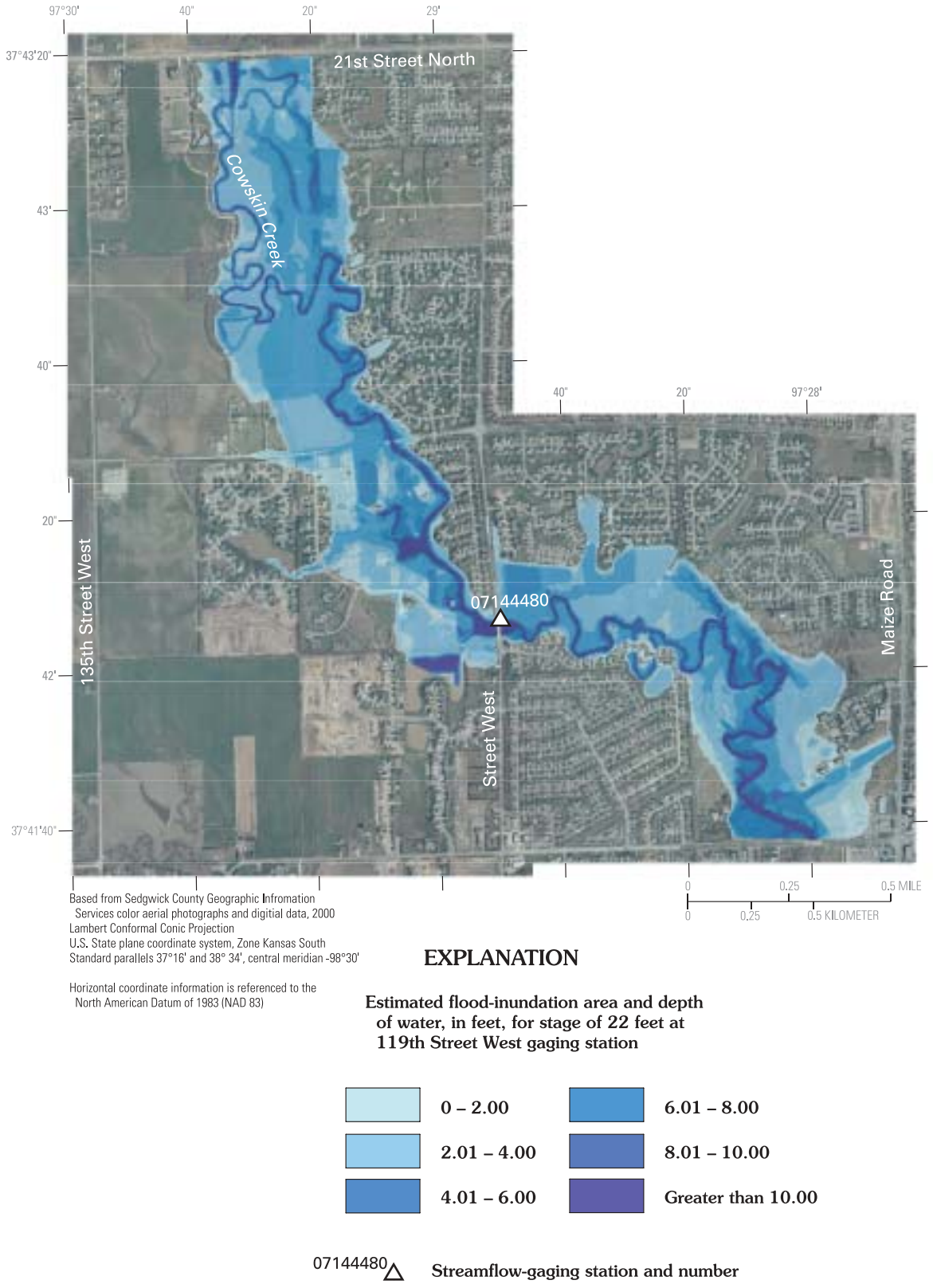

Figure 10. Estimated flood-inundation areas and estimated depths of water at Cowskin Creek at 119th Street West gaging station for stream stage of 22 feet.

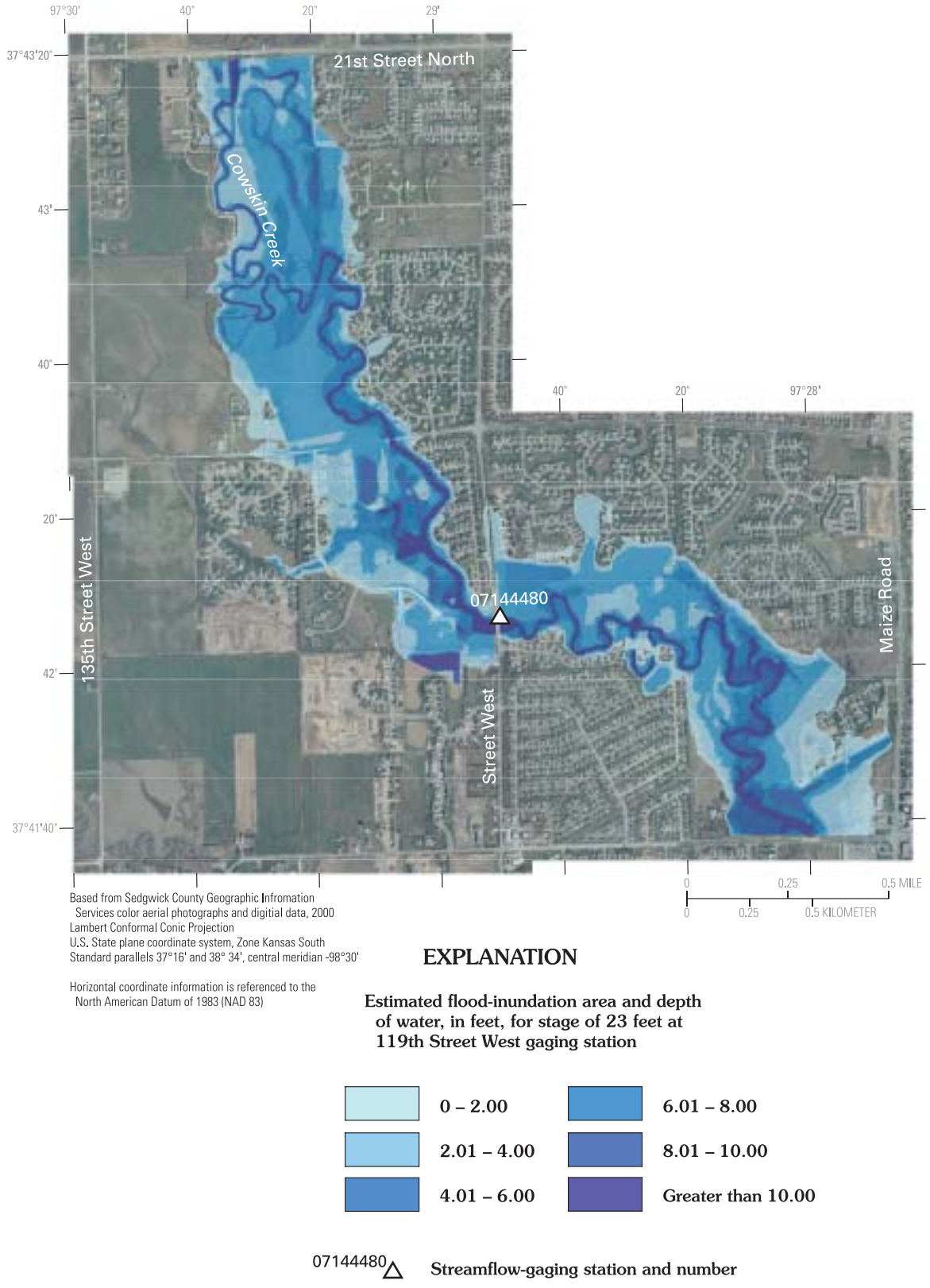

Figure 11. Estimated flood-inundation areas and estimated depths of water at Cowskin Creek at 119th Street West gaging station for stream stage of 23 feet.