Estimating Predevelopment Hydrology in the Middle Rio Grande Watershed, New Mexico

Prepared for

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Municipal Branch

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Executive Summary

The city of Albuquerque is located in the heart of the Middle Rio Grande watershed in New Mexico. The climate of the watershed is arid with an average annual rainfall of approximate 9.5 inches per year (NOAA 2013). The local climate affects soils and vegetation, which in turn affect runoff and hydrology. The goal of this study was to determine representative predevelopment hydrology conditions for Middle Rio Grande Watershed. Managing stormwater to predevelopment hydrological conditions for newly developed and redeveloped sites is a goal of the existing Phase I Albuquerque municipal separate storm sewer system (MS4) permit and the proposed Middle Rio Grande watershed MS4 permit to improve water quality. These permits use a percentile storm event approach as a surrogate for mimicking predevelopment hydrology. The Phase I Albuquerque permit requires capture of the 90^{th} percentile storm event. The proposed Middle Rio Grande watershed MS4 permit is proposing a similar standard. This study aims to clarify the link between the goal of mimicking predevelopment hydrology in this watershed and the percentile storm event approach used in the permits.

A recent case study conducted by Tetra Tech under contract with the U.S. Environmental Protection Agency (EPA) Office of Research and Development focused on investigating both site- and regional-scale stormwater management questions in the Middle Rio Grande watershed (Shoemaker et al. 2013). That study provided some useful baseline data for this analysis.

The first step to determine representative predevelopment hydrology conditions for Middle Rio Grande Watershed was to characterize local rainfall patterns to identify a range of 24-hour rainfall depths where measureable runoff might first occur. It was important that the methods applied were proven to be representative given the arid climate and infrequent rainfall. The second step was to characterize the physical characteristics within the regulated MS4 boundary of the watershed in terms of soils, geology, and land cover to define predevelopment hydrologic conditions. Finally, TR-55 was used to assess the combinations of rainfall and land cover conditions where runoff was expected to occur. Given the well-draining nature of soil conditions in the regulated MS4 area, sensitivity tests suggested that the threshold where measureable runoff occurs would most likely be somewhere between the 90th and 95th percentile 24-hour rainfall depths (0.615 to 0.78 inches).

Given these results, the performance standard to capture the 90^{th} percentile storm event in the current Phase I Albuquerque permit and the proposed Middle Rio Grande watershed MS4 permit is a reasonable surrogate for mimicking predevelopment hydrology for this watershed.

Managing stormwater to pre-development runoff condition will reduce water quality impacts on the receiving water as development occurs in the watershed. It is anticipated that it will also provide cost savings for new development and achieve multiple benefits such as reducing local flooding, reducing drought impacts, making communities more resilient to extreme wet weather events, making neighborhoods more livable, reducing the urban heat island effect, reducing energy demands, and improving air quality. Those benefits are also not explicitly quantified in this analysis, but could be possible indicators to evaluate in future analyses.

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1 Introduction

The city of Albuquerque is located in the Middle Rio Grande watershed in New Mexico. The Rio Grande actually has its headwaters in Colorado. By the time the river reaches Albuquerque, New Mexico, the drainage area encompasses approximately 14,000 square miles. The climate in the Albuquerque area is arid with an average annual rainfall of approximate 9.5 inches per year (NOAA 2013). The local climate affects soils and vegetation, which in turn affect runoff and hydrology.

The goal of this study was to determine representative predevelopment hydrology conditions for Middle Rio Grande Watershed. Managing stormwater to predevelopment hydrological conditions for newly developed and redeveloped sites is a goal of the existing Phase I Albuquerque municipal separate storm sewer system (MS4) permit and the proposed Middle Rio Grande watershed MS4 permit to improve water quality. These permits include a post construction standard which uses a percentile storm event approach as a surrogate for mimicking predevelopment hydrology. The Phase I Albuquerque permit requires capture of the 90th percentile storm event. The proposed Middle Rio Grande watershed MS4 permit is proposing a similar standard. This study aims to clarify the link between the goal of mimicking predevelopment hydrology in this watershed and the percentile storm event approach used in the permits.

A recent case study conducted by Tetra Tech under contract with the U.S. Environmental Protection Agency (EPA) Office of Research and Development focused on investigating both site- and regional-scale stormwater management questions in the Middle Rio Grande watershed (Shoemaker et al. 2013). In that study, the System for Urban Stormwater Treatment and Integration Analysis (*SUSTAIN*) was used to identify cost-effective stormwater management strategies through cost-benefit optimization that reduced *E. coli* loading by 66 percent, based on target requirements established by the Middle Rio Grande *E. Coli* Total Maximum Daily Load (TMDL). A literature search conducted during that study provided meaningful guidance about the types of management practices that are commonly used in the region with estimates of expected treatment effectiveness (Gautam et al. 2010; MRGARWG 2008), as well as a list of practices that did not work well in arid climates (LaBadie 2010). That study provided some useful baseline data for this analysis.

Tetra Tech technical direction for this effort was as follows:

- Determine representative predevelopment hydrology conditions for Middle Rio Grande Watershed, Albuquerque, NM. Model natural, predevelopment conditions considering the appropriate parameters including rainfall, soil types, land cover, evaporation, and others to estimate the average predevelopment hydrology for the watershed. The watershed has been well studied, including a recent *SUSTAIN* modeling project (Shoemaker et al. 2013), and therefore baseline data are readily available.
- Estimate an average natural retention/runoff ratio in order to estimate a corresponding percentile storm event for the watershed that the performance standard can be based on given the results of the predevelopment hydrology analysis.
- Provide a chart showing the 95th, 90th, 85th percentile storm event for this watershed based on local precipitation.

This report describes the analysis that was conducted in fulfillment of these technical directions. First, an analysis of local rainfall data was conducted to characterize storm behavior (in terms of volumes and frequencies). That analysis component culminated with estimates of 85th, 90th, and 95th percentile storms. Second, regional spatial data were analyzed to characterize the spatial variability and distribution of geological and physical conditions that are typical of natural conditions in the regulated MS4 permit area of the watershed. Finally, a modeling analysis was conducted using TR-55 to test the combinations of rainfall and physical watershed conditions to identify the combinations where measurable runoff first occurred under predevelopment conditions. Sensitivity tests were performed to assess the impact of a range of different percentile rainfall depths and land cover hydrologic conditions on projected runoff volume. Results of this analysis provide clarify the link between predevelopment hydrology and the percentile storm event approach of the performance standard in the MS4 permits for this watershed.

2 Rainfall Analysis

Understanding the regional weather patterns is essential to accurately reflect expected volume, intensity, and duration of expected storm events with high spatial variability in meteorology. Given the arid desert climate of Albuquerque where rainfall is sparse, this understanding becomes even more important. The area has 300 days of sunshine and about 9 inches of rainfall annually (NOAA 2013).

The method used to calculate the 95th percentile rainfall event is discussed in section 2.1. The rainfall analysis conducted for the Albuquerque MS4 area is discussed in section 2.2.

2.1 CALCULATING THE 95TH PERCENTILE RAINFALL EVENT

Chapter 4 of the Center for Watershed Protection's (CWP) guidance document for building an effective post-construction stormwater management program (Hirshman and Kosco 2008) recommends using daily time step data as an approximation for estimating 24-hour rainfall distributions. Figure 2-1, taken from the CWP guidance, describes the process of developing a rainfall frequency spectrum which is used to calculate percentile storms for an area. In general, a weather station with at least 30 years of daily rainfall records is used. Small storms of less than 0.1 inch are edited out and the entire rainfall record is sorted from largest to smallest and numbered. A percentile is then assigned based on the total number of rainfall records (for example, the 10th largest storm out of a total record of 500 days of recorded rainfall greater than 0.1 inch would be in the 98th percentile → (500-10)/500 x 100% = 98%).

Why are small storms not included in calculating the percentile rainfall event?

The rainfall from minor storms may be entirely stored in surface depressions and eventually lost to evaporation or infiltration. As a result, no runoff is produced.

Schueler (1987) developed a Simple Method for estimating storm pollutant load export delivered from urban development sites. From the analysis of National Urban Runoff Program (NURP) data and storm events recorded at National Airport, Schueler found that the runoff coefficient needed to be corrected to eliminate the portion of annual rainfall which does not produce any direct runoff. The analysis found that about 10% of the annual rainfall volume is so slight that no appreciable runoff is produced.

As also discussed in Section 4, the NRCS Curve Number (CN) method is a simple, widely used and efficient method for determining the approximant amount of runoff from a rainfall event in a particular area. TR-55 uses the curve number method and approximates the initial abstraction (I_a) to be equal to $0.2S$ where S is related to the Curve Number (CN) as:

$$S = \frac{1000}{CN} - 10 \qquad (1)$$

Runoff (Q) is computed as:

$$Q = \frac{(P - I_a)^2}{(P + I_a) + S} \quad or \quad \frac{(P - 0.2S)^2}{(P + 0.8S)} \qquad (2)$$

Where

Q = runoff (inches)

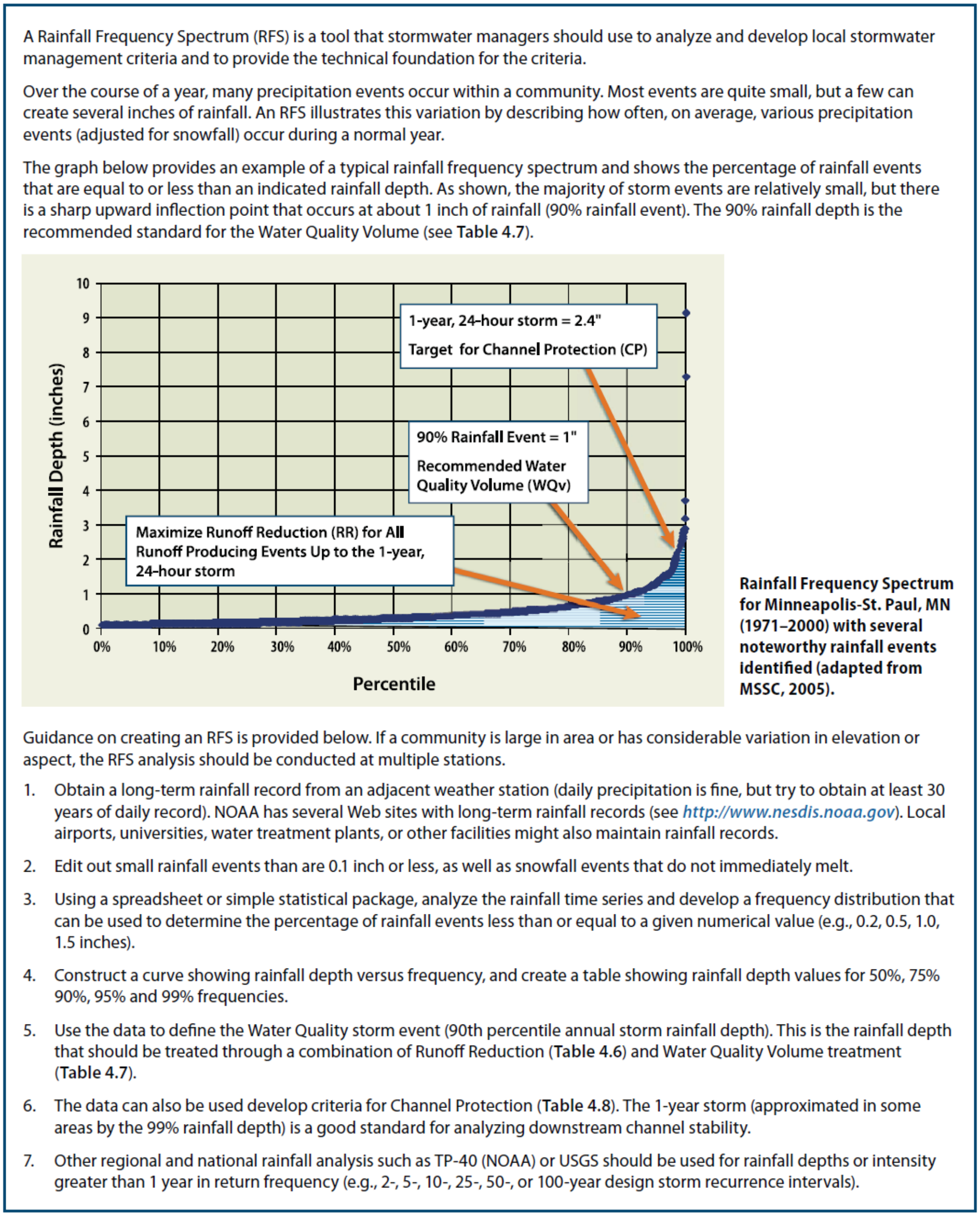
P = rainfall (inches)

S = potential maximum retention after runoff begins (inches)

I_a = initial abstraction (inches), or the amount of water before runoff, such as infiltration, or rainfall interception by vegetation

If you assume Ia = 0.1 inch and back calculate CN you get a CN of 95. So all CN's less than 95 inherently have an initial abstraction greater than 0.1-inch. Urban districts (commercial and business areas) are assigned up to a 95 curve number for the poorest soil conditions, so rainfall below 0.1 inches is not expected to produce runoff.

Also, Pitt (1999) found that in Milwaukee, rains less than about 0.05 inches did not produce noticeable runoff and rain events less than 0.5 inches account for most of the events but little of the runoff and pollutant load discharges and are easiest to control.



A Rainfall Frequency Spectrum (RFS) is a tool that stormwater managers should use to analyze and develop local stormwater management criteria and to provide the technical foundation for the criteria.

Over the course of a year, many precipitation events occur within a community. Most events are quite small, but a few can create several inches of rainfall. An RFS illustrates this variation by describing how often, on average, various precipitation events (adjusted for snowfall) occur during a normal year.

The graph below provides an example of a typical rainfall frequency spectrum and shows the percentage of rainfall events that are equal to or less than an indicated rainfall depth. As shown, the majority of storm events are relatively small, but there is a sharp upward inflection point that occurs at about 1 inch of rainfall (90% rainfall event). The 90% rainfall depth is the recommended standard for the Water Quality Volume (see **Table 4.7**).

Rainfall Frequency Spectrum for Minneapolis-St. Paul, MN (1971–2000) with several noteworthy rainfall events identified (adapted from MSSC, 2005).

Guidance on creating an RFS is provided below. If a community is large in area or has considerable variation in elevation or aspect, the RFS analysis should be conducted at multiple stations.

1. Obtain a long-term rainfall record from an adjacent weather station (daily precipitation is fine, but try to obtain at least 30 years of daily record). NOAA has several Web sites with long-term rainfall records (see *http://www.nesdis.noaa.gov*). Local airports, universities, water treatment plants, or other facilities might also maintain rainfall records.
2. Edit out small rainfall events than are 0.1 inch or less, as well as snowfall events that do not immediately melt.
3. Using a spreadsheet or simple statistical package, analyze the rainfall time series and develop a frequency distribution that can be used to determine the percentage of rainfall events less than or equal to a given numerical value (e.g., 0.2, 0.5, 1.0, 1.5 inches).
4. Construct a curve showing rainfall depth versus frequency, and create a table showing rainfall depth values for 50%, 75% 90%, 95% and 99% frequencies.
5. Use the data to define the Water Quality storm event (90th percentile annual storm rainfall depth). This is the rainfall depth that should be treated through a combination of Runoff Reduction (**Table 4.6**) and Water Quality Volume treatment (**Table 4.7**).
6. The data can also be used develop criteria for Channel Protection (**Table 4.8**). The 1-year storm (approximated in some areas by the 99% rainfall depth) is a good standard for analyzing downstream channel stability.
7. Other regional and national rainfall analysis such as TP-40 (NOAA) or USGS should be used for rainfall depths or intensity greater than 1 year in return frequency (e.g., 2-, 5-, 10-, 25-, 50-, or 100-year design storm recurrence intervals).

Figure 2-1. Guidance on creating a rainfall frequency spectrum (Hirshman and Kosco 2008)

2.2 RAINFALL ANALYSIS FOR ALBUQUERQUE MS4 AREA

Tetra Tech reviewed rainfall records from NOAA's Global Historical Climatology Network-Daily (GHCND) precipitation gauges in the Albuquerque area. Precipitation data at the Albuquerque International Airport (NCDC 290234) was used in this analysis because it represented the gauge with the longest period of daily rainfall records. However, Tetra Tech also reviewed data from other gauges in the Albuquerque area to compare rainfall records. As illustrated in Figure 2-2, four gauges have daily rainfall records with three other gauges having less than daily records and therefore not appropriate for a percentile rainfall analysis. Figure 2-3 compares the percentile storms for the four gauges with daily rainfall records. The percentile storms from all four gauges fell in a relatively narrow range, but the Albuquerque International Airport gauge was generally the lowest.

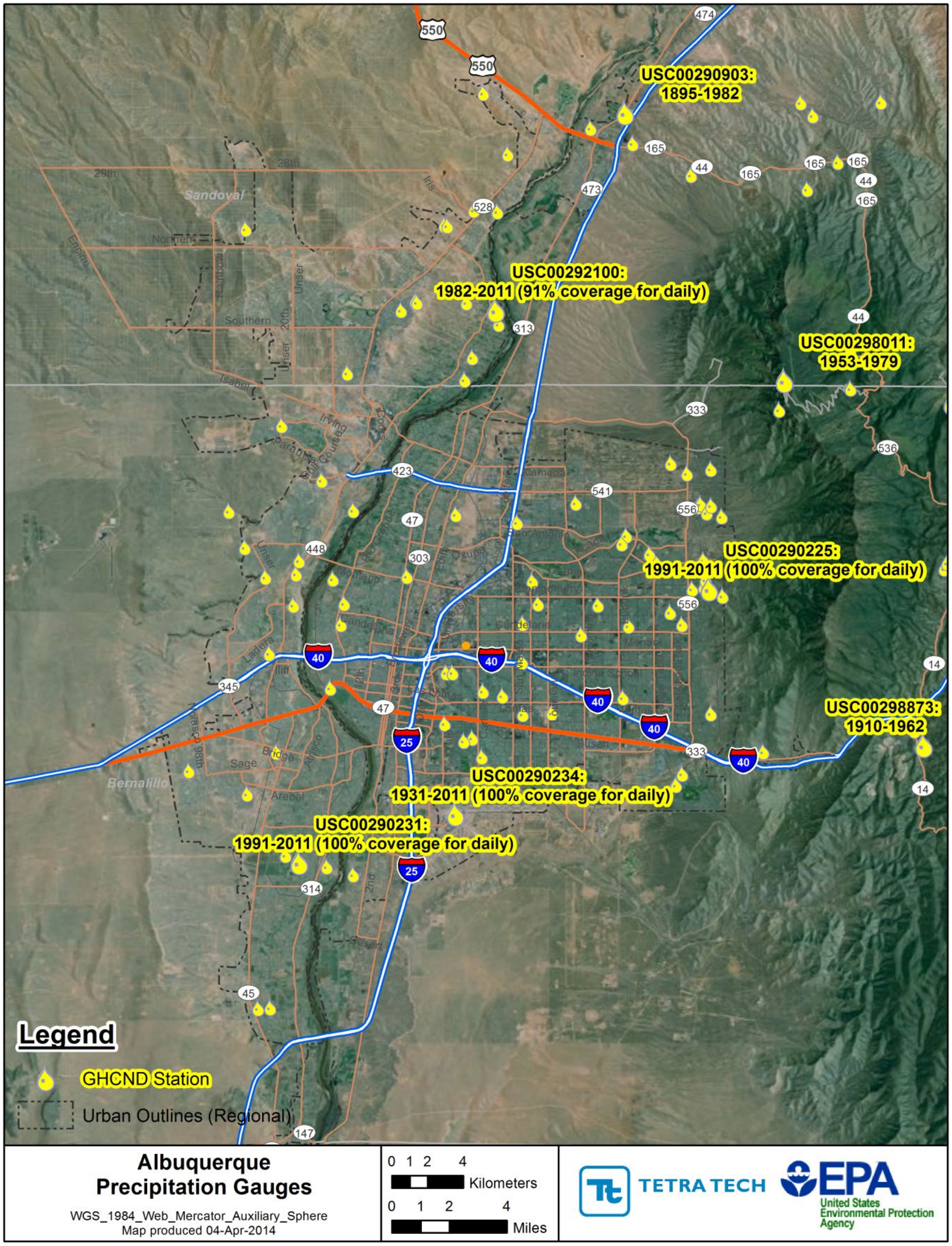


Figure 2-2. Albuquerque precipitation gauges with dates of coverage

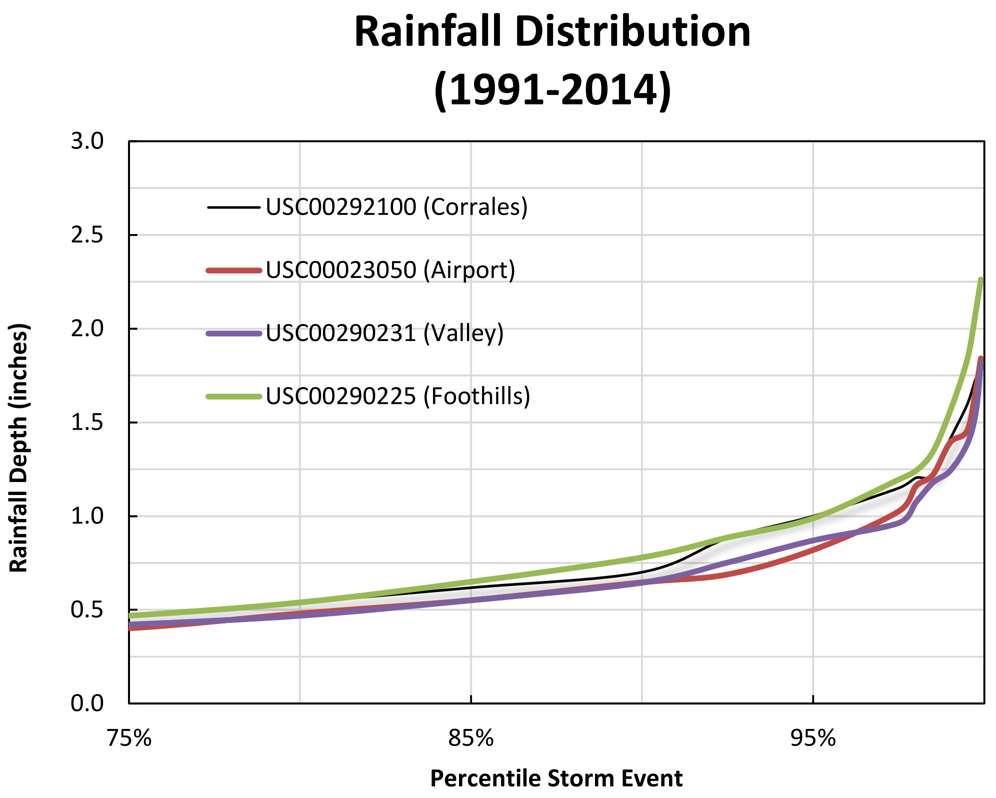


Figure 2-3. Comparison of percentile storms for Albuquerque-area precipitation gauges

Using observed data from the Albuquerque International Airport from January 1, 1948, through December 31, 2012, individual precipitation events were categorized assuming a 6-hour inter-event interval and a minimum storm size of 0.1 inches. The resulting precipitation event distribution from that period (with about 22 events per year) is presented in Figure 2-4. Of the precipitation events summarized, over 80 percent were less than 0.5 inch, and 97 percent were less than 1 inch. Knowing the storm distribution in an arid environment with well-draining soils is important because only the largest of storms are likely to generate runoff under predevelopment conditions.

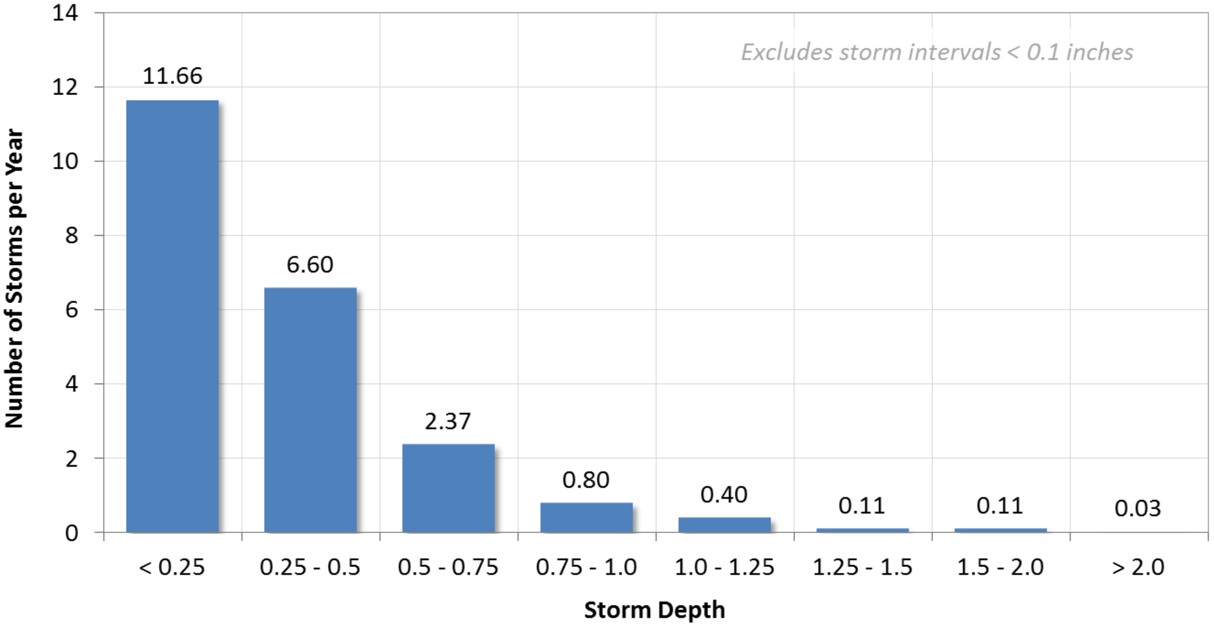


Figure 2-4. Distribution of storm events at Albuquerque International Airport (1948–2012).

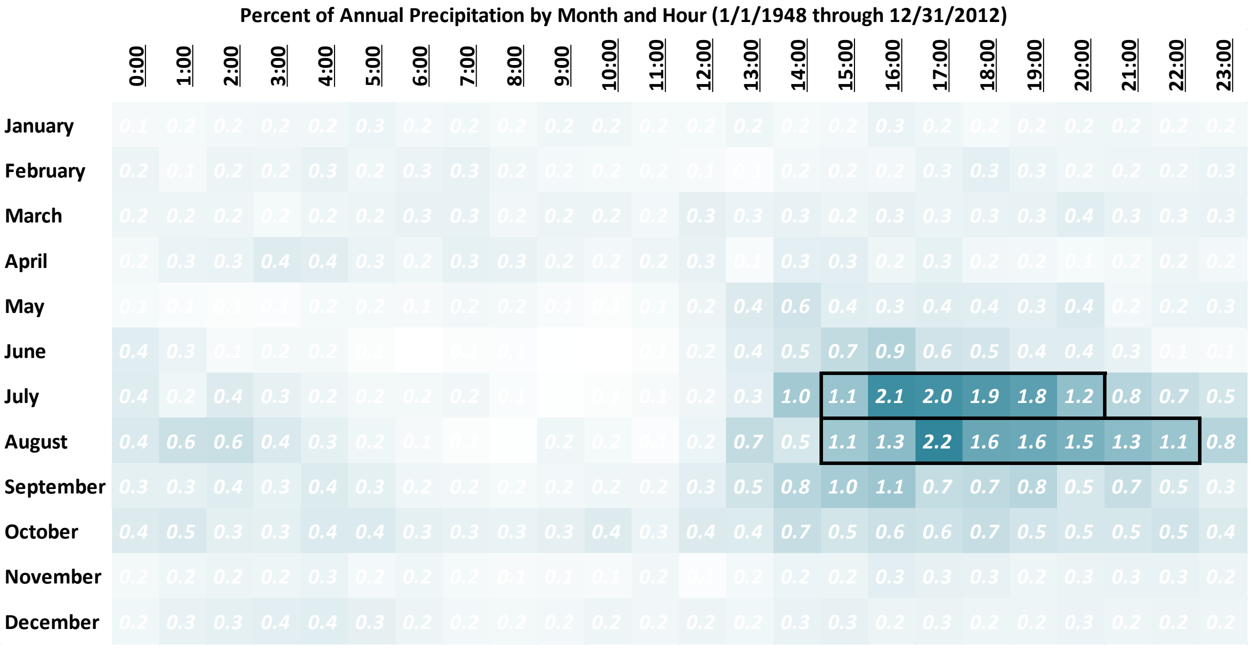
Chapter 4 of the Center for Watershed Protection's (CWP) guidance document for building an effective post-construction stormwater management program (Hirshman and Kosco 2008) recommends using daily time step data as an approximation for estimating 24-hour rainfall distributions. That was the approach used for estimating the 85th, 90th, and 95th percentile rainfall depths in the Albuquerque MS4 region. Recognizing that weather patterns vary significantly by location, it is possible that the use of a static 24-hour timeframe may introduce a temporal bias in certain climate regions. Nevertheless, the longer the historical record used, the less impact of that assumption becomes. To test the sensitivity of the static 24-hour timeframe methodology for weather in Albuquerque, two other analytical methods were compared with the CWP-recommended approach to see if they produced similar results. Precipitation data at the Albuquerque International Airport (NCDC 290234) for data collected between January 1, 1948 and December 31, 2012 were used for all three methods. Also, total storm values less than or equal to 0.1 inches were excluded from the analysis. The three methods were as follows:

1. Recommended: Using a daily time step precipitation data (static 24-hour timeframes)
2. Using a rolling 24-hour window with hourly time step precipitation data
3. Using a storm separation technique with a location-specific inter-event time

For Method 1, daily precipitation totals were first ranked in descending order based on depth and all values less than or equal to 0.1 inches were excluded. This resulted in 1,898 samples (i.e. daily totals greater than 0.1 inches) for performing the percentile calculation.

For Method 2, a daily total precipitation depth was computed for each hour that consisted of that hour's value plus the previous 23 hours. Those daily totals were then ranked in descending order based on depth and all values less than or equal to 0.1 inches were excluded. This resulted in 36,194 samples for performing a percentile calculation, compared to 1,898 for Method 1.

For Method 3, performing storm separation first required defining an inter-event time, or the number of dry hours observed between storms. Unlike the other two methods, storm separation results in storms with variable durations. Local regulatory frameworks or guidance often define an inter-event time based on rainfall patterns or management practice draw-down times. In the absence of such specific guidance, patterns in observed precipitation data can be used to set a representative inter-event time. A long-term hourly precipitation diurnal was developed for each month using long-term observed data at the Albuquerque International Airport. This diurnal presented as Figure 2-5 expresses long-term cumulative precipitation as the percent that fell during each hour or each month.


Percent of Annual Precipitation by Month and Hour (1/1/1948 through 12/31/2012)

	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
January	0.1	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
February	0.2	0.1	0.2	0.2	0.3	0.2	0.3	0.3	0.2	0.2	0.2	0.2	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.2	0.2	0.2	0.3
March	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.2	0.3	0.3	0.3	0.3	0.4	0.3	0.3	0.3
April	0.2	0.3	0.3	0.4	0.4	0.3	0.2	0.3	0.3	0.2	0.2	0.2	0.3	0.1	0.3	0.3	0.2	0.3	0.2	0.2	0.1	0.2	0.2	0.2
May	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.2	0.1	0.1	0.1	0.2	0.4	0.6	0.4	0.3	0.4	0.4	0.3	0.4	0.2	0.2	0.3
June	0.4	0.3	0.1	0.2	0.2	0.1		0.1	0.1			0.1	0.2	0.4	0.5	0.7	0.9	0.6	0.5	0.4	0.4	0.3	0.1	0.1
July	0.4	0.2	0.4	0.3	0.2	0.2	0.2	0.2	0.1		0.1	0.1	0.2	0.3	1.0	1.1	2.1	2.0	1.9	1.8	1.2	0.8	0.7	0.5
August	0.4	0.6	0.6	0.4	0.3	0.2	0.1	0.1		0.2	0.2	0.1	0.2	0.7	0.5	1.1	1.3	2.2	1.6	1.6	1.5	1.3	1.1	0.8
September	0.3	0.3	0.4	0.3	0.4	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.5	0.8	1.0	1.1	0.7	0.7	0.8	0.5	0.7	0.5	0.3
October	0.4	0.5	0.3	0.3	0.4	0.4	0.3	0.3	0.3	0.3	0.4	0.3	0.4	0.4	0.7	0.5	0.6	0.6	0.7	0.5	0.5	0.5	0.5	0.4
November	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.2	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.2	0.3	0.3	0.3	0.2
December	0.2	0.3	0.3	0.4	0.4	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.2	0.3	0.2	0.2	0.3	0.2	0.2	0.2

Figure 2-5. Cumulative long-term hourly precipitation diurnal for the Albuquerque International Airport (NCDC 290234).

Representation of long-term precipitation using this monthly-hourly diurnal format highlights systematic temporal and seasonal patterns that may not be as evident from time series plots. The data show that roughly 10 percent of the total *annual* rainfall falls in the six hour window between 3:00 PM and 9:00 PM in July, while another 11 percent falls between 3:00 PM and 11:00 PM in August (both outlined in black on the graph above). Based on the analysis presented in Figure 2-5, a six hour inter-event time was selected as the locally-representative threshold criteria for performing storm separation. Similar to the previous two methods, precipitation totals for each resulting storm interval were also ranked in descending order based on depth and all values less than or equal to 0.1 inches were excluded. This resulted in 1,435, the fewest number of samples for performing a percentile calculation.

The ranked precipitation series were used to calculate the 85th, 90th, and 95th percentile storm depth for each of the three methods. A comparison of the three methods and resulting percentile storm depths is presented below in Table 2-1.

Table 2-1. Comparison of rainfall percentiles using three methods

Calculation Method	Observed Data Time Step	Number of Samples	Percentile Rainfall Depths (inches)		
			85th	90th	95th
Method 1 – Fixed 24-hour window	Daily	1,989	0.53	0.615	0.78
Method 2 – Rolling 24-hour window	Hourly	36,194	0.50	0.60	0.77
Method 3 – Storm separation	Hourly	1,435	0.53	0.635	0.84

The results showed that the three methods produced very similar rainfall duration depths, suggesting that using daily rainfall as a 24-hour storm approximation in arid Albuquerque produced representative estimates for the 85th, 90th, and 95th percentile rainfall depths. There was a long enough historical record to produce a diverse sample space of daily rainfall totals using a fixed 24-hour stepping time window. As expected, using the rolling 24-hour window produced the smoothest curve because it used the highest number of samples. In cases where only short historical records are available that method would offer some advantages. It also minimizes the impact of imposing a human construct (i.e. the clock or calendar) into the analysis, since any continuous 24-hour period could technically be considered a day. The storm separation approach results deviated from the other two methods at higher percentiles. This also made sense given that storm separation imposes no maximum duration on storm periods. Figure 2-6 presents the final storm percentile curves for all three methods derived using rainfall data from the Albuquerque International Airport (NCDC 290324) from 1/1/1948 through 12/31/2012. Figure 2-7 shows the same curves zoomed into the 85th to 95th percentile range.

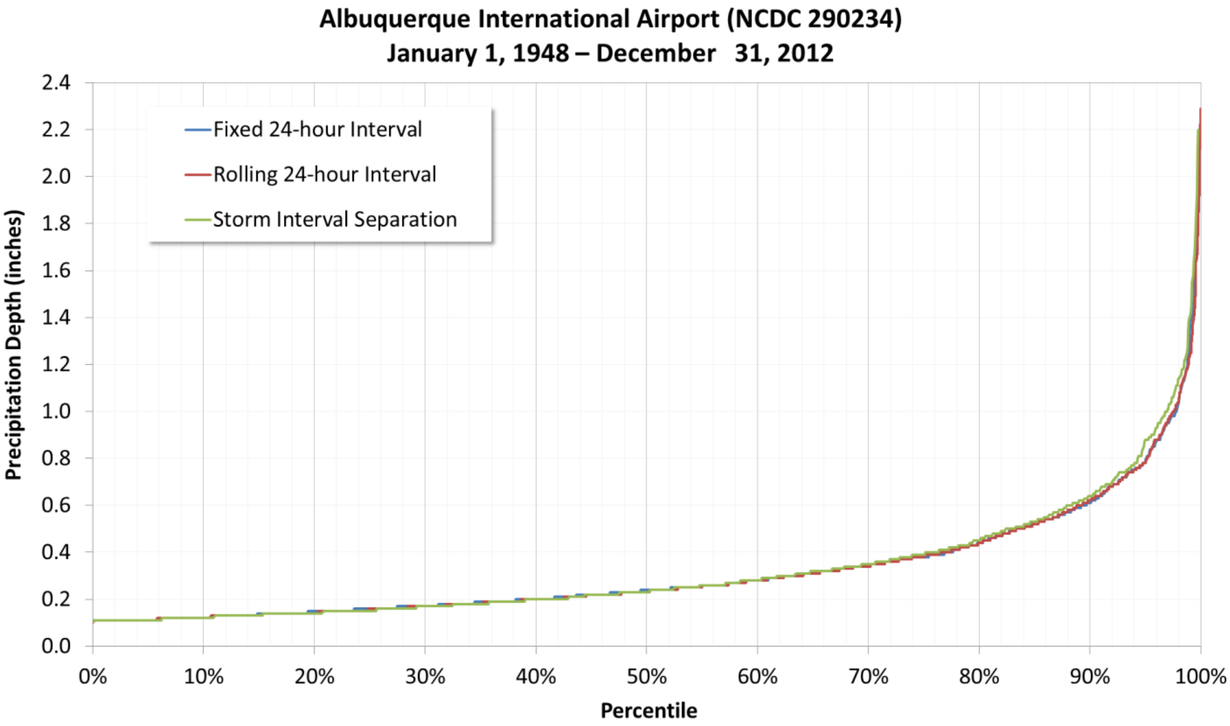


Figure 2-6. Comparison of rainfall duration curves for the Albuquerque International Airport using three storm classification methods.

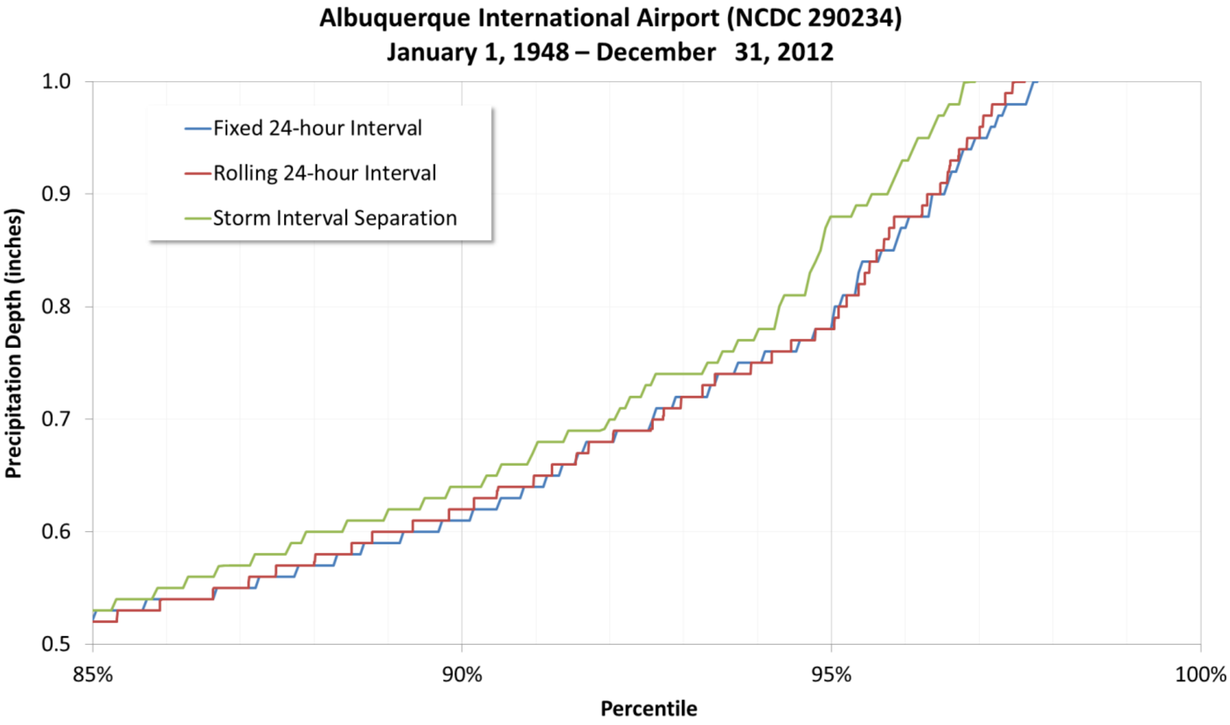


Figure 2-7. Comparison of rainfall duration curves for the Albuquerque International Airport using three storm classification methods (85th to 95th percentile range).

3 Watershed Characterization

Located in north-central New Mexico, the focus area for this analysis is the regulated MS4 permitted area in the Middle Rio Grande watershed. The 2000 and 2010 Census urbanized areas along with municipal boundaries are shown on Figure 3-1. The 2010 Census urbanized area boundary was used to indicate the MS4 permitted area in the watershed as depicted on Figure 3-3. It covers an area of approximately 250 square miles (650 square kilometers), with an average elevation of approximately 1,600 meters (5,200 feet) above sea level. The Middle Rio Grande watershed drains to the Rio Grande River. The Rio Grande River begins in the Rocky Mountains in Colorado and flows through New Mexico on its way to the Gulf of Mexico. The Rio Grande River bisects the study area and is the subject of an *E. coli* TMDL that was approved by EPA in 2010. The current Phase I Albuquerque MS4 permit has four co-permittees including the city of Albuquerque, Albuquerque Metropolitan Arroyo Flood Control Authority, New Mexico Department of Transportation, and University of New Mexico. The Phase II MS4 permit covers the following entities: City of Albuquerque, Kirtland Air Force Base, NM Dept. of Transportation, City of Rio Rancho, Village of Los Ranchos de Albuquerque, Bernalillo County, Sandoval County, Southern Sandoval County Arroyo Flood Control Authority, Town of Bernalillo, Village of Corrales, Pueblo of Isleta, Pueblo of Sandia, and Pueblo of Santa Ana. The proposed Middle Rio Grande watershed MS4 permit would supersede the existing Phase I and II permits and could also permit the Eastern Sandoval Flood Control Authority, EXPO (State Fairgrounds) and Sandia Laboratories, Dept. of Energy.

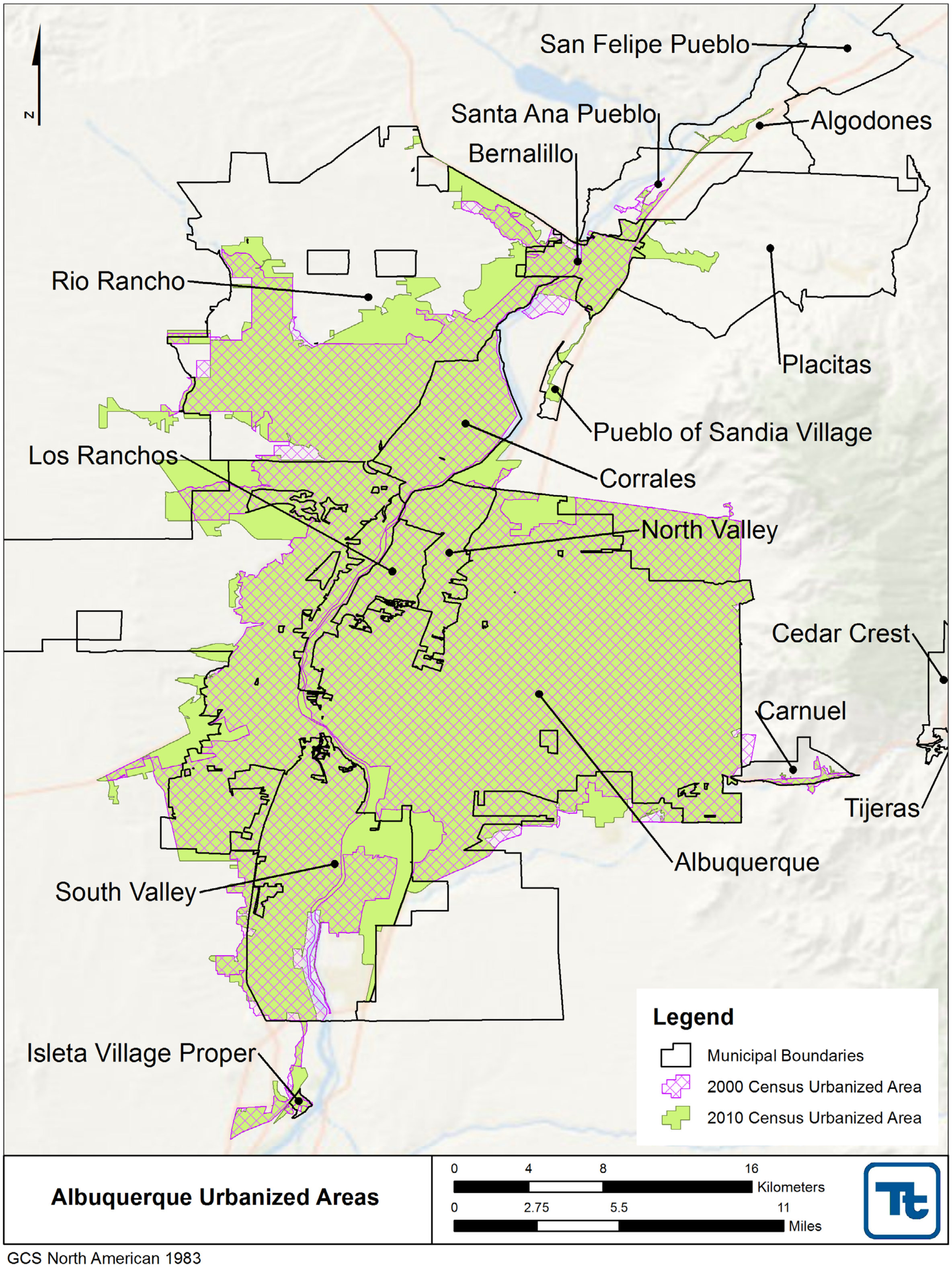
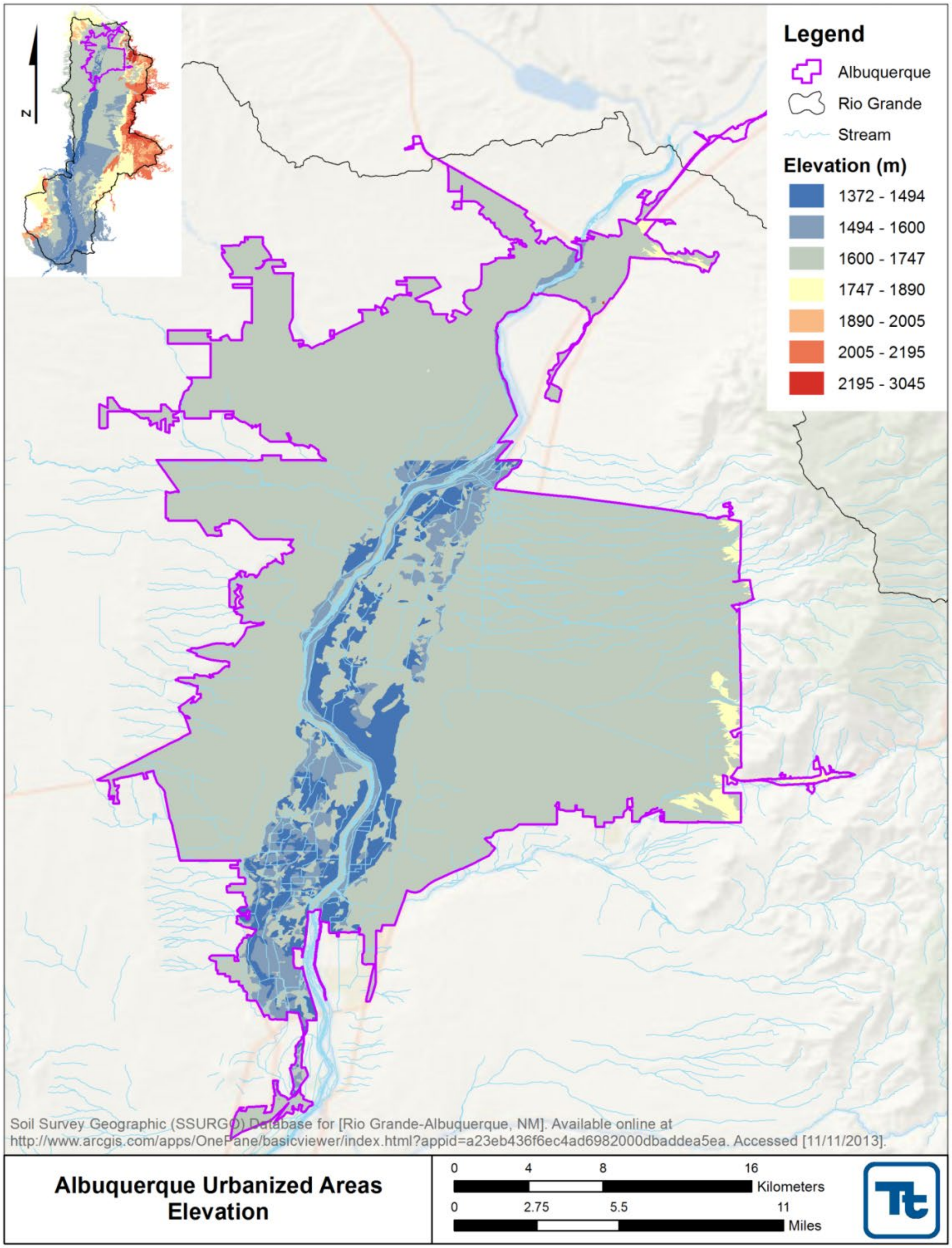


Figure 3-2. Albuquerque Urbanized Areas and Municipal Boundaries.



Soil Survey Geographic (SSURGO) Database for [Rio Grande-Albuquerque, NM]. Available online at http://www.arcgis.com/apps/OnePane/basicviewer/index.html?appid=a23eb436f6ec4ad6982000dbaddea5ea. Accessed [11/11/2013].

GCS North American 1983

Figure 3-3. Study area 2010 Urbanized Areas and elevation.

3.1 GEOLOGY AND SOILS

The study area lies in the valley between the Sandia Mountains to the east and the divide between the Rio Grande and Rio Puerco drainage basins to the west. The valley is filled with thick alluvial deposits which allow for much of the rainfall to infiltrate (Figure 3-4). Other geologic formations are present in the study area including clastic and volcanic formations. The majority of the study area is fairly flat, with slopes less than 5 percent (Figure 3-5). The data presented in this section are derived from the Soil Survey Geographic Database (SSURGO) which is maintained by the U.S. Department of Agriculture Natural Resources Conservation Service.

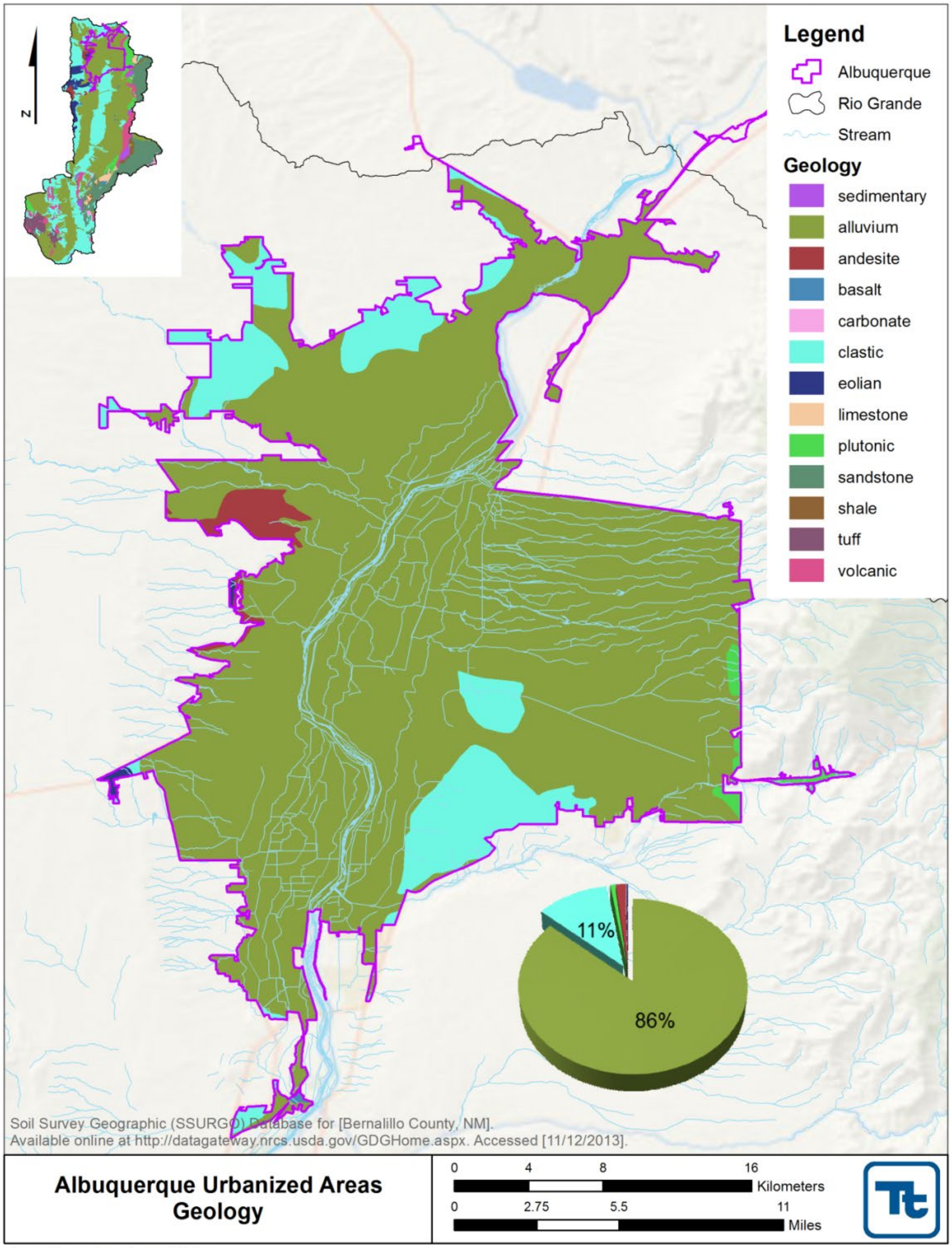
The National Cooperative Soil Survey publishes soil surveys for each county within the U.S. These soil surveys contain predictions of soil behavior for selected land uses. The soil surveys are designed for many different uses, including land use planning, the identification of special practices needed to ensure proper performance, and mapping of hydrologic soil groups (HSGs).

HSGs refer to the grouping of soils according to their runoff potential. Soil properties that influence the HSGs include depth to seasonal high water table, infiltration rate and permeability after prolonged wetting, and depth to slow permeable layer. There are four groups of HSGs: Group A, B, C, and D as described in Table 3-1. Figure 3-6 presents the spatial distribution of HSGs in the study area. The majority of the regulated MS4 area in the watershed (70 percent) is HSG B. Sandier soils (HSG A) tend to be present in areas with high slope (greater than 5 percent slope).

Table 3-1. Hydrologic soil group descriptions

HSG	Group Description
A	Sand, loamy sand or sandy loam types of soils. Low runoff potential and high infiltration rates even when thoroughly wetted. Consist chiefly of deep, well to excessively drained sands or gravels with a high rate of water transmission.
B	Silt loam or loam. Moderate infiltration rates when thoroughly wetted. Consist chiefly or moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures.
C	Soils are sandy clay loam. Low infiltration rates when thoroughly wetted. Consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine structure.
D	Soils are clay loam, silty clay loam, sandy clay, silty clay or clay. Group D has the highest runoff potential. Low infiltration rates when thoroughly wetted. Consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a clay pan or clay layer at or near the surface and shallow soils over nearly impervious material.

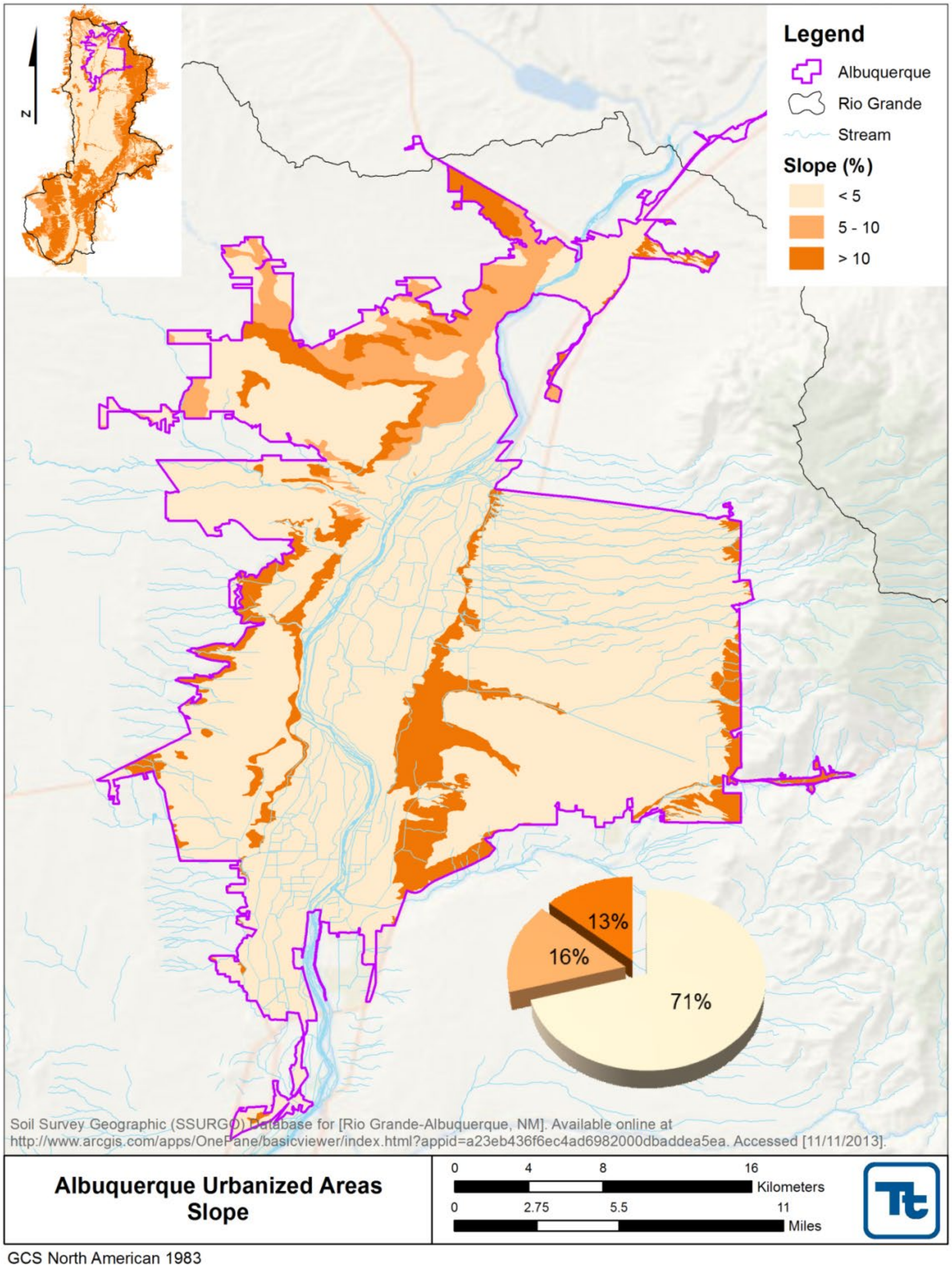
The SSURGO layer also provides independently estimated runoff potential on a relative scale ranging from “Negligible” to “Very High,” as shown in Figure 3-7. About 91 percent of the regulated MS4 area in the watershed has either “Low” or “Very Low” runoff potential, while about another 6 percent has “Medium” runoff potential. Less than 3 percent of the MS4 area has “High” or “Very High” runoff potential.



Soil Survey Geographic (SSURGO) Database for [Bernalillo County, NM]. Available online at http://datagateway.nrcs.usda.gov/GDGHome.aspx. Accessed [11/12/2013].

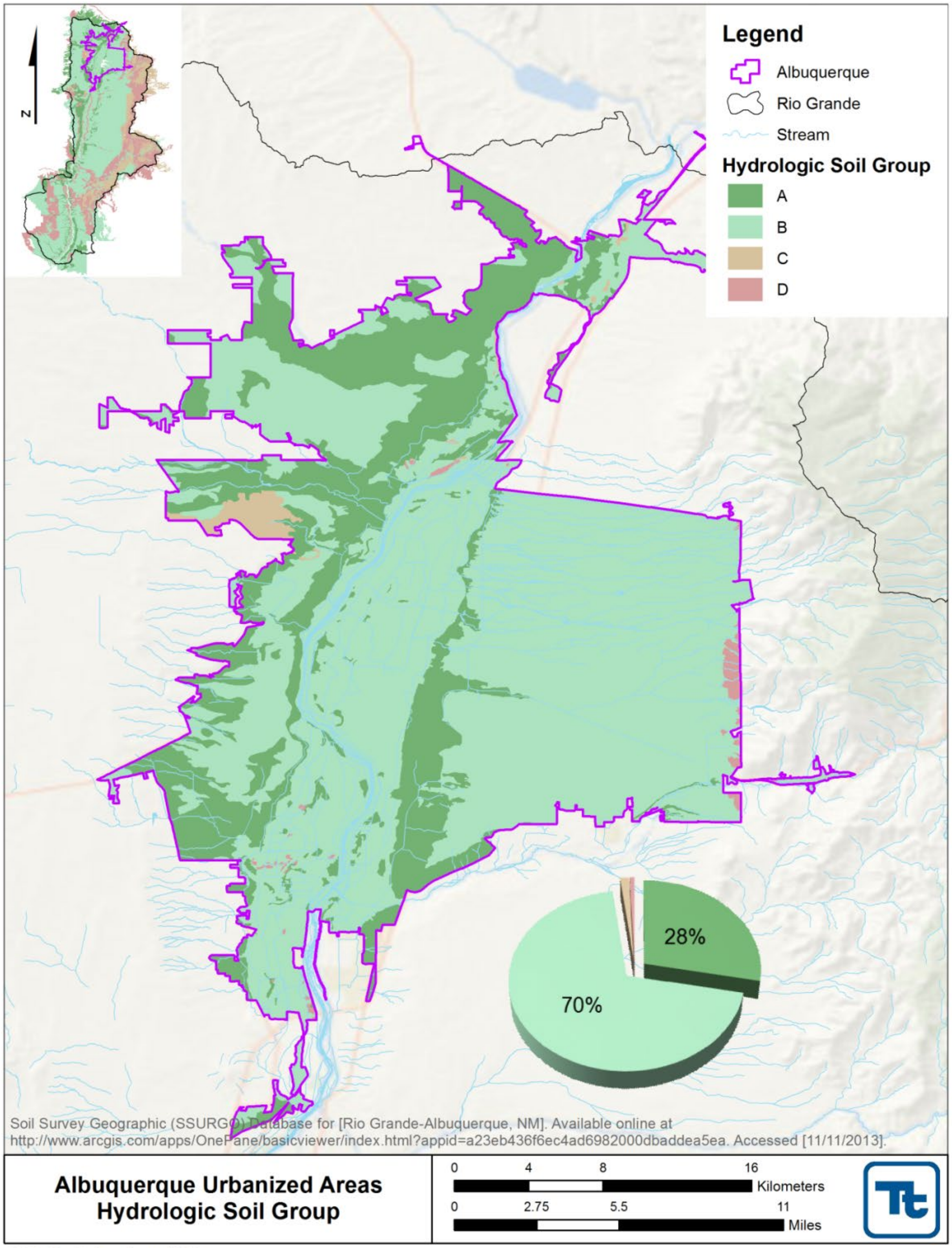
GCS North American 1983

Figure 3-4. Geology in the study area.



Soil Survey Geographic (SSURGO) Database for [Rio Grande-Albuquerque, NM]. Available online at http://www.arcgis.com/apps/OnePane/basicviewer/index.html?appid=a23eb436f6ec4ad6982000dbaddea5ea. Accessed [11/11/2013].

Figure 3-5. Slope in study area.

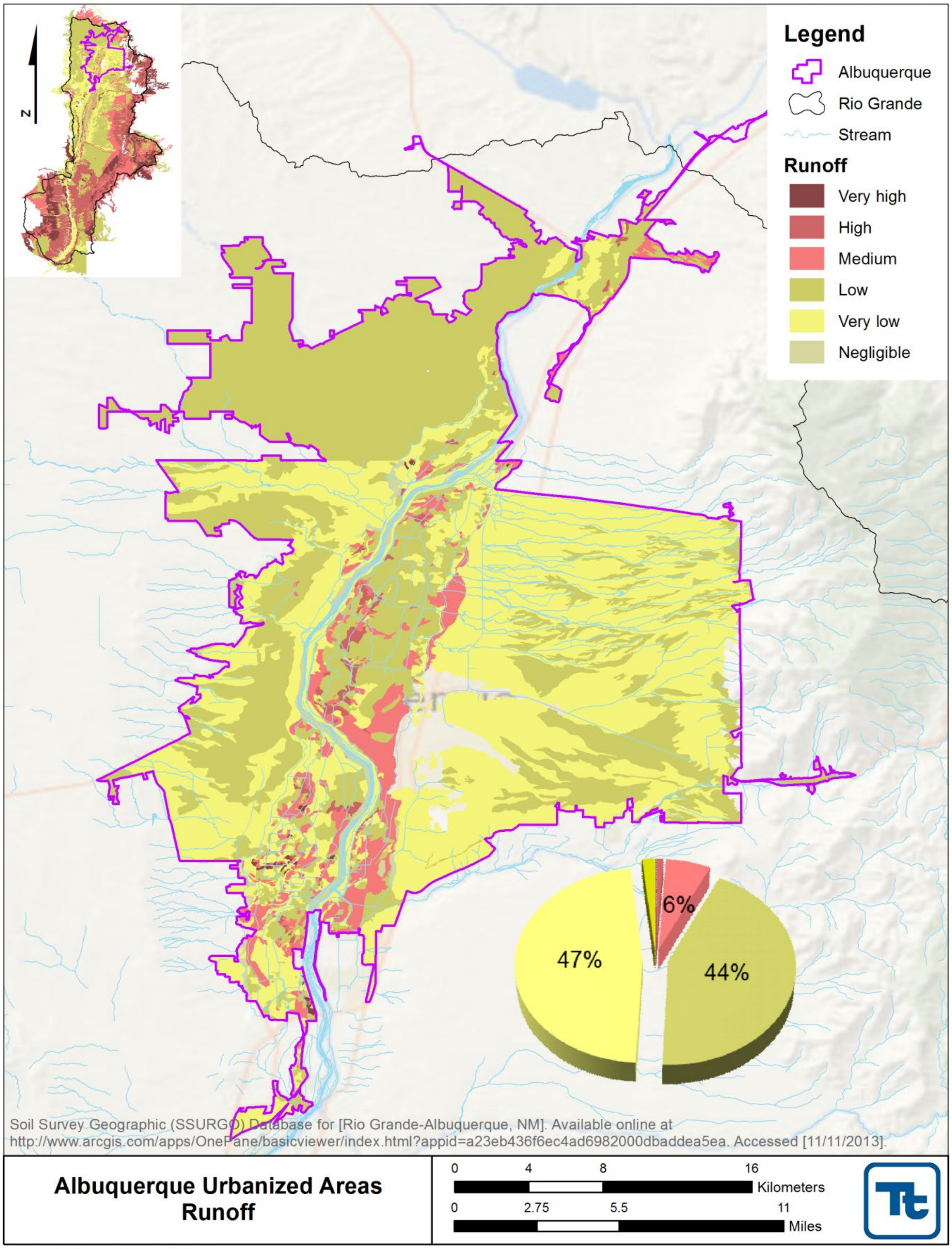


Soil Survey Geographic (SSURGO) Database for [Rio Grande-Albuquerque, NM]. Available online at http://www.arcgis.com/apps/OnePane/basicviewer/index.html?appid=a23eb436f6ec4ad6982000dbaddea5ea. Accessed [11/11/2013].

Albuquerque Urbanized Areas Hydrologic Soil Group

GCS North American 1983

Figure 3-6. Hydrologic soil groups.



Soil Survey Geographic (SSURGO) Database for [Rio Grande-Albuquerque, NM]. Available online at http://www.arcgis.com/apps/OnePane/basicviewer/index.html?appid=a23eb436f6ec4ad6982000dbaddea5ea. Accessed [11/11/2013].

Albuquerque Urbanized Areas Runoff

GCS North American 1983

Figure 3-7. Study area runoff potential.

3.2 LAND COVER

The objective of this study was to characterize predevelopment conditions for stormwater management targets; therefore, land cover, which is mostly a reflection of existing conditions, is not as important to the analysis as underlying geology or soils. Land use and impervious data are provided by the Multi-Resolution Land Characteristics Consortium (MRLC). The MLRC distributes the National Land Cover Database (NLCD), a 30-meter resolution land cover database. Land cover in the study area is comprised predominately of developed land uses with shrub/scrub and pasture common near the river and along steep slopes in the northwest (Figure 3-5 and Figure 3-8). Impervious areas are common throughout the study area due to the developed state of the watershed (Figure 3-9).

Table 3-2. Land cover summary (2006 NLCD)

Land cover	Percent of MS4 area (%)	Total land area (acres)
Developed (high, medium, low intensity and open space)	66%	106,650
Grassland and shrubland	22%	35,127
Pasture and crops	9%	14,205
Wetland and water	3%	5,321
Other (forest and barren)	<1%	784

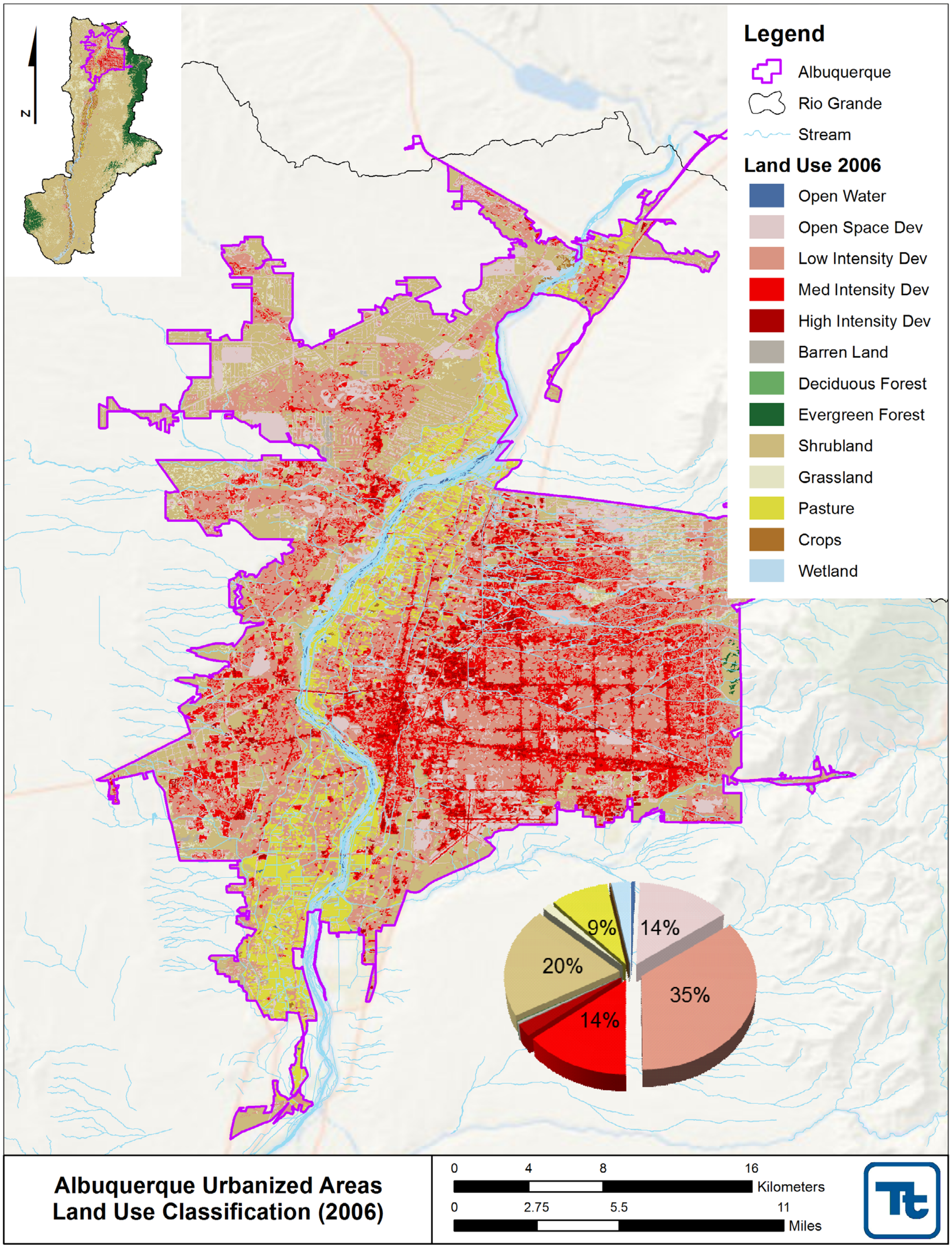


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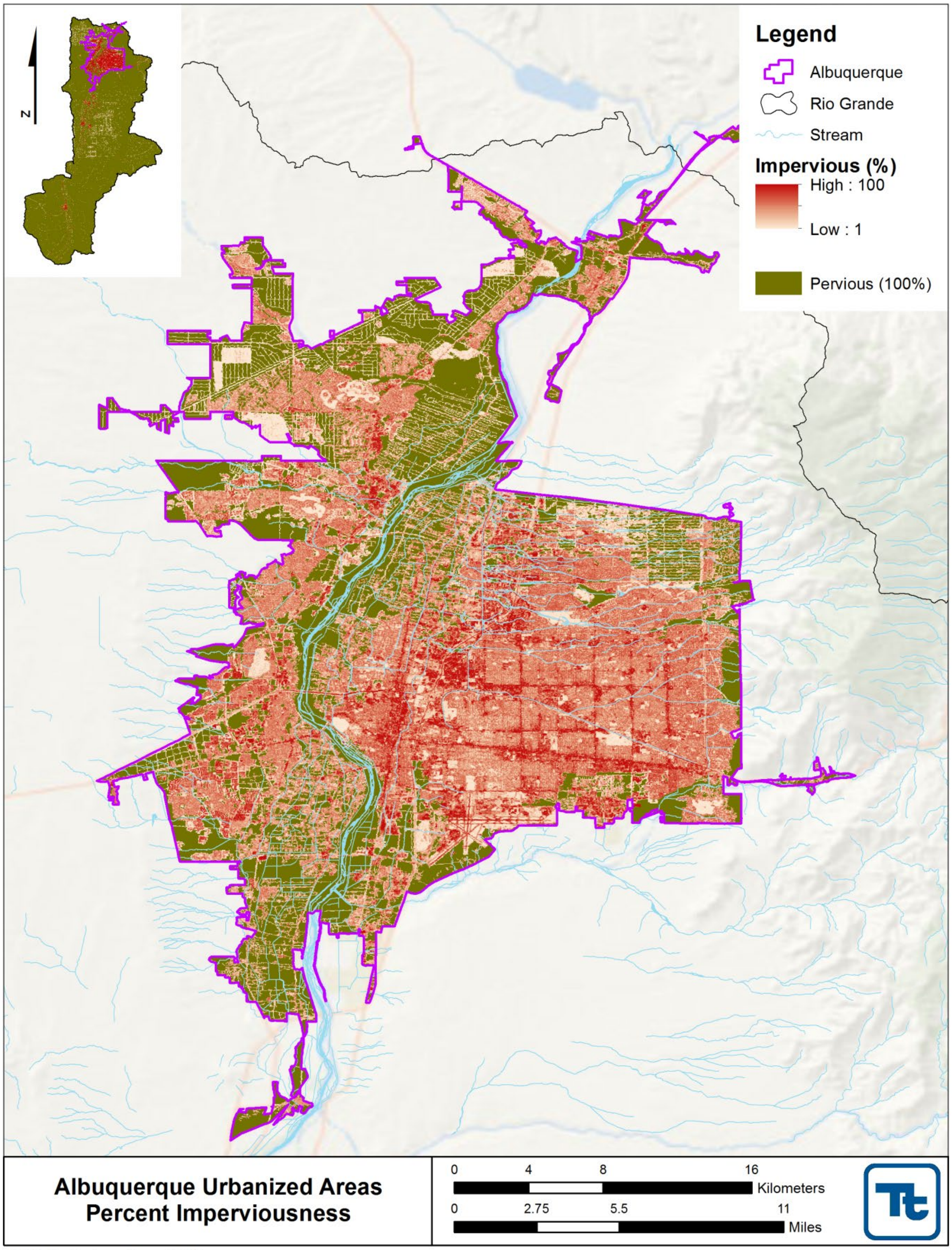
Figure 3-8. Existing land cover.



GCS North American 1983

Figure 3-9. Existing imperviousness.

4 Runoff Analysis

TR-55 is perhaps the most widely used model for predicting hydrology in the United States. It is a simplified empirical method that uses the Soil Conservation Service runoff equation for estimating runoff volumes from rainfall and times of concentration as a function of precipitation and land conditions. The simplifications often limit the use of the procedures for runoff estimation because they provide less accurate results than more detailed deterministic hydrology models would provide. However, the effects of simplification are more of a concern when predicting peak discharges or runoff hydrographs. The TR-55 documentation advises users to examine the sensitivity of the analysis being conducted to ensure that the degree of error is tolerable (NRCS 1986).

For this study, the objective was to identify the rainfall volume associated with predevelopment conditions. Consequently, TR-55 was only used to estimate the earliest portions of the hydrograph when measurable runoff begins. TR-55 approximates the initial abstraction (I_a) to be equal to $0.2S$ where S is related to the Curve Number (CN) as:

$$S = \frac{1000}{CN} - 10 \tag{1}$$

Runoff (Q) is computed as:

$$Q = \frac{(P - I_a)^2}{(P + I_a) + S} \quad or \quad \frac{(P - 0.2S)^2}{(P + 0.8S)} \tag{2}$$

Where

Q = runoff (inches)

P = rainfall (inches)

S = potential maximum retention after runoff begins (inches)

I_a = initial abstraction (inches).

Initial abstraction represents all surface capture or losses before runoff begins. As observed in Equation 1 above, smaller CN values will yield a larger value of S, and in turn, larger initial abstraction values. This empirical parameter assumes that the initial abstraction is correlated to surface depressions, soil type, vegetation cover, evaporation, and infiltration. The soil and land use influences are expressed by way of the CN. Using Equations 1 and 2, a nomograph can be generated to estimate the direct runoff volume as a function of precipitation and CN. It is recognized that the peak flow would still vary for a given runoff depth since it is a function of the time of concentration (and I_a/P) for a given drainage area; nevertheless, because we are only interested in the point of the hydrograph where measureable runoff first occurs, there is more confidence (and less uncertainty) about that prediction.

4.1 METHODOLOGY

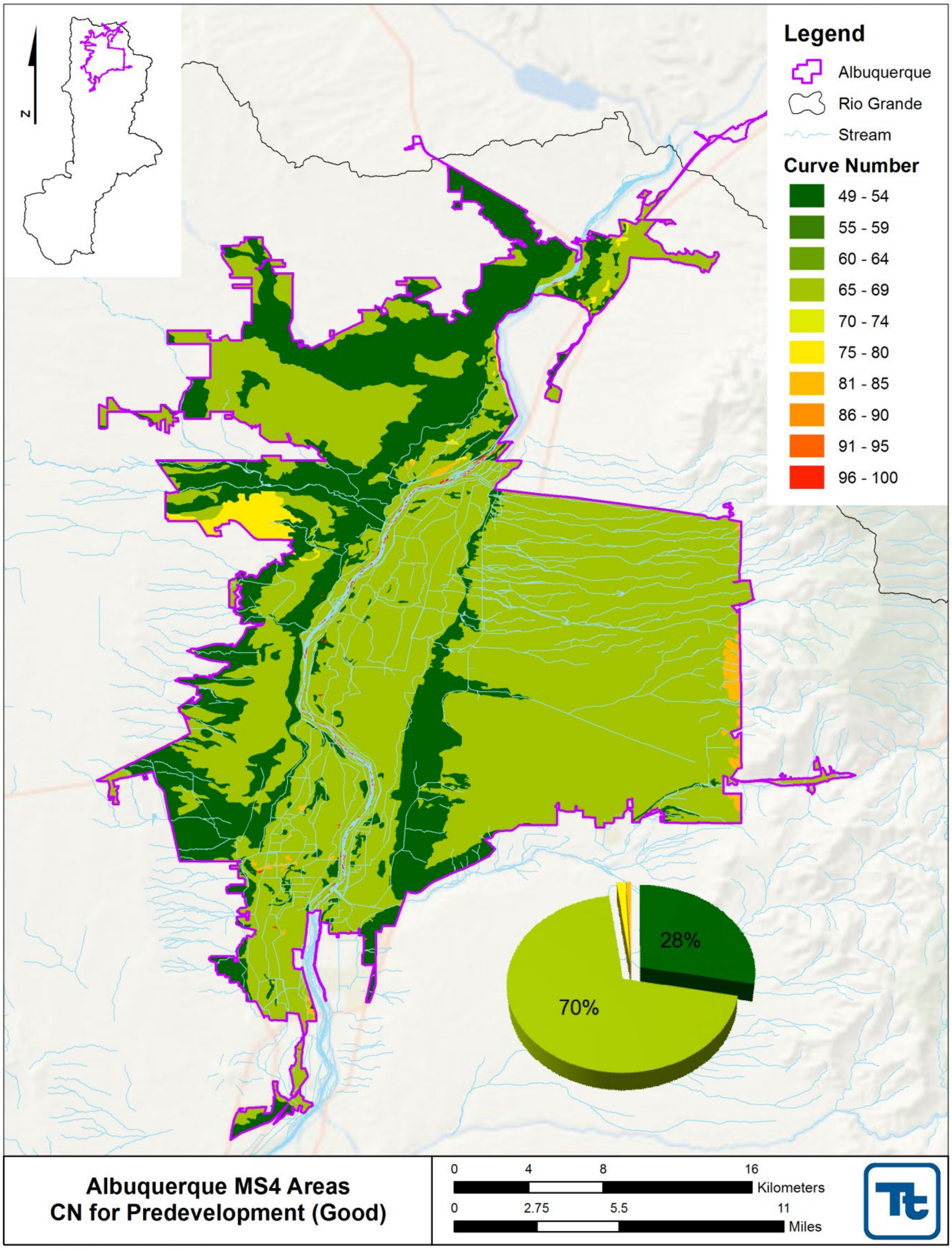
Inputs for the TR-55 procedure are derived from local land cover, soil, and precipitation data. Rainfall inputs to TR-55 were derived from the analysis in Section 2. In fact, rainfall depths between 0.1 extending all the way to 1.5 inches were evaluated, which included the 85th, 90th, 95th percentile rainfall depths and beyond.

CNs in TR-55 are typically between 30 and 98, with the smaller CN indicating less runoff. In fact, some CN values are lower than 30; however TR-55 suggests using 30 as a minimum value for calculations. A CN of 98 is often used to represent impervious areas. Because Albuquerque is in the arid southwestern United States, CN values for “Desert Shrub”—where major plants include saltbush, greasewood, creosotebush, blackbrush, bursage, palo verde, mesquite, and cactus—were used to characterize predevelopment conditions. TR-55 further qualifies CN values for that category into "Poor," "Fair," or "Good" hydrologic conditions. "Poor" means <30 percent ground cover (e.g. litter, grass, and brush overstory), while "Good" indicates >70 percent ground cover—"Fair" is between 30 to 70 percent (NRCS 1986). The land cover values for predevelopment and developed urban areas vary by HSG as shown in Table 4-1. For reference purposes, CN values for "woods in good condition" and "woods in poor condition" are also shown for comparison with desert shrub values. Those values might typically have been used to represent predevelopment conditions for most of the United States. The differences between "woods" and "desert shrub" are more pronounced for A and B soils than for C and D soils. The published "desert shrub" values are also higher than "woods" because rainfall totals are lower in the desert southwest. For comparison, "desert shrub" values in "good" and "poor" condition were used for predevelopment conditions to test the implication of predevelopment hydrologic condition on estimated runoff—"good" condition (Figure 4-1) yields less runoff than the "poor" condition (Figure 4-2).

Table 4-1. TR-55 CN assumptions for the Albuquerque region (Source: NRCS 1986)

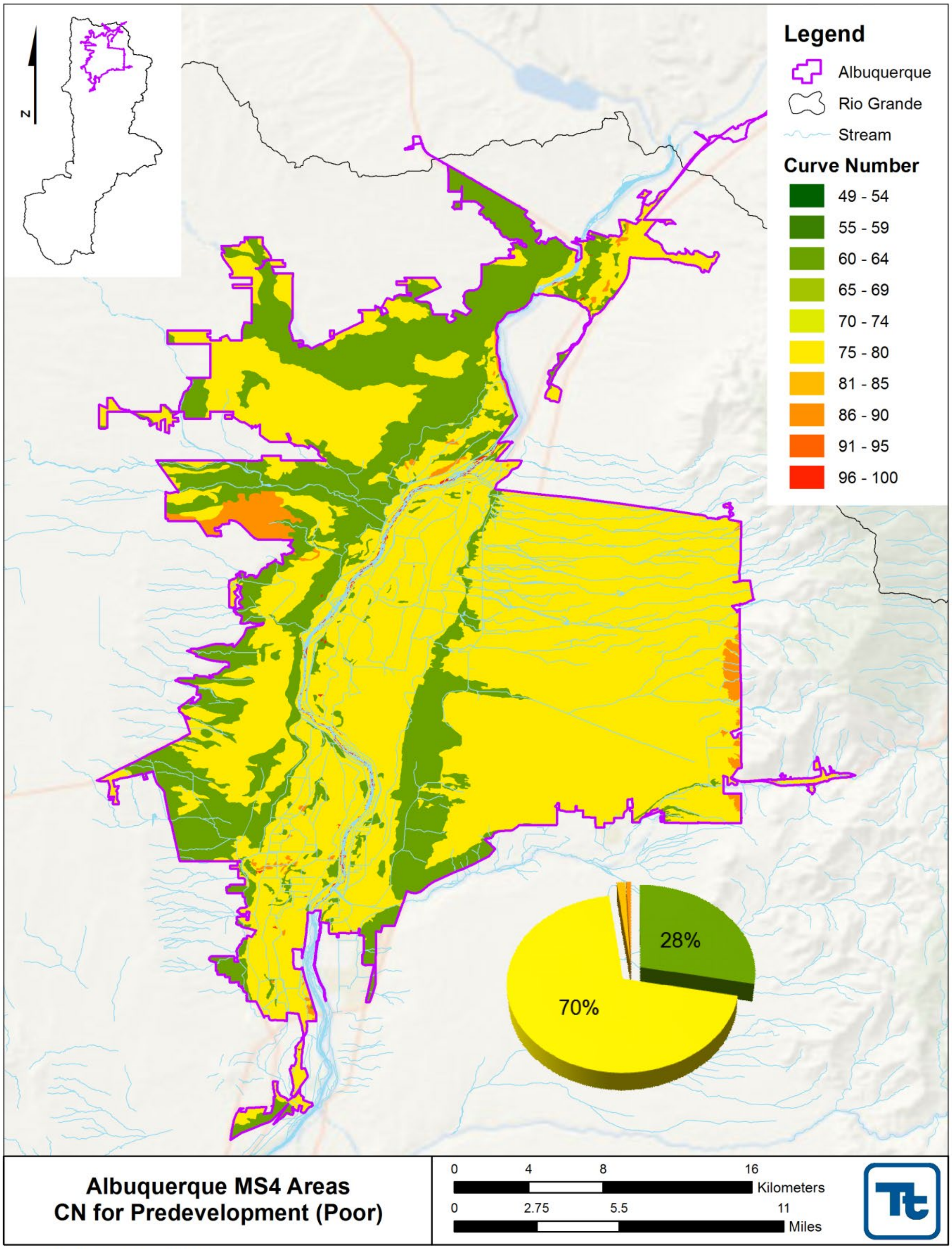
Land Cover		**Curve Number (CN) by Hydrologic Soil Group (HSG)**			
		A	**B**	**C**	**D**
Predevelopment Conditions	Woods in good condition[1]	30	55	70	77
	Woods in poor condition[1]	45	66	77	83
	Desert shrub in good condition	49	68	79	84
	Desert shrub in poor condition	63	77	85	88
Western Desert Urban Areas	Natural desert landscaping[2]	63	77	85	88
	Artificial desert landscaping with impervious weed barrier	96	96	96	96
Impervious Surfaces	Parking lots, roofs, driveways (excluding rights-of-way)	98	98	98	98
Mixed Urban Land Cover	Composite pervious/ impervious land cover	*Composite CNs are usually calculated using area-weighting of directly-connected/unconnected impervious with pervious*			

1: Shown for reference purposes only for comparison with desert shrub CN values
2: TR-55 assumes the same values as "Desert shrub in poor condition"



GCS North American 1983

Figure 4-1. Predevelopment CNs (Good hydrologic condition).



GCS North American 1983

Figure 4-2. Predevelopment CNs (Poor hydrologic condition).

The post-developed condition curve numbers were developed by area-weighting poor-condition pervious CN values with an impervious CN value of 98 for NLCD 2006 land cover and impervious area distribution. Figure 4-3 shows percent imperviousness and land cover distribution summarized by land cover type within the MS4 jurisdictional boundary. Although high intensity development is about 75 percent impervious on average, it only makes up 3 percent of the MS4 area. There is some impervious cover within the undeveloped land areas (about 2 percent on average); however, these are most likely small distributed structures or hard surfaces that are most likely not directly connected impervious area. Given the prevalence of well-draining A and B soils, all impervious areas were assumed to be directly connected for generating composite CN values through area-weighting (as a conservative assumption). Figure 4-4 is a map of the composite CN spatial distribution within the MS4 jurisdictional boundary.

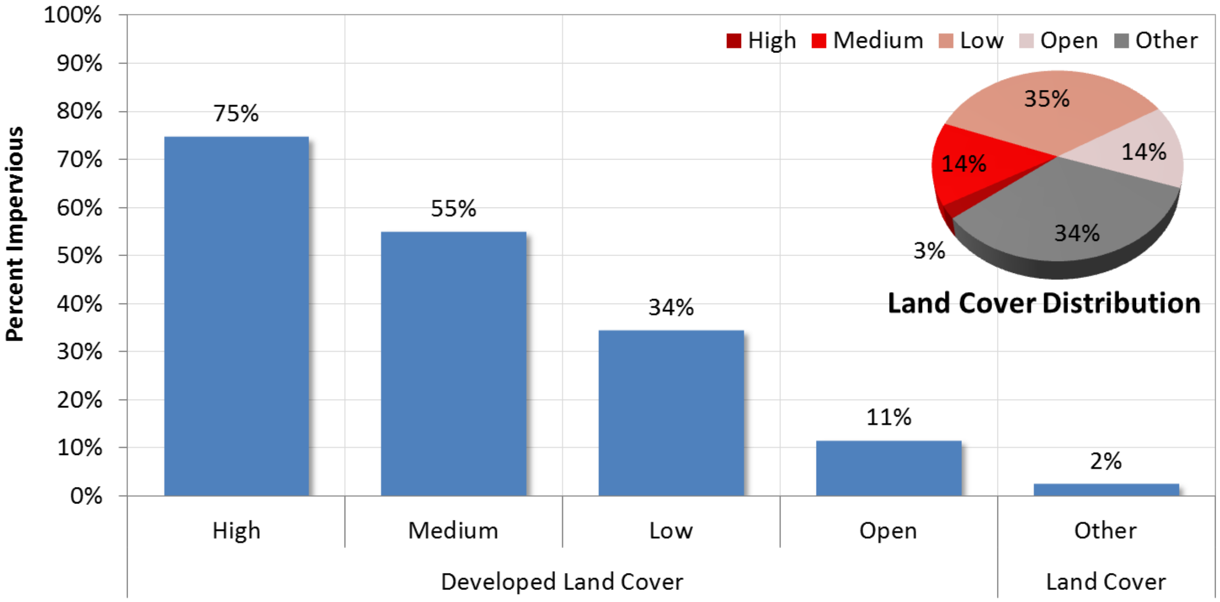
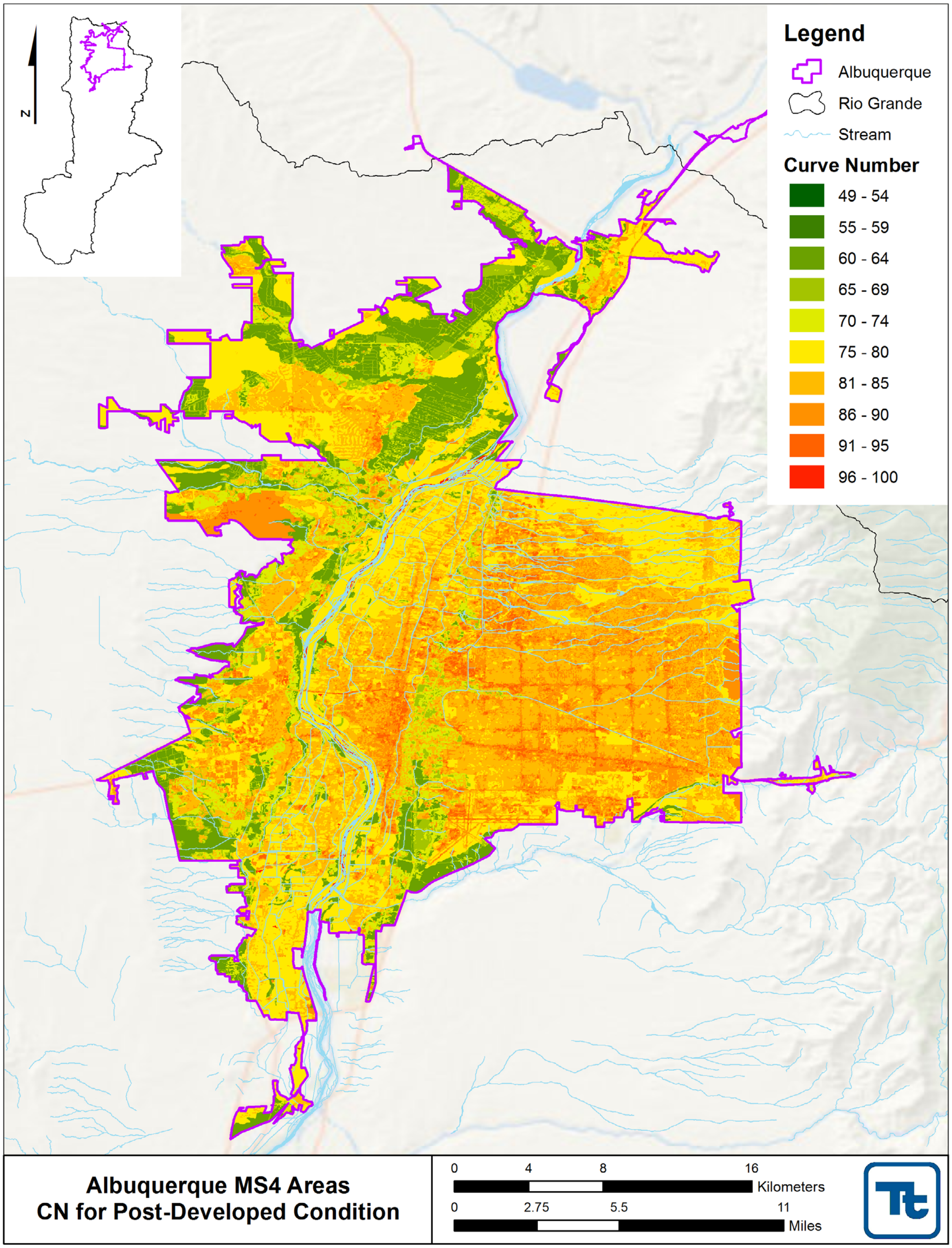


Figure 4-3. Percent imperviousness and land cover distribution summarized by land cover type.



GCS North American 1983

Figure 4-4. Post-developed CNs (Poor pervious hydrologic condition with impervious mix).

4.2 RESULTS

The TR-55 equations described previously were used to generate a runoff nomograph using regionally-representative CN and rainfall depth combinations as presented in Figure 4-5. The nomograph presents runoff depths between 0.01 and 1.5 inches depending on the rainfall and CN combination. Runoff depths between 0.01 and 0.1 inches were considered as part of the analysis to provide a broader sample space to define points where measureable runoff first occurs. Three sets of runoff estimates (each set having three rainfall depths 85th, 90th, and 95th percentile) were generated using TR-55 assuming:

1. Predevelopment CNs and good hydrologic condition (from Figure 4-1)
2. Predevelopment CNs and poor hydrologic condition (from Figure 4-2)
3. Post-development CNs and poor hydrologic condition (from Figure 4-4).

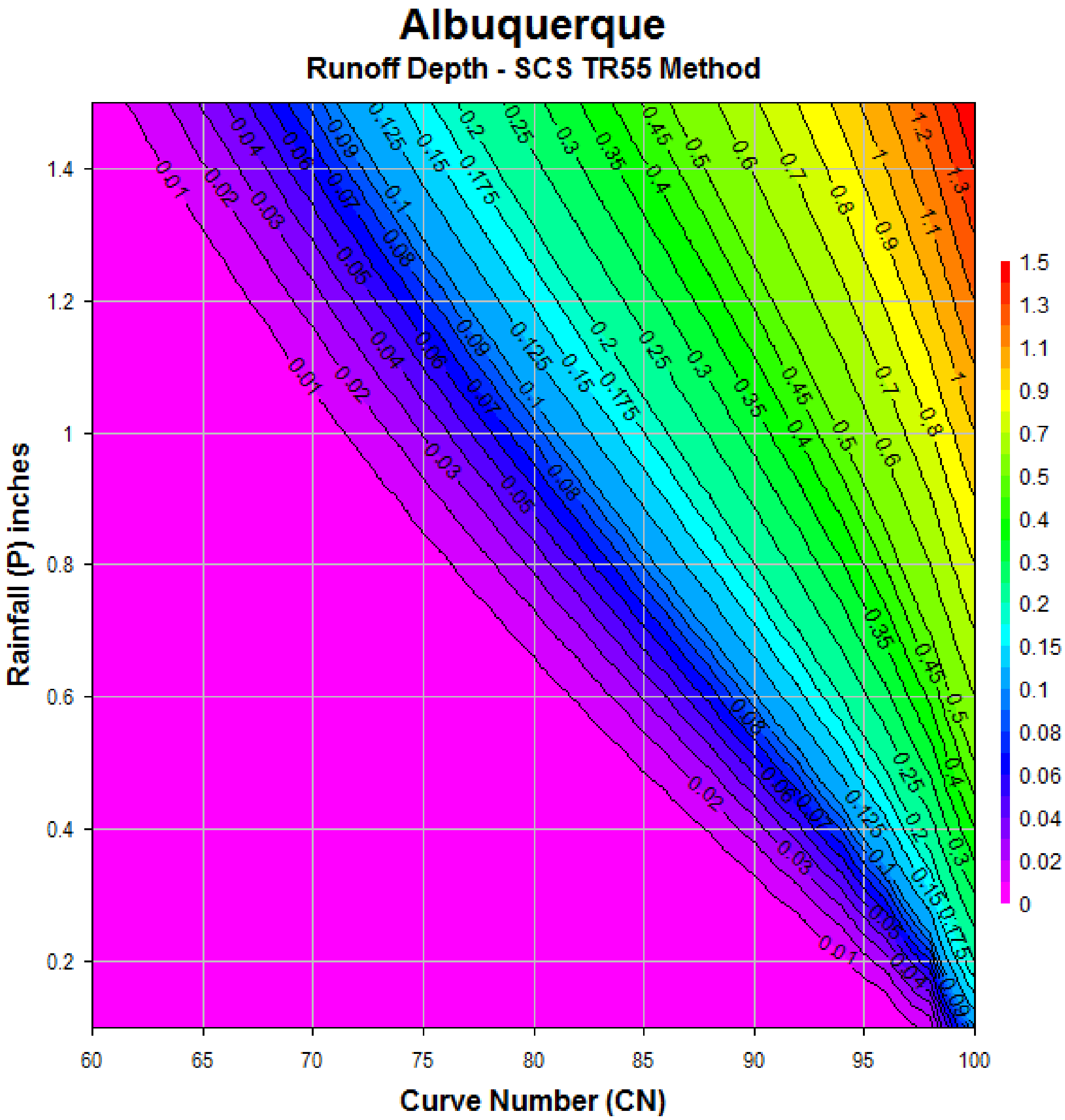


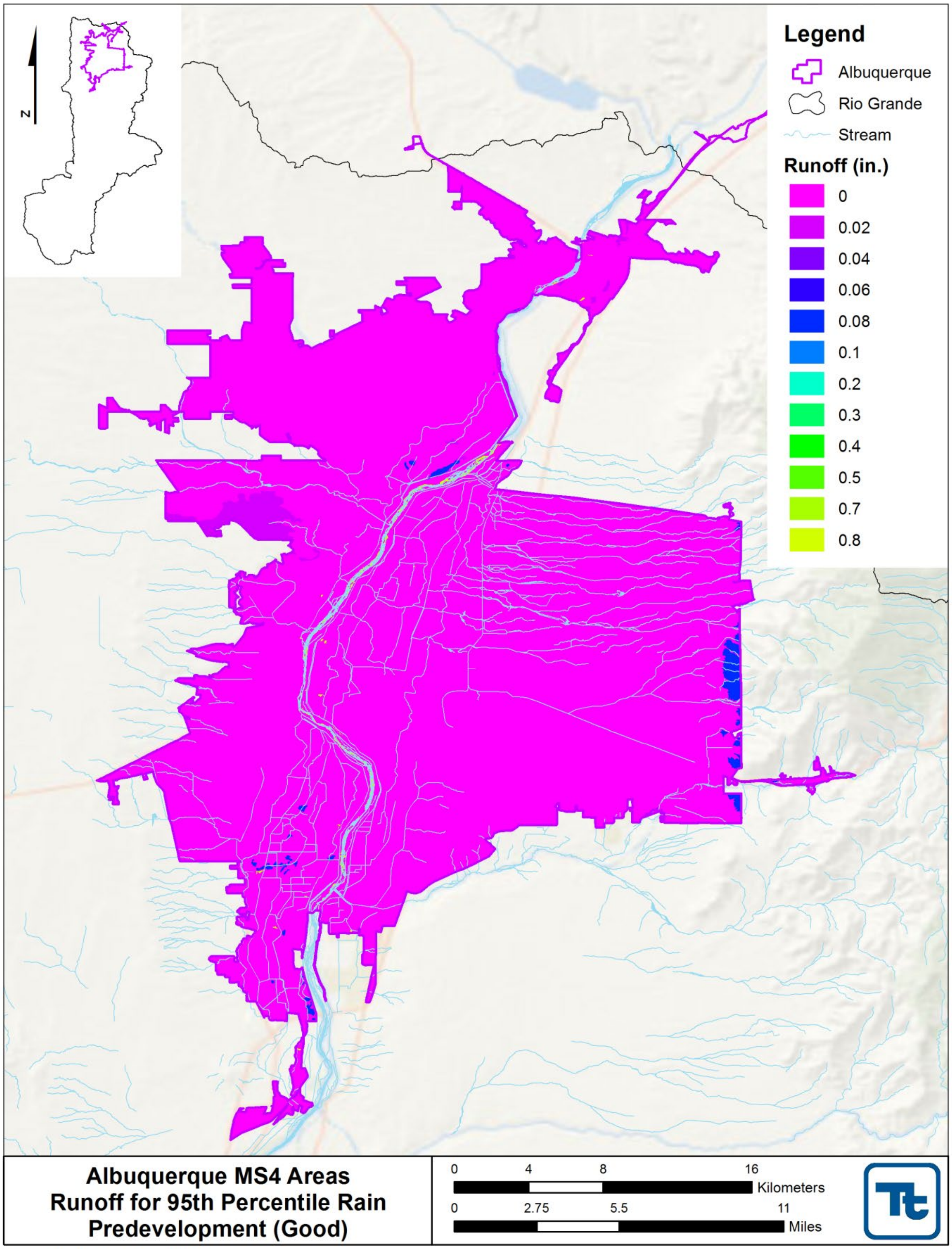
Figure 4-5. Nomograph depicting runoff depth as a function of rainfall and CN.

Because the CWP guidance already excludes rainfall events less than 0.1 inches, selecting an even lower runoff threshold provides a more conservative definition of "measurable" runoff. For this analysis, the runoff threshold range between 0.01 and 0.1 inches was considered for the range where measureable runoff first occurs. The 85th, 90th, and 95th percentile rainfall depths result in measureable runoff occurring above CN values greater than or equal to 77. These data indicate that under predevelopment conditions, there would only be measurable runoff occurring from very small pockets within the study area where the CN is 77 or greater and around the 95th percentile rainfall depth (0.78 inches of rainfall). Very little predevelopment runoff is expected for much of the watershed because HSG is mostly A and B. Table 4-1 summarizes TR-55 runoff simulations for the three rainfall depths and the range of CN values above which runoff (defined as ≥ 0.01 inches) occurs. Spatial maps of runoff were generated by joining the underlying TR-55 runoff estimates (plotted in Figure 4-5 and partially summarized in Table 4-1) with the curve number maps previously shown. Of the six predevelopment runoff maps that were evaluated, only the 95th percentile rainfall depth produced sizeable areas of measureable runoff, as plotted in Figure 4-6 for good hydrologic condition and Figure 4-7 for poor hydrologic condition.

Table 4-2. Runoff depths for various rainfall percentiles and CNs

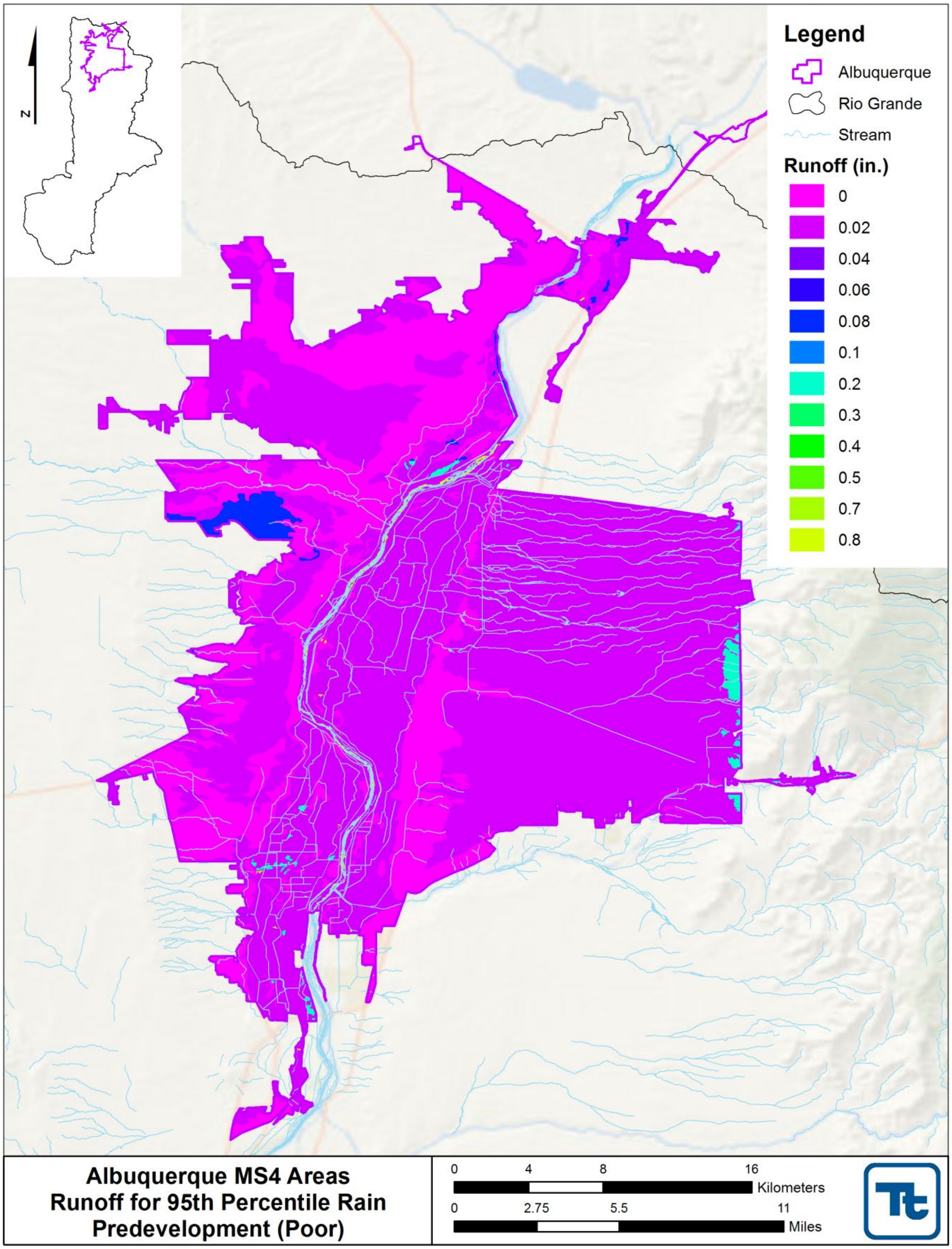
Rainfall Percentile:	**85th**	**90th**	**95th**
Rainfall Depth (in.):	0.53	0.615	0.78
Curve Number (CN)	**Runoff depth (inches)**		
≤74	0.00	0.00	0.00
76	0.00	0.00	0.01
78	0.00	0.00	0.02
80	0.00	0.01	0.03
82	0.00	0.01	0.05
84	0.01	0.03	0.07
86	0.02	0.04	0.10
88	0.04	0.07	0.14
90	0.07	0.10	0.19
92	0.10	0.15	0.25
94	0.16	0.21	0.33
96	0.23	0.30	0.44
98	0.35	0.42	0.58
100	0.53	0.62	0.78

Runoff: Low → High



GCS North American 1983

Figure 4-6. Predevelopment runoff for 95th percentile rainfall (good hydrologic condition).



GCS North American 1983

Figure 4-7. Predevelopment runoff for 95th percentile rainfall (poor hydrologic condition).

5 Conclusions and Recommendations

This analysis evaluates a range of rainfall depths and estimated runoff responses that constitute and describe predevelopment conditions. Here are some observations from this analysis in the regulated MS4 area of the watershed:

1. Estimated rainfall depths for the 85th, 90th, and 95th percentile are 0.53, 0.615, and 0.78 inches, respectively.
2. The regulated MS4 area of the watershed is well drained, fairly flat, and has a low potential for runoff in areas with low imperviousness (A and B type soils).
3. Under natural/predevelopment conditions, there is little to no measureable runoff generated in the study area for about 95 percent of all rainfall events.
4. If the predevelopment condition in the regulated MS4 area of the watershed is defined as the rainfall depth above which measurable runoff first occurs under natural conditions, then that threshold is somewhere between the 90th and 95th percentile 24-hour rainfall depths (0.615 to 0.78 inches)

The predevelopment hydrology of the watershed is based on the critical combinations of rainfall, soils, and land cover that results in measureable runoff. For this analysis CN is used as a surrogate indicator of soil and land cover conditions, with higher values indicating more runoff potential. Using the TR-55 equations, the 85th percentile rainfall event (0.53 inches) begins to generate measureable runoff (≥ 0.01 inches) at a CN of 84; however, under predevelopment conditions, the worst-case CN values for desert shrub in poor hydrologic condition are 85 and 88 for C and D soils respectively, but only 77 for B soils and 63 for A soils, which together represent 98 percent of the soil within the MS4 focus area. Only the 90th and 95th percentile storms begin generating runoff at lower CN values of 80 and 76, respectively.

This analysis excludes all 24-hour storms less than 0.1 inches. For this reason, the level of runoff considered to be “measurable” was tested within a range of values ranging between 0.01 and 0.1 inches of runoff. Depending on whether 0.01 or 0.1 inches is considered as the threshold for “measurable” runoff, even some developed areas (i.e. low intensity or open space) did not generate enough runoff to meet that threshold.

Given these results, the performance standard to capture the 90th percentile storm event in the current Phase I Albuquerque permit and the proposed Middle Rio Grande watershed MS4 permit is a reasonable surrogate for mimicking predevelopment hydrology for this watershed.

Managing stormwater to pre-development runoff condition will reduce water quality impacts on the receiving water as development occurs in the watershed. It is anticipated that it will also provide cost savings for new development and achieve multiple benefits such as reducing local flooding, reducing drought impacts, making communities more resilient to extreme wet weather events, making neighborhoods more livable, reducing the urban heat island effect, reducing energy demands, and improving air quality. Those benefits are also not explicitly quantified in this analysis, but could be possible indicators to evaluate in future analyses.

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