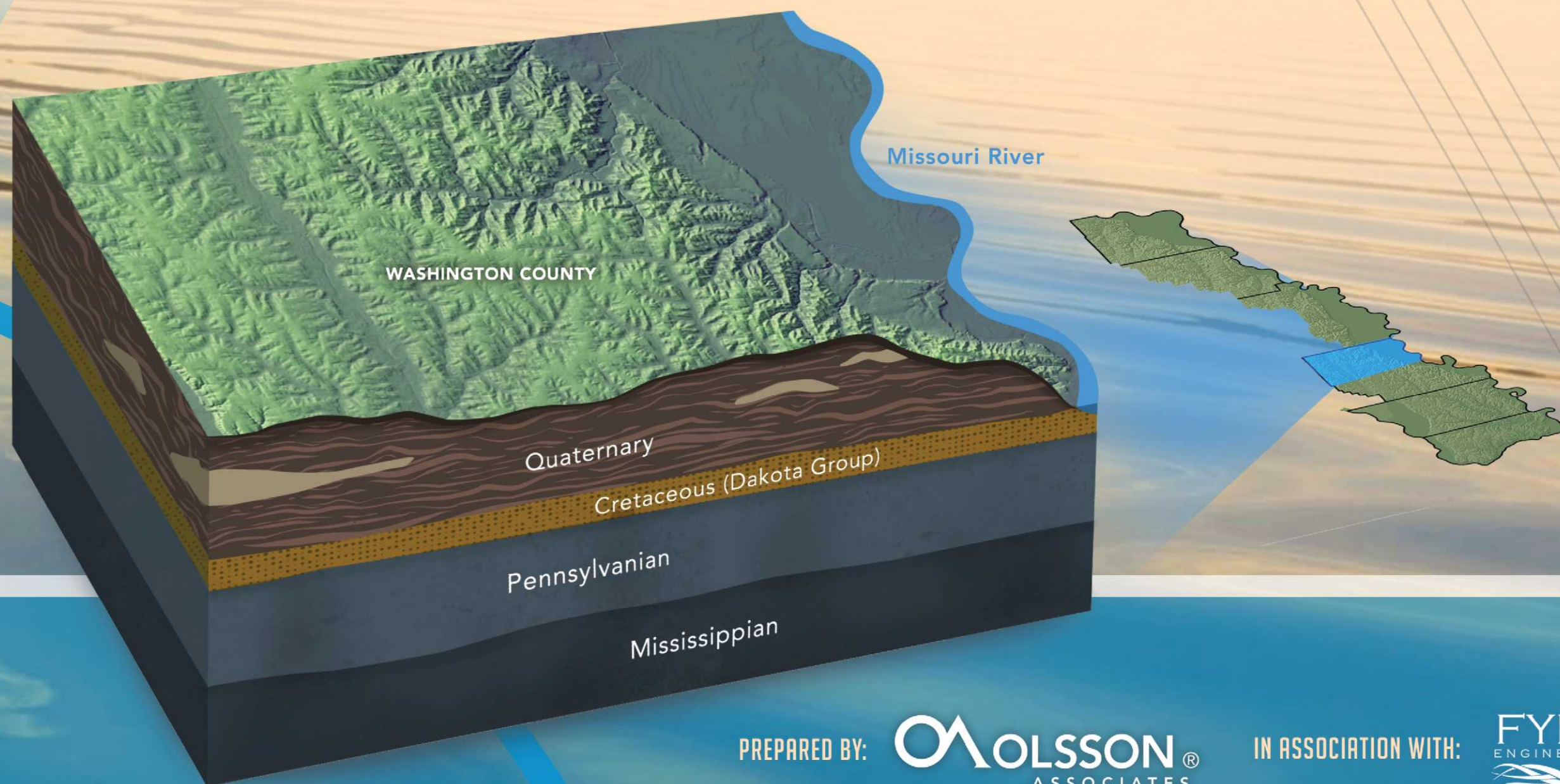


THE PAPIO-MISSOURI RIVER NATURAL RESOURCES DISTRICT

GROUNDWATER MANAGEMENT PLAN

JULY 24, 2017 VOLUME II

PREPARED FOR: PAPIO-MISSOURI RIVER NATURAL RESOURCES DISTRICT



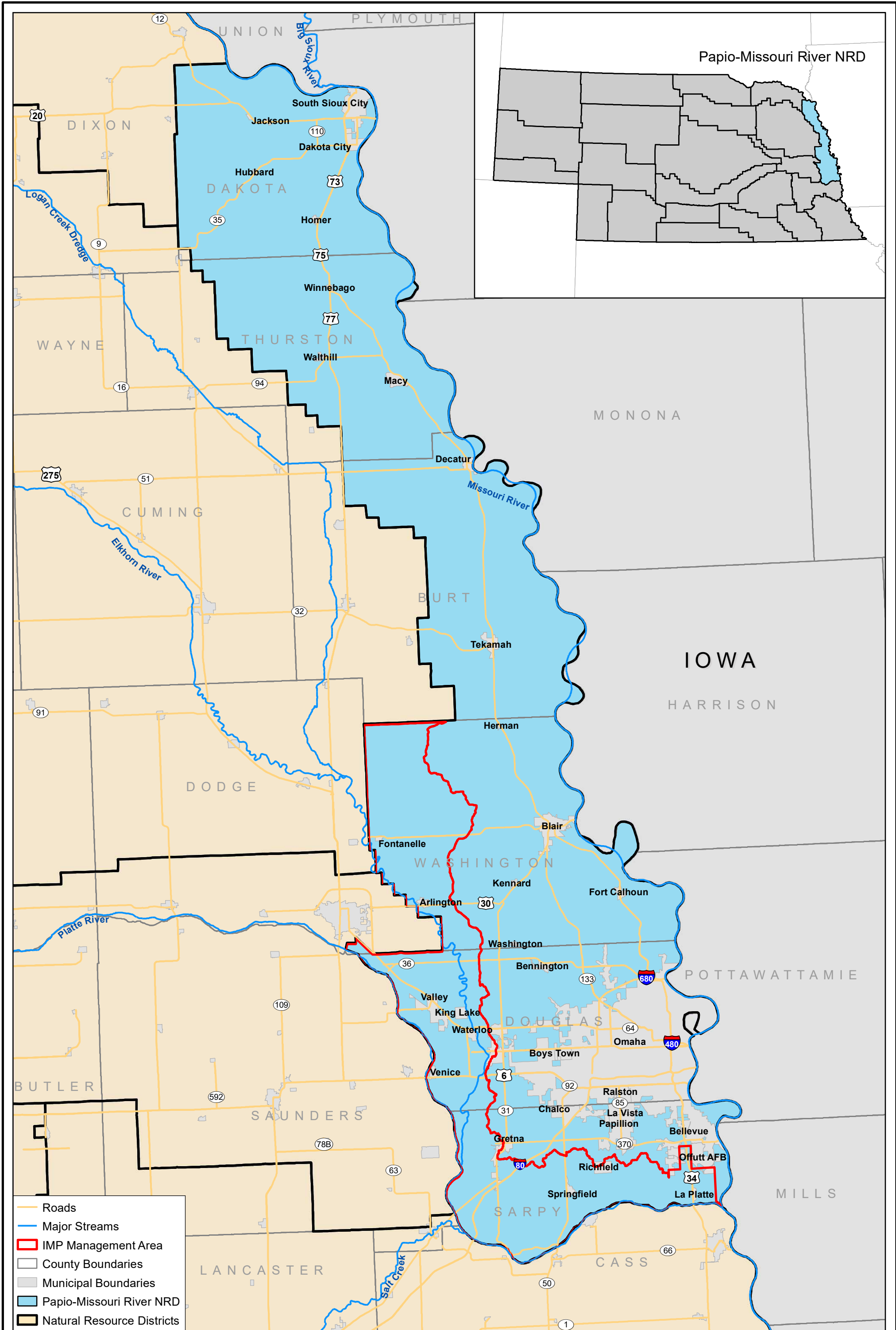
PREPARED BY: **OLSSON** ASSOCIATES

IN ASSOCIATION WITH: **FYRA** ENGINEERING

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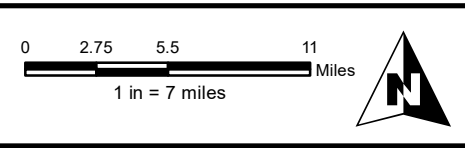
Volume II

- Map 1 P-MRNRD Location Map
- Map 2 ENWRA Flight Paths
- Map 3 Extent of Glacial Till Deposits
- Map 4 Bedrock Geology
- Map 5 Estimated Transmissivity of the Primary Aquifer
- Map 6 Reviewed Wells and Aquifer Designations
- Map 7 USGS Primary Aquifer Delineation
- Map 8 Thickness of Saturated Sand and Gravel Aquifers
- Map 9 Secondary Aquifer Distribution
- Map 10 General Soil Types
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- Map 19 Current Groundwater Model Areas
- Map 20 Groundwater Vulnerability
- Map 21 Proposed Phase II Groundwater Management Areas



PROJECT: 015-3424 DATE: July 24, 2017 DRAWN BY: MCG

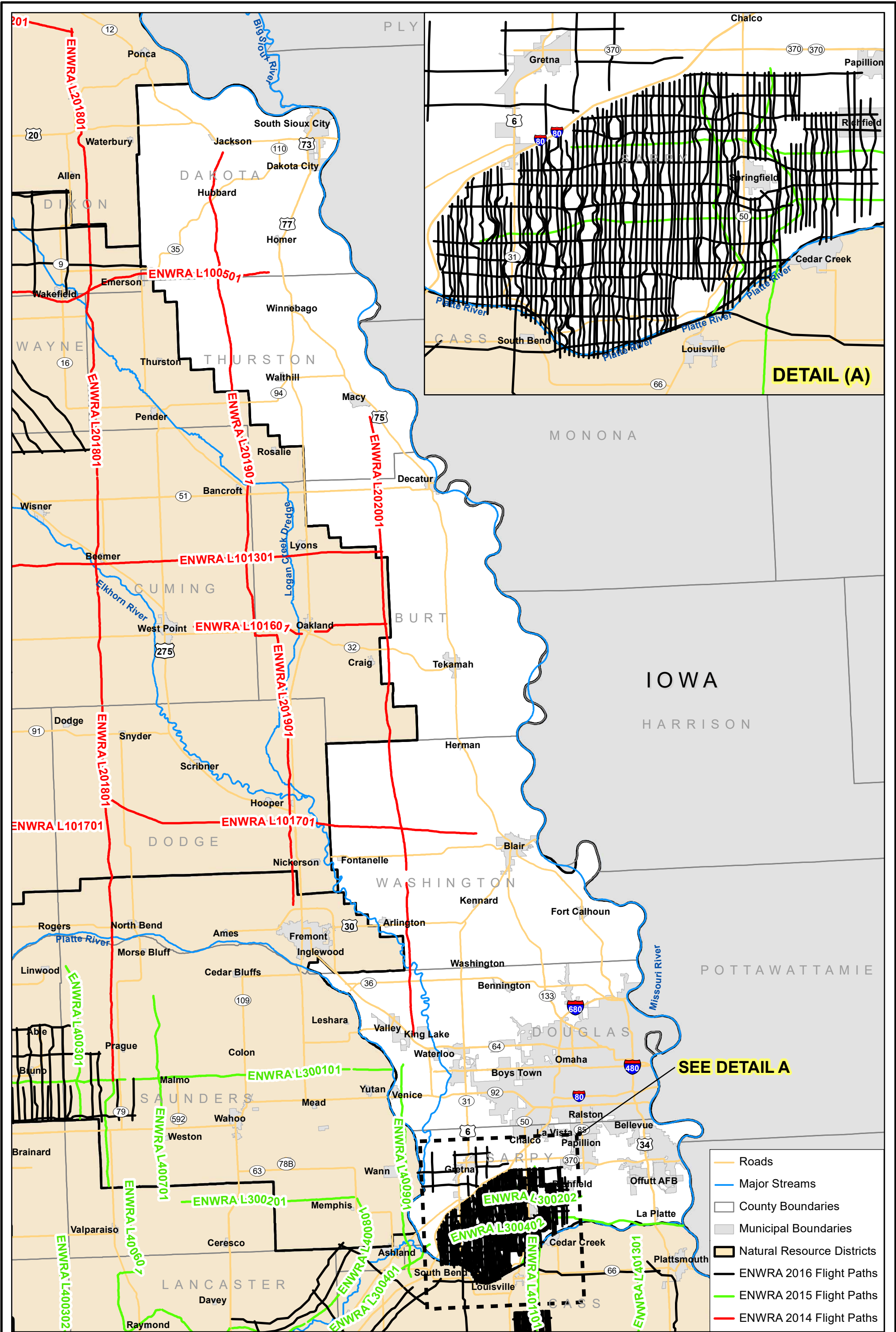
Sources:
 NDNR: NRD Boundaries
 PRISM: Normal Annual Precipitation (1981-2010)
 USGS: National Hydrography Dataset
 U.S. Census Bureau: Roads, County Boundaries, Municipal Boundaries



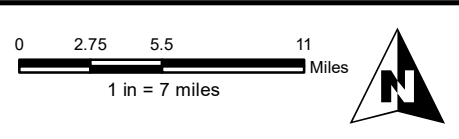
P-MNRD LOCATION MAP
Papio-Missouri River NRD

MAP
1

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PROJECT: 015-3424 DATE: July 24, 2017 DRAWN BY: MCG
 Sources: NRD Boundaries
 USGS: National Hydrography Dataset
 U.S. Census Bureau: Roads, County Boundaries, Municipal Boundaries
 ENWRA: Flight Paths



ENWRA Flight Paths
Pappio-Missouri River NRD

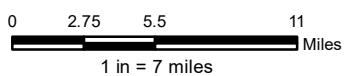
MAP
2

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PROJECT: 015-3424 DATE: July 24, 2017 DRAWN BY: MCG

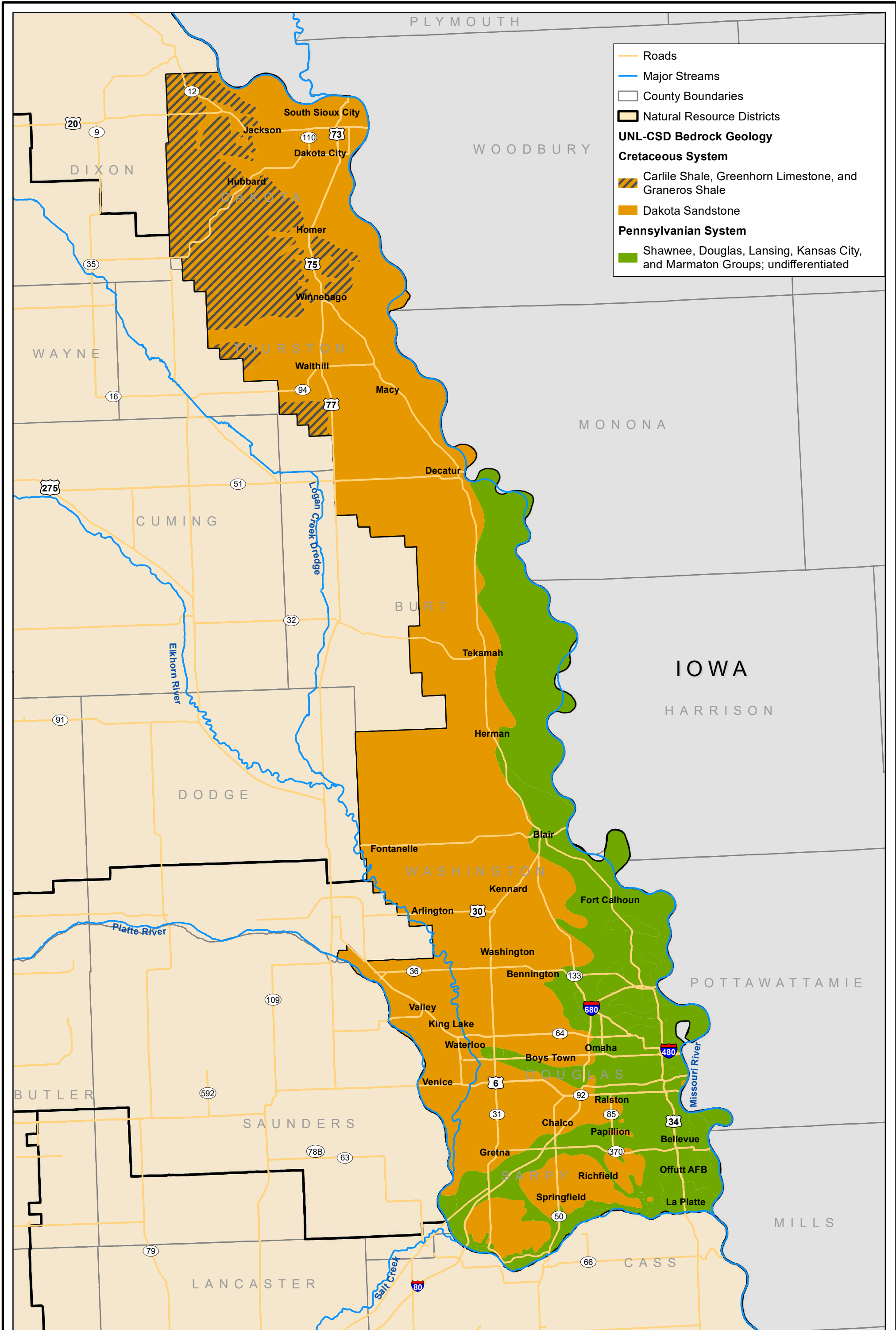
Sources:
 NDNR: NRD Boundaries
 USGS: National Hydrography Dataset
 U.S. Census Bureau: Roads, County Boundaries, Municipal Boundaries
 UNL-CSD: Glacial Till Deposits



**EXTENT OF GLACIAL TILL DEPOSITS
 Pappio-Missouri River NRD**

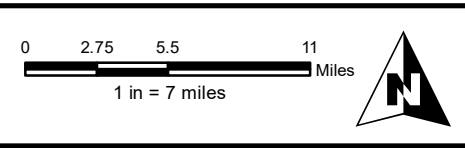


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PROJECT: 015-3424 DATE: July 24, 2017 DRAWN BY: MCG

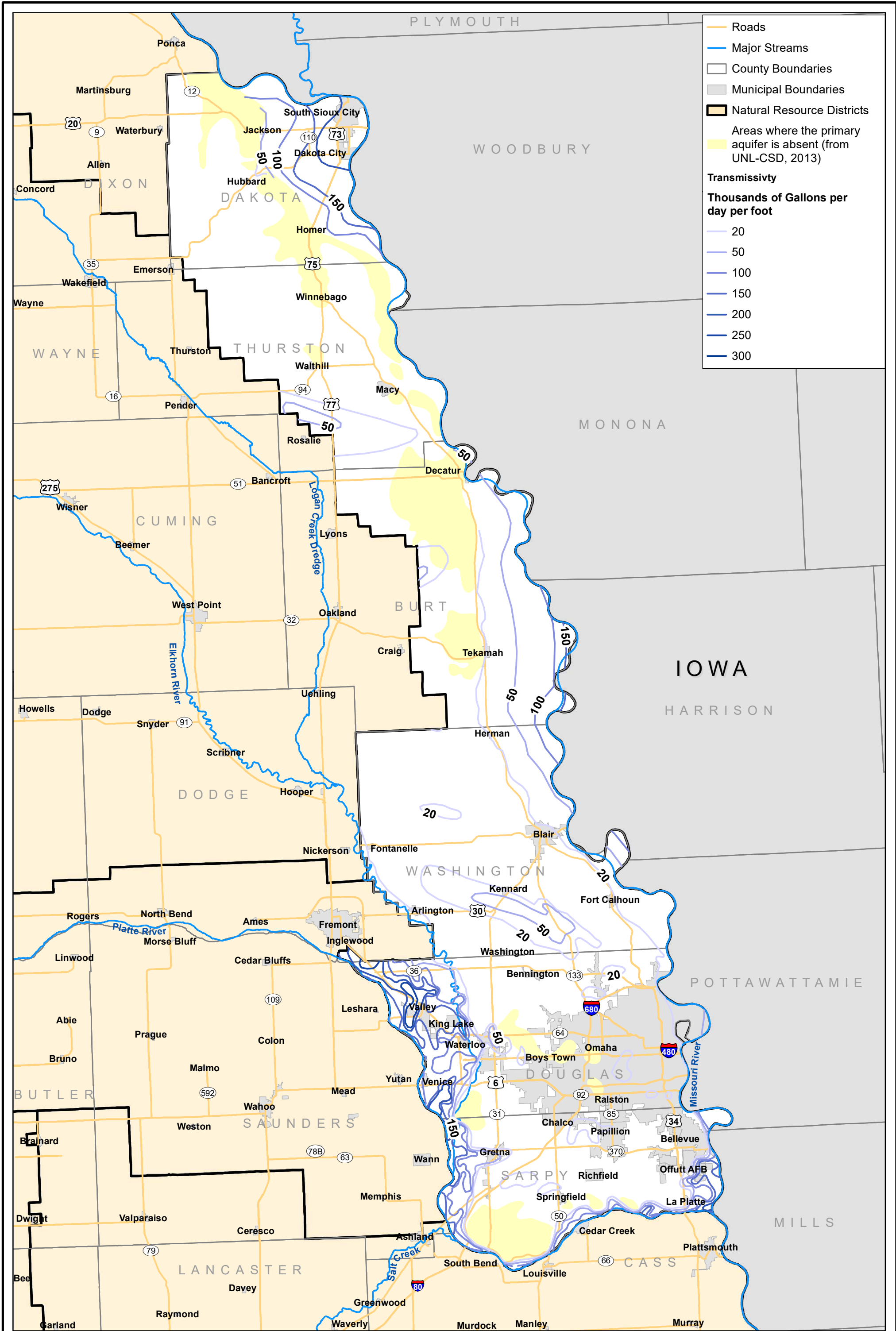
Sources:
 NDNR: NRD Boundaries
 USGS: National Hydrography Dataset
 U.S. Census Bureau: Roads, County Boundaries, Municipal Boundaries
 UNL-CSD: Bedrock Geology



BEDROCK GEOLOGY MAP
Pappio-Missouri River NRD



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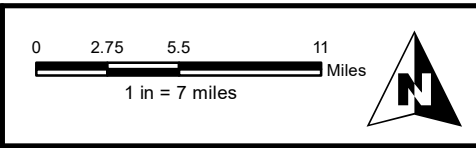


— Roads
— Major Streams
 County Boundaries
 Municipal Boundaries
 Natural Resource Districts
 Areas where the primary aquifer is absent (from UNL-CSD, 2013)

Transmissivity
Thousands of Gallons per day per foot

- 20
- 50
- 100
- 150
- 200
- 250
- 300

PROJECT: 015-3424 DATE: July 24, 2017 DRAWN BY: CBT
 Sources:
 NDNR: NRD Boundaries, Registered Wells
 USGS: National Hydrography Dataset
 U.S. Census Bureau: Roads, County Boundaries, Municipal Boundaries
 UNL-CSD (2013): Areas where primary aquifer is absent
 HDR (2013): Estimated Transmissivity

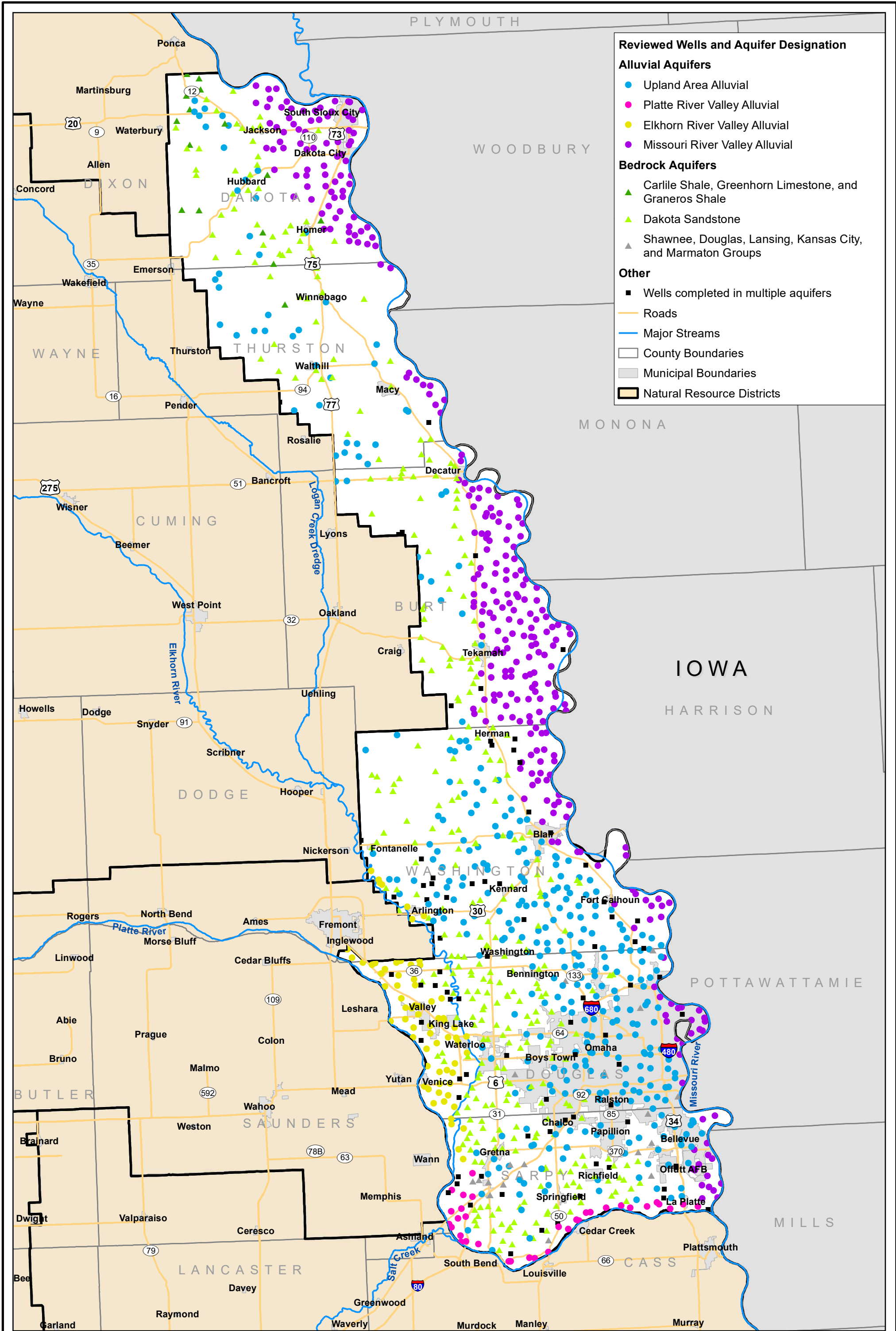


**ESTIMATED TRANSMISSIVITY OF
 PRIMARY AQUIFER
 Pappio-Missouri River NRD**

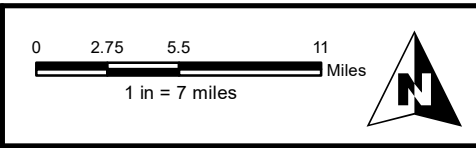
MAP

5

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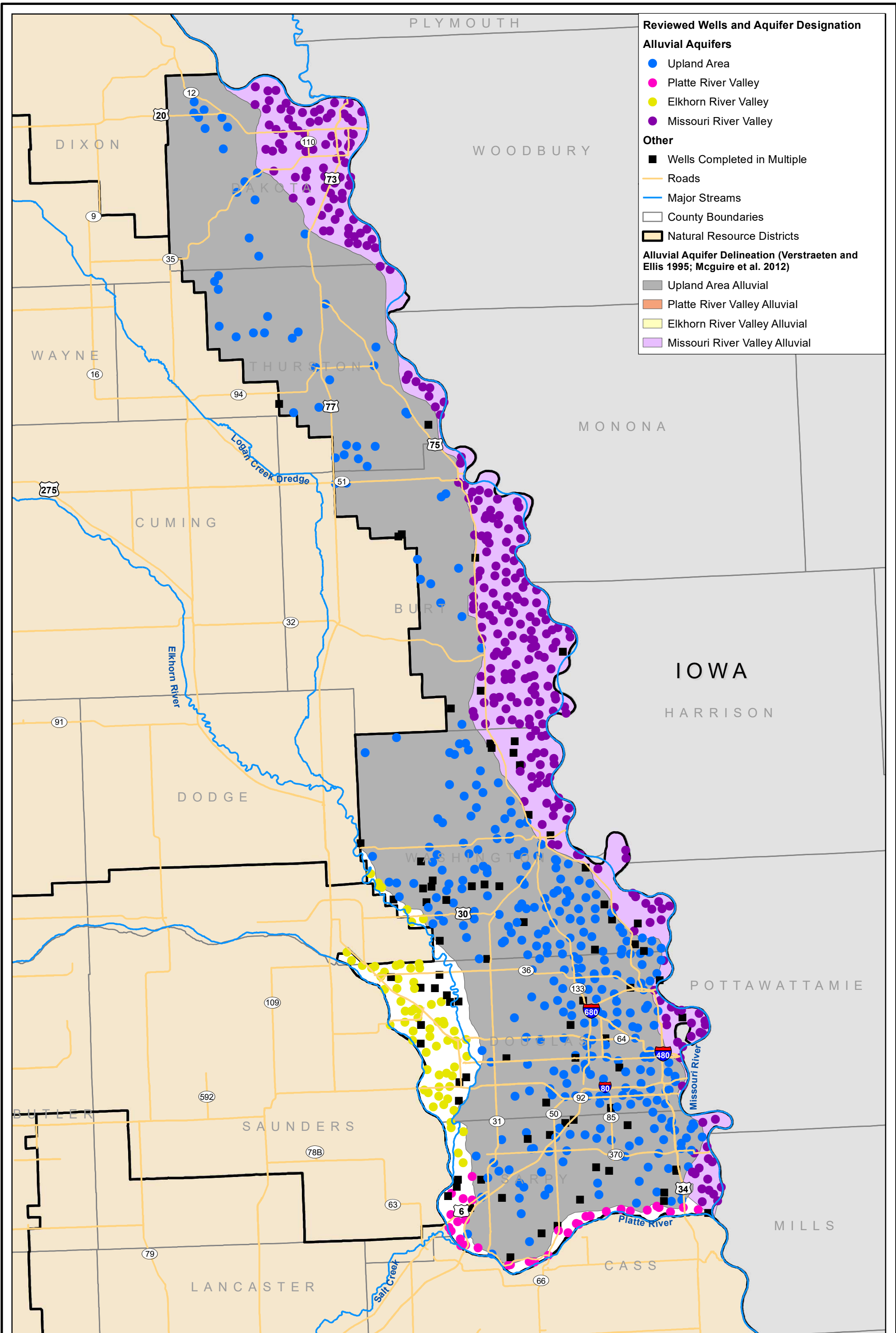
PROJECT: 015-3424 DATE: July 24, 2017 DRAWN BY: MCG
 Sources: NDNR: NRD Boundaries, Registered Wells
 USGS: National Hydrography Dataset
 U.S. Census Bureau: Roads, County Boundaries, Municipal Boundaries



REVIEWED WELLS AND AQUIFER DESIGNATIONS
Pappio-Missouri River NRD

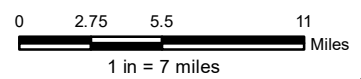
MAP 6

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PROJECT: 015-3424 DATE: July 24, 2017 DRAWN BY: MCG

Sources:
 NDNR: NRD Boundaries, Registered Wells,
 USGS: National Hydrography Dataset
 U.S. Census Bureau: Roads, County Boundaries, Municipal Boundaries
 Verstraeten and Ellis (1995): Alluvial Aquifer Extent



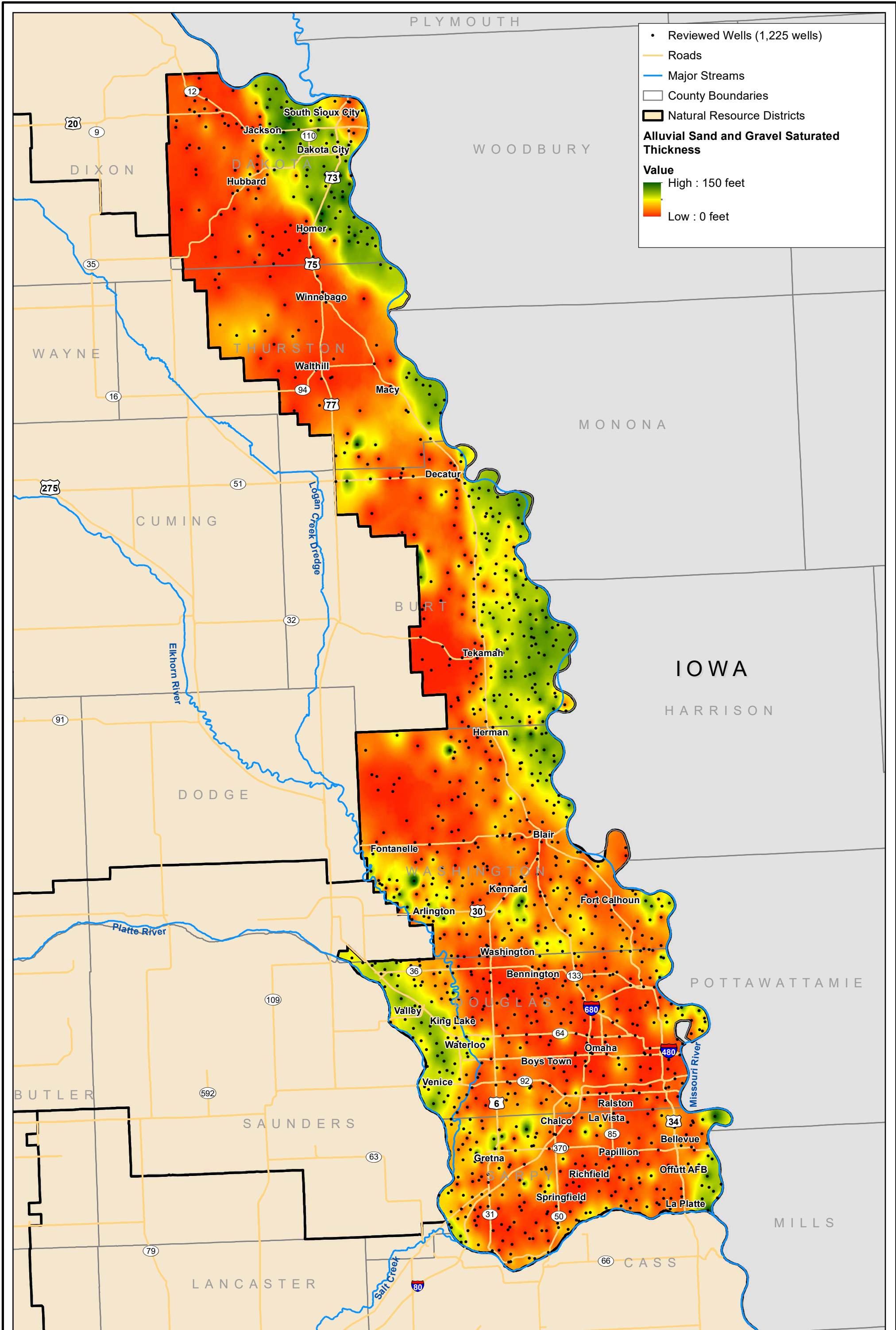
USGS PRIMARY AQUIFER DELINEATION
Papio-Missouri River NRD



MAP

7

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- Reviewed Wells (1,225 wells)
- Roads
- Major Streams
- County Boundaries
- ▭ Natural Resource Districts

Alluvial Sand and Gravel Saturated Thickness

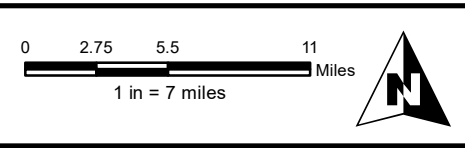
Value

High : 150 feet

Low : 0 feet

PROJECT: 015-3424 DATE: Jul. 24, 2017 DRAWN BY: MCG

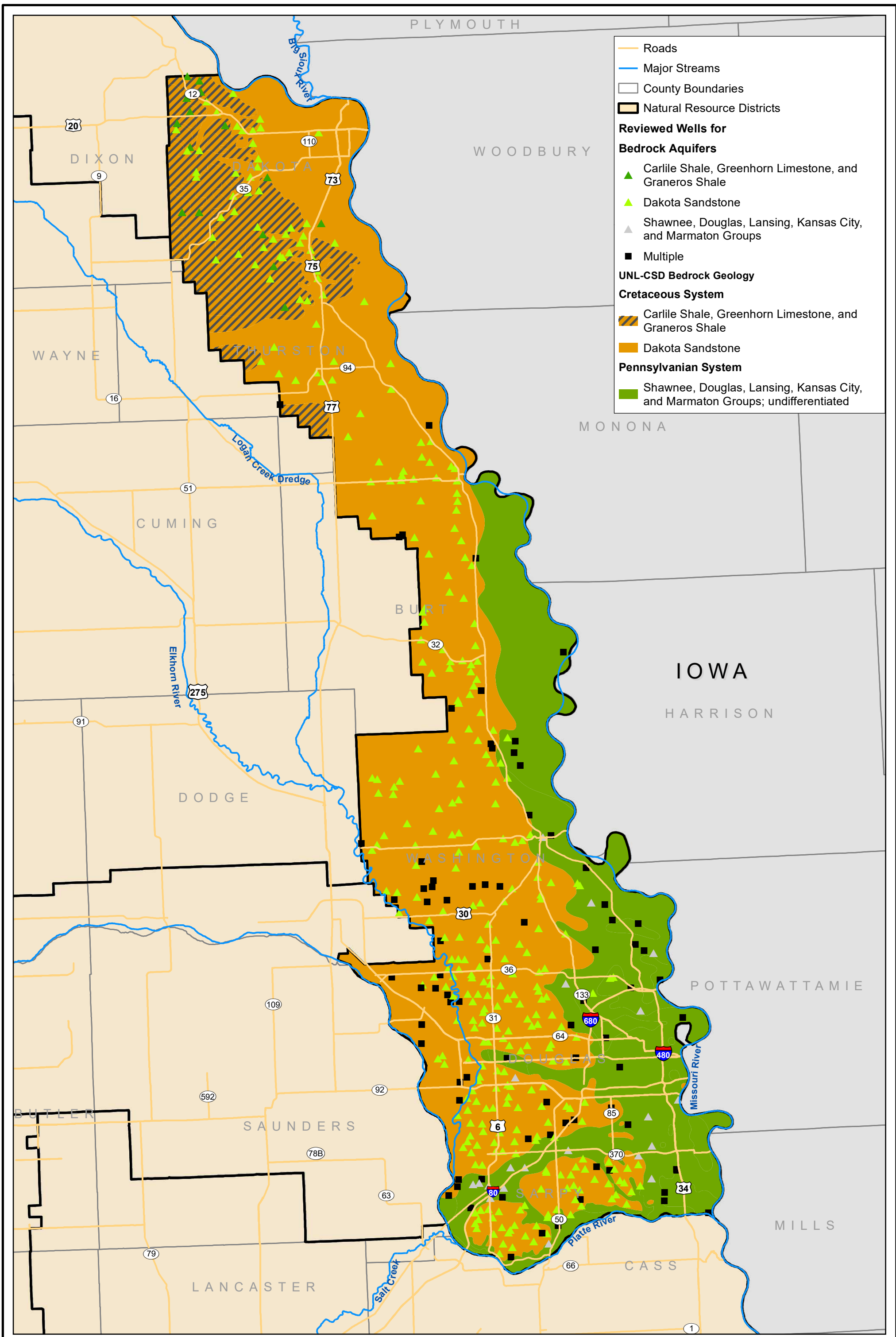
Sources:
 NDNR: NRD Boundaries, Registered Wells
 USGS: National Hydrography Dataset
 U.S. Census Bureau: Roads, County Boundaries, Municipal Boundaries



THICKNESS OF SATURATED SAND AND GRAVEL AQUIFERS
Pappio-Missouri River NRD

MAP 8

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— Roads
 — Major Streams
 □ County Boundaries
 ■ Natural Resource Districts

Reviewed Wells for Bedrock Aquifers

- ▲ Carlile Shale, Greenhorn Limestone, and Graneros Shale
- ▲ Dakota Sandstone
- ▲ Shawnee, Douglas, Lansing, Kansas City, and Marmaton Groups
- Multiple

UNL-CSD Bedrock Geology

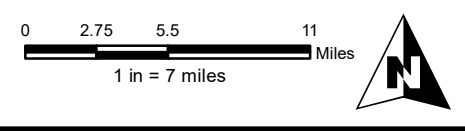
Cretaceous System

- ▨ Carlile Shale, Greenhorn Limestone, and Graneros Shale
- Dakota Sandstone

Pennsylvanian System

- Shawnee, Douglas, Lansing, Kansas City, and Marmaton Groups; undifferentiated

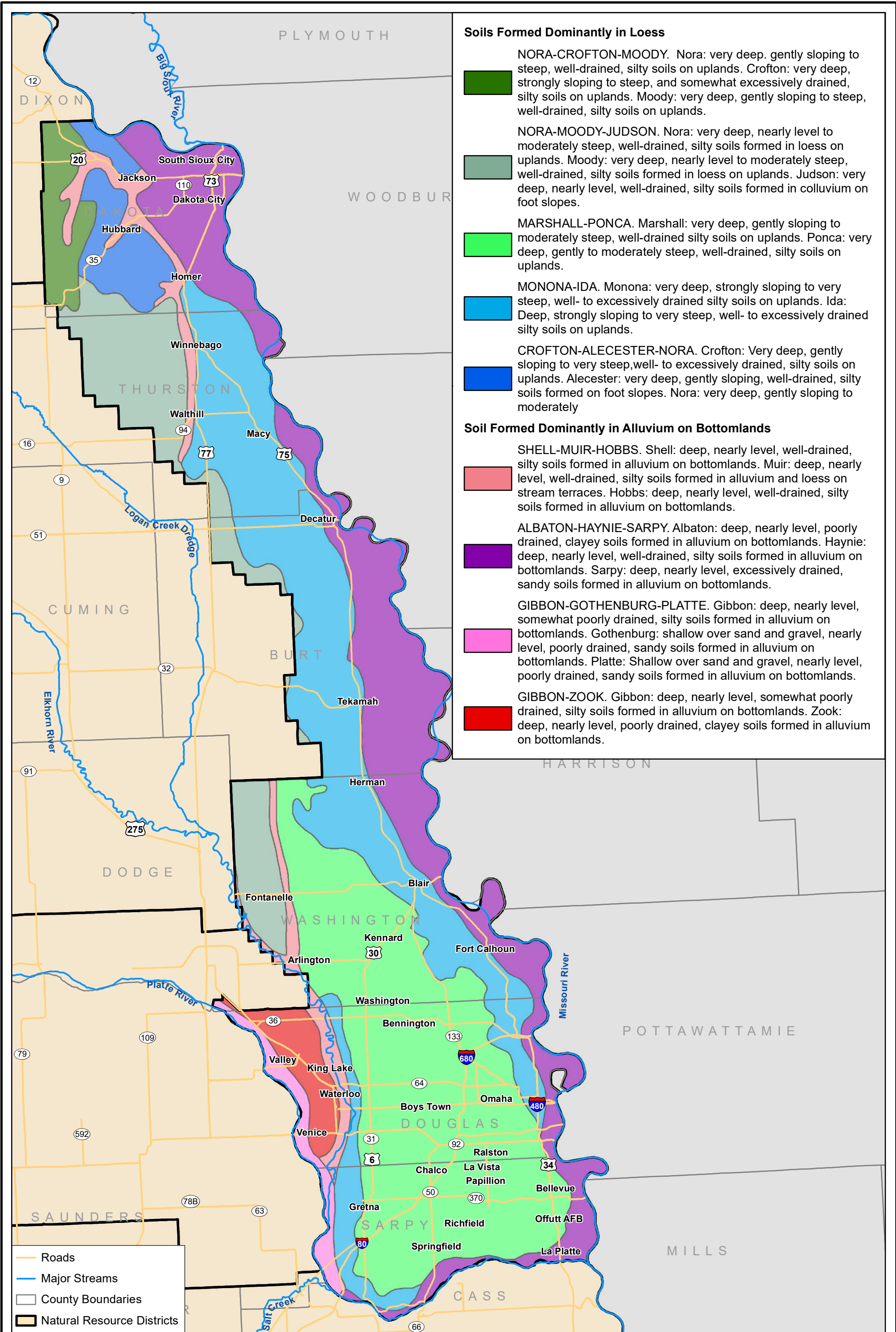
PROJECT: 015-3424 DATE: July 24, 2017 DRAWN BY: MCG
Sources:
 NDNR: NRD Boundaries, Registered Wells
 USGS: National Hydrography Dataset
 U.S. Census Bureau: Roads, County Boundaries, Municipal Boundaries



SECONDARY AQUIFER DISTRIBUTION
Papio-Missouri River NRD



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Soils Formed Dominantly in Loess

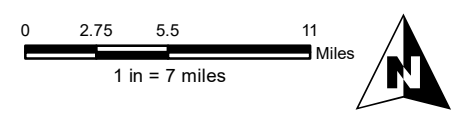
- NORA-CROFTON-MOODY. Nora: very deep, gently sloping to steep, well-drained, silty soils on uplands. Crofton: very deep, strongly sloping to steep, and somewhat excessively drained, silty soils on uplands. Moody: very deep, gently sloping to steep, well-drained, silty soils on uplands.
- NORA-MOODY-JUDSON. Nora: very deep, nearly level to moderately steep, well-drained, silty soils formed in loess on uplands. Moody: very deep, nearly level to moderately steep, well-drained, silty soils formed in loess on uplands. Judson: very deep, nearly level, well-drained, silty soils formed in colluvium on foot slopes.
- MARSHALL-PONCA. Marshall: very deep, gently sloping to moderately steep, well-drained silty soils on uplands. Ponca: very deep, gently to moderately steep, well-drained, silty soils on uplands.
- MONONA-IDA. Monona: very deep, strongly sloping to very steep, well- to excessively drained silty soils on uplands. Ida: Deep, strongly sloping to very steep, well- to excessively drained silty soils on uplands.
- CROFTON-ALECESTER-NORA. Crofton: Very deep, gently sloping to very steep, well- to excessively drained, silty soils on uplands. Alecester: very deep, gently sloping, well-drained, silty soils formed on foot slopes. Nora: very deep, gently sloping to moderately

Soil Formed Dominantly in Alluvium on Bottomlands

- SHELL-MUIR-HOBBS. Shell: deep, nearly level, well-drained, silty soils formed in alluvium on bottomlands. Muir: deep, nearly level, well-drained, silty soils formed in alluvium and loess on stream terraces. Hobbs: deep, nearly level, well-drained, silty soils formed in alluvium on bottomlands.
- ALBATON-HAYNIE-SARPY. Albaton: deep, nearly level, poorly drained, clayey soils formed in alluvium on bottomlands. Haynie: deep, nearly level, well-drained, silty soils formed in alluvium on bottomlands. Sarpy: deep, nearly level, excessively drained, sandy soils formed in alluvium on bottomlands.
- GIBBON-GOTHENBURG-PLATTE. Gibbon: deep, nearly level, somewhat poorly drained, silty soils formed in alluvium on bottomlands. Gothenburg: shallow over sand and gravel, nearly level, poorly drained, sandy soils formed in alluvium on bottomlands. Platte: Shallow over sand and gravel, nearly level, poorly drained, sandy soils formed in alluvium on bottomlands.
- GIBBON-ZOOK. Gibbon: deep, nearly level, somewhat poorly drained, silty soils formed in alluvium on bottomlands. Zook: deep, nearly level, poorly drained, clayey soils formed in alluvium on bottomlands.

- Roads
- Major Streams
- County Boundaries
- Natural Resource Districts

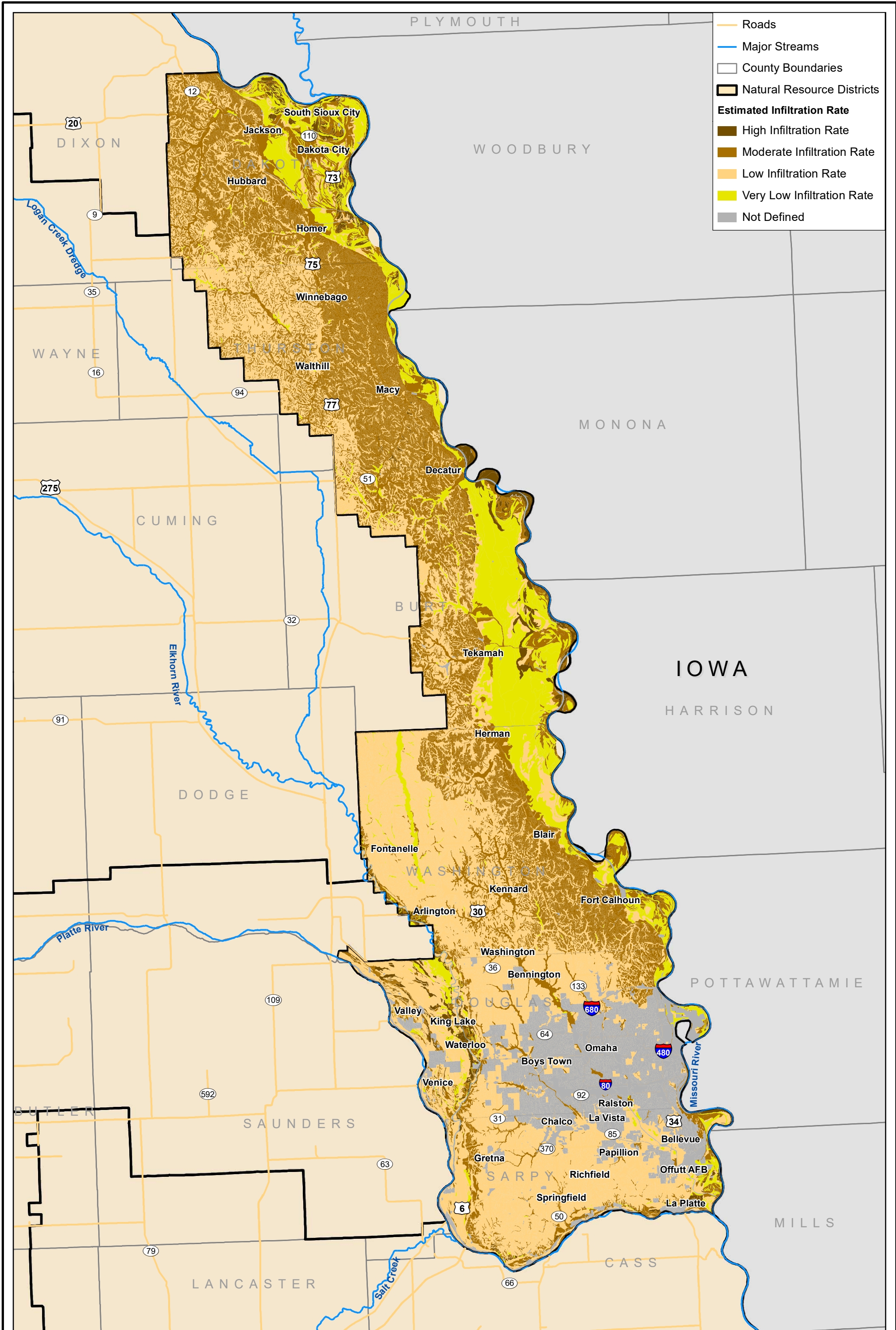
PROJECT: 015-3424 DATE: July 24, 2017 DRAWN BY: MCG
 Sources:
 NDNR: NRD Boundaries
 USGS: National Hydrography Dataset
 U.S. Census Bureau: Roads, County Boundaries, Municipal Boundaries
 NRCS: STATSGO2 NE



**GENERAL SOIL TYPES
Pappio-Missouri River NRD**

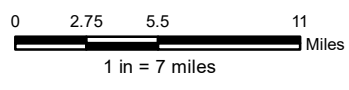


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PROJECT: 015-3424 DATE: July 24, 2017 DRAWN BY: MCG

Sources:
 NDNR: Registered Wells, NRD Boundaries
 USGS: National Hydrography Dataset
 U.S. Census Bureau: Roads, County Boundaries, Municipal Boundaries
 USDA: SSURGO Soils Hydrologic Soils Group



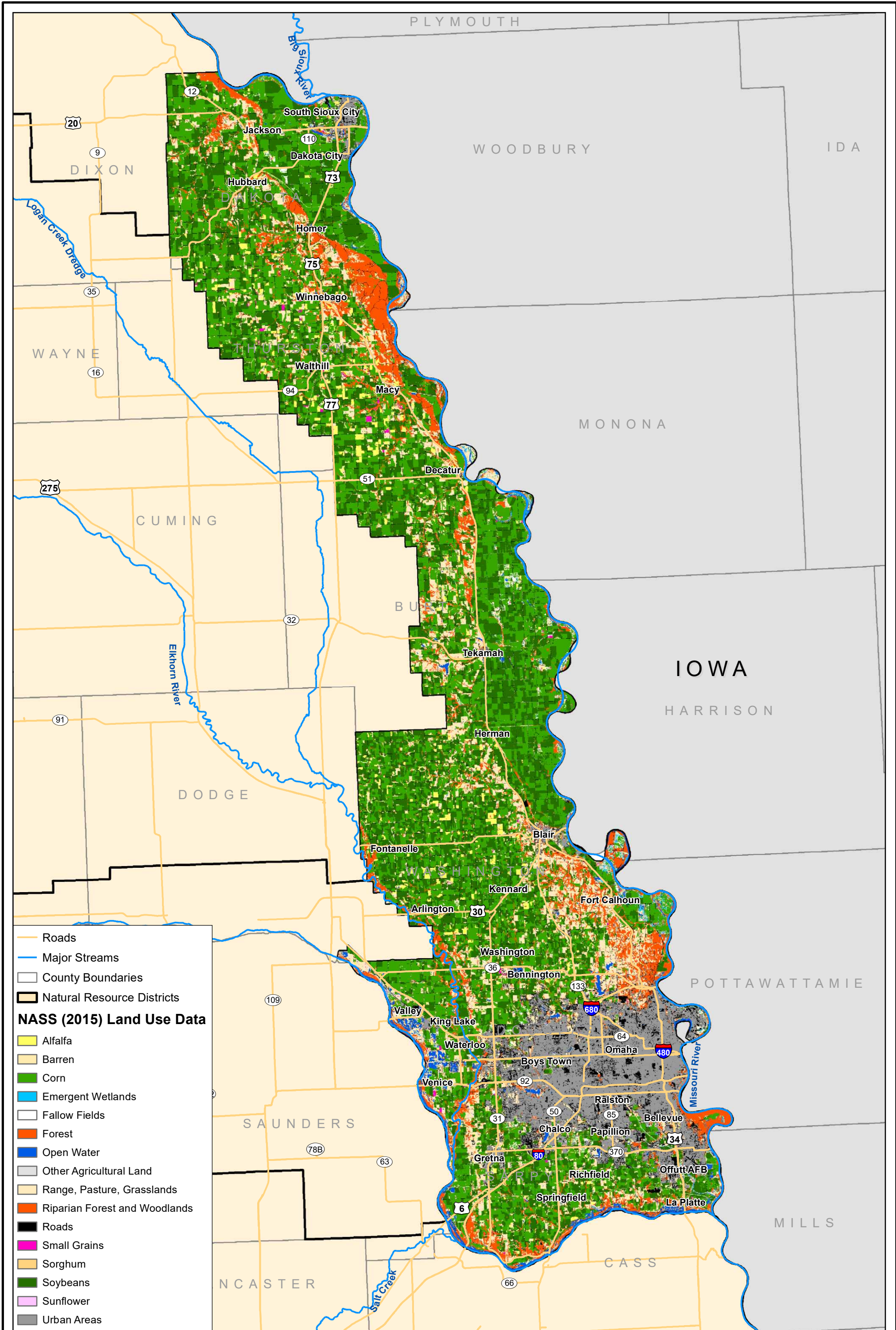
**ESTIMATED SOIL INFILTRATION RATES
 Pappio-Missouri River NRD**



MAP

11

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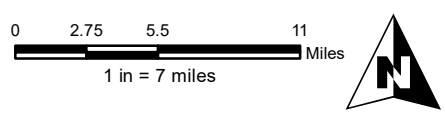
— Roads
 — Major Streams
 □ County Boundaries
 ■ Natural Resource Districts

NASS (2015) Land Use Data

- Alfalfa
- Barren
- Corn
- Emergent Wetlands
- Fallow Fields
- Forest
- Open Water
- Other Agricultural Land
- Range, Pasture, Grasslands
- Riparian Forest and Woodlands
- Roads
- Small Grains
- Sorghum
- Soybeans
- Sunflower
- Urban Areas

PROJECT: 015-3424 DATE: July 24, 2017 DRAWN BY: CBT

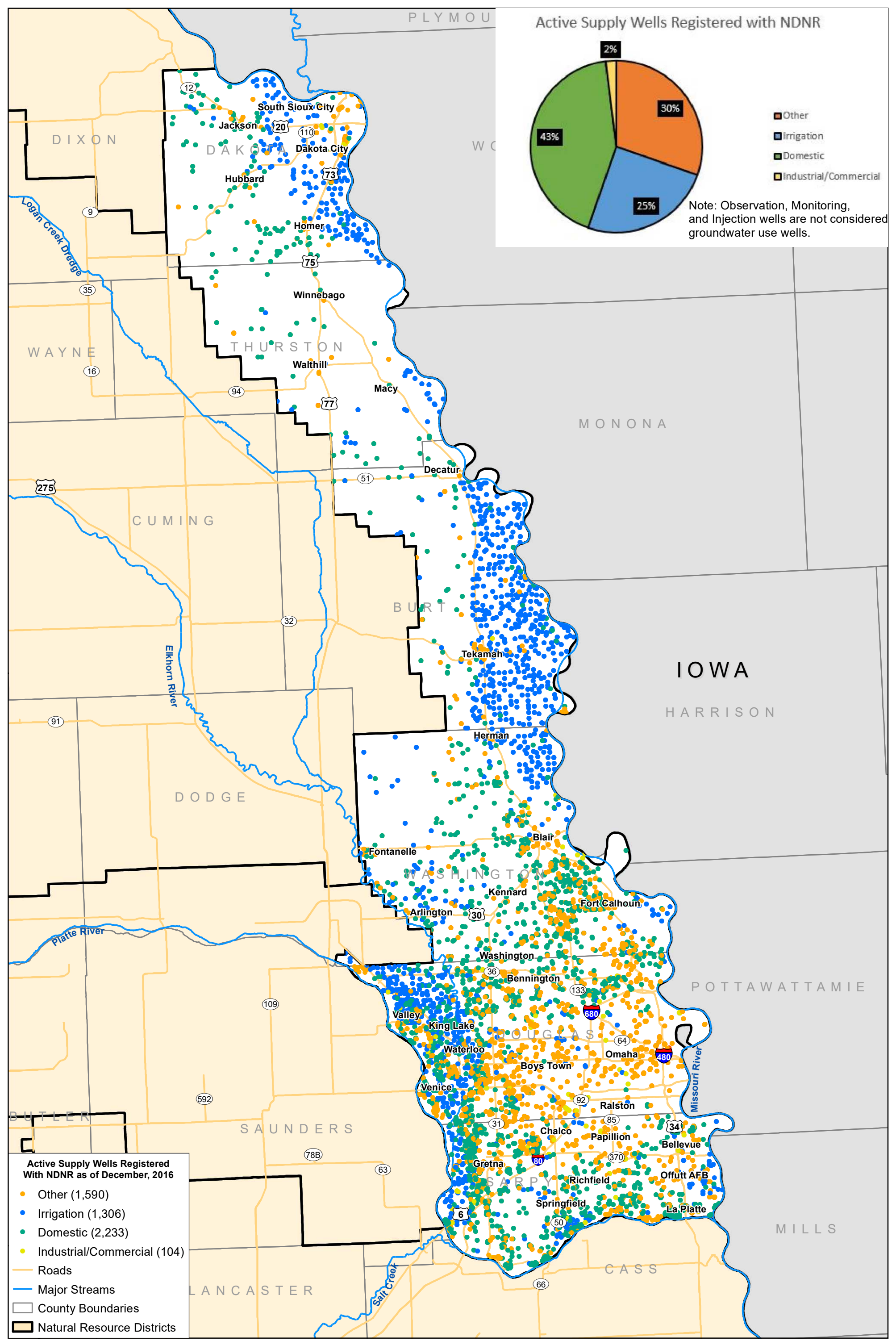
Sources:
 NDNR: NRD Boundaries
 USGS: National Hydrography Dataset
 U.S. Census Bureau: Roads, County Boundaries, Municipal Boundaries
 NASS (2015): Land Use Data



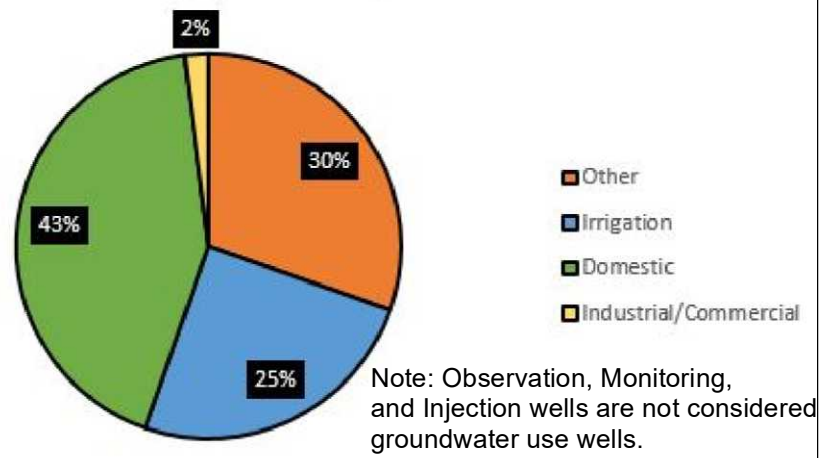
2015 NATIONAL AGRICULTURAL STATISTICS
 SERVICE (NASS) LAND USE DATA
 Papio-Missouri River NRD



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Active Supply Wells Registered with NDNR

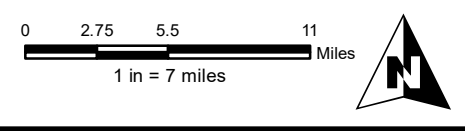


Active Supply Wells Registered With NDNR as of December, 2016

- Other (1,590)
- Irrigation (1,306)
- Domestic (2,233)
- Industrial/Commercial (104)

- Roads
- Major Streams
- County Boundaries
- Natural Resource Districts

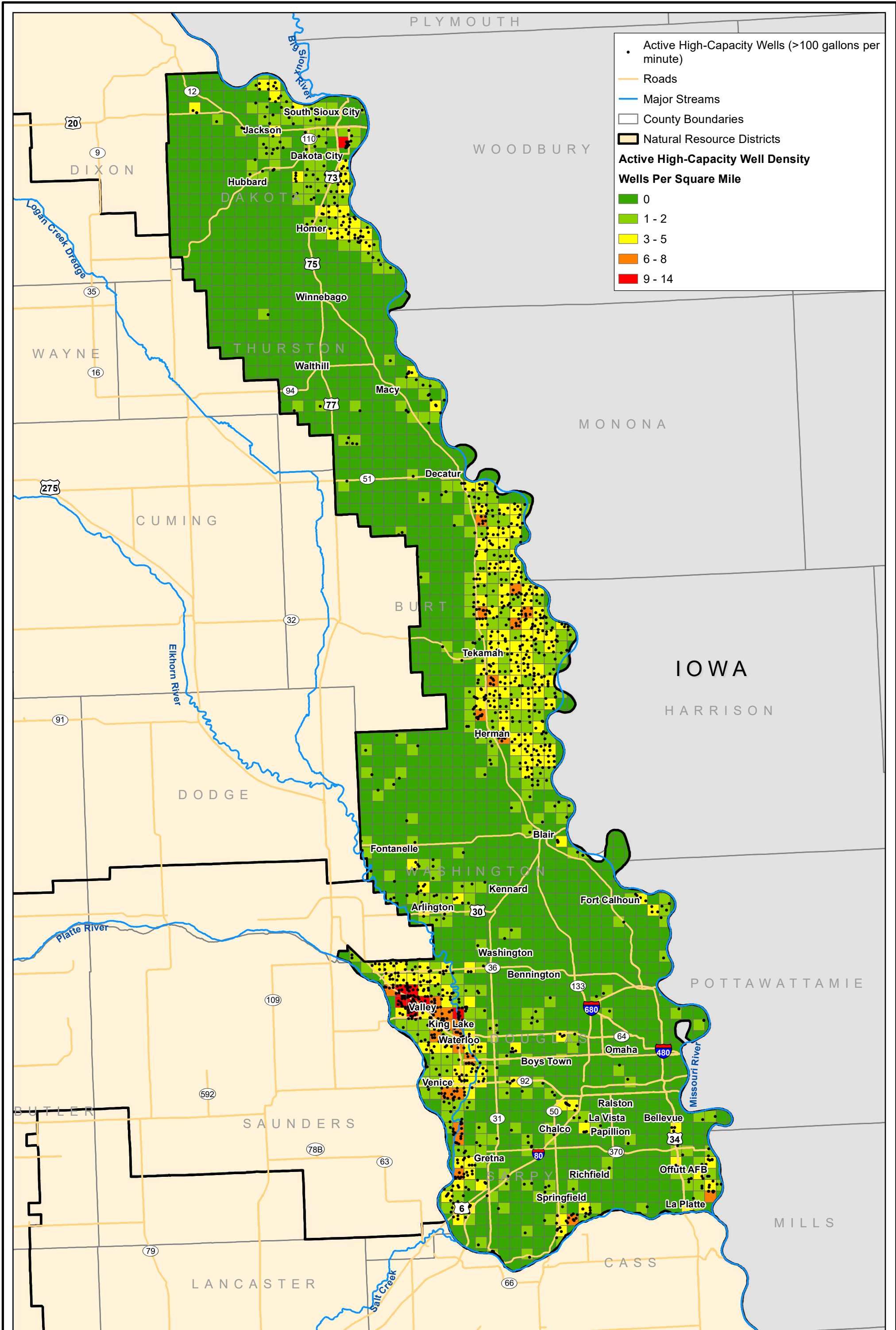
PROJECT: 015-3424 DATE: July 24, 2017 DRAWN BY: CBT
 Sources:
 NDNR: Registered Wells, NRD Boundaries
 USGS: National Hydrography Dataset
 U.S. Census Bureau: Roads, County Boundaries, Municipal Boundaries



CURRENT GROUNDWATER USERS
Papio-Missouri River NRD

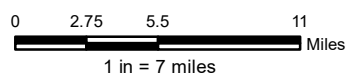


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PROJECT: 015-3424 DATE: July 24, 2017 DRAWN BY: CBT

Sources:
 NDNR: NRD Boundaries, Registered Wells
 USGS: National Hydrography Dataset
 U.S. Census Bureau: Roads, County Boundaries, Municipal Boundaries

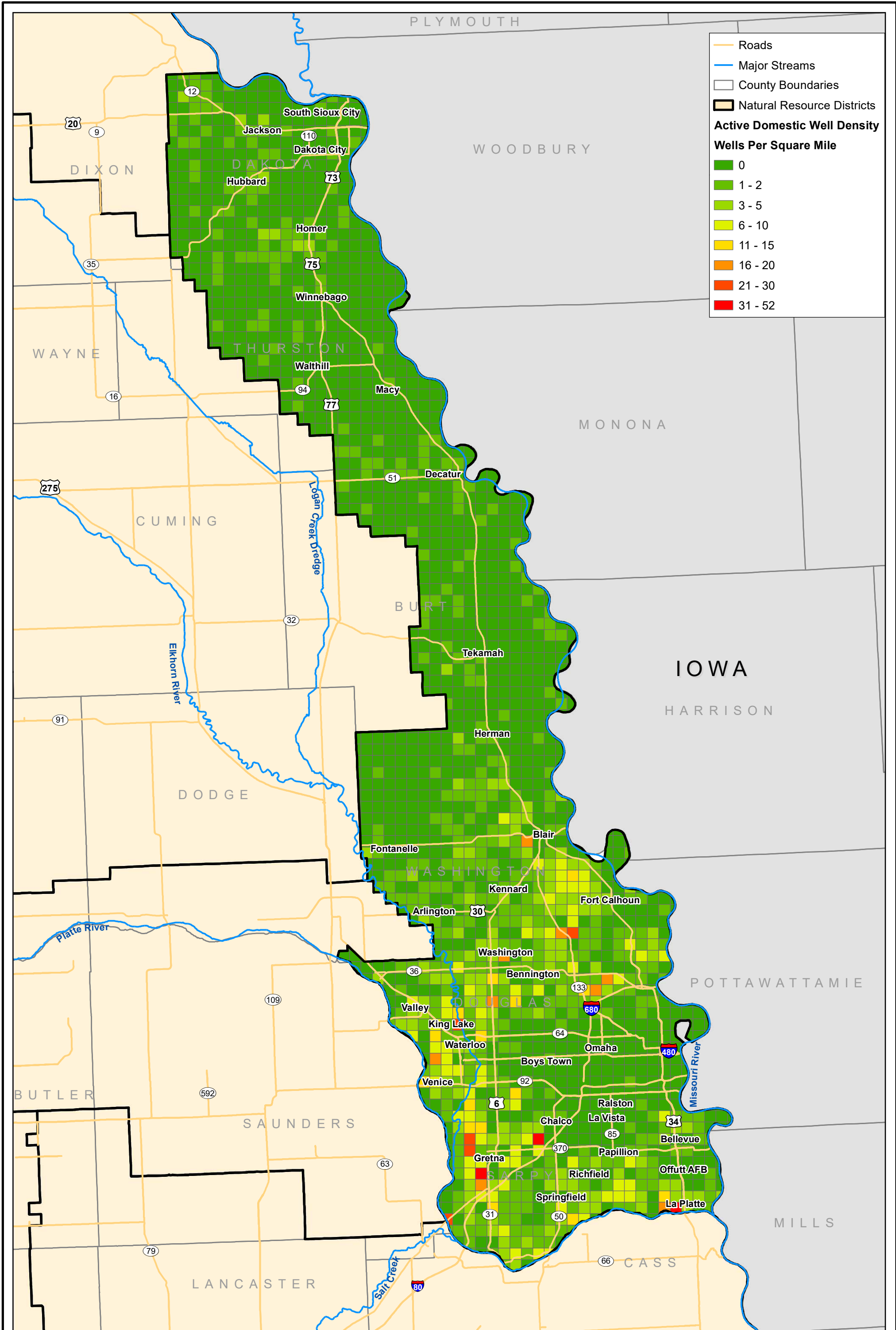


ACTIVE HIGH-CAPACITY WELL DENSITY
Papio-Missouri River NRD



MAP

14



PROJECT: 015-3424 DATE: July 24, 2017 DRAWN BY: CBT

Sources:
 NDNR: NRD Boundaries, Registered Wells
 USGS: National Hydrography Dataset
 U.S. Census Bureau: Roads, County Boundaries, Municipal Boundaries
 P-MRNRD: Public Supply Water Systems

0 2.75 5.5 11 Miles
1 in = 7 miles



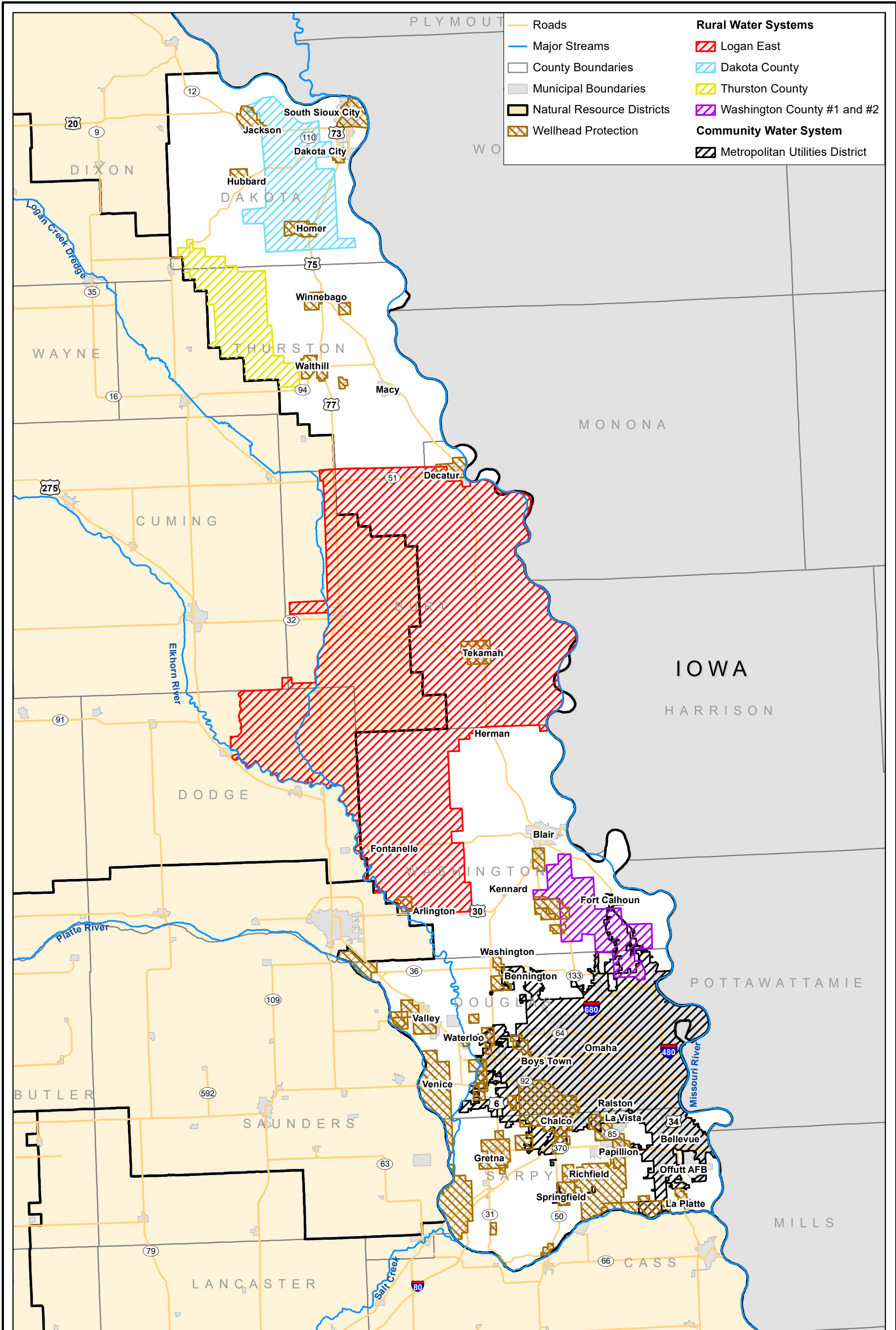
ACTIVE DOMESTIC WELL DENSITY
Papio-Missouri River NRD

OLSSON
 ASSOCIATES

MAP

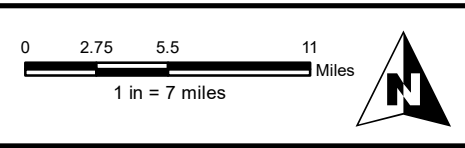
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PROJECT: 015-3424 DATE: July 24, 2017 DRAWN BY: CBT

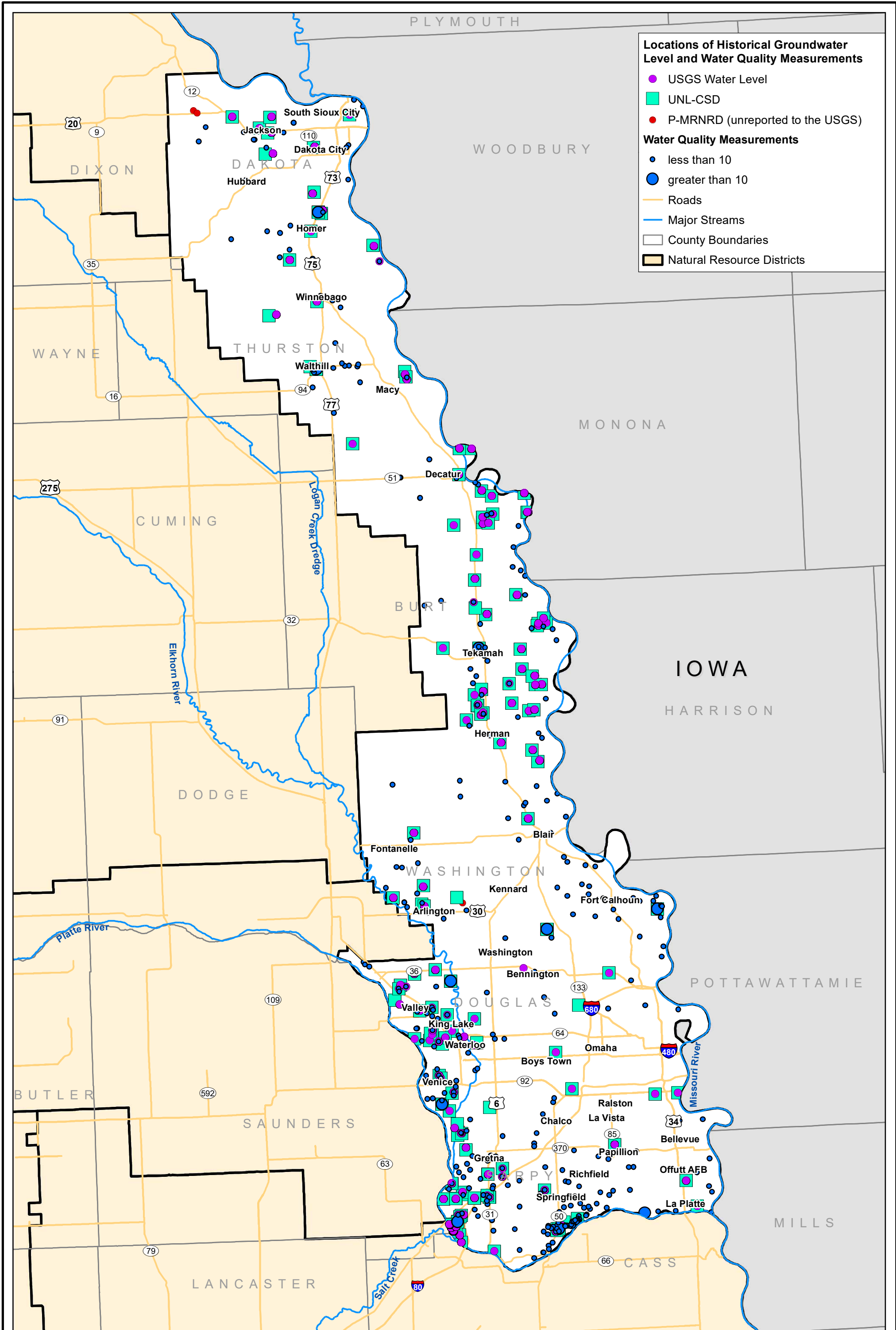
Sources: NDNR: NRD Boundaries, Public Supply Wells, P-MRNRD: Public Supply Water Systems, USGS: National Hydrography Dataset
 U.S. Census Bureau: Roads, County Boundaries, Municipal Boundaries
 DEQ: Well Head Protection Areas



WELLHEAD PROTECTION AREAS AND PUBLIC SUPPLY WATER SYSTEMS
Pappio-Missouri River NRD



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Locations of Historical Groundwater Level and Water Quality Measurements

- USGS Water Level
- UNL-CSD
- P-MRNRD (unreported to the USGS)

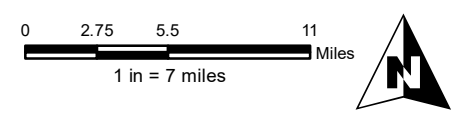
Water Quality Measurements

- less than 10
- greater than 10

— Roads
— Major Streams
 County Boundaries
 Natural Resource Districts

PROJECT: 015-3424 DATE: July 24, 2017 DRAWN BY: CBT

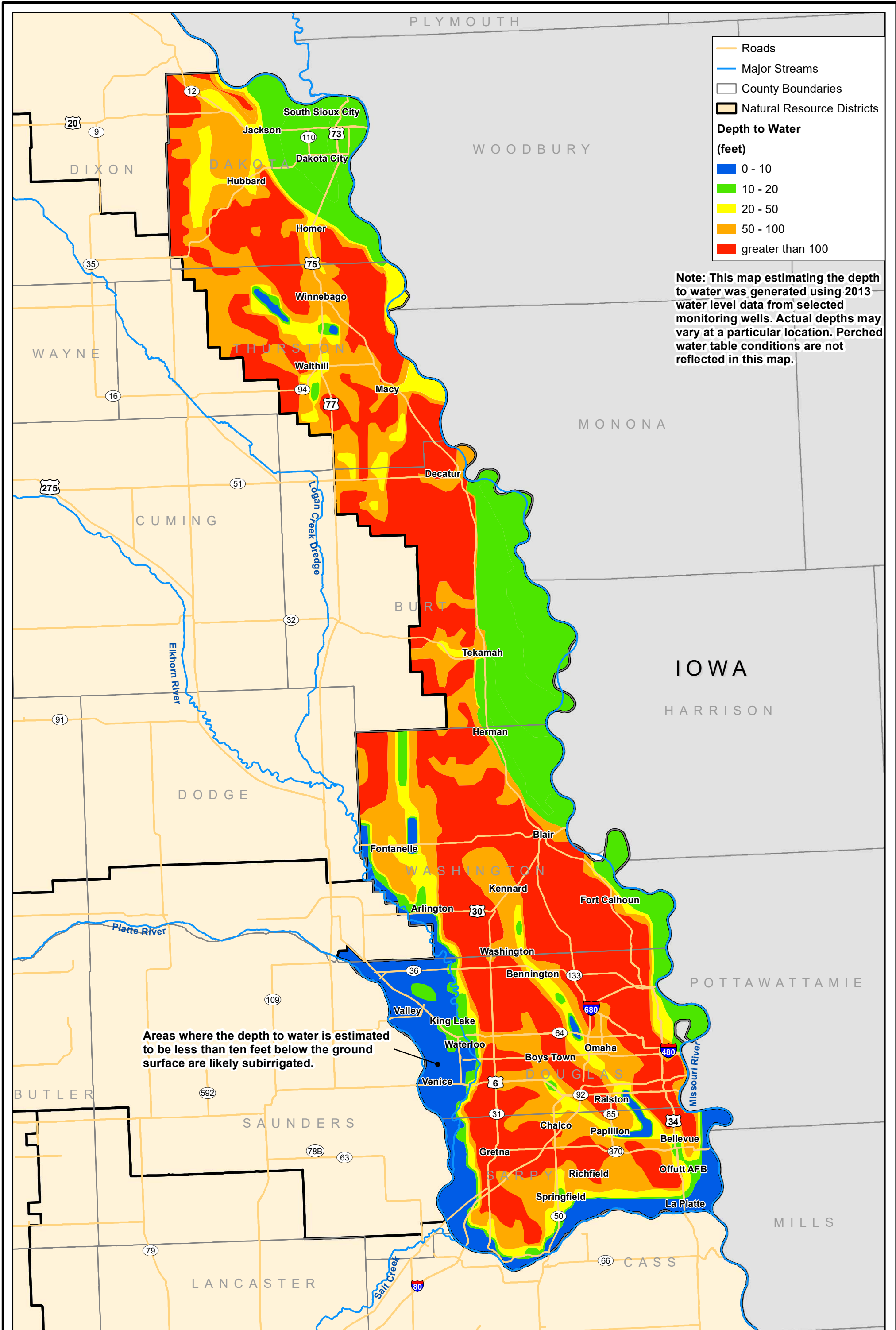
Sources:
 NDNR: NRD Boundaries; USGS: National Hydrography Dataset, Groundwater Level Measurements; P-MRNRD: Monitoring Wells
 U.S. Census Bureau: Roads, County Boundaries, Municipal Boundaries
 UNL-CSD: Statewide Groundwater Level Monitoring Program



GROUNDWATER MONITORING SITES
Pappio-Missouri River NRD



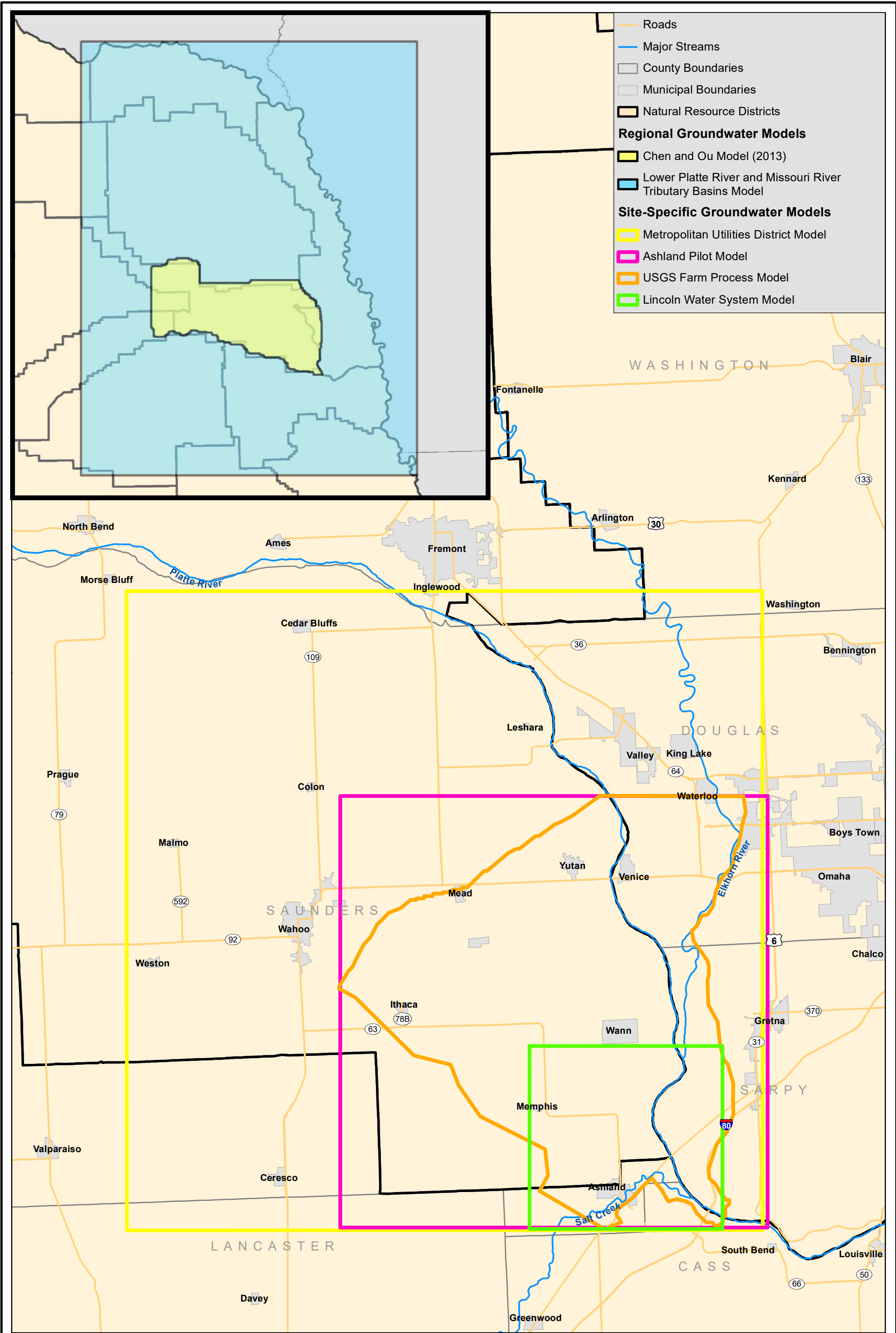
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Note: This map estimating the depth to water was generated using 2013 water level data from selected monitoring wells. Actual depths may vary at a particular location. Perched water table conditions are not reflected in this map.

Areas where the depth to water is estimated to be less than ten feet below the ground surface are likely subirrigated.

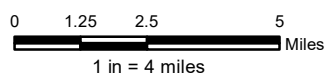




- Roads
- Major Streams
- County Boundaries
- Municipal Boundaries
- Natural Resource Districts
- Regional Groundwater Models**
- Chen and Ou Model (2013)
- Lower Platte River and Missouri River Tributary Basins Model
- Site-Specific Groundwater Models**
- Metropolitan Utilities District Model
- Ashland Pilot Model
- USGS Farm Process Model
- Lincoln Water System Model

PROJECT: 015-3424 DATE: July 24, 2017 DRAWN BY: CBT

Sources: NDNr: NRD Boundaries, Lower Platte/Missouri River Trib. Model; USGS: NHD, Farm Process Model; P-MRNRD: MUD and LWS Models
 U.S. Census Bureau: Roads, County Boundaries, Municipal Boundaries
 Chen and Ou (2013): LPNMRD Model; ENWRA: Ashland Pilot Model



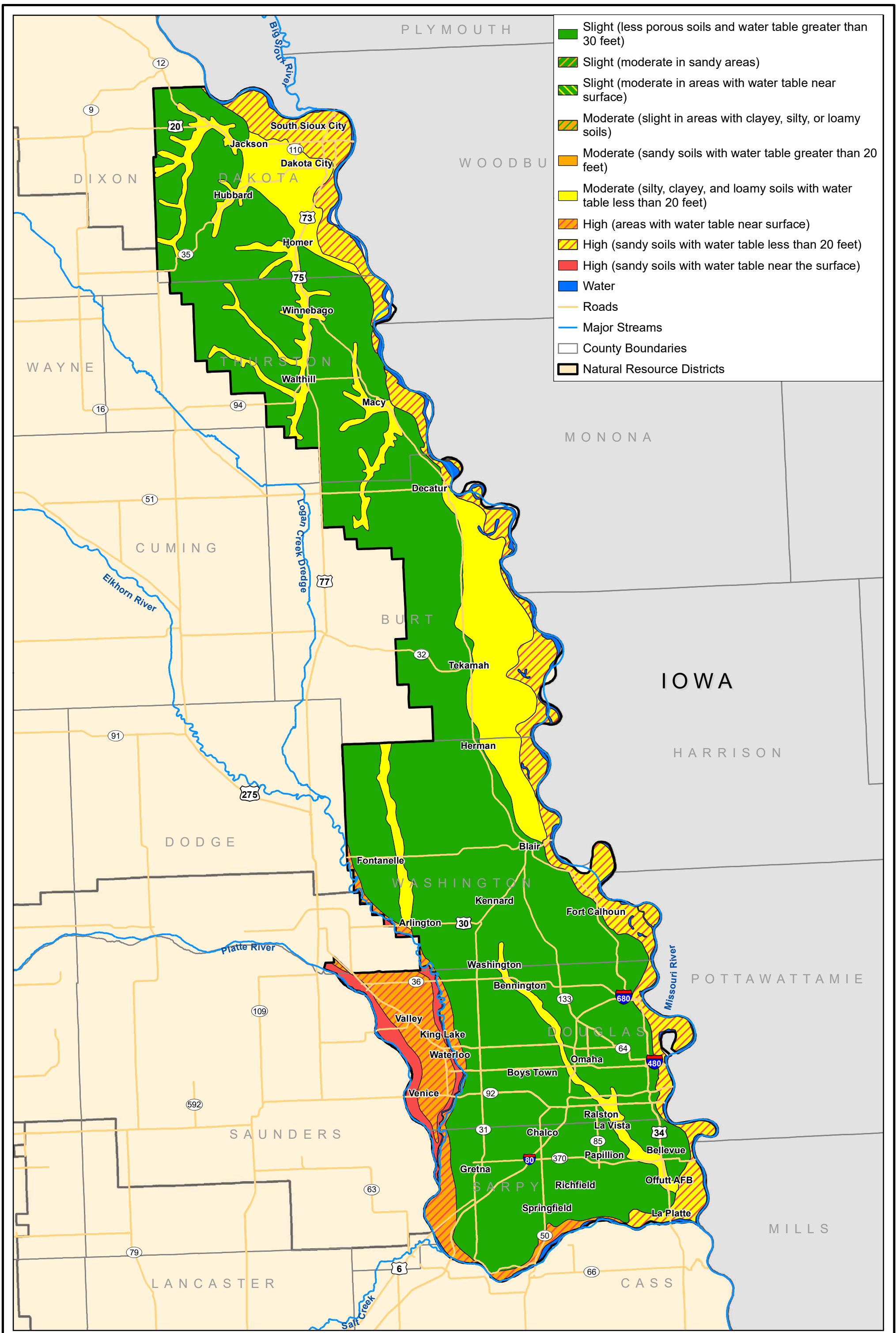
CURRENT GROUNDWATER MODEL AREAS
Papio-Missouri River NRD



MAP

19

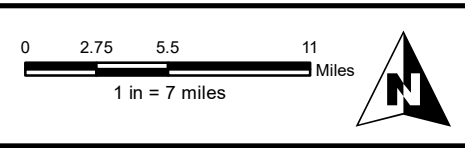
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- Slight (less porous soils and water table greater than 30 feet)
- Slight (moderate in sandy areas)
- Slight (moderate in areas with water table near surface)
- Moderate (slight in areas with clayey, silty, or loamy soils)
- Moderate (sandy soils with water table greater than 20 feet)
- Moderate (silty, clayey, and loamy soils with water table less than 20 feet)
- High (areas with water table near surface)
- High (sandy soils with water table less than 20 feet)
- High (sandy soils with water table near the surface)
- Water
- Roads
- Major Streams
- County Boundaries
- Natural Resource Districts

PROJECT: 015-3424 DATE: July 24, 2017 DRAWN BY: CBT

Sources:
 NDNR: NRD Boundaries
 USGS: National Hydrography Dataset
 U.S. Census Bureau: Roads, County Boundaries, Municipal Boundaries
 NDEQ: Groundwater Vulnerability

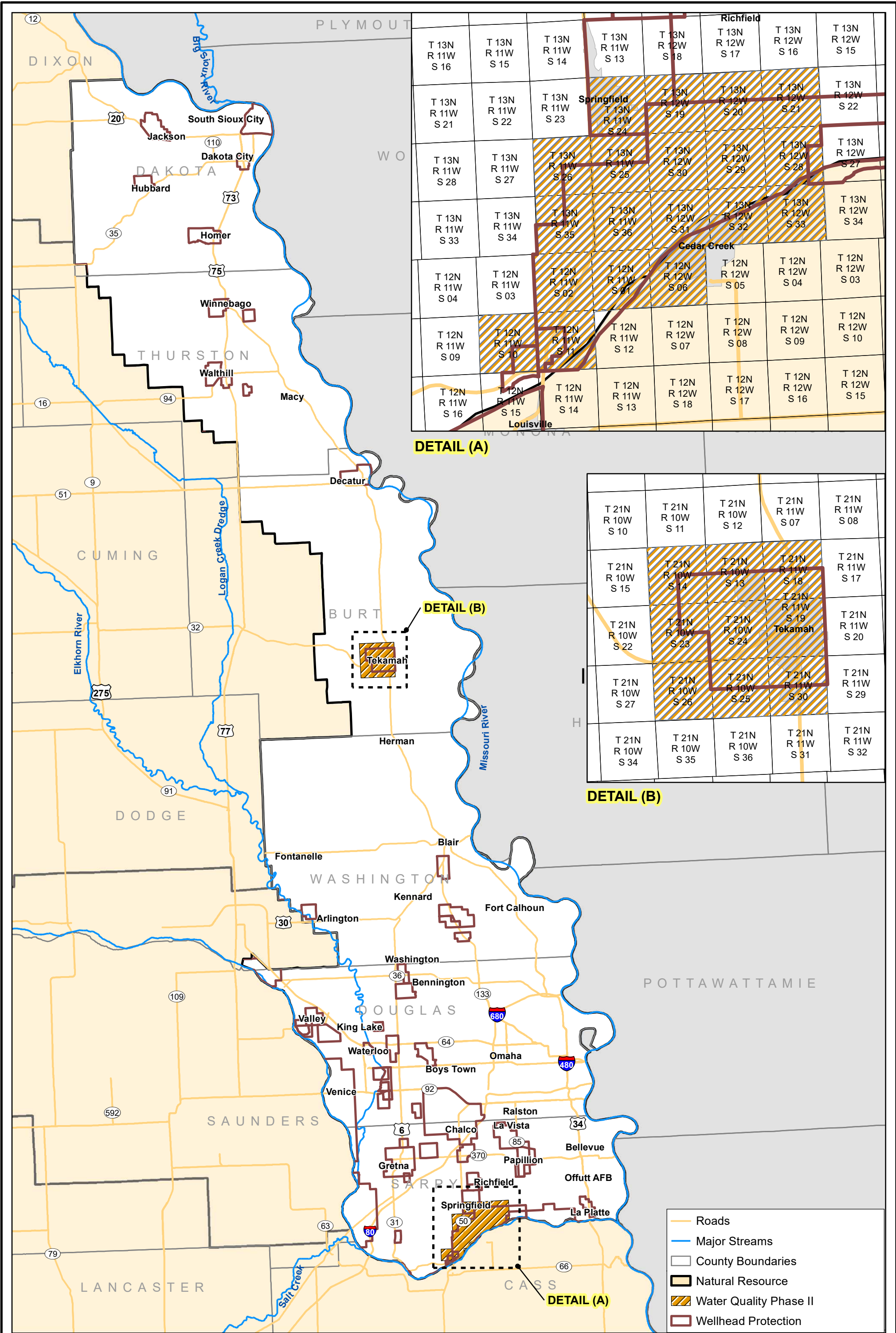


GROUNDWATER VULNERABILITY
Papio-Missouri River NRD

MAP

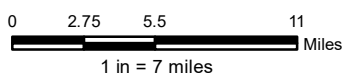
20

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PROJECT: 015-3424 DATE: July 24, 2017 DRAWN BY: CBT

Sources:
 NDNR: NRD Boundaries, Registered Wells
 USGS: National Hydrography Dataset
 U.S. Census Bureau: Roads, County Boundaries, Municipal Boundaries
 HPRCC: Weather Stations; NCDC: Weather Stations



**PROPOSED PHASE II
 GROUNDWATER MANAGEMENT AREAS
 Pappio-Missouri River NRD**



MAP

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