4. Pollutant Sources

The following section describes the methodologies used to determine the source and magnitude of pollutant loading from the watershed. The source assessment focuses on flow (as a critical component to load determination – see water quality discussion for further information), nitrogen, phosphorus, sediment and bacteria. The methodology for determining the magnitude of loading for flow, nitrogen, phosphorus and sediment was to construct a Soil and Water Assessment Tool (SWAT) Model whereas the methodology for determining the source of bacteria (*E. coli*) was based on estimates of various source types (animals, humans), bacteria production rates and delivery factors.

4.1. SWAT Modeling

The amount of flow and water quality pollutants in a river at any given point in time is a result of a complex set of processes occurring within its upstream watershed. The extents of rainfall and evaporation in both the short term (days) and longer-term (weeks, months) are the primary factors in river flow and water quality patterns. The degree to which soils allow rainfall to soak into the soil and enter the nearest stream via shallow groundwater or drain tile vs. runoff across the land surface is also extremely important.

The proportion of surface runoff vs. groundwater flow greatly influences river water quality in terms of pollutants such as nitrogen, phosphorus and sediment. In the Squaw Creek watershed, because of the nature of the soils and flat, prairie pothole topography, sediment enter rivers via surface runoff while phosphorus and nitrogen are transported to rivers in both surface runoff and drain tile (and/or groundwater flow). Land management such as agricultural cropping and tillage practices as well as urban stormwater practices also affects the nature of flow and pollutants.

To better understand the distribution of flow, nitrogen, phosphorus and sediment sources in the Squaw Creek watershed a hydrologic and water quality model was built using the SWAT modeling framework. SWAT's primary strength is simulation of watershed flow and pollutant loading in agricultural watersheds. Results from the model were critical in targeting and prioritizing source areas for improving water quality downstream. The goal of the modeling phase was to generate a map of small watersheds (<1000 acres) identifying where the most significant pollutant sources were predicted to exist. These "hotspot" subwatersheds would then serve as priority areas to explore reduction strategies by implementing best management practices (BMPs).

The model was used to simulate average annual flow and water quality (nitrate, total phosphorus, sediment) for the period 1994-2010 (i.e., 17-year annual averages). Data required to set up and run the model focused on properties and processes in the watershed that are the primary drivers of flow and water quality: rainfall and evaporation, soils, land cover and management practices, and topography. A summary of data sources is presented in Table 4-1.

Table 4-1. Data sources used by the SWAT watershed model

Required Model Data	Source
Precipitation	2 NWS COOP stations and gridded weather data
Evaporation	Temperature, wind speed, dew point, solar radiation from gridded weather data
Soils	SSURGO high resolution data (digital county soil survey)
Land Cover	Field/Parcel scale data of crop rotations, non-ag land uses
Management practices Timing, tillage, fert. Feedlots and manure Drain tile	TAC and local agricultural professionals Iowa DNR maps of feedlots, manure applied areas Public ditch and tile maps; advice from local drain tile professionals
Topography	Hydro-corrected LiDAR digital elevation data

The model was calibrated for flow and nutrient concentrations found at the USGS gaging station in Ames. Calibration is process whereby simulated model data is compared with observed data to evaluate its predictive capability. Model parameters are then adjusted until the model matches the observed data to an acceptable level. In this case, continuous daily flow data measured at the Squaw Creek USGS gauging station in Ames was used to calibrate flow. Nutrient calibration was done through a comparison to annual mean concentrations at the same monitoring station. The model was less rigorously calibrated than is the case with models designed for more intensive uses such TMDL projects. This model was deemed calibrated when reasonable confidence of the model's ability to determine the *relative* distribution of flow and pollutants was reached.

4.1.1. **Priority Source Areas: Volume, Sediment, Phosphorus, Nitrate**

Model results for flow are presented in Figure 4-1. Note that areas of higher flow in the watershed are driven by agricultural tile drainage which drains a higher fraction of infiltrated rainfall to streams than un-tiled land. This is the reason that agricultural land is predicted to have higher flows than urban and residential Ames area. Model results for nitrate are presented in Figure 4-2. Note that areas of higher nitrate are primary a function of drain tile and corn rotations. This combination of practices is predicted to have the highest export of nitrate. Model results for phosphorus are presented in Figure 4-3 and results for sediment are presented in Figure 4-4. Note that areas of higher total phosphorus and sediment are driven by higher slope agricultural areas that are more susceptible to soil erosion. Since soil binds to applied phosphorus fertilizer and manure, sediment and phosphorus export are very interrelated. Additional areas with high phosphorus loading occur in the developed portion of the watershed. The range of values associated with the rankings is found in Table 4-2.

Table 4-2 Range of Values for Low/Medium/High Ranking for Figures

Constituent	Low Range	Medium Range	High Range
Sediment – tons/acre	< 0.12	0.12 – 0.21	> 0.21
Total Phosphorus – lb/acre	< 0.50	0.50 – 0.77	> 0.77
Flow – inches/year	< 9.0	9.0 – 9.6	> 9.6
Nitrate lb/acre	< 15.4	15.4 – 32.0	> 32.0

Four key general conclusions from the SWAT modeling were:

- Corn and soybean agriculture are estimated to contribute 97% of the nitrogen and 92% of the phosphorus loading in the Squaw Creek watershed.
- Tile drained land (which is estimated to comprise 70% of the total agricultural area) is estimated to contribute 86% of the total nitrogen loading in the Squaw Creek watershed.
- Approximately 33% of the total agricultural N and P loads are estimated to originate from 20% of the agricultural land.
- Urban areas are estimated to contribute roughly equivalent amounts of phosphorus per acre compared to corn and soybean agriculture; given urban landuse comprises about 5% of the total land area, it contributes about 5% of the total watershed P loading.

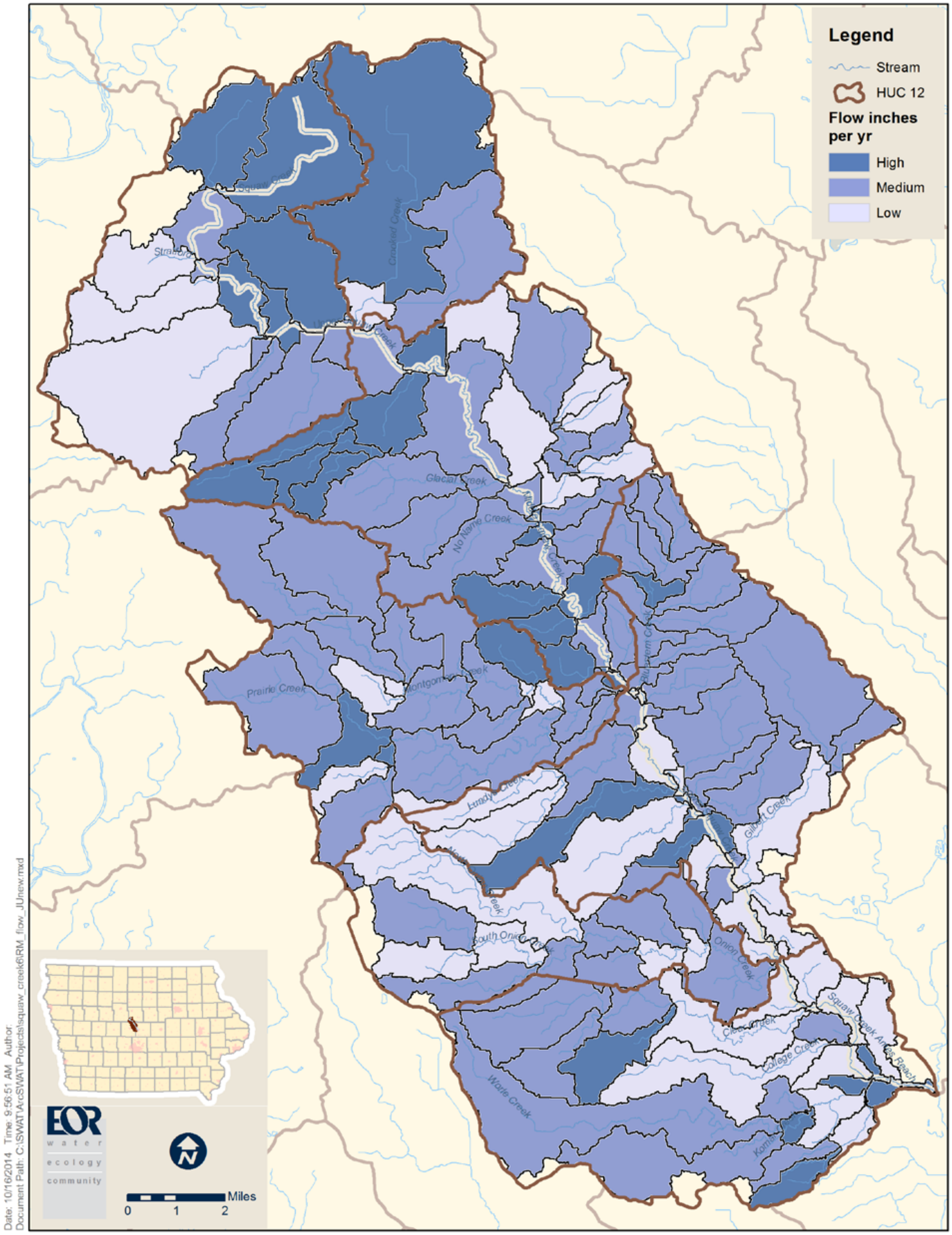


Figure 4-1. SWAT Model Flow by Drainage Area (inches/year)

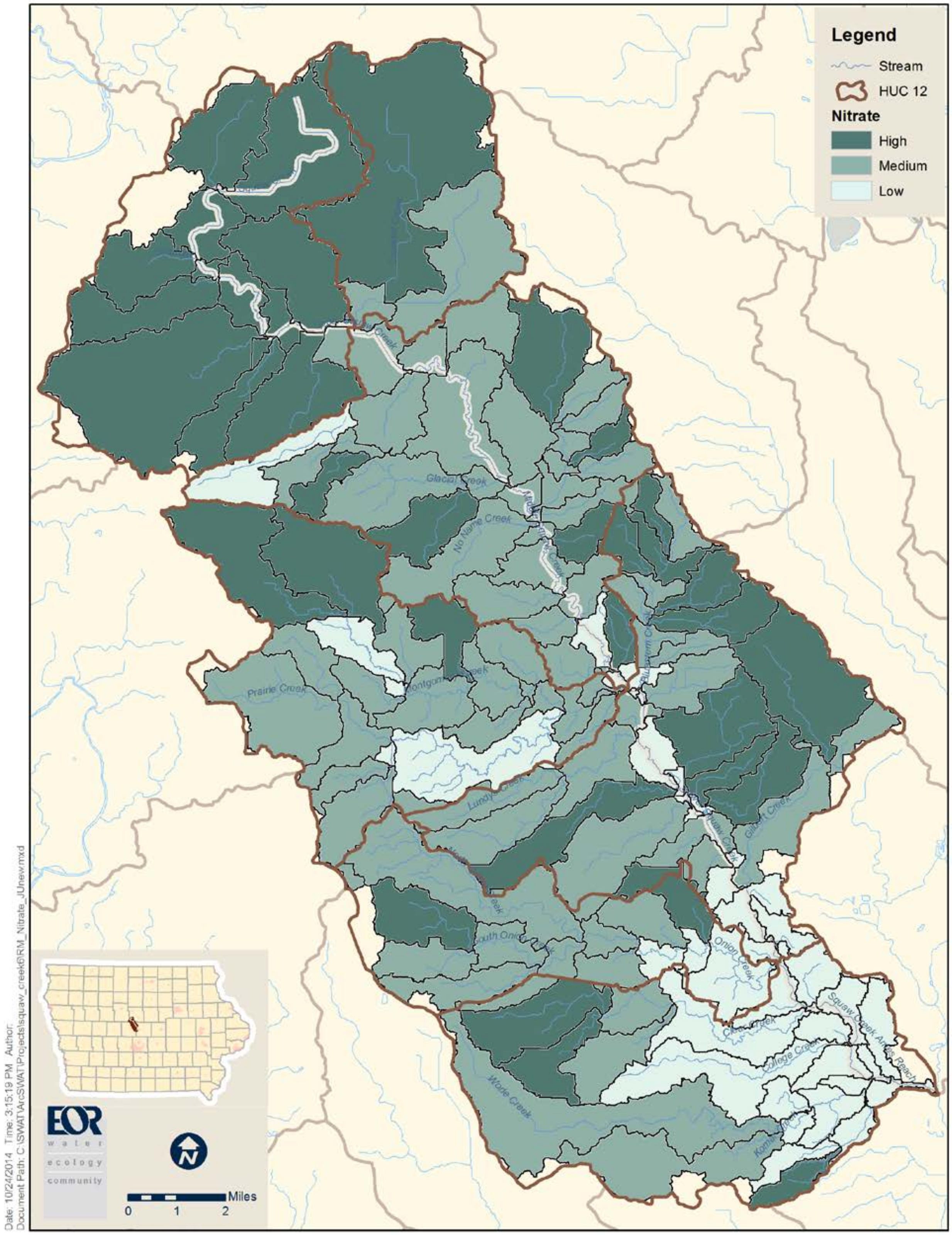


Figure 4-2. SWAT Model Nitrate Load by Drainage Area (lbs/acre per year)

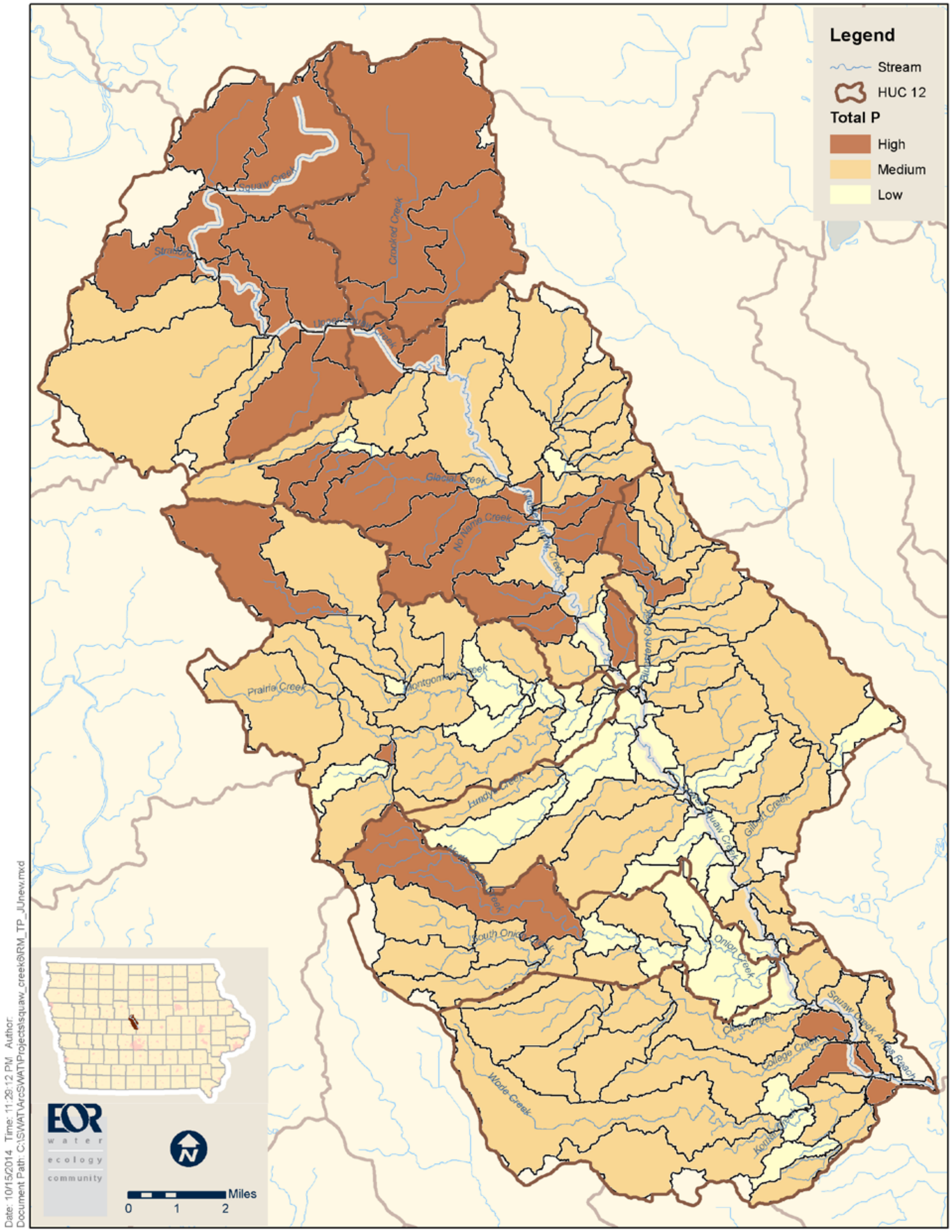


Figure 4-3. SWAT Model Phosphorus Load by Drainage Area (lbs/acre per year)

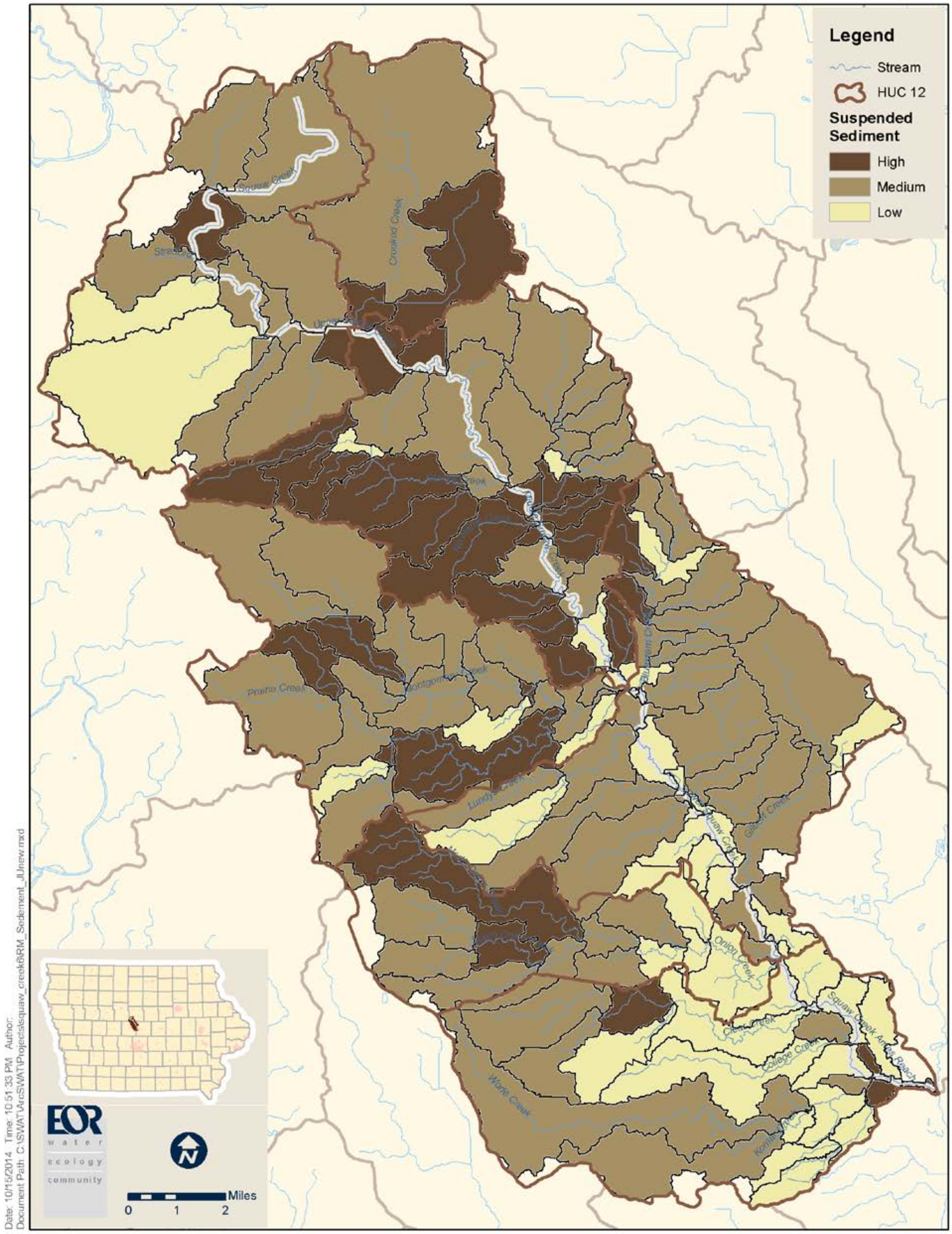


Figure 4-4. SWAT Model Sediment Load by Drainage Area (tons/acre per year)

4.2. Bacteria Source Assessment

Humans, pets, livestock, and wildlife all contribute bacteria to the environment. These bacteria, after appearing in animal waste, are dispersed throughout the environment by an array of natural and man-made mechanisms. Bacteria fate and transport is affected by disposal and treatment mechanisms, methods of manure reuse, imperviousness of land surfaces, and natural decay and die-off due to environmental factors such as ultraviolet (UV) exposure and detention time in the landscape. The following discussion highlights sources of bacteria in the environment and mechanisms that drive the delivery of bacteria to surface waters.

To evaluate the potential sources of bacteria to surface waters and to assist in targeting future reduction strategies, a desktop analysis was conducted for sources that are potentially contributing *E. coli* in the watershed. These populations may include livestock (cattle, swine or poultry), humans and wildlife (deer).

Populations were calculated using published estimates for each source on an individual subwatershed basis in the Squaw Creek Watershed. This is typically a GIS exercise where population estimates are clipped to the individual subwatershed boundaries.

Bacteria production estimates are based on the bacteria content in feces and an average excretion rate (with units of colony forming units (cfu)/day-head; where *head* implies an individual animal). Bacteria content and excretion rates vary by animal type, as shown in Table 4-3. All production rates obtained from the literature are for fecal coliform rather than *E. coli* due to the lack of *E. coli* data. The fecal coliform production rates were converted to *E. coli* production rates based on 200 fecal coliforms to 126 *E. coli* per 100 mL.

Table 4-3. Bacteria production by source

Source Category	Producer	*E. coli* Production Rate [cfu/day-head]	Literature Source
Humans	Humans	1.26 x 109	Metcalf and Eddy 1991
Companion Animals	Dogs	3.15 x 109	Horsley and Witten 1996
Livestock	Cattle	2.08 x 1010	Zeckoski et al. 2005
	Hogs	6.93 x 109	Zeckoski et al. 2005
	Poultry	6.76 x 107	Zeckoski et al. 2005
Wildlife	Deer	2.21 x 108	Zeckoski et al. 2005

4.2.1. **Humans**

Human sources are divided by whether the waste is collected and sent to a Waste Water Treatment Facility (WWTF) or if it is treated by an individual system.

Waste Water Treatment Facilities

The WWTFs located in the Squaw Creek Watershed with surface water discharges are summarized in Table 4-4. Bacteria loads from NPDES-permitted WWTFs was estimated based on the design flow and permitted bacteria effluent limit of 126 org/ 100 mL (Table 4-4). Note that while a large portion of the City of Ames is in the watershed the discharge location of the waste water treatment facility is into the South Skunk River rather than Squaw Creek so it is not included here. Issues related to the maintenance and potential breaks of the waste water collection system would still have an impact on Squaw Creek but those sources are not accounted for in this methodology since known issues have been addressed in the past and the City and volunteers actively monitor the system for failures and address them when found.

Table 4-4. WWTP design flows and permitted bacteria loads

Subbasin	Name of WWTF	Permit #	Design Flow [mgd]	Equivalent Bacteria Load as *E. coli*: (billion org/day)
Crooked Creek	Stanhope STP	4045001	0.085	0.405
Lundys Creek – Squaw Creek	Gilbert STP	8531001	0.125	0.596
	South Squaw Valley	8500302	0.020	0.095
Worle Creek – Squaw Creek	United Community School	0800500	0.0037	0.018

Individual Septic Systems

Unsewered populations were determined using the 2010 Census data (U.S. Census Bureau 2011). Total unsewered population was obtained for each subwatershed using block groups; census block groups that overlap subwatershed boundaries were distributed between each applicable subwatershed on an area-weighted basis. Only rural populations were assumed to be unsewered. So, block groups that fell within the city limits of Ames, Stanhope, Gilbert, and Stratford were not included. It was assumed that subsurface sewage treatment systems (SSTS) were installed to treat raw sewage from this rural population. "Failing" SSTS are specifically defined as systems that are failing to protect groundwater from contamination. Failing SSTS were not considered a source of fecal pollution to surface water. However, systems which discharge partially treated sewage to the ground surface, road ditches, tile lines, and directly into streams, rivers and lakes are considered an imminent threat to public health and safety (ITPHS). ITPHS systems also include illicit discharges from unsewered communities (sometimes called "straight-pipes"). Straight pipes are illegal and pose an imminent threat to public health as they convey raw sewage from homes and businesses directly to surface water. Community straight pipes are more commonly found in small rural communities. The number and specific location of ITPHS are unknown for the watershed so two thresholds were used so that the relative contribution from ITPHS to the total load of bacteria in the watershed could be determined Table 4-5. This table is not intended to suggest that ITPHS systems contribute excess bacteria to Squaw Creek.

Table 4-5. Estimates of rural population based on 2010 Census data and ITPHS population in each subwatershed

Subwatershed	Estimated Rural Population	ITPHS Load 10% Failure Rate (billion org/day)	ITPHS Load 50% Failure Rate (billion org/day)
Crooked Creek	189	23.8	119.1
Drainage Ditch 192 – Squaw Creek	346	43.6	218.0
Montgomery Creek	504	63.5	317.5
Crooked Creek – Squaw Creek	495	62.4	311.9
Onion Creek	639	80.5	402.6
Lundys Creek – Squaw Creek	1,205	151.8	759.2
Worle Creek – Squaw Creek	777	97.9	489.5

4.2.2. **Livestock**

The total number of livestock in each subwatershed was estimated by the Iowa DNR animal feeding operation (AFO) database and the 2012 USDA Agricultural Census county data. The DNR AFO database is current to 2014 and the registered number of animals is known. AFO's with less than 500 animal units (AU) are not required to register with the Iowa DNR or obtain a manure management plan. Therefore, in order to estimate the number of unregistered animals in the watershed, data from the 2012 USDA Agricultural Census was used and then area-weighted to each subwatershed.

Table 4-6. Livestock summary results by subwatershed in animal units

	Registered		Estimated Unregistered		
Subwatershed	Pigs (billion org/day)	Cows (billion org/day)	Pigs (billion org/day)	Cows (billion org/day)	Poultry (billion org/day)
Drainage Ditch 192 – Squaw Creek	26,805	0	310	3,296	0.29
Crooked Creek	84,906	0	633	7,811	0.60
Crooked Creek – Squaw Creek	51,656	30,146	337	11,670	0.73
Montgomery Creek	4,990	0	513	12,105	0.82
Lundys Creek – Squaw Creek	6,071	0	302	6,615	0.40
Onion Creek	16,632	0	1,213	13,075	0.75
Worle Creek – Squaw Creek	12,058	17,048	468	7,956	0.48

4.2.3. **Wildlife**

Bacteria can be contributed to surface water by wildlife (e.g. raccoons, deer, geese, and ducks) dwelling in waterbodies, within conveyances to waterbodies, or when their waste is carried to stormwater inlets, creeks, and ditches during stormwater runoff events.

No reliable wildlife population estimates were available besides for annual deer estimates by county. Therefore, only deer were included in wildlife as a source. Surveys conducted by the DNR from 2007 through 2012 were used to calculate an average deer population by county and then area-weighted to each subwatershed. Based on previous assessment deer represent approximately one half of the wildlife *E. coli* contribution. Table 4-7 summarizes the estimate contribution from deer based on DNR survey and the resultant estimate for all wildlife by subwatershed.

Table 4-7. Deer bacteria estimates by subwatershed

Subwatershed	Deer *E. coli* (billion org/day)	Wildlife *E. coli* (billion org/day)
Drainage Ditch 192 – Squaw Creek	8.3	16.6
Crooked Creek	21.3	42.6
Crooked Creek – Squaw Creek	39.5	79
Montgomery Creek	38.4	76.8
Lundys Creek – Squaw Creek	21.9	43.8
Onion Creek	39.6	79.2
Worle Creek – Squaw Creek	34.3	68.6

4.2.4. **Pets**

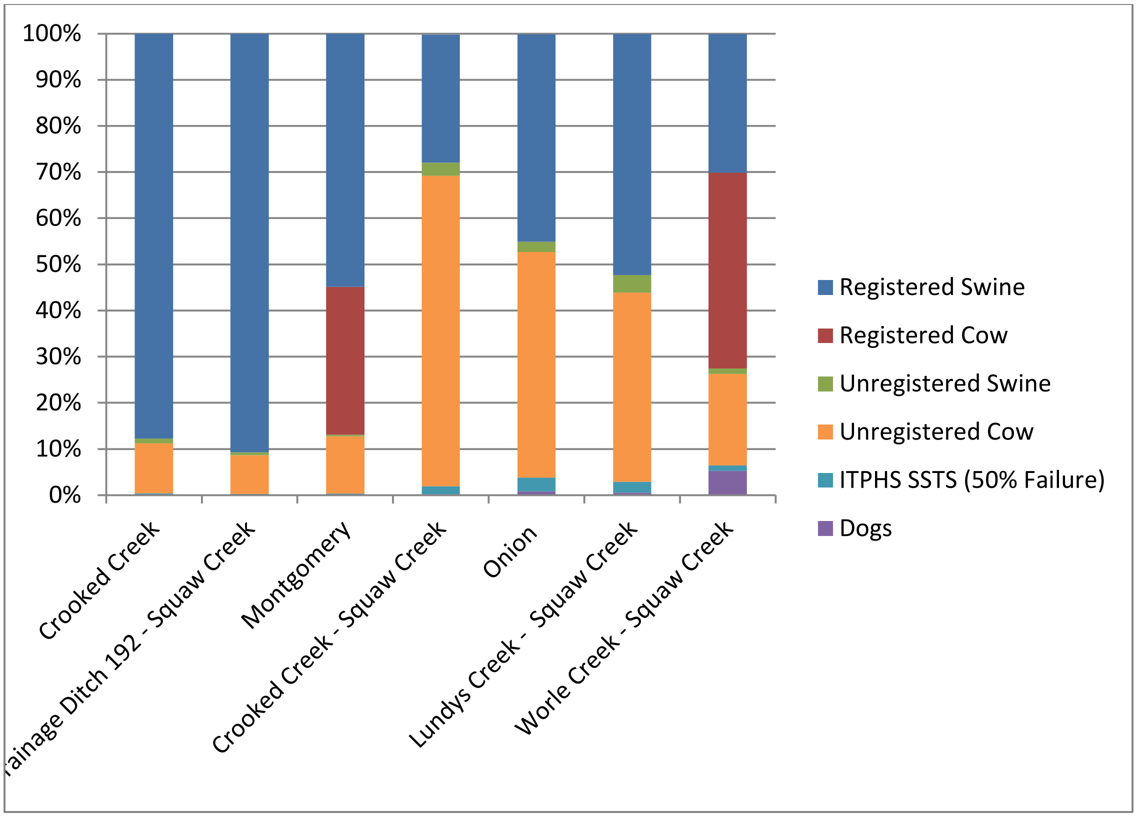
Pets (dogs and cats) can contribute bacteria to a watershed when their waste is not properly managed. When this occurs, bacteria can be introduced to waterways. The contribution of pet waste to waterbodies is more pronounce in urban areas where impervious surfaces and storm sewer network allow waste to easily wash off into streams. It is less significant in rural areas where the waste is typically trapped on the landscape. Pet populations within the watershed were estimated using American Veterinary Association estimates of dogs and cats per household and Tiger block census data. An adjustment factor was applied to impervious surfaces.

Table 4-8 Pet bacteria estimates by subwatershed

Subwatershed	Pets *E. coli* (billion org/day)
Drainage Ditch 192 – Squaw Creek	15
Crooked Creek	52
Crooked Creek – Squaw Creek	29
Montgomery Creek	36
Lundys Creek – Squaw Creek	108
Onion Creek	167
Worle Creek – Squaw Creek	2109

4.2.5. **Priority Bacteria Source Areas**

The source assessment information is summarized by subwatershed in Figure 4-5 with the relative abundance of each source shown. Note, again, that these numbers refer to the production of bacteria from each source based on the estimated populations within the watershed as described above. There is no direct correlation from any of these sources to the bacteria concentrations that are found in the stream. The assessment is provided to show what the likely sources are so that efforts can be prioritized. The locational information developed in estimating the livestock numbers is provided in Figure 4-6 as a way of identifying potential hot spots for bacteria. Further prioritization is provided in Figure 4-7 where areas of likely high bacteria production are intersected with the streams. The priority areas indicate where manure could potentially be applied within 1000 ft of a stream based on the assessment methodology conducted. Note that there is NO evidence to suggest that manure is actually being applied near the streams in any of these areas.



*Note that WWTP, unregistered poultry estimates, and wildlife are not shown because they contribute <1% of the total bacteria load in each subwatershed.

Figure 4-5. Relative bacteria load by source in each subwatershed

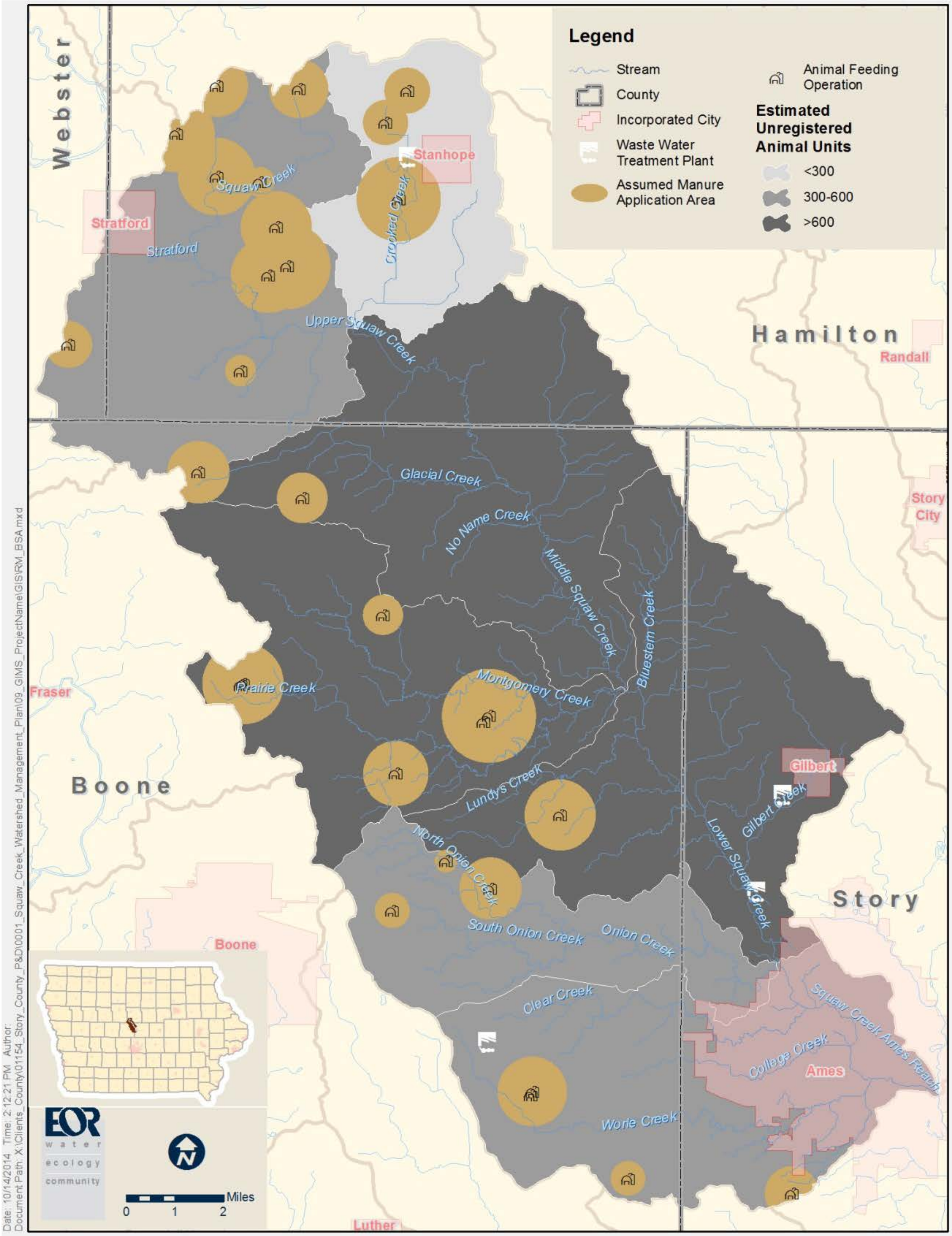


Figure 4-6. Bacteria sources in the Squaw Creek Watershed

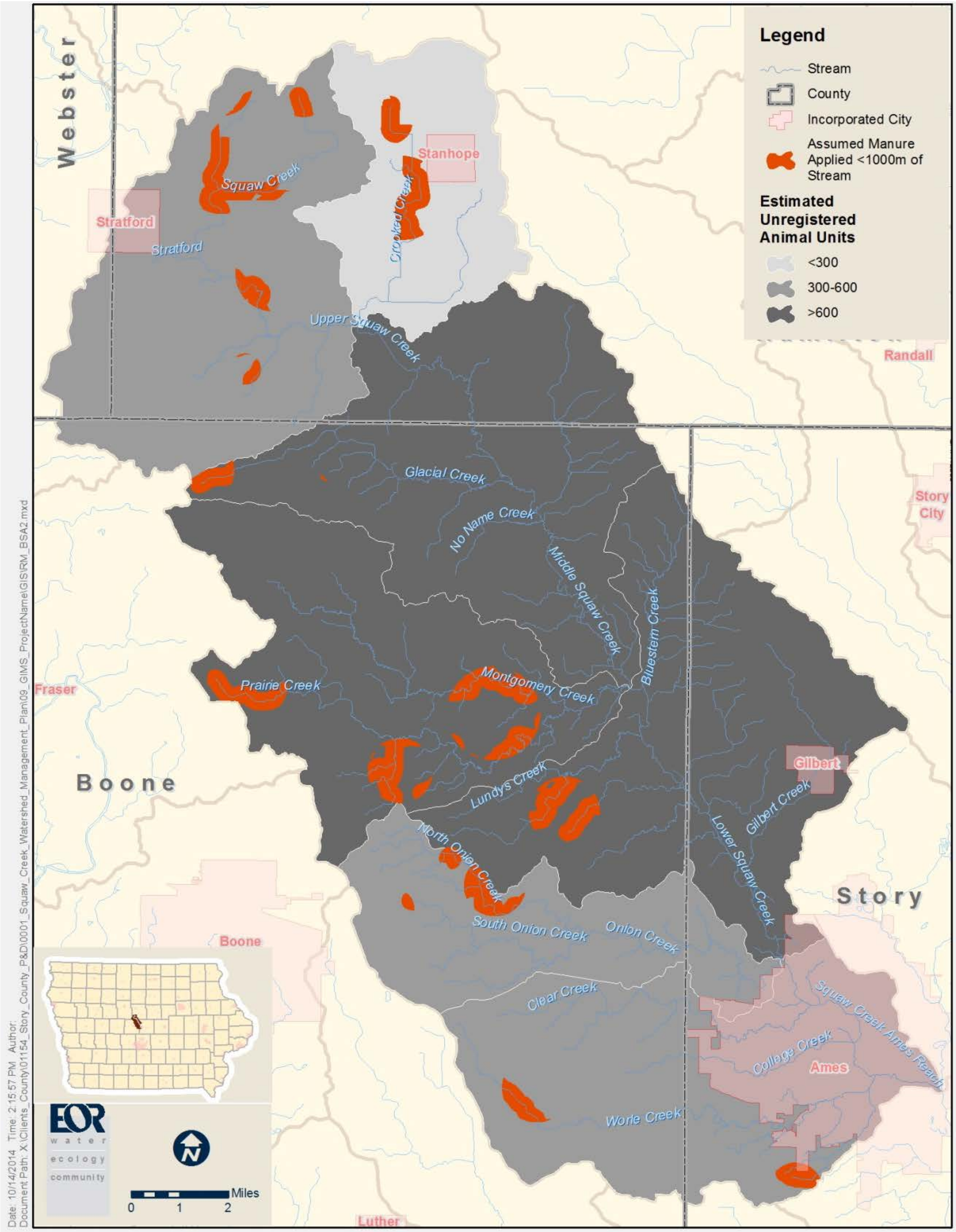


Figure 4-7. Manure Management Priority Areas