3. Stream Health

The following section describes the current state of the watershed streams. The section begins with a discussion of water quality conditions in the various streams of the watershed. This assessment is based on the water quality monitoring that has been done in various locations throughout the watershed by the City of Ames and by the Squaw Creek Watershed Coalition from 2007 to 2013.

The second topic covered is the stream assessment. This assessment looks beyond the quality of water within the streams and focuses on the factors that shape the stream; stream flows, sediment load and streambank stability factors. These two sub-sections summarize the current conditions of the streams and serve as the framework for setting future goals for the watershed and illustrate the challenges the WMA faces. Following this section, which identifies what the issues in the watershed are, the focus changes to look at what are the causes. The Pollutant Source Assessment looks into the specific sources of pollutants; nutrients, bacteria and sediment as well as stream flow. While stream flow is not a pollutant it is included since the volume and rate of flow within the stream is intricately tied to the delivery of pollutants and excess flows can lead to degradation in stream quality and habitat. Sources of sediment, nutrients and stream-flow were assessed using a hydrologic model and the source of bacteria, specifically *E. coli*, was assessed using a methodology that examines the generation of fecal material within the watershed as well as the potential of that material to be delivered to the stream.

3.1. Stream Water Quality

Stream flows, or the amount of water that runs off the land and its water quality are inseparable watershed responses. As more water is diverted from agricultural and urban surfaces, it has a greater power to move soil and pollutants such as nitrogen and phosphorus from the land. This sub-section summarizes the water quality of Squaw Creek and watershed tributaries (based on several years of volunteer monitoring data) and compares this data to available stream water quality criteria. **In short, water quality within Squaw Creek and watershed tributaries is quite poor, exceeding several water quality criteria and standards.**

Several national and regional studies have documented relationships of stream water quality (sediments, nutrient and bacteria) and beneficial uses relating to recreation suitability and aquatic biological communities. Nutrients, particularly nitrogen and phosphorus are natural components of aquatic ecosystem function. However, excessive amounts can lead to detrimental effects upon aquatic biota and recreation opportunities. Nutrients originate from a variety of sources both natural and man-made. Human activities include industrial sources, municipal sources (stormwater, wastewater) and agricultural (animal wastes, fertilizer and erosion-caused sediments). The loss of nutrients is increased by intensive land uses such as impervious surfaces in urban areas (streets, curbs/gutters, rooftops, parking lots) and agricultural equivalent practices (exposed soil, tile drainage and ditches). Both intensive land uses are essential for maintaining society; however, additional treatment is required to prevent degradation of downstream receiving water bodies. As was learned during the 1970’s-1990’s from industrial and municipal ‘pipe’ discharges, receiving water bodies have limited pollutant assimilative capacities for nutrients and sediments. Excess amounts cause imbalances that degrade conditions for fisheries, insects, aquatic life and downstream water supplies.

Nutrient enrichment (eutrophication) leads to modification of the aquatic food web by increased aquatic plant growth, frequently producing nuisance conditions such as green algae covering on rocks and substrates and increased bacteria. Increased amounts of aquatic plants and bacteria in turn result in an increase in respiration, decreased dissolved oxygen (particularly at night), altered food resources and habitat structures. In general, these changes can lead to invasion by nonnative species and increases in blue-green algae that can produce algal toxins harmful to aquatic and terrestrial organisms as well as drinking water supplies.

Much of this assessment will focus on water flow and nutrients, particularly phosphorus and nitrogen as these nutrients drive a wide array of river, stream and lake biological responses affecting beneficial uses. In small rivers and wadeable streams, nutrient loading is more likely to result in increased amounts of benthic algae (periphyton) attached to rocks and hard substrates creating slippery surfaces, increased organic matter and bacteria. Increased organic matter causes increased respiration (at night) and consumption of dissolved oxygen. As nutrient concentrations increase, the daily summer oxygen concentrations may reach high levels (e.g. over 8 mg/L) and then collapse to very low levels (e.g. less than 4 mg/L) in the night. These boom-bust oxygen cycles are accompanied by loss of biota and shift to more pollution tolerant species with negative affects to native species and recreational beneficial uses. Periodic scouring of stream attached (benthic) algae is possible during high flow events, washing all of the organic matter to downstream water bodies.

3.1.1. Water Classification and Designated Uses

Iowa's surface water classifications are described in IAC 61.3(1) as two main categories, General Uses and Designated Uses. Designated use segments are water bodies which maintain flow throughout the year or contain sufficient pooled areas during intermittent flow periods to maintain a viable aquatic community. Squaw Creek has been classified as a Class A1 and B (WW-2) stream from its Mouth (S12, T83N, R24W, Story County) to the confluence with Glacial Creek).

2014 Lake Erie Algal Bloom

In early August, 2014 a severe algal bloom in Lake Erie resulted in the closure of the Toledo Water System. Over 500,000 people were left without safe drinking water and 70 people were treated at local hospitals for related health concerns. The algal bloom has been attributed to excess nutrients being washed into the lake from a heavily agricultural watershed. While algal blooms are a common occurrence in Lake Erie, their frequency and severity has increased in recent years.

Typically, algal blooms can be a nuisance, impacting recreational use of the lake. In this case, the bloom contained a type of algae known as cyanobacteria algae, or blue-green algae, which produces a toxin, microcystin, which is harmful to humans and wildlife. Tests of the Toledo Drinking Water System, which draws its water from Lake Erie, indicated levels of microcystin more than double the World Health Organization's threshold.

Clean Water Act

Under the Clean Water Act, States are required to develop lists of impaired waters. These are waters that are too polluted or otherwise degraded to meet the water quality standards set by the State. The law requires that States establish priority rankings for waters on the lists and develop a Total Maximum Daily Load (TMDL) for these waters. A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still safely meet water quality standards. While there are not currently any listed impaired waters in the Squaw Creek Watershed the area does contribute drainage to impaired waters downstream.

Class A1 Primary Contact Recreational Use Streams - waters in which recreational or other uses may result in prolonged and direct contact with the water involving considerable risk of ingesting water in quantities sufficient to pose a health hazard. Such activities would include, but not be limited to, swimming, diving, water skiing, and water contact recreational canoeing.

Class B (WW-2) Warm Water Streams - waters in which flow or other physical characteristics are capable of supporting a resident aquatic community that includes a variety of native nongame fish and invertebrate species. The flow and other physical characteristics limit the maintenance of warm water game fish populations. These waters generally consist of small perennially flowing streams.

The Iowa DNR has created multiple categories for stream reaches in Iowa using the Integrated Report (IR) method (**Table 3-1**). Although many stream reaches across the state, especially smaller tributaries, have not been categorized. IR-assessed reaches within the Squaw Creek Watershed are listed by classification in **Table 3-1**. Note that Worle, College and Onion Creeks have been listed as “potentially impaired” (e.g. Category 3b-u).

Table 3-1. Iowa Integrated Report Categories for stream designated use and assessed reaches in the Squaw Creek Watershed.

Category	Sub-category		Description	Reaches in Squaw Creek Watershed
1			All designated uses met.	None
2	a		At least one designated use met; insufficient data to determine whether other uses are met.	Squaw Creek (Aquatic Life) mouth to Glacial Creek
	b		At least one designated use is met with at least one other use potentially impaired based on an "evaluated" assessment.	None
3	a		Insufficient data to determine whether any designated uses are met.	Squaw Creek (Primary Recreation) mouth to Glacial Creek, Clear Creek, North Onion Creek, South Onion Creek, Glacial Creek, Unnamed Trib to Glacial Creek
	b		Insufficient data to determine whether any designated uses are met but at least one use is potentially impaired based on an "evaluated" assessment.	None
		3b-c	The aquatic life use of a stream segment within the calibrated range of the biological assessment protocol has been assessed as potentially impaired	None
		3b-u	The aquatic life use of a stream segment outside the calibrated range of the biological assessment protocol has been assessed as potentially impaired	Worle Creek (NS) College Creek (PS), Onion Creek (PS) mouth to confluence with North and South Onion Creeks,
	b		Impairment is based on results of biological monitoring or a fish kill investigation where specific causes and/or sources of the impairment have not yet been identified.	None

Western Corn Belt Plains

Level III subdivision of Ecoregion IV: Corn Belt and Northern Great Plains

The Western Corn Belt Plains is characterized by plains and over 75 percent of the land in agricultural uses such as corn, soybean, and feedlot operations, although there are also many urban, suburban, and industrial areas as well. The soils are nutrient-rich and greatly influence both surface and subsurface water quality. Nitrogen and phosphorus are often elevated in this region's waters due to agricultural or livestock runoff and wastewater effluent. Pesticides can also be a problem in waters, as is suspended sediment and elevated bacteria.

Lakes and streams in this ecoregion range from mildly eutrophic to hypereutrophic and are used for fishing, recreation, and are important for wildlife habitat Native vegetation was dominantly tall grass prairie. (USEPA 2000)

3.1.2. Applicable Water Quality Standards and Criteria

In an effort to define the level of water quality within the Squaw Creek watershed we need to compare monitored values to either a State Standard, when available or to a criteria that has been established for streams of similar nature.

The Iowa Department of Natural Resources is the agency delegated to manage water quality in Iowa. It does so by issuance of water quality standards that establish numeric and narrative criteria to protect present and future designated uses of the surface waters. Designated uses refers to state identified uses of waters such as public water supply, agricultural, industrial, primary contact recreation (swimming, wading), fisheries, wildlife and associated biologic communities. The term 'criteria' refers to scientific assessments of ecological and human health impacts recommended for controlling discharges or releases of pollutants. States base their enforceable water quality standards upon various pollutant criteria and are a critical basis for assessing attainment of designated uses and measuring progress toward meeting the federal Clean Water Act's water quality goals. In this case, Iowa water quality standards have been developed for E.coli (bacteria), pH, dissolved oxygen and chloride. In cases where water quality standards have not been developed, there are EPA regional and state criteria such as the new proposed stream nutrient criteria for wadeable warmwater streams including Total Kjeldahl nitrogen (TKN), total phosphorus, filamentous algae, dissolved oxygen diel range (daily minimum and maximum dissolved oxygen levels) and seston algae (floating in the water) chlorophyll-a. Other water quality criteria developed for similar areas by the USEPA or Minnesota have been recommended to guide watershed management decisions such as turbidity/total suspended solids.

Iowa State Water Quality Standards

Iowa's water body designated uses are specified by Iowa DNR (2010) with applicable water quality standards specified by Iowa Administrative Code, Chapter 61. Applicable state stream water quality standards have been developed for

Escherichia coli (*E. coli*), dissolved oxygen, pH and chloride. Iowa does not have stream nutrient standards for phosphorus or nitrogen (there are drinking water standards for nitrogen but those are not applicable here) so general aquatic eco-region criteria are described for reference purposes.

Ecoregion Water Quality Criteria

Water quality varies regionally due to natural landscape characteristics and for this purpose, aquatic ecoregions were derived by the USEPA (Omernik, 1987) to describe geographic areas of similarity based on natural communities, soils, land surface forms and use, water quality and geological characteristics. The ecoregion framework has proven utility in defining regional patterns of water quality, aquatic communities and refinement of water quality criteria and standards. The Squaw Creek Watershed falls within Ecoregion VI: Corn Belt and Northern Great Plains and more specifically within Level III aquatic ecoregion Western Corn Belt Plains.

Table 3-2. Water Quality Criteria for Ecoregion VI, stream use classes A1 and B (WW-2)

Parameter	Description/Qualification	Ecoregion Criteria	State Standard	Draft State Criteria
Total Phosphorus (TP) *See Note 1*	Reference Condition Nutrient Criteria (USEPA, 2000) Draft State Criteria based on June 15- Oct 15 (except for Daily DO Range based on July 1 – Sept. 15 data)	0.076 mg/L		0.100 mg/L*
Total Nitrogen (TN)		2.18 mg/L		
Total Kjeldhahl N (TKN)				0.80 mg/L*
Nitrate+Nitrite Nitrogen	Class C (drinking water source)		10.0 mg/L	
Nitrite			1.0 mg/L	
E. coli Bacteria Class A1 Recreation Waters	Geometric Mean (minimum 5 samples in a given year, 3/15-11/15)	126 org/100mL	126 org/100mL	
	Maximum Sample	235 org/100mL	235 org/100mL	
Dissolved Oxygen (DO)	Min for at least 16 hours of every 24-hour period		5.0 mg/L	
	Min at any time WW-2 Min at any time WW-1		4.0 mg/L 5.0 mg/L	
	Daily (Diel) DO Range			< 5.0 mg/L
Chloride (Cl)	Chronic (based on hardness and sulfate concentrations)		389 mg/L	
	Acute (based on hardness and sulfate concentrations)		620 mg/L	

* Median values.

Note 1: Orthophosphate Phosphorus estimated to very generally approximate Total Phosphorus (elemental) by conversions but further sampling and laboratory analyses are required for corroboration.

3.1.3. **Stream Flows**

Prior to evaluating nutrient and pollutant concentrations and loads it is important to understand the hydrology of the watershed. The flow network as described in Section 2.1 consists of a series of ditches, small creeks and Squaw Creek. A long-term flow monitoring station (USGS station 05470500) is located at Lincoln Way in Ames. The station shows considerable variability as estimated by average annual flows from 1970 to 2013. During this time period, average annual values varied from 13.6 cubic feet per second (cfs) (1981) to 528 cfs (1993 Flood) with an overall annual median value of about 161cfs (Figure 3-1).

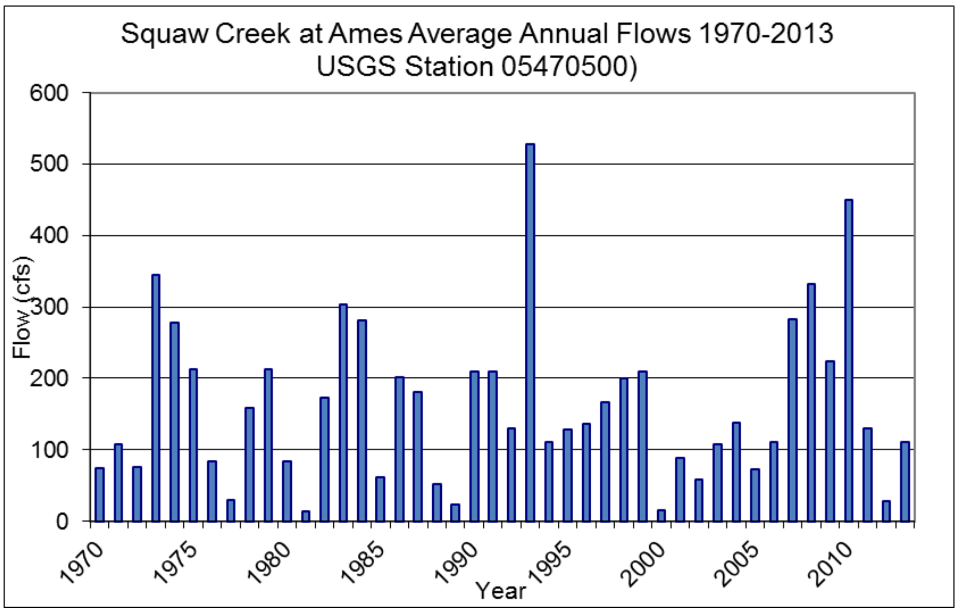

Figure 3-1. Squaw Creek at Ames, IA (USGS Station 05470500) Annual Average Flows

Average Annual Flows

Looking at the most recent years (2000-2013), the annual average flows show the considerable contrast of wet and dry years (Figure 3-2) with 10 years having less than average flows and 4 years greatly exceeding long-term averages. Transitions appear abruptly shifting from dry to wet (2006-2007) and then from wet conditions noted in 2010 to much lower flow conditions of 2011/2012. The magnitude of the wet/dry shifts are of particular note as 2001/2012 experienced average annual low flows on the order of 16-27 cfs (or drier than about 95% of annual flows from 1970-2013) to the much higher flows of 2010 (e.g. 450 cfs). In this regard, wet and dry year flows differed by a factor of about 28.

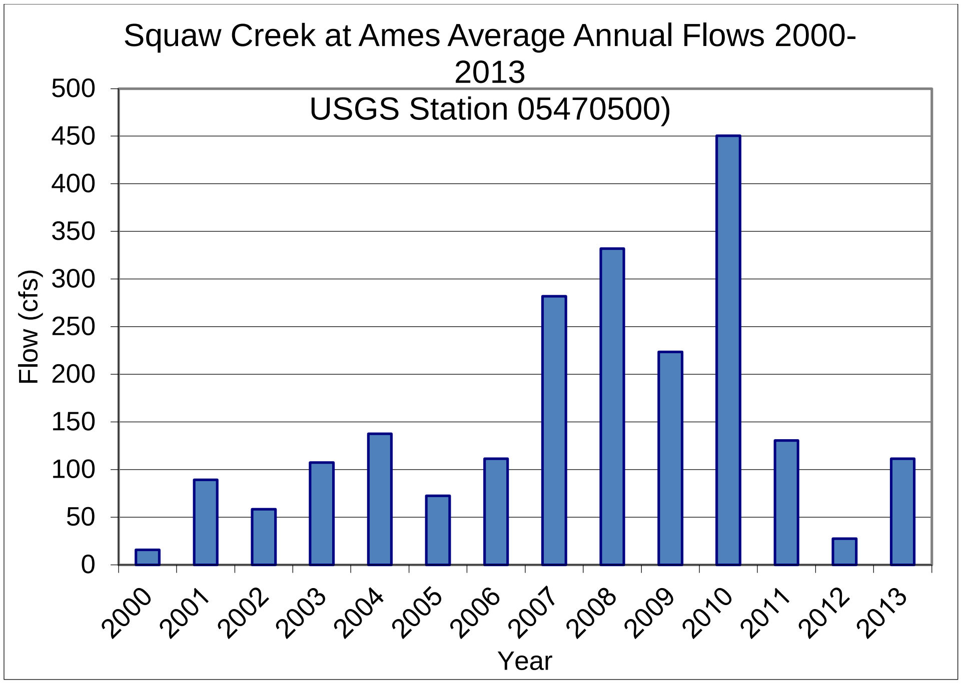

Figure 3-2. 2000-2013 Annual Average Flows at Ames, IA.

For reference, the peak annual flows of 1993 averaged about 528 cfs (Table 3-3). **This range of annual flows is extreme and indicates that Squaw Creek has relatively low upland flow buffering capabilities from storage by wetlands, lakes or ponds.**

Table 3-3. Squaw Creek At Ames, IA, frequency of annual average flows by percentile for 1970-2013 (USGS Station 05470500).

Percentile	Average Annual Flow (cfs)
10%	36
25%	81
50%	134
75%	210
90%	297

Average Monthly Flows

Shifting to a closer examination of Squaw Creek's flows, average monthly values monitored from 1970-2013, reflect the climate and precipitation patterns noted previously. Average monthly flows increase significantly from winter flows of ~ 50 cfs to typical peak flows of about 365 cfs noted by June (Figure 3-3). Sharp declines in average monthly flows were noted for the last half of the growing season (July-September) when peak evapotranspirational losses are expected.

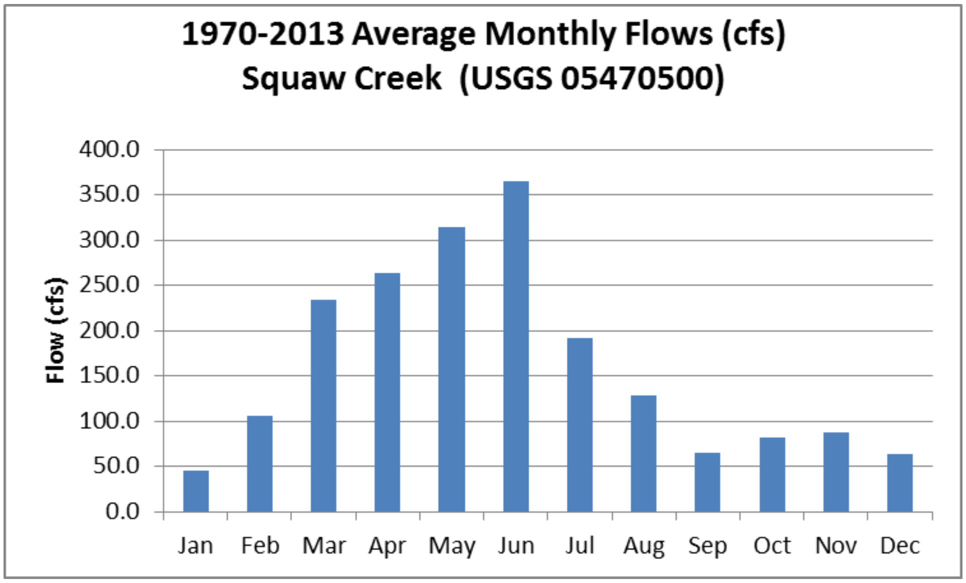

Figure 3-3. Squaw Creek (Ames, IA) average monthly flows (cubic feet per second)

Average monthly flows for Squaw Creek at Ames from the USGS from 1981 to 2014 were summarized in Table 3-4 below by 'wet'(blue) and 'dry' (grey) monthly conditions based on examining 25th percentile (dry) and 75th percentile (wet) conditions. Wet and dry periods seem to occur in series with 2000-2003 having several back-to-back dry months and the converse being true for the 2007-2010 wet period (blue patches in the table). A dry period followed in 2012-2013 with more low to very low flow months.

Table 3-4. Monthly Stream Flows USGS Gage Station, Ames IA

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000	3.9	17.7	18.0	10.2	25.7	77.3	15.6	2.3	0.2	0.3	2.7	0.6
2001	0.0	0.4	307.3	165.2	298.6	211.6	30.0	8.8	38.2	19.0	25.4	29.4
2002	16.7	38.0	43.9	80.7	234.2	125.8	40.3	41.2	2.8	29.5	25.3	12.6
2003	5.0	3.5	21.2	95.6	398.3	193.7	472.0	14.9	3.0	1.0	15.7	8.3
2004	13.1	141.2	297.1	153.4	414.8	410.9	140.4	44.6	11.4	5.8	15.9	15.6
2005	15.3	149.0	64.0	151.6	222.2	134.6	53.4	37.0	12.2	10.4	11.0	12.9
2006	67.8	33.5	62.4	241.8	293.0	68.2	63.6	51.6	422.7	180.8	140.7	146.5
2007	206.4	84.8	556.3	742.1	675.1	299.7	57.6	213.5	63.6	369.9	109.1	41.2
2008	29.5	23.4	363.9	608.3	722.3	1145.0	415.5	127.4	28.5	99.6	195.3	63.9
2009	24.6	279.3	392.5	439.5	450.7	575.0	138.4	33.3	7.1	191.9	232.9	101.2
2010	88.8	69.2	843.8	224.1	343.1	609.2	679.1	1734.0	234.3	111.8	150.4	49.1
2011	45.7	164.5	139.6	271.0	294.4	242.7	76.5	18.6	9.0	4.0	5.8	4.8
2012	2.6	6.0	29.4	105.2	127.8	32.5	4.1	3.8	2.0	0.1	0.0	0.0
2013	4.0	6.6	169.7	144.9	612.9	334.3	47.3	6.6	1.6	6.7	6.0	0.4
2014 Preliminary Data	0	1.4	66	55	141	403	514	50				
1981-2013	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly Means	42	104	223	267	340	378	225	140	55	71	78	62
Dry Months 25th %	5	23.4	62.4	94.6	139.1	99.3	40.3	14.9	3.03	5.48	11	8.34
Wet Months 75th %	63	149	325.4	311.8	512.2	575	285.3	71.6	33.2	99.6	138.5	101.2

Daily Average Flows

A more detailed view of (1) daily average flows and (2) instantaneous peak flows were examined for the 2003-2013 time period (Figure 3-4). In this plot the highest daily average flows were on the order of 15,900 cfs in August, 2010 and about 7,300 cfs in 2008. The remaining time periods had much lower variability of daily flows as 2003-2006 and 2011-2013 were below average runoff years.

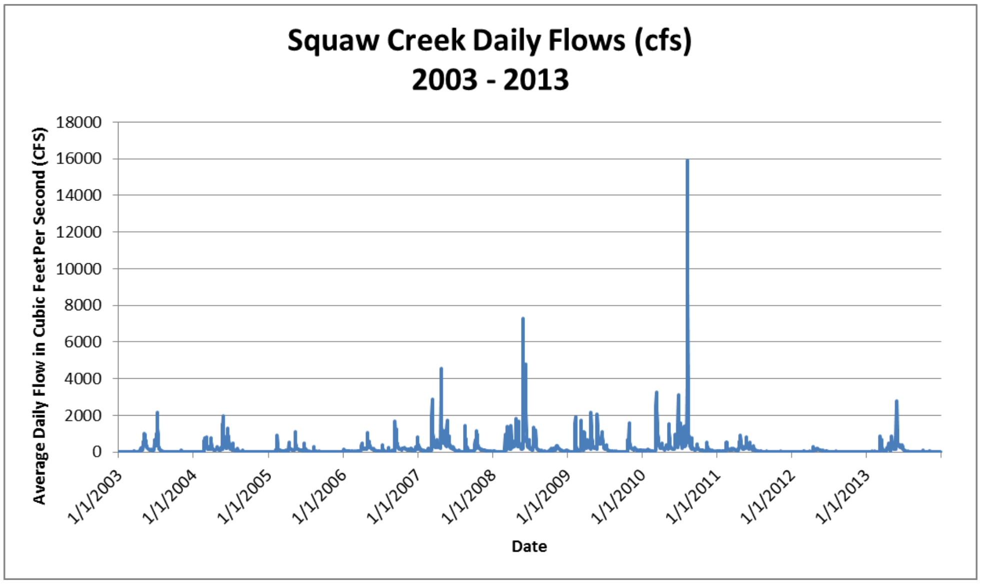

Figure 3-4. 2003-2013 Daily Flows in cfs for Squaw Creek (USGS 05470500) at Ames, IA.

Historical Peak Events

From a flooding perspective, instantaneous peak flows are of particular interest. Squaw Creek peak flows can be substantially greater than daily average flows indicating rapid runoff responses. For example, the peak flow of 12,600 cfs was noted on May 30, 2008 versus the daily average of ~7,300 cfs. In a similar fashion, the peak flow of 22,400 cfs was noted on August 11, 2010 versus the daily average of 15,900 cfs. Generally, instantaneous peak flows of the most recent 14 years were attributable to snow melt (2001, 2005, and 2009) or due to back-to-back storms of the preceding ~14 days with rainfall totals ranging from about 3 inches to 6.5 inches (2000, 2002,2003, 2004, 2007, 2008, 2011,and 2013). The massive peak flow of August 11, 2010 was preceded by a very large amount of rainfall (about 10.4 inches) in the preceding ~14 days. Back-to-back storms with total rainfalls of 3-6 inches appear to be a trigger for the large peak runoff events in the Squaw Creek Watershed.

Squaw Creek's peak flows were further summarized from the USGS flow gauging station data (Station 054070500) in Figure 3-5 where dramatically increased peak events have occurred since ~1970. Although missing data from ~1930 until 1964, peak events from 1918 through the 1920's and the 1960's were less than ~7,000 cfs. However, from 1970 to 2013, there were four years with peak flows 5,000 - 10,000 cfs, four years with peak flows 10,000 to 15,000 cfs and two years with peak flows greater than 20,000 cfs (e.g. 1993 and 2010). For perspective, flows greater than 5,000 cfs are ~25 times typical summer flows, flows greater 10,000 cfs are ~50 times typical summer flows and flows greater than 20,000 cfs are approaching ~100 times typical summer flows. **The range of peak to typical flows to intense rainfall events is indicative of the Squaw Creek system as having substantially 'flashy' or rapid runoff hydrology.**

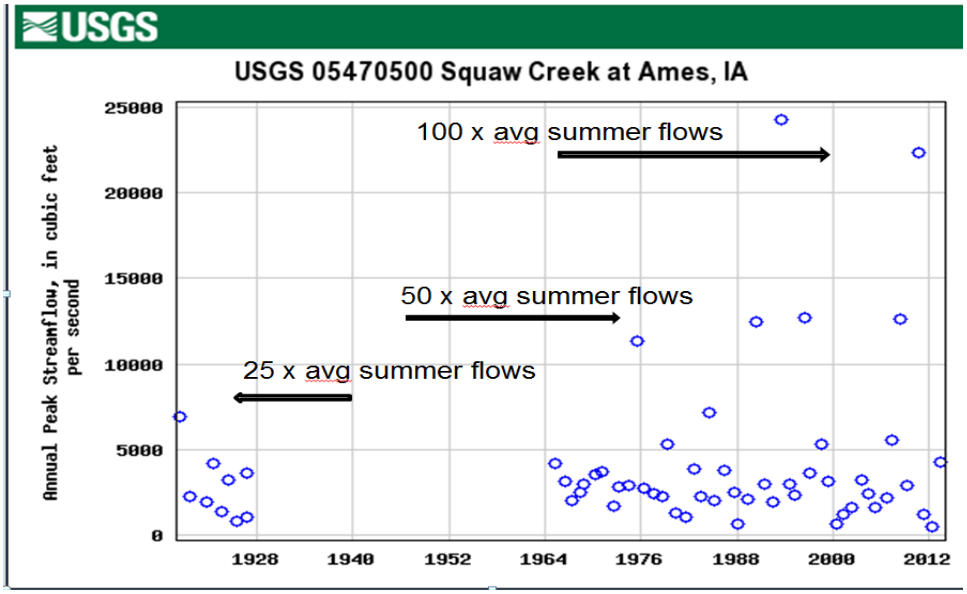

Figure 3-5. Squaw Creek annual peak flows in cfs for USGS (Station 05470500)

Additional Stream Gage Information

Water levels of Squaw Creek and its 15 tributaries are monitored at 25 gauge stations on an hourly basis, located throughout the watershed (Table 3-5). This stream gauge information is immediately uploaded to the Iowa Flood Information System (IFIS) in real-time, which is available to the public online at: http://ifis.iowafloodcenter.org/ifis/en/. The water level gauge information also includes updated flood stage information. This allows the user to observe the current water level and know the water level that would be considered a flood.

In addition to this real-time gauge data, the IFIS website contains a number of useful tools related to flood prediction. For the Inundation Maps tool, users can adjust the river water levels to simulate how much flooding will occur at various storm events and rates of flow. For example, users can adjust the tool from a 2 to 500 year storm event or the water levels up to 25 ft. and view the flooded areas respectively. This feature is available for 13 Iowa cities including Ames. Another helpful tool, called the Flood Risk Calculator, allows the user to determine the probability of a 10-year flood occurring within a 2-year period. This calculator can be scaled from 1-99 years and is capable of predicting the probability of storm events ranging up to 500 years. Thus, a user could use these tools to determine that a 100-year storm event will inundate their property and there is only a 14% chance that such an event will happen over the course of 15 years.

Table 3-5. Squaw Creek gage locations

Stream Name	Gage Location
Squaw Creek	360th Street, Hwy 175, Stratford
North Branch Crooked Creek	Inkpaduta Avenue, Stanhope
South Branch Crooked Creek	Briggs-Wood Road, Hwy 7
Squaw Creek	Inkpaduta Avenue, Stanhope
Glacial Creek	U Avenue, Story Cty

Stream Name	Gage Location
Talynns Creek	V Avenue, StoryCty
Squaw Creek	120th Street, Story Cty
Squaw Creek	Ames
Prairie Creek	160th Street, Boone
Montgomery Creek	Boone
Prairie Creek	V Avenue, Gilbert
Squaw Creek	160th Street, Gilbert
Gilbert Creek	520th Ave, G. Washington Carver Avenue, Gilbert
Squaw Creek	Ames
North Branch Onion Creek	Hwy 17, T Avenue, Boone
North Branch Onion Creek	V Avenue, Boone
South Branch North Fork Onion	U Avenue, Boone
South Branch South Fork Onion Creek	U Avenue, Boone
Squaw Creek Tributary	Stratford
Clear Creek	500th Avenue, County Road R38, Ames
Onion Creek	N 500th Ave, County Road R38, Ames
Worle Creek	X Avenue, Ames
Squaw Creek	Strange Rd, Ames
Squaw Creek	Ames
Squaw Creek	South Duff Ave, Ames

3.1.4. **Water Quality Monitoring**

Stream monitoring provides information to compare monitored conditions to stream standards and criteria, detect changes over time, and support future watershed rehabilitation efforts. The ability of a monitoring program to detect such changes and the reliability of the comparisons depend upon the nature and design of the monitoring program.

Monitoring efforts of water quality in the Squaw Creek and its tributaries have been ongoing since about 2000 and incorporate conservation programs that engage students and citizens in volunteer monitoring. Different water quality parameters have been assessed at varying sampling frequencies and dates over time and have been used to compare to water quality criteria and standards. The number of samples per site varied considerably and over time. Volunteer monitoring efforts relied upon 'kit' analyses of nitrate and phosphorus concentrations and hence, values are reported in coarse intervals such as 0.1 ppm. Bacterial samples were analyzed by an established laboratory.

Beginning at the headwaters, available data were combined into a database and analyzed along the stream network. Refer to Figure 2-2 in the Watershed Characterization section for the stream network.

Squaw Creek reaches are defined as follows:

- Upper Squaw Creek – This is the reach of Squaw Creek that is above the Primary Recreation use reach which is defined as being at the confluence with Glacial Creek.

- Middle Squaw Creek – This reach of Squaw Creek runs between the confluence with Montgomery Creek and the confluence with Glacial Creek.
- Lower Squaw Creek – This reach extends from the confluence of Onion Creek to the confluence of Montgomery Creek
- Squaw Creek Ames Reach – This is the reach of Squaw Creek that lies below Onion Creek to the outlet of Squaw Creek into South Skunk River.

Note that the data does not include flows that will increase along Squaw Creek. As previously noted in the climate section, the sampling period of record includes several wet and dry periods that will affect runoff that cannot be pro-rated without flow data. For example, the most recent five years (2009-2013) have higher runoff periods (2009-2010), a transition year (2011) followed by two drier years (2012-2013)). Hence, averaging of the data helps define the broad water quality picture.

Over the years, sampling dates have varied somewhat from January through November, however, most recent sampling (2009-2013) tended to occur in May and October. Peak events were sampled on occasion, but not sufficient to characterize loading that is highly dependent upon sampling of the higher runoff periods (such as spring runoff and storm events). Reported concentrations for parameters having less than the Minimum Detection Limits (MDLs) were halved for calculation of averages in this analysis with values exceeding the reporting level for turbidity tube transparencies of greater than 60 cm were assigned a value of 65 cm.

This evaluation begins with an examination of all of the data for patterns and exceedance of Iowa water quality standards and appropriate watershed management numeric targets or criteria. Criteria are numeric values that are used when standards are not available or have not yet been developed for common water quality measures such as nutrients. Refer to section 3.1.2 Applicable Water Quality Standards and Criteria for further explanation. The Iowa Department of Natural Resources is examining stream nutrients and biological responses at this time.

Data from 2000-2013 were summarized by Squaw Creek reach (Upper Squaw Creek, Middle Squaw Creek, Lower Squaw Creek and Squaw Creek Ames Reach) for mainstem sites (Table 3-6) and its tributaries (Table 3-7) beginning at the headwaters and proceeding downstream. Average values were calculated by parameter for nitrate plus nitrite nitrogen, orthophosphate, E.coli, transparency and chloride.

Table 3-6. Average Monitored Concentrations for Squaw Creek Mainstem Reaches

Mainstem Reach	Nitrite + Nitrate N mg/L	Ortho phosphate mg/L	*E. coli* (org/100mL)	Transparency (cm)	Chloride (mg/L)
Upper Squaw Creek	5.20	0.245	689	38.5	25.7
Middle Squaw Creek	6.74	0.297	2767	38.0	27.0
Lower Squaw Creek	6.84	0.263	NA	32.0	29.7
Squaw Creek Ames Reach	5.34	0.297	1380	41.3	39.4

Table 3-7. Average Monitored Concentrations and Number of Samples for Squaw Creek Tributaries by Subwatershed

Stream	Nitrite + Nitrate (mg/L)		Orthophosphate (mg/L)		*E. coli* (org/100mL)		Transparency (cm)		Chloride (mg/L)	
	Average	N	Average	N	Average	N	Average	N	Average	N
Drainage Ditch 192 – Squaw Creek Subwatershed										
Stratford	5.529	12	0.3	11	267	2	35	12	17.6	12
Crooked Creek Subwatershed										
Crooked Creek	3.019	8	0.314	7	N/A	0	30	8	29	7
Crooked Creek – Squaw Creek Subwatershed										
Glacial Creek	3.123	42	0.219	43	89	27	60	43	N/A	0
Scott Drainage Ditch 292	5.65	13	0.108	12	N/A	0	54	14	21.1	10
No Name Creek	6.517	12	0.185	13	N/A	0	54	13	N/A	0
Montgomery Creek Subwatershed										
Montgomery Creek	4.749	118	0.156	120	1,180	96	49	122	N/A	0
Prairie Creek	5.074	118	0.318	120	1,941	95	48	122	N/A	0
Lundy's Creek – Squaw Creek Subwatershed										
Bluestem Creek	4.373	43	0.229	41	461	29	57	43	30.1	41
Gilbert Creek	6.911	14	0.393	14	N/A	0	51	14	N/A	0
Onion Creek Subwatershed										
Onion Creek	4.901	58	0.247	60	N/A	0	42	63	N/A	0
Worle Creek – Squaw Creek Subwatershed										
Clear Creek	6.214	169	0.233	169	407	57	57	176	39.9	168
Ames High Tributary	3.321	46	0.189	47	300	5	58	47	106.1	38
College Crk	2.771	119	0.234	111	100	1	49	123	N/A	0
College Creek Trib	1.675	51	2	51	N/A	0	56	51	205.6	40
Worle Creek	7.348	59	0.186	58	1,078	6	50	63	31.5	56
Komar Creek	5.753	15	0.271	14	N/A	0	48	18	21.5	15
Worle S.Branch	7.165	13	0.242	12	N/A	0	47	13	38.5	12
Moore Park	5.485	13	0.169	13	N/A	0	43	13	23.3	13

3.1.5. **Nitrogen**

Nitrogen is an important measurement, particularly the dissolved forms, as it increases productivity on farm fields, urban lawns and streams/lakes. Nitrate nitrogen is the dominant dissolved fraction with typically very small amounts of nitrite nitrogen present (which can be quite ephemeral). Hence, discussion will focus on the combined nitrate plus nitrite nitrogen with concentrations that vary seasonally from biological activity and nutrient inputs (fertilizer, wastewater and urban runoff). While nitrate is one of the primary forms of nitrogen used by plants for growth, excess amounts to groundwater and streams can cause human health concerns. At concentrations greater than 10 mg/L, it has been linked to methemoglobinemia ("blue baby syndrome"). Hence ground water recharge areas associated with public drinking water sources can have drinking water source management area plans to limit nitrate and other drinking water pollutants. Secondly, as nitrate nitrogen is very soluble, it can be transported long distances downstream to large impoundments and the Gulf of Mexico as one of the primary contributors to low or no oxygen areas (hypoxic zones). Phosphorus is another pollutant contributing to the anoxic zones in coastal areas.

Total nitrogen consists of dissolved (nitrate plus nitrite) and organic nitrogen (total Kjeldahl nitrogen). In this case, organic nitrogen monitoring data were not available and comparisons are based on dissolved nitrogen values. Nitrate and nitrite are inorganic and dissolved forms of nitrogen used for increasing productivity, with concentrations that vary seasonally from biological activity and nutrient inputs. They are formed through the oxidation of ammonia (NH 3-N) by nitrifying bacteria (nitrification). They are converted to other nitrogen forms by denitrification and plant uptake. Nitrite concentrations are typically quite low in aquatic systems and hence, discussion will focus on nitrite plus nitrate nitrogen levels.

Dissolved nitrogen concentrations were monitored by volunteers throughout the Squaw Creek watershed. Nitrate and nitrite nitrogen concentrations were assessed by volunteers using kit analyses and hence concentration ranges were limited to coarser reporting levels, approximately 0.2 to 0.5 mg/L. All monitoring data was averaged by site and summarized in Table 3-6 and Table 3-7.

Nitrate plus nitrite concentrations range from around 5 mg/L to 7 mg/L throughout the mainstem Squaw Creek. Low tributary values were noted for Crooked Creek, Glacial, Ames High and College Creek with College Creek Tributary having the lowest value of about 1.7 mg/L. High tributary concentrations were noted for Clear and Worle Creeks with values exceeding 6.0 mg/L.

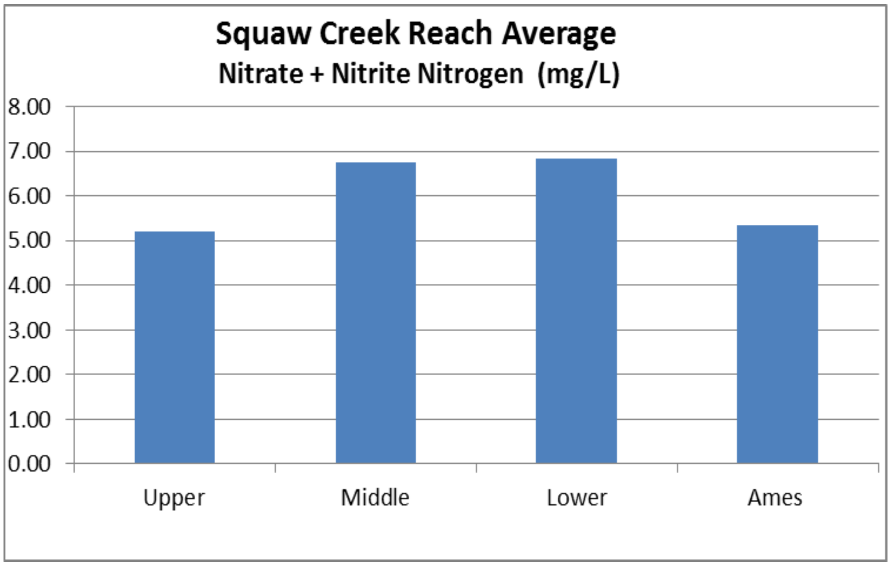

Figure 3-6. Average Nitrate + Nitrite Nitrogen Concentrations by Squaw Creek Mainstem Reach

While mainstem and tributary average nitrate plus nitrite concentrations were quite elevated throughout the monitoring network these averages do not exceed the drinking water standard of 10.0 mg/L. T**he dissolved nitrogen concentrations exceed the ecoregion total nitrogen criteria of 2.18 mg/L) generally by a factor of 1.5 to 4.** Since organic nitrogen monitoring data was not available, total nitrogen concentrations may be greater than indicated by just dissolved forms.

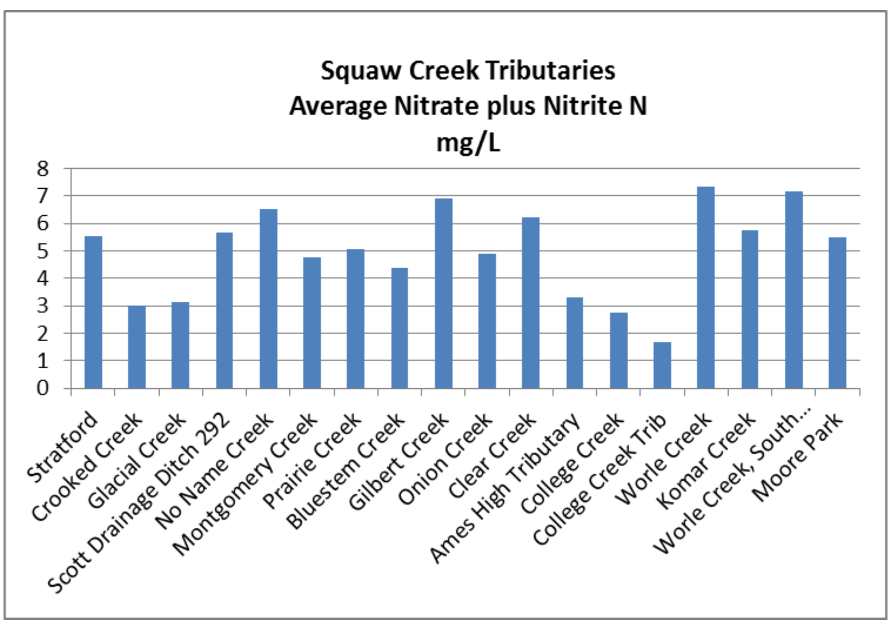

Figure 3-7. Average Nitrate + Nitrite Nitrogen Concentrations by Squaw Creek Tributaries

3.1.6. **Phosphorus**

Phosphorus is a primary nutrient for plant growth on the land and in the water. On the land, soil phosphorus concentrations measured in the part per million range are closely followed by agricultural and urban land owners. However, in water, phosphorus concentrations in the part per billion range are monitored with excess phosphorus levels occurring at concentrations **much lower** than values measured in soils.

Phosphorus concentration in water is a primary focus of applied watershed management as this element drives a wide array of river, stream and lake biological responses affecting beneficial uses. Excess phosphorus concentrations lead to increased algae that float in the stream or are attached to rocks and substrates, increased organic matter, increased bacteria that lead to boom-bust daily oxygen concentration cycles that limit aquatic life. In severe cases, massive algal mats and scums can be generated by blue-green algae that also can produce toxins such as microcystin that can affect wildlife and drinking water supplies.

Phosphorus is typically monitored in two forms: dissolved phosphorus (forms most readily used by crops as well as aquatic plants resulting in increased productivity); and total phosphorus (found in both dissolved and particulate forms). Volunteer monitoring of Squaw Creek examined dissolved orthophosphate phosphorus as determined by Chemetrics kit analyses with a range of 0 to 1.0 ppm (or 1000 ppb) of phosphate in 0.1 mg PO4/L increments. Precision and accuracy data were not analyzed. To convert the orthophosphate (PO4) to elemental orthophosphorus (P) concentrations, values are multiplied by 0.33. One more conversion was required, as most water quality criteria are expressed as total phosphorus. For this purpose, total phosphorus concentrations were assumed to be about 3 times the average dissolved phosphorus. Hence, lumping both conversions together, the original orthophosphate phosphorus concentrations measured by volunteer monitoring were estimated to be approximately equivalent to total phosphorus calculated values. Additional sampling and use of a certified laboratory will be required for more detailed comparisons.

Orthophosphate concentrations were noted to fluctuate much less than nitrate plus nitrite nitrogen, ranging from around 0.25 mg/L in Upper Squaw Creek to about 0.3 mg/L in the Squaw Creek Ames Reach. Tributary orthophosphate concentrations had a much larger range varying from lowest values observed at Scott Drainage Ditch 292 (0.108 mg/L) to typical ranges in the 0.200 to 0.300 mg/L range for most sites. The highest value was noted for the College Creek Tributary with an exceptionally high value of 2.0 mg/L.

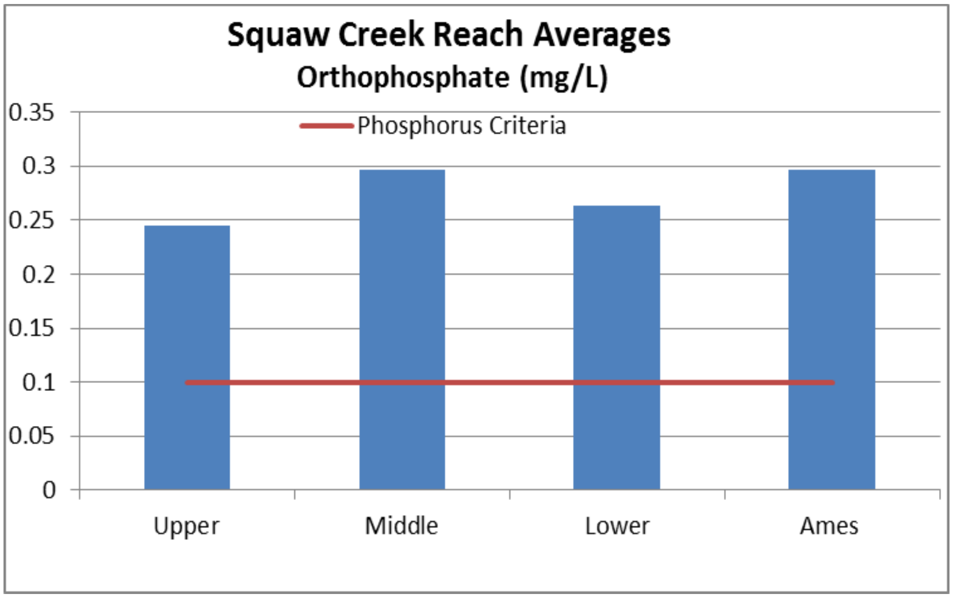

Figure 3-8. Average Orthophosphate Concentrations by Squaw Creek Mainstem Reach

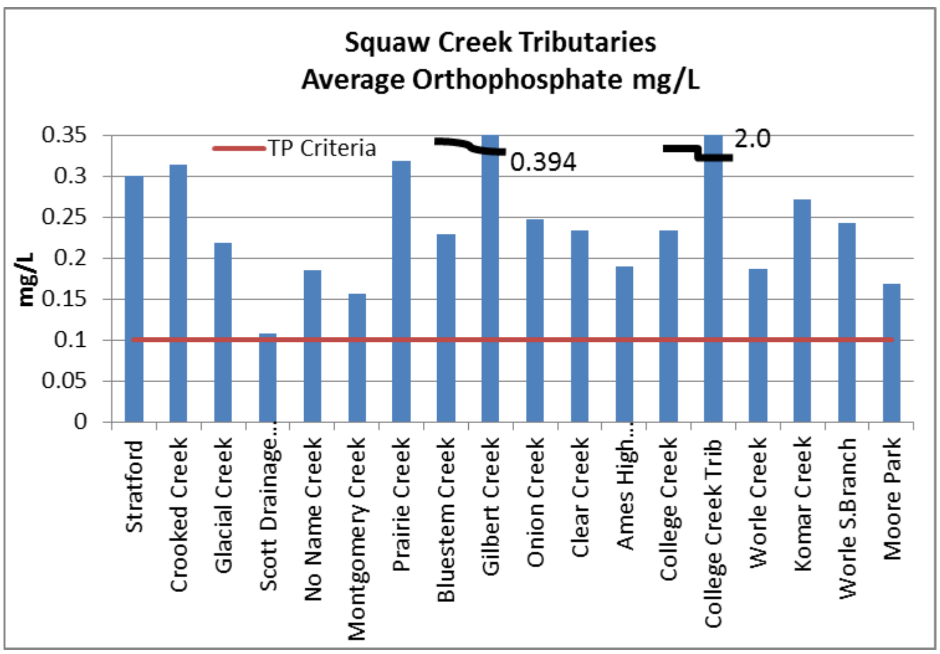

Figure 3-9. Average Orthophosphate Concentration by Squaw Creek Tributaries

The monitored orthophosphate concentrations (and generally approximately total phosphorus concentrations) for all the mainstem and tributaries exceed ecoregion derived phosphorus criteria (0.076 mg/L) and the draft State criteria of 0.1 mg/L, except for Scott Drainage Ditch 292.

3.1.7. **Transparency**

Transparency is a measure of water clarity and is affected by the amount of material suspended in water. As more material is suspended, less light can pass through, making it less transparent. Suspended materials may include soil, algae, plankton, and microbes. Transparency is measured using a transparency tube and is measured in centimeters. It is important to note that transparency is different than turbidity; transparency is a measure of water clarity measured in centimeters, while turbidity measures how much light is scattered by suspended particles using NTUs (Nephelometric Turbidity Units).

Low transparency (or high number of suspended particles) is a condition that is rarely toxic to aquatic animals, but it indirectly harms them when solids settle out and clog gills, destroy habitat, and reduce the availability of food. Furthermore, suspended materials in streams promote solar heating, which can increase water temperatures (see *Water Temperature*), and reduce light penetration, which reduces photosynthesis, both of which contribute to lower dissolved oxygen. Sediment also can carry chemicals attached to the particles, which can have harmful environmental effects. Sources of suspended particles include soil erosion, waste discharge, urban runoff, eroding stream banks, disturbance of bottom sediments by bottom-feeding fish (carp), and excess algal growth."

Transparency tube monitoring was conducted over the time 2004-2013 with average values per tributary reflecting all of the snapshot measures from January through November with more measurements typically noted for May and October during the spring and fall IOWATER statewide snapshot events (Figure 3-10). As stream flows are a dominant factor affecting erosion and runoff, higher flows (generally March through June) can be expected to be capable of carrying greater amounts of suspended materials and causing lower transparency. Squaw Creek flows are quite variable with transparency tube measurements also being highly variable. Monitoring based on storm events and peak flows (as used for defining pollutant loading) versus lower flow periods can be expected to affect average values.

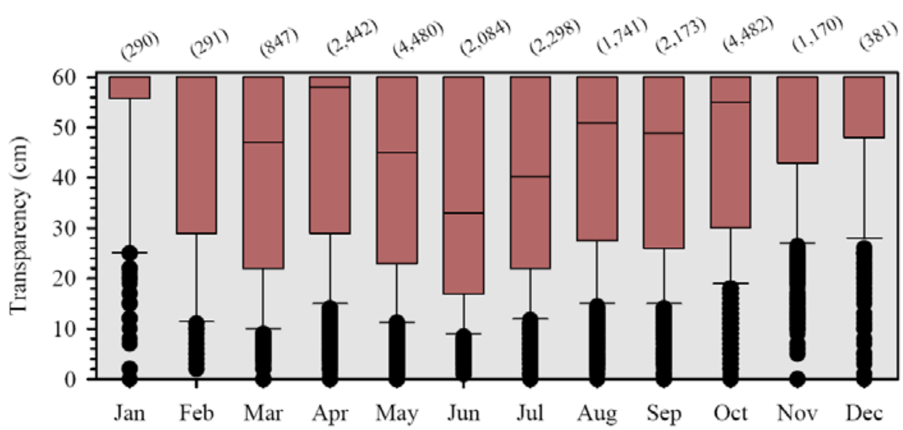

Figure 3-10. Box Plots of Statewide Transparency by Month

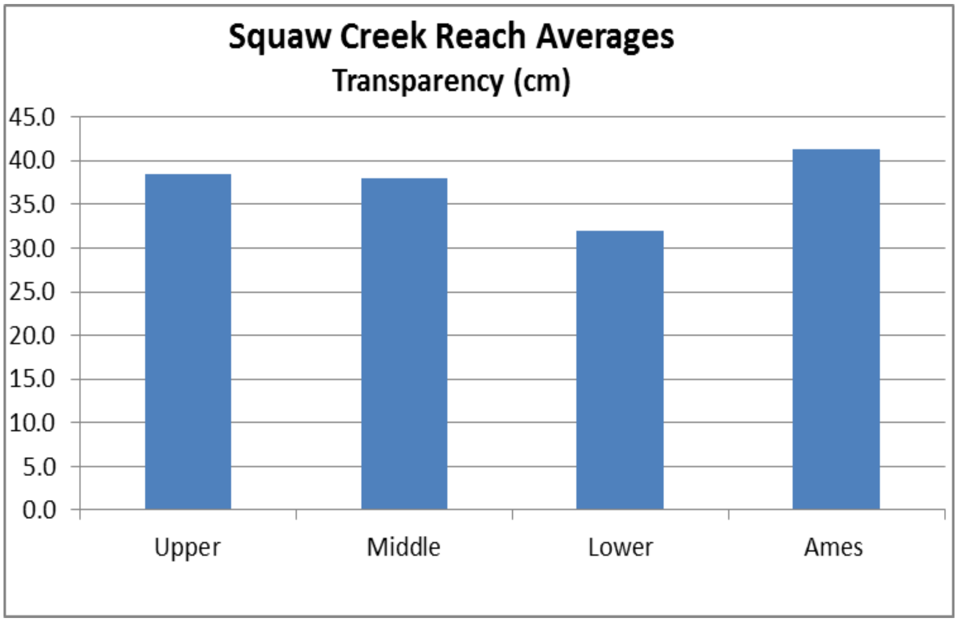

Figure 3-11. Average Transparency by Squaw Creek Mainstem Reaches

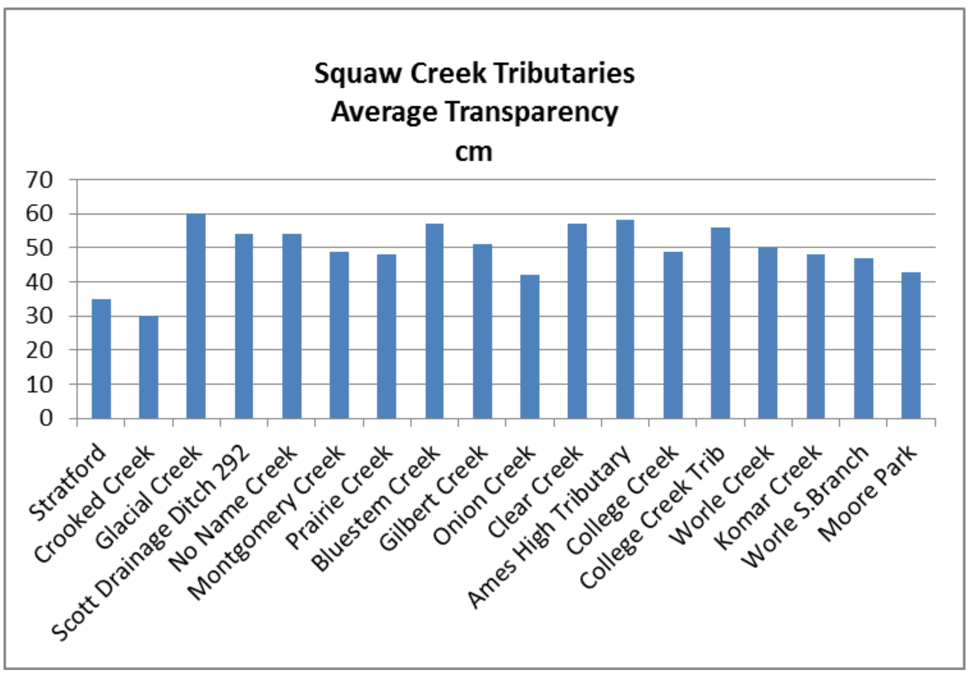

Figure 3-12. Average Transparency by Squaw Creek Tributary

3.1.8. **Chloride**

Chloride is present (generally as sodium chloride) in all natural waters, although the concentration can vary from a few milligrams per liter or less, to several thousand milligrams per liter in some ground waters. Water soluble chloride concentrations are from natural sources, industrial, municipal wastewater, septic effluent and the use of deicers applied to impervious surfaces for public safety concerns. Concentrated animal operation wastes and some agricultural inorganic fertilizers also influence chloride concentrations. Chloride concentrations in excess of 250 mg/L can be detected by taste. Iowa water quality standards for B(WW-2) waters are based on a formula with assumed hardness. The chronic and acute standards are 389 and 620 mg/L respectively.

http://www.iowadnr.gov/InsideDNR/RegulatoryWater/WaterQualityStandards/Nutrients.aspx

Average chlorides for mainstem reaches range from approximately 25-40 mg/L (Figure 3-13). All are well below the chronic standard. Tributary average chloride concentrations (Figure 3-14) generally were in the 20-40 mg/L range but Ames High Tributary and College Creek Tributary had average values of 106 and 205.6 mg/L, respectively. The lowest average concentration value of 17.6 mg/L was noted for the Stratford site. All of these averages were less than the chloride standards. However peak samples of 600 and 246 were noted for the College Creek Tributary site (2004 and 2005, respectively), suggesting that this area deserves further future examination. For this purpose, a certified laboratory should process samples including chloride, hardness and sulfate.

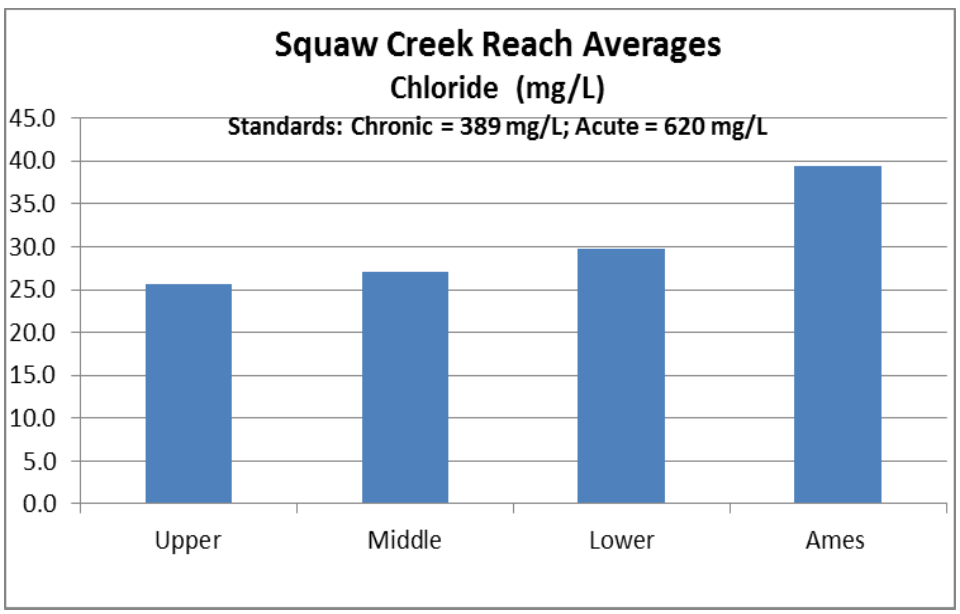

Figure 3-13. Average Chloride Concentration by Squaw Creek Mainstem Reach

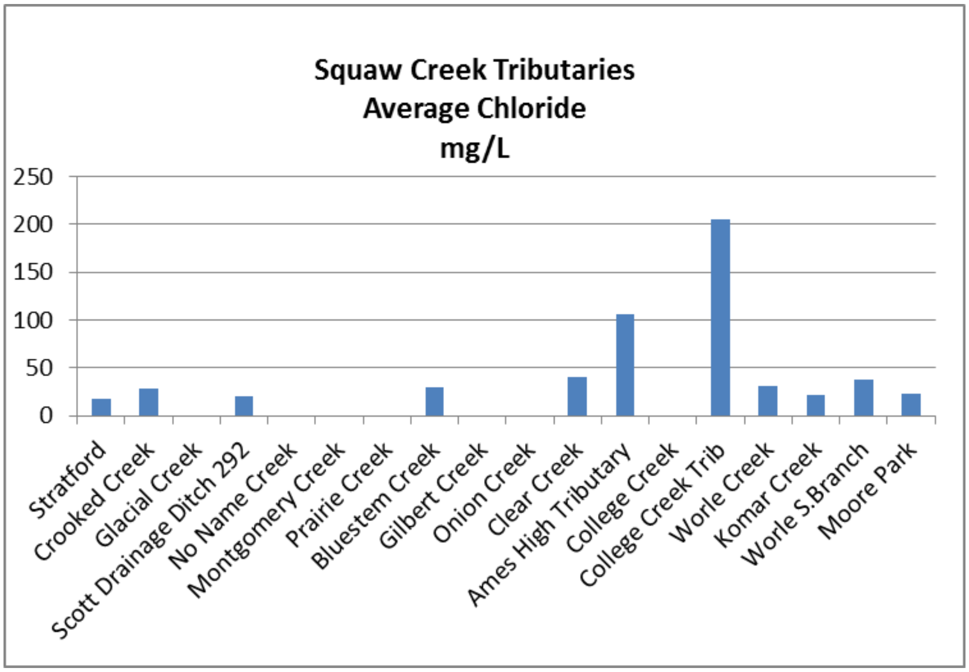

Figure 3-14. Average Chloride Concentration by Squaw Creek Tributary

3.1.9. **Dissolved Oxygen**

Iowa water quality standards for B(WW-2) waters specify a minimum dissolved oxygen value of 5.0 mg/L for at least 16 hours of every 24 hour period and a minimum value of 4.0 mg/L at any time.

Dissolved oxygen (DO) concentrations are critical for maintenance of aquatic fish and other aquatic life. DO plays an important role in the chemistry and natural degradation of pollutants in a water body and reduced DO concentrations can lead to taste and odor problems in water. DO concentrations can become very low during very high temperatures and low flow conditions, or during the fall when algae and other plants begin to die-off.

Volunteer monitoring was limited to daylight conditions when DO values are likely high. Mainstem Squaw Creek sites have a narrow range of average dissolved oxygen concentrations varying from 8.9 to 9.3 mg/L or parts per million. However, concurrently noted minimum values ranged from 4 to 6 mg/L while a maximum value of 12 mg/L was noted for each site. Tributary dissolved oxygen concentrations showed more variability with average values ranging from 6.6 mg/L to 10.3 mg/L while minimum values ranged from 1 mg/L to 6 mg/L with each station having a peak value of 12.0 mg/L. The difference between maximum and minimum dissolved oxygen concentrations is referred to as DO flux which should be about 4 mg/L or less on a daily scale. On a broader scale based on all of the data, the tributary DO flux values ranged between 4 (Scott Drainage and Crooked Creek) to 11 mg/L (College Creek) which is symptomatic of over-nutrient enriched systems. Eight of the tributaries were noted to have instantaneous minimum values of 4.0 mg/L and may violate DO standards. A closely related analyte, pH can become elevated during periods of maximum aquatic productivity resulting from enrichment.

3.1.10. **pH**

pH is an analytical term used to express the intensity of the acidity or alkalinity of a solution that varies as to water chemistry and system productivity. pH values for most aquatic systems should be around 7-8 pH units with highly productive systems having daily peak values that can be above 8.5 units (basic) from algal photosynthesis. pH is impacted by the types and concentrations of acids and bases in the water. pH affects the toxicity, reactivity, and solubility of many chemical compounds, and thus has a wide impact on the relative health of the water system.

Average pH values for the mainstem Squaw Creek sites ranged between 8.1 to 8.7 units while the tributaries had a slightly larger range of average values from 7.6 units (Stratford) to 8.7 units (Montgomery and Prairie Creeks). The range of minimum and maximum pH units per site largely reflects algal productivity with observed mainstem site values varying about 2-4 units and the tributaries having a somewhat smaller range of 1-3 units. **In conjunction with the DO values, higher pHs and pH ranges suggest elevated algal productivity within the Squaw Creek flow network.**

3.1.11. ***E. coli* Bacteria**

Water-borne pathogens include a wide variety bacteria, viruses, protozoa microorganisms such as Giardia and Cryptosporidium that are capable of producing gastrointenstinal illnesses and other symptoms that can be severe. Testing for all of the potential pathogens would be prohibitively expensive and therefore monitoring has focused on indicator organisms such as fecal coliforms and its sub-group known as Escherichia coli (*E.coli*). Bacterial levels are affected by sunlight, nutrient levels, seasonal weather, stream flows, temperatures, and distance from pollution sources such as livestock manure practices, wildlife activity, sewage overflows. Stream and pond sediments can harbor bacteria populations. These factors will vary spatially and temporally and, therefore, should be considered in sampling site selection and data interpretation. To compare values to the Iowa water quality geometric mean of 126 org/100mL, a minimum of five samples are required in a single year from March 15th to November 15th. However, stream reaches may also be listed on the 303(d) list as impaired if single samples exceed 235 org/100mL.

***E. coli* geometric means for the mainstem sites of Squaw Creek were very high and well above the state water quality standard (Figure 3-15).** Note that *E. coli* monitoring data was not available for the Lower Squaw Creek reach. Nearly half of the tributaries did not have *E.coli* data (8 out of 17 tributaries); however sites with data had a smaller range with average values ranging from 100 to 1,941 org/100 ml.

Note that the state standard for *E. coli* applies only to Class A1 Recreational Use waters so for Squaw Creek it only applies to Middle Squaw Creek, Lower Squaw Creek and Squaw Creek Ames Reach.

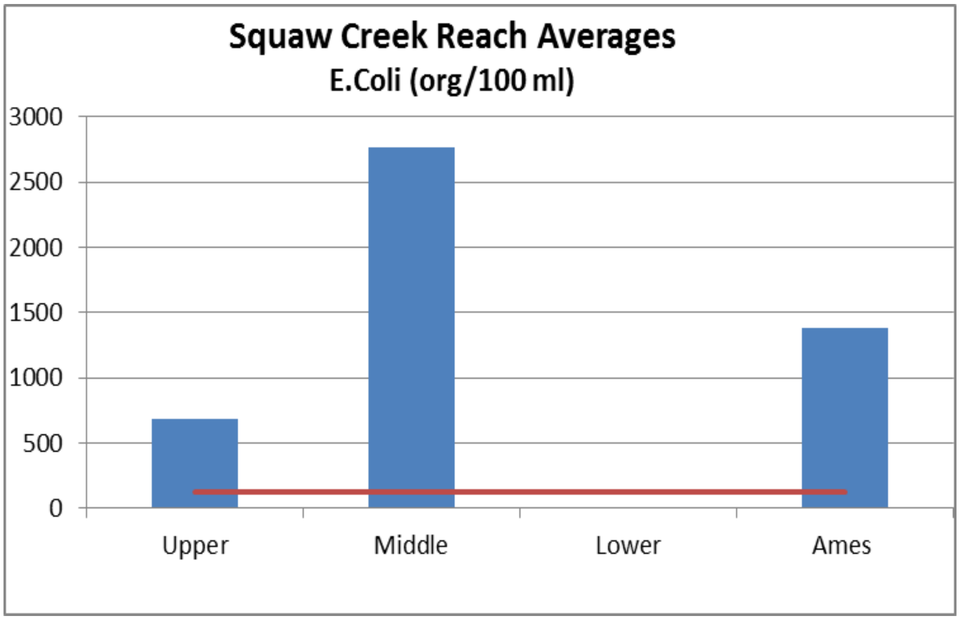

Figure 3-15. Geometric Mean *E. coli* Organism by Mainstem Reach

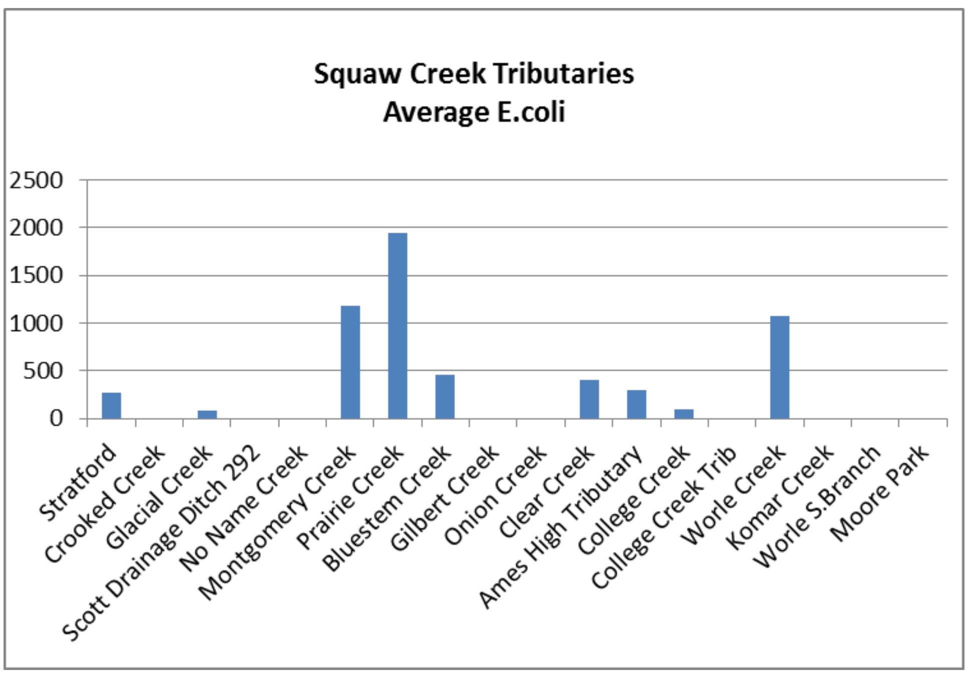

Figure 3-16. Geometric Mean of *E. coli* Organism by Squaw Creek Tributary

3.1.12. **Macroinvertebrates**

Aquatic biota can be used indicators of water quality and stream habitat. Standards have been set up for collecting and interpreting biological data used to assess stream health. Environmental stressors to stream biota include several types of factors including;

- water chemistry,
- temperature,
- dissolved oxygen,
- flow extremes,
- habitat, and
- toxins.

Standards for assessing the health of biotic communities in streams are determined at regional scales such that streams can be compared. Stream standards are set by reference reaches that support healthy aquatic communities. For Squaw Creek, Iowa IBI standards 47b (Des Moines Lobe Ecoregion) apply. A defined process is used to evaluate aquatic biotic communities to determine if a selected stream or stream reach is fully supporting the type of species and composition of species expected for a given stream type in a given location. Streams not meeting standards can be listed as “Impaired” and may trigger a more extensive study focusing on identifying the stressors to the biotic community and developing a plan for addressing the stressors and improving biotic health.

Biotic data has been collected in the Squaw Creek Watershed since 2000. These data have been collected at various locations throughout the watershed. Some sites were monitored with annual regularity and others more sporadically. Streams with a consistent, long-term, robust data record can be useful in interpreting trends, and if collected following established protocols, may be used to assess stream health against established standards. Although the available data has not been interpreted against known standards as part of this effort, it is possible to make some inferences about the relative health of streams in the Squaw Creek Watershed as well developing a list of candidate stressors that may negatively affect biotic communities. This can be accomplished by reviewing existing data and through a watershed investigation.

Squaw Creek has a reasonably robust data set that spans a 10-yr period. From the data collected it appears that during years of moderate annual flow, three key aquatic macroinvertebrate orders were consistently represented in the population. Three orders frequently used in water quality assessment include Ephemoptera (mayflies), Plecoptera (stoneflies), and Tricoptera (caddisflies). These three orders (aka “taxa”) are often referred to collectively as EPT (Table 3-8) . Note the years highlighted in red text reflect the healthiest communities and somewhat correspond with years with flows closer to the average annual (see previous flow tables).

Although the data is not conclusive, it does appear as though drought periods had a negative effect on the EPT taxa as did the extremely high flow event in 2010. In general it could be inferred that vast swings in flow is a stressor on these macroinvertebrates. This primarily stems from the habitat requirements of these that include gravel substrates (not embedded with silt), woody debris for grazing, suitable oxygen levels and good water quality. When required habitat components are missing or degraded, a negative response in population diversity and density is expected.

Table 3-8 Macroinvertebrate species presence % in stream surveys Lower Squaw Creek

Year	Number of Samples	Caddisfly	Mayfly	Stonefly
2000	1	0%	0%	0%
2001	10	20.0%	60.0%	90.0%
2002	5	20.0%	80.0%	60.0%
2003	4	0%	0%	0%
2004	7	57.1%	71.4%	100%
2005	5	100%	80.0%	100%
2006	5	100%	100%	100%
2007	1	100%	100%	100%
2008	2	100%	100%	100%
2009	7	71.4%	71.4%	71.4%
2010	1	100%	100%	100%
2011	3	0%	0%	33.3%

Looking at the monitoring results of individual streams within the watershed is more problematic than interpreting information from the more thorough Lower Squaw Creek dataset. If all data are combined, some generalizations could be interpreted for the relative health of the macroinvertebrate community for each stream. For example, Table 3-9 summarizes the number of samples taken over the 10+ years and the percentage of samples containing which taxa. Note that for the macroinvertebrate analysis only two primary reaches of Squaw Creek were used as compared to the four reaches described in the water quality analysis sections above. In this case the Lower Squaw Creek coorelates to the Ames Reach, Lower and Middle Squaw as described above.

Table 3-9. Summary of EPT taxa for biological monitoring conducted in the Squaw Creek Watershed (2001-2011)

Creek	Number of Samples	% of Samples with Tricoptera (Caddisflies)	% of Samples with Ephemoptera- (Mayflies)	% of Samples with Plecoptera (Stoneflies)
Clear Creek	10	10%	20%	0%
College Creek	33	15%	33%	9%
Lower Squaw Creek	51	45%	57%	67%
Onion Creek	11	36%	55%	27%
Upper Squaw Creek	24	33%	54%	50%
Worle Creek	8	13%	50%	50%
Grand Total	137	31%	47%	41%

From a cursory review of the table above, some conclusions may be drawn. For example Clear Creek appears to have a relatively lower representation of EPT in samples taken, however, of the 10 samples taken, the majority were taken early in the 10-yr monitoring period. As interpreted from the more thorough dataset on Lower Squaw Creek, it appears as though this time period did not support a robust EPT population. From that evidence, the health of EPT taxa on Clear Creek cannot easily be interpreted. College Creek on the other hand does have a sampling record that sufficiently spans the monitoring period and findings suggest the EPT taxa are not very consistently represented. The causal pathway resulting in poor EPT representation requires an understanding of the physical and chemical characteristics of the stream as well as its watershed. An evaluation process that carefully considers all candidate stressors and causal pathways is required.

3.2. Stream Stability

While previous sections have described the general characteristics of the watershed and the quality of water flowing within its creeks, the following section turns the focus to the health of watershed streams from a physical standpoint.

Stream geomorphology and hydrology have a direct influence on stream health and biological integrity. Streams essentially act as conveyance channels for water and sediment flowing through the watershed. Land-use and climate change have a strong influence on stream stability and water quality as described in previous sections. There have been substantial flow increases in most Iowa rivers over the past 30 years contributing to sediment loading from streambanks. The sediment that is eroded contributes to water quality degradation and in-stream aquatic life. Occasionally it can also contribute to increased water elevations downstream if sediment accumulations block conveyances or greatly reduces available storage. In the Squaw Creek watershed data suggests there is an excessive amount of sediment accumulation in the lower reaches of Squaw Creek that may be contributing to higher water levels.

In the upper part of the watershed, stream bank erosion can cause other problems as well. For example loss of farmland from bank erosion can be substantial over time. This was shown by Odgaard (1987) where he calculated that 3000 acres of farmland were lost to bank erosion along the nearby Des Moines River over a 50 year period. Although some of that land is built back via the development of point bars within the river corridor, typically those areas are too sandy and low in elevation to be usable as farmland.

3.2.1. **Past Studies**

Much of what will be described in the follow section has been derived from the following two primary studies that were conducted on Squaw Creek and its tributaries.

- Wagner, M.M. (2012). Ames Stream Assessment 2011. Ames, Iowa. Final Report, February 6, 2012.
- Wendt, A. A. (2007). Watershed Planning in Central Iowa: An Integrated Assessment of the Squaw Creek Watershed for Prioritization of Conservation Practice Establishment

The Wagner study was a quantitative analysis limited to the lower watershed (City of Ames portions of Onion Creek, Worle Creek-Squaw Creek and Lundys Creek-Squaw Creek subwatersheds). Forty-one miles of perennial streams where assessed, which includes streams outside of the study area (Ada Hayden Creek & South Skunk River). The study yielded an estimate of sediment loading (from streambanks only) and made a critical temporal comparison between 2006 & 2011 observations. The Wendt assessment covered the entire Watershed, but intentionally excluded ditches. A stream corridor assessment was conducted on randomly selected stretches of Squaw Creek and its major tributaries. Wendt utilized the Iowa Department of Natural Resource developed Rapid Assessment of Stream Condition Along Length (RASCAL) assessment protocol.

3.2.2. **Depiction of Stream Resources**

The Squaw Creek watershed contains an estimated ~290 miles of streams, most of which are smaller perennial or intermittent streams. On average about 61% of stream miles in this region are intermittent, meaning that they are dry for a period of the year.

For the purposes of understanding and communication the streams of the Squaw Creek Watershed have been defined by Stream Order. Stream Order is a hierarchy of relative stream size. Stream sizes range from the smallest, first-order, to the largest, the twelfth-order (the Mississippi River is a 10th order stream). The largest stream order within this watershed is the main stem of Squaw Creek below the Montgomery Creek confluence, which is a 4th order stream.

A portion of the lower order streams in this watershed are formally drainage ditches and/or function as drainage ditches, a percentage of which likely have intermittent flow. Squaw Creek and some if its larger tributaries do have perennial stream flow and may be able to support a variety of fish and aquatic life. See Figure 3-17 for illustration of stream order.

The Wendt (2007) study provides a general perspective of physical characteristics for Squaw Creek Watershed streams. Greater than 58% of all survey sites had sand or finer dominate streambed substrate (Table 3-10). This result is not unexpected, but of note because fine silty or sandy substrates support fewer animals, as there is less cover and reduced levels of oxygen. Additionally, fine substrate is unstable, moving around particularly during times of increased flow such as flooding and this can cause abrasive damage to animals in the waterway.

Relative streambank stability and stream health can be derived from the stream bank 1) stability, 2) % without vegetation and 3) bank height evaluations portrayed in Table 3-11

Also of note from the Wendt (2007) study was the high percentage of livestock access to streams (Table 3-12) and average poor stream condition associated with these sites.

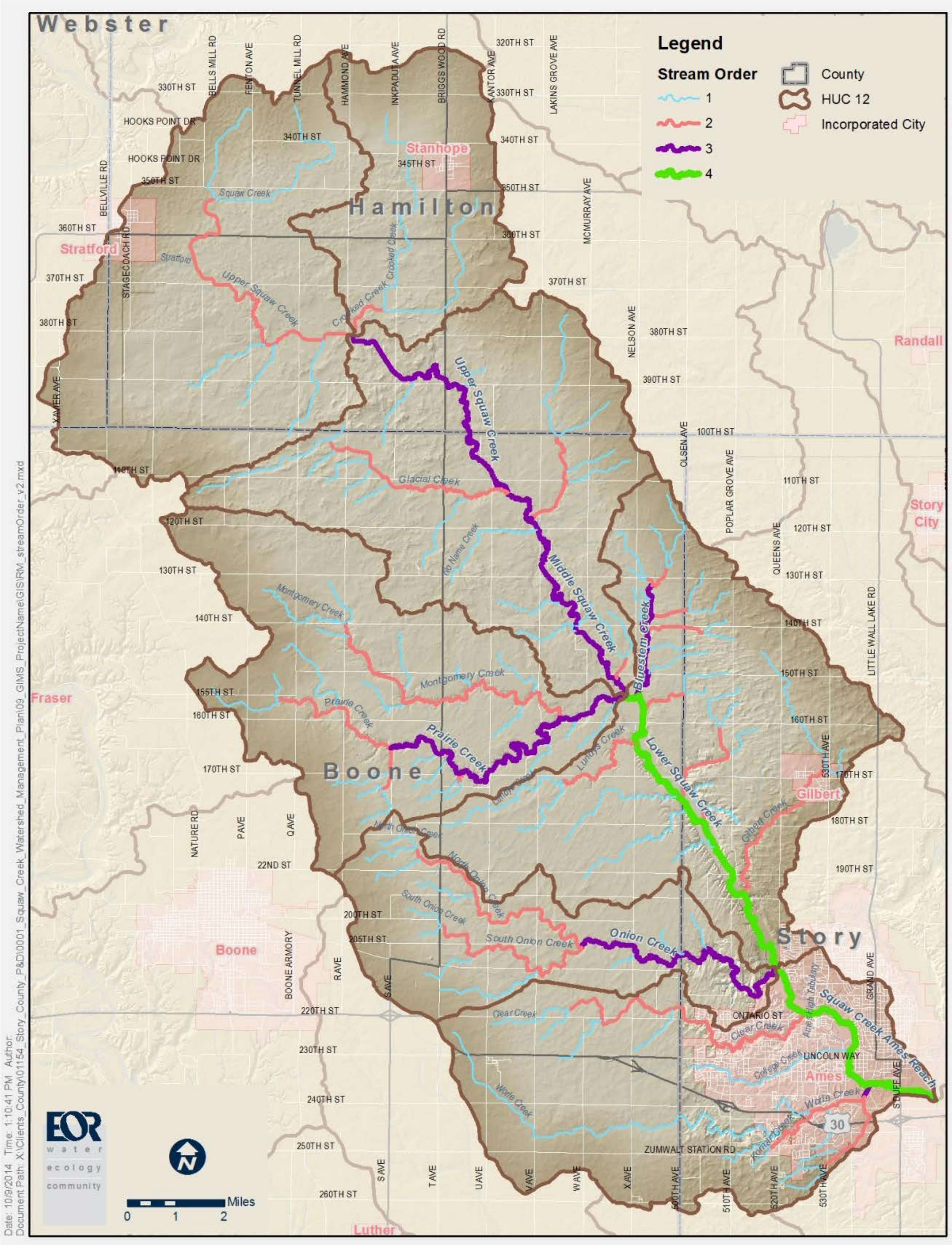

Figure 3-17. Squaw Creek Watershed illustrating Stream Order.

Table 3-10. Dominant stream substrate for all streams surveyed within the Squaw Creek Watershed by Wendt (2007); surveys were completed at 340-346 locations

Substrate	Boulder	Cobble	Gravel	Sand	Silt/clay
% of each	5	9.1	27.6	45.9	12.4

Table 3-11. Streambank condition and parameters for all streams surveyed within the Squaw Creek Watershed by Wendt (2007); surveys were completed at 340-346 locations

Bank stability	Artificially stable	Stable	Moderately Stable	Moderately Unstable	Unstable
% of surveys	1.2	11.8	48.6	29.8	8.7

% bare banks	0-20%	20-40%	40-60%	60-80%	80-100%
% of surveys	43.4	30.6	13.6	8.1	4.3

Bank height	0-3 ft	3-6 ft	6-10 ft	10-15 ft	>15 feet
% of each	8.7	74	14.5	1.4	1.4

Table 3-12. Livestock access to stream for all streams surveyed within the Squaw Creek Watershed by Wendt (2007); surveys were completed at 340-346 locations

Livestock access	Yes	No
% of each	22.3%	77.7%

3.2.3. **Stream Conditions in Squaw Creek Watershed**

The integrity of surface waters can be affected by actions on the landscape that are directly adjacent to the waterbody, or at the farthest-most up-gradient point in a watershed. In the case of the Squaw Creek Watershed the compounding hydrology manipulations and changes (e.g. direct connectivity via drainage) as well as the direct stream manipulations (e. g. ditching) have predictable impacts on the tributaries of the watershed. Watershed studies and general observations tell us that upper watershed streams are degrading (lowering of stream bed via scour) and as a result becoming isolated from the floodplain. Streams predictably respond to this unstable state and increased bank erosion occurs in an attempt to evolve to a more stable state. This increase in sediment supply has resulted in the aggradation (sediments raise the stream bed) of some downstream stream reaches. Stability conditions are exacerbated in the lower watershed streams by more impervious surfaces and more stream restrictions (i.e. crossings, bank armament, utilities, etc.).

Channel stability is an important factor determining a stream’s overall health. A stable stream is defined as one that can transport water and sediment while maintaining the channel’s width, depth, pattern, and longitudinal profile. Stable streams have predictable shapes based on their watersheds. These shapes are dynamic but their proportions stay relatively unchanged. Channel instability (excessive erosion and/or sedimentation) is more likely to be a sign of poor health and a response to stream disturbance.

Drawing on stream assessment components of the Wendt (2007) study, a general snapshot of stream health can be depicted from the bank conditions parameters of the RASCAL survey. Streambank stability is illustrated for the ~346 sites surveyed by Wendt (2007) in Figure 3-18.

More detailed data on the stability and health of stream systems within the City of Ames is available via the Wagner (2012) study. Streambank erosion potential was estimated with the Bank Erosion Hazard Index (BEHI) by Wagner (2012). BEHI is a tool originally developed by David Rosgen as a method of assessing the condition of channel banks, and their potential for erosion, as a way to inventory stream bank condition over large areas and prioritize efforts for remedial action. The system is based on assigning point values to stream segments, preferably 100 feet in length and/or 2-3 meander lengths, based upon a number of bank metrics including ratio of bank height to bankfull height, ratio of root depth to bank height, root density, surface protection, bank angle, bank materials, and stratification of bank material. Wagner collected BEHI data on 35 miles of perennial stream within the study, the results of which is illustrated in Figure 3-19.

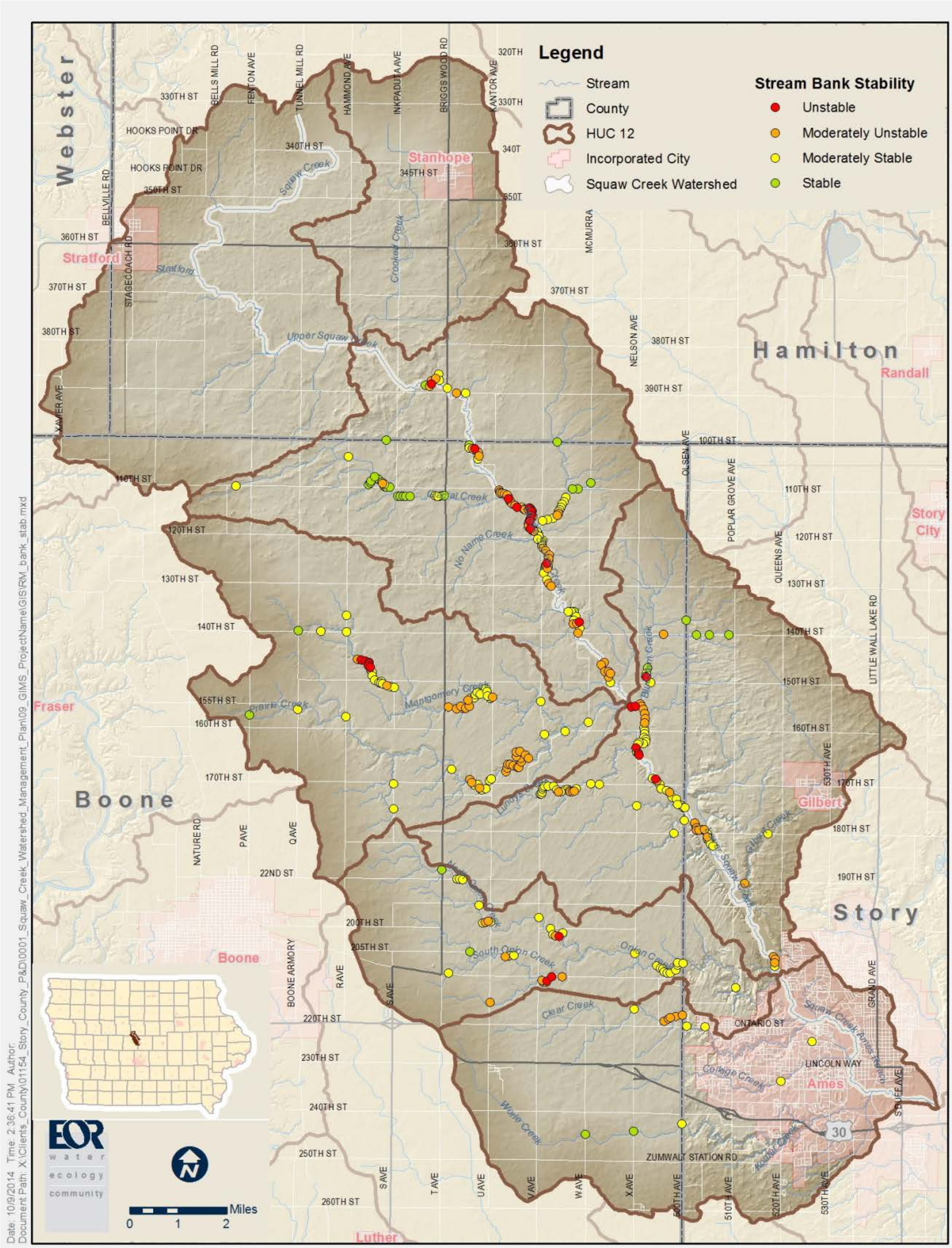

Figure 3-18. Streambank stability rating for ~346 sites surveyed; excerpt parameter from Wendt (2007)

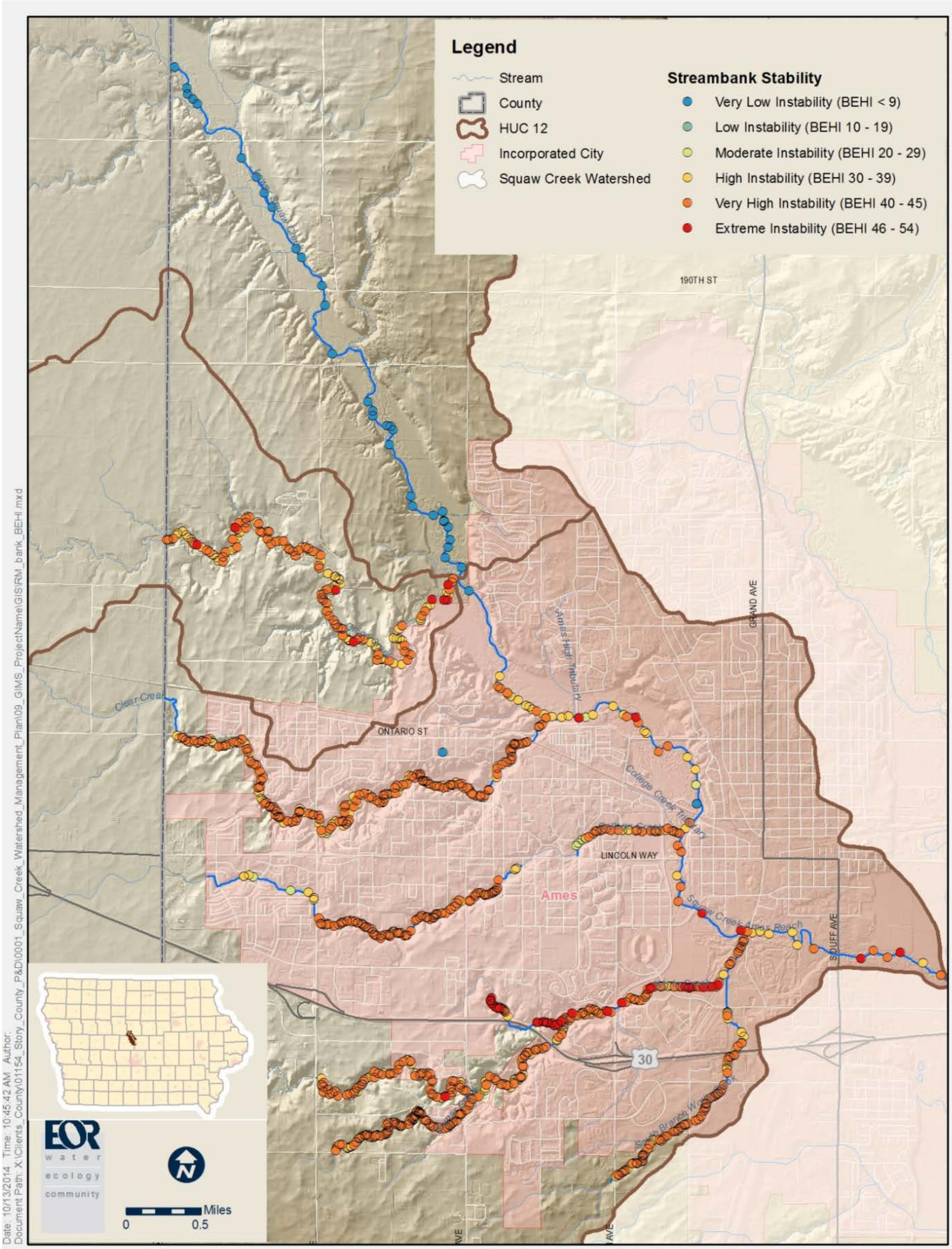

Figure 3-19. Streambank stability of Ames streams derived from Wagner (2012) Bank Erosion Hazard Index (BEHI)

Wagner (2012) also assessed and classified the Ames streams using Simon's (1989) six-stage model of channel evolution. Stream segments are reported by the dominant channel process observed: downcutting/widening, aggrading, laterally migrating or stable. Channel evolution is a conceptual model describing the relative stability or instability of stream channel segments. Stability in a channel changes based on changes in stream-edge landcover, disturbances in the channel itself or change in the nature of stormwater runoff reaching it; once a disturbance occurs, the effects on the channel stability are somewhat predictable. The current stage of evolution in a channel is useful in identifying appropriate stabilization or restoration methods. Table 3-13 summarizes the percentage of survey sites by channel stage. Of particular note are the low percentage of stable sites and the high percentage of aggrading sites. Aggradation involves the raising of the streambed elevation, an increase in width/depth ratio, and a corresponding decrease in channel capacity. Over-bank flows occur more frequently with less-than-high-water events. Excess sediment deposition in the channel and on floodplains is characteristic of the aggrading river. Often, the cause of aggradation is an increase in upstream sediment load and/or size of sediment exceeding the transport capacity of the channel. Aggradation can be a result of instability caused by over-widening of the channel with a resultant decrease in stream power and shear stress. Adverse consequences associated with aggradation include channel avulsion (complete abandonment and initiation of a new channel) and major changes in the evolution of stream types. The sediment supply and adverse effects on beneficial uses can be very high due to the corresponding adjustments of the channel.

Table 3-13. Channel stability state for streams within the City of Ames, Iowa and vicinity as assessed by Wagner (2012).

Stream name	% downcutting / widening	% aggrading	% Lateral migration moderate	% lateral migration severe	% stable
Squaw Creek	-	61	37	0	2
Onion Creek	4	18	65	4	9
Clear Creek	-	43	48	1	8
College Creek	-	9	49	17	25
Worle Creek	22	20	25	30	3

The BEHI assessment in combination with estimates of near bank shear stress (NBS) provide an estimate of sediment loading rates from streams within the City of Ames and vicinity. Based on graphs that predict lateral erosion rates from BEHI and NBS values, sediment loading was estimated at 35,000 tons of gross streambank erosion for the river reaches examined in the Wagner study area alone, not including the entire upper watershed (Table 3-14). In terms of sediment loading, streams with higher streambanks tend to contribute more sediment to the total load. In this study the mainstem of Squaw Creek had the highest streambank heights at about 10 feet. Worle Creek had the highest sediment loading rate on a per length basis (0.18 tons / linear foot / year) despite being a much smaller stream. That is because Worle Creek was assessed to be undergoing severe lateral migration over about one-third of its length.

Table 3-14. Estimates of gross bank erosion based on the Bank Erosion Hazard Index (BEHI) and near bank shear stress (NBS) for streams within the City of Ames, Iowa and vicinity (not accounting for sediment deposited in the stream) from Wagner 2012

Stream name	2011 estimated gross stream bank erosion (tons)	Length of stream surveyed (miles)	loading of sediment by stream banks (Tons/yr/linear ft)
Lower Squaw Creek	8044	9.78	0.16
Onion Creek	3528	4.5	0.15
Clear Creek	3889	5.25	0.14
College Creek	2526	4.4	0.11
Worle Creek	9353	9.75	0.18
TOTALS	28,340	35.11	0.15 (avg)

A substantial percentage of the sediment supply likely originates upstream of the area investigated by Wagner (north of Ames). However, data does not exist to specifically quantify. Coarse estimates can be made by extrapolating existing data from the Worle Creek subwatershed. Using an estimated 180 miles of streams in the watershed reported by Wendt (2007), assuming moderate BEHI and NBS scores with the bank heights in the range of 3-10 feet, a gross annual streambank erosion estimate of 133,000 tons/year is obtained.

Moving into the downstream reaches of Squaw Creek there appears to be considerable deposition of sediment occurring below the Drainage Ditch 70 confluence. Wagner found that 61% of the 9.78 miles of Squaw Creek surveyed were aggrading or accumulating sediment within the channel (Table 3-13). It is possible that much of the sediment mobilized from upstream areas in the large flood of 2010 were carried downstream and deposited in the lower reaches of Squaw Creek. In-stream sediment aggradation can be problematic in that it can increase lateral migration next to areas of sediment deposits. It can also lead to flooding issues if channel capacity is reduced by making the channel shallower. Over time the channel could cut through and/or transport these deposits depending on future stream flow and sediment load levels.