

## Table of Contents

Executive Summary.....	10
1. Introduction .....	12
1.1. Watershed Management Authority.....	12
1.2. Acknowledgements.....	14
1.3. Plan Development Process .....	14
2. Watershed Characterization .....	15
2.1. Hydrology.....	15
2.1.1. Subwatersheds.....	16
2.1.2. Hydrologic Model Drainage Areas .....	18
2.1.3. Stream Reaches.....	20
2.2. Watershed Topography .....	20
2.3. Land Cover/Land Use .....	22
2.4. Climate .....	25
2.4.1. Temperature .....	25
2.4.2. Rainfall .....	26
2.4.3. Storm Intensities and Rainfall Amounts .....	27
2.4.4. Wet Periods.....	28
2.4.5. Growing Season Length .....	28
2.4.6. Evaporation.....	29
2.4.7. Severe Weather .....	29
2.4.8. Variable and Changing Climate.....	30
2.5. Soils .....	30
2.6. Groundwater.....	32
2.6.1. Surficial Hydrogeology .....	32
2.6.2. Bedrock Hydrogeology.....	35
3. Stream Health .....	38
3.1. Stream Water Quality .....	38
3.1.1. Water Classification and Designated Uses.....	39
3.1.2. Applicable Water Quality Standards and Criteria .....	42

- 3.1.3. Stream Flows..... 44
- 3.1.4. Water Quality Monitoring..... 49
- 3.1.5. Nitrogen ..... 52
- 3.1.6. Phosphorus ..... 54
- 3.1.7. Transparency..... 56
- 3.1.8. Chloride ..... 58
- 3.1.9. Dissolved Oxygen ..... 59
- 3.1.10. pH ..... 60
- 3.1.11. *E. coli* Bacteria ..... 60
- 3.1.12. Macroinvertebrates ..... 62
- 3.2. Stream Stability ..... 64
  - 3.2.1. Past Studies ..... 64
  - 3.2.2. Depiction of Stream Resources..... 65
  - 3.2.3. Stream Conditions in Squaw Creek Watershed ..... 67
- 4. Pollutant Sources ..... 73
  - 4.1. SWAT Modeling..... 73
    - 4.1.1. Priority Source Areas: Volume, Sediment, Phosphorus, Nitrate ..... 74
  - 4.2. Bacteria Source Assessment ..... 80
    - 4.2.1. Humans ..... 81
    - 4.2.2. Livestock..... 82
    - 4.2.3. Wildlife ..... 83
    - 4.2.4. Pets..... 84
    - 4.2.5. Priority Bacteria Source Areas ..... 84
- 5. Goals and Objectives..... 88
  - 5.1. Increase people’s awareness and understanding of the individual connections and efforts within the watershed..... 89
  - 5.2. Improve water quality in the watershed. .... 90
  - 5.3. Reduce the effects associated with altered hydrology (heavy flows, diminished base flow) within the watershed..... 92
  - 5.4. Increase the variety of habitat for animal and plant life in the watershed..... 94
  - 5.5. Create outstanding recreational opportunities in the watershed..... 95

5.6. Work cooperatively to identify stakeholders and resources and facilitate partnerships to implement the watershed plan. .... 96

6. Implementation Strategies ..... 97

6.1. Education/Outreach Strategies..... 98

6.2. Strategies for Improving Water Quality..... 101

6.2.1. Introduction and Approach..... 101

6.2.2. Best Management Practice Selection ..... 103

6.2.3. BMP Performance ..... 109

6.2.4. BMP Costs ..... 110

6.2.5. Terrain Suitability ..... 112

6.2.6. BMP Scenarios and Reduction Results..... 113

6.2.7. Streambank Erosion Load ..... 120

6.2.8. Priority Bacteria Reduction Strategies ..... 121

6.3. Hydrology Strategies ..... 123

6.3.1. Background on Restoring Natural Hydrology in a Watershed..... 123

6.3.2. Recommended Approach for Restoring Hydrology ..... 124

6.4. Habitat Improvement Strategies ..... 126

6.5. Stream Restoration/Recreational Enhancement Strategies..... 127

6.5.1. General Strategies for Restoring Streams..... 127

6.5.2. Specific Stream Protection and Restoration Approaches ..... 128

6.5.3. Strategies to Enhance Recreational Opportunities..... 131

6.6. Strategies for Facilitating Partnerships ..... 132

7. Monitoring Plan ..... 134

7.1. Flows ..... 134

7.2. Pollutant Concentrations ..... 134

7.3. Bacteria (*E.coli*) Monitoring ..... 135

7.4. Biological Monitoring..... 135

7.5. Compiling the Data and Calculating Loads..... 135

7.6. Future Phased Monitoring Approach: ..... 136

8. Funding Sources..... 137

Appendix 1: Squaw Creek WMA 28E Agreement ..... 140

Appendix 2: Listening Session Input ..... 149

Appendix 3: Recreational Use Assessment and Attainability Analysis ..... 155

Appendix 4: Agricultural Conservation Planning Framework Findings..... 159

    Crooked Creek Subwatershed ACPF Findings ..... 160

    Drainage Ditch 192-Squaw Creek Subwatershed ACPF Findings..... 165

    Montgomery Creek Subwatershed ACPF findings ..... 171

    Crooked Creek-Squaw Creek Subwatershed ACPF Findings..... 176

    Onion Creek Subwatershed ACPF Finding ..... 181

    Lundy’s Creek – Squaw Creek Subwatershed ACPF Findings..... 186

    Worle Creek Squaw Creek Subwatershed ACPF Findings..... 191

## Table of Figures

Figure 1-1. Political Subdivisions within the Squaw Creek Watershed.....	13
Figure 1-2. Listening Session in Stanhope, IA .....	14
Figure 2-1. Squaw Creek Watershed Hydrologic Setting .....	15
Figure 2-2. Squaw Creek Subwatersheds.....	18
Figure 2-3. Watershed Model Drainage Areas and Stream Reaches.....	19
Figure 2-4. Slopes within the Squaw Creek Watershed.....	21
Figure 2-5. High Resolution Land Cover Squaw Creek Watershed 2009 .....	23
Figure 2-6. Land Use Squaw Creek Watershed.....	24
Figure 2-7. Average monthly climate data for Ames, IA. NOAA’s Midwestern Regional Climate Center ..	25
Figure 2-8. Annual Average Maximum Temperature 1970-2013, Ames IA.....	26
Figure 2-9. Annual Average Minimum Temperature 1970-2013, Ames IA .....	26
Figure 2-10. Annual Precipitation 1970-2013, Ames IA.....	27
Figure 2-11. Growing Season (May-Sept) Precipitation 1970-2013, Ames IA .....	27
Figure 2-12. Growing Season Length 1970-2013.....	29
Figure 2-13. Soils by Hydrologic Soil Class .....	31
Figure 2-14. Surficial Aquifers .....	33
Figure 2-15. Depth to Groundwater .....	34
Figure 2-16. Uppermost Bedrock.....	37
Figure 3-1. Squaw Creek at Ames, IA (USGS Station 05470500) Annual Average Flows.....	44
Figure 3-2. 2000-2013 Annual Average Flows at Ames, IA.....	45
Figure 3-3. Squaw Creek (Ames, IA) average monthly flows (cubic feet per second).....	46
Figure 3-4. 2003-2013 Daily Flows in cfs for Squaw Creek (USGS 05470500) at Ames, IA.....	47
Figure 3-5. Squaw Creek annual peak flows in cfs for USGS (Station 05470500).....	48
Figure 3-6. Average Nitrate + Nitrite Nitrogen Concentrations by Squaw Creek Mainstem Reach .....	53
Figure 3-7. Average Nitrate + Nitrite Nitrogen Concentrations by Squaw Creek Tributaries.....	53
Figure 3-8. Average Orthophosphate Concentrations by Squaw Creek Mainstem Reach .....	55
Figure 3-9. Average Orthophosphate Concentration by Squaw Creek Tributaries .....	55
Figure 3-10. Box Plots of Statewide Transparency by Month.....	56
Figure 3-11. Average Transparency by Squaw Creek Mainstem Reaches .....	57
Figure 3-12. Average Transparency by Squaw Creek Tributary.....	57
Figure 3-13. Average Chloride Concentration by Squaw Creek Mainstem Reach.....	58
Figure 3-14. Average Chloride Concentration by Squaw Creek Tributary .....	59
Figure 3-15. Geometric Mean <i>E. coli</i> Organism by Mainstem Reach .....	61
Figure 3-16. Geometric Mean of <i>E. coli</i> Organism by Squaw Creek Tributary .....	61
Figure 3-17. Squaw Creek Watershed illustrating Stream Order. ....	66
Figure 3-18. Streambank stability rating for ~346 sites surveyed; excerpt parameter from Wendt (2007) .....	69
<b>Figure 3-19.</b> Streambank stability of Ames streams derived from Wagner (2012) Bank Erosion Hazard Index (BEHI).....	70
<b>Figure 4-1.</b> SWAT Model Flow by Drainage Area (inches/year) .....	76

Figure 4-2. SWAT Model Nitrate Load by Drainage Area (lbs/acre per year) ..... 77

Figure 4-3. SWAT Model Phosphorus Load by Drainage Area (lbs/acre per year) ..... 78

Figure 4-4. SWAT Model Sediment Load by Drainage Area (tons/acre per year) ..... 79

Figure 4-5. Relative bacteria load by source in each subwatershed ..... 85

Figure 4-6. Bacteria sources in the Squaw Creek Watershed..... 86

Figure 4-7. Manure Management Priority Areas ..... 87

Figure 6-1. BMP scenario reduction analysis procedure for HUC-12 subwatersheds ..... 113

Figure 6-2 Changes in hydrology associated with land use changes ..... 123

Figure 6-3. Priority Stream Restoration Sites..... 130

Figure 7-1 Visualization of water quality over course of storm event..... 135

**Table of Tables**

Table 1-1. Membership of the Squaw Creek Watershed Management Authority..... 12

Table 2-1. Subwatersheds of the Squaw Creek Watershed..... 16

Table 2-2. Land Use of the Squaw Creek Watershed..... 22

Table 2-3. The Aquifers and Rocks of Central Iowa (Twenter and Coble, 1965) ..... 35

**Table 3-1.** Iowa Integrated Report Categories for stream designated use and assessed reaches in the Squaw Creek Watershed..... 41

Table 3-2. Water Quality Criteria for Ecoregion VI, stream use classes A1 and B (WW-2) ..... 43

Table 3-3. Squaw Creek At Ames, IA, frequency of annual average flows by percentile for 1970-2013 (USGS Station 05470500)..... 45

Table 3-4. Monthly Stream Flows USGS Gage Station, Ames IA..... 46

Table 3-5. Squaw Creek gage locations ..... 48

Table 3-6. Average Monitored Concentrations for Squaw Creek Mainstem Reaches ..... 50

Table 3-7. Average Monitored Concentrations and Number of Samples for Squaw Creek Tributaries by Subwatershed ..... 51

Table 3-8 Macroinvertebrate species presence % in stream surveys Lower Squaw Creek..... 63

Table 3-9. Summary of EPT taxa for biological monitoring conducted in the Squaw Creek Watershed (2001-2011)..... 63

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..... 67

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..... 67

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..... 67

Table 3-13. Channel stability state for streams within the City of Ames, Iowa and vicinity as assessed by Wagner (2012). ..... 71

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 ..... 72

Table 4-1. Data sources used by the SWAT watershed model ..... 74

Table 4-2 Range of Values for Low/Medium/High Ranking for Figures .....	74
Table 4-3. Bacteria production by source .....	80
Table 4-4. WWTP design flows and permitted bacteria loads.....	81
Table 4-5. Estimates of rural population based on 2010 Census data and ITPHS population in each subwatershed .....	82
Table 4-6. Livestock summary results by subwatershed in animal units.....	83
Table 4-7. Deer bacteria estimates by subwatershed .....	83
Table 4-8 Pet bacteria estimates by subwatershed.....	84
Table 5-1 Range of Standards/Criteria for Nutrients.....	91
Table 6-1. Selected BMPs, estimated reductions per unit area and costs .....	111
Table 6-2. Illustrative compilation of maximum application of each Ag BMP as physically feasible, excluding interactions between BMPs.....	116
Table 6-3. Approach to Meet Squaw Creek WMA Nutrient Reduction Objectives .....	119
Table 6-4. Volume control effectiveness of potential BMPs .....	125
Table 6-5. Stream sites prioritized for protection/enhancement efforts.....	128
Table 6-6. Stream sites prioritized for restoration efforts.....	129