SECTION 20 COMPLIANCE ANALYSIS FOR CBNG PRODUCED WATER DISCHARGES TO FORTIFICATION CREEK, CAMPBELL COUNTY, WYOMING

KC HARVEY

Soil & Water Resource Consulting

AN ENERCREST COMPANY

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EXECUTIVE SUMMARY

- This report presents a Section 20 "Tier 2" assessment of soils and the potential impacts to downstream agricultural uses on Fortification Creek from the proposed discharge of coalbed natural gas (CBNG) produced water to the Fortification Creek watershed in Campbell County, Wyoming.

- A field investigation was conducted on the Hayden Ranch; four fields along Fortification Creek were sampled for this assessment.

- In the Fortification Creek fields, average soil ECe values, to a depth of 48 inches, range from 3.1 to 15.9 dS/m and average ESP levels, to a depth of 48 inches, range from 2.8 to 15.5 %.

- Based on the soil salinity of the fields sampled, the estimated long-term average EC of Fortification Creek water is 5.3 dS/m.

- An end-of-pipe EC limit of 5.3 dS/m will cause no harm to existing agricultural uses on Fortification Creek.

- In addition to an end-of-pipe EC limit, an irrigation monitoring point (IMP) should be established; target water quality values at the IMP would be an EC of 5.3 dS/m and a corresponding maximum SAR value that would remain within the "no reduction in rate of infiltration" zone on Figure 1 of Hanson et al. (1999).

- The discharge of CBNG produced water to the Fortification Creek watershed in accordance with the proposed effluent limits and IMP standards is not expected to result in a measurable decrease in crop or livestock production, and would therefore be compliant with Chapter 1, Section 20 of the Wyoming Water Quality Rules and Regulations.

1.0 INTRODUCTION

This report presents a Section 20 "Tier 2" assessment of soils and the potential impacts to downstream agricultural uses on Fortification Creek from the discharge of coalbed natural gas (CBNG) produced water to Fortification Creek in Campbell County, Wyoming. This assessment was conducted for Williams RMT Production Company (Williams). The purpose of this evaluation is to demonstrate whether the produced water discharge will be in compliance with Chapter 1, Section 20 of the Wyoming Water Quality Rules and Regulations, which state:

> *All Wyoming surface waters that have the natural water quality potential for use as an agricultural water supply shall be maintained at a quality that allows continued use of such waters for agricultural purposes. Degradation of such waters shall not be of such an extent to cause a measurable decrease in crop or livestock production. Unless otherwise demonstrated, all Wyoming surface waters have the natural water quality potential for use as an agricultural water supply.*

This report includes an evaluation of land owned by the Doyle G. Hayden Revocable Trust dated July 31, 1997 and Lora Amie Hayden Revocable Trust dated July 31, 1997, along Fortification Creek. Four naturally irrigated fields were investigated (Figure 1). The sampled fields were identified using color infrared photography and field observations. While CBNG produced water has been discharged since 1999 in the Fortification Creek watershed, the fields investigated as part of this analysis are considered to have had minimal contact with the produced water. CBNG produced water has been contained in reservoirs in the headwaters of Fortification Creek and Carr Draw with full use and management of the water by the surface landowners (Love Land and Cattle, and Doyle G. Hayden Revocable Trust dated July 31, 1997 and Lora Amie Hayden Revocable Trust dated July 31, 1997, respectively). Landowners currently use the produced water for livestock watering. If any produced water has been released down the drainage, the release would have occurred only during overtopping of a reservoir during a storm event.

Regulatory guidance for conducting the following Section 20 analysis is based on the information requirements stipulated in Item 23 of the Wyoming DEQ WYPDES Application for Permit to Surface Discharge Produced Water from Coal Bed Methane New Discharges, Renewals, or Major Modifications, revised June 22, 2006, and the current draft Section 20 Agricultural Use Protection Policy (WYDEQ, 2007). Using a Tier 2 – Background Water Quality Analysis, this report recommends maximum EC effluent

limits that will cause no harm to the existing irrigation uses. To accomplish this, a certified professional soil scientist and range specialist from KC Harvey, Inc. conducted a site investigation of four fields along Fortification Creek that included soil sampling and analysis, and vegetation characterization.

The main body of this report is comprised of four sections, including this introduction (Section 1). Section 2 describes the baseline hydrologic, soil, and vegetation conditions that are representative of the naturally irrigated fields in the Fortification Creek watershed. Section 3 provides an estimate of the long-term average water quality in Fortification Creek and proposed effluent limits and irrigation monitoring point standards that are protective of the downstream irrigation uses. References cited throughout the report are provided in Section 4. Tables, figures, and appendices are located at the end of this report.

2.0 BASELINE CONDITIONS

2.1 HYDROLOGIC CONDITIONS

2.1.1 Hydrology and Irrigation Uses

The proposed CBNG produced water discharges will occur to Fortification Creek and its tributaries in Campbell County, Wyoming (Figure 1). Fortification Creek flows northwest, into Johnson County, where it converges with the Powder River. Fortification Creek and its tributaries are considered ephemeral; natural flow occurs periodically in response to rainfall and snowmelt events.

Based on a search of the Wyoming State Engineer's Office water rights database, there are no permitted irrigation diversions on Fortification Creek. The fields on the Hayden Ranch may be naturally irrigated. Actual natural irrigation could not be confirmed at the sites due to the time sampling occurred. However, based on aerial photography and the site visit, natural irrigation is highly probable in the areas sampled. Access to other potential naturally irrigated fields in the Fortification Creek drainage was not possible, either because of landowner access issues or high water levels at the Powder River crossing. For the purposes of this report, downstream agricultural use consists of natural irrigation and livestock water use.

2.1.2 Surface Water Quality

Historic surface water quality data are not available for the Fortification Creek drainage.

2.2 SOIL CONDITIONS

Four fields along Fortification Creek were investigated to document current soil conditions and vegetation characteristics (Figure 1). The Hayden 9 field is located in Section 9; the Hayden 23 field is located in Sections 14 and 23; the Hayden 25 field is located in sections 23, 25 and 26; and, the Hayden Carr Draw field is located in Section 25 (Figure 1). All fields are located in Township 51 North, Range 76 West.

2.2.1 NRCS Soil Mapping Units

Soils bordering Fortification Creek have been mapped by the Natural Resources Conservation Service (NRCS, 2003) as the Haverdad-Boruff Complex, 0 to 3 percent slopes. The official NRCS descriptions for the Haverdad and Boruff soil series are included in Appendix A along with reported soil chemical data (National Cooperative Soil Survey, 2002 and 2003; Natural Resources Conservation Service, 2003).

Haverdad soils are very deep, well-drained soils that formed in stratified alluvium on flood plains and low terraces. Textures range from sandy loam to clay loam; clay content ranges from 18 to 35 percent. Haverdad soils generally have mixed clay mineralogy. Soil electrical conductivity ranges from 0 to 4 dS/m throughout the profile; the sodium adsorption ratio (SAR) varies between 0 and 5. Haverdad soils receive an average of 11 inches of precipitation per year, with over half the precipitation occurring in late spring and early summer. Permeability ranges from 0.60 to 2.0 inches per hour. Flooding on Haverdad soils occurs for brief periods during spring runoff and after thunderstorms. These soils are typically used for grazing with principal native vegetation being big sagebrush, western wheatgrass, greasewood, and annual grasses and forbs (National Cooperative Soil Survey, 2002; Natural Resources Conservation Service, 2003).

Boruff soils are described as very deep, poorly and somewhat poorly drained soils formed in alluvium on flood plains and low stream terraces. Textures range from loam to clay, with clay fractions ranging from 35 to 60 percent. Thin, stratified layers of sandier material are commonly found in the subsurface horizons. Permeability ranges from 0.06 to 0.20 inches per hour. Boruff soils have a smectitic mineralogy class. Soil EC levels range from 0 to 4 dS/m in the surface horizons, and from 2 to 8 dS/m in the subsurface horizons. The average exchangeable sodium percentage (ESP) ranges from 0 to 10 percent, with some subsurface horizons having ESP values in excess of 10 percent. Boruff soils receive an average of 14 inches of precipitation annually, half of which falls as rain or snow from March through June. Flooding occurs for very brief or brief periods during prolonged, high intensity storms in the spring and early summer. Boruff soils are primarily used as rangeland and wildlife habitat with principal native vegetation being green needlegrass, bearded wheatgrass, slender wheatgrass, western wheatgrass,

cottonwoods, Indian saltgrass, alkai sacaton, sedges, and willows (National Cooperative Soil Survey, 2003).

2.2.2 Soil Sampling and Analysis Methods

A certified professional soil scientist from KC Harvey, Inc. conducted a soil investigation of the four Fortification Creek fields on June 27, 2007. Soil samples were collected from seven locations within each of the investigated fields. Each sample location was marked using a handheld global positioning system (GPS) unit (Figures 2, 3, 4 and 5). Soil samples were collected using a truck-mounted Giddings Probe (Giddings Machine Company, Windsor, Colorado). At each sample location, soil samples were collected from five depth increments: 0 to 12, 12 to 24, 24 to 36, 36 to 48 and 48 to 60 inches. Samples were composited by depth for a total of five samples per field. Samples were delivered to Energy Laboratories, Inc., Helena, Montana for analysis of pH, electrical conductivity (EC), dissolved calcium, dissolved magnesium, dissolved sodium, sodium adsorption ratio (SAR), saturation percentage, exchangeable sodium, cation exchange capacity (CEC), exchangeable sodium percentage (ESP), texture (percent sand, silt, and clay), percent lime, percent organic matter and clay mineralogy (0 to 12 inch samples only). Results of the physical and chemical soil analyses from the Fortification Creek fields are summarized in Tables 1 and 2. The original laboratory reports are provided in Appendix B.

2.2.3 Soil Physical Conditions

Soil physical properties affect aeration rates, water infiltration, water storage, and movement of water through the soil profile. The soil texture at the Hayden 9 and Hayden 23 fields is silty clay loam to a depth of 60 inches (Table 1). In the Hayden 25 field, soil textures include silty clay loam and clay loam to a depth of 60 inches (Table 1). Soil texture in the Hayden Carr Draw field, to a depth of 60 inches, is clay loam (Table 1). Clay contents in the four Fortification Creek fields range from 27 to 36 % in all depths sampled (Table 1). Compared to other soils in the Powder River Basin, the clay contents found in the soils at the Fortification Creek fields are considered typical.

The effects associated with sodic irrigation water may depend upon the clay mineralogy of the soil. The clay mineralogy of the Fortification Creek surface soil samples (0 to 12 inches) was analyzed using X-ray diffraction (XRD). Smectite composes 24 to 38 % of the clay fraction; followed closely by illite and kaolinite, which range from 27 to 38 % and 30 to 38 %, respectively (Table 1). Smectitic clays are 2:1 clays that expand upon wetting and shrink after drying. The degree of swelling may increase when sodic waters are applied to such clays. Non-expanding clays, such as illite and kaolinite, are less likely to be affected by sodic waters. Contrary to NRCS soil survey information for these areas (NRCS, 2003), the soils examined within the four Fortification Creek fields exhibit a mixed clay mineralogy, without a dominant mineral type.

Percent organic matter in the soil samples ranges from 1.7 to 3.8 % (Table 1), which is considered typical for Powder River Basin soils.

2.2.4 Soil Chemical Properties

Soil pH

Soil pH is perhaps the most important chemical characteristic of the soil and indicates the intensity of the acidic or basic condition of the soil. Soil pH serves as a general index to the availability of plant nutrients, potential toxicity problems, and sodic soil conditions. A soil pH of 6.5 to 8.4 is ideal for most range plants. As the soil pH increases above or decreases below this range, the availability of phosphorus, calcium, magnesium, iron, manganese, zinc, copper, cobalt, and boron may become limiting to plants. In the Fortification Creek soil samples, soil pH ranges from 7.0 to 8.1 to a depth of 60 inches (Table 2).

Soil Salinity

Soil salinity is simply the amount of soluble salts in a soil, and is measured by the electrical conductivity of the saturated paste extract (ECe). The salinity of a soil is important because high salt levels make it difficult for plants to obtain water (Bohn, et al., 1985). Saline soils are conventionally defined as having ECe values of greater than 4 dS/m, however sensitive plants can be affected at 2 dS/m and more tolerant plants (e.g., many of the native species of the Powder River Basin) are productive at ECe levels greater than 8 dS/m. In the arid western United States, naturally occurring saline soils are more common because arid regions are subject to high evaporation rates, thus allowing salt concentration to occur (Soil Improvement Committee, California Plant Health Association, 2002).

Soil sample ECe ranged from 1.1 to 21.2 dS/m in all depth increments (0 to 60 inches) within the Fortification Creek fields (Table 2). With the exception of the Hayden Carr Draw field, these values are comparable to those reported by the NRCS for the Haverdad, and Boruff soil series (National Cooperative Soil Survey, 2002 and 2003; Natural Resources Conservation Service, 2003).

An average soil ECe was calculated to a depth of 48 inches. As specified in the Agricultural Use Protection Policy, the 48-inch depth is representative of the root zone depth of the grass species present in the Fortification Creek fields. The average soil ECe is reflective of the long-term, natural, application of Fortification Creek water and is to be used to estimate the background water EC. The average soil ECe was calculated using the following formula:

Average Soil ECe = $(ECe_{0\text{-}12} + ECe_{12\text{-}24} + ECe_{24\text{-}36} + ECe_{36\text{-}48}) \div 4$

The average soil ECe for the 0 to 48 inch root zone ranged from 3.1 to 15.9 dS/m in the Fortification Creek fields with an overall average of 8.0 dS/m (Table 2). Both the Hayden 23 and Hayden Carr Draw fields exhibit average soil ECe values greater than 4.0 dS/m, which classifies these soils as saline (Table 2). Only plants moderately to highly salt tolerant, have the ability to reach maximum yields in these soils. Individual soil *horizons* within the Hayden 9 and Hayden 25 fields also exhibit saline properties; however these *soils* are not considered saline based on their average root zone soil ECe (to 48 inches).

Soil Sodicity

Sodic soils are "nonsaline soils containing sufficient exchangeable sodium to adversely affect crop production and soil structure" (Soil Science Society of America, 2001). High levels of adsorbed sodium tend to disperse clay particles thereby sealing the soil. The result can produce clogged soil pores, hard surface crusts, and reduced infiltration, permeability, and oxygen diffusion rates; all of which can interfere with or prevent plant growth. By definition, sodic soils are those that have an exchangeable sodium percentage (ESP) greater than 15 (Levy et al. 1998; Abrol et al., 1988; Evangelou, 1998; McNeal and Coleman, 1966; Sparks, 1995; Sumner et al., 1998; Shainberg et al., 1971; Soil Improvement Committee, California Plant Health Association, 2002).

Clay minerals are the most physically and chemically reactive components of the sand, silt, and clay fractions of the soil. Soil clay minerals are negatively charged and consequently attract ions with a positive charge such as calcium, magnesium, potassium, and sodium. Positively charged ions, called cations, compete with each other in the soil solution for access to bonding sites based on their valence and hydrated size. Every soil has a definite capacity to adsorb positively charged cations. This is termed the cation exchange capacity (CEC). The various adsorbed cations (such as calcium and sodium) can be exchanged one for another and the extent of exchange depends upon their relative concentrations in the soil solution (dissolved), the ionic charge (valence), the nature and amount of other cations, etc. ESP is, accordingly, the amount of adsorbed sodium on the soil exchange site expressed as a percent of the cation exchange capacity in milliequivalents per 100 grams of soil (meq/100 g). Thus,

ESP = (exchangeable sodium / cation exchange capacity) x 100.

By definition, sodic soils occur when greater than 15% of the ions bonded to the clay minerals are sodium; sodium has a +1 valence and a large hydrated radius. When the ESP exceeds 15%, the large hydrated sodium ions can wedge in-between the clay minerals, resulting in soil swelling (Levy et al., 1998). This causes negative effects on the physical structure of the soil. Upon re-wetting, the clay minerals may disperse and settle into soil pores, effectively clogging the pores and reducing the efficiency of air

exchange, water infiltration, and permeability (i.e., hydraulic conductivity). In general, soils with moderately high to high clay contents are at greater risk. The type of clay mineral is also important, with the expanding smectitic clays being the most problematic.

Soil ESP values range from 1.8 to 22 percent in the Fortification Creek soil samples (Table 2). The average soil ESP, to a depth of 48 inches, was calculated using the same approach used to calculate the average soil ECe. The average soil ESP, to a depth of 48 inches, ranges from 2.8 to 15.5 percent. Sodic soil conditions exist naturally in the Hayden Carr Draw field (based on the average ESP to a depth of 48 inches); and, when combined with the measured salinity (average ECe to a depth of 48 inches), the Hayden Carr Draw field is considered saline-sodic (Table 2). Saline-sodic soils are soils with ESP values greater than 15 percent, EC above 4 dS/m, and a pH of 8.5 or less (Brady, 1990; Soil Science Society of America, 2001). Saline-sodic soils are especially challenging to manage because the high salt content can affect plant growth, and if the salts are leached out of the soil profile the excess sodium ions can cause the clay minerals to disperse. The soil chemistry of the fields sampled along Fortification Creek indicates that these soils are naturally enriched with salinity and sodicity and that crop yield potential is likely limited.

Saturation percentage is an index of the swelling capacity and the tendency to form dispersive conditions in a soil (Merrill et al., 1987). Saturation percentage is the amount of water, by weight, necessary to form a minimally flowable paste from dry soil materials (Merrill et al., 1987). In general, a saturation percentage of less than 80% indicates the soil does not have a tendency to swell, which also reduces the tendency for dispersion. The saturation percentages measured in the Fortification Creek soils range from 49 to 60 % (Table 1), which indicates non-dispersed conditions.

2.3 VEGETATION CONDITIONS

Native and introduced grasses and forbs, native shrubs and native tree species are present at the Fortification Creek fields. Smooth brome, Western wheatgrass and Crested wheatgrass are the dominant grass species present. Introduced grass species, such as Cheatgrass and Field brome, were also observed. Western tansymustard, Western yarrow and Dandelion species are the dominant forbs present and Black greasewood, Plains cottonwood and Willow species are the dominant shrub and tree species at the Fortification Creek fields. A formal vegetation characterization was conducted on the Fortification Creek fields and is attached in Appendix C.

3.0 PROPOSED EFFLUENT LIMITS AND IMP STANDARDS

The "Tier 2 – Background Water Quality" approach included in the current draft Section 20 Agricultural Use Protection Policy (WYDEQ, 2007) is used herein to estimate the long-term average runoff water EC in Fortification Creek and derive a proposed effluent limit for EC. As mentioned in Section 2.1.2, measured historic runoff water quality data are not available for the Fortification Creek drainage. Thus, in this Tier 2 evaluation, the background water EC is estimated from the EC of soil samples collected from naturally irrigated fields downstream of the proposed discharges. Soil chemical conditions along Fortification Creek are assumed to be in equilibrium with the runoff water chemistry supplied by Fortification Creek over the long term. Soil chemistry, particularly soil ECe, is a function of the long-term average water quality received by the soil. The following equation is a frequently cited relationship that relates irrigation water quality to the soil ECe:

$$ECe = 1.5 \times ECw.$$

Where ECe is the average EC of the soil (measured in a saturated paste extract), and ECw is the long-term average EC of the applied water (Ayers and Westcot, 1985). The equation can be solved for the long-term average EC of the applied water such that:

$$ECw = ECe \div 1.5$$

The resultant equation, which is referenced in the current Section 20 Agricultural Use Protection Policy (WYDEQ, 2007), allows for the estimation of long-term average EC of the applied water, given that soil data have been collected at a specific site. The average soil ECe for the Fortification Creek fields, to a depth of 48 inches is 8.0 dS/m (Table 2). Dividing the average soil ECe by the 1.5 concentration factor yields a corresponding ECw of 5.3 dS/m (5,300 micromhos/cm). In accordance with the Policy, 5.3 dS/m would be the proposed Tier 2 end-of-pipe EC limit.

In addition to the end-of-pipe EC limit, it is proposed that any resultant WYPDES permit for CBNG discharge in this drainage include monitoring for compliance with an EC standard and the chemical relationship between EC and SAR at designated irrigation monitoring points (IMPs). The proposed EC standard at the IMP would be equivalent to the calculated average soil EC in the irrigated fields (8.0 dS/m) divided by 1.5 to estimate the allowable salinity in the stream water. This results in a proposed EC standard of 5.3 dS/m at the IMP. The proposed EC standard of 5.3 dS/m would not be a compliance limit; instead it would represent the target water quality value that should be achieved at the IMP to protect irrigated fields.

With respect to the IMP standard for SAR, it is proposed that the WDEQ establish an appropriate monitoring program to determine whether or not effluent from the discharge facilities conforms to the following equation for SAR:

$$SAR < (7.10 \times EC) - 2.48$$

This equation applies the soil-water chemical relationship between EC and SAR and is used to evaluate whether or not the long-term use of an irrigation water source would result in potential soil structural impacts and reductions in the infiltration rate of applied water. For any measured water EC value, the equation is used to calculate a corresponding maximum SAR value that would remain within the "no reduction in rate of infiltration" zone on Figure 1 of Hanson et al. (1999). For the Fortification Creek drainage, the maximum SAR standard in a water sample from the IMP would be based on the measured EC in the same sample. For example, if the EC in a water sample collected at an IMP was measured to be 3.0 dS/m, then, based on the equation above, the measured SAR in the same sample would need to be less than 18.8. In this example, the EC standard would be achieved since an EC of 3.0 dS/m is less than the proposed standard of 5.3 dS/m. The ongoing monitoring of EC and SAR at the IMP in this fashion would be used to evaluate the actual water quality that may be applied to downstream fields.

In summary, based on the analyses described herein, the discharge of CBNG produced water to the Fortification Creek watershed in accordance with the proposed effluent limits and IMP standards described above is not expected to result in a measurable decrease in crop or livestock production, and would therefore be compliant with Chapter 1, Section 20 of the Wyoming Water Quality Rules and Regulations.

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Table 1. Soil[1] physical analysis results for the Fortification Creek Section 20 site investigation.

Sample	Depth	Texture	Sand	Silt	Clay	Surface Clay Mineralogy[3]	Saturation Percentage	Organic Matter
	inches		%[2]					
Hayden 9	0 to 12	Silty Clay Loam	7	57	36	Smectite: 38 Illite: 27 Kaolinite: 35	59	2.7
	12 to 24	Silty Clay Loam	12	54	34		54	2.2
	24 to 36	Silty Clay Loam	17	51	32		55	1.8
	36 to 48	Silty Clay Loam	13	53	34		53	2.0
	48 to 60	Silty Clay Loam	18	50	32		52	1.8
Hayden 23	0 to 12	Silty Clay Loam	11	54	35	Smectite: 24 Illite: 38 Kaolinite: 38	59	3.0
	12 to 24	Silty Clay Loam	14	53	33		60	2.3
	24 to 36	Silty Clay Loam	17	52	31		60	2.1
	36 to 48	Silty Clay Loam	20	48	32		54	1.7
	48 to 60	Silty Clay Loam	17	51	32		57	2.1
Hayden 25	0 to 12	Silty Clay Loam	15	51	34	Smectite: 31 Illite: 37 Kaolinite: 32	57	2.5
	12 to 24	Silty Clay Loam	15	53	32		51	3.4
	24 to 36	Silty Clay Loam	10	57	33		53	3.0
	36 to 48	Clay Loam	27	45	28		49	2.6
	48 to 60	Silty Clay Loam	16	52	32		54	2.8
Hayden Carr Draw	0 to 12	Clay Loam	33	40	27	Smectite: 34 Illite: 36 Kaolinite: 30	55	3.8
	12 to 24	Clay Loam	31	41	28		52	1.7
	24 to 36	Clay Loam	29	42	29		53	2.2
	36 to 48	Clay Loam	25	45	30		54	2.3
	48 to 60	Clay Loam	32	41	27		50	2.4

Notes:

1 Samples were collected on June 27, 2007, and analyzed by Energy Laboratories, Inc., Helena, MT.

2 Abbreviations used are as follow: % = percent.

3 Surface clay mineralogy was determined for the 0 to 12 inch sample only. X-ray diffraction (XRD) analysis was completed by DCM Science Laboratory, Inc., Wheatridge, CO. on 7/11/07.

Table 2. Soil[1] chemical analysis results for the Fortification Creek Section 20 site investigation.

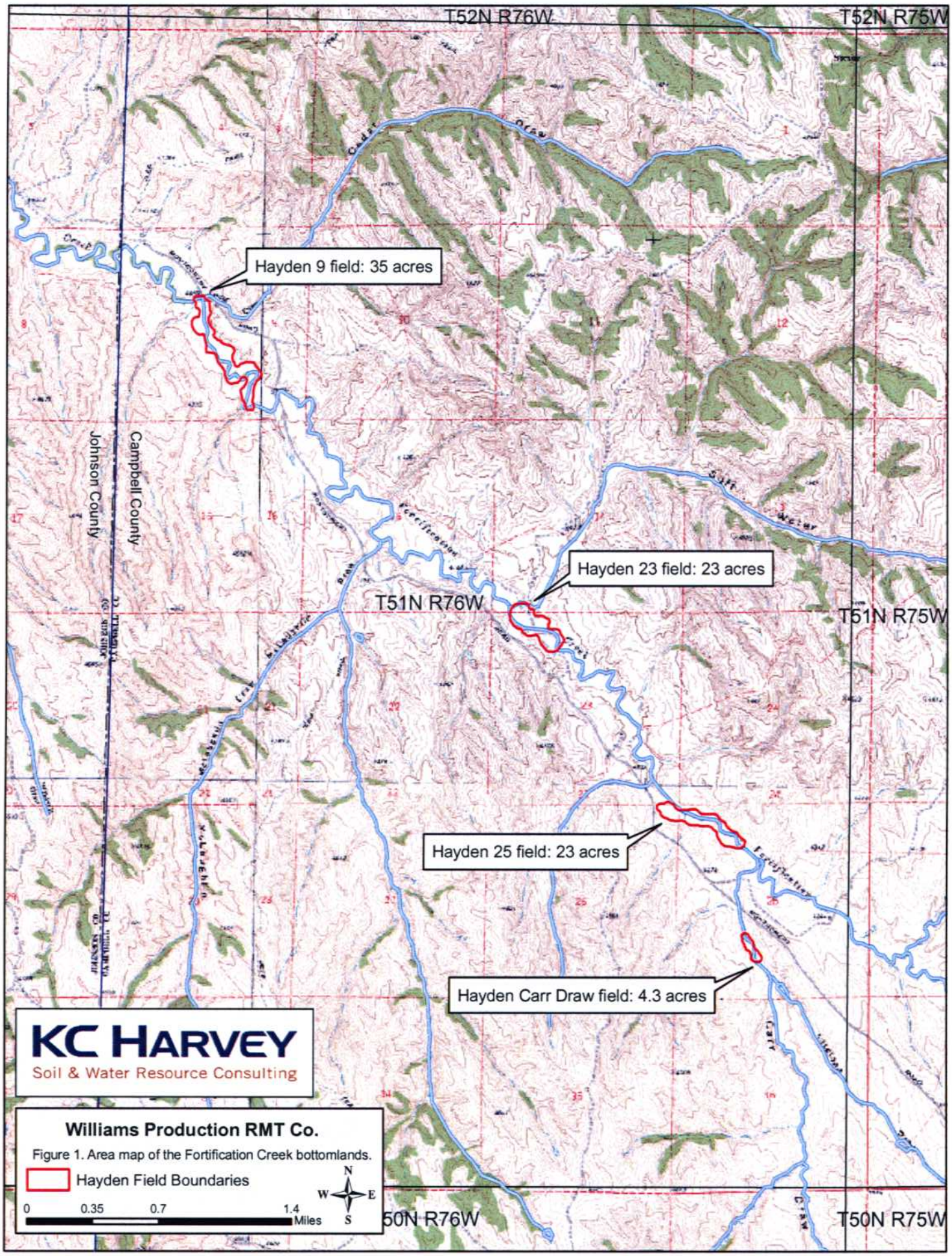
Sample	Depth	pH	Electrical Conductivity at 25° C (ECe)	Average ECe to a depth of 48 inches[3]	Calcium	Magnesium	Sodium	Sodium Adsorption Ratio (SAR)	Cation Exchange Capacity	Exchangeable Sodium	Exchangeable Sodium Percentage (ESP)	Average ESP to a Depth of 48 inches[3]	Lime as CaCO3
	inches	s.u.[2]	dS/m		meq/L				meq/100 g		%		
Hayden 9	0 to 12	7.0	1.1	3.1	8.3	2.6	1.3	0.56	28	0.40	1.5	2.8	5.0
	12 to 24	7.3	2.8		25	10	3.7	0.87	30	0.50	1.8		5.4
	24 to 36	7.4	4.4		29	17	19	3.9	31	1.2	3.8		5.3
	36 to 48	7.5	4.1		26	15	18	4.0	29	1.2	4.1		5.4
	48 to 60	7.4	4.5		28	17	18	3.8	31	1.1	3.5		5.3
Hayden 23	0 to 12	7.0	4.6	9.6	28	13	20	4.4	30	1.4	4.4	12	4.7
	12 to 24	7.6	11		27	30	90	17	31	3.8	12		5.2
	24 to 36	7.8	13		24	41	101	18	30	5.2	17		5.5
	36 to 48	7.7	10		25	36	67	12	27	3.6	13		5.4
	48 to 60	7.6	7.8		25	29	47	9.1	29	2.9	10		5.2
Hayden 25	0 to 12	7.0	1.3	3.3	8.1	3.2	2.4	1.0	32	0.60	1.8	3.1	5.0
	12 to 24	7.2	3.4		28	11	6.7	1.5	29	0.70	2.3		5.6
	24 to 36	7.3	3.8		28	12	12	2.8	31	1.0	3.2		5.5
	36 to 48	7.4	4.8		27	12	22	5.0	29	1.5	5.2		5.4
	48 to 60	7.4	4.6		28	13	24	5.2	31	1.6	5.1		5.3
Hayden Carr Draw	0 to 12	7.4	10	16	29	38	79	14	30	2.9	9.8	15	5.0
	12 to 24	8.1	21		27	92	207	27	28	4.6	16		5.1
	24 to 36	8.1	17		25	87	163	22	27	5.8	22		5.0
	36 to 48	7.9	15		26	73	124	18	29	4.0	14		4.6
	48 to 60	7.8	13		24	60	101	16	28	3.8	14		5.0
			Average:	8.0							Average:	8.2	

Notes:

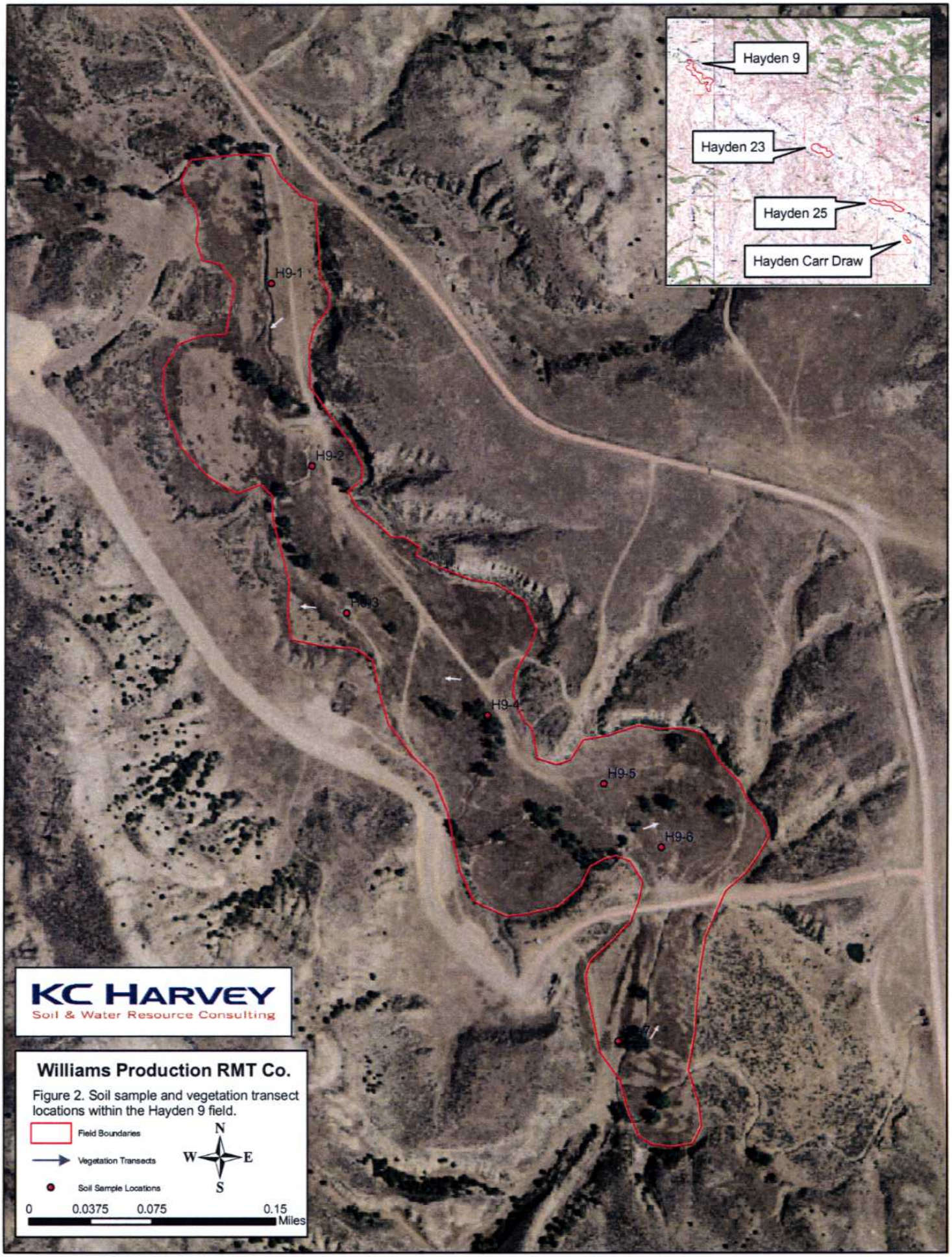
1 Samples were collected on June 27, 2007, and analyzed by Energy Laboratories, Inc., Helena, MT.

2 Abbreviations used are as follows: s.u. = standard units; dS/m = deciSiemens per meter; meq/L = milliequivalents per liter; meq/100g =milliequivalents per 100 grams; and, % = percent.

3 Average EC was calculated using the following formula: $((EC_{0\text{-}12} + EC_{12\text{-}24} + EC_{24\text{-}36} + EC_{36\text{-}48}) / 4)$. Average ESP was calculated using the following formula: $((ESP_{0\text{-}12} + ESP_{12\text{-}24} + ESP_{24\text{-}36} + ESP_{36\text{-}48}) / 4)$.


T52N R76W
T52N R75W
Hayden 9 field: 35 acres
Johnson County
Campbell County
Hayden 23 field: 23 acres
T51N R76W
T51N R75W
Hayden 25 field: 23 acres
Hayden Carr Draw field: 4.3 acres
KC HARVEY
Soil & Water Resource Consulting
Williams Production RMT Co.
Figure 1. Area map of the Fortification Creek bottomlands.
Hayden Field Boundaries
0
0.35
0.7
1.4
Miles
N
W
E
S
50N R76W
T50N R75W

Hayden 9
Hayden 23
Hayden 25
Hayden Carr Draw
H23-1
H23-2
H23-3
H23-4
H23-5
H23-6
H23-7
KC HARVEY
Soil & Water Resource Consulting
Williams Production RMT Co.
Figure 3. Soil sample and vegetation transect locations within the Hayden 23 field.
Field Boundaries
Vegetation Transects
Soil Sample Locations
N
W
E
S
0
0.025
0.05
0.1
Miles


Hayden 9
Hayden 23
Hayden 25
Hayden Carr Draw
H9-1
H9-2
H9-3
H9-4
H9-5
H9-6
KC HARVEY
Soil & Water Resource Consulting
Williams Production RMT Co.
Figure 2. Soil sample and vegetation transect locations within the Hayden 9 field.
Field Boundaries
Vegetation Transects
Soil Sample Locations
N
W
E
S
0
0.0375
0.075
0.15
Miles

Williams Production RMT Co.

Figure 4. Soil sample and vegetation transect locations within the Hayden 25 field.

Hayden 9
Hayden 23
Hayden 25
Hayden Carr Draw
HCD-1
HCD-3
HCD-2
HCD-4
HCD-7
HCD-6
HCD-5
KC HARVEY
Soil & Water Resource Consulting
Williams Production RMT Co.
Figure 5. Soil sample and vegetation transect locations within the Hayden Carr Draw field.
Field Boundaries
Vegetation Transects
Soil Sample Locations
N
W
E
S
0
0.0125
0.025
0.05
Miles

Appendix A

LOCATION HAVERDAD WY+MT UT

Established Series
Rev. JEI/MCS/SSP
06/2002

HAVERDAD SERIES

The Haverdad series consists of very deep, well drained soils formed in stratified alluvium on flood plains and low terraces. Permeability is moderate. Slopes range from 0 to 6 percent. The mean annual precipitation is about 11 inches, and the mean annual temperature is about 45 degrees F.

TAXONOMIC CLASS: Fine-loamy, mixed, superactive, calcareous, mesic Ustic Torrifluvents

TYPICAL PEDON: Haverdad loam - utilized as rangeland. (Colors are for dry soil unless otherwise stated)

A--0 to 4 inches; pale brown (10YR 6/3) loam, dark grayish brown (10YR 4/2) moist; moderate medium subangular structure parting to weak fine granular; slightly hard, friable, slightly sticky and slightly plastic; many fine roots throughout; carbonates are disseminated throughout; slightly effervescent; moderately alkaline (pH 8.0); gradual smooth boundary. (2 to 8 inches thick)

C1--4 to 14 inches; pale brown (10YR 6/3) loam, brown (10YR 4/3) moist; moderate medium subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; common fine roots throughout; carbonates are disseminated throughout; slightly effervescent; moderately alkaline (pH 8.2); clear smooth boundary.

C2--14 to 30 inches; pale brown (10YR 6/3) loam, stratified with fine sandy loam, sand loam, clay loam, and silt loam, brown (10YR 4/3) moist; weak fine and medium subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; few fine and very fine roots throughout; carbonates are disseminated throughout; slightly effervescent; strongly alkaline (pH 8.6); gradual smooth boundary.

C3--30 to 60 inches; pale brown (10YR 6/3) clay loam, stratified with fine sandy loam, loam, silt loam, and silty clay loam, brown (10YR 5/3) moist; weak fine and medium subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; few fine and very fine roots throughout; carbonates are disseminated throughout; slightly effervescent; strongly alkaline (pH 8.6); gradual smooth boundary.

TYPE LOCATION: Niobrara County, Wyoming; about 2,600 feet north and 750 feet east of the southwest corner of Sec. 12, T 38 N, R 65 W. lat. 43 degrees 17 minutes 2 seconds north and long. 104 degrees 36 minutes 54 seconds west.

RANGE IN CHARACTERISTICS:
Soil moisture: The soil is dry in the moisture control section more than half the time cumulative that the soil temperature at a depth of 20 inches is 41 degrees F. or more. This soil is moist for 60 consecutive days when the soil temperature at 20 inches is 41 degrees F., which occurs about April 21-27, but is dry in all parts of the moisture control section for at least 60 consecutive days from July 15 to October 25 and for at least 90 cumulative days during this period.

Mean annual soil temperature: 48 to 53 degrees F. and the soil temperature at a depth of 20 inches is 41 degrees F. or more for 175 to 195 days.

Organic carbon content: .5 to 1.0 percent and decreases irregularly with depth
Rock fragments: 0 to 15 percent gravel
EC (mmhos/cm): 0 to 8 mmhos throughout but where irrigated some soils may range up to 16 mmhos
Calcium sulfate occurs in some pedons.
The soil is typically calcareous to the surface, but some pedons are leached as deep as 20 inches.

A horizon:
Hue: 10YR or 2.5Y
Value: 4 through 6 dry, 3 through 5 moist
Chroma: 2 through 4 dry or moist
Texture: loam, clay loam, silt loam, silty clay loam, very fine sandy loam, fine sandy loam, sandy loam
Reaction: slightly alkaline through strongly alkaline

Some pedons have an AC horizon.

C horizon:
Hue: 10YR or 2.5Y
Value: 5 through 7 dry, 4 to 6 moist
Chroma: 2 through 4 dry or moist
Texture: variable but when averaged is loam or light clay loam with 18 to 35 percent clay
Calcium carbonate equivalent: 1 to 15 percent which changes erratically between strata
Reaction: slightly alkaline through strongly alkaline

COMPETING SERIES: These are the Hamburn, Manikan, San Mateo, and Suwanee series.

Hamburn: have pedogenic accumulations of salt and SARs greater than 13
Manikan, and Suwanee: have hue of 7.5YR or redder
San Mateo: have soil moisture control sections that are drier during April, May, and June

GEOGRAPHIC SETTING:
Parent material: alluvium from mixed sources
Landform: floodplains and low terraces
Elevations: 3,500 to 6,500 feet
Slopes: 0 to 6 percent
Mean annual precipitation: about 11 inches, ranging 10 to 17, with over half of annual precipitation falling in April, May, and June
Mean annual temperature: about 45 degrees F. and ranges from 43 to 52 degrees F.
Frost-free period: 105 to 130 days

GEOGRAPHICALLY ASSOCIATED SOILS: These are the Arvada, Forkwood, Kishona, and Shingle soils. Arvada soils have a natric horizon. Forkwood soils have an argillic horizon. Kishona soils lack stratification. Shingle soils have bedrock at a depth of 4 to 20 inches.

DRAINAGE AND PERMEABILITY: Well drained; slow runoff; moderate permeability. Flooding for brief periods occurs during spring runoff and after thunder showers.

USE AND VEGETATION: These soils are used principally for grazing. Principal native vegetation is big sagebrush, western wheatgrass, greasewood, and annual grasses and forbs.

DISTRIBUTION AND EXTENT: Big Horn Basin, central, eastern Wyoming, Colorado, and Utah.

MLRA OFFICE RESPONSIBLE: Lakewood, Colorado

SERIES ESTABLISHED: Washakie County, Wyoming; 1980.

REMARKS: Diagnostic horizons and features recognized in this pedon are:

Ochric epipedon - 0 to 6 inches (A)

The type location for this series was moved from Washakie County, Wyoming to its current location in Niobrara County, Wyoming to better reflect the moisture regime concept, June 2002.

National Cooperative Soil Survey
U.S.A.

LOCATION BORUFF WY

Established Series
CAP
03/2003

BORUFF SERIES

The Boruff series consists of very deep, poorly and somewhat poorly drained soils formed in alluvium on flood plains and low stream terraces. Slope ranges from 0 to 3 percent. The mean annual precipitation is about 14 inches and the mean annual air temperature is about 48 degrees F.,

TAXONOMIC CLASS: Fine, smectitic, calcareous, mesic Vertic Fluvaquents

TYPICAL PEDON: Boruff silty clay - on a west facing slope of 1 percent in rangeland. (Colors are for dry soil unless otherwise noted)

A--0 to 2 inches; olive brown (2.5Y 4/3) silty clay, dark olive brown (2.5Y 3/3) moist; common fine distinct dark yellowish brown (10YR 4/6) redoximorphic concentrations; moderate fine and medium granular structure; slightly hard, friable, moderately sticky and moderately plastic; many very fine roots throughout and common medium throughout; many fine pores; slightly effervescent; slightly alkaline; EC of 3.5; abrupt smooth boundary. (2 to 10 inches thick)

C1--2 to 6 inches; stratified light yellowish brown (2.5Y 6/3) silty clay, light olive brown (2.5Y 5/3) and olive brown (2.5Y 4/3) moist; common fine distinct gray (N 6/0) redoximorphic depletions and common fine prominent dark yellowish brown (10YR 4/6) redoximorphic concentrations; moderate coarse prismatic structure parting to moderate medium subangular blocky; hard, firm, very sticky and very plastic; common very fine roots throughout and common medium throughout; many fine pores; few distinct discontinuous dark brown (10YR 3/3) organic coats in root channels and/or pores; common fine irregular white (10YR 8/1) nests of gypsum throughout; slightly effervescent; moderately alkaline; EC of 5; abrupt wavy boundary.

C2--6 to 46 inches; grayish brown (2.5Y 5/2) silty clay, dark grayish brown (2.5Y 4/2) moist, stratified with thin layers of silty clay loam, clay loam, silt loam and fine sandy loam; many fine distinct gray (N 5/0) redoximorphic depletions and many fine prominent strong brown (7.5YR 4/6) redoximorphic concentrations; massive; hard, friable, slightly sticky and moderately plastic; common very fine roots throughout; many fine pores; few fine rounded white (10YR 8/1) nests of gypsum throughout; slightly effervescent; moderately alkaline; EC of 6; clear wavy boundary.

C3--46 to 60 inches; light brownish gray (2.5Y 6/2) silty clay, grayish brown (2.5Y 5/2) moist, stratified with thin layers of silty clay loam, clay loam, silt loam and fine sandy loam; many fine and medium distinct gray (N 5/0) redoximorphic depletions, many fine and medium distinct light olive brown (2.5Y 5/6) redoximorphic concentrations, and common fine prominent dark yellowish brown (10YR 4/6) redoximorphic concentrations; massive; hard, friable, moderately sticky and moderately plastic; common very fine roots throughout; many fine pores; few fine rounded white (10YR 8/1) nests of gypsum throughout; slightly effervescent; EC of 5.5; moderately alkaline.

TYPE LOCATION: Campbell County, Wyoming; about 900 feet east and 2300 feet north of the southwest corner of Sec. 9, T 75 N, R 55 W.; USGS Kline Draw, WY topographic quadrangle; lat. 44 degrees 45 minutes 23 seconds N. and long. 105 degrees 54 minutes 1 seconds W.

RANGE IN CHARACTERISTICS: The organic carbon content ranges from 1 to 3 percent in the A horizon and from 0 to 3 percent in the C horizon and decreases irregularly with depth. Depth to continuous accumulations of carbonates is 0 to 10 inches. The average exchangeable sodium ranges from 0 to 10 percent, but some pedon have subhorizons that are greater than 10 percent. Redoximorphic features are common in the upper 18 inches. The average annual soil temperature is 47 to 50 degrees F.

The A horizon has hue of 5Y, 2.5Y or 10YR, value of 4 to 7 dry and 3 to 5 moist, and chroma of 1 to 3. Texture is clay loam, loam, silt loam, silty clay loam, silty clay or clay. Reaction is neutral to moderately alkaline. The EC is 0 to 4 mmhos/cm and the calcium carbonate equivalent is 0 to 5 percent. Some pedons have an AC horizon.

The C horizon has hue of 5Y, 2.5Y or 10YR, value of 5 to 7 dry and 3 to 5 moist, and chroma of 1 to 4. Texture is silty clay, clay, clay loam or silty clay loam, stratified with very fine sandy loam, fine sandy loam, sandy loam, loam, silt loam or loamy fine sand. In some pedons it has accumulations of carbonates, gypsum or salts. Reaction is slightly alkaline to strongly alkaline. The EC is 2 to 8 mmhos/cm and the calcium carbonate equivalent is 1 to 12 percent.

COMPETING SERIES: These are the Abbott and Apishapa series. The Abbott series have and EC of more than 8 mmhos/cm throughout. In addition, the Abbott soils occur in locations with 11 inches or less of annual precipitation. Apishapa soils average more than 2 percent gypsum in the lower part of the particle-size control section. In addition, Apishapa soils occur in areas that a frost-free season of more than 135 days.

GEOGRAPHIC SETTING: Boruff soils are on flood plains and low stream terraces. They formed in stratified recent alluvium derived from mixed sedimentary sources. Slopes are 0 to 3 percent. Elevations are 3,500 to 5,000 feet. The mean annual precipitation ranges from 10 to 19 inches, half of which falls as rain or snow from March through June. The mean annual air temperature ranges from 44 to 50 degrees F. The frost-free season is about 105 to 130 days.

GEOGRAPHICALLY ASSOCIATED SOILS: These are the Bidman, Clarkelon, Deekay, Draknab, Forkwood, Haverdad, Iwait, Jaywest, Kishona, Moorhead, Rockypoint and Ulm soils. These soils are all on higher lying fans or terraces. They are all better drained than the Boruff soils. In addition, Bidman, Deekay, Forkwood, Jaywest, Moorhead and Ulm soil have argillic horizons; Clarkelon soils are coarse-loamy; Draknab soils are sandy; and Iwait and Kishona soils do not have stratified horizons.

DRAINAGE AND PERMEABILITY: Poorly and somewhat poorly drained; slow runoff; slow permeability. These soils are subject to rare to frequent flooding for very brief or brief periods during prolonged, high intensity storms in the spring and early summer. A seasonal high water table is at a depth of 0.5 to 1.5 feet at some time during the period April through July.

USE AND VEGETATION: These soils are utilized primarily as rangeland and wildlife habitat. The native vegetation is mainly green needlegrass, bearded wheatgrass, slender wheatgrass, western wheatgrass and cottonwoods.
Indian saltgrass, alkali sacaton, sedges and willows.

DISTRIBUTION AND EXTENT: North-eastern Wyoming and possibly south-eastern Montana. These soils are of limited extent.

MLRA OFFICE RESPONSIBLE: Bismarck, North Dakota.

SERIES ESTABLISHED: Crook County, Wyoming (Correlation Amendment); 2003.

REMARKS: Diagnostic horizons and features recognized in this pedon are: ochric epipedon - 0 to 2 inches

(A horizon); aquic moisture regime - redoximorphic concentrations and chroma of 2 in 40 to 50 cm layer; vertic subgroup criteria - LE of more than 6 in the top meter.

ADDITIONAL DATA: S98WY005-010, type location.

National Cooperative Soil Survey
U.S.A.

Appendix B

ENERGY LABORATORIES, INC. • P.O. Box 5688 • 3161 East Lyndale Ave. • Helena, MT 59604
877-472-0711 • 406-442-0711 • 406-442-0712 fax • helena@energylab.com

Date: *20-Jul-07*

CLIENT: Williams Production RMT
Project: Fortification Creek Section 20 Analysis
Sample Delivery Group: H07070005

CASE NARRATIVE

Samples 001, 006, 011 & 016 were submitted to DCM Laboratory in Wheat Ridge CO for Clay Minerology. Attached is the original report.

DCM Science Laboratory, Inc.
12421 W. 49th Avenue, Unit #6
Wheat Ridge, CO 80033 - (303) 463-8270

Quantitative Clay Analysis (XRD)

Client:
Energy Laboratories, Inc.
3161 E. Lyndale
Helena, MT 59601

Analysis Date:	7-11-07
Reporting Date:	7-12-07
Receipt Date:	7-9-07
Client Job No.:	H11645
Project Title:	None Given
DCMSL Project:	ELAB20

Client Sample No.:	**H07070005 001**	**H07070005 006**	**H07070005 011**	**H0707005 016**
Clay Fraction <2μm				
Smectite	24	34	31	38
Illite	38	36	37	27
Kaolinite	38	30	32	35

Oriented clay mounts (<2μm) were prepared for x-ray diffraction and scanned over a range of 3° to 45° 2Θ using CuKα radiation, 40kV, 25mA. The mount was analyzed air-dried (RH ~25%) and glycolated. Clay concentrations are based on peak areas and intensity factors measured in-house on known standards or computer calculated.

Ron Schott

Ron Schott, Analyst

877-472-0711 • 406-442-0711 • 406-442-0712 fax • helena@energylab.com

LABORATORY ANALYTICAL REPORT

Client: Williams Production RMT
Project: Fortification Creek Section 20 Analysis
Workorder: H07070005

Report Date: 07/20/07
Date Received: 07/02/07

		Analysis		pH-SatPst	COND	Percent Sat	SAR	Ca-SatPst	Mg-SatPst	Na-SatPst	Sand	Silt	Clay	Texture
		Units		s_u_	mmhos/cm	%	unitless	meq/l	meq/l	meq/l	%	%	%	unitless
Sample ID	Client Sample ID	Up	Low	Results	Results	Results	Results	Results	Results	Results	Results	Results	Results	Results
H07070005-001	Hayden 23 0-12"	0	12	7.0	4.60	58.6	4.4	28.1	13.3	20.2	11	54	35	SiCL
H07070005-002	Hayden 23 12-24"	12	24	7.6	11.0	59.8	17	26.8	30.3	89.7	14	53	33	SiCL
H07070005-003	Hayden 23 24-36"	24	36	7.8	12.8	60.4	18	24.4	41.1	101	17	52	31	SiCL
H07070005-004	Hayden 23 36-48"	36	48	7.7	10.1	54.3	12	25.1	35.7	67.2	20	48	32	SiCL
H07070005-005	Hayden 23 48-60"	48	60	7.6	7.76	56.7	9.1	25.2	28.7	47.0	17	51	32	SiCL
H07070005-006	Hayden Carr Draw 0-12"	0	12	7.4	10.2	54.7	14	29.4	37.5	78.7	33	40	27	CL
H07070005-007	Hayden Carr Draw 12-24"	12	24	8.1	21.2	52.2	27	27.4	91.6	207	31	41	28	CL
H07070005-008	Hayden Carr Draw 24-36"	24	36	8.1	17.4	53.1	22	25.4	87.2	163	29	42	29	CL
H07070005-009	Hayden Carr Draw 36-48"	36	48	7.9	14.8	53.6	18	26.0	73.0	124	25	45	30	CL
H07070005-010	Hayden Carr Draw 48-60"	48	60	7.8	12.9	49.8	16	24.3	60.3	101	32	41	27	CL
H07070005-011	Hayden 25 0-12"	0	12	7.0	1.27	56.7	1.0	8.11	3.17	2.37	15	51	34	SiCL
H07070005-012	Hayden 25 12-24"	12	24	7.2	3.41	51.2	1.5	27.5	10.9	6.68	15	53	32	SiCL
H07070005-013	Hayden 25 24-36"	24	36	7.3	3.81	53.4	2.8	27.8	12.4	12.4	10	57	33	SiCL
H07070005-014	Hayden 25 36-48"	36	48	7.4	4.78	48.5	5.0	26.7	11.6	21.7	27	45	28	CL
H07070005-015	Hayden 25 48-60"	48	60	7.4	4.59	54.1	5.2	27.9	12.7	23.6	16	52	32	SiCL
H07070005-016	Hayden 9 0-12"	0	12	7.0	1.12	59.3	0.56	8.30	2.55	1.30	7	57	36	SiCL
H07070005-017	Hayden 9 12-24"	12	24	7.3	2.81	54.4	0.87	25.3	9.73	3.65	12	54	34	SiCL
H07070005-018	Hayden 9 24-36"	24	36	7.4	4.41	54.5	3.9	28.8	16.7	18.6	17	51	32	SiCL
H07070005-019	Hayden 9 36-48"	36	48	7.5	4.13	53.4	4.0	25.5	14.6	17.8	13	53	34	SiCL
H07070005-020	Hayden 9 48-60"	48	60	7.4	4.47	51.7	3.8	27.7	16.8	18.1	18	50	32	SiCL

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877-472-0711 • 406-442-0711 • 406-442-0712 fax • helena@energylab.com

LABORATORY ANALYTICAL REPORT

Client: Williams Production RMT
Project: Fortification Creek Section 20 Analysis
Workorder: H07070005

Report Date: 07/20/07
Date Received: 07/02/07

		Analysis		OM-WB	CEC	Lime	Na-Ext	Exch Na	ESP
		Units		%	meq/100g	%	meq/100g	meq/100g	%
Sample ID	**Client Sample ID**	**Up**	**Low**	**Results**	**Results**	**Results**	**Results**	**Results**	**Results**
H07070005-001	Hayden 23 0-12"	0	12	2.97	30.4	4.7	2.53	1.4	4.4
H07070005-002	Hayden 23 12-24"	12	24	2.29	30.9	5.2	9.19	3.8	12
H07070005-003	Hayden 23 24-36"	24	36	2.10	30.2	5.5	11.3	5.2	17
H07070005-004	Hayden 23 36-48"	36	48	1.74	27.4	5.4	7.21	3.6	13
H07070005-005	Hayden 23 48-60"	48	60	2.13	28.6	5.2	5.53	2.9	10
H07070005-006	Hayden Carr Draw 0-12"	0	12	3.84	29.7	5.0	7.22	2.9	9.8
H07070005-007	Hayden Carr Draw 12-24"	12	24	1.74	28.0	5.1	15.4	4.6	16
H07070005-008	Hayden Carr Draw 24-36"	24	36	2.19	27.2	5.0	14.5	5.8	22
H07070005-009	Hayden Carr Draw 36-48"	36	48	2.32	28.6	4.6	10.7	4.0	14
H07070005-010	Hayden Carr Draw 48-60"	48	60	2.35	27.6	5.0	8.88	3.8	14
H07070005-011	Hayden 25 0-12"	0	12	2.45	31.8	5.0	0.71	0.6	1.8
H07070005-012	Hayden 25 12-24"	12	24	3.35	29.1	5.6	1.00	0.7	2.3
H07070005-013	Hayden 25 24-36"	24	36	3.00	31.4	5.5	1.68	1.0	3.2
H07070005-014	Hayden 25 36-48"	36	48	2.55	28.5	5.4	2.52	1.5	5.2
H07070005-015	Hayden 25 48-60"	48	60	2.84	30.7	5.3	2.83	1.6	5.1
H07070005-016	Hayden 9 0-12"	0	12	2.71	28.4	5.0	0.52	0.4	1.5
H07070005-017	Hayden 9 12-24"	12	24	0.06	30.1	5.4	0.73	0.5	1.8
H07070005-018	Hayden 9 24-36"	24	36	1.84	31.2	5.3	2.20	1.2	3.8
H07070005-019	Hayden 9 36-48"	36	48	2.00	28.5	5.4	2.13	1.2	4.1
H07070005-020	Hayden 9 48-60"	48	60	1.84	30.5	5.3	2.02	1.1	3.5

Appendix C

MEMORANDUM

KC HARVEY

AN ENERCREST COMPANY

233 Edelweiss Drive, Suite 11
Bozeman, Montana 59718

T 406-585-7402
F 406-585-7428
www.kcharvey.com

TO: Dina Brown, *KC Harvey, Inc.*

FROM: Samantha Gundlach, *KC Harvey, Inc.*

DATE: August 8, 2007

SUBJECT: Fortification Creek Section 20 Vegetation Survey

A vegetation survey was conducted July 15, 2007 in Fortification Creek to determine the plant species present in the area and their relative abundance.

Vegetation surveys were completed for four fields within the Fortification Creek watershed. Vegetation data was collected by randomly placing a 50 foot transect in an area representative of the site or zone. At least two transects were completed in each field. Each transect position and bearing was noted and marked by GPS. Data was collected using a 50 by 50 centimeter frame placed every ten feet along the transect. Each species present within a frame was identified. If species were undecipherable (e.g. juvenile plants), they were grouped by life-form and designated weedy or desired species, with each species given a unique identification number (e.g. weedy forb 1, weedy forb 2). The canopy cover per species and for rock, bare ground and litter was recorded for each frame. Canopy cover is the percentage of the soil surface covered by the vertical projection of a species regardless of what is below. The total vegetative canopy cover was then used to calculate the percent composition of each species to determine their relative dominance. In addition, a list of all the species present in each field was populated, along with the relative abundance (high, moderate or low) of that species.

A minimum of two transects were placed in each of the four fields, Hayden 9, Hayden 23, Hayden 25 and Hayden Carr Draw. More transects were placed in larger fields or in fields with more variation in plant composition, i.e. five in Hayden 9 and four in Hayden 25. Canopy cover data was then averaged over the transects. Table 1 lists the canopy cover for each species present in a frame during data collection. Species were present in the field that were not found in a frame, but the frame data is representative of the field as a whole.

Table 2 provides a complete list of the species in each field, along with the relative abundance of each species. Those at high abundance made up a significant portion of the field, moderate abundance species were found at lower numbers, and low abundance species were present, but not an important part of the vegetation community. The species lists are split into native and introduced grasses, forbs, shrubs and trees, however no introduced shrubs or trees were found.

Cheatgrass, field brome, quackgrass and foxtail barley are undesirable grasses for agricultural use as they are invasive and provide little forage value. The remaining grasses, whether introduced or native, are desirable forage grasses. Smooth brome and western wheatgrass are the two most productive forage grasses in the Fortification Creek fields, making up a significant portion of the cover in each field, although smooth brome was not present in Carr Draw.

All of the introduced forbs present are undesirable for agricultural use, with western tansymustard and dandelion as the two most prominent invasive weeds. The native forbs, trees and shrubs found in Fortification Creek do not significantly impact the agricultural use of the riparian area. They are mostly found at low abundance and those at higher abundance provide little forage for livestock, although the trees do provide shade.

Table 1. Canopy cover by species in the Fortification Creek watershed based on transect data.

Hayden 9	
Alyssum species	0.36%
American vetch	0.20%
Cheatgrass	0.20%
Crested wheatgrass	8.00%
Curly dock	0.40%
Dandelion	8.64%
Field pennycress	0.76%
Foxtail barley	0.12%
Kentucky bluegrass	1.20%
Lambsquarter	0.08%
Smooth brome	37.68%
Unknown weedy forb	0.16%
Western tansymustard	8.60%
Western wheatgrass	12.08%
Western yarrow	2.44%
Litter	10.64%
Bare ground	8.44%

Hayden 23	
Alyssum species	0.10%
Cheatgrass	0.20%
Dandelion	3.10%
Field pennycress	3.00%
Foxtail barley	1.00%
Kentucky bluegrass	3.50%
Lambsquarter	0.50%
Smooth brome	38.50%
Western tansymustard	0.20%
Western wheatgrass	29.60%
Litter	8.00%
Bare ground	12.30%

Hayden 25	
Alyssum species	1.15%
American vetch	1.15%
Cheatgrass	7.30%
Dandelion	6.10%
Field pennycress	0.25%
Kentucky bluegrass	3.30%
Salsify	1.25%
Smooth brome	15.40%
Timothy	1.50%
Western tansymustard	1.95%
Western wheatgrass	39.60%
Western yarrow	5.50%
Litter	10.90%
Bare ground	4.65%

Hayden Carrdraw	
Alyssum species	1.60%
Cheatgrass	35.20%
Crested wheatgrass	2.50%
Common pepperweed	1.30%
Curleycup gumweed	0.40%
Dandelion	5.80%
Field pennycress	0.20%
Foxtail barley	1.00%
Kentucky bluegrass	2.00%
Lambsquarter	0.40%
Prickly lettuce	0.50%
Redroot pigweed	5.50%
Thistle species	2.20%
Unknown weedy forb	3.70%
Western tansymustard	2.20%
Western wheatgrass	18.40%
Western yarrow	0.50%
Whorled milkweed	0.60%
Yellow sweetclover	0.50%
Litter	7.70%
Bare ground	7.80%

Table 2. Complete species list with relative abundance for the Fortification Creek fields.

Hayden 9			
Common Name	**Scientific Name**	**Acronym**	**Relative Abundance**
Native Grasses			
Foxtail barley	*Hordeum jubatum*	HOJU	Low
Green needlegrass	*Nassella viridula*	NAVI	Low
Western wheatgrass	*Pascopyrum smithii*	PASM	High
Introduced Grasses			
Crested wheatgrass	*Agropyron cristatum*	AGCR	Moderate
Field brome	*Bromus arvensis*	BRAR	Low
Smooth Brome	*Bromus inermis*	BRIN	High
Cheatgrass	*Bromus tectorum*	BRTE	Moderate
Kentucky bluegrass	*Poa pratensis*	POPR	Moderate
Native Forbs			
Western yarrow	*Achillea millefolium*	ACMI	Moderate
American vetch	*Vicia americana*	VIAM	Low
Introduced Forbs			
Alyssum species	*Alyssum spp.*	ALSPP	Low
Redroot pigweed	*Amaranthus retroflexus*	AMRE	Moderate
Sheperd's purse	*Capsella bursa-pastoris*	CABU	Low
Lambsquarters	*Chenopodium album*	CHAL	Low
Crossflower	*Chorispora tenella*	CHTE	Moderate
Thistle species	*Cirsium spp.*	CISPP	High
Western tansymustard	*Descurainia pinnata*	DEPI	High
Pepperweed species	*Lepidium spp.*	LESPP	Low
Erect knotweed	*Polygonum erectum*	POER	Low
Curley dock	*Rumex crispus*	RUCR	Low
Dandelion	*Taraxacum officinale*	TAOF	High
Field pennycress	*Thlaspi arvense*	THAR	Low
Salsify	*Tragopogon dubius*	TRDU	Low
Western dock	*Rumex aquaticus*	RUAQ	Low
Unknown weedy forb		UNWF1	Low
Native Trees			
Plains cottonwood	*Populus deltoides*	PODE	High
Willow species	*Salix spp.*	SASPP	Low

Hayden 23			
Common Name	**Scientific Name**	**Acronym**	**Relative Abundance**
Native Grasses			
Prairie sandreed	*Calamovilfa longifolia*	CALO	Moderate
Fescue species	*Festuca spp.*	FESPP	Low
Foxtail barley	*Hordeum jubatum*	HOJU	Moderate
Western wheatgrass	*Pascopyrum smithii*	PASM	High
Introduced Grasses			
Crested wheatgrass	*Agropyron cristatum*	AGCR	Low
Field brome	*Bromus arvensis*	BRAR	Low
Smooth Brome	*Bromus inermis*	BRIN	High
Cheatgrass	*Bromus tectorum*	BRTE	Moderate
Orchardgrass	*Dactylis glomerata*	DAGL	Low
Quackgrass	*Elymus repens*	ELRE	Low
Timothy	*Phleum pratense*	PHPR	Moderate
Kentucky bluegrass	*Poa pratensis*	POPR	Moderate
Native Forbs			
Western yarrow	*Achillea millefolium*	ACMI	Moderate
Showy milkweed	*Asclepias speciosa*	ASSP	Low
American vetch	*Vicia americana*	VIAM	Low
Introduced Forbs			
Alyssum species	*Alyssum spp.*	ALSPP	Moderate
Lambsquarters	*Chenopodium album*	CHAL	High
Crossflower	*Chorispora tenella*	CHTE	Low
Thistle species	*Cirsium spp.*	CISPP	Moderate
Western tansymustard	*Descurainia pinnata*	DEPI	High
Curleycup gumweed	*Grindelia squarrosa*	GRSQ	Low
Yellow sweetclover	*Melilotus officinalis*	MEOF	Low
Black medick	*Medicago lupulina*	MELU	Low
Curley dock	*Rumex crispus*	RUCR	Low
Dandelion	*Taraxacum officinale*	TAOF	High
Field pennycress	*Thlaspi arvense*	THAR	Low
Salsify	*Tragopogon dubius*	TRDU	Low
Western dock	*Rumex aquaticus*	RUAQ	Moderate
Unknown weedy forb		UNWF2	Moderate
Native Shrubs			
Black greasewood	*Sarcobatus vermiculatus*	SAVE	Low

Table 2. Continued. Complete species list with relative abundance for the Fortification Creek fields.

Hayden 25			
Common Name	**Scientific Name**	**Acronym**	**Relative Abundance**
Native Grasses			
Foxtail barley	*Hordeum jubatum*	HOJU	High
Baltic rush	*Juncus balticus*	JUBA	Low
Western wheatgrass	*Pascopyrum smithii*	PASM	High
Introduced Grasses			
Crested wheatgrass	*Agropyron cristatum*	AGCR	Low
Field brome	*Bromus arvensis*	BRAR	Low
Smooth Brome	*Bromus inermis*	BRIN	High
Cheatgrass	*Bromus tectorum*	BRTE	Moderate
Timothy	*Phleum pratense*	PHPR	Moderate
Kentucky bluegrass	*Poa pratensis*	POPR	High
Native Forbs			
Western yarrow	*Achillea millefolium*	ACMI	Moderate
Twogrooved milkvetch	*Astragalus bisulcatus*	ASBI	Low
American vetch	*Vicia americana*	VIAM	Low
Introduced Forbs			
Alyssum species	*Alyssum spp.*	ALSPP	High
Lambsquarters	*Chenopodium album*	CHAL	Low
Crossflower	*Chorispora tenella*	CHTE	Low
Thistle species	*Cirsium spp.*	CISPP	High
Western tansymustard	*Descurainia pinnata*	DEPI	Moderate
Curleycup gumweed	*Grindelia squarrosa*	GRSQ	Low
Clasping pepperweed	*Lepidium perfoliatum*	LEPE	Low
Curley dock	*Rumex crispus*	RUCR	Low
Dandelion	*Taraxacum officinale*	TAOF	High
Field pennycress	*Thlaspi arvense*	THAR	Moderate
Salsify	*Tragopogon dubius*	TRDU	Moderate
Unknown weedy forb		UNWF1	Low
Native Trees			
Plains cottonwood	*Populus deltoides*	PODE	Low

Hayden Carrdraw			
Common Name	**Scientific Name**	**Acronym**	**Relative Abundance**
Native Grasses			
Sedge species	*Carex spp.*	CASPP	Moderate
Prairie sandreed	*Calamovilfa longifolia*	CALO	High
Foxtail barley	*Hordeum jubatum*	HOJU	Moderate
Baltic rush	*Juncus balticus*	JUBA	Low
Introduced Grasses			
Crested wheatgrass	*Agropyron cristatum*	AGCR	Low
Cheatgrass	*Bromus tectorum*	BRTE	High
Timothy	*Phleum pratense*	PHPR	Moderate
Kentucky bluegrass	*Poa pratensis*	POPR	High
Native Forbs			
Western yarrow	*Achillea millefolium*	ACMI	Low
Twogrooved milkvetch	*Astragalus bisulcatus*	ASBI	Low
Showy milkweed	*Asclepias speciosa*	ASSP	Low
Whorled milkweed	*Asclepias verticillata*	ASVE	Low
American vetch	*Vicia americana*	VIAM	Low
Introduced Forbs			
Redroot pigweed	*Amaranthus retroflexus*	AMRE	Moderate
Thistle species	*Cirsium spp.*	CISPP	Moderate
Curleycup gumweed	*Grindelia squarrosa*	GRSQ	Low
Prickly lettuce	*Lactuca serriola*	LASE	Low
Common pepperweed	*Lepidium densiflorum*	LEDE	High
Yellow sweetclover	*Melilotus officinalis*	MEOF	Low
Pepperweed species	*Lepidium spp.*	LESPP	Moderate
Dandelion	*Taraxacum officinale*	TAOF	High
Salsify	*Tragopogon dubius*	TRDU	Moderate
Unknown weedy forb		UNWF1	High