NRCS and Soil Health in the Big Horn Basin: What is working?

Rory Karhu

District Conservationist

USDA-NRCS, Powell, WY

rory.karhu@wy.usda.gov

(307) 271-3128 work

(307) 462-1748 cell

USDA Natural Resources Conservation Service
U.S. DEPARTMENT OF AGRICULTURE

NRCS: Who we are and what we do.

- Natural Resources Conservation Service
  - Mission Statement: Helping People Help The Land
    - Assist clients to identify and solve Resource Concerns
      - Resource Concerns Categories are:
        - Soil, Water, Air, Plant, Animal, Energy, Humans

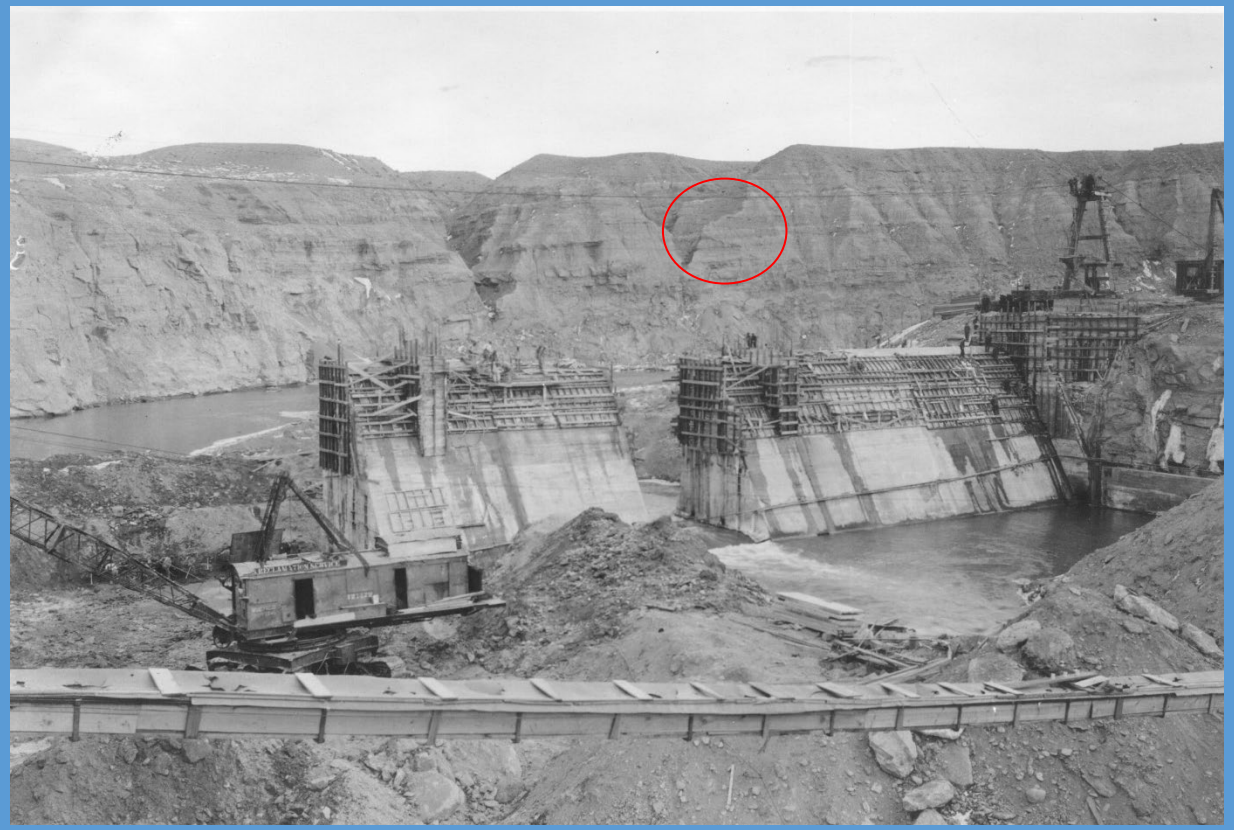
Field Sediment, nutrient and Pathogen Loss

- Sediment transported to surface water
- Nutrients transported to surface water
- Nutrients transported to ground water

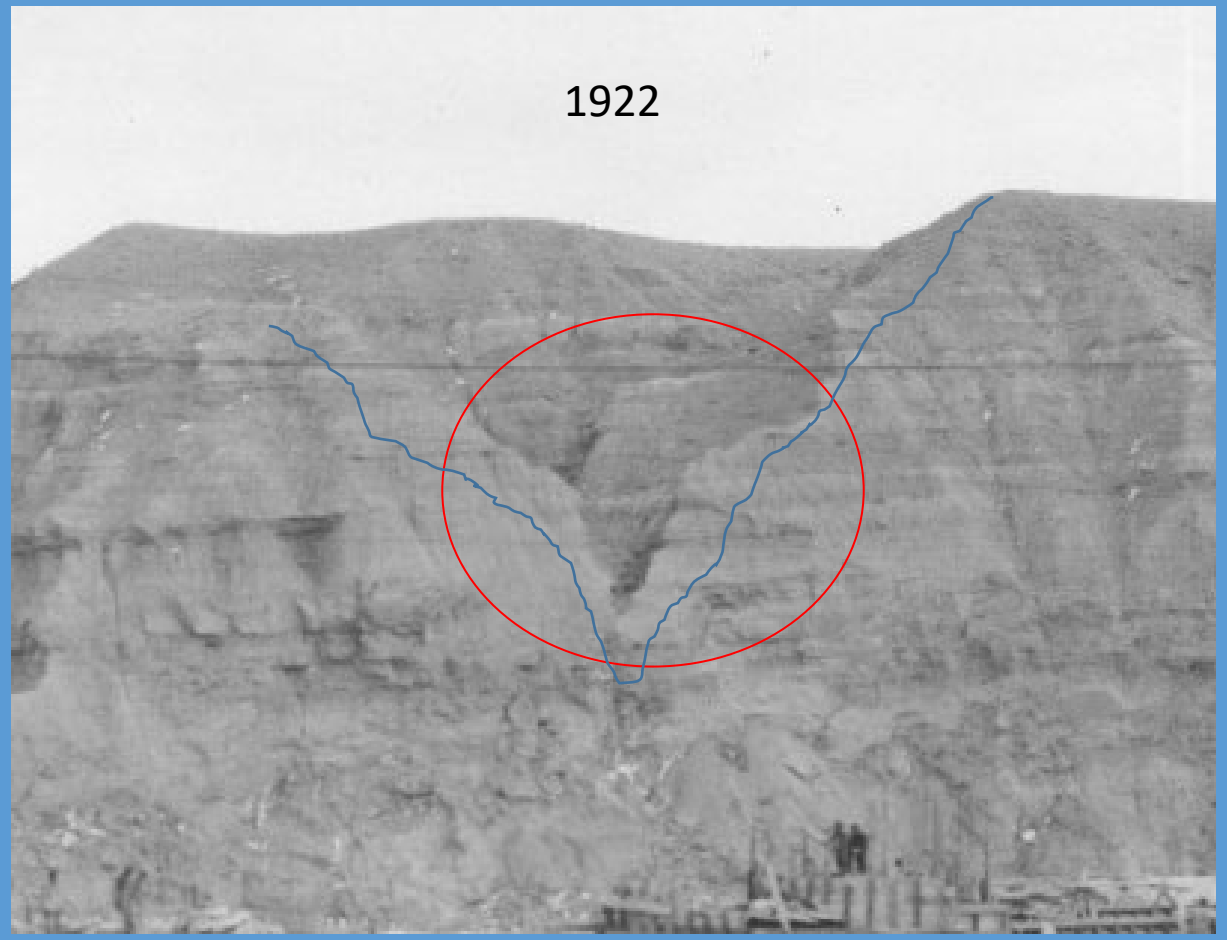

Field Sediment, nutrient and Pathogen Loss
- Sediment transported to surface water
- Nutrients transported to surface water

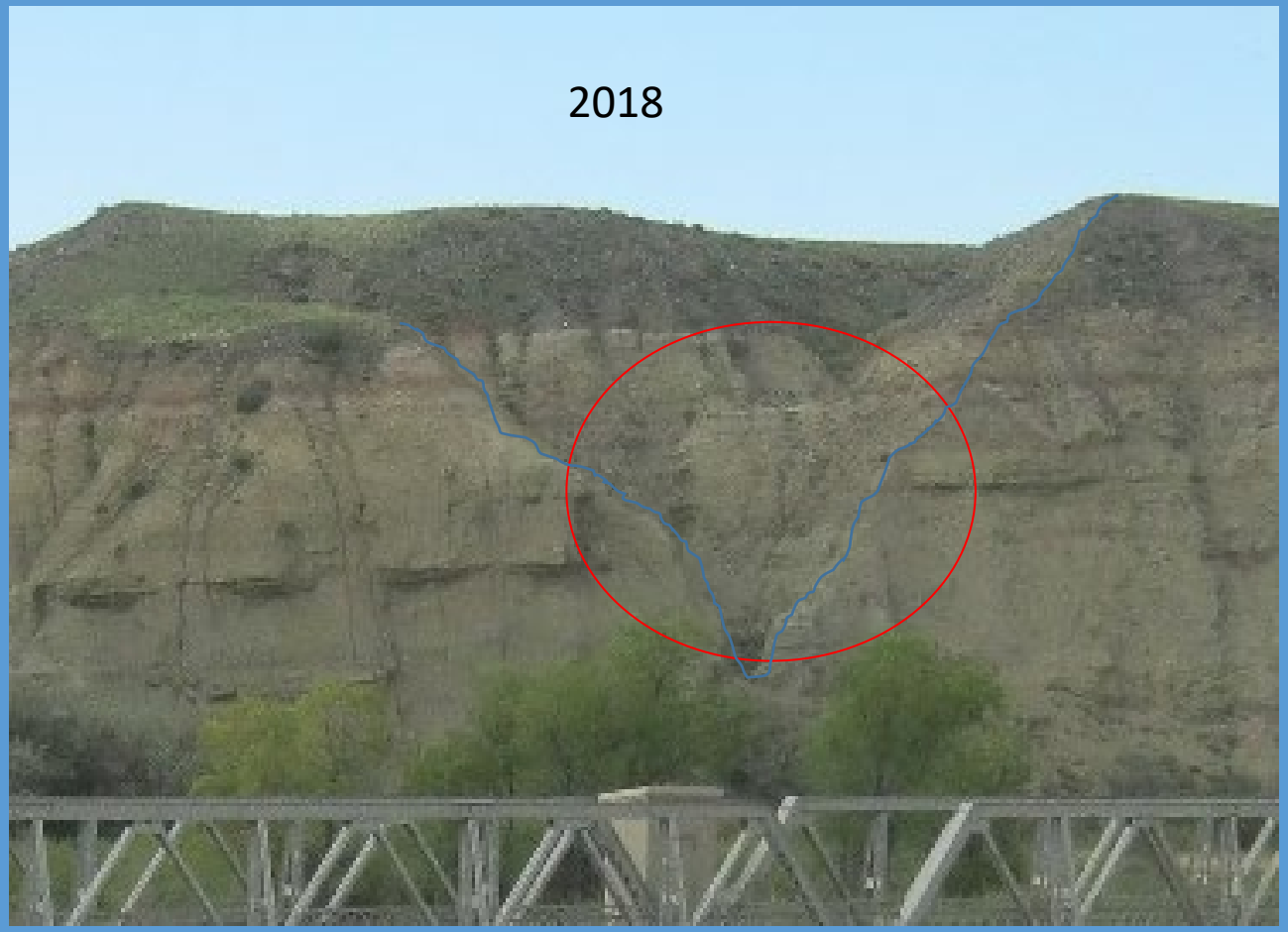

86 ft

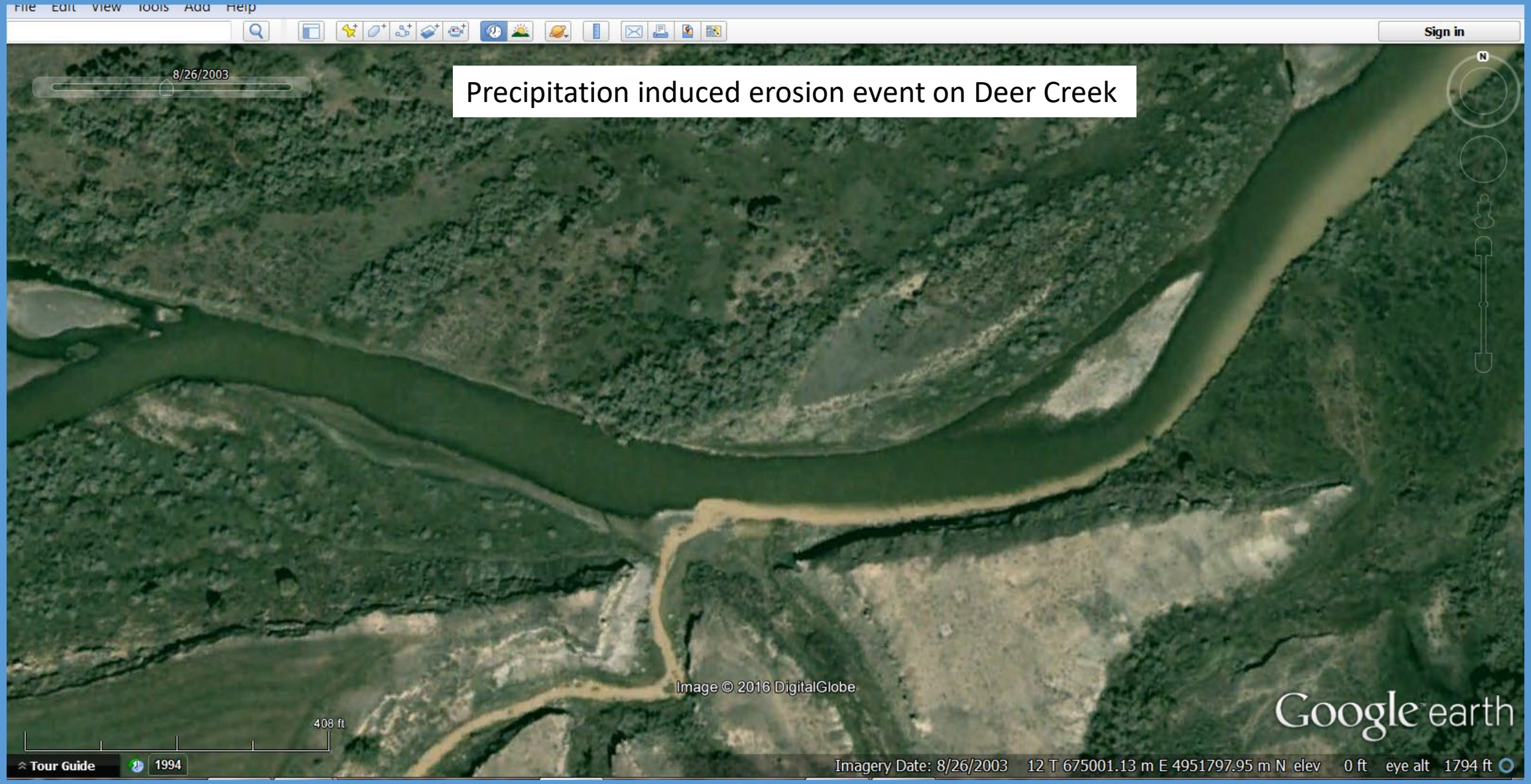

N
447 ft
1985
Google Earth
Imagery Date: 8/3/2013 44°38'56.73" N 108°56'05.82" W elev 4599 ft eye alt 6685 ft




05/30/2018


1922


2018


File Edit View Tools Add Help
Sign in
8/26/2003
Precipitation induced erosion event on Deer Creek
N
Image © 2016 DigitalGlobe
Google earth
408 ft
Tour Guide
1994
Imagery Date: 8/26/2003 12 T 675001.13 m E 4951797.95 m N elev 0 ft eye alt 1794 ft

Soil Category

- Concentration of salts or other chemicals

- Concentration of salts leading to salinity and/or sodicity reducing productivity or limiting desired use.

Soil Category

- Aggregate Instability

- Management-induced degradation of water stable soil aggregates.

  - reduced water infiltration
  - reduced water holding capacity
  - reduced resilience to extreme weather
  - reduced habitat and soil biological activity.
  - increased ponding and flooding
  - increased soil erosion and plant stress
  - Increased surface crusting


Sprinkler Irrigation


Wheel-line Irrigation

Surge Valve Irrigation Systems


04/21/2015 16:20


04/21/2015 09:18


04/20/2015 11:10


04/20/2015 11:30


60% less water and 80% less sediment transport
06/13/2017 10:59

Sprinkler Irrigation

Wheel-line Irrigation

Cover Crops

-Planted after barley harvest

-September 1, 2023

-NRCS cost incentive = $76/ac

Cover Crop 340 Seeding Tool (Planned) - NRCS Wyoming

Name:	Big Horn Basin Producer
Tract and Field Number:	Tract 00, Field 1, Partial Pivot
Acres:	32
Soil map unit:	45AB - Sandy Clay Loam

Plant Species	Cultivar	*Seed Rate PLS Lbs/ac	Seeds per Lbs	Seed per Acre	Total PLS Planned Lbs/field
LEGUMES					
Pea, Austrian Winter		16.0	4,000	64,000	512
Vetch, Common		8.0	8,000	64,000	256
GRASSES					
BRASSICAS					
Collards, Impact Forage		2.5	175,000	437,500	80
Turnip, Purple top		2.0	175,000	350,000	64
Radish, Diakon		2.5	25,000	62,500	80
BROADLEAFS					
Total		**31**		**978,000**	**992**


Oilseed Radish (*Raphanus sativus*)
11/10/2016

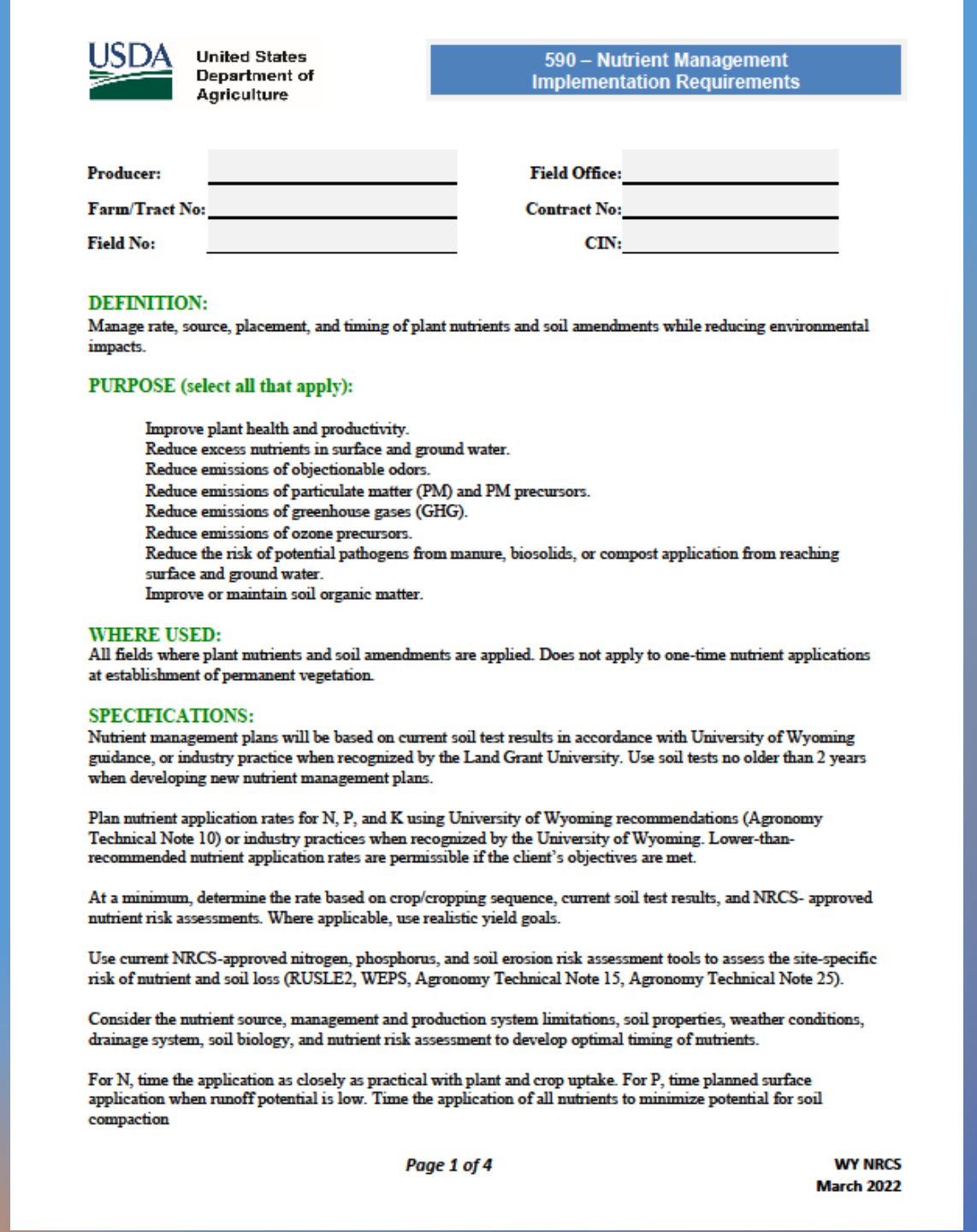

Winter Pea
Forage Collards
Nitro Radish
Common Vetch

Nutrient Management

-Recent soil test

-Follow UW Fertilizer recommendation*

-NRCS cost incentive = $21/ac



USDA United States Department of Agriculture

590 – Nutrient Management Implementation Requirements

Producer: _____ **Field Office:** _____

Farm/Tract No: _____ **Contract No:** _____

Field No: _____ **CIN:** _____

DEFINITION:

Manage rate, source, placement, and timing of plant nutrients and soil amendments while reducing environmental impacts.

PURPOSE (select all that apply):

Improve plant health and productivity.
Reduce excess nutrients in surface and ground water.
Reduce emissions of objectionable odors.
Reduce emissions of particulate matter (PM) and PM precursors.
Reduce emissions of greenhouse gases (GHG).
Reduce emissions of ozone precursors.
Reduce the risk of potential pathogens from manure, biosolids, or compost application from reaching surface and ground water.
Improve or maintain soil organic matter.

WHERE USED:

All fields where plant nutrients and soil amendments are applied. Does not apply to one-time nutrient applications at establishment of permanent vegetation.

SPECIFICATIONS:

Nutrient management plans will be based on current soil test results in accordance with University of Wyoming guidance, or industry practice when recognized by the Land Grant University. Use soil tests no older than 2 years when developing new nutrient management plans.

Plan nutrient application rates for N, P, and K using University of Wyoming recommendations (Agronomy Technical Note 10) or industry practices when recognized by the University of Wyoming. Lower-than-recommended nutrient application rates are permissible if the client's objectives are met.

At a minimum, determine the rate based on crop/cropping sequence, current soil test results, and NRCS- approved nutrient risk assessments. Where applicable, use realistic yield goals.

Use current NRCS-approved nitrogen, phosphorus, and soil erosion risk assessment tools to assess the site-specific risk of nutrient and soil loss (RUSLE2, WEPS, Agronomy Technical Note 15, Agronomy Technical Note 25).

Consider the nutrient source, management and production system limitations, soil properties, weather conditions, drainage system, soil biology, and nutrient risk assessment to develop optimal timing of nutrients.

For N, time the application as closely as practical with plant and crop uptake. For P, time planned surface application when runoff potential is low. Time the application of all nutrients to minimize potential for soil compaction

Nutrient Management

-NRCS Implementation Requirement (IR)

- *Lower-than-recommended nutrient application rates are permissible if the client's objectives are met

USDA United States Department of Agriculture

590 – Nutrient Management Implementation Requirements

Producer:	Big Horn Basin Farmer	**Field Office:**	Powell
Farm/Tract No:		**Contract No:**	
Field No:	1	**CIN:**	1

DEFINITION:
Manage rate, source, placement, and timing of plant nutrients and soil amendments while reducing environmental impacts.

PURPOSE (select all that apply):

- ☑ Improve plant health and productivity.
- ☑ Reduce excess nutrients in surface and ground water.
- ☑ Reduce emissions of objectionable odors.
- ☑ Reduce emissions of particulate matter (PM) and PM precursors.
- ☑ Reduce emissions of greenhouse gases (GHG).
- ☑ Reduce emissions of ozone precursors.
- ☐ Reduce the risk of potential pathogens from manure, biosolids, or compost application from reaching surface and ground water.
- ☑ Improve or maintain soil organic matter.

WHERE USED:
All fields where plant nutrients and soil amendments are applied. Does not apply to one-time nutrient applications at establishment of permanent vegetation.

SPECIFICATIONS:
Nutrient management plans will be based on current soil test results in accordance with University of Wyoming guidance, or industry practice when recognized by the Land Grant University. Use soil tests no older than 2 years when developing new nutrient management plans.

Plan nutrient application rates for N, P, and K using University of Wyoming recommendations (Agronomy Technical Note 10) or industry practices when recognized by the University of Wyoming. Lower-than-recommended nutrient application rates are permissible if the client's objectives are met.

At a minimum, determine the rate based on crop/cropping sequence, current soil test results, and NRCS- approved nutrient risk assessments. Where applicable, use realistic yield goals.

Use current NRCS-approved nitrogen, phosphorus, and soil erosion risk assessment tools to assess the site-specific risk of nutrient and soil loss (RUSLE2, WEPS, Agronomy Technical Note 15, Agronomy Technical Note 25).

Consider the nutrient source, management and production system limitations, soil properties, weather conditions, drainage system, soil biology, and nutrient risk assessment to develop optimal timing of nutrients.

For N, time the application as closely as practical with plant and crop uptake. For P, time planned surface application when runoff potential is low. Time the application of all nutrients to minimize potential for soil compaction

USDA United States Department of Agriculture
Natural Resources Conservation Service

WY-ECS-44
March 2022

NUTRIENT MANAGEMENT DESIGN AND SPECIFICATIONS

Landuser Big Horn Basin Farmer Tract/Field Sparks 35

Assisted by Rory Karhu Date 4/20/2023

Table 1. Field Conditions and Recommendations

CROP SEQUENCE/ROTATION (check current crop in small box)								EXPECTED YIELD
2022		2023	X					120 bu
Dry Beans		Barley						

CURRENT SOIL TEST LEVELS (specify ppm or lb./ac)						
N	P	K	pH	OM%	EC	Texture
28	12	156	8.3	1.0	0.6 mmhos/cm	Sandy Clay Loam

RECOMMENDED NUTRIENTS/AMENDMENTS TO MEET EXPECTED YIELD					
N^1	$P_2O_5{}^1$	K_2O^1	LIME	Other	Other
81	34	0			

Table 2. Nutrient Sources

Nitrogen Credits		N		P_2O_5		K_2O	
		pounds per acre					
1. Nitrogen credits from previous legume crop[2]		0					
2. Residual from long-term manure application[3]		0					
3. Irrigation water[4]		0					
4. Other (e.g., atmospheric deposition)[5] (Sprinkler credit)		24					
5. **Total credits**		24					
Plant-Available Nutrients Applied to Field		N		P_2O_5		K_2O	
(Circle column that is landuser's decision)		Current	Plan	Current	Plan	Current	Plan
6. Credits (from row 5, above)			24		0		0
7. Fertilizer	Starter/Plow Down/Fertigation		0		0		0
	Side Dress/Other (specify by circling)		0		0		0
8. Manure / Organic Materials			0		0		0
9. Subtotal (sum of lines 6, 7 and 8)			24		0		0
10. Nutrients Recommended (from Table 1)			81		34		0
11. Nutrient Status (subtract line 10 from line 9)			-57		-34		0
If line 11 is a negative number, this is the amount of additional nutrients needed to meet the crop recommendation.							
If line 11 is a positive number, this is the amount by which the available nutrients exceed the crop requirements.							

NUTRIENT MANAGEMENT SPECIFICATIONS						
Amount to be Applied (lb./ac)	**N**	57	**P_2O_5**	34	**K_2O**	0
Method, Form, and Timing of Application:						
N credit given for application of irrigation water with sprinkler pivot that results in reduced loss of N to ground and surface water and improved soil organism populations and more efficient N uptake at the root zone. (30% reduction of UW flood irrigation system recommendation.)						

Reduced Tillage

-Soil Tillage Intensity Rating of 80 or less

-Leave residue on surface

-25% fuel savings or greater

-NRCS Cost Incentive: $16/ac

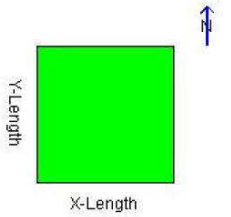
Run Summary

NRCS Natural Resources Conservation Service

Sparks 35 Benchmark

Run Date:	Monday, April 24, 2023, 12:57 PM
Client Name:	[redacted]
Farm No:	[redacted] **Tract No:** [redacted] **Field No:**Sparks 35
Run Location:	[redacted]
Management:	2023 Sparks 35 Barley Benchmark_calib.man
Soil:	Lostwells_like_45AB_40_SCL.ifc

Location Site Information



X-Length:	1234.9 ft	**Mode:**	NRCS
Y-Length:	1234.9 ft	**Soil Loss Tolerance (T):**	5.0 t/ac/yr
Area:	35.0 ac	**Site:**	UNITED STATES WYOMING BIG HORN
Elevation:	4058.4 ft	**Location:**	44.43682° N, 108.28322° W
Orientation:	0.0 °	**Cligen:**	WORLAND
		Windgen:	WORLAND

Erosion

Period	Crop/Residue	Gross Loss t/ac	Net Soil Loss From Field (t/ac) Total	Creep/Salt.	Suspen.	PM10
Rot. year: 1	Barley, spring	17.8	17.8	9.3	8.5	0.20
Ave. Annual		17.8	17.8	9.3	8.5	0.20

Crop Interval Erosion

Date Range	Days	Crop	Gross Loss t/ac	Net Soil Loss From Field (t/ac) Total	Creep/Salt.	Suspen.	PM10
Aug 01, 01 - Aug 01, 01	365	Barley, spring					

Harvests

Date	Crop	Residue lb/ac	Harvest Yield	Yield % Moisture
Aug 01, 01	Barley, spring	9,486	148.0 bu/ac	9.6

SCI Summary

Soil Conditioning Index:	-1.0	**SCI Subfactors**	
Energy Calculator:	7.2 gal diesel/ac	**OM:**	0.95
Average Annual STIR:	159.0	**FO:**	-0.57
Wind Erosion Soil Loss:	17.8 t/ac	**ER:**	-6.00
Water Erosion Soil	0.0 t/ac		

Run Summary

NRCS Natural Resources Conservation Service

Sparks 35 Benchmark

Rotation Stir Energy

Date	Operation	Fuel	Stir	Energy Btu/ac	Cost USD/ac
Mar 15, 01	Fert applic. surface broadcast	Diesel	0.1	24,695	0.71
Mar 15, 01	Plow, moldboard	Diesel	65.0	287,964	8.23
Mar 16, 01	Disk, offset, heavy	Diesel	39.0	138,594	3.96
Mar 17, 01	Cultipacker, roller	Diesel	35.6	95,489	2.73
Mar 17, 01	Land plane	Diesel	10.4	138,594	3.96
Mar 17, 01	Furrow shaper, torpedo	Diesel	2.2	53,881	1.54
Mar 20, 01	Drill or airseeder, double disk	Diesel	6.3	55,378	1.58
May 01, 01	Irrigation, Start Monitor (Border, Furrow)	Diesel	0.0	0	0.00
May 15, 01	Sprayer, post emergence	Diesel	0.1	20,056	0.57
Aug 01, 01	Harvest, killing crop 30pct standing stubble	Diesel	0.1	235,579	6.73
Aug 05, 01	Bale straw or residue	Diesel	0.1	58,521	1.67
Oct 15, 01	Irrigation, Stop Monitor	Diesel	0.0	0	0.00
		Total / ac		1,108,750	31.69
		Total	159.0	38,816,387	1,109.37

Crop Interval Stir Energy

Date Range	Days	Crop	Stir	Energy Btu/ac	Cost USD/ac
Aug 01, 01 - Aug 01, 01	365	Barley, spring	159.0	1,108,750	31.69

Notes

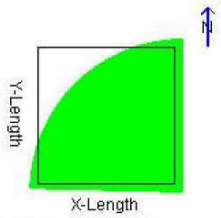
Run Summary

NRCS Natural Resources Conservation Service

Sparks 35 Planned Barley_1

Run Date:	Monday, April 24, 2023, 12:51 PM
Client Name:	[redacted]
Farm No:	[redacted] **Tract No:** [redacted] **Field No:**Sparks 35
Run Location:	[redacted]
Management:	2023 Sparks 35 Barley Planned.man
Soil:	Lostwells_like_45AB_40_SCL.ifc

Location Site Information



Field shape approximate

X-Length:	1234.9 ft
Y-Length:	1234.9 ft
Radius:	1393.4 ft
Area:	35.0 ac
Elevation:	4058.4 ft
Orientation:	0.0 °

Mode: NRCS

Soil Loss Tolerance (T): 5.0 t/ac/yr

Site: UNITED STATES
WYOMING
BIG HORN

Location: 44.43682° N, 108.28322° W

Cligen: WORLAND

Windgen: WORLAND

Erosion

Period	Crop/Residue	Gross Loss t/ac	Net Soil Loss From Field (t/ac) Total	Creep/Salt.	Suspen.	PM10
Rot. year: 1	Barley, spring	0.0	0.0	0.0	0.0	0.00
Ave. Annual		0.0	0.0	0.0	0.0	0.00

Crop Interval Erosion

Date Range	Days	Crop	Gross Loss t/ac	Net Soil Loss From Field (t/ac) Total	Creep/Salt.	Suspen.	PM10
Aug 01, 01 - Aug 01, 01	365	Barley, spring					

Harvests

Date	Crop	Residue lb/ac	Harvest Yield	Yield % Moisture
Aug 01, 01	Barley, spring	12,245	194.4 bu/ac	9.6

SCI Summary

Soil Conditioning Index:	1.0	**SCI Subfactors**	
Energy Calculator:	2.9 gal diesel/ac	**OM:**	1.02
Average Annual STIR:	11.7	**FO:**	0.88
Wind Erosion Soil Loss:	0.0 t/ac	**ER:**	1.00
Water Erosion Soil	0.0 t/ac		

Run Summary

NRCS Natural Resources Conservation Service

Sparks 35 Planned Barley_1

Rotation Stir Energy

Date	Operation	Fuel	Stir	Energy Btu/ac	Cost USD/ac
Mar 15, 01	Fert applic. surface broadcast	Diesel	0.1	24,695	0.71
Mar 17, 01	Strip till bed conditioner	Diesel	4.9	49,241	1.41
Mar 20, 01	Drill or airseeder, double disk	Diesel	6.3	55,378	1.58
May 01, 01	Irrigation, Start Monitor (pivot, linear, wheelline)	Diesel	0.0	0	0.00
May 15, 01	Sprayer, post emergence	Diesel	0.1	20,056	0.57
Aug 01, 01	Harvest, killing crop 30pct standing stubble	Diesel	0.1	235,579	6.73
Aug 05, 01	Bale straw or residue	Diesel	0.1	58,521	1.67
Oct 15, 01	Irrigation, Stop Monitor	Diesel	0.0	0	0.00
		Total / ac		443,470	12.67
		Total	11.7	15,525,507	443.72

Crop Interval Stir Energy

Date Range	Days	Crop	Stir	Energy Btu/ac	Cost USD/ac
Aug 01, 01 - Aug 01, 01	365	Barley, spring	11.7	443,470	12.67

Notes

Advanced Irrigation Water Management

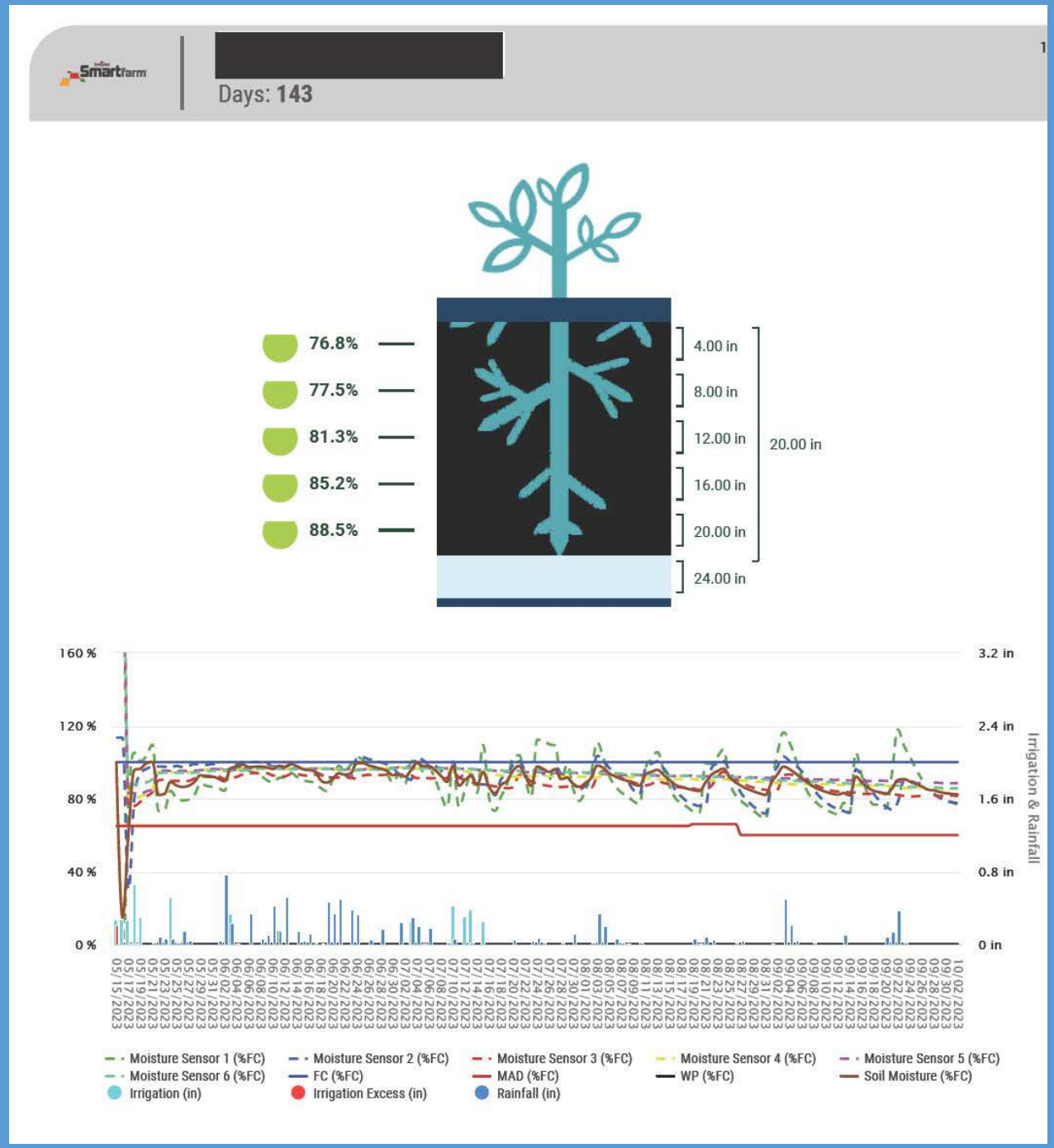
- Soil moisture sensor or local climate station

- Flow meter

-minimum 3 years

-NRCS Cost Incentive: $573/Yr 2-3

-NRCS Cost Incentive: $3143/Yr 1



Conservation Cover (Pollinator Habitat)

Soil Health Toolbox


02/10/2016 10:23


02/10/2016 10:16

Summary

- Irrigation System
  - Pivot Sprinkler
  - Wheel-line
  - Surge Irrigation

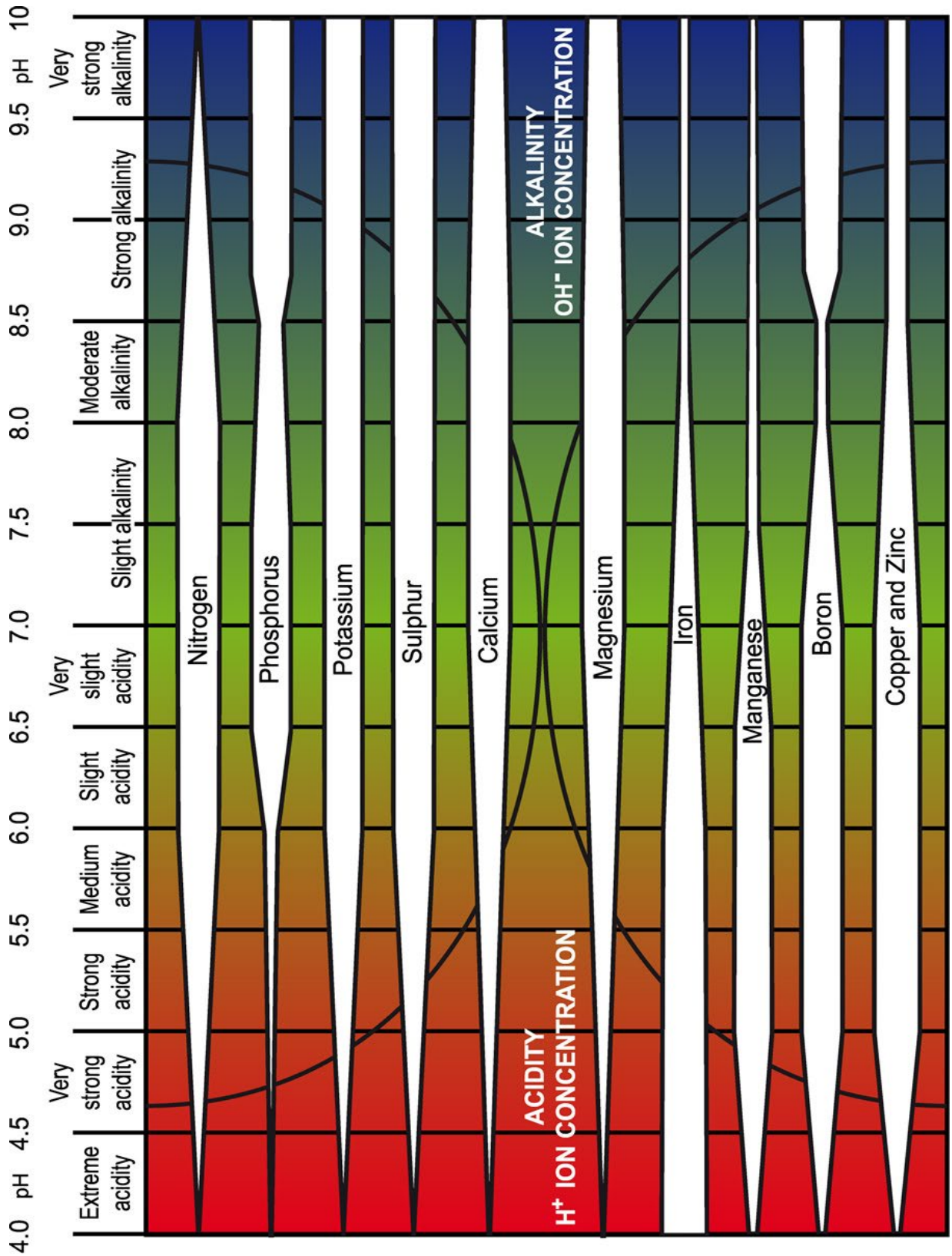
- Cover Crop after barley
- Nutrient Management Plan
- Reduced Tillage
- Advanced Irrigation Water Management
- Conservation Cover (pollinator habitat)

Rory Karhu
District Conservationist
1017 HWY 14A, Powell, WY
rory.karhu@wy.usda.gov
(307) 271-3128 work
(307) 462-1748 cell

Natural Resources Conservation Service

Appendix:

How Soil pH Affects Plant Nutrient Availability



Nutrient Use Spreadsheet for Plants

Nutrient	Symbol	Role in Plants	Absorption Form	Normal (ppm) found in Foliage	Deficiency in Plants	Toxicity	Deficiency in Symptoms in Plants
Nitrogen	N	Amino acids, protein synthesis, nucleic acids	NO_3^-, NH_4^+	1-4%	<1% grasses <2% legumes	None	Chlorosis/yellowing of leaves, stunted growth
Phosphorus	P	Utilizes energy from food reserves, used in early life cycle, root formation, nucleic acid	$H_2PO_4^-$, HPO_4^-	0.25-0.5%	<0.2%	Very low in plants	Purple or reddish leaves and/or stems and stunted growth
Potassium	K	Enzyme activation, winter hardiness, water relations, N uptake and protein synthesis, disease resistance	K^+	2-4%	<1%	Low to None	Spotted leaf tips in alfalfa, reduced cold and disease resistance
Calcium	Ca	Pectate and membrane function, cell regulation	Ca^{2+}	0.5-2.0%	<0.0002%	Very low in plants	Slowed development and eventual death of apical buds of shoots and roots
Magnesium	Mg	Component of chlorophyll, co-factor ATP metabolism	Mg^{2+}	0.2-0.8%	<0.05%	Low to None	Sandy Soils: leaf chlorosis (interveinal areas) while veins remain green
Sulfur	S	Sulfhydryl groups, amino acids	SO_4^{2-}	0.2-0.3%	<0.15	Very low in plants	Leaf chlorosis, low cysteine, and methionine levels, low vitamin and chlorophyll synthesis, possible nitrate accumulation
Boron	B	Amino acids & protein synthesis, nodule formation	H_3BO_3	10-50 ppm	<10 ppm	>75	Stunted growth, yellowing in young tissue
Chlorine	Cl	Photosynthetic phosphorylation, charge balance, osmotic pressure.	Cl^-	500-10,000 ppm	Not required	>20,000	Leaf curling, chlorosis abnormal root growth
Chromium	Cr	Possibly not required	Cr^{3+}, Cr^{6+}	0.2 ppm	Not required	Not present	None
Cobalt	Co	Nitrogen fixation in alfalfa	CO^{2+}	0.05-2 ppm	<0.02 ppm	Very low in plants	Impaired legume nodulation
Copper	Cu	Nitrate reduction, photosynthetic electron transfer	Cu^+, Cu^{2+}	5-15 ppm	>5 ppm	>20ppm in plants	None
Iodine	I	Possible minor role in tissue culture	I^-	3 ppm	Not required	None	None
Iron	Fe	Component of chlorophyll, cytochromes, and enzyme	Fe^{2+}, Fe^{3+}	50 - 1000 ppm	< 35 ppm	Very low in plants	Interveinal chlorosis in younger leaves
Manganese	Mn	Formation of amino acids, chloroplast membrane	Mn^{2+}	30-300 ppm	<20 ppm	>500	None
Molybdenum	Mo	Component of nitrate reductases, N fixation	MoO_4^{2-}	1-100 ppm	<0.2 ppm	>2000	Impaired N uptake and metabolism, resulting in N deficiency symptoms
Nickel	Ni	Component of urease, nitrogen fixation in legumes	Ni^{2+}	0.2 - 2 ppm	< 0.1 ppm	> 30 ppm	None
Selenium	Se	Possibly not required	SeO_3	0.15 ppm	Not required	None	None
Silicon	Si	Not essential/possible role in drought resistance	$Si(OH)_4$	400-10,000 ppm	Not required	None	None
Sodium	Na	Not essential but when present acts with K to regulate osmotic pressure and charge balance	Na^+	100-200 ppm	Not required	None	None
Zinc	Zn	Enzymatic activities	Zn^{2+}	10-100 ppm	<10	>200	White or stripped leaves

Source: Collins, M., Nelson, C. J., Moore, K. J., & Barnes, R. F. (2018). Chapter 12. In Forages: An introduction to grassland agriculture (7th ed., Vol. 1, pp. 237–243). essay, Wiley.

Nutrient Use Spreadsheet for Animals

	Symbol	Role in Animals	Absorption Form	Normal (ppm) found in Foliage	Deficiency in Livestock	Deficiency Symptoms in Animals
Nitrogen	N	Protein synthesis	NO_3^-, NH_4^+	1-4%	<1 N:S ratio should not exceed 10:1	Low growth rates, poor production
Phosphorus	P	Skeletal component, energy metabolism, nucleic acids	$H_2PO_4^-$, HPO_4^-	0.25-0.5%	<0.1% with a Ca:P ratio between 2:1 and 1:1	Unthrifty, poor growth, poor milk production
Potassium	K	Maintain acid-base balance, enzyme reactions, carbohydrate metabolism	K^+	2-4%	<0.9%	Rare: but occurs in productive and lactating cattle, reduced intake, weight loss, hair loss, weakness, production loss
Calcium	Ca	Component of structure (skeleton), blood coagulation, cell regulation	Ca^{2+}	0.5-2.0%	<0.4 Desirable C:P ratio is between 2:1 to 1:1	Impaired bone growth resulting in slow growth and osteoporosis
Magnesium	Mg	Skeleton development, phosphorylation, enzyme activation	Mg^{2+}	0.2-0.8%	<0.1 (0.3) Mg uptake can also be depressed by excessive K and Ca	Hypomagnesemia
Sulfur	S	Present in amino acids, acid-base balance, intracellular constituent, carbohydrate metabolism	SO_4^{2-}	0.2-0.3%	<0.2 N:S ratio should not exceed 10:1	Low protein synthesis, resulting in slow growth and poor production
Boron	B	Possibly not required	H_3BO_3	10-50 ppm	Very low to none	Not required
Chlorine	Cl	Regulation of extracellular osmotic pressure, maintain acid-base balance.	Cl^-	500-10,000 ppm	<2,000 ppm	Anorexia, lethargy, eye defects, reduced respiration, blood in feces
Chromium	Cr	Glucose tolerance factor--insulin regulation	Cr^{3+} , Cr^{6+}	0.2 ppm	Very low to none	None
Cobalt	Co	Synthesis of vitamin B12 in ruminants	CO^{2+}	0.05-2 ppm	<0.11 ppm	Vitamin B12 deficiency, chronic wasting disease, unthriftiness and weight loss
Copper	Cu	Needed in enzymes and iron metabolism, immune system	Cu^+ , Cu^{2+}	5-15 ppm	<0.6 ppm Cu absorption subject to interference from Zn, Mo, S, and Fe	Loss of hair pigmentation, scours, anemia, reduced immune function
Iodine	I	Thyroid gland function	I^-	3 ppm	<0.3 ppm	Enlarged thyroid, especially in calves
Iron	Fe	Component of hemoglobin - oxygen transport in the blood, component of cytochromes of the electron transport chain.	Fe^{2+}, Fe^{3+}	50 - 1000 ppm	< 0.1 (<1.0) ppm	Rare but can occur in calves: anemia and high mortality due to impaired immune response.
Manganese	Mn	Needed for bone matrix formation	Mn^{2+}	30-300 ppm	<15 ppm	Impaired growth, skeletal abnormalities, poor reproduction, abnormal births
Molybdenum	Mo	Component of metalloenzymes	MoO_4^{2-}	1-100 ppm	<1g ppm Mo values exceeding 5-10 ppm can impair Cu uptake in livestock	Deficiency is rare, no consistent symptoms have been found
Nickel	Ni	Has been shown to be essential in rats and is assumed to be essential in livestock	Ni^{2+}	0.2 - 2 ppm	Very low to none	Reduced growth, low rumen urease activity in lambs
Selenium	Se	Component of glutathione peroxidase, cell membranes, immune system function	SeO_4^{2-}	0.15 ppm	<0.3 ppm May be toxic to livestock above 8.5 ppm	White muscle disease
Silicon	Si	Mineralization of bones	$Si(OH)_4$	400-10,000 ppm	Si values exceeding 0.2% of diet will depress intake	Si is so abundant that no deficiency symptoms have been observed
Sodium	Na	Acts with K and Cl to balance extra cellular fluid, maintain osmotic pressure, heart and nerve function	Na^+	100-200 ppm	<1,000 (<2,000) ppm	Licking and chewing, salt craving, urine drinking, unthrifty, rough hair coat
Zinc	Zn	Activates enzymes, component of metalloenzymes	Zn^{2+}	10-100 ppm	<4 (<6) ppm	Reduced feed intake and growth, parakeratosis of skin on head, legs, and neck

Source: Collins, M., Nelson, C. J., Moore, K. J., & Barnes, R. F. (2018). Chapter 12. In Forages: An introduction to grassland agriculture (7th ed., Vol. 1, pp. 237–243). essay, Wiley.

Estimated Nutrient Removal in Harvested Portion of crops

Crop	Unit	lb/bu	N	P_2O_5	K_2O	Ca	Mg	S	Fe	Zn	Mn	Cu	B
			lbs										
Barley - grain	bu	48	0.87	0.36	0.25	0.025	0.05	0.08	-	0.0015	0.0008	0.0008	0.001
Barley - straw	ton	-	14	4.1	30	7.6	2	3.8	-	0.045	0.3	0.01	-
Oat - grain	bu	32	0.6	0.24	0.17	0.024	0.04	0.06	-	0.0006	0.001	0.0004	-
Oat - straw	ton	-	12.2	5.8	33	0.4	4	4.6	-	0.145	-	0.015	-
Wheat - grain	bu	60	1.25	0.62	0.38	0.025	0.15	0.08	-	0.0035	0.002	0.0008	0.001
Wheat - straw	ton	-	14.5	3.6	25	4.4	2.2	3.7	-	0.03	0.11	0.007	-

Crop	Unit	lb/bu	N	P_2O_5	K_2O	Ca	Mg	S	Fe	Zn	Mn	Cu	B
			lbs										
Corn - grain	bu	56	0.73	0.6	0.27	0.015	0.05	0.07	0.0055	0.001	0.0006	0.0004	-
Corn - stover	ton	-	19.8	8.8	40	5.8	4.5	3.2	-	0.067	0.33	0.01	-
Corn - silage	ton	-	9.7	3.1	7.3	-	-	1.1	-	-	-	-	-

Crop	Unit	N	P_2O_5	K_2O	Ca	Mg	S	Fe	Zn	Mn	Cu	B
		lbs										
Alfalfa	ton	48	11	53	28	5	5.5	0.38	0.11	0.11	0.02	0.02

Crop	Unit	N	P_2O_5	K_2O	Ca	Mg	S	Fe	Zn	Mn	Cu	B
		lbs/ton										
Grass	ton	25	10	38	7	2.5	2	-	0.08	0.13	0.01	-

Crop	Unit	N	P_2O_5	K_2O	Ca	Mg	S	Fe	Zn	Mn	Cu	B
		lbs/ton										
Sugarbeet	ton	25	10	38	7	2.5	2	-	0.08	0.13	0.01	-

Crop	Unit	lb/bu	N	P_2O_5	K_2O	Ca	Mg	S	Fe	Zn	Mn	Cu
			lbs									
Dry bean	bu	60	3	0.79	0.92	0.18	0.06	0.52	0.03	0.004	0.002	0.0015

"Nutrient Uptake & Removal." *Nutrient Uptake - MSU Extension Soil Fertility | Montana State University*, landresources.montana.edu/soilfertility/nutuptake.html#corn.

Crop Nutrient Uptake Guide

Pounds of nutrient per production unit

CROP	Unit	N	P_2O_5	K_2O
Alfalfa	tons	56.60	13.30	60.00
Alfalfa Haylage	tons	33.48	9.11	33.41
Corn Grain	bu	0.90	0.37	0.87
Corn Silage	bu	9.00	3.10	9.00
Grass Hay	tons	40.00	12.86	58.80
Wheat (fall dry)	bu	2.00	0.75	2.00
Wheat (irrigated)	bu	1.70	0.70	2.00

Bowcutt, Jim, et al. *The Fundamentals of Nutrient Management*, Utah State University Cooperative Extension, Mar. 2011, extension.usu.edu/agwastemanagement/files/Fundamentals_of_Nutrient_Management_2011.pdf.

Yield goals used for field crops

Crop		Adjustment Factors lbs. nutrient/ yield unit N	P_2O_5	K_20	Yield Units
Forage					
	Grass and/or	40	15	35	T/A
	legume	40	15	40	
Grains					
	Corn, ensilage	9.0	3.0	8	T/A
	Shelled corn	1.6	0.6	1.2	Bu/A
	Sorghum, etc. [1]	9.0	3.0	8	T/A
	Millet	2.0	0.6	1.7	Bu/A
	Barley	1.6	0.7	1.6	Bu/A
	Oats	1.2	0.5	1.3	Bu/A
	Wheat	1.7	1.0	2	Bu/A
Commercial Crops					
	Dry bean	N/A	1.75	4.0	Cwt/A
	Potato	0.5	0.2	1.0	Cwt/A
	Sugarbeet	9.0	3	9.0	T/A
	Sunflower	6.0	2	2.0	Cwt/A

[1] Sorghum, Sudan, or hybrids for ensilage, hay, or pasture

N/A No adjustment

Blaylock, Alan D, et al. "Guide to Wyoming Fertilizer Recommendations." University of Wyoming Cooperative Extension Services, Nov. 1996.