Project Abstract
For the Period Ending June 30, 2021

PROJECT TITLE: Using Perennial Grain Crops in Wellhead Protection Areas to Protect Groundwater
PROJECT MANAGER: Margaret Wagner
AFFILIATION: Minnesota Department of Agriculture
MAILING ADDRESS: 625 Robert Street North
CITY/STATE/ZIP: St. Paul, MN 55115
PHONE: 651-201-6488
E-MAIL: Margaret.wagner@state.mn.us
WEBSITE: https://www.mda.state.mn.us/
FUNDING SOURCE: Environment and Natural Resources Trust Fund
LEGAL CITATION: M.L. 2018, Chp. 214, Art. 4, Sec. 02, Subd. 04j as extended by M.L. 2020, First Special Session, Chp. 4, Sec. 2

APPROPRIATION AMOUNT: $250,000
AMOUNT SPENT: $248,977
AMOUNT REMAINING: $1,023

Sound bite of Project Outcomes and Results
This study established demonstration fields of Intermediate wheatgrass (Kernza®) within wellhead protection areas in central and southeast Minnesota and research results showed the nitrate reduction potential of targeted placement of perennials in areas with vulnerable groundwater.

Overall Project Outcome and Results
Nitrate-nitrogen is one of the most common pollutants in Minnesota's groundwater. In some areas of the state, public and private wells have elevated nitrate levels. Groundwater is most vulnerable to nitrate contamination in central and southeast Minnesota. Areas in central are vulnerable because of widespread sandy soil and in southeast because of shallow bedrock, sinkholes and other geologic features. Intermediate wheatgrass (IWG) is a perennial grass that produces a novel grain, Kernza® and has the potential to reduce nitrate leaching compared to common annual row crop production. This study 1) established demonstration fields of IWG within wellhead protection areas in central and southeast Minnesota and 2) conducted an experiment that compared grain yields, biomass yields, soil nitrate, soil water content, and root biomass under IWG and a corn-soybean rotation for three years on a sandy soil in Central Minnesota. We also 3) conducted grain testing to determine optimum processing of Kernza for various end-use products (crackers, bread, beer, etc). Outcomes included targeted planting of 68 acres of IWG in wellhead protection areas near Chatfield and Verdi. A field day was held at both sites, engaging over 60 people. Results from Activity 2 found that the mean soil nitrate was 77 to 96% lower under IWG than an annual rotation of corn and soybean. Total soil water content did not differ among cropping treatments. Root biomass was 82% lower under soybean than under IWG. Results from Activity 3 include the development of multiple Kernza cleaning and dehulling process workflows that include equipment needs, costs, and Kernza grain quality outcomes. The results from this project show that IWG effectively reduces the risk of nitrate leaching when grown on wellhead protection areas, and that the farming and food community is eager to continue exploring IWG as a new crop for water protection.

Project Results Use and Dissemination
Field days at two locations with ~60 participants on site. Events highlighted in newspaper articles. Case study/ project summaries written by Green Lands Blue Waters. Master's student research is in process of being submitted for publication in a peer-reviewed journal. Deliverable for Activity 3 includes a technical report on cleaning intermediate wheatgrass (Kernza) as well as resources for food processors to integrate it into their business operations.

The research supported by this grant is part of a larger network of research and implementation efforts around Kernza. Resources are compiled on a Kernza website, including resources for the cleaning and dehulling process.

Today's Date: July 30, 2021

Date of Next Status Update Report:

Date of Work Plan Approval: 06/05/2018

Project Completion Date: 06-30-2021

Does this submission include an amendment request? Yes

PROJECT TITLE: Using Perennial Grain Crops in Wellhead Protection Areas to Protect Groundwater

Project Manager: Margaret Wagner

Organization: Minnesota Department of Agriculture

College/Department/Division: Pesticide and Fertilizer Management Division

Mailing Address: 625 Robert Street North

City/State/Zip Code: St. Paul, MN 55155

Telephone Number: 651-201-6488

Email Address: Margaret.wagner@state.mn.us

Web Address:

Location: Lincoln, Olmsted, and Wadena Counties

Total Project Budget: $250,000

Amount Spent: $248,977

Balance: $1,023

Legal Citation: M.L. 2018, Chp. 214, Art. 4, Sec. 02, Subd. 04j as extended by M.L. 2020, First Special Session, Chp. 4, Sec. 2

Appropriation Language: $250,000 the second year is from the trust fund to the commissioner of agriculture to establish demonstration plots of Kernza, a new intermediate perennial grain crop, to evaluate the potential to profitably reduce nitrate contamination of groundwater in vulnerable wellhead protection regions of Minnesota. Any income generated as part of this appropriation may be used to expand the project.

M.L. 2020 - Sec. 2. ENVIRONMENT AND NATURAL RESOURCES TRUST FUND; EXTENSIONS. [to June 30, 2021]

I. PROJECT STATEMENT:

Annual row-crop production on coarse textured soils above shallow aquifers contributes to nitrate leaching and drinking water contamination. Preventing nitrate contamination through innovative land-use practices could be a cost-effective method to protecting groundwater. Converting row-crop agriculture to perennial cover is known to reduce nitrate leaching; however, converting annual crops to perennials is rarely an economically viable solution to improve water quality, until now. Almost two decades of traditional plant breeding (non-GMO) has resulted in a new perennial grain crop from intermediate wheatgrass (IWG) called Kernza®. The University of Minnesota has partnered with The Land Institute (a non-profit from Kansas) to develop IWG into a new perennial grain crop, which requires fewer pesticides since it is resistant to most wheat diseases and crop pests. IWG has a deep, dense root system that filters nitrate from soil water before it pollutes groundwater. **This project will establish production-scale fields of IWG to demonstrate and confirm that reductions in nitrate leaching below the perennial crop can reduce nitrate in groundwater compared to annual row crops in vulnerable wellhead catchment areas**.

This project will be Phase 1 (2 years) of a long-term (6-10 years) study to reduce groundwater nitrate contamination in high-risk, wellhead protection areas using IWG. Phase 1 will establish a network of instrumented IWG demonstration and research fields at three diverse locations to measure water and soil quality improvements compared to an annual row-crop. The three locations and partnering entities are:

- **Lincoln-Pipestone Rural Water** (LPRW) 54 acres planted in a highly vulnerable wellhead protection area (pumps 1.8 billion gallons of water annually to 36 municipalities and rural residents in a 10 county region). These are not lands protected with a conservation easement through a previous ENRTF-funded project because that project was not completed when planting began with in-kind funds for this project. Instead, we will plant on lands owned by Lincoln-Pipestone that were previously rented to farmers planting corn and soybean. This land will be made available for use rent free during the project period by Lincoln-Pipestone.
- **City of Chatfield** (Olmsted and Fillmore counties) 10 acres planted on land with karst soil owned by the city and a private party. Seven acres are planted on private land within a wellhead protection acre and three acres planted on public land directly adjacent to the wellhead protection area. Rental payment will be based on current market value.
- **Central Lakes College** Four acres planted at the Ag and Energy Center operated by Central Lakes College (Staples, Wadena County) in the Central Sands Region with coarse-textured soil that would be typical of land in a wellhead protection area and is vulnerable to nitrate leaching. This land typically has low annual crop yield unless irrigated. Rental payment will be based on current market value.

II. OVERALL PROJECT STATUS UPDATES:

First Update January 31, 2019

The project was successfully established. Subaward agreements with the University of Minnesota and Central Lakes College were signed. Approximately 54 acres of land in the Verdi wellfield near Pipestone, a wellhead protection area, was converted from annual row crop agriculture to intermediate wheatgrass (IWG). An additional 13 acres of IWG was planted in Chatfield, MN, 3 of which were in wellhead protection areas. An acre of IWG was planted at Central Lakes College in Staples, MN for the replicated experiments to monitor groundwater quality. Lysimeters were installed at all locations. Samples were collected from the Staples site and analyzed for nitrate leaching. The demonstration fields in Pipestone and Chatfield were harvested for grain. Three field days were held, one at each location, to describe the project to various water quality and agricultural stakeholder groups. Preliminary data from this project was presented at the Water Resources Conference in October, 2018.

Second Update June 30, 2019

The project has progressed as planned. Baseline soil samples were collected from all sites (Lincoln-Pipestone, Chatfield, and Staples) in April of 2019. Soil moisture access tubes were installed; 12 in Staples, 8 in Pipestone,

and 4 in Chatfield, and moisture readings were collected about every two weeks. Water quality sampling started in April of 2019 and has continued about every week. Grain harvest will occur within the next week.

Third Update January 31, 2020

The project is progressing as planned. Despite the challenging year for most annual crops, IWG grew back well in the spring and produced harvestable grain at all locations in year two. This demonstrates the logistical benefits of a perennial grain crop like IWG. Since the last update, various meetings among team members have taken place to summarize the 2019 project status and to plan for the 2020 season. Research samples have been processed in the lab and preliminary data analysis has been conducted to prepare outreach materials.

AMENDMENT REQUEST May 25, 2020

We are requesting that funds be shifted across funding categories to accommodate travel and personnel hiring restrictions in accordance with statewide and University policies and restrictions in response to COVID-19. We were unable to hire undergraduate interns to finish processing samples during the spring of 2020, thus we are requesting to move funds from the undergraduate labor category to the technician category. Lab work has ceased at the University of Minnesota, thus we are requesting to move funds from the analyses category to the technician category. Statewide travel has also been restricted, thus we are requesting to move funds from the travel category to the technician category.

- Undergraduate labor will be reduced by $5,805 to a revised budget of $6,675
- Soil water nitrate analyses will be reduced by $8,496 to a revised budget of $18,000
- Travel will be reduced by $15,000 to a revised budget of $3,000
- Technician labor will be increased by $28,373 to a revised budget of $53,039
- Graduate student will be increased by $928 to a revised budget of $62,234

Amendment approved by LCCMR 6/10/20

Project extended to June 30, 2021 by LCCMR 6/18/20 as a result of M.L. 2020, First Special Session, Chp. 4, Sec. 2, legislative extension criteria being met.

Fourth Status Update August 18, 2020:

Prior to the University shut down in March as a result of COVID-19, the project team finished threshing grain samples for 2019 yield estimation. Preliminary analyses of soil moisture and lysimeter data were conducted to present research findings to project partners. The research team met with J. Overby and B. Burkholder to discuss the future of the Kernza fields in the wellhead protection areas. Both fields were scheduled for harvest again in 2020. Field activities were delayed in spring of 2020 due to travel restrictions, and all lab activities were abruptly halted to adhere to CDC and MDH guidelines to prevent the spread of COVID-19. Fieldwork resumed in May on a limited basis after our travel request was reviewed and approved by the University of Minnesota. Data collection from the Staples site was prioritized to ensure a robust dataset from the replicated experiment. Soybeans were planted in June, soil moisture and lysimeter data were collected throughout the summer and into the fall. Crop yields were harvested starting with Kernza in August and soybeans in late September. Soil samples were collected from the Staples site.

Fifth Status as of January 1, 2021:

All of the field data have been collected including crop yields, soil samples, root samples, soil water samples, and soil moisture data. Most of the samples have been processed in the lab and data have been aggregated. Data analysis has started and some preliminary results have been shared through virtual presentations. The team is on track to complete the final reports on schedule.

Final Update June 30, 2021:
All laboratory and statistical analyses have been completed. A case-study handout has been developed and distributed at field days and other virtual events based on results and observations related to Activity 1. Results from the field experiment (Activity 2) were presented by Evelyn Reilly during her MS degree defense seminar, which can be found here. Results can also be found in Evelyn's thesis, which will be made available publicly when published. The thesis chapter is being modified for submission to a peer-reviewed journal, which will be made available upon publication.

Overall, this project developed new information confirming the ability of intermediate wheatgrass (IWG) to limit nitrate leaching to groundwater. Our results showed that nitrate in soil water beneath the rooting zone was 77 to 96% lower beneath IWG compared to a soybean and corn rotation. This reduction in soil water nitrate was associated with an 82% increase in root biomass beneath IWG compared to corn. Along with the water quality benefits provided by IWG, the crop produced economically viable grain yields during the first two years of production, but grains yields declined by 75% in year three compared to year one. This suggests that research is needed to identify agronomic methods to sustain grain yields as stands age to maximize the water quality benefits this crop can provide in ecologically sensitive areas. This study also demonstrated that IWG can be farmed in drinking water supply management areas (DWSMAs) in various regions of Minnesota. The production-scale fields that were established as part of this project were essential for connecting with local businesses, farmers, natural resource advocates, and others on the potential for IWG to improve rural economies and environment. The partnerships formed around these demonstration fields during this project have resulted in new, innovative projects funded by national-scale grants that are positioning Minnesota as a national leader in drinking water protection. The work conducted by AURI in Activity 3 has ensured that this strategy of protecting drinking water is profitable for farmers, processors, and end-users; demonstrating that complete economic impact IWG can have on Minnesota communities. All of these lessons and outcomes have been disseminated to a wide range of audiences and stakeholders, which has resulted in new opportunities to continue research and implementation of IWG production in DWSMAs.

AMENDMENT REQUEST June 30, 2021

We are requesting that funds be shifted across funding categories to accommodate for adaptations to COVID-19. These adaptations are explained in May 2020 amendment request, but slight changes to budget values were made to account for labor availability and the number of samples collected in 2021.

- Technician labor will be increased by $13,596 to a revised budget of $66,635
- Graduate student will be increased by $3,054 to a revised budget of $65,289
- Process Scientist will be increase by $1,633 to a revised budget of $24,513
- Travel expenses in Minnesota increased by $2 to a revised budget of $3,002
- Travel (AURI) will be reduced by $2,000 to a revised budget of $0
- Soil water nitrate analyses will be reduced by $9,640 to a revised budget of $8,360
- Lysimeters will be reduced by $504 to a revised budget of $5,896
- Professional/Technical/Service Contracts will be reduced by $6,141 to a revised budget of $2,606

Amendment approved by LCCMR 10/11/2021

Overall Project Outcome and Results
Nitrate-nitrogen is one of the most common pollutants in Minnesota's groundwater. In some areas of the state, public and private wells have elevated nitrate levels. Groundwater is most vulnerable to nitrate contamination in central and southeast Minnesota. Areas in central are vulnerable because of widespread sandy soil and in southeast because of shallow bedrock, sinkholes and other geologic features. Intermediate wheatgrass (IWG) is a perennial grass that produces a novel grain, Kernza® and has the potential to reduce nitrate leaching compared to common annual row crop production. This study 1) established demonstration fields of IWG within wellhead protection areas

in central and southeast Minnesota and 2) conducted an experiment that compared grain yields, biomass yields, soil nitrate, soil water content, and root biomass under IWG and a corn-soybean rotation for three years on a sandy soil in Central Minnesota. We also 3) conducted grain testing to determine optimum processing of Kernza for various end-use products (crackers, bread, beer, etc). Outcomes included targeted planting of 68 acres of IWG in wellhead protection areas near Chatfield and Verdi. A field day was held at both sites, engaging over 60 people. Results from Activity 2 found that the mean soil nitrate was 77 to 96% lower under IWG than an annual rotation of corn and soybean. Total soil water content did not differ among cropping treatments. Root biomass was 82% lower under soybean than under IWG. Results from Activity 3 include the development of multiple Kernza cleaning and dehulling process workflows that include equipment needs, costs, and Kernza grain quality outcomes. The results from this project show that IWG effectively reduces the risk of nitrate leaching when grown on wellhead protection areas, and that the farming and food community is eager to continue exploring IWG as a new crop for water protection.

III. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: ***Establish and maintain IWG fields for demonstration and research***
Description: Establish approximately 68 acres of IWG. Fifty-seven acres will be located within two wellhead protection areas considered high priority for protection by the Minnesota Department of Health (MDH) and Minnesota Department of Agriculture (MDA). The remaining acres will be on land typical of soils present on wellhead protection areas in that region. Activity includes securing land, preparing land for planting, and seeding IWG. All lands will be planted in order to evaluate the ability of IWG to reduce nitrogen from reaching groundwater. Two of the three sites will also be used for an IWG field day in 2019. One of these field days will be held in conjunction with *Green Lands Blue Waters* (a regional consortium of Mississippi River watershed partners) and will leverage technical and financial resources.
ENRTF BUDGET: $57,466

Outcome	Completion Date
1. Establish stands of IWG	July 1, 2018
2. Host IWG field day at two of three sites and develop outreach materials	October 30, 2019

First Update January 31, 2019
All 68 acres were planted as planned. Grain was harvested from the 54 acres in Pipestone on Aug. 18, 2018, and from 13 acres in Chatfield on Aug. 18, 2018. A field day was held in Pipestone on Aug 23, which attracted about 40 people. Coverage of the event by local media can be viewed here. A field day was held in Chatfield on Aug 22, which attracted about 50 people. Local media coverage of the event can be found here. Lysimeters were installed in the demonstration fields, but because of the timeline for the initiation of the subaward agreement between MDA and UMN (September 4, 2018) no lysimeter samples were collected from Chatfield and Pipestone.

Second Update June 30, 2019
Since field days were held in fall of 2018 to showcase the plantings and inform the public about the project, the next field day will be held in the Spring of 2020. This timeline will allow the project team to analyze the water quality and yield data for dissemination during the field day events.

Third Update January 31, 2020
Approximately 10,250 pounds of Kernza grain was harvested from the 41-acre Lincoln Pipestone Rural Water (LPRW) field on August 29, 2019. A new harvesting technique was tested on this field. Kernza grain was harvested using direct combining methods and a stripper head, which is designed to reduce the amount of chaff entering the combining. This results in cleaner and drier seed. The grain was transported and dried in a bin in Madison, MN before shipped to Healthy Foods Ingredients (HFI) for cleaning and dehulling. Approximately 3,280 pounds of Kernza grain was harvested from the 7-acre field in Chatfield. The field was swathed on August 21, 2019 before being combined on August 23, 2019. This grain was shipped to Madison, MN for drying before

being shipped to HFI for cleaning and dehulling. Clean grain was transported to Sprowt Labs for milling and distribution for food use.

Fourth Update July 1, 2020:
Hand-samples of seed and biomass that was collected in summer/fall of 2019 were weighed and processed (threshed) in early winter 2020. Field day preparations were taking place prior to COVID-19, but all in-person demonstration events were cancelled. Minimal lysimeter sampling and soil moisture data were collected from these fields prior to COVID-19 travel restrictions put in place. Production-scale harvest was conducted at both the LPRW and the Chatfield sites. Grains samples were analyzed for DON and other toxins.

Fifth Update January 1, 2021:
No activities occurred for activity 1 during this period of updates.

Final Update June 30, 2021
These demonstration fields proved to be incredibly valuable as they 1) fostered new partnerships across water and agricultural stakeholder groups, 2) served as a source of Kernza grain for AURI and other Minnesota-based companies interested in processing and marketing Kernza, and 3) accumulated nitrate from the soil that would have otherwise leached into the groundwater – thus having a direct impact on water quality in the region. A case-study handout describing the LPRW Kernza planting and water quality issue was developed and can be found here.

ACTIVITY 2: ***Initiate field instrumentation and data collection of IWG water studies***
Description: Install and execute a replicated experiment at Central Lakes College to measure nitrogen use dynamics and nitrate leaching beneath IWG and annual row crops. This sites will include detailed soil nutrient analyses, lysimeters for soil water analyses, and soil moisture sensors. Project partners will collect soil nitrate data at various depths, measure root growth and turnover, measure crop yields, and report baseline data. Partners will also install lysimeters to monitor soil water nitrogen and measure soil nitrogen throughout the growing at the two IWG plantings in Lincoln and Olmstead Counties. The focus of the latter two plantings will be on evaluating nitrogen and water movement below the root zone of IWG (4'), which is deeper than has been previously studied.

ENRTF BUDGET: $159,767

Outcome	Completion Date
1. Report soil water nitrate vulnerable to leaching below IWG and annual crops	June 30, 2020
2. Monitor changes in nitrate leaching parameters below IWG in Lincoln & Olmstead Counties	June 30, 2020
3. Report IWG grain and biomass yields for economic comparisons	June 30, 2020

First Update January 31, 2019
The experiment was successfully established at Central Lakes College in Staples, MN. Intermediate wheatgrass and soybean were grown in experimental plots arranged in a randomized design with six replicates. Four lysimeters were installed in each plot, two at a depth of 2' and two at 4'. Throughout the 2018 growing season, lysimeter samples were collected on 17 dates and analyzed for nitrate concentration. IWG grain yields were estimated at harvest on August 16, and soybean yields were estimated at harvest on October 17. A field day was held on August 24.

Second Update June 30, 2019
Lysimeters were checked and re-installed if necessary this spring so that there were 8 pairs (one at 2' depth and one at 4' depth) in Pipestone (total of 16 lysimeters), 4 pairs in Chatfield (total of 8 lysimeters), and 12 pairs in Staples (total of 24 lysimeters). A soil moisture access tube was installed adjacent to each pair of lysimeters to

measure soil moisture. To date, samples were collected on 7, 6, and 6 dates at Staples, Pipestone, and Chatfield, respectively. Kernza grain harvest is expected to occur during the week of August 13 at all locations.

Third Update January 31, 2020

Soil and water samples and soil moisture readings were collected throughout the growing season at the three sites. Baseline soil samples were taken at the beginning of the growing season at each site and will provide information on organic matter, organic N, and mineral N content. Soil moisture readings (at 10, 20, 30, 40, 60, and 100cm) were taken eight times in Pipestone, four times in Staples, and eight times in Chatfield. Preliminary analysis suggests that there are significant differences in soil moisture at some of the measured depths. This information will contribute to the development of models that can be used to predict the reduction in nitrate leaching under Kernza. Lysimeters were sampled eleven times at Pipestone, eighteen times in Staples, and fifteen times in Chatfield. Nitrate levels were extremely low (<1 mg L^{-1}) at all sampling dates in Chatfield and Pipestone. Preliminary analysis shows that nitrate levels slightly were higher under the fertilized Kernza in Staples, but were still very low during most of the growing season, and were significantly lower than corn throughout. Two 30" quadrat samples were harvested from all sites in August 2019 and used to calculate estimated yields. Once samples had been collected, fields were harvested at Chatfield and Pipestone and mowed off in Staples.

Fourth Update July 1, 2020:

Hand samples of biomass for yield estimates were processed in the lab in early 2020. After UMN imposed travel restrictions in response to COVID-19, the team was able to obtain approval by the College Dean's Office to visit the research site in Staples to plant soybean and collect soil moisture data. Lysimeter samples were collected from the Staples experiment during the spring and summer season. Despite travel restrictions, all critical data were collected including crop biomass samples for yield estimation and soil samples. New safety plans are being developed as the research team transitions from field work to laboratory work. These plans must be reviewed and approved by the University of Minnesota before laboratory analyses can begin.

Fifth Update January 1, 2021:

Soybeans were sampled on Sept 25, 2020 for yield estimation. Soil cores were extracted for root biomass estimation and nutrient analysis. Roots were washed from soil cores in winter 2021. Grain was threshed from the harvested IWG and soybean plants in the lab for yield estimation. Soil samples were dried and shipped to the analytical lab for analyses (ongoing). Lysimeter samples were collected from the plots until October 20, 2020. Over the course of the growing season, lysimeter samples were collected on 21 dates. Soil moisture data was collected after grain harvest. Masters student Evelyn Reilly has analyzed most of the yield and soil water nitrate data, some of which she presented at the UMN Applied Plant Sciences Seminar. A recording of that presentation can be found here: https://www.youtube.com/watch?v=_bd3mo_PbtY&t=2344s

Final Update June 30, 2021

Results from this activity were presented by Evelyn Reilly during her MS degree defense seminar, which can be found here. This presentation includes data on nitrate leaching reductions beneath Kernza compared to a soybean – corn – soybean rotation, changes in soil moisture during the year and across years, and provides a summary of both grain and straw/stover yields for estimating profitability from these cropping systems. Results can also be found in Evelyn's thesis, which will be published and made publicly available by September 2021. Results will also be published in a peer-reviewed research article that we expect to publish in a special issue of a journal with international readership. A summary of the 2019 data and project progress can be found in project meeting notes here.

ACTIVITY 3: ***Grain testing to determine optimal end-use for IWG***

Description: Measure IWG grain quality for nutritional, storage, and processing information. Report grain quality measures including protein, carbohydrate, and gluten content. Measure food safety metrics including mycotoxin and ergot levels. Identify potential commercial processors and end-users for Minnesota markets.

Some grain testing on Kernza has been done, but most of the food science research was conducted on very early germplasm (e.g. populations that were not nearly as advanced as those that we have now). As breeding has increased seed size and yield, this alters the composition of nutrients, fatty acids, and other characteristics related to food quality.

The initial work by UMN food scientists was to generally characterize Kernza grain. They determined protein and carbohydrate content, fatty acid profiles, and characterized gluten composition. Depending on what type of product Kernza will be used in, there are other metrics of concern that should be tested (e.g. gelatinization temperature for brewing).

Our project will characterize composition of nutrients, fatty acids, and other characteristics related to food quality in the newest germplasm and also look at specific metrics related to use in a variety of products. The metrics will be determined based on the target market for the grain (bread, beer, cereal, etc.). The target market(s) and metrics will be decided at the beginning of the project, based on discussion with project partners.

ENRTF BUDGET: $31,744

Outcome	Completion Date
1. Report of IWG grain quality for nutritional, storage, and processing information	June 30, 2020
2. Report indicating potential processors and end-users of IWG grain	June 30, 2020

First Update January 31, 2019

The subaward agreement between UMN and AURI has been initiated. Grain testing will occur following harvest in August, 2019.

Second Update June 30, 2019

Grain will be delivered to AURI for testing in August, 2019. Straw will also be prepared for ammonification testing following harvest.

Third Update January 31, 2020

At the time of this update, AURI has completed several tasks under Activity 3. Using UMN Clearwater (newest Kernza variety) grain supplied from the 2019 harvest in Minnesota, the AURI team was able to clean grain samples at the Waseca facility, and has worked with private sector grain cleaners and equipment providers to identify multiple pieces of dehulling equipment which work well on Kernza. Equipment tests both provided grain samples for analytical testing and allowed to validate equipment for future use at AURI to clean and dehull Kernza grain.

Milling testing has been done at the Northern Crops Institute in Fargo, ND, findings of which will be included in the final report submitted to LCCMR. Using flour and grain samples produced through equipment trials, analytical testing work has been carried out. A full malting analysis and comparison has been completed by Montana State University, and flour and grain samples were sent to MVTL labs for a host of nutritional testing on the newest 1504 Kernza germplasm. Results from analytical tests will be used as information for the final report, and will be in the form of short, one-page pull out informational sheets which will support the business development team when meeting with potential end users. Work to identify higher value sugars and polyphenol content in the straw is also underway. Lastly, the Coproducts lab in Waseca currently has animal bedding analysis trials underway to compare both Kernza straw and hulls on various performance characteristics to those of conventional bedding materials.

Fourth Update July 1, 2020:
Results from AURI's Kernza processing and coproduct development work are being synthesized into short "application guidelines" for various stakeholder groups. These guideline documents will be broadly circulated as resources for community businesses interested in utilizing this new, sustainable grain. AURI has been actively involved with providing Minnesota's newest start-up company – Perennial Pantry – with information and advice as they invest in processing equipment specific for Kernza production.

Fifth Update January 1, 2021:
AURI continues to develop their Kernza cleaning and end-use specification sheets for industry and other interested parties. Drafts of these specification sheets have been reviewed by various project team members and other experts. These specification sheets are included in the AURI Final Report, which has been drafted and is currently being reviewed by project partners.

Final Update June 30, 2021
A separate, comprehensive final report has been prepared and can be found here. This project resulted in identifying fundamental characteristics of Kernza grain lots following harvest, such as dockage levels, dehulling efficiency, methods for reaching clean grain standards, and instances of mycotoxin and mold contamination. The report provides step-by-step instructions and equipment needed to reach quality grain standards for Kernza in clear, concise format. The report also includes a comparison of specific models of equipment available for Kernza processing, and provides a summary of cost and processing rates for the equipment. Finally, the report also includes results on Kernza flour analytics including variables related to functionality and nutrition. Similar to the other activities, this activity resulted in new partnerships with individuals and companies that will continue into the future and further innovate in the food science and manufacturing space around Kernza.

IV. DISSEMINATION: ***Dissemination of project results will be done through reports and a field day.***

Description: Research results will be summarized and presented in the LCCMR final report document. Data and information from the final report will be divided into three categories: 1) experimental results, 2) field monitoring data, and 3) grain quality and end-use; each organized into a separate report. A field day will be held in 2019 that will showcase the LCCMR funded research and provide a broad overview of the growing Kernza enterprise in Minnesota. Outreach materials, designed for a public audience, will be developed and disseminated.

First Update January 31, 2019
Data from 2018 are being analyzed and will be made available in the Central Lakes College Ag and Energy Center Report. Field days have already been conducted and will be repeated in 2019. Preliminary data from research findings at the Central Lakes College site were presented at the Minnesota Water Resources Conference.

Second Update June 30, 2019
Results from this study have been incorporated into multiple outreach events including the Kernza growers handbook. This document was publicly released during a Kernza Grower Meeting held by UMN researchers in March of 2019. More than 50 people currently growing, or planning to grow, Kernza were in attendance. Water quality information from this study was also presented at a Kernza field day hosted by a Kernza farmer in Western Minnesota.

Third Update January 31, 2020
The team has started planning Kernza field days in Pipestone County and Olmstead County for June 2020.

Fourth Update July 1, 2020:
Field days that were planned for spring 2020 have been cancelled in hopes that live, in-person events could be held in fall 2020. Planning has begun for virtual field days in case in-person meetings are still not possible in 2020.

Fifth Update January 1, 2021:
An additional in-person field day specific to this project was not held in 2020 as a result of COVID-19. Results were disseminated virtually during Evelyn Reilly's Applied Plant Sciences Seminar (MS thesis defense) and will be published again in the Central Lakes College Ag and Energy Center report. Preliminary results from this project were included in a virtual presentation for the UMN Extension Connect event on Nov. 30, 2020.

Final Update June 30, 2021
Two field days were held, one at each of the demonstration sites (Chatfield and Verdi) in 2018. The project was also discussed during field days at Central Lakes College in 2018 and 2019. Data from this project have been incorporated into various other presentations, meetings, and virtual field days. The AURI final report will be distributed to current and future Kernza grain processors and made available online. A recording of Evelyn Reilly's defense seminar will be made public and accessible online. Technical results will be published open-source in an international peer-reviewed journal (target journal: Journal of Soil and Water Conservation). The case-study handout developed in partnership with Green Lands Blue Waters will be updated with the latest research results.

Project Results Use and Dissemination
Field days at two locations with ~60 participants on site. Events highlighted in newspaper articles. Case study/ project summaries written by Green Lands Blue Waters. Master's student research is in process of being submitted for publication in a peer-reviewed journal. Deliverable for Activity 3 includes a technical report on cleaning intermediate wheatgrass (Kernza) as well as resources for food processors to integrate it into their business operations.

The research supported by this grant is part of a larger network of research and implementation efforts around Kernza. Resources are compiled on a Kernza website, including resources for the cleaning and dehulling process.

V. PROJECT BUDGET SUMMARY:

A. **Preliminary ENRTF Budget Overview:** Grant dollars will be administered by the Minnesota Department of Agriculture and managed through a contract with the University of Minnesota.

See attached budget spreadsheet

Explanation of Capital Expenditures Greater Than $5,000:

Explanation of Use of Classified Staff: NA

Total Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation:

Enter Total Estimated Personnel Hours: NA, all in-kind	Divide by 2,080 = TOTAL FTE: None

Total Number of Full-time Equivalents (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation:

Enter Total Estimated Personnel Hours: 5,408	Divide by 2,080 = TOTAL FTE: 2.6

B. Other Funds:

SOURCE OF AND USE OF OTHER FUNDS	Amount Proposed	Amount Spent	Status and Timeframe
Other Non-State $ To Be Applied To Project During Project Period: None			
	$	$	
Other State $ To Be Applied To Project During Project Period: None			
	$	$	
Past and Current ENRTF Appropriation*:* None			
	$	$	
Other Funding History: ***Awarded to project team at the University of Minnesota:*** UMN Institute for Renewable Energy and the Environment - $600,000: Funded the preliminary, plot-scale lysimeter study showing that intermediate wheatgrass has less nitrate in the soil water compared to corn. MDA + Forever Green - $98,405: Funding to study agronomic aspects of intermediate wheatgrass grain production. Perennial Agriculture Project - $100,712: Funded additional environmental and agronomic studies on intermediate wheatgrass. In kind provided by the University of Minnesota, Lincoln-Pipestone Rural Water, and the City of Chatfield to plant sites already seeded in Chatfield and Lincoln-Pipestone as well as for Lincoln-Pipestone to provide land for research and demonstration sites.			
	$ 799,117	$	Secured

VI. PROJECT PARTNERS:

A. Partners receiving ENRTF funding

Name	Title	Affiliation	Role
Drs. Jacob Jungers, Craig Sheaffer and Jessica Gutknecht	Research Scientists	University of Minnesota	Oversee the experiments including crop agronomics, plant and soil sampling, and data analysis
Michael Sparby and Al Doering	Research Scientists	Agricultural Utilization Research Initiative (AURI)	Conduct lab analysis of crop biomass and grain samples related gluten quality
Keith Olander and student worker	Dean of Agricultural Studies	Central Lakes College (CLC)	Lab analysis of water quality samples, manage field research in Wadena County, and oversee student worker
Brian Burkholder	Superintendent of City Services	City of Chatfield	Coordinate land arrangements in Fillmore and Olmstead counties, project advisory role and review outreach materials
Jason Overby	General Manager	Lincoln Pipestone Rural Water (LPRW)	Coordinate farmer involvement and land-use through LPRW, project

			advisory role and review outreach materials

B. Partners NOT receiving ENRTF funding

Name	Title	Affiliation	Role
Margaret Wagner	Supervisor, Clean Water Technical Assitance Unit	Minnesota Department of Agriculture (MDA)	Serve as project manager: manage budgets, oversee experimental design and coordinate MDA staff providing in-kind support
Randy Ellingboe (now retired)	Manager, Drinking Water Protection	Minnesota Department of Health (MDH)	Advise on project objectives and deliverables, review reports
Aaron Meyer and Scott Hanson	Source Water Specialists	Minnesota Rural Water Association (MRWA)	Advise on project objectives and deliverables, review reports and outreach materials

VII. LONG-TERM- IMPLEMENTATION AND FUNDING:

Four million Minnesotans depend on groundwater for drinking water. This two-year project will initiate the framework and establishment of an IWG research, production, and education network to allow the project team an opportunity to secure federal and private funds for an additional four to six year project. It balances the need for implementation and continued research on a new perennial grain crop in Minnesota. In the short-term, citizens of the project communities will directly benefit through reduced nitrate leaching to their drinking water source; long-term impacts could be statewide as this project will support our understanding of the environmental benefits and economic viability of IWG to Minnesota's farmers and landowners. This unique opportunity is timely because General Mills, Inc. has recently committed to using IWG as a food ingredient[1], which will catalyzed the market. IWG fields established for this project will be used to demonstrate production and to introduce this new crop into rural Minnesota communities during an educational field day. Fields will be managed as full-scale production fields; from which we will collect both water quality and economic data (e.g. cost savings from reduced chemical inputs, tillage, and annual reseeding), which will be made available for future use to produce enterprise budgets for IWG profitability.

VIII. REPORTING REQUIREMENTS:

- **The project is for 3 years, will begin on July 1, 2018, and end on June 30, 2021.**
- **Periodic project status update reports will be submitted January 31 and June 30 of each year.**
- **A final report and associated products will be submitted June 30, 2021.**

IX. SEE ADDITIONAL WORK PLAN COMPONENTS:

A. Budget Spreadsheet
B. Visual Component or Map
C. Parcel List Spreadsheet- N/A
D. Acquisition, Easements, and Restoration Requirements- N/A

E. Research Addendum- N/A

Attachment A:
Environment and Natural Resources Trust Fund
M.L. 2018 Budget Spreadsheet

Project Title: Using perennial grain crops in wellhead protection areas to protect groundwa
Legal Citation: M.L. 2018
Project Manager: Margaret Wagner
Organization: Minnesota Department of Agriculture
College/Department/Division: Pesticide and Fertilizer Manage
M.L. 2018 ENRTF Appropriation:
Project Length and Completion Date: 2 years, 06/30/2020
Date of Report: June 30, 2021

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Revised budget June 2021	TOTAL SPENT	TOTAL BALANCE
BUDGET ITEM			
Professional/Technical/Service Contracts: Central Lakes College			
Personnel: Field Technician - 60% FTE per year for 2 years, 100% salary and no fringe.	$29,952	$29,952	$0
Professional/Technical/Service Contracts: Agricultural Utilization Research Institute			$0
Personnel: Process Scientist - 10% FTE per year for 2 years, 80% salary and 20% fringe.	$24,513	$24,513	$0
Personnel: Process Scientist - 3% FTE per year for 2 years, 80% salary and 20% fringe.	$6,864	$6,864	$0
Travel: AURI personnel to travel from Marshall office to St. Paul for three project meetings per year for two years (Mileage: 6 trips @ ~315 miles trip @ $0.545 per mile = $1030; M&IE @ $64 per day = $384). AURI personnel travel from Marshall location to Crookston location for microbial analysis of grain, two trips per year for two years (Mileage: 4 trips @ ~270 miles per trip @ $0.545 per mile = $586	$0	$0	$0
Professional/Technical/Service Contracts: University of Minnesota			
Personnel: Graduate Student - 50% FTE per year for 2 years, to oversee field and lab research and produce deliverables.	$65,289	$65,289	$0
Personnel: Technician - 20% FTE per year for 2 years, 73.8% salary and 27.2% fringe conduct field research tasks such as planting, weeding, and harvesting research plots. Oversee processing of research samples	$66,635	$66,635	$0
Personnel: Hourly undergraduate interns - 25% FTE per year year for two years, 100% salary 0% fringe to collect soil water samples from the demonstration fields.	$6,675	$6,675	$0
Equipment/Tools/Supplies			
Lysimeters to collect soil water samples from research fields and demonstration plots - 80 lysimeters @ $80/lysimeter	$5,896	$5,896	$0
Soil moisture sensors to determine soil moisture content at various depths to determine soil perculation rates - 120 sensors @ $150/sensor	$18,000	$18,000	$0
Analysis			$0

Soil carbon and nitrogen - Combustion analysis of soil samples to determine carbon and nitrogen - 336 samples per year for 2 years at $4/samples	$2,688	$2,688	$0
Soil P, K, pH, OM - Baseline soil characteristics to determine nitrogen cycling and leaching - 72 samples per year for 2 years @ $14 per sample	$2,016	$2,016	$0
Soil texture (%sand, silt, and clay) - Baseline soil texture to determine soil water perculation rates - 72 samples per year for 1 year @ $20 per sample	$1,440	$1,440	$0
Soil nitrate - Analysis to determine changes in soil nitrate through time 504 samples per year for 2 years @ $5 per sample	$5,040	$5,040	$0
Plant carbon and nitrogen - Combustion analysis of plant tissue to determine carbon and nitrogen - 128 samples per year for 2 years @ $4 per sample	$1,024	$1,024	$0
Soil water nitrate - Analysis of lysimeter soil water samples to determin nitrate content - 1472 samples per year for 2 years @ $9 per sample	$8,360	$7,337	$1,023
Travel expenses in Minnesota			$0
Funds for 2 UMN personnel to make 13 trips per year from St. Paul to Verdi (400 miles round trip) to collect soil water samples. Expenses include M&IE each day and lodging for 10 nights. Travel expenses for 2 UMN personnel to make 13 trips per year from St. Paul to Chatfield (225 miles roundtrip) to collect soil water samples. Expenses include M&IE each day and no lodging	$3,002	$3,002	$0
Professional/Technical/Service Contracts: Unknown - Contract for services to hire a custom harvester to combine grain from IWG demonstration plots and cut, bale, and remove residue from fields.	$2,606	$ 2,606	$0
COLUMN TOTAL	**$ 250,000**	**$248,977**	$1,023