Innovative Conservation Approaches to Invasive Plant Management in the Missouri River Watershed: From Invasive Species Prevention and Control, to Biomass Utilization and Bioenergy Generation

FINAL REPORT

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Deliverables

1. Establish and monitor herbicide treatment and control sites for short- and long-term ecological changes, riparian system function, environmental protection, and natural resource enhancement in Montana, Nebraska, South Dakota, and Wyoming sections of the Missouri River Watershed. *Status: completed.*
2. Investigate and demonstrate the use of innovative bioenergy technologies that promote the utilization of invasive plant biomass as a fuel source. *Status: completed.*
3. Utilize established management and communications infrastructure and networks to coordinate project and to transfer project findings, products, and technologies to a broad range of regional stakeholders. *Status: completed.*
4. Produce and distribute a new technology and innovative approach fact sheet. *Status: completed.*
5. Attend at least one NRCS CIG showcase or comparable NRCS event during the period of the agreement. *Status: In January 2013, NRCS informed the project PI that the NRCS CIG showcase event was cancelled due to federal travel restrictions and sequestration, and that this deliverable was to be disregarded. The MSU project team did, however, travel to Washington, DC and on September 18, 2014 gave a formal final project presentation to CIG staff and other invited partners. The presentation was streamed via webinar to other federal agency partners, and was recorded for future use. A project poster and fact sheets were also presented and distributed during that event.*
6. Provide the Natural Resources Conservation Service with quarterly progress reports and a final report outlining all deliverables at the end of the fiscal year. *Status: completed.*

Acknowledgments

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Many individuals and organizations helped to make this project a success. We would like to thank: Andrew Canham, Dave Burch, Slade Franklin, Ron Moehring, Joyce Schwartzentruber, Mark Peterson, John Gaskin, Jennifer Muscha, Erin Espeland, Mary Mayer, Ken Frazier, Cleve Schuster, Jerry Altermatt, Steve Brill, Patrick Brown, Levi Cheff, Brett Burditt, Jerry Dawson, Angela Farr, Rachel Frost, Dale Grant, Andrew Haden, Mary Halstvedt, Nathan Jagim, Julie Kies, Nicole McClain, Tom Miles, Rich Walters, Steve Young, Celestine Duncan, Barbara Bunge, Mary Engel, Brian O'Connor, Lois Evans, Ana Murphy, Tina Widhalm, Melody Schimpf, Merry Paceley, the Missouri River Watershed Coalition Exec-utive Committee, Johnson Brothers Forest Resources LLC, Montana Association of Counties, Montana Department of Natural Resources and Conservation, Montana Society of Foresters (Region 1), Montana Weed Control Association, Montana Conservation District Council, Missouri River Conservation Council, Missouri River Natural Resource Commit-tee, Native Plant Society, North America Invasive Species Association, South Dakota Weed and Pest Commission, South Dakota Invasive Species Management Association, Tamarisk Coalition, Wyoming Weed and Pest Association, Montana Fish, Wildlife and Parks, and Wyoming Fish and Game.

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EXECUTIVE SUMMARY

This national Conservation Innovation Grant (CIG) supported a comprehensive effort to develop innovative ideas for managing Russian olive and saltcedar throughout the Missouri River Watershed region. The Center for Invasive Species Management (CISM) at Montana State University (MSU) and the Missouri River Watershed Coalition (MRWC) successfully completed the three project objectives:

1. Foster the adoption of innovative conservation approaches to invasive riparian plant management by monitoring mechanical and herbicide treatment and control sites infested with Russian olive and saltcedar for short- and long-term ecological changes, riparian system health and function, environmental protection, and natural resource enhancement.
2. Investigate and demonstrate the use of innovative bioenergy technologies that promote the utilization of invasive plant biomass as a fuel source.
3. Utilize the CISM/MSU/MRWC management and communications infrastructure to coordinate all components of the project, and transfer project findings, products, and technologies to a broad range of regional stakeholders, including the private sector and NRCS.

Many customers benefitted from this grant, including: landowners and managers, and federal, state, and local government programs which are involved in conservation and invasive plant management activities in the Missouri River Basin. Specific CIG priorities that this project addressed include: program outreach and conservation technology transfer to targeted groups; energy; and priority landscapes.

Widespread regional flooding events in 2011 delayed the start of the project; consequently, an additional year was required to complete the tasks outlined in the project work plan. As a result, we sought a one-year, no-cost extension to complete the project. Changes to the budget included transferring funds from the travel, communications, and contracted services line items to salaries and benefits to enable project staff to complete the required project deliverables.

The primary treatment methods employed in this project (cut-stump treatment of Russian olive and basal bark treatment of saltcedar) are effective practices for the target species. Based on annual assessments and site observations we found that it is critical to the overall success of Russian olive and saltcedar control to conduct follow-up site assessments and herbicide treatments to address re-growth, in addition to conducting treatments to control existing terrestrial weed infestations which are common in riparian areas. Site-specific post-treatment land use planning should also be included as part of any management goals in order to support desirable ecological site potential and sustainability. Furthermore, our vegetation sampling efforts validated the importance of applying adaptive management strategies as an effective method to control Russian olive and saltcedar in riparian areas.

Although laboratory tests demonstrated that Russian olive and saltcedar biomass materials could be safely used as a bioenergy source, our assessments indicated limited feasibility of woody biomass as an alternative energy source. The biggest economic challenge with woody biomass is the cost of transporting the material to end user locations, which are limited in the region. This is especially pertinent as recent expansion of oil and gas production in the western US (including the Bakken Oil Field) has reduced fossil fuel prices to historically low levels. However, when consideration is given to the potential environmental benefits of reducing fossil fuel consumption and emissions, and the value of improving the ecological conditions of our forests and riparian areas, investigations such as this project are of great importance for broadening the energy portfolio for the future.

A variety of outreach methods, including formal presentations, webinars, printed materials, and a project website, were used to transfer project findings and technologies to interested stakeholders and partners

from across the country. Several site tours and field demonstrations were held, allowing participants to see first-hand how the project's Russian olive and saltcedar treatment and removal efforts were progressing, and learn more about the biomass pelletization process. Overall, these events reached nearly 4,700 individuals.

In conclusion, we offer the following recommendations:

- It is necessary to explore funding sources to conduct and collect regional inventory information of Russian olive and saltcedar in order to determine a comprehensive scale of potential energy values.
- Efforts should be made to strengthen coordination with government, public, and private forestry interests and include Russian olive and saltcedar as a component of riparian forest management and planning efforts for future energy utilization.
- Expansion of woody biomass fueled systems and/or products throughout the region would improve existing biomass utilization and should be encouraged.
- It is necessary to continue collaborations with regional invasive plant management programs to emphasize riparian areas as a priority in order to assist in mitigating the negative ecological impacts caused by the spread of invasive woody species.

INTRODUCTION

In 2010, the Center for Species Management (CISM) and the Missouri River Watershed Coalition (MRWC) were awarded a national Conservation Innovation Grant (CIG) by the Natural Resources Conservation Service (NRCS) to develop innovative ideas for managing Russian olive *(Elaeagnus angustifolia)* and saltcedar *(Tamarix* spp.) throughout the Missouri River Watershed region. The project was completed on September 23, 2014.

The project was sponsored by, and conducted through, a well-established and synergistic partnership between the MRWC and CISM, which is housed in the Department of Land Resources and Environmental Sciences (LRES) at Montana State University (MSU). The MRWC was formed in 2006 in response to a critical need to protect the natural resources of the Missouri River Watershed area. In partnership with CISM since 2008, the MRWC coordinates its efforts with federal, state, and local agencies, tribes, businesses, universities, conservation groups, and private landowners. MSU was the CIG applicant, grantee, and co-sponsor of the project. Administrative and technical leadership for the project was the responsibility of CISM and MSU personnel, and project oversight was provided by the MRWC's Executive Committee. All project activities were coordinated with input and participation from local, state, and federal government agencies, tribes, businesses, universities and colleges, conservation groups, and public and private landowners from throughout the western region.

A multi-faceted, multi-year collaboration was necessary for undertaking such a broad-scale conservation project at a regional level, and the project effectively tapped and pooled the resources of CISM, MSU, MRWC, NRCS CIG program, skilled subcontractors, and private and public landowners.

Project Objectives

As outlined in the NRCS grant request, the project had three primary objectives:

1. Foster the adoption of innovative conservation approaches to invasive riparian plant management by monitoring herbicide treatment and control sites for short- and long-term ecological changes, riparian system function, environmental protection, and natural resource enhancement.
2. Investigate and demonstrate the use of innovative bioenergy technologies that promote the utilization of invasive plant biomass as a fuel source.
3. Utilize existing MRWC, CISM, and MSU management and communications infrastructures and networks to coordinate all components of the project, and transfer project findings, products, and technologies to a broad range of regional stakeholders, including the private sector and NRCS.

Scope of Project Tasks

The scope of the project was designed to integrate established methods in order to evaluate the impacts and results of conducting woody invasive plant management activities in riparian areas with adaptive management strategies applied based upon ecological response and site-specific results. Detailed vegetation community changes were monitored and documented to provide scientific guidance for future implementation of riparian conservation practices.

The project team consulted with commercial and government bioenergy professionals to develop appropriate testing requirements for verifying the biomass feasibility of Russian olive and saltcedar. Furthermore, the project team investigated existing biomass technology to create an extensive catalog of procedural and economic information for regional stakeholders relating to biomass utilization. Testing activities were coordinated with certified laboratories to establish the fuel quality of the materials, and comparative analyses of existing biomass sources were used to further document bioenergy feasibility and potential.

CISM and MSU personnel coordinated all aspects of the project; kept the project on track, on time, within budget, and well documented; and communicated on a regular basis with a wide array of regional stakeholders and project partners, including NRCS. Timely dissemination of information to MRWC members, producers and landowners, government agencies, and the concerned public was a key component of this project. CISM and MSU made all information generated available via the project website, email communications, outreach activities and materials, tours and field demonstrations, publications, and NRCS technical materials. The project team fostered critical citizen engagement in the process by educating people about invasive species management challenges and solutions in the Missouri River Watershed, and transferring innovative conservation and management strategies to combat those problems.

Project Location

This project involved the seven Missouri River headwater states of Montana, Wyoming, South Dakota, North Dakota, Nebraska, Colorado, and Kansas (a geographic area of 529,350 square miles); and was a pilot project for the western region. Nine project treatment and monitoring sites (totaling 101 acres) were established and data was collected in three states: Montana, Wyoming and South Dakota. Data will continued to be collected at these sites by state-based partners for many years into the future. Technology transfer and outreach activities were conducted in 11 states and provinces in the United States and Canada: Montana, Wyoming, South Dakota, Nebraska, Nevada, Washington, Idaho, Colorado, Florida, Washington DC, and Ontario. Nine project treatment and monitoring sites (totaling 101 acres) were established and data was collected in three states: Montana, Wyoming and South Dakota. Data will continued to be collected at these sites by state-based partners for many years into the future.

Key Project Personnel

- *Dr. Tracy Sterling* is a Professor of Weed Science and MSU LRES Department Head. She took over as the Principal Investigator on October 1, 2013. Tracy has 30 years of research, outreach, and teaching experience in understanding invasive plant success in managed and wildland systems, has managed over $5 million in grants as lead PI, and currently leads a large department focused on understanding and improving management of land resources.
- *Elizabeth Galli-Noble* was the CISM Director from 2008 to 2013, and functioned as the Principal Investigator from September 23, 2010 to September 30, 2013. She re-joined the project team from August 2014 to assist with project wrap-up activities. Liz has 25 years of national and international research and natural resource management experience, including: editing scientific documents for the Interior Columbia Basin Ecosystem Management Project; managing the Upper Yellowstone River Cumulative Effects Investigation; and working as the Assistant Director for Research (Director of Whirling Disease and Wild Fish Habitat Initiatives) at the Montana Water Center. She now operates Galli-Noble Consulting.
- *Scott Bockness* was hired as the CIG Project Leader by CISM in December 2010. Prior to joining the CIG team, he was the Yellowstone County (Montana) Weed Department Superintendent. Scott has over 20 years of invasive plant coordination experience and served for eight years on the Montana Governor's Noxious Weed Advisory Council. He was the Vice President of the MRWC from 2006 to 2010.
- *Dr. Amy Ganguli* is an Assistant Professor of Range Science in the Department of Animal and Range Sciences at New Mexico State University. She was hired by the project's subaward contractor, Synergy Resource Solutions, Inc. in 2010 as the project's Field Technical Leader. Amy has 10 years of experience in large landscape conservation planning, ecosystem rehabilitation planning and implementation, and has research, outreach, and teaching experience in invasive plant management, restoration ecology, and fire ecology.

- *Emily Rindos* is the Assistant Director of CISM. She coordinated all of the project's technology transfer activities and was responsible for report writing and editing. Emily has over five years of invasive species outreach, technology transfer, and technical writing experience.
- *Kitty Weiss* is CISM's E-Communications Coordinator. She assisted with technology transfer and outreach activities, including developing the project website. Kitty has more than 10 years of experience as a communications specialist and graphic designer, and has worked extensively in both print and online mediums.
- *Jack Alexander* is a Senior Resource Specialist and President of Synergy Resource Solutions, Inc., which was a subaward contractor on this project. He has more than 20 years of experience in vegetation monitoring, data analysis, range management practices and principles, erosion-control, and permit preparation. Jack is certified by the Society for Range Management as a Certified Range Management Consultant and a Certified Professional in Rangeland Management. He is also certified by the International Erosion Control Association as a Certified Sediment and Erosion Control Specialist.

Project Partners

Project partners included: private landowners and producers; private sector/industry; federal, state, and local governments; Yellowstone River Conservation District Council (Billings, MT); USDA-ARS Fort Keogh Range and Livestock Research Station (Miles City, MT); Sturgis School (Sturgis, SD); Yellowtail Coordinated Resource Management Group (Lovell, WY); and Harry and Ellen Allen (Allen Ranch, Hardin, MT).

Subcontractors for the Russian olive and saltcedar removal and treatment activities included: Stan's Weed Control, Inc. (Billings, MT); Dynamic Enterprises, Inc. (Molt, MT); Summitt Forests, Inc. (Ashland, OR); Tiger Tree, Inc. (Laramie, WY); Meade County Weed and Pest District (Sturgis, SD); Monture Creek Land Management, Inc. (Seeley Lake, MT), and Midwest Laboratories, Inc. (Omaha, NE). Subcontractors and vendors for the bioenergy investigation included: T. R. Miles Technical Consultants, Inc. (Portland, OR); Keystone Laboratories, Inc. (Newton, IA); and Hazen Research, Inc. (Golden, CO).

Funding

This project was funded by a national NRCS CIG Agreement. The states of Wyoming and Montana contributed more than $2 million in documented cash and in-kind match (see Appendix A. Final Budget and Match Summary). Many additional hours of in-kind support were informally contributed by MRWC members, MSU and LRES staff, and regional producers and stakeholders. Widespread regional flooding events in 2011 delayed the start of the project; consequently, an additional year was required to complete all of the tasks outlined in our work plan. A one-year extension and budget revision was approved by NRCS in September 2013 (Appendix B. Grant Extension Request, Justification, and Budget Revision). Changes to the budget included transferring funds from the travel, communications, and contracted services line items to salaries and benefits to enable project staff to complete the required deliverables.

Furthermore, on four occasions, project personnel collaborated with fellow regional university and industry partners in efforts to secure follow-up grant funding for the bioenergy- and restoration-related aspects of this project. None of those follow-up funding efforts were successful.

Figure 1. Russian olive slash burn pile

BACKGROUND

Russian olive and saltcedar were introduced to the US in the 1800s. They escaped cultivation and are now established in more than one million acres of floodplains and riparian areas. Both species cause numerous ecological problems in riparian areas, and are projected to cause billions of dollars in economic losses over the next 50 years.

Many states rely heavily upon the Missouri River system for economic and ecological stability. Waters of the system support and provide for agriculture, recreation, tourism, wildlife habitat, irrigation, drinking water, industry, power generation, and livestock. Russian olive and saltcedar threaten these many uses. Dense non-native plant infestations choke river systems and restrict access for irrigation, wildlife, and outdoor enthusiasts; degrade or eliminate habitat for threatened and endangered species; and reduce the quantity and quality of essential water. Although there are numerous techniques for removing Russian olive and saltcedar, not all result in desired long-term effects, and there is little published information to guide treatment and restoration efforts in the upper Missouri River Watershed.

Russian olive and saltcedar displace many native plant species, such as cottonwood and willow, which provide valuable habitat for a broad spectrum of wildlife species. Intact riparian areas with a wide variety of native woody species and wildlife are vital to hunting and outdoor recreation enthusiasts throughout the region. In addition, the expansion of Russian olive and saltcedar has led to losses in herbaceous production and subsequent loss to domestic livestock grazing potential. This expansion has also been associated with decreased irrigation systems functionality, which supplies water to a wide variety of agricultural crops, causing direct economic loss to regional agricultural producers.

Common treatment methods for Russian olive include cutting the tree and applying triclopyr mixtures to the stump (known as cut-stump treatments) or mechanically masticating (commonly known as mulching) the entire tree along with herbicide treatments in subsequent years. Common treatment methods for saltcedar include applying triclopyr mixed with viscous oil to the basal portion of the tree (known as basal bark treatments) and foliar application of imazapyr. The resulting herbicide-treated biomass is then piled and burned on-site (Figure 1). This can cause soil erosion and make the sites vulnerable to infestation by additional invasive plants, such as Canada thistle *(Cirsium arvense)*, Russian knapweed *(Acroptilon repens)*, and leafy spurge *(Euphorbia esula)*, which may coexist with the target species and expand their range after Russian olive and saltcedar removal.

These control techniques are generally successful in the initial removal control of Russian olive and saltcedar, but their removal may not be sufficient to promote the reestablishment of a native riparian community. Prior to this project limited comprehensive studies had evaluated the success of Russian olive and saltcedar removal and native species restoration projects on a watershed level. Thus, land managers do not have solid information on which to draw when designing site-based removal and restoration projects on Russian olive and saltcedar invaded sites. In fact, many projects involving federal, state, and private funding are implemented with no knowledge of how the acts may affect the future riparian community, and the outcome is no better—and sometimes worse if other invasive species come to dominate—than if no treatment had been done. To improve management and to spend limited resources more wisely, information needed to be gathered on the efficacy of treatment methods under a range of circumstances, including: hydrologic condition; age, size and density of infestation; land use; and native plant community composition. Moreover, the feasibility and economic potential of using these species as biomass feedstock candidates for bioenergy development has historically been overlooked.

REVIEW OF METHODS

Although the treatment and monitoring methods utilized in this project are commonly accepted practice, this project's approach was innovative in several ways. First, a limited number of attempts had been made to determine the long-term efficacy of Russian olive and saltcedar treatments and site recovery under such a range of conditions or at a regional, watershed scale. Second, the monitoring component of this project (which will continue into the future) will provide valuable information for future management of Russian olive and saltcedar. Funding is rarely allocated for monitoring efforts in treatment activities, making this project unique. Furthermore, the information generated from monitoring can augment future restoration and rehabilitation management on these sites.

Another innovative aspect of this project was its investigation of alternative uses for the resulting biomass in order to reduce the environmental impacts caused by the standard approach of on-site pile burning, which causes soil damage and increases weed populations at treatment sites. The project utilized commercial wood chipping machines and transport trailers to mechanically remove biomass generated from treatment activities at the project areas for bioenergy testing and analysis. Although wood chipping in itself is not an innovative process for harvesting woody biomass, it is an innovative approach to managing woody invasive species. The process eliminated the need for on-site burning activities and increased the effectiveness of follow-up vegetation treatments.

At present, woody biomass utilization is almost exclusive to National Forest System areas within the Missouri River Watershed, and forest waste materials have been the primary feedstocks. While efforts are ongoing with both research and management of Russian olive and saltcedar, one of the biggest challenges associated with mitigating the ecological impacts of these riparian invaders is how to effectively deal with the biomass created from management and removal practices. The innovative approach of this project, to investigate the feasibility of utilizing the biomass as a potential energy feedstock, has been successful in identifying a plausible alternative to on-site pile burning that causes additional site degradation and elevated restoration costs.

Additional costs for sampling labor and data analysis increased the cost but provided valuable information regarding the vegetative response to the treatment methods applied. Limited quantitative economic information exists for woody plant species mastication methods; information extracted from a 2012 report by the Wyoming Wildlife and Natural Resource Trust (WWNRTB 2012) revealed that the overall commercial cost for mastication is approximately $400 per acre, with additional herbicide treatment (product/labor) cost averages of $231 per acre for treatments conducted at Yellowtail Wildlife Habitat Area (Lovell, WY).

The bioenergy investigation utilized existing economic data, commercially supplied contracting costs, along with cost estimate information provided by commercial vendors to evaluate the economic feasibility of utilizing invasive plant biomass as an alternative energy source. Extensive studies have been done by forestry experts to evaluate woody biomass feasibility and further research is currently being conducted (for example, the Biomass Research Development Initiative's effort to improve biomass technologies that could be directly applied to improving the utilization capacity of invasive plant biomass as an additional energy source).

Although this project did not involve the actual marketing of any specific products, extensive efforts were made to identify the economic feasibility of invasive plant biomass as a possible alternative energy source in the region, which could generate economic value.

All treatment and monitoring activities were conducted by members of the project team and/or commercial vendors. Producer and landowner participation in the project merely required coordinating short-term standard land use activities, such as grazing and recreational access. The bioenergy objective utilized commercial vendors to harvest and remove biomass from the project sites. These activities were short-term (less than 10 days) and did not cause any changes to land use operations.

Historic flooding throughout the region in 2011 caused a delay in the establishment of project locations and onset of treatments. Project treatment site selection was completed in June 2012 (Appendix C. Treatment Site Selection Report and Appendix D. Site Location Maps). Site-specific treatment plans were developed in January 2012 (Appendix E. Site-Specific Treatment Plans). Pre-treatment vegetation and soil sampling was completed in August 2012. Russian olive and saltcedar treatments were initiated in September 2012 and completed by March 2013 (Appendix F. Data Collection Methods and Data Summary 2011–2014). In June and July 2013 follow-up herbicide treatments were applied to control woody species regrowth and existing non-target terrestrial weed populations. The second round of vegetation sampling and photo documentation was conducted in August 2013. The third and final round of treatments was conducted in June and July 2014, and the final round of vegetation sampling was completed in August 2014. All field activities were planned in accordance with growth stages previously shown to be effective for herbicide treatments, and to accommodate consistent data acquisition.

Russian olive and saltcedar samples were collected from five sites in Montana and Wyoming in 2010 and 2011 and sent to two independent laboratories for fuel quality analysis testing. Wood pellet conversion tests were conducted by the project team in September 2011, and the technology was demonstrated for stakeholders during a field demonstration in Miles City, Montana in October 2011. On-site chipping of slash-piled plant material for samples was conducted in June and July 2011. Russian olive and saltcedar chipped biomass samples were tested by bioenergy laboratories in summer and fall 2011. In winter 2011, the test results were evaluated by the project team, as well as biomass experts from the government, university, and the private/commercial sectors. The results were incorporated into reports and outreach materials. In January 2012, additional tests (elemental analysis and ash fusion testing) were conducted. Test results and additional biomass information were sent to an independent consultant who conducted an assessment on the invasive plant materials to determine bioenergy feasibility in May 2012. In August 2014, attempts were made to contract with biomass suppliers to conduct chip/haul activities from two of the project locations in order to use the materials in a variety of biomass applications (such as: facility-scale burn tests to validate fuel quality; ornamental landscaping; filler for animal bedding products; and water absorption materials used in oil field drilling operations). However, due to limited contractor availability we were unable to complete these activities prior to the project's closing date.

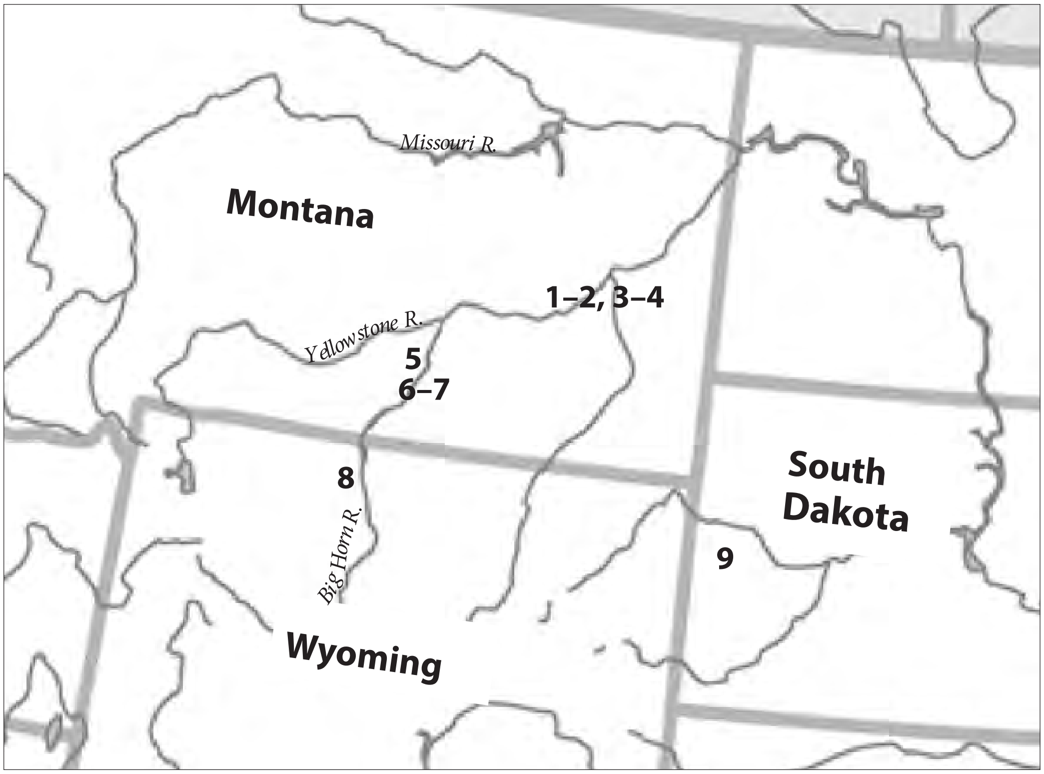
From a weed control standpoint, the treatment activities we conducted were effective. As expected, the sites experienced regrowth due to the vigorous vegetative capacity of Russian olive and saltcedar and, to varying degrees, from existing seed sources. Analysis of the vegetation sampling data indicated that the removal of canopy cover created opportunities for increased abundance of desirable grass and forb species, which supports both improved wildlife habitat and livestock grazing potential. Post-project site monitoring, which will be conducted by MRWC member states, will offer greater insight into long-term vegetation response trends, and will complement future adaptive restoration strategies.

A goal of the of the bioenergy investigation was to attempt to convert Russian olive and saltcedar biomass to wood pellets on-site. Upon researching the technology and consulting with bioenergy conversion design experts, it became clear that the technology for on-site wood pellet conversion is cost-prohibitive and requires commercial scale production to meet quality control standards. Although a wood pellet conversion demonstration was completed successfully, it required the use of a commercial laboratory to assist with additional particle reduction processing. Further evaluation revealed that the most effective use of woody biomass in the region is to simply chip the plant material and transport it to existing facilities for use in high-efficiency wood chip boiler systems. These systems are currently used at multiple locations in western Montana and are designed to accommodate a variety of wood chip materials in facility scale operations. Additional aspects of invasive plant biomass conversion should be explored, including stack testing to verify that air quality emissions are within EPA standards (by burning the materials in a commercial system operated by certified technicians) and possibly including the chip and haul process as part of the treatment procedure in order to investigate potential cost savings.

If the project were started today, we would modify the treatment and monitoring design to expand the scale or number of treatment sites and improve practices to better verify the ecological response of removing invasive species from riparian areas at a regional level. In the original project design we conducted vegetative survey work on a project location that used mechanical mastication as the primary treatment/removal method. Mastication is an alternative method that has been utilized in limited areas to manage invasive woody species such as Russian olive and saltcedar. Due to an unrelated incident, a rangeland wildfire in the Yellowtail Wildlife Habitat Area in 2013 burned both the Lovell and Lovell Mulch project sites and may have altered our ability to accurately evaluate vegetative response to treatment methods in the absence of fire, making these treatments case studies. If we expanded the number of mastication sites in our original project design we may have had a more robust comparison of the two different management strategies.

Another way we could have improved the project is by establishing a coordinated effort with forestry, conservation, and biomass experts to incorporate invasive plant species into the biomass energy portfolio during the initial treatment phase of the project to better determine economic feasibility. Efforts are continually being made within the forestry arena to develop effective methods and plans to manage our forest systems but limited progress has been made to incorporate riparian forest information into the overall planning and resource inventory process. Federal and state forestry biomass specialists in the western region offered tremendous assistance to this project's bioenergy investigation, and much of the success of the project is due to their willingness to share information and contacts. The biomass investigation

Figure 2. Treatment and monitoring activities were conducted at nine project sites: 1–2. Cottonwood Flats / Fort Keogh 1 (Miles City, MT); 3–4. East Yellowstone / Fort Keogh 2 (Miles City, MT); 5. Allen (Big Horn County, MT); 6–7. Arapooish (Hardin, MT); 8. Classroom (Lovell, MT); and 9. Sturgis School (Sturgis, SD). *Note: Arapooish, Cottonwood Flats, East Yellowstone are defined as two sites because they each contain separate Russian olive and saltcedar treatment areas.*



generated much interest from both potential stakeholders and the research community, and thus was a priority focus in all of our outreach activities and efforts.

The project team conducted several workshops and field events throughout the duration of the project. These events included demonstrations of on-site processing, transport, conversion processes of biomass pelletization, and other bioenergy technologies. Producers and landowners were introduced to innovative technologies that have the potential to generate income and develop community-based jobs, offset the costs of weed control, produce an effective heating source, improve grazing land, reduce restoration costs, enhance fish and wildlife habitat, and promote long-term conservation strategies.

CISM, LRES, and MSU staff facilitated and coordinated all project activities undertaken through this grant award. The project management and leadership kept the project within budget, on track, on time, and well documented. We collaborated with the MSU offices of Sponsored Programs, Purchasing, and Personnel on all grant agreement, subaward, and subcontract administration. CISM and MSU personnel submitted semi-annual progress reports, supplemental narratives to explain and support payment requests, quarterly financial reports, specific measurable project performance items that indicated progress, new technology and innovative approach fact sheets, and this final project report to NRCS.

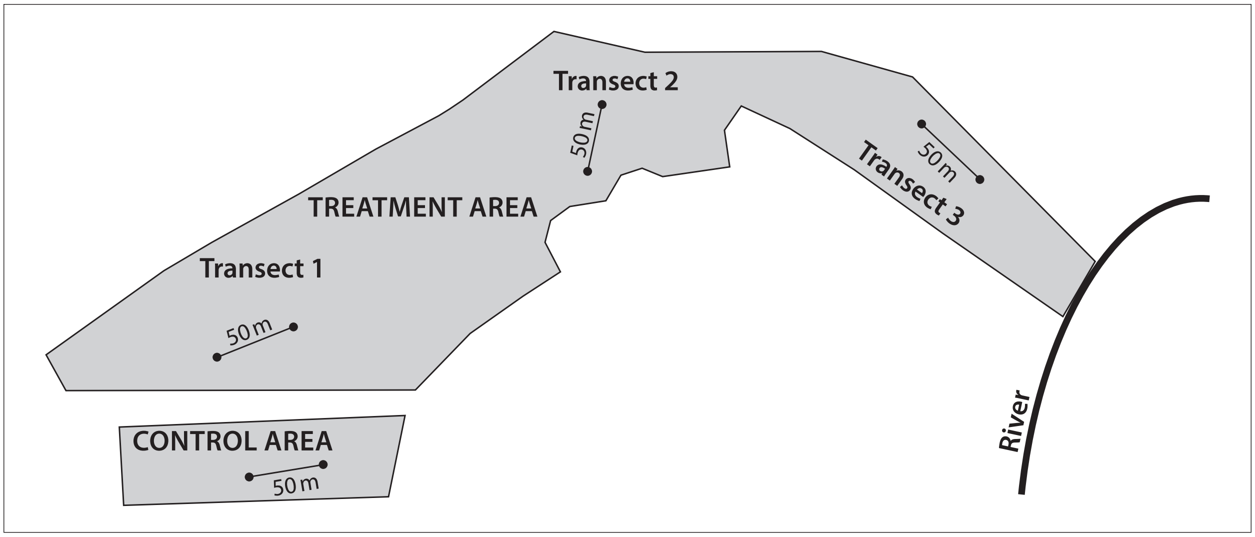


Figure 3. The treatment and monitoring site layout used at the Allen Project Area in Big Horn County, MT. The gray areas represent Russian olive infestation. Each project area was 5.6–6 hectares (14–15 acres), depending on infestation size and site configuration, and monitoring occurred on three 50-meter transects in each treatment area. The transect endpoints (circles) were used as photo points. The Allen Project Area is on privately-owned agricultural land that met NRCS EQIP qualifications standards (Appendix G. 2012 EQIP Eligibility Letter for Allen Site).

DISCUSSION OF QUALITY ASSURANCE

In fall 2011, nine project treatment sites infested with Russian olive (total of 82 acres) and saltcedar (total of 17 acres) were selected in Montana, Wyoming, and South Dakota (Figure 2). The sites were designed to approximate management scale treatment units to increase the applicability of the project's findings. We believe that this approach replicated realistic examples of Russian olive and saltcedar invasions that landowners and land managers are faced with managing. The sites were also selected to represent regional invasive plant community age classes and densities, in addition to land use functions such as domestic livestock grazing and natural habitat areas.

Each project site was comprised of a large treatment area along with a small control area to provide a non-treated reference area for future comparisons. Permanent monitoring transects were established at all nine sites (Figure 3), and detailed vegetation sampling was conducted both prior to and after the treatments were implemented. Monitoring changes in site vegetation composition and density allowed the project team to evaluate the efficacy of the treatments, in addition to monitoring changes in overall rangeland riparian health conditions.

All plant community data except for woody plant density were entered directly into the Database for Inventory Management and Analysis (DIMA) on field tablet computers. Data were collected using six protocols: line-point intercept, dry weight rank with comparative yield plots, belt transects for woody plant density, canopy and basal gap intercept, and soil stability. A site description was recorded using slope, aspect, azimuth, slope shape, landscape unit, and hillslope profile. Soil samples were collected for laboratory analysis to provide a baseline site characterization for future assessment. The monitoring protocols used for this project are standard for assessing rangeland conditions and can be used to assist riparian conservation planning in the future.

Line-point intercept using a laser point-intercept device was used to determine canopy cover, basal cover, litter cover, soil surface cover, and woody debris cover (Herrick et al. 2009). Data were collected at 1-m increments and in some cases, vegetation made a 50 m transect impossible, so the line was shortened to 25 m and point-intercept data were collected every 0.5 m. Dry weight rank with comparative yield plots was used to determine species composition and production for herbaceous and shrubby plants. Circular 0.25 m^2 hoops were placed at each location and all current-year production within the hoop was clipped, weighed, and saved to be weighed again when dried. After identifying comparative yield plots, dry weight rank was conducted at predetermined points along the 50 m transect line starting at the 5 m mark, and every 10 m thereafter.

Belt transects were used to determine the density of live and dead trees within each plot. Belt width varied depending on plot-specific densities, and in some cases seedling densities were so high that 20 cm × 20 cm quadrats were used to estimate density. In all cases, the unit of density was reported as plants per hectare. Canopy and basal gaps were determined along the permanent transects where the minimum gap size for both canopy and basal gap was 20 cm.

Soil stability was determined by taking nine samples at each transect, beginning at the 10 m mark on the transect line, and every 10 m thereafter. For heavily wooded areas where a 25 m transect line was used, samples were taken beginning at the 5 m mark and every 5 m thereafter. Soil stability was determined utilizing the rapid soil aggregate stability protocol (Herrick et al. 2009). Samples were collected beginning at the 10 m mark on the transect line, and every 10 m thereafter, for a total of nine samples at each plot. For heavily wooded areas where a 25 m transect line was used, samples were taken beginning at the 5 m mark and every 5 m thereafter. To establish baseline soil characteristics, a soil coring device was used to collect 10 sub-samples at each transect, with sampling locations distributed in a roughly systematic fashion within 5 m of the transect line. Sub-samples were combined by site, air-dried, crushed, and sieved with a 2 mm mesh sieve. Midwest Laboratories analyzed the samples for organic matter, available phosphorous, exchangeable potassium, magnesium, calcium, hydrogen, soil pH; buffer index; cation exchange capacity, percent base saturation of cation elements, and soil texture (Appendix H. Soil Analysis Results).

Data were collected by Synergy Resource Solutions, Inc. and were provided in raw form in a Microsoft Access database. For the Russian olive and saltcedar treatments, annual site specific treatment plans were developed and oversight was provided by the project leader. Monitoring activities and data reporting were overseen by Jack Alexander of Synergy Resource Solutions, Inc.

Sampling and quality control procedures for the bioenergy investigation were established through multiple communications between the project leader and two laboratories: Keystone Materials Testing, Inc. and Hazen Research, Inc., both of which had previously conducted fuel quality testing for biomass programs. Random samples of plant materials were collected from the project sites in 2011 and 2012. The samples were hand collected from trees that had been cut, slash piled, and processed through standard commercial grade wood chipping equipment in order to reduce the particles to the recommended size (two inches or less), then bagged, labeled, and stored in a secure storage building. Small (200 g) samples were later extracted from the samples and shipped directly to the two laboratories in compliance with each lab's chain of custody and documentation procedures, and in accordance with American Society for Testing Materials (ASTM) standards for quality assurance. All calibration of testing equipment was part of the standard operating procedures of the laboratories used to conduct the testing. All related fuel quality testing was conducted by the laboratory personnel, and portions of each sample were retained by the laboratories in order to conduct replicated tests if needed. See Appendix I. Bioenergy Laboratory Reports and Appendix J. Bioenergy Testing Summary Report.

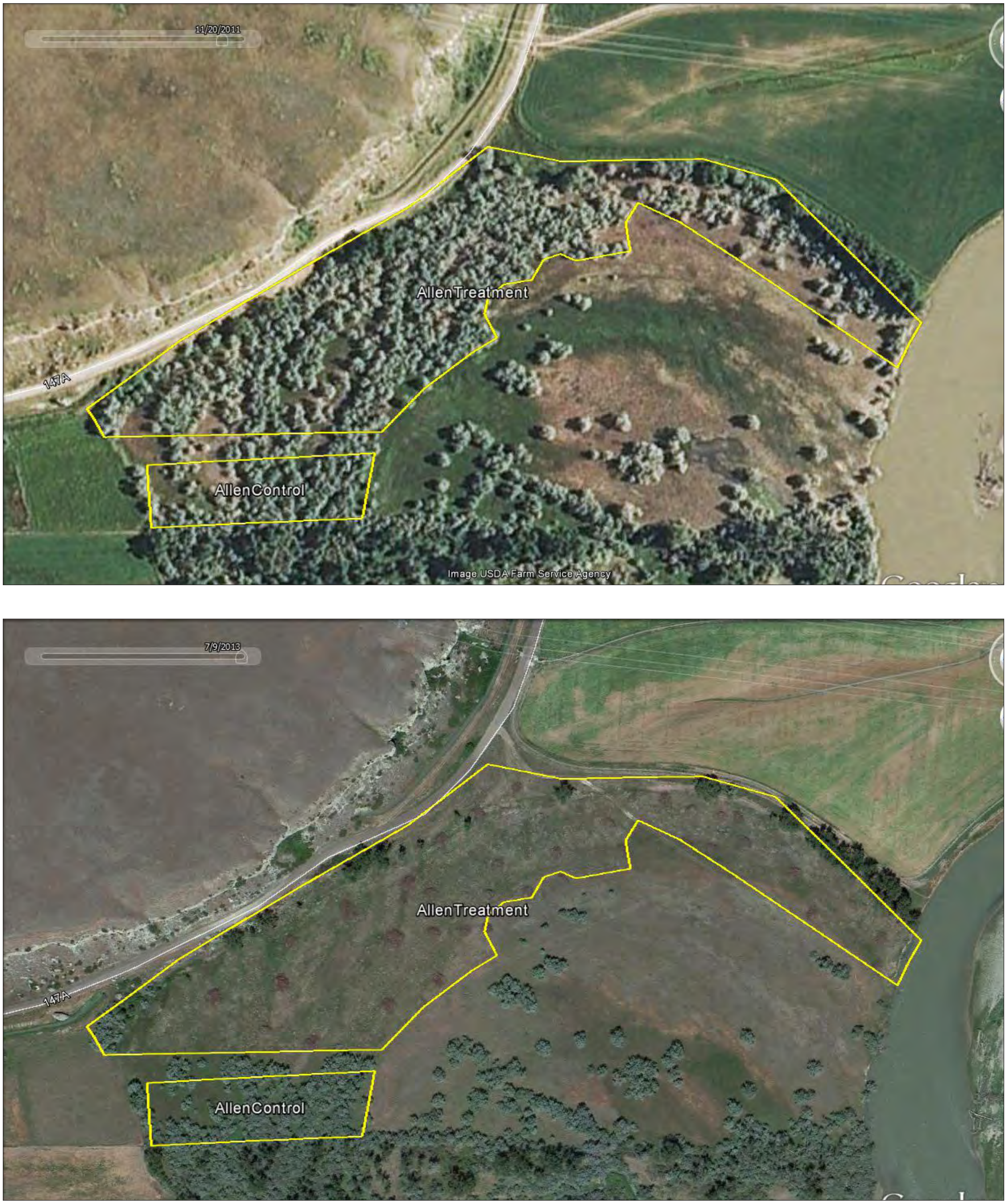


Figure 4. Russian olive and saltcedar treatments drastically altered plant community characteristics following treatments. The reduction in Russian olive cover resulted in a release of pasture grasses, which responded to the treatments with increased canopy cover and productivity. *(Top)* Aerial image of the Allen site near Hardin, MT prior to Russian olive treatment activities in 2012. *(Bottom)* The same site in August 2014, after treatment and follow-up treatment activities.

Table 1. Comparison of fuel properties of Russian olive, saltcedar, and woody species used in bioenergy applications

Species	HHV[1] BTU/lb od	GHV[2] BTU/lb MC20	BTU/lb MC50	Ash % od
Saltcedar	8,275	6,620	4,138	2.88
Russian olive	8,332	6,665	4,166	1.38
Ponderosa pine (hog fuel)	8,821	7,056	4,410	2.37
Douglas fir (mill waste)	8,779	7,023	4,390	0.41

[1] Higher heating value (HHV)
[2] Gross heating value (GHV) = HHV (1-MCwb/100)
Source: "Analysis of Fuel Properties and Bioenergy Potential of Saltcedar and Russian Olive Wood." 2012. T. R. Miles Technical Consultants, Inc. 2012.

The testing procedures described above provided sample specific percentages of the four primary components of determining wood fuel qualities, defined as: calorific value (amount of heat generated in BTUs); ash (amount of ash generated from burning the sample); moisture (the moisture level of the sample); and volatile matter (the percentage of the sample that contains combustible materials). In addition to the proximate (ASTM D5142) and ultimate analysis (ASTM D3176), elemental testing (ASTM E1756) was also conducted to ascertain detailed information regarding the overall composition of the sample materials.

Based upon recommendations from bioenergy experts and communications with laboratory specialists, the testing criteria was intended to provide scientific data to establish baseline wood fuel characteristics information. The resulting information was then compared with woody biomass data on forestry species traditionally used in biomass utilization activities.

In an attempt to assess the product quality and to further evaluate the overall feasibility of Russian olive and saltcedar as feedstocks for biomass utilization, bioenergy expert Tom Miles of T. R. Miles Technical Consulting, Inc. was contracted to conduct an independent assessment. All project-related test data and reports were provided to Miles, along with supplemental biomass information gathered from a variety of data sources. Miles summarized the potential of the invasive plants for bioenergy applications in a detailed report (Appendix K. Analysis of Fuel Properties and Bioenergy Potential) in May 2012.

All project data will be held in a data repository at MSU. All project activities, results, conclusions, and deliverables have been conveyed to regional and national stakeholders via technology transfer activities and publications, and are also available on the project website.

FINDINGS

Analysis of sampling data indicated that the treatment methods used to control Russian olive and saltcedar were very successful. Plant community responses on the treated sites varied due to a suite of environmental factors, such as species composition and historical site use. The sampling data detailed short-term trends of the vegetative response to the treatment methods, and post-project monitoring efforts will be continued in order to obtain valuable information on long-term ecological changes that can be used to support future riparian invasive woody species treatment efforts in the region. The sampling datum with synthesis was compiled into a comprehensive data summary report that includes all data collection methods, protocols, and analysis.

Control treatments effectively eliminated Russian olive and saltcedar cover and standing biomass across all of the treatment sites. In the years following the treatments, Russian olive and saltcedar establishment varied across the treatment sites and was highest in 2013, particularly on the Cottonwood Flats and East Yellowstone sites (Ft. Keogh 1 and 2) and on the Lovell Mulch site. Many of the plants that established on the Lovell Mulch site made it to the sapling stage (e.g., 1–2 m) at the end of the first growing season following the treatment and wildfire. Follow-up herbicide application treatments were effective for controlling Russian olive and saltcedar establishment post-treatment across sites, and demonstrate the importance of post-treatment monitoring and rapid follow-up treatment response to reduce the potential for site reinvasion. See Appendix L. Photo Summary Series by Transect.

Across sites, treatment areas had increases in cover and productivity of desirable herbaceous species, often with concomitant declines in undesirable weed and noxious weed species (Figure 4). In some instances control areas had increases in herbaceous production; however, these were often accompanied by increases in undesirable weeds. Soil stability was consistently high across sites with only minor or no differences between control and treatment locations within a site. In 2013, however, stability decreased in control and treatment locations on the Lovell site, presumably due to a wildfire that burned across the site that spring. In addition, another exception was the East Yellowstone (Ft. Keogh 2) site where stability was more variable, presumably due to disturbance events like flooding and grazing. Aerial canopy cover gaps were also consistently low across sites (e.g., less than 10%), with the exception again being the East Yellowstone site, which had a much higher percentage of canopy gaps in larger size classes presumably due to site disturbances.

Russian olive and saltcedar are viable candidates for woody biomass energy utilization. The fuel characteristics of both species are comparable to the fuel qualities of forest waste materials that have been used in wood-fired systems for many years throughout the West. Testing and analysis of Russian olive and saltcedar biomass samples showed that, if processed to meet industry standards, the biomass could be used in bioenergy applications. An independent assessment of the laboratory test results concluded that while all wood-based energy resources are currently being under-utilized, Russian olive and saltcedar could fit into a variety of energy applications such as wood-chip boilers, wood pellet production, and possibly biochar as an on-site soil amendment for vegetation restoration. Table 1 compares specific heat values for Russian olive, saltcedar, and two conifer species used extensively in bioenergy applications. Fuel quality testing also revealed that saltcedar contains higher levels of sulfur, potassium, sodium, chlorine and ash, which would make it less desirable for as a stand alone material but very compatible as a blend with other woody materials or a good candidate for biochar restoration projects.

The biomass harvesting aspects of this project required commercial technical skills and equipment that are outside the ability of agricultural producers and most land managers. According to regional bioenergy experts, the current market value of woody biomass is approximately $40 per ton (delivered). The harvesting/handling (chipping) costs for biomass averages between $14 and $20 per ton, which is scale driven. Transportation costs averaged from $2 to $3 per mile. The estimated volume of usable biomass that can be generated from Russian olive is between five and 10 tons per acre, and varies depending on plant density and age class. Using current market value information, the overall average value of potential woody species biomass is $200 to $400 per acre. While the marketable value of the biomass is not sufficient to offset the treatment and chip/haul costs, it could provide some level of economic incentive.

Commercial treatment costs for the initial cut-stump methods averaged $1,300 per acre, including herbicide application (labor and product). Although the cut-stump method is more expensive during the initial phase of the treatments, evaluations made to compare the practices indicate that mastication treatments require multiple years of extensive follow-up herbicide treatments to effectively manage the target species, which can ultimately be more expensive and result in plant community degradation. Cut-stump sites showed significant improvement in desirable vegetation composition compared to the mastication site.

Although the data is short-term and contains limited site replications, the cut-stump methods appear to be more ecologically sound and should require decreased levels of treatments to achieve sustainable desirable vegetative cover. In addition, once the woody species have been removed, the vegetation composition and production capacity improve considerably. For example, one of the project sites studied showed an increase of approximately 4,000 pounds per acre of desirable grass from 2012 to 2014, offering beneficial forage for livestock, structure for wildlife habitat, and cover to reduce the probability of terrestrial plant reinvasion.

CONCLUSIONS AND RECOMMENDATIONS

This project demonstrated how conventional methods (cut-stump and basal bark treatments) can effectively be used for Russian olive and saltcedar control in riparian restoration projects across the Missouri River Watershed. Our findings highlight the importance of pre-treatment planning and post-treatment monitoring; proper planning and monitoring are essential for the implementation of adaptive management, which is often required when projects are designed to reduce or remove tenacious invasive species like Russian olive and saltcedar. The project team used monitoring data to identify locations that required follow-up treatment for the target species and for other noxious weeds that established following chemical and mechanical treatments. In addition, we are using the monitoring data to develop site-specific management plans which include restoration or rehabilitation treatments based on site potential concepts (e.g., existing species composition, soils conditions, hydrology, etc.).

To improve the success of future riparian management projects, four factors should be considered as contributing to an area's inherent site potential: (1) pre-treatment management; (2) pre-treatment plant community composition; (3) natural disturbance regime (e.g., flooding, fire, drought); and (4) post-treatment management. When site potential has been described, realistic and attainable goals can be set and used as a benchmark to measure project success. Existing tools like Ecological Site Descriptions (ESD) with their associated State and Transition Models can be used to facilitate this planning process. For example, ESDs describe the range of plant communities or states that can occur for a given ecological site and the abiotic and biotic factors and management practices that encourage state change. This information can provide considerable guidance into the management practices required to achieve desired plant community improvements as part of rehabilitation or restoration plans.

Although fuel quality testing verified that Russian olive and saltcedar are viable candidate species for use in bioenergy applications, further efforts should be made to validate product quality, including facility-scale testing at biomass operating facilities, and air quality emissions testing and analysis to ensure that the use of the materials meets existing air quality emissions standards. In addition, further studies should be made to incorporate the materials into the biomass supply chain. Currently, woody biomass is not being utilized outside of National Forest System areas largely due to costs associated with transporting the materials to biomass operating facilities. Conducting updated feasibility assessments of public and private facilities in the West is a critical step toward identifying low efficiency systems, and an emphasis should be placed on rural areas that are currently using fuel sources such as fuel oil or propane. Montana NRCS has provided assistance to producers to address the removal of Russian olive and saltcedar through the implementation of a Special Initiative for Russian olive and saltcedar management as a conservation practice. This model could be replicated by NRCS throughout the region. Further evaluations could be made to incorporate the practice as a component within the Conservation Securities Program to further the ecological improvements of high-production riparian areas throughout the western region as part of efforts to combat the effects of invasive weeds on rangelands.

Major recommendations resulting from the bioenergy investigation are as follows:

- It is necessary to explore funding sources to conduct and collect regional inventory information of Russian olive and saltcedar in order to determine a comprehensive scale of potential energy values.
- Efforts should be made to strengthen coordination with government, public, and private forestry interests and include the target invasive species as a component of riparian forest management and planning efforts for future energy utilization.
- Expansion of woody biomass fueled systems and/or products throughout the region that could improve existing biomass utilization should be encouraged.
- It is necessary to continue collaborations with regional invasive plant management programs to emphasize riparian areas as a priority in order to assist in mitigating the negative ecological impacts caused by the spread of invasive woody species.

As a whole, this project provided innovative ideas for producers and landowners and other interested parties to directly and indirectly take action—and responsibility—for controlling invasive species on their properties and in their communities, which is crucial for sustainable, long-term conservation and management of riparian areas in the West. The project team and MRWC Executive Committee members fostered citizen and stakeholder engagement and technology transfer through multiple mediums, including dozens of presentations, workshops, field demonstrations, site tours, and media interviews (Appendix M. Technology Transfer Summary Table). Audiences and participants included producers and private citizens, tribes, conservation organizations, educators, university colleagues, congressional delegations, and local, state, and federal agency personnel. We also produced numerous informational materials, such as project briefings, fact sheets, and posters (Appendix N. Outreach and Technology Transfer Products).These materials were disseminated at in-person events and via a comprehensive project website (www.weedcenter.org/cig) and the MRWC's email listserv. The website will remain available as a project archive well into the future.

TECHNOLOGY REVIEW CRITERIA

N/A

REFERENCES

Wyoming Wildlife and Natural Resource Trust Board. 2012. "Yellowtail Area CRM Invasive Plant Management Project Completion Report." 21 p.

Herrick JE, Van Zee JW, Havstad KM, Burkett LM, and Whitford WG. 2009. Monitoring Manual for Grassland, Shrubland and Savanna Ecosystems. Volume I: Quick Start. USDA–ARS Jornada Experimental Range, Las Cruces, NM.

Appendix A. Final Budget and Match Summary

Project Completion Date: September 23, 2014
NRCS Agreement #69-3A75-10-175
MSU Index #4W3339

Note: These are not final spending amounts.

Budget category	Amount ($)
MSU personnel	
Salaries	289,184
Benefits	112,541
Subcontracts	162,688
Contracted services	250,000
Supplies	13,000
Communications	5,000
Travel	49,500
Rent	1,000
Other expenses	1,000
Total direct costs	883,913
In-direct costs (15%)	116,087
Total project budget	1,000,000
Amount unspent	1,290

Grant Match Summary
Final: April 29, 2013

Date submitted	Contributor	Time period	Amount ($)
March 30, 2012	Goshen County Weed & Pest District (Torrington, WY) *Contact: Steven Brill*	2011	76,132
March 30, 2012	WY Fish & Game, CRM (Lovell, WY) *Contact: Jerry Altermatt*	2011	221,258
March 30, 2012	MT Department of Agriculture, MT Noxious Weed Trust Fund (Helena, MT), *Contact: Dave Burch*	Sept. 2010 – Oct. 2011	159,133
March 19, 2013	MT Department of Agriculture, MT Noxious Weed Trust Fund (Helena, MT), *Contact: Dave Burch*	June 2011 – Oct. 2012	74,000
March 29, 2013	WY Fish and Game, CRM (Lovell, WY) *Contact: Jerry Altermatt*	2012	338,162
April 26, 2013	WY Department of Agriculture (Sheraton, WY) *Contact: Slade Franklin*	Jan. 2012 – April 2013	1,201,318
			2,070,003

Match contributed by the states of Montana and Wyoming is documented and kept on file by the Center for Invasive Species Management and Montana State University.

OPAS REQUEST FORM

No Cost Extension (NCE) Request

TO: *Organization Prior Approval System*
C/O Leslie L. Schmidt
Office of Sponsored Programs

OSP Fund#: 4W3339
Agency: NRCS, National CIG
New End Date Requested: 23-Sep-14

FROM: Center for Invasive Species Management
DEPT: LRES
DEPT Phone: 994.6832
DATE: *8/1/2013*

[X] *Check box if this is your first NCE request*

Reason for Request: See attached Extension Justification Summary.

Principal Investigator: ______ 8-1-2013
Signature

PLEASE NOTE: ***This one-time no cost extension may not be exercised merely for the purpose of using unobligated balances. This justification may also be forwarded to the sponsor verbatim.***

Please be advised that only one 1-year no cost extension may be granted through MSU OPAS authority on a particular grant. Subsequent requests must be submitted directly to your sponsor, with a copy of the request sent to OSP.

Subcontracts from MSU - All extensions for subcontracts issued by MSU must be requested separately. Forward requests to the OSP Subcontract Manager.

Action taken by Sponsored Programs

OSP signature: ______ ___ Approved ___ Denied
New End Date: ______

REASON FOR DENIAL: ______

MSU OSP April 2011

Center for Invasive Species Management

MSU Administrative Contact:
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Office of Sponsored Programs
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Administrative Contact:
Dan Lukash
Grants and Agreement Specialist
NRCS, Customer Service Division
PO Box 2890, Room 6219 South Building
Washington, DC 20013-2890

August 1, 2013

RE: Request for a one-year, no-cost extension for Conservation Innovation Grant Project, *Innovative approaches to invasive plant management in the Missouri River Watershed – From invasive species prevention and control, to biomass utilization/bioenergy creation,* NRCS Agreement # 69-3A75-10-175 and MSU #4W3339.

Note: In October 2012, the Center for Invasive Plant Management officially changed its name to the Center for Invasive Species Management. All references to the Center in this document use its new name: Center for Invasive Species Management or CISM.

The following is a request and required information for a one-year, no-cost extension from the Center for Invasive Species Management (CISM) and Montana State University(MSU) for Conservation Innovation Grant Project, *Innovative approaches to invasive plant management in the Missouri River Watershed – From invasive species prevention and control, to biomass utilization/bioenergy creation,* NRCS Agreement # 69-3A75-10-175 and MSU #4W3339. This three-year project is currently due to end on September 23, 2013.

a. ***Length of additional time required to complete the project and a justification for the extension.***

CISM will require an additional 12 months to complete the project, which will make the new project completion date September 23, 2014.

As has been communicated to the Natural Resources Conservation Service (NRCS) in semi-annual project progress reports submitted in 2011, 2012, and 2013, in spring and summer 2011, rivers within the Missouri River Watershed states experienced historical flood events, which did not recede to below-flood-stage levels until late August or early September. The flooding was triggered by 200-800% levels of precipitation in May 2011 in the upper Missouri River Watershed. In addition, a 212% (of normal) snowpack existed in the Rocky Mountains of Montana and Wyoming. Despite multiple attempts to conduct on-site evaluations of potential inventory and monitoring project sites from May through August 2011, prolonged high-water levels throughout the region made the sites inaccessible. Thus, due to uncontrollable flood conditions, which made project site selection impossible and prevented the project team from conducting the first cycle of inventory and monitoring, three of the tasks identified in Objective 1 scheduled to be conducted in 2011 had to be postponed until 2012. These delays have caused the entire CIG project to be one full field season behind schedule; consequently, one additional project year is required to complete all of the tasks outlined in our project work plan.

b. A summary of progress to date.

In accordance with monitoring and reporting requirements (Section IX. of the NRCS Agreement), CISM and MSU have reported to the NRCS our day-to-day project performance and costs through the submittal of timely progress and financial reports (see Attachments A, B, C, D, and E for semi-annual progress reports for the time period of October 2010 through June 30, 2013).

With the exception of Year 1 field work scheduling delays due to regional flooding, the CIG project has been completely successful, has spurred great interest from many regional and national stakeholders, and is proceeding well within budget.

In 2012, the site selection process, and site vegetation sampling and surveys were completed by the CISM project team and Synergy Resource Solutions, Inc. as outlined and contracted in the CIG project subaward.

In addition, site-specific treatment plans were developed by CISM staff to guide contracted service activities for all nine of the project sites. Initial field management activities (mechanical cutting and/or herbicide applications) were conducted by commercial contractors under the supervision of Scott Bockness (CISM, CIG Project Leader). All 2012 and 2013 contracted service agreements and subsequent activities were facilitated through Montana State University purchasing processes and standards, performed by CISM and MSU personnel.

Bioenergy feasibility testing was conducted by certified laboratories in 2011 and 2012 to determine the potential use of invasive plant species biomass (Russian olive, saltcedar and phragmites) as feedstock for woody biomass energy products, such as wood pellets. Independent evaluation of the bioenergy test data was completed by Tom Miles, a nationally-renowned bioenergy expert (see Attachment D, Appendix C, *Analysis of Fuel Properties and Bioenergy Potential of Saltcedar and Russian Olive Wood* report). Additionally, in 2013, biomass samples collected at CIG project sites were sent to the International Biomass Group for testing and were approved for future commercial pellet production plans.

In 2013, secondary (Year 2) treatments were conducted on the CIG project sites (1) to mitigate regrowth of the target species (Russian olive and/or saltcedar) and other existing terrestrial weed complexes, and (2) to promote site transition to desirable plant communities. Follow-up vegetation surveys are scheduled for August 2013; and subsequent analyses will be conducted to document changes to the site vegetation communities and to evaluate impacts to the riparian system as a result of invasive plant management at those sites.

c. An estimate of funds expected to remain unobligated on the scheduled expiration date.

Given the project team's inability to conduct much of the site-specific field work and data collection originally scheduled for 2011 (due to flooding in the watershed), there remains adequate funding to complete field work tasks and all other tasks in project Year 4 (late 2013 and 2014). It is estimated that on September 23, 2013, **$430,000** funds will remain unobligated, which will cover all project expenses anticipated for Year 4 of this project.

A request for a budget revision (Attachment F) is also included with this one-year extension request, which corresponds to anticipated project costs through September 2014.

d. A projected timetable to complete the portions of the project for which the extension is being required.

During Year 4 of this project (September 24, 2013 to September 23, 2014), the third and final round of site treatment activities will be conducted. Project activities will include: work plan development, the bid and contracting processes for treatment contracts, on-site commercial treatments, a final round of site surveys and sampling conducted by Synergy Resource Solutions, Inc., and the submission of a final report summarizing scientific outcomes and outreach activities of the project. Ongoing education and outreach activities through formal presentations, articles, webinars, and educational products will continue in late 2013 and throughout 2014.

e. Signature of the grantee and the project director.

MSU Grantee

____

Leslie L. Schmidt
Assistant Vice President for Research, Montana State University

Project Director/Principal Investigator

____

Elizabeth Galli-Noble
Director, Center for Invasive Species Management

f. A status of cost-sharing to date.

As of May 2013, 100 percent of all cost-share obligations for this project (more than $2 million) have been fully met and documented. See Attachment E, Appendix A for project match/cost-share summary table.

This document was written and submitted by:

Elizabeth Galli-Noble, CISM Director and Project Co-PI; and
Scott Bockness, CISM Co-PI and Project Leader
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W: 406.994.6832, 406.208.7657
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OPAS REQUEST FORM

Budget Revision

TO: *Organization Prior Approval System c/o Leslie L. Schmidt Office of Sponsored Programs*

OSP Fund#: 4W3339

AGENCY: NRCS, National CIG

FROM: Elizabeth Galli-Noble and Scott Bockness, Co-PIs

DEPT: Center for Invasive Species Management, LRES

DEPT PHONE: 994.6832

DATE: *8/1/2013*

	Current Budget	Requested Changes +/-	New Proposed Budget
Salaries	187,184.00	102,000.00	289,184.00
Benefits	74,541.00	38,000.00	112,541.00
Subcontracts	162,688.00		162,688.00
Contracted Services	330,000.00	(80,000.00)	250,000.00
Supplies	15,000.00	(2,000.00)	13,000.00
Communications	30,000.00	(25,000.00)	5,000.00
Foreign Travel	-		-
Domestic Travel	54,500.00	(5,000.00)	49,500.00
Rent		1,000.00	1,000.00
Repair and Maint		1,000.00	1,000.00
Awards			-
Participant Support			-
Equipment	30,000.00	(30,000.00)	-
Capital Expend/Fac Serv			-
Facilities and Admin	116,087.00		116,087.00
	$1,000,000.00	**$0.00**	**$1,000,000.00**

Please note: ***Moving budget between categories may affect F&As; please adjust accordingly.***

JUSTIFICATION: See attached Justification Summary.

Principal Investigator: [signature] 8-1-2013
Signature

Action taken by Sponsored Programs

OSP signature: ______ Approved ______ Denied

REASON FOR DENIAL:

Fiscal Manager, please verify:

☐ F&As on new budget are calculated correctly.

☐ Budget changes does not exceed sponsor limits.

MSU OSP July 2011

Missouri River Watershed Coalition – Conservation Innovation Grant Project
Treatment Site Selection Report

Prepared by:
Synergy Resource Solutions, Inc.
March 28, 2012

The Missouri River Watershed (MRW) comprises 529,350 square miles and incorporates the states of Colorado, Montana, Nebraska, North Dakota, South Dakota, and Wyoming. These states rely heavily upon the Missouri River system for economic and ecological stability. Waters of the system support and provide for agriculture, recreation, tourism, wildlife habitat, irrigation, drinking water, industry, power generation, and livestock production.

Dense non-native plant infestations choke river systems thereby restricting access for irrigation, wildlife, and outdoor enthusiasts; degrading or eliminating habitat for threatened and endangered species; and reducing the amount and quality of essential water. Two invasive plant species, saltcedar *(Tamarix* spp.) and Russian olive *(Elaeagnus angustifolia)*, particularly threaten these many uses within the MRW.

The MRWC–CIG (Missouri River Watershed Coalition Conservation Innovation Grant) project has been initiated to provide the knowledge necessary to support management of saltcedar and Russian olive in a more efficient and environmentally suitable manner over the entire MRW. This watershed-based project involves all six Missouri River states and is a pilot project for the western region and potentially the nation.

These invasive species will be removed from riparian areas on at least 103 acres to improve ecosystem structure and function and enhance agricultural productivity. Producers and landowners within the project area will be introduced to innovative conservation practices that can improve the quality and reduce the cost of grazing land restoration, enhance fish and wildlife habitat, and promote more effective long-term conservation strategies.

This multi-state project includes stakeholders from the entire MRW. However, sample collection, workshops and field demonstrations, and treatment and monitoring sites will be located in three MRW states.

In contrast to previous research studies, treatment areas within this project will be approximately 14 acres in size. This size provides the opportunity to both measure effects of treatment on a practical scale and the opportunity for education and technology transfer by providing demonstration plots on a practical scale that landowners can apply directly to their own situations. Larger plots were also used to allow commercial-scale treatment with equipment that would be expected to be used in “real-world” situations.

Sample areas within the plots were selected to best represent treatment effects and minimize edge effects.

Site Selection

- A total of nine sites infested with saltcedar or Russian olive or both in at least three MRW states have been selected.
- To minimize contractor mobilization costs and maximize efficiency, several of the sites may be located within one general area. Sites that encompass the range of saltcedar and Russian olive infestation sizes, ages, and densities will be selected.
- Sites will not be stratified by the regulated or unregulated status of a river; rather, the river’s status will be noted and taken into consideration during data analysis.

Initial Monitoring

- Detailed baseline monitoring will be performed at each site prior to any treatments. For each planned treatment area and control area, three permanent 50-meter transects will be established and geo-referenced.
- Photo points will be established to document general trends.

- Data will be collected to monitor biotic (vegetation) and abiotic (soil) resource attributes.
- Vegetation monitoring will be conducted in accordance with the USDS-ARS Monitoring Manual for Grassland, Shrubland, and Savanna Ecosystems, Volumes I and II.
- A suite of several protocols will be used to measure specific indicators of those attributes including canopy and basal cover, plant density, canopy and basal gap, species composition, production, plant structure, and soil stability.
- These data will provide information on ecological functionality of the site and for analysis of resource values related to wildlife habitat, livestock grazing, and soil erosion.
- Data will also be collected for litter and ground cover which will provide information on plant species composition, erosion risk, plant vigor, seedling establishment, community structure, and habitat attributes.
- Presence and density of special status species—both desirable and undesirable—will also be determined. These data will report the success of seedlings, efficacy of saltcedar/Russian olive treatment, invasion of noxious weeds, and density of desirable woody species.
- The frequency, size, and distribution of gaps between plants will be measured to evaluate wind and water erosion risk and provide input for descriptions of habitat structure.
- Production data will be measured to determine the biomass produced by each species and/or lifeform. These data provide comparison to Ecological Site Descriptions, allow analysis of at-risk communities, and will be used to evaluate habitat objectives and livestock/wildlife forage objectives.
- Vegetative structure protocols will provide data for analysis of the vertical structure of the plant community and data on the quality of visual obstruction or hiding cover for wildlife species.
- Soil testing will provide data on soil chemistry and structure changes created by removal of undesirable species and colonization by other species.

Treatments

- Sites will have defined treatment areas designed according to existing plant distribution and a defined control plot.
- While foliar treatment for phragmites is still commonly used, it is already known to have potentially significant off-target effects. Thus, it will be used in only limited amounts (~10 acres total) based on the producer's willingness to have it applied on their property and the appropriateness of the treatment for the site.
- Treatments will be implemented at the sites in the fall/winter of 2012.
- Commercially licensed contractors will be provided with treatment specifications to ensure that all treatments are performed and data collected in the same manner at each site.
- The two treatment method options will be implemented:
    - Option 1 (cut-stump of Russian olive) will consist of the mechanical cutting at the base of the tree with a variety of excavator-type apparatuses (and possibly some hand cutting with chainsaws). An immediate follow-up of triclopyr ester herbicide and a basal oil mixture will be applied to the exposed stump area of the trees.
    - Option 2 (basal bark of saltcedar) will consist of the application of a triclopyr ester or amine herbicide and basal oil mixtures to the individual plants, applying the herbicide mixture to all live stems emerging from the ground up to a height of 18 inches. Year 2 and Year 3 follow-up treatments on the re-growth will be done, applying the same herbicide mixtures as foliar applications to the individual plants displaying visible regrowth. Additional foliar herbicide mixtures may be applied as needed to address a variety of terrestrial noxious species that may exist within the individual treatment plot areas at the conclusion of Year 3.
- During the treatment work, detailed information will be collected to evaluate the economics and generate an accurate cost of each type of treatment. Volume of herbicide and bark oil, time to implement treatments, cost of operating the machinery, and costs of removing biomass (where applicable) will all

be recorded. This information, in conjunction with monitoring data, will allow the calculation of return on investment for each of the treatment scenarios.

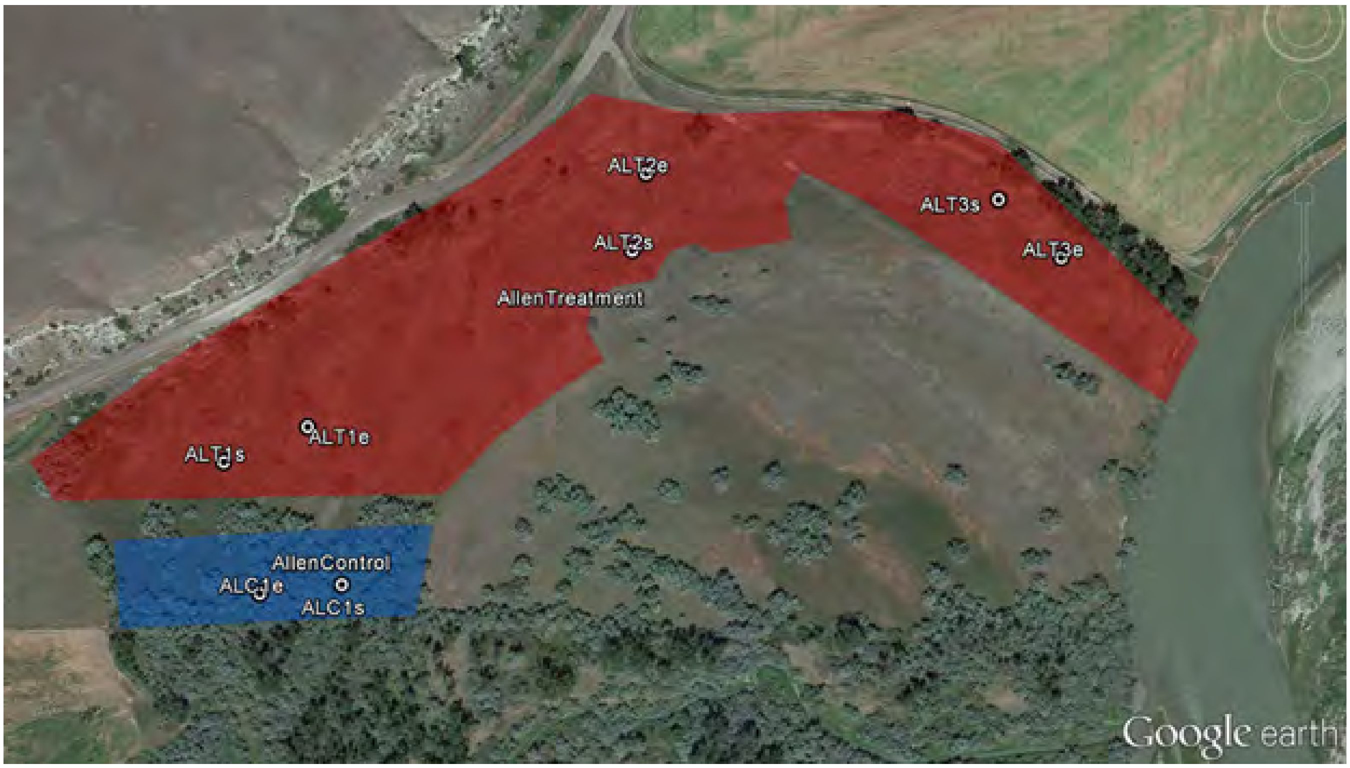
Follow-up Monitoring

- Monitoring in Year 2 and early Year 3 will consist of brief site visits and taking photos at the photo points. The purpose of this limited monitoring will be to determine if the vegetation community is moving toward or away from the desired goal. These preliminary data will determine the course of action for the end of Year 3.
- Some treatments may not succeed in moving the system toward a functioning native community (for conservation areas) or increased forage (for livestock production areas), and may result in other noxious weed problems. In such cases, funds intended for intensive transect monitoring will be diverted to additional treatments (using methods that preliminary data show to be more effective) to redirect vegetation recovery.
- In cases where preliminary data indicate initial success, the monitoring methods used for the baseline monitoring will be employed to evaluate riparian system functioning and/or suitability for livestock production.
- Monitoring data will also allow the determination of which treatment methods and time of year provide the best results. They will also demonstrate how the results vary by initial site conditions, river status (regulated or unregulated), river reach, and land use.

Data Analysis

- The percent cover of each herbaceous, shrub, and tree species will be calculated along transects. Richness will be the sum of all the species encountered. Further plant community analyses will be based on species richness and species diversity. Differences in community composition between treatments, river conditions, and land uses will be addressed.
- After preliminary data analysis, appropriate transformations will be made and additional analyses will be used to assess significant differences in community composition between sites and within site treatments. Appropriate univariate analysis will be performed for species richness, cover, and diversity to assess site differences. Linear regression will be used to assess the impacts of different treatments on community composition.

Figure A1. Map of the Allen treatment site targeting Russian olive, near Hardin, MT.

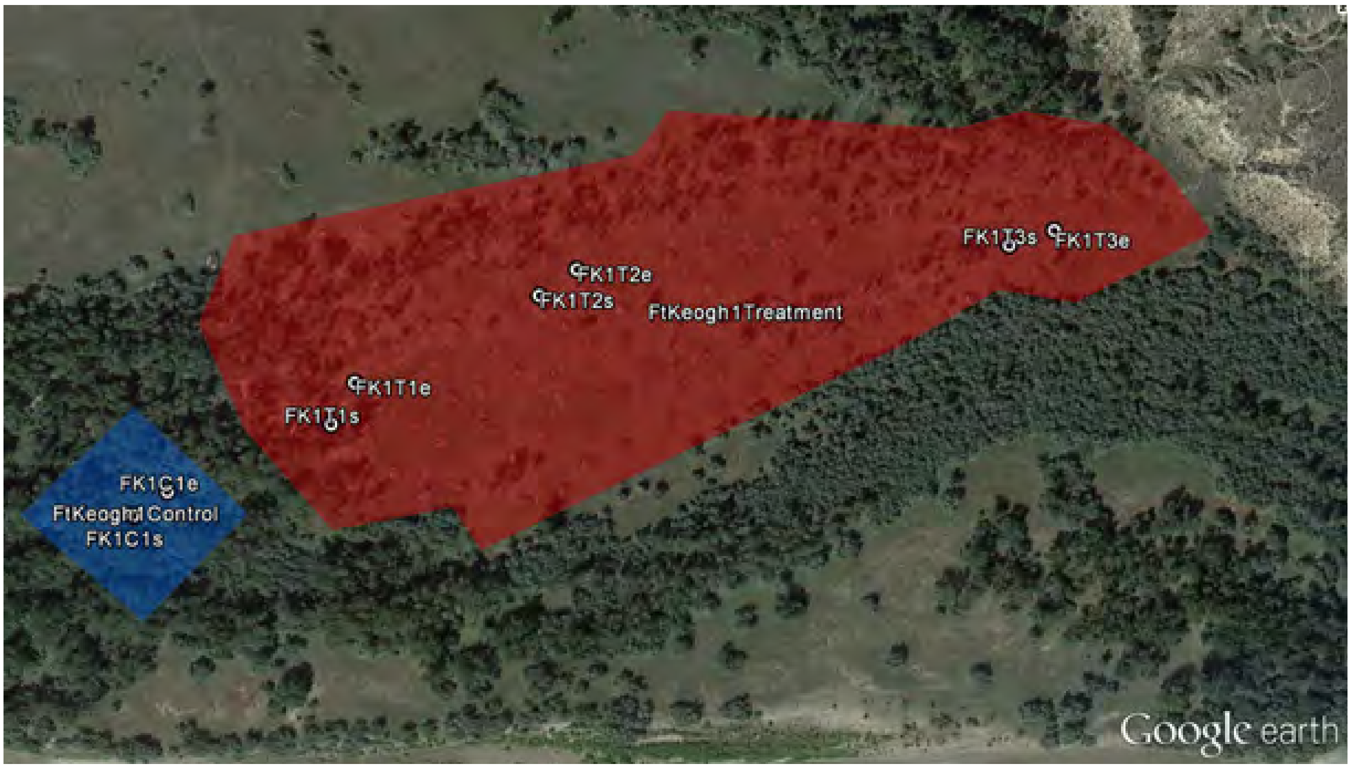


The area shown in red included Russian olive mechanical cut-stump treatment with slash piling, immediate application of a triclopyr ester (27% triclopyr + 73% basal bark oil), and biomass removal for further assessment (see Objective 3). The control area, shown in blue, did not have any treatments applied. Starting and ending points for each transect are shown for the treatment area (N=3) and the control area (N=1).

Figure A2. Map of the Arapooish treatment site targeting Russian olive and saltcedar, near Hardin, MT.

The area shown in red included basal bark herbicide treatments (triclopyr amine) to individual saltcedar plants from the ground to 18 inches. In addition, Russian olive was treated mechanically using cut-stump methods with slash piling, immediate application of a triclopyr ester (27% triclopyr + 73% basal bark oil), and biomass removal for further assessment (see Objective 3). Saltcedar was treated approximately 30 days prior to Russian olive treatments to effectively cause mortality of saltcedar and facilitate mechanical cut-stump treatments with slash piling of each species. The control area, shown in blue, did not have any treatments applied. Starting and ending points for each transect are shown for the treatment area (N=3) and the control area (N=1).

Figure A3. Map of the Fort Keogh 1 treatment site (Cottonwood Flats) targeting Russian olive, in Miles City, MT.



The area shown in red included basal bark herbicide treatments (triclopyr amine) to individual saltcedar plants from the ground to 18 inches. In addition, the area shown in red included Russian olive mechanical cut-stump treatment with slash piling and immediate application of a triclopyr ester (27% triclopyr + 73% basal bark oil). The control area, shown in blue, did not have any treatments applied. Starting and ending points for each transect are shown for the treatment area (N=3) and the control area (N=1).

Figure A4. Map of Fort Keogh 2 treatment site (East Yellowstone) targeting Russian olive and saltcedar, in Miles City, MT.

The area shown in red included basal bark herbicide treatments (triclopyr amine) to individual saltcedar plants from the ground to 18 inches. In addition, Russian olive was treated mechanically using cut-stump methods with slash piling, immediate application of a triclopyr ester (27% triclopyr + 73% basal bark oil), and biomass removal for further assessment (see Objective 3). Saltcedar was treated approximately 30 days prior to Russian olive treatments to effectively cause mortality of saltcedar and facilitate mechanical cut-stump treatments with slash piling of each species. The control area, shown in blue, did not have any treatments applied. Starting and ending points for each transect are shown for the treatment area (N=3) and the control area (N=1).

Figure A5. Map of the Lovell Mulch treatment site targeting Russian olive, near Lovell, WY.

The area shown in red included Russian olive and saltcedar mastication treatments in Fall 2012, followed by a wildfire in spring 2013, and foliar herbicide application of a triclopyr ester (27% triclopyr + 73% basal bark oil) for both species. Starting and ending points for each transect are shown for the treatment area (N=3).

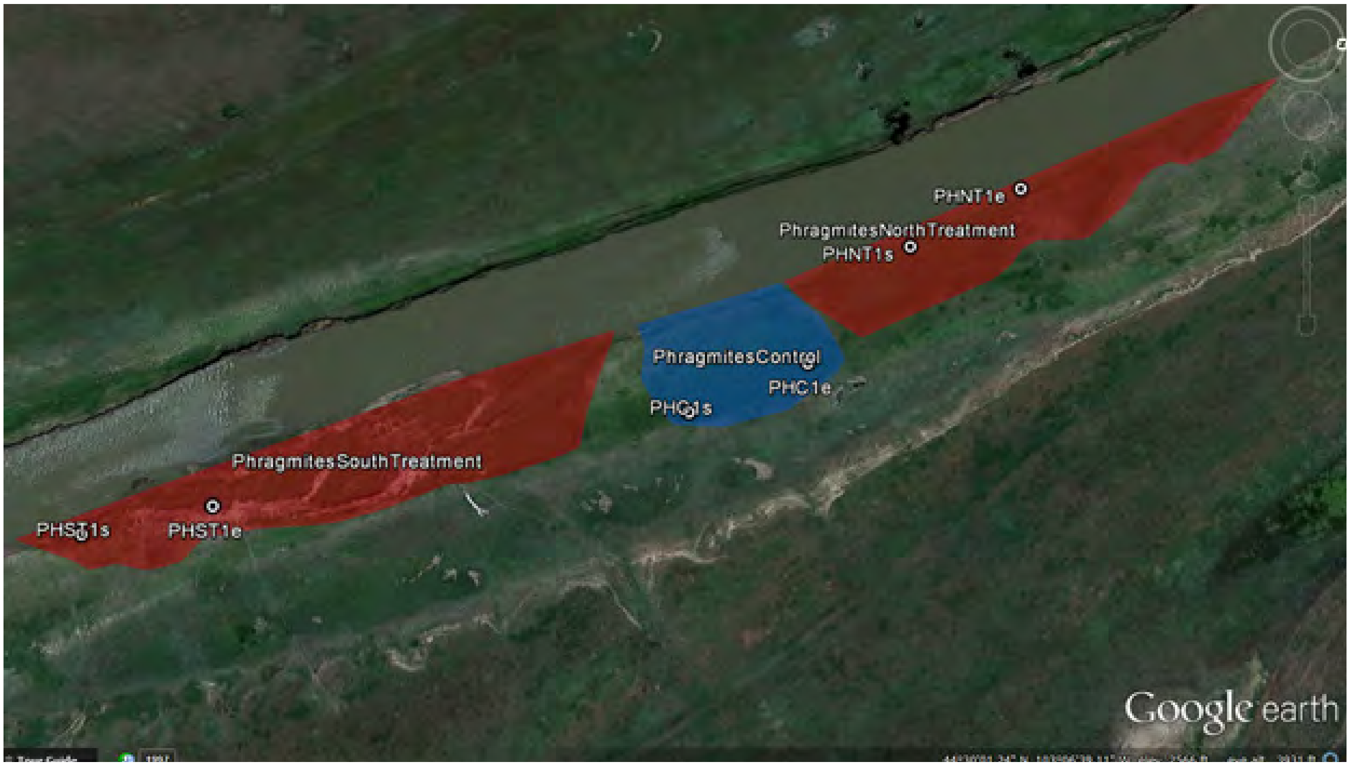
Figure A6. Map of the Lovell treatment site targeting Russian olive, near Lovell, WY.

The areas shown in red included Russian olive mechanical cut-stump treatment with slash piling, immediate application of a triclopyr ester (27% triclopyr + 73% basal bark oil), and wildfire. The control area, shown in blue, did not have any treatments applied. Starting and ending points for each transect are shown for the treatment area (N=3) and the control area (N=1).

Figure A7. Map of the Sturgis treatment site targeting Russian olive, in Sturgis, SD.

The areas shown in red included Russian olive mechanical cut-stump treatment with slash piling, immediate application of a triclopyr ester (27% triclopyr + 73% basal bark oil), and slash pile burning. Two treatment and control areas were identified to address the different age classes of Russian olive. The following modifications were made to this experimental design: (1) control site 1 was removed due to accidental treatment, described above; and (2) the ST1T2 transect was removed because it was not deemed representative of the site. The control area, shown in blue, did not have any treatments applied. Starting and ending points for each transect are shown for the treatment areas (N=3) and the control area (N=1).

Figure A8. Map of the Phragmites treatment site targeting phragmities removal, near Sturgis, SD.



The areas shown in red included foliar application of an aquatic imazamox solution (Phragmites South), and a foliar application of an aquatic glyphosate solution (Phragmites North). The control area, shown in blue, did not have any treatments applied. Starting and ending points for each transect are shown for the treatment area (N=2) and the control area (N=1).

Conservation Innovation Grant Project
Missouri River Watershed Coalition
Center for Invasive Plant Management (Montana State University)

Statement of Work
Invasive Plant Treatment and Management Services
Allen Property
Big Horn County, Montana

Allen Project Area
Russian Olive Management
1-6-2012

SCOPE OF WORK

1. **Summary:** The requirement for the project is for Russian olive vegetation treatment/control, manipulation, and inventory. The project work will be conducted on a site location within Allen private property lands in northern Big Horn County, Montana. The project activities will begin at the time the contract is awarded and continue through the end date of the contracts. All areas treated shall have GPS coordinates, maps, and electronic file for locations according to specifications and guidelines as set forth within this Statement of Work.

   The contractor shall furnish all tools, equipment, materials, supplies, personnel, labor, and supervision necessary to complete the contract work requirements.

2. **Project Location(s)/Descriptions/Maps:** The project treatment activities on Allen lands will be conducted on a location hereby referred to as the **Allen Project Area**. Site specific maps are included in the project Statement of Work (see Hardin, MT area map, page 2; Allen Project Area map, page 3).

   The Allen Project Area is located along the riparian buffer area of the Big Horn River, within Allen privately-owned property. The project site has a well-maintained access road, and the existing road will be used to access the project work areas. Off-road travel is restricted to the actual treatment areas.

3. **Target Species for Vegetation Control:** Plant species targeted for control include: Russian olive (*Elaeagnus angustifolia*).

4. **Work Requirements/Specifications:** The contract requires "cut-stump" treatment of, and the slash piling of the Russian olive within the designated project area. The mechanical cutting of the target species shall be made as close to the ground surface as possible. The previously-treated saltcedar plants will be mechanically cut and slash piled simultaneously, with the performance of the Russian olive "cut-stump" activities. The slash piling of the cut plant material and debris shall be piled in a consistent and orderly manner. Specific pile locations may be requested or identified by the Project Leader (or designee).

   The contractor's equipment shall meet or exceed all current federal, state, and local safety requirements. The contractor and employees shall be required to wear all appropriate personal protective equipment while conducting project treatment activities. Extreme care shall be exercised at all times by the contractor to protect desirable (non-targeted) species from damages by the required chemical and/or mechanical cutting treatments. The equipment may be stored on-site while the contract work is being performed.

   The treatment/removal work shall be conducted between September 1, 2012 and December 30, 2012; with uncontrollable weather and/or unfavorable site conditions considered. The Allen Project Area Russian olive mechanical removal/treatment work being offered for this contract will consist of a total area of **fourteen (14)** acres. The treatment area is defined on the treatment area map on page 3 of this document.

5. **Pesticides:** The products (pesticides/oils/adjuvants) used will be provided by the contractor and will need to be included in the bid estimate. Only EPA registered chemicals approved for use in the State of Montana shall be applied. Chemicals shall be mixed and applied at rates consistent with their perspective labels and manufacturers recommendations. Manufacturer’s label directions and warnings relative to temperature, wind, or other weather conditions shall be strictly adhered to.

   The specific chemicals, methods, and rates to be used on the Allen Project Area is as follows:

   Russian olive (cut-stump): a 33% triclopyr ester / 67% basal oil (v/v) mixture applied to cover the entire exposed stump within one hour of the mechanical cutting.

6. **Record Keeping (Pesticides):** The contractor shall be required to complete a daily accurate Pesticide Application Record (PAR) form. The contractor shall submit the completed application records to the Project Leader (or designee) on a weekly basis for inspection of the treatment areas.

7. **GPS:** The contractor will provide and use a GPS data logger that will support ArcGIS 9.2 software, and be able to export to Arcview/Map shapefiles. The contractor will furnish the Project Leader with treatment inventory data CDs containing all collected data files by project name.

8. **Weather Conditions:** The contractor shall provide a continuous operation from day to day; weather permitting, until completion of the work required within the allotted contract time frame. Modification of the project work schedule due to weather or site conditions must be approved by the Project Leader (or designee).

2

Allen Property (near Hardin, MT)

3

Conservation Innovation Grant Project
Missouri River Watershed Coalition
Center for Invasive Plant Management (Montana State University)

Statement of Work
Invasive Plant Treatment and Management Services
Montana Fish, Wildlife, and Parks
Hardin, Montana

Arapooish Project Area
Saltcedar Management
1-6-2012

SCOPE OF WORK

1. **Summary:** The requirement for the project is for saltcedar vegetation treatment/control, manipulation, and inventory. The project work will be conducted on Montana Fish, Wildlife, and Parks lands in Hardin, Montana. The project activities will begin at the time the contract is awarded and continue through the end date of the contracts. All areas treated shall have GPS coordinates, maps, and electronic file for locations according to specifications and guidelines as set forth within this Statement of Work.

   The contractor shall furnish all tools, equipment, materials, supplies, personnel, labor, and supervision necessary to complete the contract work requirements.

2. **Project Location(s)/Descriptions/Maps:** The project treatment activities on Montana Fish, Wildlife, and Parks lands will be conducted in a location hereby referred to as **Arapooish Project Area**. Site specific maps are included in the project Statement of Work (see Hardin, MT area map, page 2; Arapooish Project Area map, page 3).

   The Arapooish Project Area is located along the riparian buffer area of the Big Horn River, north of Hardin, Montana. The project site has a well-maintained access road, and the existing road will be used to access the project work areas. Off-road travel is restricted to the actual treatment areas.

3. **Target Species for Vegetation Control:** Plant species targeted for control include: saltcedar (*Tamarix* spp).

4. **Work Requirements/Specifications:** The contract requires basal bark treatments (individual plants) conducted on the saltcedar plants within the designated project area(s).

   The contractor’s equipment shall meet or exceed all current federal, state, and local safety requirements. The contractor and employees shall be required to wear all appropriate personal protective equipment while conducting project treatment activities. Extreme care shall be exercised at all times by the contractor to protect desirable (non-targeted) species from damages by the required chemical and/or mechanical cutting treatments. The equipment may be stored on-site while the contract work is being performed.

   The treatment work shall be conducted between September 1, 2012 and September 30, 2012; with uncontrollable weather and/or unfavorable site conditions considered. The Arapooish Project Area saltcedar herbicide treatment work being offered for this contract will consist of a total area of **eleven (11)** acres. The saltcedar treatments will be conducted within the area that is defined on the treatment area map on page 3 of this document.

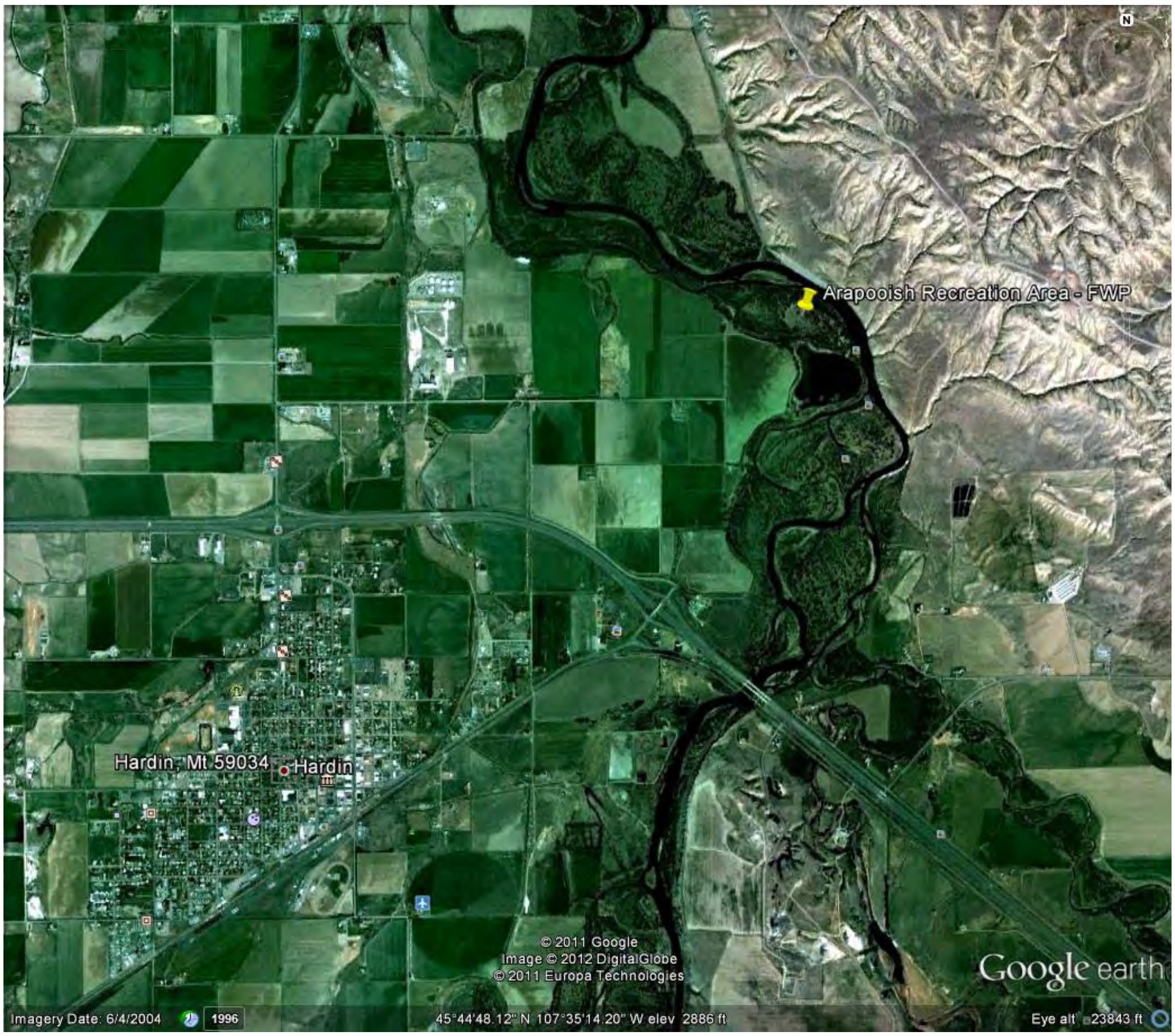
5. **Pesticides:** The products (pesticides/oils/adjuvants) used will be provided by the contractor and will need to be included in the bid estimate. Only EPA registered chemicals approved for use in the State of Montana shall be applied. Chemicals shall be mixed and applied at rates consistent with their perspective

labels and manufacturers recommendations. Manufacturer's label directions and warnings relative to temperature, wind, or other weather conditions shall be strictly adhered to.

The specific chemicals, methods, and rates to be used on the Arapooish Project Area are as follows:

Saltcedar (basal bark treatments): a 27% triclopyr ester / 73% basal oil (v/v) mixture should be applied to the bark from the root collar up the stems 18 inches covering all sides/stems of the plant.

6. **Record Keeping (Pesticides):** The contractor shall be required to complete a daily accurate Pesticide Application Record (PAR) form. The contractor shall submit the completed application records to the Project Leader (or designee) on a weekly basis for inspection of the treatment areas.
7. **GPS:** The contractor will provide and use a GPS data logger that will support ArcGIS 9.2 software, and be able to export to Arcview/Map shapefiles. The contractor will furnish the Project Leader with treatment inventory data CDs containing all collected data files by project name.
8. **Weather Conditions:** The contractor shall provide a continuous operation from day to day; weather permitting, until completion of the work required within the allotted contract time frame. Modification of the project work schedule due to weather or site conditions must be approved by the Project Leader (or designee).



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Arapooish Pond (near Hardin, MT)

3

Conservation Innovation Grant Project
Missouri River Watershed Coalition
Center for Invasive Plant Management (Montana State University)

Statement of Work
Invasive Plant Treatment and Management Services
USDA-ARS Livestock and Range Research Laboratory
Miles City, Montana

Cottonwood Flats Project Area
Russian Olive Management
1-6-2012

SCOPE OF WORK

1. **Summary:** The requirement for the project is for Russian olive vegetation treatment/control, manipulation, and inventory. The project work will be conducted on a site location within USDA-ARS Livestock and Range Research Laboratory lands in Miles City, Montana. The project activities will begin at the time the contract is awarded and continue through the end date of the contracts. All areas treated shall have GPS coordinates, maps, and electronic file for locations according to specifications and guidelines as set forth within this Statement of Work.

   The contractor shall furnish all tools, equipment, materials, supplies, personnel, labor, and supervision necessary to complete the contract work requirements.

2. **Project Location(s)/Descriptions/Maps:** The project treatment activities on USDA-ARS Livestock and Range Research Laboratory (Fort Keogh) lands will be conducted on a location hereby referred to as the **Cottonwood Flats Project Area**. Site specific maps are included in the project Statement of Work (see Miles City/Ft. Keogh area map, page 2; Cottonwood Flats Project Area map, page 3).

   The Cottonwood Flats Project Area is located along the riparian buffer area of the Yellowstone River, within Fort Keogh property. The project site has an existing access road, and the existing road will be used to access the project work areas. Off-road travel is restricted to the actual treatment areas.

3. **Target Species for Vegetation Control:** Plant species targeted for control include: Russian olive (*Elaeagnus angustifolia*).

4. **Work Requirements/Specifications:** The contract requires "cut-stump" treatment of, and the slash piling of the Russian olive within the designated project area. The mechanical cutting of the target species shall be made as close to the ground surface as possible. The previously-treated saltcedar plants will be mechanically cut and slash piled simultaneously, with the performance of the Russian olive "cut-stump" activities. The slash piling of the cut plant material and debris shall be piled in a consistent and orderly manner. Specific pile locations may be requested or identified by the Project Leader (or designee).

   The contractor's equipment shall meet or exceed all current federal, state, and local safety requirements. The contractor and employees shall be required to wear all appropriate personal protective equipment while conducting project treatment activities. Extreme care shall be exercised at all times by the contractor to protect desirable (non-targeted) species from damages by the required chemical and/or mechanical cutting treatments. The equipment may be stored on-site while the contract work is being performed.

   The treatment /removal work shall be conducted between October 30, 2012 and December 30, 2012; with uncontrollable weather and/or unfavorable site conditions considered. The Cottonwood Flats Project Area Russian olive mechanical cutting/ herbicide treatment work being offered for this contract will consist of a total area of **fifteen (15)** acres. The treatment area is broadly defined on the treatment area map on page 3 of this document.

5. **Pesticides:** The products (pesticides/oils/adjuvants) used will be provided by the contractor and will need to be included in the bid estimate. Only EPA registered chemicals approved for use in the State of Montana shall be applied. Chemicals shall be mixed and applied at rates consistent with their perspective labels and manufacturers recommendations. Manufacturer's label directions and warnings relative to temperature, wind, or other weather conditions shall be strictly adhered to.

   The specific chemicals, methods, and rates to be used on the Fort Keogh Project Areas are as follows:

   Russian olive (cut-stump): a 33% triclopyr ester / 67% basal oil (v/v) mixture applied to cover the entire exposed stump within one hour of the mechanical cutting.

6. **Record Keeping (Pesticides):** The contractor shall be required to complete a daily accurate Pesticide Application Record (PAR) form. The contractor shall submit the completed application records to the Project Leader (or designee) on a weekly basis for inspection of the treatment areas.

7. **GPS:** The contractor will provide and use a GPS data logger that will support ArcGIS 9.2 software, and be able to export to Arcview/Map shapefiles. The contractor will furnish the Project Leader with treatment inventory data CDs containing all collected data files by project name.

8. **Weather Conditions:** The contractor shall provide a continuous operation from day to day; weather permitting, until completion of the work required within the allotted contract time frame. Modification of the project work schedule due to weather or site conditions must be approved by the Project Leader (or designee).

2

Fort Keogh (Miles City, MT)

Conservation Innovation Grant Project
Missouri River Watershed Coalition
Center for Invasive Plant Management (Montana State University)

Statement of Work
Invasive Plant Treatment and Management Services
USDA-ARS Livestock and Range Research Laboratory
Miles City, Montana

Cottonwood Flats Project Area
Saltcedar Management
1-6-2012

SCOPE OF WORK

1. **Summary:** The requirement for the project is for saltcedar vegetation treatment/control, manipulation, and inventory. The project work will be conducted on a site location within USDA-ARS Livestock and Range Research Laboratory lands in Miles City, Montana. The project activities will begin at the time the contract is awarded and continue through the end date of the contracts. All areas treated shall have GPS coordinates, maps, and electronic file for locations according to specifications and guidelines as set forth within this Statement of Work.

   The contractor shall furnish all tools, equipment, materials, supplies, personnel, labor, and supervision necessary to complete the contract work requirements.

2. **Project Location(s)/Descriptions/Maps:** The project treatment activities on USDA-ARS Livestock and Range Research Laboratory (Fort Keogh) lands will be conducted on a location hereby referred to as the **Cottonwood Flats Project Area**. Site specific maps are included in the project Statement of Work (see Miles City/Ft. Keogh area map, page 2; Cottonwood Flats Project Area map, page 3).

   The Cottonwood Flats Project Area is located along the riparian buffer area of the Yellowstone River, within Fort Keogh property. The project site has an existing access road, and the existing road will be used to access the project work areas. Off-road travel is restricted to the actual treatment areas.

3. **Target Species for Vegetation Control:** Plant species targeted for control include: saltcedar (*Tamarix* spp).

4. **Work Requirements/Specifications:** The contract requires basal bark treatments (individual plants/I.P.T.) conducted on the saltcedar plants within the designated project area(s).

   The contractor's equipment shall meet or exceed all current federal, state, and local safety requirements. The contractor and employees shall be required to wear all appropriate personal protective equipment while conducting project treatment activities. Extreme care shall be exercised at all times by the contractor to protect desirable (non-targeted) species from damages by the required chemical and/or mechanical cutting treatments. The equipment may be stored on-site while the contract work is being performed.

   The treatment /removal work shall be conducted between September 1, 2012 and September 30, 2012; with uncontrollable weather and/or unfavorable site conditions considered. The Cottonwood Flats Project Area saltcedar herbicide treatment work being offered for this contract will consist of a total area of **three (3)** acres. The treatment area is defined on the treatment area map on page 3 of this document.

5. **Pesticides:** The products (pesticides/oils/adjuvants) used will be provided by the contractor and will need to be included in the bid estimate. Only EPA registered chemicals approved for use in the State of Montana shall be applied. Chemicals shall be mixed and applied at rates consistent with their perspective

labels and manufacturers recommendations. Manufacturer's label directions and warnings relative to temperature, wind, or other weather conditions shall be strictly adhered to.

The specific chemicals, methods, and rates to be used on the Fort Keogh Project Areas are as follows:

Saltcedar (basal bark treatments): a 27% triclopyr ester / 73% basal oil (v/v) mixture should be applied to the bark from the root collar up the stems 18 inches covering all sides/stems of the plant.

6. **Record Keeping (Pesticides):** The contractor shall be required to complete a daily accurate Pesticide Application Record (PAR) form. The contractor shall submit the completed application records to the Project Leader (or designee) on a weekly basis for inspection of the treatment areas.
7. **GPS:** The contractor will provide and use a GPS data logger that will support ArcGIS 9.2 software, and be able to export to Arcview/Map shapefiles. The contractor will furnish the Project Leader with treatment inventory data CDs containing all collected data files by project name.
8. **Weather Conditions:** The contractor shall provide a continuous operation from day to day; weather permitting, until completion of the work required within the allotted contract time frame. Modification of the project work schedule due to weather or site conditions must be approved by the Project Leader (or designee).

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Fort Keogh (Miles City, MT)

3

Conservation Innovation Grant Project
Missouri River Watershed Coalition
Center for Invasive Plant Management (Montana State University)

Statement of Work
Invasive Plant Treatment and Management Services
USDA-ARS Livestock and Range Research Laboratory
Miles City, Montana

East Yellowstone Project Area
Russian Olive Management
1-6-2012

SCOPE OF WORK

1. **Summary:** The requirement for the project is for Russian olive vegetation treatment/control, manipulation, and inventory. The project work will be conducted on a site location within USDA-ARS Livestock and Range Research Laboratory lands in Miles City, Montana. The project activities will begin at the time the contract is awarded and continue through the end date of the contracts. All areas treated shall have GPS coordinates, maps, and electronic file for locations according to specifications and guidelines as set forth within this Statement of Work.

   The contractor shall furnish all tools, equipment, materials, supplies, personnel, labor, and supervision necessary to complete the contract work requirements.

2. **Project Location(s)/Descriptions/Maps:** The project treatment activities on USDA-ARS Livestock and Range Research Laboratory (Fort Keogh) lands will be conducted on a location hereby referred to as the **East Yellowstone Project Area**. Site specific maps are included in the project Statement of Work (see Miles City/Ft. Keogh area map, page 2; East Yellowstone Project Area map, page 3).

   The East Yellowstone Project Area is located along the riparian buffer area of the Yellowstone River, within Fort Keogh property. The project site has a well-maintained access road, and the existing road will be used to access the project work areas. Off-road travel is restricted to the actual treatment areas.

3. **Target Species for Vegetation Control:** Plant species targeted for control include: Russian olive (*Elaeagnus angustifolia*).

4. **Work Requirements/Specifications:** The contract requires “cut-stump” treatment of, and the slash piling of the Russian olive within the designated project area. The mechanical cutting of the target species shall be made as close to the ground surface as possible. The previously-treated saltcedar plants will be mechanically cut and slash piled simultaneously, with the performance of the Russian olive “cut-stump” activities. The slash piling of the cut plant material and debris shall be piled in a consistent and orderly manner. Specific pile locations may be requested or identified by the Project Leader (or designee).

   The contractor’s equipment shall meet or exceed all current federal, state, and local safety requirements. The contractor and employees shall be required to wear all appropriate personal protective equipment while conducting project treatment activities. Extreme care shall be exercised at all times by the contractor to protect desirable (non-targeted) species from damages by the required chemical and/or mechanical cutting treatments. The equipment may be stored on-site while the contract work is being performed.

   The treatment /removal work shall be conducted between October 30, 2012 and December 30, 2012; with uncontrollable weather and/or unfavorable site conditions considered. The East Yellowstone Project Area Russian olive mechanical cutting/ herbicide treatment work being offered for this contract will consist of a total area of **fourteen (14)** acres. The treatment area is defined on the treatment area map on page 3 of this document.

5. **Pesticides:** The products (pesticides/oils/adjuvants) used will be provided by the contractor and will need to be included in the bid estimate. Only EPA registered chemicals approved for use in the State of Montana shall be applied. Chemicals shall be mixed and applied at rates consistent with their perspective labels and manufacturers recommendations. Manufacturer's label directions and warnings relative to temperature, wind, or other weather conditions shall be strictly adhered to.

   The specific chemicals, methods, and rates to be used on the Fort Keogh Project Areas are as follows:

   Russian olive (cut-stump): a 33% triclopyr ester / 67% basal oil (v/v) mixture applied to cover the entire exposed stump within one hour of the mechanical cutting.

6. **Record Keeping (Pesticides):** The contractor shall be required to complete a daily accurate Pesticide Application Record (PAR) form. The contractor shall submit the completed application records to the Project Leader (or designee) on a weekly basis for inspection of the treatment areas.

7. **GPS:** The contractor will provide and use a GPS data logger that will support ArcGIS 9.2 software, and be able to export to Arcview/Map shapefiles. The contractor will furnish the Project Leader with treatment inventory data CDs containing all collected data files by project name.

8. **Weather Conditions:** The contractor shall provide a continuous operation from day to day; weather permitting, until completion of the work required within the allotted contract time frame. Modification of the project work schedule due to weather or site conditions must be approved by the Project Leader (or designee).

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Fort Keogh (Miles City, MT)

3

Conservation Innovation Grant Project
Missouri River Watershed Coalition
Center for Invasive Plant Management (Montana State University)

Statement of Work
Invasive Plant Treatment and Management Services
USDA-ARS Livestock and Range Research Laboratory
Miles City, Montana

East Yellowstone Project Area
Saltcedar Management
1-6-2012

SCOPE OF WORK

1. **Summary:** The requirement for the project is for saltcedar vegetation treatment/control, manipulation, and inventory. The project work will be conducted on a site location within USDA-ARS Livestock and Range Research Laboratory lands in Miles City, Montana. The project activities will begin at the time the contract is awarded and continue through the end date of the contracts. All areas treated shall have GPS coordinates, maps, and electronic file for locations according to specifications and guidelines as set forth within this Statement of Work.

   The contractor shall furnish all tools, equipment, materials, supplies, personnel, labor, and supervision necessary to complete the contract work requirements.

2. **Project Location(s)/Descriptions/Maps:** The project treatment activities on USDA-ARS Livestock and Range Research Laboratory (Ft. Keogh) lands will be conducted on a location hereby referred to as the **East Yellowstone Project Area**. Site specific maps are included in the project Statement of Work (see Miles City/Ft. Keogh area map, page 2; East Yellowstone Project Area map, page 3).

   The East Yellowstone Project Area is located along the riparian buffer area of the Yellowstone River, within Fort Keogh property. The project site has a well-maintained access road, and the existing road will be used to access the project work areas. Off-road travel is restricted to the actual treatment areas.

3. **Target Species for Vegetation Control:** Plant species targeted for control include: saltcedar (*Tamarix* spp).

4. **Work Requirements/Specifications:** The contract requires basal bark treatments (individual plants) conducted on the saltcedar plants within the designated project area(s).

   The contractor's equipment shall meet or exceed all current federal, state, and local safety requirements. The contractor and employees shall be required to wear all appropriate personal protective equipment while conducting project treatment activities. Extreme care shall be exercised at all times by the contractor to protect desirable (non-targeted) species from damages by the required chemical and/or mechanical cutting treatments. The equipment may be stored on-site while the contract work is being performed.

   The treatment work shall be conducted between September 1, 2012 and September 30, 2012; with uncontrollable weather and/or unfavorable site conditions considered. The East Yellowstone Project Area saltcedar herbicide treatment work being offered for this contract will consist of a total area of **three (3)** acres. The treatment area is defined on the treatment area map on page 3 of this document.

5. **Pesticides:** The products (pesticides/oils/adjuvants) used will be provided by the contractor and will need to be included in the bid estimate. Only EPA registered chemicals approved for use in the State of Montana shall be applied. Chemicals shall be mixed and applied at rates consistent with their perspective

labels and manufacturers recommendations. Manufacturer's label directions and warnings relative to temperature, wind, or other weather conditions shall be strictly adhered to.

The specific chemicals, methods, and rates to be used on the Fort Keogh Project Areas are as follows:

Saltcedar (basal bark treatments): a 27% triclopyr ester / 73% basal oil (v/v) mixture should be applied to the bark from the root collar up the stems 18 inches covering all sides/stems of the plant.

6. **Record Keeping (Pesticides):** The contractor shall be required to complete a daily accurate Pesticide Application Record (PAR) form. The contractor shall submit the completed application records to the Project Leader (or designee) on a weekly basis for inspection of the treatment areas.
7. **GPS:** The contractor will provide and use a GPS data logger that will support ArcGIS 9.2 software, and be able to export to Arcview/Map shapefiles. The contractor will furnish the Project Leader with treatment inventory data CDs containing all collected data files by project name.
8. **Weather Conditions:** The contractor shall provide a continuous operation from day to day; weather permitting, until completion of the work required within the allotted contract time frame. Modification of the project work schedule due to weather or site conditions must be approved by the Project Leader (or designee).

Fort Keogh (Miles City, MT)

3

Conservation Innovation Grant Project
Missouri River Watershed Coalition
Center for Invasive Plant Management (Montana State University)

Statement of Work
Invasive Plant Treatment and Management Services
Yellowtail Coordinated Resource Management Area
Lovell, Wyoming

Classroom Project Area
Russian Olive and Saltcedar Management
1-18-2012

SCOPE OF WORK

1. **Summary:** The requirement for the project is for Russian olive and saltcedar vegetation treatment/control, manipulation, and inventory. The project work will be conducted on Bureau of Reclamation lands that are located within the Yellowtail Coordinated Resource Management Area. The project activities will begin at the time the contract is awarded and continue through the end date of the contracts. All areas treated shall have GPS coordinates, maps, and electronic file for locations according to specifications and guidelines as set forth within this Statement of Work.

   The contractor shall furnish all tools, equipment, materials, supplies, personnel, labor, and supervision necessary to complete the contract work requirements.

2. **Project Location(s)/Descriptions/Maps:** The project treatment activities on Yellowtail CRM lands will be conducted in a location hereby referred to as the **Classroom Project Area**. Site specific maps are included in the project Statement of Work (see Lovell, WY area map, page 2; Classroom Project Area map, page 3).

   The Classroom Project Area is located along the riparian buffer area of the Shoshone River, northeast of Lovell, Wyoming. The project site has a well-maintained access road, a perimeter two-track road, and the existing roads will be used to access the project work areas. Off-road travel is restricted to the actual treatment areas.

3. **Target Species for Vegetation Control:** Plant species targeted for control include: Russian olive (*Elaeagnus angustifolia*) and saltcedar (*Tamarix* spp).

4. **Work Requirements/Specifications:** The contract requires “cut-stump” treatment of, and the slash piling of the Russian olive within the designated project area. The mechanical cutting of the target species shall be made as close to the ground surface as possible. The previously-treated saltcedar plants will be mechanically cut and slash piled simultaneously, with the performance of the Russian olive “cut-stump” activities. The slash piling of the cut plant material and debris shall be piled in a consistent and orderly manner. Specific pile locations may be requested or identified by the Project Leader (or designee).

   The contractor’s equipment shall meet or exceed all current federal, state, and local safety requirements. The contractor and employees shall be required to wear all appropriate personal protective equipment while conducting project treatment activities. Extreme care shall be exercised at all times by the contractor to protect desirable (non-targeted) species from damages by the required chemical and/or mechanical cutting treatments. The equipment may be stored on-site while the contract work is being performed.

   The mechanical removal/treatment work of the Russian olive and saltcedar shall be conducted between January 1, 2013 and March 31, 2013; with unfavorable weather or site conditions taken into consideration. The Classroom Project Area Russian olive and saltcedar mechanical removal/treatment work being offered for this contract will consist of a total area of **fourteen (14)** acres. The treatment area is defined on the treatment area map on page 3 of this document.

5. **Pesticides:** The products (pesticides/oils/adjuvants) used will be provided by the contractor and will need to be included in the bid estimate. Only EPA registered chemicals approved for use in the State of Wyoming shall be applied. Chemicals shall be mixed and applied at rates consistent with their perspective labels and manufacturers recommendations. Manufacturer's label directions and warnings relative to temperature, wind, or other weather conditions shall be strictly adhered to.

   The specific chemicals, methods, and rates to be used on the Classroom Project Area are as follows:

   Russian olive (cut-stump): a 27% triclopyr ester / 73% basal oil (v/v) mixture applied to cover the entire exposed stump within one hour of the mechanical cutting.

6. **Record Keeping (Pesticides):** The contractor shall be required to complete a daily accurate Pesticide Application Record (PAR) form. The contractor shall submit the completed application records to the Project Leader (or designee) on a weekly basis for inspection of the treatment areas.

7. **GPS:** The contractor will provide and use a GPS data logger that will support ArcGIS 9.2 software, and be able to export to Arcview/Map shapefiles. The contractor will furnish the Project Leader with treatment inventory data CDs containing all collected data files by project name.

8. **Weather Conditions:** The contractor shall provide a continuous operation from day to day; weather permitting, until completion of the work required within the allotted contract time frame. Modification of the project work schedule due to weather or site conditions must be approved by the Project Leader (or designee).

2

Classroom Location (Lovell, WY)

3

Conservation Innovation Grant Project
Missouri River Watershed Coalition
Center for Invasive Plant Management (Montana State University)

Statement of Work
Invasive Plant Treatment and Management Services
Meade 46-1 School District
Sturgis, South Dakota

Sturgis School Project Area
1-23-2012

SCOPE OF WORK

1. **Summary:** The requirement for the project is for Russian olive vegetation treatment/control, manipulation, and inventory. The project work will be conducted on Meade 46-1 School District lands that are located within the undeveloped portions of the Sturgis School District property. The project activities will begin at the time the contract is awarded and continue through the end date of the contract. All areas treated shall have GPS coordinates, maps, and electronic file for locations according to specifications and guidelines as set forth within this Statement of Work.

   The contractor shall furnish all tools, equipment, materials, supplies, personnel, labor, and supervision necessary to complete the contract work requirements.

2. **Project Location(s)/Descriptions/Maps:** The project treatment activities on Meade 46-1 School District lands will be conducted in a location hereby referred to as **Sturgis School Project Area**. Site specific maps are included in the project Statement of Work (see Sturgis, SD School District area map, page 2; Sturgis School Project Area map, page 3).

   The Sturgis School Project Area is located along the riparian buffer area of the Bear Butte Creek, northeast of the school district facilities in Sturgis, South Dakota. The project site has a well-maintained access road, a perimeter two-track road, and the existing roads will be used to access the project work areas. Off-road travel is restricted to the actual treatment areas.

3. **Target Species for Vegetation Control:** Plant species targeted for control include: Russian olive (*Elaeagnus angustifolia*).

4. **Work Requirements/Specifications:** The contract requires “cut-stump” treatment of, and the slash piling of the Russian olive within the designated project area. The mechanical cutting of the target species shall be made as close to the ground surface as possible. The slash piling of the cut plant material and debris shall be piled in a consistent and orderly manner. Specific pile locations may be requested or identified by the Project Leader (or designee).

   The contractor’s equipment shall meet or exceed all current federal, state, and local safety requirements. The contractor and employees shall be required to wear all appropriate personal protective equipment while conducting project treatment activities. Extreme care shall be exercised at all times by the contractor to protect desirable (non-targeted) species from damages by the required chemical and/or mechanical cutting treatments. The equipment may be stored on-site while the contract work is being performed.

   The Russian olive mechanical cutting/ herbicide treatment work shall be conducted between September 1, 2012 and December 30, 2012; with uncontrollable weather and/or unfavorable site conditions considered. The Sturgis School Project Area Russian olive mechanical removal/treatment work being offered for this contract will consist of a total area of **seven (7)** acres. The treatment area is defined on the treatment area map on page 3 of this document.

5. **Pesticides:** The products (pesticides/oils/adjuvants) used will be provided by the contractor and will need to be included in the bid estimate. Only EPA registered chemicals approved for use in the State of South Dakota shall be applied. Chemicals shall be mixed and applied at rates consistent with their perspective labels and manufacturers recommendations. Manufacturer's label directions and warnings relative to temperature, wind, or other weather conditions shall be strictly adhered to.

   The specific chemicals, methods, and rates to be used on the project area are as follows:

   Russian olive (cut-stump): a 27% triclopyr ester / 73% basal oil (v/v) mixture applied to cover the entire exposed stump within one hour of the mechanical cutting.

6. **Record Keeping (Pesticides):** The contractor shall be required to complete a daily accurate Pesticide Application Record (PAR) form. The contractor shall submit the completed application records to the Project Leader (or designee) on a weekly basis for inspection of the treatment areas.

7. **GPS:** The contractor will provide and use a GPS data logger that will support ArcGIS 9.2 software, and be able to export to Arcview/Map shapefiles. The contractor will furnish the Project Leader with treatment inventory data CDs containing all collected data files by project name.

8. **Weather Conditions:** The contractor shall provide a continuous operation from day to day; weather permitting, until completion of the work required within the allotted contract time frame. Modification of the project work schedule due to weather or site conditions must be approved by the Project Leader (or designee).

2

Sturgis School Site (Sturgis, SD)

3

Missouri River Watershed Coalition
Center for Invasive Plant Management (Montana State University)
Conservation Innovation Grant Project

Statement of Work
Invasive Plant Treatment and Management Services
Allen Property, Big Horn County, Montana

Allen Project Area
4-18-2014

SCOPE OF WORK

1. **Summary:** The requirement for the project is for noxious/invasive plant treatment and inventory. The project work will be conducted on a site location within Allen private property lands in northern Big Horn County, Montana. The project activities will begin at the time the contract is awarded and continue through the end date of the contracts. All areas treated shall have GPS coordinates, maps, and electronic file for locations according to specifications and guidelines as set forth within this Statement of Work.

   The contractor shall furnish all tools, equipment, materials, supplies, personnel, labor, and supervision necessary to complete the contract work requirements.

2. **Project Location(s)/Descriptions/Maps:** The project treatment activities on Allen lands will be conducted on a location hereby referred to as the **Allen Project Area**. Site specific maps are included in the project Statement of Work (see Hardin, MT area map, page 2; Allen Project Area map, page 3).

   The Allen Project Area is located along the riparian buffer area of the Big Horn River, within Allen privately-owned property. The project site has a well-maintained access road, and the existing road will be used to access the project work areas. Off-road travel is restricted to the actual treatment areas.

3. **Target Species for Vegetation Control:** Plant species targeted for control include: Russian olive (*Elaeagnus angustifolia*), Canada thistle (*Cirsium arvense*), and houndstongue (*Cynoglossum officinale*), as identified in the weed assessment surveys.

4. **Work Requirements/Specifications:** The contract requires "spot" treatment of the target weed locations within the designated project area. GPS point collection data of all treatment locations is required to be provided by the contractor to the Project Leader (or designee).

   The contractor's equipment shall meet or exceed all current federal, state, and local safety requirements. The contractor and employees shall be required to wear all appropriate personal protective equipment while conducting project treatment activities. Extreme care shall be exercised at all times by the contractor to protect desirable (non-targeted) species from damages by the required chemical and/or mechanical cutting treatments. The equipment may be stored on-site while the contract work is being performed.

   The treatment /removal work shall be conducted between June 23, 2013 and July 25, 2014; with uncontrollable weather and/or unfavorable site conditions considered. The Allen Project Area Russian olive mechanical removal/treatment work being offered for this contract will consist of weed locations within a total area of **fourteen (14)** acres. The treatment area is defined on the treatment area map on page 3 of this document.

5. **Pesticides:** The products (pesticides/oils/adjuvants) used will be provided by the contractor and will need to be included in the bid estimate. Only EPA registered chemicals approved for use in the State of Montana shall be applied. Chemicals shall be mixed and applied at rates consistent with their perspective labels and manufacturers recommendations. Manufacturer's label directions and warnings relative to temperature, wind, or other weather conditions shall be strictly adhered to.

The specific chemicals, methods, and rates to be used on the Allen Project Area is as follows:

Russian olive (regrowth): a 33% triclopyr ester / 67% basal oil (v/v) mixture applied to cover any visible foliage at the time of treatment. The herbicides/rates to be used for the target terrestrial weed species are: aminopyralid (5 oz/acre) and chlorsulfuron (1 oz/acre) plus non-ionic surfactant (.25% v/v) applied with a total volume spray rate of 30 gallons per acre.

6. **Record Keeping (Pesticides):** The contractor shall be required to complete a daily accurate Pesticide Application Record (PAR) form. The contractor shall submit the completed application records to the Project Leader (or designee) on a weekly basis for inspection of the treatment areas.
7. **GPS:** The contractor will provide and use a GPS data logger that will support ArcGIS 9.2 software, and be able to export to Arcview/Map shapefiles and generate pdf format - site maps of the treatment locations. The contractor will furnish the Project Leader with treatment inventory data CDs containing all collected data files by project name.
8. **Weather Conditions:** The contractor shall provide a continuous operation from day to day; weather permitting, until completion of the work required within the allotted contract time frame. Modification of the project work schedule due to weather or site conditions must be approved by the Project Leader (or designee).

2


Allen Property (near Hardin, MT)
N
W
E
S
0
0.04
0.08
0.16 Miles
Treatment Area
14.0 Acres
Control Area
2.0 Acres

3

Conservation Innovation Grant Project
Missouri River Watershed Coalition
Center for Invasive Plant Management (Montana State University)

Statement of Work
Invasive Plant Treatment and Management Services
Montana Fish, Wildlife, and Parks
Hardin, Montana

Arapooish Project Area
4-30-2013

SCOPE OF WORK

1. **Summary:** The requirement for the project is for noxious/invasive plant treatment and inventory. The project work will be conducted on Montana Fish, Wildlife, and Parks lands in Hardin, Montana. The project activities will begin at the time the contract is awarded and continue through the end date of the contracts. All areas treated shall have GPS coordinates, maps, and electronic file for locations according to specifications and guidelines as set forth within this Statement of Work.

   The contractor shall furnish all tools, equipment, materials, supplies, personnel, labor, and supervision necessary to complete the contract work requirements.

2. **Project Location(s)/Descriptions/Maps:** The project treatment activities on Montana Fish, Wildlife, and Parks lands will be conducted in a location hereby referred to as: **Arapooish Project Area**. Site specific maps are included in the project Statement of Work (see Hardin, MT area map, page 2; Arapooish Project Area map, page 3).

   The Arapooish Project Area is located along the riparian buffer area of the Big Horn River, north of Hardin, Montana. The project site has a well-maintained access road, and the existing road will be used to access the project work areas. Off-road travel is restricted to the actual treatment areas.

3. **Target Species for Vegetation Control:** Plant species targeted for control include: Russian olive (*Elaeagnus angustifolia*), saltcedar (*Tamarix* spp.), Canada thistle (*Cirsium arvense*), and houndstongue (*Cynoglossum officinale*), as identified in the weed assessment surveys.

4. **Work Requirements/Specifications:** The contract requires "spot" herbicide treatments of the target weed locations within the designated project area(s). GPS point collection data of all treatment locations is required to be provided by the contractor to the Project Leader (or designee).

   The contractor's equipment shall meet or exceed all current federal, state, and local safety requirements. The contractor and employees shall be required to wear all appropriate personal protective equipment while conducting project treatment activities. Extreme care shall be exercised at all times by the contractor to protect desirable (non-targeted) species from damages by the required chemical and/or mechanical cutting treatments. The equipment may be stored on-site while the contract work is being performed.

   The treatment work shall be conducted between June 24, 2013 and July 26, 2013; with uncontrollable weather and/or unfavorable site conditions considered. The Arapooish Project Area Russian olive and/or saltcedar herbicide treatment work being offered for this contract will consist of weed locations within a total area of **fourteen (14)** acres. The treatment will be conducted within the area that is defined on the treatment area map on page 3 of this document.

5. **Pesticides:** The products (pesticides/oils/adjuvants) used will be provided by the contractor and will need to be included in the bid estimate. Only EPA registered chemicals approved for use in the State of Montana shall be applied. Chemicals shall be mixed and applied at rates consistent with their perspective

labels and manufacturers recommendations. Manufacturer's label directions and warnings relative to temperature, wind, or other weather conditions shall be strictly adhered to.

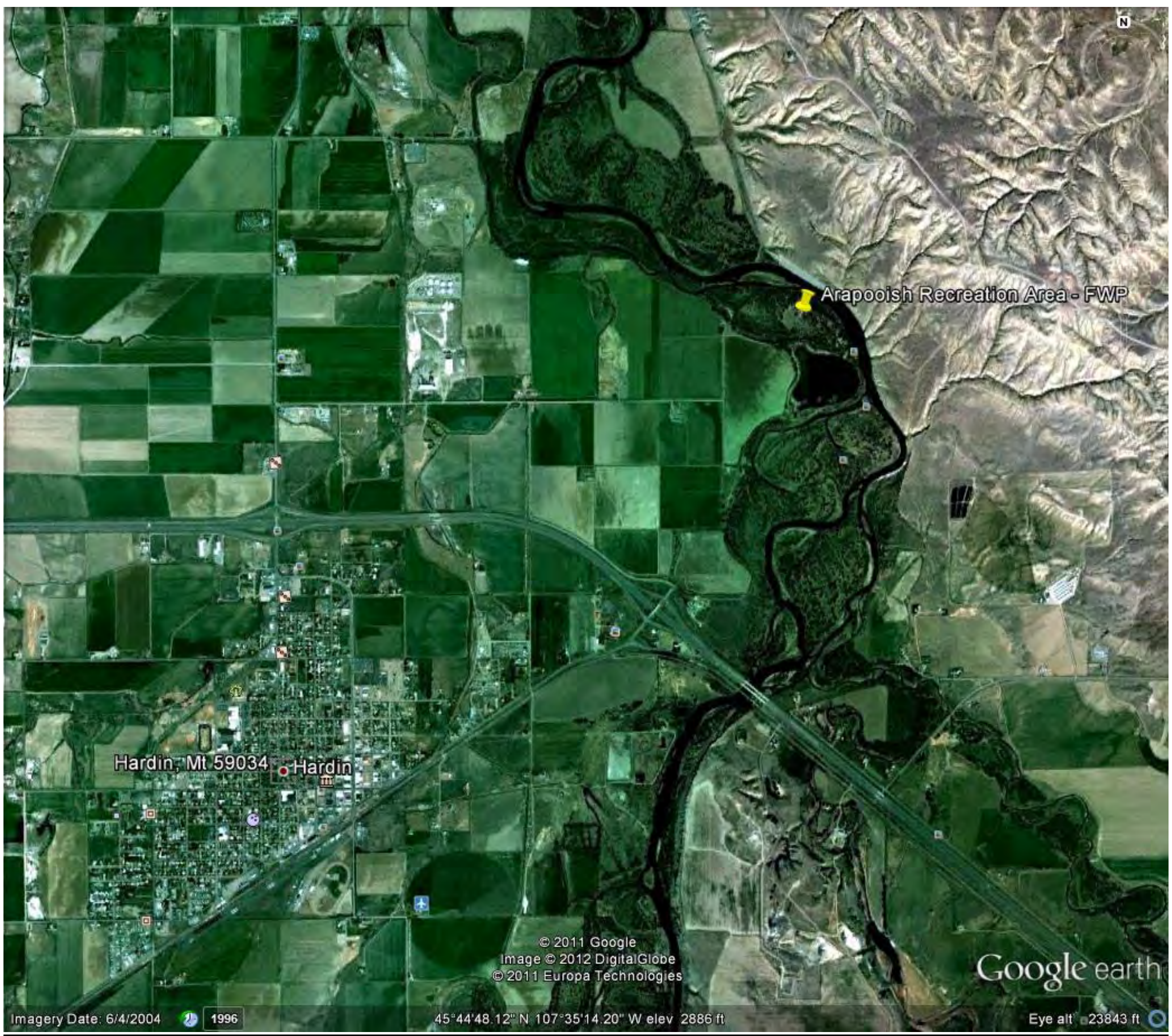
The specific chemicals, methods, and rates to be used on the Arapooish Project Area are as follows:

Russian olive/Saltcedar (regrowth): a 27% triclopyr ester / 73% basal oil (v/v) mixture "spot" applied to cover any visible foliage at the time of treatment. The herbicides/rates to be used for the target terrestrial weed species are: aminopyralid (5 oz/acre) and chlorsulfuron (1 oz/acre) plus non-ionic surfactant (.25% v/v) applied with a total volume spray rate of 30 gallons per acre.

6. **Record Keeping (Pesticides):** The contractor shall be required to complete a daily accurate Pesticide Application Record (PAR) form. The contractor shall submit the completed application records to the Project Leader (or designee) on a weekly basis for inspection of the treatment areas.

7. **GPS:** The contractor will provide and use a GPS data logger that will support ArcGIS 9.2 software, and be able to export to Arcview/Map shapefiles. The contractor will furnish the Project Leader with treatment inventory data CDs containing all collected data files by project name.

8. **Weather Conditions:** The contractor shall provide a continuous operation from day to day; weather permitting, until completion of the work required within the allotted contract time frame. Modification of the project work schedule due to weather or site conditions must be approved by the Project Leader (or designee).



2

Arapooish Pond (near Hardin, MT)

3

Conservation Innovation Grant Project
Missouri River Watershed Coalition
Center for Invasive Plant Management (Montana State University)

Statement of Work
Invasive Plant Treatment and Management Services
USDA-ARS Livestock and Range Research Laboratory
Miles City, Montana

Cottonwood Flats Project Area
4-30-2013

SCOPE OF WORK

1. **Summary:** The requirement for the project is for noxious/invasive plant treatment and inventory. The project work will be conducted on a site location within USDA-ARS Livestock and Range Research Laboratory lands in Miles City, Montana. The project activities will begin at the time the contract is awarded and continue through the end date of the contracts. All areas treated shall have GPS coordinates, maps, and electronic file for locations according to specifications and guidelines as set forth within this Statement of Work.

   The contractor shall furnish all tools, equipment, materials, supplies, personnel, labor, and supervision necessary to complete the contract work requirements.

2. **Project Location(s)/Descriptions/Maps:** The project treatment activities on USDA-ARS Livestock and Range Research Laboratory (Fort Keogh) lands will be conducted on a location hereby referred to as the**: Cottonwood Flats Project Area**. Site specific maps are included in the project Statement of Work (see Miles City/Ft. Keogh area map, page 2; Cottonwood Flats Project Area map, page 3).

   The Cottonwood Flats Project Area is located along the riparian buffer area of the Yellowstone River, within Fort Keogh property. The project site has an existing access road, and the existing road will be used to access the project work areas. Off-road travel is restricted to the actual treatment areas.

3. **Target Species for Vegetation Control:** Plant species targeted for control include: Russian olive (*Elaeagnus angustifolia*), Canada thistle (*Cirsium arvense*), and bull thistle (*Cirsium vulgare*), as identified in the weed assessment surveys.

4. **Work Requirements/Specifications:** The contract requires "spot" treatment of the target weed locations within the designated project area. GPS point collection data of all treatment locations is required to be provided by the contractor to the Project Leader (or designee).

   The contractor's equipment shall meet or exceed all current federal, state, and local safety requirements. The contractor and employees shall be required to wear all appropriate personal protective equipment while conducting project treatment activities. Extreme care shall be exercised at all times by the contractor to protect desirable (non-targeted) species from damages by the required chemical and/or mechanical cutting treatments. The equipment may be stored on-site while the contract work is being performed.

   The treatment /removal work shall be conducted between June 24, 2013 and July 26, 2013; with uncontrollable weather and/or unfavorable site conditions considered. The Cottonwood Flats Project Area herbicide treatment work being offered for this contract will consist of weed locations within a total area of **fifteen (15)** acres. The treatment area is broadly defined on the treatment area map on page 3 of this document.

5. **Pesticides:** The products (pesticides/oils/adjuvants) used will be provided by the contractor and will need to be included in the bid estimate. Only EPA registered chemicals approved for use in the State of

Montana shall be applied. Chemicals shall be mixed and applied at rates consistent with their perspective labels and manufacturers recommendations. Manufacturer's label directions and warnings relative to temperature, wind, or other weather conditions shall be strictly adhered to.

The specific chemicals, methods, and rates to be used on the Fort Keogh Project Areas are as follows:

Russian olive (regrowth): a 33% triclopyr ester / 67% basal oil (v/v) mixture applied to cover any visible foliage at the time of treatment. The herbicides/rates to be used for the target terrestrial weed species are: aminopyralid (5 oz/acre) plus non-ionic surfactant (.25% v/v) applied with a total volume spray rate of 30 gallons per acre.

6. **Record Keeping (Pesticides):** The contractor shall be required to complete a daily accurate Pesticide Application Record (PAR) form. The contractor shall submit the completed application records to the Project Leader (or designee) on a weekly basis for inspection of the treatment areas.
7. **GPS:** The contractor will provide and use a GPS data logger that will support ArcGIS 9.2 software, and be able to export to Arcview/Map shapefiles. The contractor will furnish the Project Leader with treatment inventory data CDs containing all collected data files by project name.
8. **Weather Conditions:** The contractor shall provide a continuous operation from day to day; weather permitting, until completion of the work required within the allotted contract time frame. Modification of the project work schedule due to weather or site conditions must be approved by the Project Leader (or designee).

2

Fort Keogh (Miles City, MT)

3

Conservation Innovation Grant Project
Missouri River Watershed Coalition
Center for Invasive Plant Management (Montana State University)

Statement of Work
Invasive Plant Treatment and Management Services
USDA-ARS Livestock and Range Research Laboratory
Miles City, Montana

East Yellowstone Project Area
4-30-2013

SCOPE OF WORK

1. **Summary:** The requirement for the project is for noxious/invasive plant treatment and inventory. The project work will be conducted on a site location within USDA-ARS Livestock and Range Research Laboratory lands in Miles City, Montana. The project activities will begin at the time the contract is awarded and continue through the end date of the contracts. All areas treated shall have GPS coordinates, maps, and electronic file for locations according to specifications and guidelines as set forth within this Statement of Work.

   The contractor shall furnish all tools, equipment, materials, supplies, personnel, labor, and supervision necessary to complete the contract work requirements.

2. **Project Location(s)/Descriptions/Maps:** The project treatment activities on USDA-ARS Livestock and Range Research Laboratory (Fort Keogh) lands will be conducted on a location hereby referred to as the **East Yellowstone Project Area**. Site specific maps are included in the project Statement of Work (see Miles City/Ft. Keogh area map, page 2; East Yellowstone Project Area map, page 3).

   The East Yellowstone Project Area is located along the riparian buffer area of the Yellowstone River, within Fort Keogh property. The project site has a well-maintained access road, and the existing road will be used to access the project work areas. Off-road travel is restricted to the actual treatment areas.

3. **Target Species for Vegetation Control:** Plant species targeted for control include: Russian olive (*Elaeagnus angustifolia*), saltcedar (*Tamarix spp*.), Canada thistle (*Cirsium arvense*), and spotted knapweed (*Centaurea maculosa*), as identified in the weed assessment surveys.

4. **Work Requirements/Specifications:** The contract requires "spot" treatment of the target weed locations within the designated project area. GPS point collection data of all treatment locations is required to be provided by the contractor to the Project Leader (or designee).

   The contractor's equipment shall meet or exceed all current federal, state, and local safety requirements. The contractor and employees shall be required to wear all appropriate personal protective equipment while conducting project treatment activities. Extreme care shall be exercised at all times by the contractor to protect desirable (non-targeted) species from damages by the required chemical and/or mechanical cutting treatments. The equipment may be stored on-site while the contract work is being performed.

   The herbicide treatment work shall be conducted between June 24, 2013 and July 26, 2013; with uncontrollable weather and/or unfavorable site conditions considered. The East Yellowstone Project Area herbicide treatment work being offered for this contract will consist of weed locations within a total area of **fourteen (14)** acres. The treatment area is defined on the treatment area map on page 3 of this document.

5. **Pesticides:** The products (pesticides/oils/adjuvants) used will be provided by the contractor and will need to be included in the bid estimate. Only EPA registered chemicals approved for use in the State of

Montana shall be applied. Chemicals shall be mixed and applied at rates consistent with their perspective labels and manufacturers recommendations. Manufacturer's label directions and warnings relative to temperature, wind, or other weather conditions shall be strictly adhered to.

The specific chemicals, methods, and rates to be used on the Fort Keogh Project Areas are as follows:

Russian olive/Saltcedar (regrowth): a 33% triclopyr ester / 67% basal oil (v/v) mixture "spot" applied to cover any visible foliage at the time of treatment. The herbicides/rates to be used for the target terrestrial weed species are: aminopyralid (5 oz/acre) plus non-ionic surfactant (.25% v/v) applied with a total volume spray rate of 30 gallons per acre.

6. **Record Keeping (Pesticides):** The contractor shall be required to complete a daily accurate Pesticide Application Record (PAR) form. The contractor shall submit the completed application records to the Project Leader (or designee) on a weekly basis for inspection of the treatment areas.
7. **GPS:** The contractor will provide and use a GPS data logger that will support ArcGIS 9.2 software, and be able to export to Arcview/Map shapefiles. The contractor will furnish the Project Leader with treatment inventory data CDs containing all collected data files by project name.
8. **Weather Conditions:** The contractor shall provide a continuous operation from day to day; weather permitting, until completion of the work required within the allotted contract time frame. Modification of the project work schedule due to weather or site conditions must be approved by the Project Leader (or designee).

Fort Keogh (Miles City, MT)

3

Conservation Innovation Grant Project
Missouri River Watershed Coalition
Center for Invasive Plant Management (Montana State University)

Statement of Work
Invasive Plant Treatment and Management Services
Yellowtail Coordinated Resource Management Area
Lovell, Wyoming

Classroom Project Area
4-30-2013

SCOPE OF WORK

1. **Summary:** The requirement for the project is for noxious/invasive plant treatment and inventory. The project work will be conducted on Bureau of Reclamation lands that are located within the Yellowtail Coordinated Resource Management Area. The project activities will begin at the time the contract is awarded and continue through the end date of the contracts. All areas treated shall have GPS coordinates, maps, and electronic file for locations according to specifications and guidelines as set forth within this Statement of Work.

   The contractor shall furnish all tools, equipment, materials, supplies, personnel, labor, and supervision necessary to complete the contract work requirements.

2. **Project Location(s)/Descriptions/Maps:** The project treatment activities on Yellowtail CRM lands will be conducted in a location hereby referred to as: **Classroom Project Area**. Site specific maps are included in the project Statement of Work (see Lovell, WY area map, page 2; Classroom Project Area map, page 3).

   The Classroom Project Area is located along the riparian buffer area of the Shoshone River, northeast of Lovell, Wyoming. The project site has a well-maintained access road, a perimeter two-track road, and the existing roads will be used to access the project work areas. Off-road travel is restricted to the actual treatment areas.

3. **Target Species for Vegetation Control:** Plant species targeted for control include: Russian olive (*Elaeagnus angustifolia*), saltcedar (*Tamarix* spp), hoary cress/whitetop (*Cardaria draba L.*), and Canada thistle (*Cirsium arvense*), as identified in the weed assessment surveys.

4. **Work Requirements/Specifications:** The contract requires "spot" treatment of the target weed locations within the designated project area. GPS point collection data of all treatment locations is required to be provided by the contractor to the Project Leader (or designee).

   The contractor's equipment shall meet or exceed all current federal, state, and local safety requirements. The contractor and employees shall be required to wear all appropriate personal protective equipment while conducting project treatment activities. Extreme care shall be exercised at all times by the contractor to protect desirable (non-targeted) species from damages by the required chemical and/or mechanical cutting treatments. The equipment may be stored on-site while the contract work is being performed.

   The herbicide treatment work shall be conducted between June 24, 2013 and July 26, 2013; with unfavorable weather or site conditions taken into consideration. The Classroom Project Area treatment work being offered for this contract will consist of weed locations within a total area of **fourteen (14)** acres. The treatment area is defined on the treatment area map on page 3 of this document.

5. **Pesticides:** The products (pesticides/oils/adjuvants) used will be provided by the contractor and will need to be included in the bid estimate. Only EPA registered chemicals approved for use in the State of

1

Wyoming shall be applied. Chemicals shall be mixed and applied at rates consistent with their perspective labels and manufacturers recommendations. Manufacturer's label directions and warnings relative to temperature, wind, or other weather conditions shall be strictly adhered to.

The specific chemicals, methods, and rates to be used on the Classroom Project Area are as follows:

Russian olive/Saltcedar (regrowth): a 27% triclopyr ester / 73% basal oil (v/v) mixture applied to cover any visible foliage at the time of treatment. . The herbicides/rates to be used for the target terrestrial weed species are: aminopyralid (5 oz/acre) and chlorsulfuron (1 oz/acre) plus non-ionic surfactant (.25% v/v) applied with a total volume spray rate of 30 gallons per acre.

6. **Record Keeping (Pesticides):** The contractor shall be required to complete a daily accurate Pesticide Application Record (PAR) form. The contractor shall submit the completed application records to the Project Leader (or designee) on a weekly basis for inspection of the treatment areas.
7. **GPS:** The contractor will provide and use a GPS data logger that will support ArcGIS 9.2 software, and be able to export to Arcview/Map shapefiles. The contractor will furnish the Project Leader with treatment inventory data CDs containing all collected data files by project name.
8. **Weather Conditions:** The contractor shall provide a continuous operation from day to day; weather permitting, until completion of the work required within the allotted contract time frame. Modification of the project work schedule due to weather or site conditions must be approved by the Project Leader (or designee).

2

Classroom Location (Lovell, WY)

3

Conservation Innovation Grant Project
Missouri River Watershed Coalition
Center for Invasive Plant Management (Montana State University)

Statement of Work
Invasive Plant Treatment and Management Services
Meade 46-1 School District
Sturgis, South Dakota

Sturgis School Project Area
4-30-2013

SCOPE OF WORK

1. **Summary:** The requirement for the project is for noxious/invasive plant treatment and inventory. The project work will be conducted on Meade 46-1 School District lands that are located within the undeveloped portions of the Sturgis School District property. The project activities will begin at the time the contract is awarded and continue through the end date of the contract. All areas treated shall have GPS coordinates, maps, and electronic file for locations according to specifications and guidelines as set forth within this Statement of Work.

   The contractor shall furnish all tools, equipment, materials, supplies, personnel, labor, and supervision necessary to complete the contract work requirements.

2. **Project Location(s)/Descriptions/Maps:** The project treatment activities on Meade 46-1 School District lands will be conducted in a location hereby referred to as the **Sturgis School Project Area**. Site specific maps are included in the project Statement of Work (see Sturgis, SD School District area map, page 2; Sturgis School Project Area map, page 3).

   The Sturgis School Project Area is located along the riparian buffer area of the Bear Butte Creek, northeast of the school district facilities in Sturgis, South Dakota. The project site has a well-maintained access road, a perimeter two-track road, and the existing roads will be used to access the project work areas. Off-road travel is restricted to the actual treatment areas.

3. **Target Species for Vegetation Control:** Plant species targeted for control include: Russian olive (*Elaeagnus angustifolia*), Canada thistle (*Cirsium arvense*), bull thistle (*Cirsium vulgare*), and houndstongue (*Cynoglossum officinale*), as identified in the weed assessment surveys.

4. **Work Requirements/Specifications:** The contract requires “spot” herbicide treatment of the target weed locations within the designated project area. GPS point collection data of all treatment locations is required to be provided by the contractor to the Project Leader (or designee).

   The contractor’s equipment shall meet or exceed all current federal, state, and local safety requirements. The contractor and employees shall be required to wear all appropriate personal protective equipment while conducting project treatment activities. Extreme care shall be exercised at all times by the contractor to protect desirable (non-targeted) species from damages by the required chemical treatments. The equipment may be stored on-site while the contract work is being performed.

   The herbicide treatment work shall be conducted between June 24, 2013 and July 26, 2013; with uncontrollable weather and/or unfavorable site conditions considered. The Sturgis School Project Area treatment work being offered for this contract will consist of weed locations within a total area of **seven (7)** acres. The treatment area is defined on the treatment area map on page 3 of this document.

5. **Pesticides:** The products (pesticides/oils/adjuvants) used will be provided by the contractor and will need to be included in the bid estimate. Only EPA registered chemicals approved for use in the State of South Dakota shall be applied. Chemicals shall be mixed and applied at rates consistent with their perspective

labels and manufacturers recommendations. Manufacturer's label directions and warnings relative to temperature, wind, or other weather conditions shall be strictly adhered to.

The specific chemicals, methods, and rates to be used on the Sturgis School Project Area are as follows:

Russian olive (regrowth): a 27% triclopyr ester / 73% basal oil (v/v) mixture "spot" applied to cover any visible foliage at the time of treatment. The herbicides/rates to be used for the target terrestrial weed species are: aminopyralid (5 oz/acre) and chlorsulfuron (1 oz/acre) plus non-ionic surfactant (.25% v/v) applied with a total volume spray rate of 30 gallons per acre.

6. **Record Keeping (Pesticides):** The contractor shall be required to complete a daily accurate Pesticide Application Record (PAR) form. The contractor shall submit the completed application records to the Project Leader (or designee) on a weekly basis for inspection of the treatment areas.
7. **GPS:** The contractor will provide and use a GPS data logger that will support ArcGIS 9.2 software, and be able to export to Arcview/Map shapefiles. The contractor will furnish the Project Leader with treatment inventory data CDs containing all collected data files by project name.
8. **Weather Conditions:** The contractor shall provide a continuous operation from day to day; weather permitting, until completion of the work required within the allotted contract time frame. Modification of the project work schedule due to weather or site conditions must be approved by the Project Leader (or designee).

Sturgis School Site (Sturgis, SD)

3

Conservation Innovation Grant Project
Missouri River Watershed Coalition
Center for Invasive Plant Management (Montana State University)

Statement of Work
Invasive Plant Treatment and Management Services
Allen Property
Big Horn County, Montana

Allen Project Area
4-18-2014

SCOPE OF WORK

1. **Summary:** The requirement for the project is for noxious/invasive plant treatment and inventory. The project work will be conducted on a site location within Allen private property lands in northern Big Horn County, Montana. The project activities will begin at the time the contract is awarded and continue through the end date of the contracts. All areas treated shall have GPS coordinates, maps, and electronic file for locations according to specifications and guidelines as set forth within this Statement of Work.

   The contractor shall furnish all tools, equipment, materials, supplies, personnel, labor, and supervision necessary to complete the contract work requirements.

2. **Project Location(s)/Descriptions/Maps:** The project treatment activities on Allen lands will be conducted on a location hereby referred to as the **Allen Project Area**. Site specific maps are included in the project Statement of Work (see Hardin, MT area map, page 2; Allen Project Area map, page 3).

   The Allen Project Area is located along the riparian buffer area of the Big Horn River, within Allen privately-owned property. The project site has a well-maintained access road, and the existing road will be used to access the project work areas. Off-road travel is restricted to the actual treatment areas.

3. **Target Species for Vegetation Control:** Plant species targeted for control include: Russian olive (*Elaeagnus angustifolia*), Canada thistle (*Cirsium arvense*), and houndstongue (*Cynoglossum officinale*), as identified in the weed assessment surveys.

4. **Work Requirements/Specifications:** The contract requires “spot” treatment of the target weed locations within the designated project area. GPS point collection data of all treatment locations is required to be provided by the contractor to the Project Leader (or designee).

   The contractor’s equipment shall meet or exceed all current federal, state, and local safety requirements. The contractor and employees shall be required to wear all appropriate personal protective equipment while conducting project treatment activities. Extreme care shall be exercised at all times by the contractor to protect desirable (non-targeted) species from damages by the required chemical and/or mechanical cutting treatments. The equipment may be stored on-site while the contract work is being performed.

   The treatment /removal work shall be conducted between June 23, 2013 and July 25, 2014; with uncontrollable weather and/or unfavorable site conditions considered. The Allen Project Area Russian olive mechanical removal/treatment work being offered for this contract will consist of weed locations within a total area of **fourteen (14)** acres. The treatment area is defined on the treatment area map on page 3 of this document.

5. **Pesticides:** The products (pesticides/oils/adjuvants) used will be provided by the contractor and will need to be included in the bid estimate. Only EPA registered chemicals approved for use in the State of Montana shall be applied. Chemicals shall be mixed and applied at rates consistent with their perspective

labels and manufacturers recommendations. Manufacturer's label directions and warnings relative to temperature, wind, or other weather conditions shall be strictly adhered to.

The specific chemicals, methods, and rates to be used on the Allen Project Area is as follows:

Russian olive (regrowth): a 33% triclopyr ester / 67% basal oil (v/v) mixture applied to cover any visible foliage at the time of treatment. The herbicides/rates to be used for the target terrestrial weed species are: aminopyralid (5 oz/acre) and chlorsulfuron (1 oz/acre) plus non-ionic surfactant (.25% v/v) applied with a total volume spray rate of 30 gallons per acre.

6. **Record Keeping (Pesticides):** The contractor shall be required to complete a daily accurate Pesticide Application Record (PAR) form. The contractor shall submit the completed application records to the Project Leader (or designee) on a weekly basis for inspection of the treatment areas.
7. **GPS:** The contractor will provide and use a GPS data logger that will support ArcGIS 9.2 software, and be able to export to Arcview/Map shapefiles and generate pdf format - site maps of the treatment locations. The contractor will furnish the Project Leader with treatment inventory data CDs containing all collected data files by project name.
8. **Weather Conditions:** The contractor shall provide a continuous operation from day to day; weather permitting, until completion of the work required within the allotted contract time frame. Modification of the project work schedule due to weather or site conditions must be approved by the Project Leader (or designee).

2


Allen Property (near Hardin, MT)
N
W
E
S
0
0.04
0.08
0.16 Miles
Treatment Area
14.0 Acres
Control Area
2.0 Acres

Conservation Innovation Grant Project
Missouri River Watershed Coalition
Center for Invasive Plant Management (Montana State University)

Statement of Work
Invasive Plant Treatment and Management Services
Montana Fish, Wildlife, and Parks
Hardin, Montana

Arapooish Project Area
4-18-2014

SCOPE OF WORK

1. **Summary:** The requirement for the project is for noxious/invasive plant treatment and inventory. The project work will be conducted on Montana Fish, Wildlife, and Parks lands in Hardin, Montana. The project activities will begin at the time the contract is awarded and continue through the end date of the contracts. All areas treated shall have GPS coordinates, maps, and electronic file for locations according to specifications and guidelines as set forth within this Statement of Work.

   The contractor shall furnish all tools, equipment, materials, supplies, personnel, labor, and supervision necessary to complete the contract work requirements.

2. **Project Location(s)/Descriptions/Maps:** The project treatment activities on Montana Fish, Wildlife, and Parks lands will be conducted in a location hereby referred to as the **Arapooish Project Area**. Site specific maps are included in the project Statement of Work (see Hardin, MT area map, page 2; Arapooish Project Area map, page 3).

   The Arapooish Project Area is located along the riparian buffer area of the Big Horn River, north of Hardin, Montana. The project site has a well-maintained access road, and the existing road will be used to access the project work areas. Off-road travel is restricted to the actual treatment areas.

3. **Target Species for Vegetation Control:** Plant species targeted for control include: Russian olive (*Elaeagnus angustifolia*), saltcedar (*Tamarix* spp.), Canada thistle (*Cirsium arvense*), and houndstongue (*Cynoglossum officinale*), as identified in the weed assessment surveys.

4. **Work Requirements/Specifications:** The contract requires "spot" herbicide treatments of the target weed locations within the designated project area(s). GPS point collection data of all treatment locations is required to be provided by the contractor to the Project Leader (or designee).

   The contractor's equipment shall meet or exceed all current federal, state, and local safety requirements. The contractor and employees shall be required to wear all appropriate personal protective equipment while conducting project treatment activities. Extreme care shall be exercised at all times by the contractor to protect desirable (non-targeted) species from damages by the required chemical and/or mechanical cutting treatments. The equipment may be stored on-site while the contract work is being performed.

   The treatment work shall be conducted between June 23, 2014 and July 25, 2014; with uncontrollable weather and/or unfavorable site conditions considered. The Arapooish Project Area Russian olive and/or saltcedar herbicide treatment work being offered for this contract will consist of weed locations within a total area of **fourteen (14)** acres. The treatment will be conducted within the area that is defined on the treatment area map on page 3 of this document.

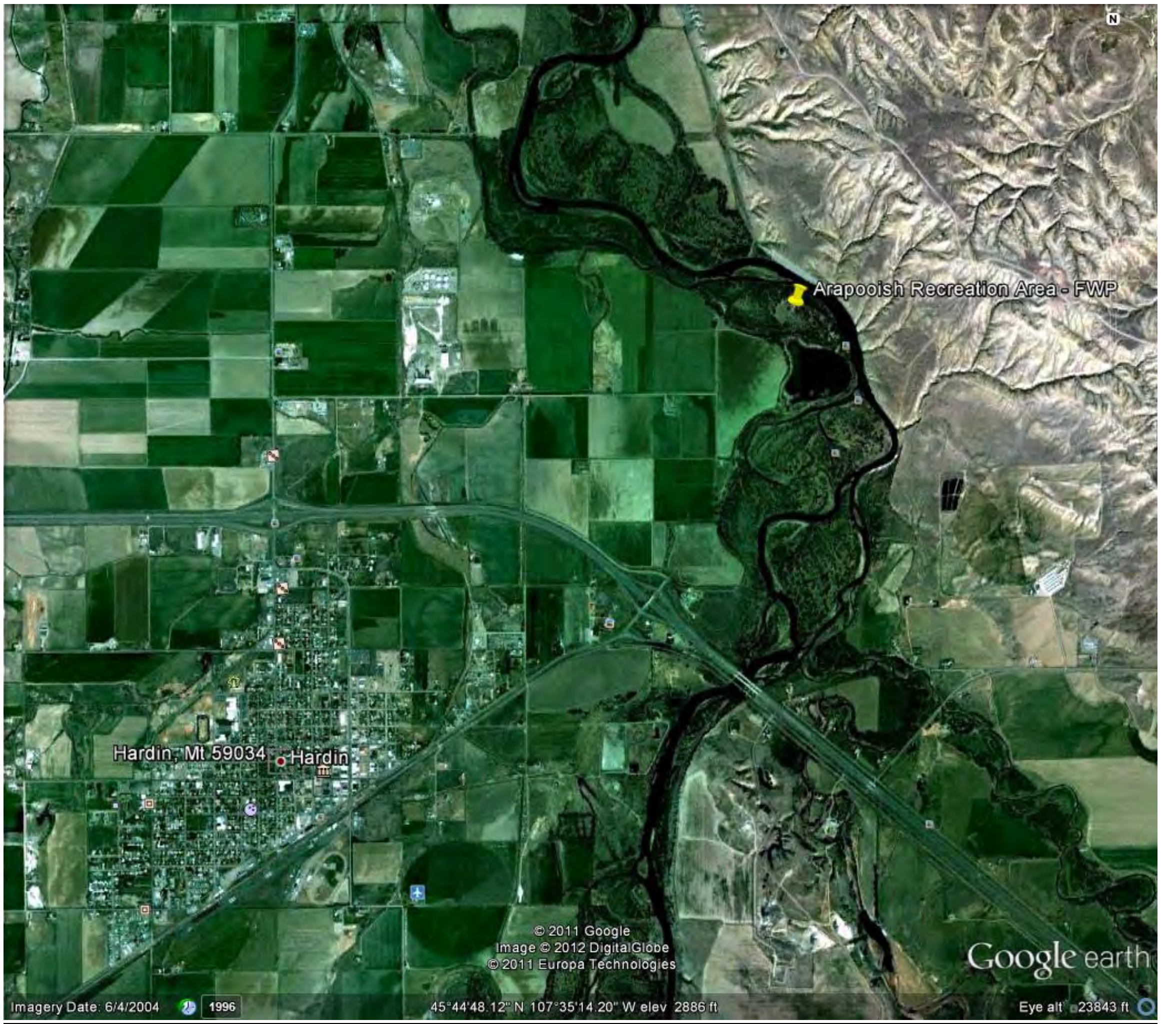
5. **Pesticides:** The products (pesticides/oils/adjuvants) used will be provided by the contractor and will need to be included in the bid estimate. Only EPA registered chemicals approved for use in the State of Montana shall be applied. Chemicals shall be mixed and applied at rates consistent with their perspective

labels and manufacturers recommendations. Manufacturer's label directions and warnings relative to temperature, wind, or other weather conditions shall be strictly adhered to.

The specific chemicals, methods, and rates to be used on the Arapooish Project Area are as follows:

Russian olive/Saltcedar (regrowth): a 27% triclopyr ester / 73% basal oil (v/v) mixture "spot" applied to cover any visible foliage at the time of treatment. The herbicides/rates to be used for the target terrestrial weed species are: aminopyralid (5 oz/acre) and chlorsulfuron (1 oz/acre) plus non-ionic surfactant (.25% v/v) applied with a total volume spray rate of 30 gallons per acre.

6. **Record Keeping (Pesticides):** The contractor shall be required to complete a daily accurate Pesticide Application Record (PAR) form. The contractor shall submit the completed application records to the Project Leader (or designee) on a weekly basis for inspection of the treatment areas.
7. **GPS:** The contractor will provide and use a GPS data logger that will support ArcGIS 9.2 software, and be able to export to Arcview/Map shapefiles, and generate pdf format – site maps showing the treatment locations. The contractor will furnish the Project Leader with treatment inventory data CDs containing all collected data files by project name.
8. **Weather Conditions:** The contractor shall provide a continuous operation from day to day; weather permitting, until completion of the work required within the allotted contract time frame. Modification of the project work schedule due to weather or site conditions must be approved by the Project Leader (or designee).



2


Arapooish Pond (near Hardin, MT)
Control Area
5 Acres
Treatment Area
18 Acres
0 295 590 1,180 Feet
N
W
E
S

3

Conservation Innovation Grant Project
Missouri River Watershed Coalition
Center for Invasive Plant Management (Montana State University)

Statement of Work
Invasive Plant Treatment and Management Services
USDA-ARS Livestock and Range Research Laboratory
Miles City, Montana

Cottonwood Flats Project Area
4-18-2014

SCOPE OF WORK

1. **Summary:** The requirement for the project is for noxious/invasive plant treatment and inventory. The project work will be conducted on a site location within USDA-ARS Livestock and Range Research Laboratory lands in Miles City, Montana. The project activities will begin at the time the contract is awarded and continue through the end date of the contracts. All areas treated shall have GPS coordinates, maps, and electronic file for locations according to specifications and guidelines as set forth within this Statement of Work.

   The contractor shall furnish all tools, equipment, materials, supplies, personnel, labor, and supervision necessary to complete the contract work requirements.

2. **Project Location(s)/Descriptions/Maps:** The project treatment activities on USDA-ARS Livestock and Range Research Laboratory (Fort Keogh) lands will be conducted on a location hereby referred to as the **Cottonwood Flats Project Area**. Site specific maps are included in the project Statement of Work (see Miles City/ Ft. Keogh area map, page 2; Cottonwood Flats Project Area map, page 3).

   The Cottonwood Flats Project Area is located along the riparian buffer area of the Yellowstone River, within Fort Keogh property. The project site has an existing access road, and the existing road will be used to access the project work areas. Off-road travel is restricted to the actual treatment areas.

3. **Target Species for Vegetation Control:** Plant species targeted for control include: Russian olive (*Elaeagnus angustifolia*), Canada thistle (*Cirsium arvense*), and bull thistle (*Cirsium vulgare*), as identified in the weed assessment surveys.

4. **Work Requirements/Specifications:** The contract requires “spot” treatment of the target weed locations within the designated project area. GPS point collection data of all treatment locations is required to be provided by the contractor to the Project Leader (or designee).

   The contractor’s equipment shall meet or exceed all current federal, state, and local safety requirements. The contractor and employees shall be required to wear all appropriate personal protective equipment while conducting project treatment activities. Extreme care shall be exercised at all times by the contractor to protect desirable (non-targeted) species from damages by the required chemical and/or mechanical cutting treatments. The equipment may be stored on-site while the contract work is being performed.

   The treatment /removal work shall be conducted between June 23, 2014 and July 25, 2014; with uncontrollable weather and/or unfavorable site conditions considered. The Cottonwood Flats Project Area herbicide treatment work being offered for this contract will consist of weed locations within a total area of **fifteen (15)** acres. The treatment area is broadly defined on the treatment area map on page 3 of this document.

5. **Pesticides:** The products (pesticides/oils/adjuvants) used will be provided by the contractor and will need to be included in the bid estimate. Only EPA registered chemicals approved for use in the State of

Montana shall be applied. Chemicals shall be mixed and applied at rates consistent with their perspective labels and manufacturers recommendations. Manufacturer's label directions and warnings relative to temperature, wind, or other weather conditions shall be strictly adhered to.

The specific chemicals, methods, and rates to be used on the Fort Keogh Project Areas are as follows:

Russian olive (regrowth): a 33% triclopyr ester / 67% basal oil (v/v) mixture applied to cover any visible foliage at the time of treatment. The herbicides/rates to be used for the target terrestrial weed species are: aminopyralid (5 oz/acre) plus non-ionic surfactant (.25% v/v) applied with a total volume spray rate of 30 gallons per acre.

6. **Record Keeping (Pesticides):** The contractor shall be required to complete a daily accurate Pesticide Application Record (PAR) form. The contractor shall submit the completed application records to the Project Leader (or designee) on a weekly basis for inspection of the treatment areas.
7. **GPS:** The contractor will provide and use a GPS data logger that will support ArcGIS 9.2 software, and be able to export to Arcview/Map shapefiles, and generate pdf format – site maps showing the treatment locations. The contractor will furnish the Project Leader with treatment inventory data CDs containing all collected data files by project name.
8. **Weather Conditions:** The contractor shall provide a continuous operation from day to day; weather permitting, until completion of the work required within the allotted contract time frame. Modification of the project work schedule due to weather or site conditions must be approved by the Project Leader (or designee).

Fort Keogh (Miles City, MT)

3

Conservation Innovation Grant Project
Missouri River Watershed Coalition
Center for Invasive Plant Management (Montana State University)

Statement of Work
Invasive Plant Treatment and Management Services
USDA-ARS Livestock and Range Research Laboratory
Miles City, Montana

East Yellowstone Project Area
4-18-2014

SCOPE OF WORK

1. **Summary:** The requirement for the project is for noxious/invasive plant treatment and inventory. The project work will be conducted on a site location within USDA-ARS Livestock and Range Research Laboratory lands in Miles City, Montana. The project activities will begin at the time the contract is awarded and continue through the end date of the contracts. All areas treated shall have GPS coordinates, maps, and electronic file for locations according to specifications and guidelines as set forth within this Statement of Work.

   The contractor shall furnish all tools, equipment, materials, supplies, personnel, labor, and supervision necessary to complete the contract work requirements.

2. **Project Location(s)/Descriptions/Maps:** The project treatment activities on USDA-ARS Livestock and Range Research Laboratory (Fort Keogh) lands will be conducted on a location hereby referred to as the **East Yellowstone Project Area**. Site specific maps are included in the project Statement of Work (see Miles City/Ft. Keogh area map, page 2; East Yellowstone Project Area map, page 3).

   The East Yellowstone Project Area is located along the riparian buffer area of the Yellowstone River, within Fort Keogh property. The project site has a well-maintained access road, and the existing road will be used to access the project work areas. Off-road travel is restricted to the actual treatment areas.

3. **Target Species for Vegetation Control:** Plant species targeted for control include: Russian olive (*Elaeagnus angustifolia*), saltcedar (*Tamarix spp*.), Canada thistle (*Cirsium arvense*), and spotted knapweed (*Centaurea maculosa*), as identified in the weed assessment surveys.

4. **Work Requirements/Specifications:** The contract requires “spot” treatment of the target weed locations within the designated project area. GPS point collection data of all treatment locations is required to be provided by the contractor to the Project Leader (or designee).

   The contractor’s equipment shall meet or exceed all current federal, state, and local safety requirements. The contractor and employees shall be required to wear all appropriate personal protective equipment while conducting project treatment activities. Extreme care shall be exercised at all times by the contractor to protect desirable (non-targeted) species from damages by the required chemical and/or mechanical cutting treatments. The equipment may be stored on-site while the contract work is being performed.

   The herbicide treatment work shall be conducted between June 23, 2014 and July 25, 2014; with uncontrollable weather and/or unfavorable site conditions considered. The East Yellowstone Project Area herbicide treatment work being offered for this contract will consist of weed locations within a total area of **fourteen (14)** acres. The treatment area is defined on the treatment area map on page 3 of this document.

5. **Pesticides:** The products (pesticides/oils/adjuvants) used will be provided by the contractor and will need to be included in the bid estimate. Only EPA registered chemicals approved for use in the State of

Montana shall be applied. Chemicals shall be mixed and applied at rates consistent with their perspective labels and manufacturers recommendations. Manufacturer's label directions and warnings relative to temperature, wind, or other weather conditions shall be strictly adhered to.

The specific chemicals, methods, and rates to be used on the Fort Keogh Project Areas are as follows:

Russian olive/Saltcedar (regrowth): a 33% triclopyr ester / 67% basal oil (v/v) mixture "spot" applied to cover any visible foliage at the time of treatment. The herbicides/rates to be used for the target terrestrial weed species are: aminopyralid (5 oz/acre) plus non-ionic surfactant (.25% v/v) applied with a total volume spray rate of 30 gallons per acre.

6. **Record Keeping (Pesticides):** The contractor shall be required to complete a daily accurate Pesticide Application Record (PAR) form. The contractor shall submit the completed application records to the Project Leader (or designee) on a weekly basis for inspection of the treatment areas.
7. **GPS:** The contractor will provide and use a GPS data logger that will support ArcGIS 9.2 software, and be able to export to Arcview/Map shapefiles, and generate pdf format – site maps showing the treatment locations. The contractor will furnish the Project Leader with treatment inventory data CDs containing all collected data files by project name.
8. **Weather Conditions:** The contractor shall provide a continuous operation from day to day; weather permitting, until completion of the work required within the allotted contract time frame. Modification of the project work schedule due to weather or site conditions must be approved by the Project Leader (or designee).

2

Fort Keogh (Miles City, MT)

3

Missouri River Watershed Coalition
Center for Invasive Plant Management (Montana State University)
Conservation Innovation Grant Project

Statement of Work
Invasive Plant Treatment and Management Services
Yellowtail Coordinated Resource Management Area
Lovell, Wyoming

Classroom Project Area
4-18-2014

SCOPE OF WORK

1. **Summary:** The requirement for the project is for noxious/invasive plant treatment and inventory. The project work will be conducted on Bureau of Reclamation lands that are located within the Yellowtail Coordinated Resource Management Area. The project activities will begin at the time the contract is awarded and continue through the end date of the contracts. All areas treated shall have GPS coordinates, maps, and electronic file for locations according to specifications and guidelines as set forth within this Statement of Work.

   The contractor shall furnish all tools, equipment, materials, supplies, personnel, labor, and supervision necessary to complete the contract work requirements.

2. **Project Location(s)/Descriptions/Maps:** The project treatment activities on Yellowtail CRM lands will be conducted in a location hereby referred to as: **Classroom Project Area**. Site specific maps are included in the project Statement of Work (see Lovell, WY area map, page 2; Classroom Project Area map, page 3).

   The Classroom Project Area is located along the riparian buffer area of the Shoshone River, northeast of Lovell, Wyoming. The project site has a well-maintained access road, a perimeter two-track road, and the existing roads will be used to access the project work areas. Off-road travel is restricted to the actual treatment areas.

3. **Target Species for Vegetation Control:** Plant species targeted for control include: Russian olive (*Elaeagnus angustifolia*), saltcedar (*Tamarix* spp), hoary cress/whitetop (*Cardaria draba L.*), and Canada thistle (*Cirsium arvense*), as identified in the weed assessment surveys.

4. **Work Requirements/Specifications:** The contract requires "spot" treatment of the target weed locations within the designated project area. GPS point collection data of all treatment locations is required to be provided by the contractor to the Project Leader (or designee).

   The contractor's equipment shall meet or exceed all current federal, state, and local safety requirements. The contractor and employees shall be required to wear all appropriate personal protective equipment while conducting project treatment activities. Extreme care shall be exercised at all times by the contractor to protect desirable (non-targeted) species from damages by the required chemical and/or mechanical cutting treatments. The equipment may be stored on-site while the contract work is being performed.

   The herbicide treatment work shall be conducted between June 23, 2014 and July 25, 2014; with unfavorable weather or site conditions taken into consideration. The Classroom Project Area treatment work being offered for this contract will consist of weed locations within a total area of **fourteen (14)** acres. The treatment area is defined on the treatment area map on page 3 of this document.

5. **Pesticides:** The products (pesticides/oils/adjuvants) used will be provided by the contractor and will need to be included in the bid estimate. Only EPA registered chemicals approved for use in the State of

Wyoming shall be applied. Chemicals shall be mixed and applied at rates consistent with their perspective labels and manufacturers recommendations. Manufacturer's label directions and warnings relative to temperature, wind, or other weather conditions shall be strictly adhered to.

The specific chemicals, methods, and rates to be used on the Classroom Project Area are as follows:

Russian olive/Saltcedar (regrowth): a 27% triclopyr ester / 73% basal oil (v/v) mixture applied to cover any visible foliage at the time of treatment. The herbicides/rates to be used for the target terrestrial weed species are: aminopyralid (5 oz/acre) and chlorsulfuron (1 oz/acre) plus non-ionic surfactant (.25% v/v) applied with a total volume spray rate of 30 gallons per acre.

6. **Record Keeping (Pesticides):** The contractor shall be required to complete a daily accurate Pesticide Application Record (PAR) form. The contractor shall submit the completed application records to the Project Leader (or designee) on a weekly basis for inspection of the treatment areas.
7. **GPS:** The contractor will provide and use a GPS data logger that will support ArcGIS 9.2 software, and be able to export to Arcview/Map shapefiles, and generate pdf format – site maps showing the treatment locations. The contractor will furnish the Project Leader with treatment inventory data CDs containing all collected data files by project name.
8. **Weather Conditions:** The contractor shall provide a continuous operation from day to day; weather permitting, until completion of the work required within the allotted contract time frame. Modification of the project work schedule due to weather or site conditions must be approved by the Project Leader (or designee).

2

Classroom Location (Lovell, WY)

3

Conservation Innovation Grant Project
Missouri River Watershed Coalition
Center for Invasive Plant Management (Montana State University)

Statement of Work
Invasive Plant Treatment and Management Services
Meade 46-1 School District
Sturgis, South Dakota

Sturgis School Project Area
4-30-2014

SCOPE OF WORK

1. **Summary:** The requirement for the project is for noxious/invasive plant treatment and inventory. The project work will be conducted on Meade 46-1 School District lands that are located within the undeveloped portions of the Sturgis School District property. The project activities will begin at the time the contract is awarded and continue through the end date of the contract. All areas treated shall have GPS coordinates, maps, and electronic file for locations according to specifications and guidelines as set forth within this Statement of Work.

   The contractor shall furnish all tools, equipment, materials, supplies, personnel, labor, and supervision necessary to complete the contract work requirements.

2. **Project Location(s)/Descriptions/Maps:** The project treatment activities on Meade 46-1 School District lands will be conducted in a location hereby referred to as: **Sturgis School Project Area**. Site specific maps are included in the project Statement of Work (see Sturgis, SD School District area map, page 2; Sturgis School Project Area map, page 3).

   The Sturgis School Project Area is located along the riparian buffer area of the Bear Butte Creek, northeast of the school district facilities in Sturgis, South Dakota. The project site has a well-maintained access road, a perimeter two-track road, and the existing roads will be used to access the project work areas. Off-road travel is restricted to the actual treatment areas.

3. **Target Species for Vegetation Control:** Plant species targeted for control include: Russian olive (*Elaeagnus angustifolia*), Canada thistle (*Cirsium arvense*), bull thistle (*Cirsium vulgare*), and houndstongue (*Cynoglossum officinale*), as identified in the weed assessment surveys.

4. **Work Requirements/Specifications:** The contract requires “spot” herbicide treatment of the target weed locations within the designated project area. GPS point collection data of all treatment locations is required to be provided by the contractor to the Project Leader (or designee).

   The contractor’s equipment shall meet or exceed all current federal, state, and local safety requirements. The contractor and employees shall be required to wear all appropriate personal protective equipment while conducting project treatment activities. Extreme care shall be exercised at all times by the contractor to protect desirable (non-targeted) species from damages by the required chemical treatments. The equipment may be stored on-site while the contract work is being performed.

   The herbicide treatment work shall be conducted between July 1, 2014 and July 26, 2014; with uncontrollable weather and/or unfavorable site conditions considered. The Sturgis School Project Area treatment work being offered for this contract will consist of weed locations within a total area of **seven (7)** acres. The treatment area is defined on the treatment area map on page 3 of this document.

5. **Pesticides:** The products (pesticides/oils/adjuvants) used will be provided by the contractor and will need to be included in the bid estimate. Only EPA registered chemicals approved for use in the State of South Dakota shall be applied. Chemicals shall be mixed and applied at rates consistent with their perspective

labels and manufacturers recommendations. Manufacturer's label directions and warnings relative to temperature, wind, or other weather conditions shall be strictly adhered to.

The specific chemicals, methods, and rates to be used on the Sturgis School Project Area are as follows:

Russian olive (regrowth): mechanical cutting of the seedlings with a 27% triclopyr ester / 73% basal oil (v/v) mixture "spot" applied to cover the "stump" area at the time of cutting. The herbicides/rates to be used for the target terrestrial weed species are: aminopyralid (5 oz/acre) and chlorsulfuron (1 oz/acre) plus non-ionic surfactant (.25% v/v) applied with a total volume spray rate of 30 gallons per acre.

6. **Record Keeping (Pesticides):** The contractor shall be required to complete a daily accurate Pesticide Application Record (PAR) form. The contractor shall submit the completed application records to the Project Leader (or designee) on a weekly basis for inspection of the treatment areas.
7. **GPS:** The contractor will provide and use a GPS data logger that will support ArcGIS 9.2 software, and be able to export to Arcview/Map shapefiles. The contractor will furnish the Project Leader with treatment inventory data CDs containing all collected data files by project name.
8. **Weather Conditions:** The contractor shall provide a continuous operation from day to day; weather permitting, until completion of the work required within the allotted contract time frame. Modification of the project work schedule due to weather or site conditions must be approved by the Project Leader (or designee).

Sturgis School Site (Sturgis, SD)

3

Center for Invasive Species Management
and
Missouri River Watershed Coalition

Conservation Innovation Grant

Russian Olive, Saltcedar and Phragmites Study Sites: Post-Treatment Data Collection Protocols and Data Summary

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Plot Locations and Transect Layout

Plot locations were chosen on the ground to be representative of vegetation density and structure within predetermined polygons (sites). Each site contained treatment plots and one control plot. At each plot a 50 m or 25 m transect line was established, with the start and end points recorded as waypoints using a Montana 650t GPS. Transect ends were also marked with metal U-posts labeled with metal tags. Tag information included plot title, transect number, and whether it was a treatment or control site. The same information, along with azimuth of the transect line, was written on a dry-erase board as part of photo documentation. Photos were taken at both ends of each transect and included photos of the transect line. Table 1 summarizes the plot layouts.

Table 1: Site names and plot layouts (Note: Ft. Keogh 1 is also known as Cottonwood Flats, and Ft. Keogh 2 is also known as East Yellowstone)

Site	Number of Plots	Transect Length	Photos	2012 Date Sampled	2013 Date Sampled	2014 Date Sampled
Allen Treatment	3	50 m	Transect + 4 directions	8/8/2012	8/16/2013	8/21/2014
Allen Control	1	50 m	Transect + 4 directions	8/9/2012	8/16/2013	8/21/2014
Arapooish Treatment	3	50 m	Transect + 4 directions	8/8/2012	8/16/2013	8/22/2014
Arapooish Control	1	50 m	Transect + 4 directions	8/8/2012	8/16/2013	8/22/2014
Ft. Keogh 1 Treatment	3	25 m	Transect + 4 directions	8/10/2012	8/13/2013	8/20/2014
Ft. Keogh 1 Control	1	25 m	Transect + 4 directions	8/10/2012	8/13/2013	8/20/2014
Ft. Keogh 2 Treatment	3	50 m	Transect + 4 directions	8/9/2012	8/12/2013	8/21/2014
Ft. Keogh 2 Control	1	50 m	Transect + 4 directions	8/9/2012	8/12/2013	8/21/2014
Lovell Treatment	3	50 m	Transect + 4 directions	8/6/2012	8/14/2013	8/22/2014
Lovell Mulch	2	50 m	Transect + 2 landscape	8/30/2012	8/14/2013	8/23/2014
Lovell Control	1	50 m	Transect + 4 directions	8/6/2012	8/14/2013	8/25/2014
Sturgis Site 1 Treatment	2	50 m	Transect + 2 landscape	8/27/2012	8/15/2013	8/20/2014
Sturgis Site 2 Treatment	1	50 m	Transect + 2 landscape	8/28/2012	8/15/2013	8/19/2014
Sturgis Site 2 Control	1	50 m	Transect + 2 landscape	8/28/2012	8/15/2013	8/19/2014
Phragmites Treatment	2	50 m	Transect + 2 landscape	8/29/2012	Not Sampled	Not Sampled
Phragmites Control	1	50 m	Transect + 2 landscape	8/29/2012	Not Sampled	Not Sampled

Data Collection Protocols

Data collection was conducted by range, soil, and botany specialists and technicians. All data except for woody plant density were entered directly into the Database for Inventory Management and Analysis (DIMA)[1] on field tablet computers. Data were collected using six protocols: line-point intercept, dry weight rank with comparative yield plots, belt transects for woody plant density, canopy and basal gap intercept, and soil stability. A site description was also entered using slope, aspect, azimuth, slope shape, landscape unit, and hillslope profile. Soil samples were also collected for laboratory analysis.

Line-Point Intercept

Line-point intercept was used to determine canopy cover, basal cover, litter cover, soil surface cover, and woody debris cover. Methods established by Herrick, et al.[2] were used with a laser point-intercept device. Data were collected at 1-m increments, starting at the zero end of each transect line. In some cases, vegetation made a 50 m transect impossible, so the line was shortened to 25 m and point-intercept data were collected every 0.5 m. To collect data at each point on the line the laser point-intercept device was leveled and aimed through the canopy. Each layer of canopy intercepted by the laser, as well as those above, was identified all the way to the basal component.

Dry Weight Rank with Comparative Yield Plots

Dry weight rank with comparative yield plots was the protocol used to collect data on species composition and production for herbaceous and shrubby plants. Comparative yield plots were first determined by walking around the plot and choosing three locations of representative low (rank one), medium (rank two) and high (rank three) production, as estimated by dry weight of current-year production. Circular 0.25 m^2 hoops were placed at each location and all current-year production within the hoop was clipped, weighed, and saved for weighing again when dried. After identifying comparative yield plots, dry weight rank was conducted at predetermined points along the 50 m transect line starting at the 5 m mark, and every 10 m thereafter. At each point the observer walked in a straight line perpendicular to the transect line and placed a 20 cm x20 cm quadrat frame every two steps, centered on his/her toe to prevent bias. Upon placing the frame on the ground, the three species within the frame with the greatest anticipated dry weights were identified. The record was then given a dry weight rank (one, two, or three from the comparative yield plots). Ten frames were placed along each perpendicular line, with perpendicular lines alternating on either side of the transect, for a total of 50 frames. A slightly different method was used for determining production at the *Phragmites* sites, due to the monoculture nature of the sites. Instead of assigning rank one, two, or three to each hoop, comparative yield plots were established at predetermined locations along the transect line: 12.5 m, 25 m, and 37.5 m. All three locations were clipped using a 0.5 m^2 hoop, and ranked as a two.

Belt Transect for Woody Plant Density

Belt transects were used to determine the density of live and dead trees within each plot. Observers walked along each side of the transect and counted number of woody species according to size classes. For multi-stemmed species such as saltcedar and willow, the size classes were all based on height: <20 cm; 20-100 cm; 1-2 m; 2-4 m; >4 m; or dead. For single-stemmed species such as Russian olive, size classes were based on height up to 180 cm and then on diameter breast height (DBH): <30 cm; 30-180 cm; DBH 2.5-15 cm; DBH 15-25 cm; DBH >25 cm; or dead. Belt width varied depending on plot-specific densities, and in some cases seedling densities were very high that 20 cm x 20 cm quadrats were used to estimate density. In all cases, the unit of density was reported as plants per hectare.

Canopy and Basal Gap Intercept

Canopy and basal gap provide information about changes in spatial distribution of vegetation particularly as it relates to erosion resistance. Canopy and basal gap protocol followed Herrick et al.[3] The minimum gap size for both canopy and basal gap was 20 cm. Any plant canopy (annual or perennial) that intersected the transect line for more than 1.7 cm broke the canopy gap. Any plant base, regardless of size, broke the basal gap.

Soil Stability

Soil stability provides information about the degree of soil structural development and erosion resistance. Soil stability protocol followed Herrick, et al.[4] Samples were collected beginning at the 10 m mark on the transect line, and every 10 m thereafter, for a total of nine samples at each plot. For heavily wooded areas where a 25 m transect line was used, samples were taken beginning at the 5m mark and every 5 m thereafter. Following the removal of litter, each sample was collected from the soil surface. Observers recorded whether or not a plant canopy was present over the point where each sample was taken. After the dipping portion of the protocol was completed, the sample was assigned a value of 1-6 as follows: 1—50% of structural integrity lost within 5 seconds or soil too unstable to sample; 2—50% of structural integrity lost 5-30 seconds after immersion; 3—50% of structural integrity lost 30-300 seconds after immersion, or <10% of soil remaining on sieve after five dipping cycles; 4—10-25% of soil remains on sieve after dipping cycles; 5—25-75% of soil remains on sieve after dipping cycles; 6—75-100% of soil remains on sieve after dipping cycles.

Soil Sampling for Texture and Nutrient Analysis

A soil coring device was used to collect 10 sub-samples at each plot, with sampling locations distributed in a roughly systematic fashion within 5 m of the transect line. Sub-samples were combined by site, air-dried, crushed, and sieved with a 2 mm mesh sieve prior to shipment to Midwest Laboratories[5]. Midwest Laboratories will conduct testing for organic matter; available phosphorous; exchangeable potassium, magnesium, calcium and hydrogen; soil pH; buffer index; cation exchange capacity; percent base saturation of cation elements; and soil texture.

Preliminary Data Summary

Initial observations in the first year after treatment:

- All the large trees were removed from treated plots
- On all treatment plots that did not burn, Russian olive resprouts exceeded 10,000 resprouts per hectare
- Species composition of perennial grass and forbs varied widely
- Herbaceous noxious weeds increased
- Treated plots had few, if any, saltcedar resprouts.

In analyzing the first two years of data collected for this project, very few meaningful conclusions can be drawn regarding the overall efficacy or impacts of these treatments. As expected, there was a 100% decrease in large Russian olives and saltcedars at all treatment sites. The complete removal of large Russian olives resulted in a significant number of Russian olive resprouts at most treatment sites. The number of Russian olive resprouts was highly variable across treatment sites. For example, at the Allen Treatment sites Russian olive saplings per hectare increased by only 33 individuals between 2012 and 2013, whereas at the Ft. Keogh 1 Treatment sites Russian olive saplings per hectare increased by 99,400 between 2012 and 2013. Saltcedar did not similarly respond. Treated plots had few, if any, saltcedar resprouts.

Several other variables were used to assess the impact of these treatments. Increases in perennial grass and forb composition could indicate ecosystem recovery following the removal of woody invasives. No trends were observable for change in percent composition of perennial grasses or forbs. For perennial grasses five sites decreased in percent composition while the remaining three increased. Change in percent composition of forbs was split with four sites increasing and four sites decreasing. The variability in perennial grass and forb composition could be explained by seasonal weather patterns and other environmental influences such as fire or flooding at the sites. The percent composition of native species increased in only three sites and decreased at five sites, while the percent composition of non-native composition was split evenly with four sites increasing and four sites decreasing. There was an increase in percent composition of noxious weeds at six of eight treatment sites. This increase in terrestrial noxious weeds is likely the result of heavy disturbance at the treatment sites, coupled with increased human and animal traffic to the site following treatment.

A note about data summarized in this report

Data presented in this report are based on site averages—that is, for sites with more than one transect (most treatment sites), data is averaged across all transects within the site. While this is convenient for reporting, the reader should be aware that sites were often extremely heterogeneous and each plot may be worth considering on its own. This summary report is not an exhaustive display of all data collected. Original plot data can be obtained from the organizers of this project. All plant codes that appear in the data tables or graphs are standard codes that can be found on the USDA Plants Database[6].

The transect established in 2012 as Sturgis 1 Control was inadvertently treated during the same time as the treatment plots. Upon visitation for data collection in 2013, it was determined that Sturgis 1 Treatment 2 be abandoned, and that the inadvertently treated Sturgis 1 Control take its place.

The Phragmites sites were not sampled in 2013 because during the treatment period in 2012, the conditions were such that the treatments could not be conducted according to protocol.

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[1] http://jornada.nmsu.edu/monit-assess/dima
[2] Herrick, J.E., J.W. Van Zee, K.M Havstad, L.M. Burkett and W.G. Whitford. 2009. Monitoring Manual for Grassland, Shrubland and Savanna Ecosystems. Volume I: Quick Start. USDA-ARS Jornada Experimental Range, Las Cruces, NM.
[3] Ibid.
[4] Ibid.
[5] https://www.midwestlabs.com/
[6] http://plants.usda.gov/about_plants.html

Data Tables for Foliar and Basal Cover by Site

Allen Treatment Transects

Species	Scientific Name	Common Name	2012 Foliar Cover (%)	2013 Foliar Cover (%)	2014 Foliar Cover (%)	2012 Basal Cover (%)	2013 Basal Cover (%)	2014 Basal Cover (%)
ELAN	*Elaeagnus angustifolia*	Russian olive	80.7	0.0	0.0	0.7	0.0	0.0
CHENO	*Chenopodium*	goosefoot	46.0	25.3	6.0	0.0	4.7	0.0
THIN6	*Thinopyrum intermedium*	intermediate wheatgrass	54.7	64.0	95.3	12.0	22.0	22.0
CIRSI	*Cirsium*	thistle	0.7	0.0	0.7	0.0	0.0	0.0
POLYG4	*Polygonum*	knotweed	0.7	0.0	0.0	0.0	0.0	0.0
CYOF	*Cynoglossum officinale*	houndstongue	1.3	0.0	0.0	0.0	0.0	0.0
GALIU	*Galium*	bedstraw	1.3	0.0	1.3	0.0	0.0	0.0
PHPR3	*Phleum pratense*	timothy	0.7	0.7	0.0	0.0	0.0	0.0
POPR	*Poa pratensis*	Kentucky bluegrass	0.7	2.0	3.3	0.0	0.0	0.0
SIAL2	*Sisymbrium altissimum*	tall tumblemustard	0.0	0.0	2.7	0.0	0.0	0.0
JUAC	*Juncus acuminatus*	tapertip rush	0.0	0.0	0.7	0.0	0.0	0.0

Allen Control Transect

Species	Scientific Name	Common Name	2012 Foliar Cover (%)	2013 Foliar Cover (%)	2014 Foliar Cover (%)	2012 Basal Cover (%)	2013 Basal Cover (%)	2014 Basal Cover (%)
ELAN	*Elaeagnus angustifolia*	Russian olive	94.0	96.0	96.0	0.0	0.0	2.0
THIN6	*Thinopyrum intermedium*	intermediate wheatgrass	82.0	98.0	98.0	10.0	12.0	10.0
CHENO	*Chenopodium*	goosefoot	30.0	12.0	0.0	0.0	0.0	0.0
POPR	*Poa pratensis*	Kentucky bluegrass	6.0	0.0	0.0	0.0	0.0	0.0
NECA2	*Nepeta cataria*	catnip	2.0	8.0	16.0	0.0	0.0	0.0
GALIU	*Galium*	bedstraw	2.0	0.0	0.0	0.0	0.0	0.0
CIRSI	*Cirsium*	thistle	0.0	0.0	2.0	0.0	0.0	0.0

Data Tables for Foliar and Basal Cover by Site

Arapooish Treatment Transect								
Species	**Scientific Name**	**Common Name**	**2012 Foliar Cover (%)**	**2013 Foliar Cover (%)**	**2014 Foliar Cover (%)**	**2012 Basal Cover (%)**	**2013 Basal Cover (%)**	**2014 Basal Cover (%)**
THIN6	*Thinopyrum intermedium*	intermediate wheatgrass	76.7	56.0	78.0	10.7	13.3	4.0
PODE3	*Populus deltoides*	eastern cottonwood	32.0	26.7	20.7	0.0	0.0	1.3
ELAN	*Elaeagnus angustifolia*	Russian olive	30.0	0.0	0.0	0.0	0.0	0.0
CIRSI	*Cirsium*	thistle	10.7	3.3	1.3	0.0	1.3	0.0
POPR	*Poa pratensis*	Kentucky bluegrass	10.7	12.7	11.3	0.0	2.7	1.3
CHENO	*Chenopodium*	goosefoot	10.0	3.3	2.0	0.0	2.7	0.0
TAMAR2	*Tamarix*	tamarisk	7.3	0.0	0.0	0.0	0.0	0.0
SYOC	*Symphoricarpos occidentalis*	western snowberry	4.7	0.7	0.7	0.0	0.7	0.0
BRIN2	*Bromus inermis*	smooth brome	3.3	11.3	12.7	0.0	2.0	0.0
TORY	*Toxicodendron rydbergii*	western poison ivy	2.0	0.0	0.0	0.0	0.0	0.0
ASSP	*Asclepias speciosa*	showy milkweed	1.3	0.0	0.7	0.0	0.0	0.0
CYOF	*Cynoglossum officinale*	houndstongue	1.3	2.0	0.0	0.0	0.0	0.0
CLEMA	*Clematis*	leather flower	1.3	0.0	0.0	0.0	0.0	0.0
GLLE3	*Glycyrrhiza lepidota*	American licorice	1.3	0.0	0.0	0.0	0.0	0.0
POCO	*Poa compressa*	Canada bluegrass	0.7	0.0	0.0	0.0	0.0	0.0
BRAR5	*Bromus arvensis*	field brome	0.7	0.0	0.7	0.0	0.0	0.0
ROSA5	*Rosa*	rose	0.7	0.7	0.0	0.0	0.0	0.0
ELTR7	*Elymus trachycaulus*	slender wheatgrass	0.7	0.0	0.0	0.0	0.0	0.0
RIBES	*Ribes*	currant	0.7	0.0	0.0	0.0	0.0	0.0
AMBRO	*Ambrosia*	ragweed	0.7	0.0	0.0	0.0	0.0	0.0
SPPE	*Spartina pectinata*	prairie cordgrass	0.7	2.0	2.7	0.0	0.0	0.0
SHCA	*Shepherdia canadensis*	russet buffaloberry	0.0	2.7	3.3	0.0	0.0	0.7
DISP	*Distichlis spicata*	saltgrass	0.0	2.7	0.0	0.0	0.7	0.0
SIAL2	*Sisymbrium altissimum*	tall tumblemustard	0.0	0.0	4.0	0.0	0.0	0.0
DAGL	*Dactylis glomerata*	orchardgrass	0.0	0.0	0.7	0.0	0.0	0.0
EQFL	*Equisetum fluviatile*	water horsetail	0.0	0.0	0.7	0.0	0.0	0.0
GALIU	*Galium*	bedstraw	0.0	0.0	0.7	0.0	0.0	0.0

Data Tables for Foliar and Basal Cover by Site

Arapooish Treatment Transect *(continued)*

Species	Scientific Name	Common Name	2012 Foliar Cover (%)	2013Foliar Cover (%)	2014 Foliar Cover (%)	2012 Basal Cover (%)	2013 Basal Cover (%)	2014 Basal Cover (%)
LACTU	*Lactuca*	lettuce	0.0	0.0	0.7	0.0	0.0	0.0
MEOF	*Melilotus officinalis*	sweetclover	0.0	0.0	0.7	0.0	0.0	0.0

Arapooish Control Transect

Species	Scientific Name	Common Name	2012 Foliar Cover (%)	2013 Foliar Cover (%)	2014 Foliar Cover (%)	2012 Basal Cover (%)	2013 Basal Cover (%)	2014 Basal Cover (%)
THIN6	*Thinopyrum intermedium*	intermediate wheatgrass	80.0	56.0	52.0	12.0	10.0	8.0
ELAN	*Elaeagnus angustifolia*	Russian olive	54.0	40.0	40.0	0.0	0.0	0.0
TAMAR2	*Tamarix*	tamarisk	28.0	22.0	8.0	0.0	0.0	0.0
PODE3	*Populus deltoides*	eastern cottonwood	20.0	12.0	8.0	0.0	0.0	0.0
BRAR5	*Bromus arvensis*	field brome	6.0	10.0	6.0	0.0	2.0	0.0
CHENO	*Chenopodium*	goosefoot	4.0	22.0	24.0	0.0	4.0	2.0
POPR	*Poa pratensis*	Kentucky bluegrass	2.0	0.0	2.0	0.0	0.0	0.0
CIRSI	*Cirsium*	thistle	0.0	8.0	0.0	0.0	4.0	0.0
BRIN2	*Bromus inermis*	smooth brome	0.0	16.0	26.0	0.0	8.0	10.0
SYMPH	*Symphoricarpos occidentalis*	snowberry	0.0	2.0	2.0	0.0	0.0	0.0
COMA2	*Conium maculatum*	poison hemlock	0.0	0.0	2.0	0.0	0.0	0.0
GALIU	*Galium*	bedstraw	0.0	0.0	2.0	0.0	0.0	0.0
SIAL2	*Sisymbrium altissimum*	tall tumblemustard	0.0	0.0	2.0	0.0	0.0	0.0

Data Tables for Foliar and Basal Cover by Site

Fort Keogh 1 (Cottonwood Flats) Treatment Transects

Species	Scientific Name	Common Name	2012 Foliar Cover (%)	2013 Foliar Cover (%)	2014 Foliar Cover (%)	2012 Basal Cover (%)	2013 Basal Cover (%)	2014 Basal Cover (%)
ELAN	*Elaeagnus angustifolia*	Russian olive	98.7	1.3	4.0	0.0	0.0	0.0
BRAR5	*Bromus arvensis*	field brome	12.0	22.7	14.7	0.0	0.0	0.7
ELTR7	*Elymus trachycaulus*	slender wheatgrass	6.0	0.0	0.0	0.0	0.0	0.0
POPR	*Poa pratensis*	Kentucky bluegrass	1.3	6.0	28.7	0.0	0.0	10.0
CIRSI	*Cirsium*	thistle	1.3	1.3	4.0	1.3	0.0	0.0
FRPE	*Fraxinus pennsylvanica*	green ash	1.3	0.0	0.0	0.0	0.0	0.0
BRIN2	*Bromus inermis*	smooth brome	0.7	5.3	22.7	0.0	0.7	4.0
DESCU	*Descurainia*	tansymustard	0.7	0.0	0.0	0.0	0.0	0.0
PASM	*Pascopyrum smithii*	western wheatgrass	0.7	1.3	24.0	0.0	0.0	8.0
CHENO	*Chenopodium*	goosefoot	0.7	1.3	0.0	0.0	0.0	0.0
NECA2	*Nepeta cataria*	catnip	0.7	8.7	18.7	0.0	0.7	0.7
MUHLE	*Muhlenbergia*	muhly	0.7	0.0	0.0	0.0	0.0	0.0
POLYG4	*Polygonum*	knotweed	0.7	3.3	0.0	0.0	0.0	0.0
MELIL	*Melilotus*	sweetclover	0.7	0.0	0.7	0.0	0.0	0.0
POBI7	*Potentilla biennis*	biennial cinquefoil	0.7	0.0	0.0	0.0	0.0	0.0
THIN6	*Thinopyrum intermedium*	intermediate wheatgrass	0.0	24.0	32.7	0.0	6.0	6.0
VEBR	*Verbena bracteata*	bigbract verbena	0.0	5.3	0.0	0.0	0.0	0.0
THAR5	*Thlaspi arvense*	field pennycress	0.0	0.7	0.0	0.0	0.0	0.0
AGCR	*Agropyron cristatum*	crested wheatgrass	0.0	1.3	0.7	0.0	0.7	0.0
TRIFO	*Trifolium*	clover	0.0	2.7	0.0	0.0	0.7	0.0
SEVI4	*Setaria viridis*	green bristlegrass	0.0	3.3	0.0	0.0	0.0	0.0
TAOF	*Taraxacum officinale*	common dandelion	0.0	0.7	0.0	0.0	0.0	0.0
DAGL	*Dactylis glomerata*	orchardgrass	0.0	2.7	2.0	0.0	0.7	0.0
PACA6	*Panicum capillare*	witchgrass	0.0	1.3	0.0	0.0	0.0	0.0
BRTE	*Bromus tectorum*	cheatgrass	0.0	1.3	0.0	0.0	0.0	0.0
PHAR15	*Phalaris arundinacea*	reed canarygrass	0.0	0.0	1.3	0.0	0.0	0.0
COCA5	*Conyza canadensis*	Canadian horseweed	0.0	0.0	0.7	0.0	0.0	0.0

Data Tables for Foliar and Basal Cover by Site

Fort Keogh 1 (Cottonwood Flat) Control Transect								
Species	**Scientific Name**	**Common Name**	**2012 Foliar Cover (%)**	**2013 Foliar Cover (%)**	**2014 Foliar Cover (%)**	**2012 Basal Cover (%)**	**2013 Basal Cover (%)**	**2014 Basal Cover (%)**
ELAN	*Elaeagnus angustifolia*	Russian olive	96.0	100.0	100.0	0.0	0.0	0.0
AGCR	*Agropyron cristatum*	crested wheatgrass	36.0	0.0	0.0	0.0	0.0	0.0
BRIN2	*Bromus inermis*	smooth brome	16.0	0.0	10.0	0.0	0.0	0.0
POPR	*Poa pratensis*	Kentucky bluegrass	8.0	54.0	46.0	0.0	0.0	2.0
PASM	*Pascopyrum smithii*	western wheatgrass	2.0	36.0	24.0	0.0	0.0	0.0
POCO	*Poa compressa*	Canada bluegrass	0.0	8.0	0.0	0.0	0.0	0.0
DAGL	*Dactylis glomerata*	orchardgrass	0.0	16.0	0.0	0.0	0.0	0.0
TAOF	*Taraxacum officinale*	common dandelion	0.0	2.0	0.0	0.0	0.0	0.0
NECA2	*Nepeta cataria*	catnip	0.0	2.0	14.0	0.0	0.0	2.0
EPILO	*Epilobium*	willowherb	0.0	2.0	0.0	0.0	0.0	0.0
THIN6	*Thinopyrum intermedium*	intermediate wheatgrass	0.0	4.0	6.0	0.0	0.0	0.0
VIOLA	*Viola*	violet	0.0	0.0	4.0	0.0	0.0	0.0
COAR4	*Convolvulus arvensis*	field bindweed	0.0	0.0	2.0	0.0	0.0	0.0
COCA5	*Conyza canadensis*	Canadian horseweed	0.0	0.0	2.0	0.0	0.0	0.0

Data Tables for Foliar and Basal Cover by Site

Fort Keogh 2 (East Yellowstone) Treatment Transects								
Species	**Scientific Name**	**Common Name**	**2012 Foliar Cover (%)**	**2013 Foliar Cover (%)**	**2014 Foliar Cover (%)**	**2012 Basal Cover (%)**	**2013 Basal Cover (%)**	**2014 Basal Cover (%)**
ELAN	*Elaeagnus angustifolia*	Russian olive	81.3	0.7	0.7	1.3	0.0	0.0
PODE3	*Populus deltoides*	eastern cottonwood	13.3	18.0	16.0	0.0	0.0	0.0
TAMAR2	*Tamarix*	tamarisk	9.3	0.0	0.0	0.0	0.0	0.0
PASM	*Pascopyrum smithii*	western wheatgrass	7.3	7.3	18.0	0.0	0.7	0.7
CHENO	*Chenopodium*	goosefoot	4.0	1.3	4.7	0.0	0.0	0.0
SALIX	*Salix*	willow	4.0	10.0	11.3	0.0	0.0	0.0
PHAR3	*Phalaris arundinacea*	reed canarygrass	2.7	0.0	2.7	0.7	0.0	0.0
DESCU	*Descurainia*	tansymustard	2.0	0.7	0.0	0.0	0.0	0.0
VEBR	*Verbena bracteata*	bigbract verbena	2.0	15.3	26.0	0.0	0.0	0.0
POBI7	*Potentilla biennis*	biennial cinquefoil	2.0	0.0	0.0	0.0	0.0	0.0
PACA6	*Panicum capillare*	witchgrass	0.0	3.3	8.7	0.0	0.0	0.0
NECA2	*Nepeta cataria*	catnip	0.0	1.3	0.7	0.0	0.0	0.0
SIAL2	*Sisymbrium altissimum*	tall tumblemustard	0.0	6.0	6.0	0.0	0.0	0.7
SALSO	*Salsola*	Russian thistle	0.0	1.3	2.7	0.0	0.0	0.0
CIRSI	*Cirsium*	thistle	0.0	0.7	0.7	0.0	0.0	0.0
DESCU	*Descurainia*	tansymustard	0.0	0.7	0.0	0.0	0.0	0.0
BRIN2	*Bromus inermis*	smooth brome	0.0	0.7	8.7	0.0	0.7	2.0
THIN6	*Thinopyrum intermedium*	intermediate wheatgrass	0.0	0.0	12.0	0.0	0.0	0.0
POAV	*Polygonum aviculare*	prostrate knotweed	0.0	0.0	8.0	0.0	0.0	0.0
AGCR	*Agropyron cristatum*	crested wheatgrass	0.0	0.0	4.0	0.0	0.0	0.0
POCO	*Poa compressa*	Canada bluegrass	0.0	0.0	2.7	0.0	0.0	0.7
XAST	*Xanthium strumarium*	rough cocklebur	0.0	0.0	2.7	0.0	0.0	0.0
COAR4	*Convolvulus arvensis*	field bindweed	0.0	0.0	2.0	0.0	0.0	0.0
COCA5	*Conyza canadensis*	Canadian horseweed	0.0	0.0	2.0	0.0	0.0	0.0
MEOF	*Melilotus officinalis*	sweetclover	0.0	0.0	2.0	0.0	0.0	0.0
POLYG4	*Polygonum*	knotweed	0.0	0.0	2.0	0.0	0.0	0.0
BRAR5	*Bromus arvensis*	field brome	0.0	0.0	1.3	0.0	0.0	0.0

Data Tables for Foliar and Basal Cover by Site

Fort Keogh 2 (East Yellowstone) Treatment Transects *(continued)*

Species	Scientific Name	Common Name	2012 Foliar Cover (%)	2013 Foliar Cover (%)	2014 Foliar Cover (%)	2012 Basal Cover (%)	2013 Basal Cover (%)	2014 Basal Cover (%)
PLMA2	*Plantago major*	common plantain	0.0	0.0	1.3	0.0	0.0	0.0
THAR5	*Thlaspi arvense*	field pennycress	0.0	0.0	1.3	0.0	0.0	0.0
AMBRO	*Ambrosia*	ragweed	0.0	0.0	0.7	0.0	0.0	0.0
CALO	*Calamovilfa longifolia*	prairie sandreed	0.0	0.0	0.7	0.0	0.0	0.0
DISTI	*Distichlis*	saltgrass	0.0	0.0	0.7	0.0	0.0	0.0
ECCR	*Echinochloa crus-galli*	barnyardgrass	0.0	0.0	0.7	0.0	0.0	0.0
LACTU	*Lactuca*	lettuce	0.0	0.0	0.7	0.0	0.0	0.0
OEBI	*Oenothera biennis*	common evening primrose	0.0	0.0	0.7	0.0	0.0	0.0
SOLID	*Solidago*	goldenrod	0.0	0.0	0.7	0.0	0.0	0.0

Data Tables for Foliar and Basal Cover by Site

Fort Keogh 2 (East Yellowstone Control) Transect								
Species	**Scientific Name**	**Common Name**	**2012 Foliar Cover (%)**	**2013 Foliar Cover (%)**	**2014 Foliar Cover (%)**	**2012 Basal Cover (%)**	**2013 Basal Cover (%)**	**2014 Basal Cover (%)**
ELAN	*Elaeagnus angustifolia*	Russian olive	86.0	92.0	78.0	0.0	2.0	0.0
DISP	*Distichlis spicata*	saltgrass	16.0	0.0	0.0	0.0	0.0	0.0
TAMAR2	*Tamarix*	tamarisk	8.0	8.0	6.0	0.0	0.0	0.0
BRIN2	*Bromus inermis*	smooth brome	8.0	12.0	16.0	0.0	0.0	4.0
PASM	*Pascopyrum smithii*	western wheatgrass	6.0	4.0	22.0	0.0	0.0	2.0
EQUIS	*Equisetum*	horsetail	4.0	0.0	0.0	0.0	0.0	0.0
POPR	*Poa pratensis*	Kentucky bluegrass	4.0	6.0	4.0	0.0	0.0	4.0
SYOC	*Symphoricarpos occidentalis*	western snowberry	2.0	0.0	0.0	0.0	0.0	0.0
THIN6	*Thinopyrum intermedium*	intermediate wheatgrass	2.0	8.0	28.0	0.0	0.0	2.0
DESCU	*Descurainia*	tansymustard	2.0	0.0	0.0	0.0	0.0	0.0
AGCR	*Agropyron cristatum*	crested wheatgrass	0.0	6.0	20.0	0.0	0.0	2.0
BRAR5	*Bromus arvensis*	field brome	0.0	24.0	8.0	0.0	4.0	0.0
POAV	*Polygonum*	knotweed	0.0	6.0	0.0	0.0	0.0	0.0
SEVI4	*Setaria viridis*	green bristlegrass	0.0	2.0	0.0	0.0	0.0	0.0
ELTR7	*Elymus trachycaulus*	slender wheatgrass	0.0	10.0	0.0	0.0	2.0	0.0
SIAL2	*Sisymbrium altissimum*	tall tumblemustard	0.0	22.0	44.0	0.0	4.0	0.0
POCO	*Poa compressa*	Canada bluegrass	0.0	4.0	0.0	0.0	0.0	0.0
CALO	*Calamovilfa longifolia*	prairie sandreed	0.0	0.0	6.0	0.0	0.0	0.0
CHENO	*Chenopodium*	goosefoot	0.0	0.0	6.0	0.0	0.0	0.0
AMBRO	*Ambrosia*	ragweed	0.0	0.0	4.0	0.0	0.0	2.0
COCA5	*Conyza canadensis*	Canadian horseweed	0.0	0.0	4.0	0.0	0.0	0.0
NECA2	*Nepeta cataria*	catnip	0.0	0.0	4.0	0.0	0.0	0.0
XAST	*Xanthium strumarium*	rough cocklebur	0.0	0.0	4.0	0.0	0.0	0.0
CYXA	*Cyclachaena xanthifolia*	giant sumpweed	0.0	0.0	2.0	0.0	0.0	0.0
GAURA	*Gaura*	beeblossom	0.0	0.0	2.0	0.0	0.0	0.0

Data Tables for Foliar and Basal Cover by Site

Lovell Treatment Transects

Species	Scientific Name	Common Name	2012 Foliar Cover (%)	2013 Foliar Cover (%)	2014 Foliar Cover (%)	2012 Basal Cover (%)	2013 Basal Cover (%)	2014 Basal Cover (%)
ELAN	*Elaeagnus angustifolia*	Russian olive	38.7	0.0	0.0	0.0	0.0	0.0
THIN6	*Thinopyrum intermedium*	intermediate wheatgrass	30.0	11.3	48.0	0.0	0.7	2.7
PODE3	*Populus deltoides*	eastern cottonwood	25.3	5.3	0.0	0.0	0.0	0.0
SYOC	*Symphoricarpos occidentalis*	western snowberry	20.7	17.3	30.0	0.0	2.0	0.7
POPR	*Poa pratensis*	Kentucky bluegrass	18.0	0.7	15.3	2.0	0.0	1.3
SALIX	*Salix*	willow	6.0	0.0	0.0	0.0	0.0	0.0
BRIN2	*Bromus inermis*	smooth brome	6.0	2.0	2.0	0.0	0.0	0.0
ELTR7	*Elymus trachycaulus*	slender wheatgrass	6.0	8.7	0.0	0.0	1.3	0.0
GLLE3	*Glycyrrhiza lepidota*	American licorice	5.3	4.0	2.0	0.0	0.7	0.0
CADR	*Cardaria draba*	whitetop	3.3	3.3	4.7	0.0	1.3	0.0
ELCA4	*Elymus canadensis*	Canada wildrye	2.0	0.0	0.7	0.0	0.0	0.0
MAIAN	*Maianthemum*	mayflower	2.0	0.0	0.0	0.0	0.0	0.0
SPSA3	*Sphaerophysa salsula*	alkali swainsonpea	1.3	0.0	0.0	0.0	0.0	0.0
MELIL	*Melilotus*	sweetclover	0.7	0.0	0.0	0.0	0.0	0.0
CIRSI	*Cirsium*	thistle	0.7	0.7	1.3	0.0	0.0	0.0
RHTR	*Rhus trilobata*	skunkbush sumac	0.7	0.0	0.0	0.0	0.0	0.0
AMBRO	*Ambrosia*	ragweed	0.7	0.0	0.0	0.0	0.0	0.0
POAN3	*Populus angustifolia*	narrowleaf cottonwood	0.0	1.3	0.0	0.0	0.0	0.0
SPCR	*Sporobolus cryptandrus*	sand dropseed	0.0	2.7	0.7	0.0	0.0	0.7
ASTRA	*Astragalus*	milkvetch	0.0	1.3	1.3	0.0	0.7	0.0
ASSP	*Asclepias speciosa*	showy milkweed	0.0	0.7	0.7	0.0	0.0	0.0
MUHLE	*Muhlenbergia*	muhly	0.0	0.0	1.3	0.0	0.0	0.0
PHPR3	*Phleum pratense*	timothy	0.0	0.0	1.3	0.0	0.0	0.7

Data Tables for Foliar and Basal Cover by Site

Lovell Mulch Transects

Species	Scientific Name	Common Name	2012 Foliar Cover (%)	2013 Foliar Cover (%)	2014 Foliar Cover (%)	2012 Basal Cover (%)	2013 Basal Cover (%)	2014 Basal Cover (%)
ELAN	*Elaeagnus angustifolia*	Russian olive	67.0	3.0	0.0	0.0	1.0	0.0
THIN6	*Thinopyrum intermedium*	intermediate wheatgrass	19.0	26.0	52.0	0.0	3.0	6.0
TAMAR2	*Tamarix*	tamarisk	17.0	2.0	2.0	0.0	0.0	0.0
CIRSI	*Cirsium*	thistle	14.0	13.0	13.0	0.0	3.0	1.0
CHENO	*Chenopodium*	goosefoot	10.0	4.0	3.0	0.0	1.0	0.0
GLLE3	*Glycyrrhiza lepidota*	American licorice	10.0	16.0	7.0	0.0	0.0	0.0
SPAI	*Sporobolus airoides*	alkali sacaton	7.0	0.0	0.0	0.0	0.0	0.0
ASSP	*Asclepias speciosa*	showy milkweed	4.0	1.0	1.0	0.0	0.0	0.0
ALPR3	*Alopecurus pratensis*	meadow foxtail	4.0	0.0	0.0	0.0	0.0	0.0
SYOC	*Symphoricarpos occidentalis*	western snowberry	3.0	6.0	5.0	0.0	1.0	0.0
CADR	*Cardaria draba*	whitetop	3.0	9.0	2.0	0.0	0.0	0.0
RIBES	*Ribes*	currant	2.0	0.0	0.0	0.0	0.0	0.0
JUBA	*Juncus balticus*	mountain rush	2.0	1.0	1.0	0.0	0.0	0.0
PACA6	*Panicum capillare*	witchgrass	2.0	0.0	0.0	0.0	0.0	0.0
CAREX	*Carex*	sedge	2.0	1.0	1.0	0.0	1.0	0.0
COUM	*Comandra umbellata*	bastard toadflax	2.0	2.0	12.0	0.0	0.0	1.0
SPSA3	*Sphaerophysa salsula*	alkali swainsonpea	2.0	0.0	0.0	0.0	0.0	0.0
APOCY	*Apocynum*	dogbane	1.0	0.0	0.0	0.0	0.0	0.0
GRSQ	*Grindelia squarrosa*	curlycup gumweed	1.0	0.0	0.0	0.0	0.0	0.0
MAIAN	*Maianthemum*	mayflower	1.0	0.0	0.0	0.0	0.0	0.0
PHPR3	*Phleum pratense*	timothy	37.0	24.0	13.0	0.0	11.0	11.0
TRIFO	*Trifolium*	clover	0.0	2.0	0.0	0.0	0.0	0.0
SOMO	*Solidago mollis*	velvety goldenrod	0.0	1.0	0.0	0.0	1.0	0.0
HOPU	*Hordeum pusillum*	little barley	0.0	1.0	0.0	0.0	0.0	0.0
ASTRA	*Astragalus*	milkvetch	0.0	5.0	2.0	0.0	0.0	0.0
DISP	*Distichlis spicata*	saltgrass	0.0	5.0	4.0	0.0	0.0	0.0
SPCR	*Sporobolus cryptandrus*	sand dropseed	0.0	1.0	0.0	0.0	0.0	0.0

Data Tables for Foliar and Basal Cover by Site

Lovell Mulch Transects *(continued)*

Species	Scientific Name	Common Name	2012 Foliar Cover (%)	2013 Foliar Cover (%)	2014 Foliar Cover (%)	2012 Basal Cover (%)	2013 Basal Cover (%)	2014 Basal Cover (%)
PASM	*Pascopyrum smithii*	western wheatgrass	0.0	1.0	0.0	0.0	0.0	0.0
SALSO	*Salsola*	Russian thistle	0.0	0.0	1.0	0.0	0.0	0.0

Lovell Control Transect

Species	Scientific Name	Common Name	2012 Foliar Cover (%)	2013 Foliar Cover (%)	2014 Foliar Cover (%)	2012 Basal Cover (%)	2013 Basal Cover (%)	2014 Basal Cover (%)
ELAN	*Elaeagnus angustifolia*	Russian olive	54.0	32.0	42.0	0.0	0.0	0.0
THIN6	*Thinopyrum intermedium*	intermediate wheatgrass	62.0	40.0	86.0	2.0	4.0	6.0
PODE3	*Populus deltoides*	eastern cottonwood	36.0	30.0	0.0	0.0	0.0	0.0
POPR	*Poa pratensis*	Kentucky bluegrass	12.0	0.0	0.0	0.0	0.0	0.0
GLLE3	*Glycyrrhiza lepidota*	American licorice	4.0	6.0	10.0	0.0	0.0	0.0
SYOC	*Symphoricarpos occidentalis*	western snowberry	4.0	2.0	10.0	0.0	0.0	0.0
SPAI	*Sporobolus airoides*	alkali sacaton	4.0	0.0	0.0	0.0	0.0	0.0
RHTR	*Rhus trilobata*	skunkbush sumac	2.0	0.0	0.0	0.0	0.0	0.0
BRIN2	*Bromus inermis*	smooth brome	0.0	6.0	0.0	0.0	0.0	0.0
SPCR	*Sporobolus cryptandrus*	sand dropseed	0.0	4.0	2.0	0.0	2.0	0.0
DISP	*Distichlis spicata*	saltgrass	0.0	2.0	0.0	0.0	0.0	0.0
POAN3	*Populus angustifolia*	narrowleaf cottonwood	0.0	4.0	0.0	0.0	0.0	0.0
PASM	*Pascopyrum smithii*	western wheatgrass	0.0	2.0	0.0	0.0	0.0	0.0
SALIX	*Salix*	willow	0.0	0.0	8.0	0.0	0.0	0.0
ASSP	*Asclepias speciosa*	showy milkweed	0.0	0.0	2.0	0.0	0.0	0.0

Data Tables for Foliar and Basal Cover by Site

Sturgis Site 1 Treatment Transects

Species	Scientific Name	Common Name	2012 Foliar Cover (%)	2013 Foliar Cover (%)	2014 Foliar Cover (%)	2012 Basal Cover (%)	2013 Basal Cover (%)	2014 Basal Cover (%)
BRIN2	*Bromus inermis*	smooth brome	15.0	15.0	4.0	3.0	3.0	0.0
THIN6	*Thinopyrum intermedium*	intermediate wheatgrass	21.0	22.0	40.0	1.0	5.0	10.0
ELAN	*Elaeagnus angustifolia*	Russian olive	43.0	0.0	1.0	0.0	0.0	0.0
COAR4	*Convolvulus arvensis*	field bindweed	3.0	5.0	0.0	0.0	0.0	0.0
POPR	*Poa pratensis*	Kentucky bluegrass	26.0	50.0	64.0	0.0	11.0	20.0
JUBA	*Juncus balticus*	mountain rush	5.0	6.0	4.0	0.0	0.0	0.0
CAREX	*Carex*	sedge	2.0	0.0	0.0	0.0	0.0	0.0
TRIFO	*Trifolium*	clover	3.0	1.0	0.0	0.0	0.0	0.0
AMBRO	*Ambrosia*	ragweed	1.0	0.0	0.0	0.0	0.0	0.0
MELU	*Medicago lupulina*	black medic	0.0	2.0	3.0	0.0	1.0	0.0
CICHO	*Cichorium*	chicory	0.0	1.0	0.0	0.0	0.0	0.0
CIRSI	*Cirsium*	thistle	0.0	3.0	4.0	0.0	1.0	0.0
TAOF	*Taraxacum officinale*	common dandelion	0.0	6.0	5.0	0.0	0.0	0.0
AGST2	*Agrostis stolonifera*	creeping bentgrass	46.0	32.0	30.0	0.0	10.0	4.0
CIVU	*Cirsium vulgare*	bull thistle	0.0	2.0	0.0	0.0	0.0	0.0
PHPR3	*Phleum pratense*	timothy	0.0	0.0	17.0	0.0	0.0	3.0
COAR4	*Convolvulus arvensis*	field bindweed	0.0	0.0	6.0	0.0	0.0	0.0
NAVI4	*Nassella viridula*	green needlegrass	0.0	0.0	1.0	0.0	0.0	0.0

Data Tables for Foliar and Basal Cover by Site

Sturgis Site 2 Treatment Transect

Species	Scientific Name	Common Name	2012 Foliar Cover (%)	2013 Foliar Cover (%)	2014 Foliar Cover (%)	2012 Basal Cover (%)	2013 Basal Cover (%)	2014 Basal Cover (%)
BRIN2	*Bromus inermis*	smooth brome	52.0	60.0	46.0	4.0	20.0	20.0
ELAN	*Elaeagnus angustifolia*	Russian olive	32.0	0.0	0.0	0.0	0.0	0.0
POPR	*Poa pratensis*	Kentucky bluegrass	24.0	44.0	56.0	0.0	12.0	6.0
CAREX	*Carex*	sedge	18.0	16.0	28.0	0.0	6.0	12.0
JUBA	*Juncus balticus*	mountain rush	6.0	6.0	6.0	0.0	0.0	2.0
CIVU	*Cirsium vulgare*	bull thistle	2.0	0.0	0.0	0.0	0.0	0.0
PHPR3	*Phleum pratense*	timothy	2.0	6.0	0.0	0.0	0.0	0.0
CYOF	*Cynoglossum officinale*	houndstongue	2.0	2.0	0.0	0.0	0.0	0.0
SCIRP	*Scirpus*	bulrush	2.0	0.0	0.0	0.0	0.0	0.0
PAVI2	*Panicum virgatum*	switchgrass	2.0	0.0	0.0	0.0	0.0	0.0
MELU	*Medicago lupulina*	black medick	0.0	2.0	10.0	0.0	0.0	0.0
AMBRO	*Ambrosia*	ragweed	0.0	4.0	0.0	0.0	0.0	0.0
TAOF	*Taraxacum officinale*	common dandelion	0.0	2.0	2.0	0.0	2.0	0.0
GLLE3	*Glycyrrhiza lepidota*	American licorice	0.0	0.0	2.0	0.0	0.0	0.0
SEVI4	*Setaria viridis*	green bristlegrass	0.0	0.0	2.0	0.0	0.0	0.0

Data Tables for Foliar and Basal Cover by Site

Sturgis Site 2 Control Transect

Species	Scientific Name	Common Name	2012 Foliar Cover (%)	2013 Foliar Cover (%)	2014 Foliar Cover (%)	2012 Basal Cover (%)	2013 Basal Cover (%)	2014 Basal Cover (%)
BRIN2	*Bromus inermis*	smooth brome	62.0	64.0	42.0	2.0	24.0	12.0
ELAN	*Elaeagnus angustifolia*	Russian olive	44.0	36.0	38.0	0.0	0.0	0.0
ANGE	*Andropogon gerardii*	big bluestem	24.0	6.0	2.0	2.0	2.0	0.0
SPPE	*Spartina pectinata*	prairie cordgrass	14.0	20.0	10.0	0.0	2.0	0.0
POPR	*Poa pratensis*	Kentucky bluegrass	8.0	0.0	0.0	0.0	0.0	0.0
CYOF	*Cynoglossum officinale*	houndstongue	4.0	6.0	8.0	0.0	0.0	0.0
JUBA	*Juncus balticus*	mountain rush	2.0	6.0	2.0	0.0	0.0	0.0
AGST2	*Agrostis stolonifera*	creeping bentgrass	2.0	0.0	0.0	0.0	0.0	0.0
PAVI2	*Panicum virgatum*	switchgrass	2.0	0.0	0.0	0.0	0.0	0.0
CRYPT	*Cryptantha*	cryptantha	0.0	2.0	0.0	0.0	0.0	0.0
SONU2	*Sorghastrum nutans*	Indiangrass	0.0	16.0	22.0	0.0	10.0	10.0
TRIFO	*Trifolium L.*	clover	0.0	4.0	0.0	0.0	2.0	0.0
CIRSI	*Cirsium*	thistle	0.0	2.0	10.0	0.0	0.0	0.0
CIVU	*Cirsium vulgare*	bull thistle	0.0	2.0	0.0	0.0	0.0	0.0
AGST2	*Agrostis stolonifera*	creeping bentgrass	0.0	0.0	8.0	0.0	0.0	2.0
MOFI	*Monarda fistulosa*	wild bergamot	0.0	0.0	2.0	0.0	0.0	0.0
VERBE	*Verbena*	vervain	0.0	0.0	2.0	0.0	0.0	0.0

Data Tables for Foliar and Basal Cover by Site

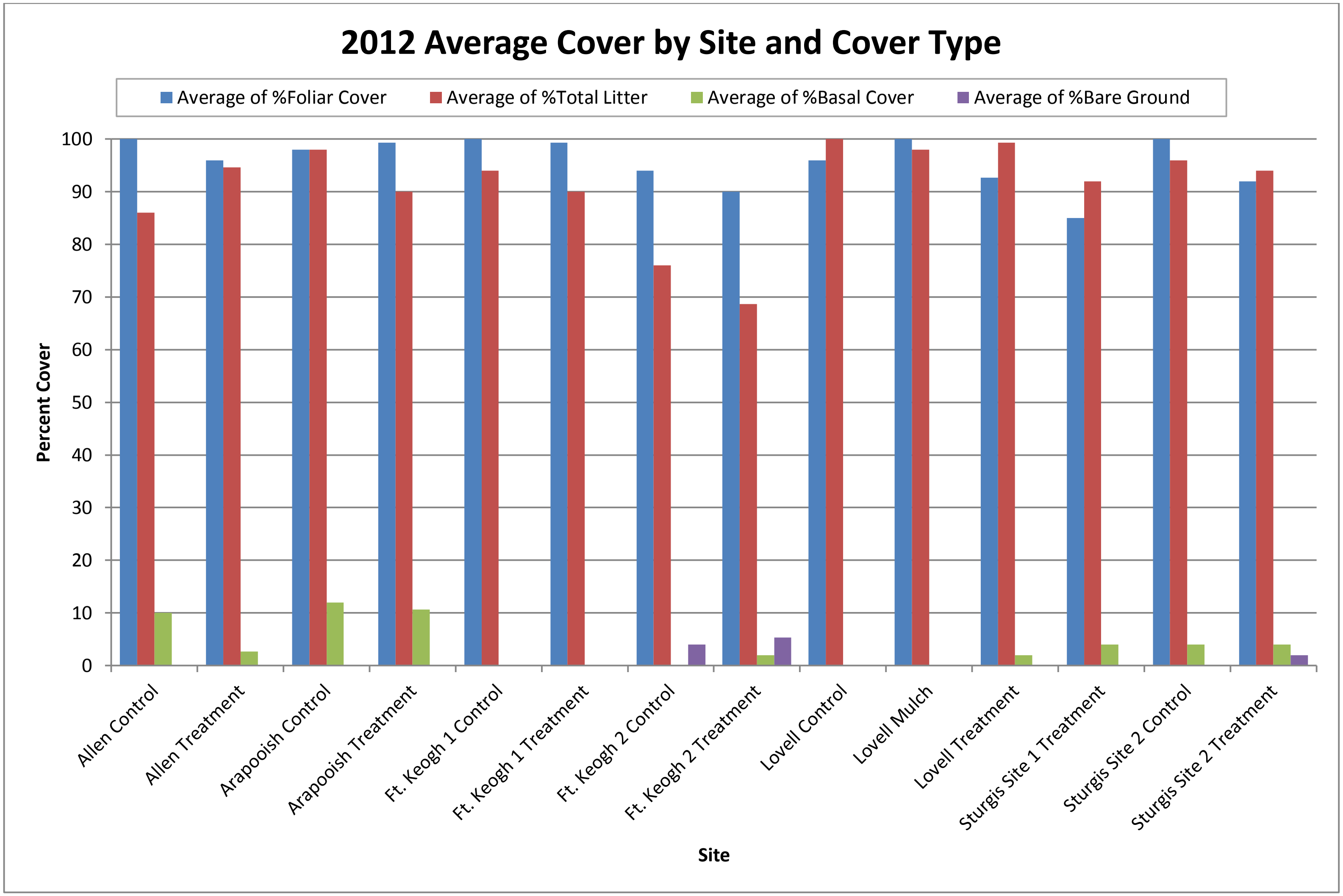
Phragmites North and South Transects

Species	Scientific Name	Common Name	2012 Foliar Cover (%)	2013 Foliar Cover (%)	2014 Foliar Cover (%)	2012 Basal Cover (%)	2013 Basal Cover (%)	2014 Basal Cover (%)
PHAU7	*Phragmites australis*	common reed	82.0	No Data	No Data	0.0	No Data	No Data
SPPE	*Spartina pectinata*	prairie cordgrass	8.0	No Data	No Data	0.0	No Data	No Data
CAREX	*Carex*	sedge	2.0	No Data	No Data	0.0	No Data	No Data
AMBRO	*Ambrosia*	ragweed	1.0	No Data	No Data	0.0	No Data	No Data

Phragmites Control Transect

Species	Scientific Name	Common Name	2012 Foliar Cover (%)	2013 Foliar Cover (%)	2014 Foliar Cover (%)	2012 Basal Cover (%)	2013 Basal Cover (%)	2014 Basal Cover (%)
PHAU7	*Phragmites australis*	common reed	90.0	No Data	No Data	0.0	No Data	No Data
SYOC	*Symphoricarpos occidentalis*	western snowberry	2.0	No Data	No Data	0.0	No Data	No Data

Graph of Average Cover by Site and Cover Type



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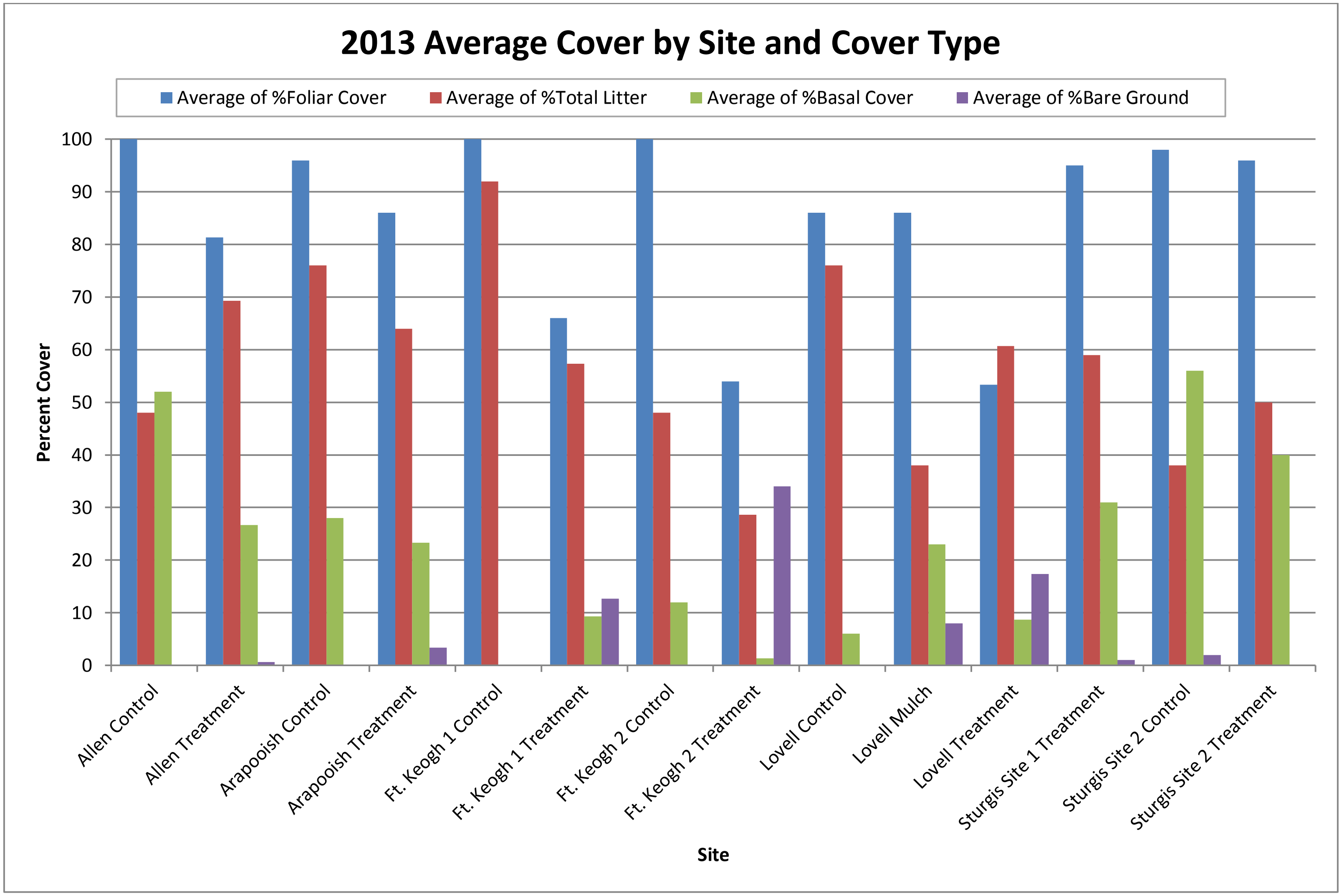
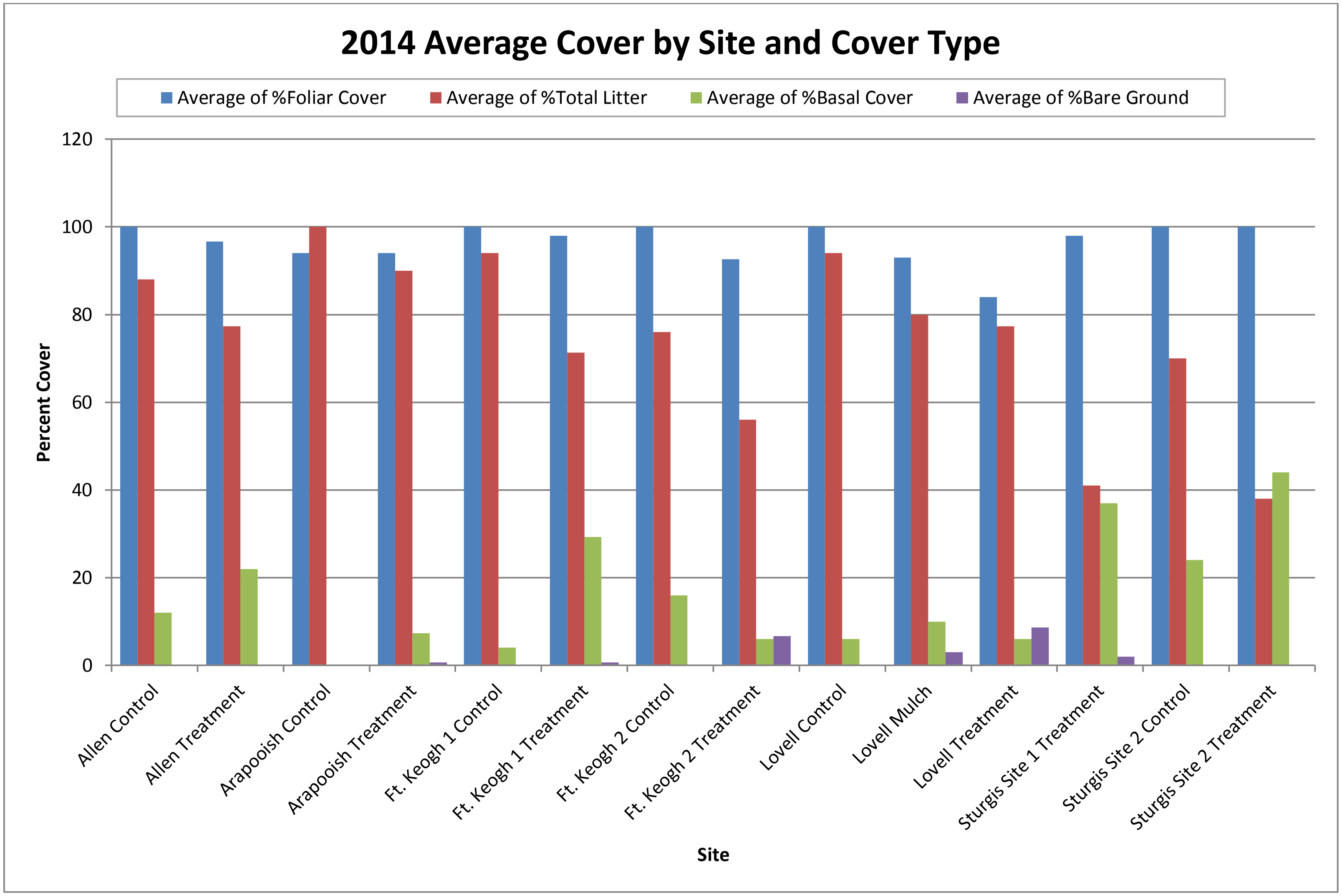
Graph of Average Cover by Site and Cover Type



Synergy Resource Solutions, Inc. – 23

Graph of Average Cover by Site and Cover Type



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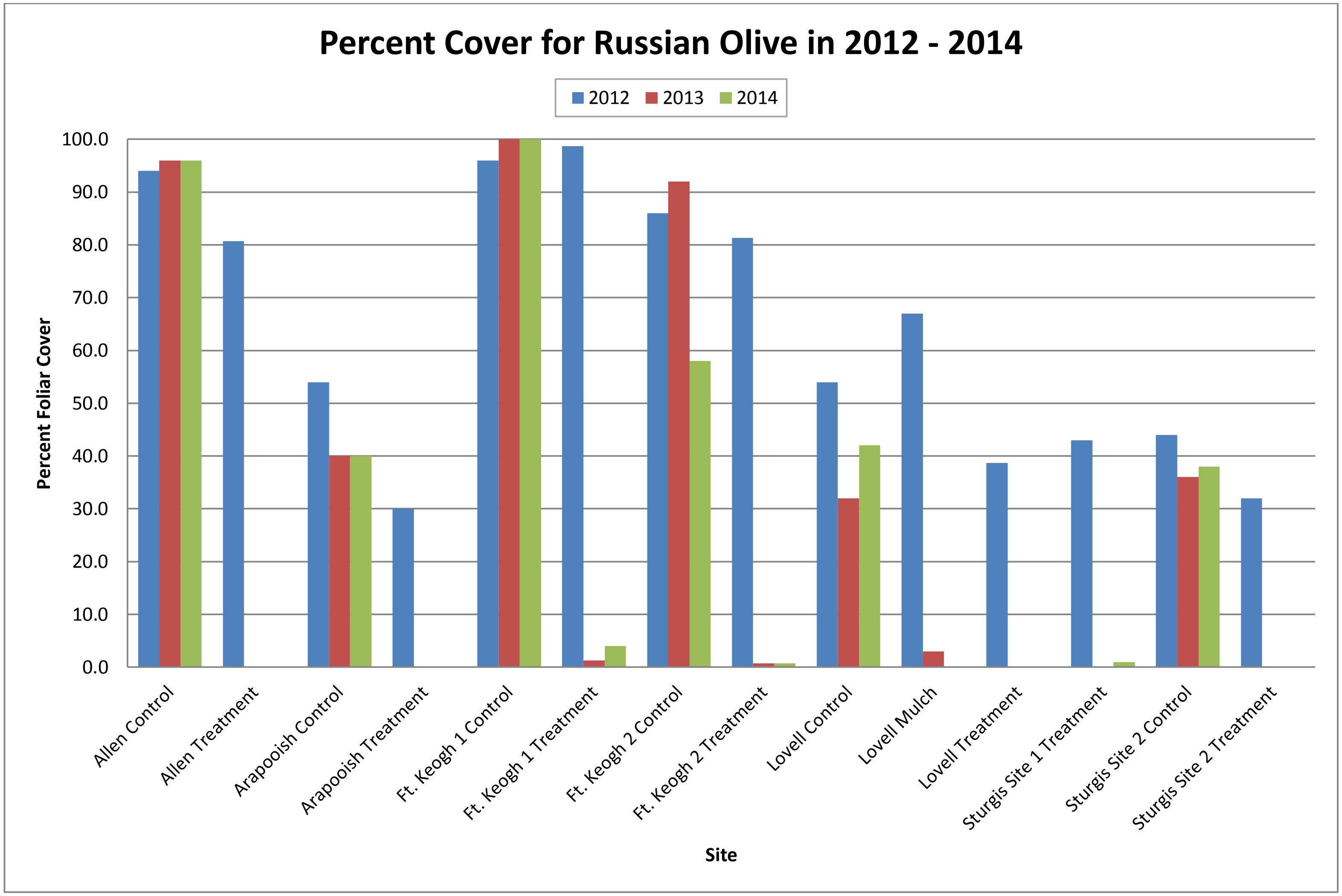
Graph of Percent Cover for Main Species of Interest



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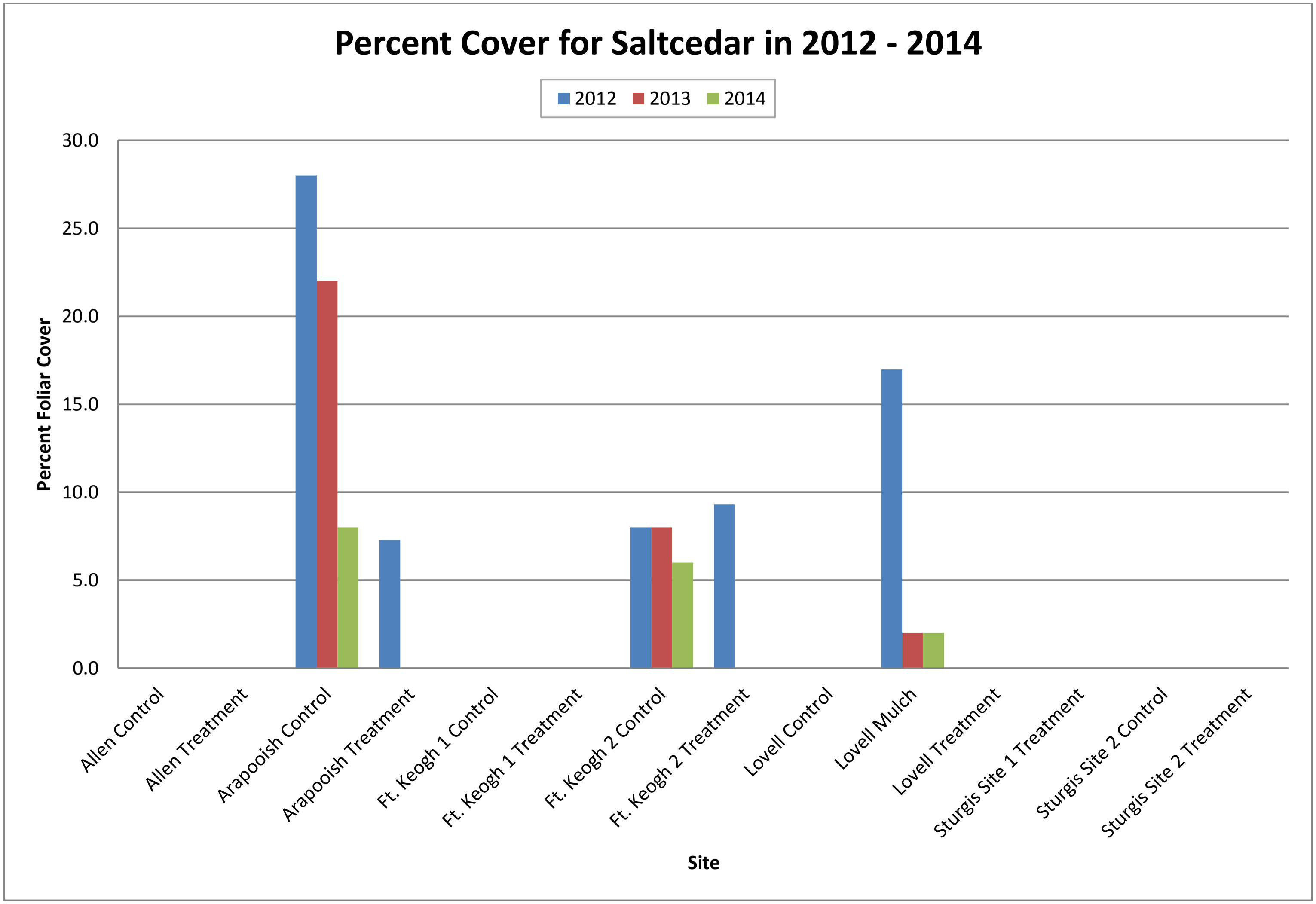
Graph of Percent Cover for Main Species of Interest



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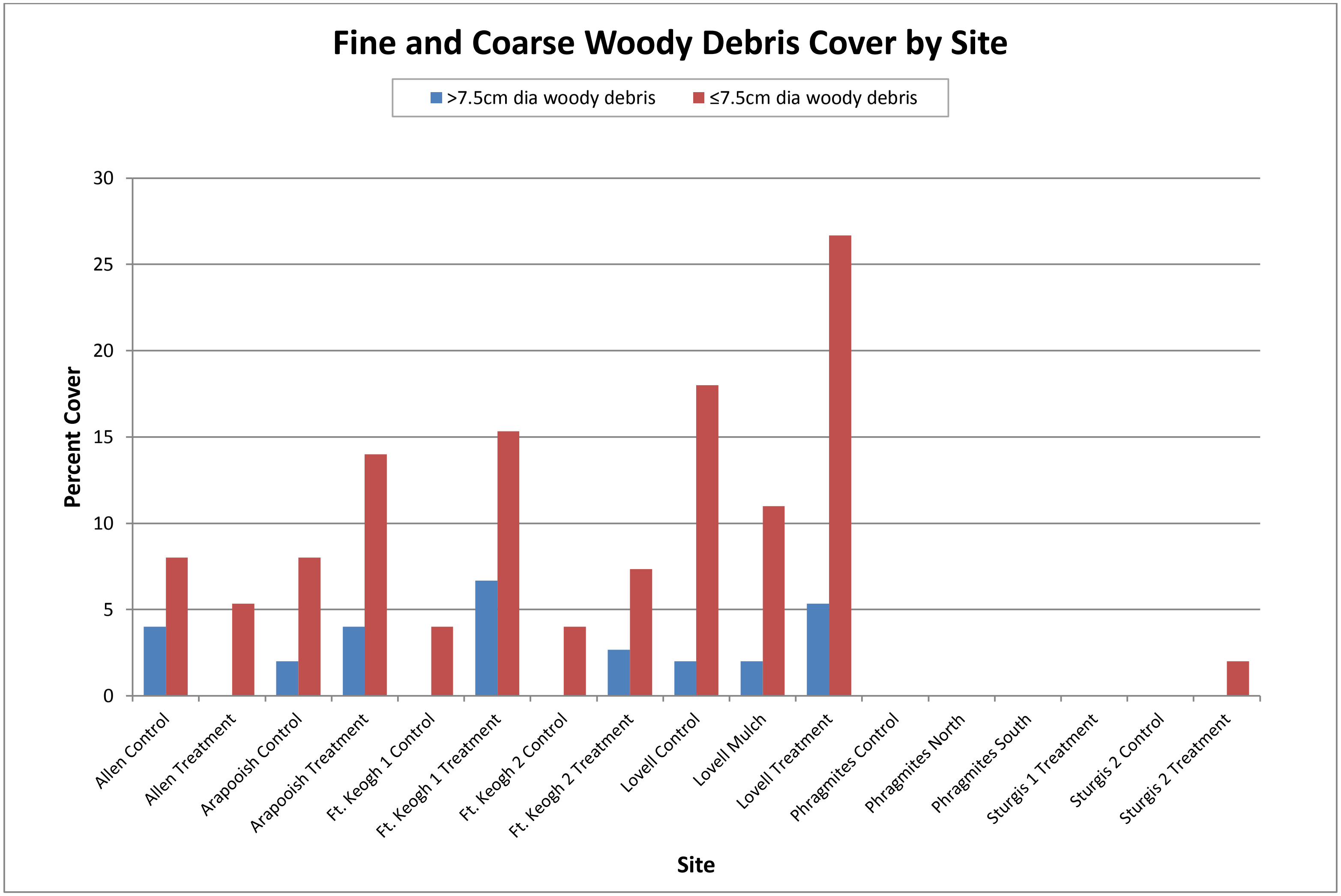
Percent Cover for Woody Debris



Given the removal of woody debris during treatments, no woody debris data was gathered in 2013 and 2014.

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Data Tables for Herbaceous Composition and Production by Site

Allen Treatment Transects								
Species	Scientific Name	Common Name	2012 Composition (%)	2013 Composition (%)	2014 Composition (%)	2012 Production (lbs/acre)	2013 Production (lbs/acre)	2014 Production (lbs/acre)
CHENO	*Chenopodium*	goosefoot	44	27	5	1437	1285	259
THIN6	*Thinopyrum intermedium*	intermediate wheatgrass	45	65	84	1485	3051	4126
CYOF	*Cynoglossum officinale*	gypsyflower	4	0	0	138	4	0
POPR	*Poa pratensis*	Kentucky bluegrass	5	2	2	174	97	90
CIRSI	*Cirsium*	thistle	1	1	1	30	66	28
PHPR3	*Phleum pratense*	timothy	0	1	0	8	40	0
JUAC	*Juncus acuminatus*	tapertip rush	0	0	1	3	0	47
DESCU	*Descurainia*	tansymustard	0	0	0	3	0	0
AMBRO	*Ambrosia*	ragweed	0	0	0	0	2	0
BRAR5	*Bromus arvensis*	field brome	0	1	1	0	25	52
ELAN	*Elaeagnus angustifolia*	Russian olive	0	0	1	0	13	42
EPILO	*Epilobium*	willowherb	0	0	0	0	12	0
EQUIS	*Equisetum*	horsetail	0	0	0	0	4	0
LACTU	*Lactuca*	lettuce	0	1	0	0	34	0
NECA2	*Nepeta cataria*	catnip	0	1	0	0	31	0
POAN3	*Populus angustifolia*	narrowleaf cottonwood	0	0	0	0	5	0
SIAL2	*Sisymbrium altissimum*	tall tumblemustard	0	0	1	0	19	57
SYOC	*Symphoricarpos occidentalis*	western snowberry	0	0	0	0	4	0
GALIU	*Galium*	bedstraw	0	0	2	0	0	90
MEOF	*Melilotus officinalis*	sweetclover	0	0	1	0	0	38
TRDU	*Tragopogon dubius*	yellow salsify	0	0	1	0	0	38
POLYG4	*Polygonum*	knotweed	0	0	0	0	0	24
ASCLE	*Asclepias*	milkweed	0	0	0	0	0	19
		Total	100	100	100	3279	4691	4908

Data Tables for Herbaceous Composition and Production by Site

Allen Control Transect

Species	Scientific Name	Common Name	2012 Composition (%)	2013 Composition (%)	2014 Composition (%)	2012 Production (lbs/acre)	2013 Production (lbs/acre)	2014 Production (lbs/acre)
THIN6	*Thinopyrum intermedium*	intermediate wheatgrass	70	79	81	1862	2960	2954
CHENO	*Chenopodium*	goosefoot	30	9	5	785	351	189
CIRSI	*Cirsium*	thistle	0	1	3	5	37	95
CYOF	*Cynoglossum officinale*	gypsyflower	0	1	1	0	52	51
EPILO	*Epilobium*	willowherb	0	1	0	0	22	0
NECA2	*Nepeta cataria*	catnip	0	8	7	0	292	269
SIAL2	*Sisymbrium altissimum.*	tall tumblemustard	0	1	0	0	22	0
GALIU	*Galium*	bedstraw	0	0	1	0	0	44
COAR4	*Convolvulus arvensis*	field bindweed	0	0	0	0	0	15
POPR	*Poa pratensis*	Kentucky bluegrass	0	0	0	0	0	15
MAIAN	*Maianthemum*	mayflower	0	0	0	0	0	7
		Total	100	100	100	2652	3738	3638

Data Tables for Herbaceous Composition and Production by Site

Arapooish Treatment Transects

Species	Scientific Name	Common Name	2012 Composition (%)	2013 Composition (%)	2014 Composition (%)	2012 Production (lbs/acre)	2013 Production (lbs/acre)	2014 Production (lbs/acre)
THIN6	*Thinopyrum intermedium*	intermediate wheatgrass	54	51	61	1669	1513	1884
BRIN2	*Bromus inermis*	smooth brome	11	17	8	333	496	241
CIRSI	*Cirsium*	thistle	13	5	1	402	150	30
CHENO	*Chenopodium*	goosefoot	8	8	2	247	233	53
POPR	*Poa pratensis*	Kentucky bluegrass	7	9	7	227	266	210
SYOC	*Symphoricarpos occidentalis*	western snowberry	4	2	4	113	45	127
PHPR3	*Phleum pratense*	timothy	1	0	0	18	0	0
ASCLE	*Asclepias*	milkweed	1	0	0	30	2	0
MAIAN	*Maianthemum*	mayflower	0	0	0	11	0	0
DESCU	*Descurainia*	tansymustard	0	0	0	13	2	0
CYOF	*Cynoglossum officinale*	gypsyflower	0	1	0	9	37	11
ROSA5	*Rosa*	rose	0	0	0	9	0	0
AMBRO	*Ambrosia*	ragweed	0	0	0	4	0	0
COUM	*Comandra umbellata*	bastard toadflax	0	0	1	2	8	33
RHTR	*Rhus trilobata*	skunkbush sumac	0	0	0	2	0	0
BRAR5	*Bromus arvensis*	field brome	0	0	2	0	10	58
DAGL	*Dactylis glomerata*	orchardgrass	0	1	0	0	33	0
DISP	*Distichlis spicata*	saltgrass	0	3	1	0	82	22
ELAN	*Elaeagnus angustifolia*	Russian olive	0	0	1	0	12	30
GLLE3	*Glycyrrhiza lepidota*	American licorice	0	0	0	0	12	11
MELU	*Medicago lupulina*	black medick	0	0	0	0	4	6
NECA2	*Nepeta cataria*	catnip	0	0	0	0	4	0
SIAL2	*Sisymbrium altissimum*	tall tumblemustard	0	0	3	0	4	83
SPCR	*Spartina pectinata*	prairie cordgrass	0	2	1	0	49	22
SPPE	*Sporobolus cryptandrus*	sand dropseed	0	1	4	0	18	138
TAOF	*Taraxacum officinale*	common dandelion	0	0	0	0	6	0

Data Tables for Herbaceous Composition and Production by Site

Arapooish Treatment Transects *(continued)*

Species	Scientific Name	Common Name	2012 Composition (%)	2013 Composition (%)	2014 Composition (%)	2012 Production (lbs/acre)	2013 Production (lbs/acre)	2014 Production (lbs/acre)
ASSP	*Asclepias speciosa*	showy milkweed	0	0	2	0	0	50
GALIU	*Galium*	bedstraw	0	0	1	0	0	28
LACTU	*Lactuca*	lettuce	0	0	0	0	0	11
MEOF	*Melilotus officinalis*	sweetclover	0	0	0	0	0	11
TAMAR2	*Tamarix*	tamarisk	0	0	0	0	0	11
CAMI2	*Camelina microcarpa*	littlepod false flax	0	0	0	0	0	6
		Total	100	100	100	3091.4	2985.0	3077.0

Arapooish Control Transect

Species	Scientific Name	Common Name	2012 Composition (%)	2013 Composition (%)	2014 Composition (%)	2012 Production (lbs/acre)	2013 Production (lbs/acre)	2014 Production (lbs/acre)
THIN6	*Thinopyrum intermedium*	intermediate wheatgrass	70	44	44	1803	916	879
BRIN2	*Bromus inermis*	smooth brome	11	10	16	272	203	312
CHENO	*Chenopodium*	goosefoot	6	19	10	159	390	200
POPR	*Poa pratensis*	Kentucky bluegrass	5	0	0	133	0	8
DESCU	*Descurainia*	tansymustard	4	0	0	92	0	0
SYOC	*Symphoricarpos occidentalis*	western snowberry	2	3	1	56	54	16
AMBRO	*Ambrosia*	ragweed	1	1	0	31	29	0
MAIAN	*Maianthemum*	mayflower	0	0	0	10	0	0
CYOF	*Cynoglossum officinale*	gypsyflower	0	1	1	5	21	20
ASTRA	*Astragalus*	milkvetch	0	0	0	0	8	0
BRAR5	*Bromus arvensis*	field brome	0	7	6	0	149	120
ELAN	*Elaeagnus angustifolia*	Russian olive	0	0	0	0	4	0
MELU	*Medicago lupulina*	black medick	0	0	0	0	8	0
SPPE	*Spartina pectinata*	prairie cordgrass	0	1	0	0	29	0
TAOF	*Taraxacum officinale*	common dandelion	0	0	0	0	8	0

Data Tables for Herbaceous Composition and Production by Site

Arapooish Control Transect *(continued)*

Species	Scientific Name	Common Name	2012 Composition (%)	2013 Composition (%)	2014 Composition (%)	2012 Production (lbs/acre)	2013 Production (lbs/acre)	2014 Production (lbs/acre)
CIRSI	*Cirsium*	thistle	0	12	14	0	253	280
SIAL2	*Sisymbrium altissimum*	tall tumblemustard	0	0	4	0	0	72
DISP	*Distichlis spicata*	saltgrass	0	0	1	0	0	28
GALIU	*Galium*	bedstraw	0	0	1	0	0	28
TAMAR2	*Tamarix*	tamarisk	0	0	1	0	0	12
ASSP	*Asclepias speciosa*	showy milkweed	0	0	0	0	0	8
POAV	*Polygonum aviculare*	prostrate knotweed	0	0	0	0	0	8
CAMI2	*Camelina microcarpa*	littlepod false flax	0	0	0	0	0	4
MEOF	*Melilotus officinalis*	sweetclover	0	0	0	0	0	4
		Total	100	100	100	2561	2073	1998

Data Tables for Herbaceous Composition and Production by Site

Fort Keogh 1 (Cottonwood Flats) Treatment Transects								
Species	**Scientific Name**	**Common Name**	**2012 Composition (%)**	**2013 Composition (%)**	**2014 Composition (%)**	**2012 Production (lbs/acre)**	**2013 Production (lbs/acre)**	**2014 Production (lbs/acre)**
ELTR7	*Elymus trachycaulus*	slender wheatgrass	22	0	0	105	0	0
BRIN2	*Bromus inermis*	smooth brome	5	10	10	26	214	226
THIN6	*Thinopyrum intermedium*	intermediate wheatgrass	10	41	37	49	850	864
BRAR5	*Bromus arvensis*	field brome	17	5	2	84	104	51
NECA2	*Nepeta cataria*	catnip	16	16	17	78	334	409
CIRSI	*Cirsium*	thistle	7	7	3	34	142	74
SYOC	*Symphoricarpos occidentalis*	western snowberry	1	0	0	6	0	0
CHENO	*Chenopodium*	goosefoot	4	2	0	21	43	0
POLYG4	*Polygonum*	knotweed	2	2	0	8	32	0
LEPID	*Lepidium*	pepperweed	3	0	0	16	0	0
POPR	*Poa pratensis*	Kentucky bluegrass	3	0	7	16	10	165
EPILO	*Epilobium*	willowherb	4	0	0	17	0	0
POBI7	*Potentilla biennis*	biennial cinquefoil	2	0	0	8	0	0
THAR5	*Thlaspi arvense*	field pennycress	0	4	1	2	88	27
DESCU	*Descurainia*	tansymustard	1	0	0	3	3	0
GAURA	*Gaura*	beeblossom	1	0	0	3	0	0
LACTU	*Lactuca*	lettuce	1	0	0	3	7	4
CALO	*Calamovilfa longifolia*	prairie sandreed	0	0	0	2	0	0
AMBRO	*Ambrosia*	ragweed	0	0	0	0	0	9
AGCR	*Agropyron cristatum*	crested wheatgrass	0	0	1	0	2	16
ASPR	*Asperugo procumbens*	German-madwort	0	1	0	0	18	0
BRTE	*Bromus tectorum*	cheatgrass	0	0	0	0	5	0
COCA5	*Conyza canadensis*	Canadian horseweed	0	0	1	0	3	27
DAGL	*Dactylis glomerata*	orchardgrass	0	0	2	0	4	36
ELAN	*Elaeagnus angustifolia*	Russian olive	0	7	4	0	146	92
HOPU	*Hordeum pusillum*	little barley	0	1	0	0	30	0

Data Tables for Herbaceous Composition and Production by Site

Fort Keogh 1 (Cottonwood Flats) Treatment Transects *(continued)*

Species	Scientific Name	Common Name	2012 Composition (%)	2013 Composition (%)	2014 Composition (%)	2012 Production (lbs/acre)	2013 Production (lbs/acre)	2014 Production (lbs/acre)
PACA6	*Panicum capillare*	witchgrass	0	0	2	0	10	40
PASM	*Pascopyrum smithii*	western wheatgrass	0	0	11	0	4	257
SALSO	*Salsola*	Russian thistle	0	0	0	0	3	0
SEVI4	*Setaria viridis*	green bristlegrass	0	1	0	0	13	0
SIAL2	*Sisymbrium altissimum*	tall tumblemustard	0	0	0	0	3	0
TAOF	*Taraxacum officinale*	common dandelion	0	1	1	0	13	27
TRDU	*Tragopogon dubius*	yellow salsify	0	0	0	0	2	0
TRIFO	*Trifolium*	clover	0	0	0	0	2	0
VEBR	*Verbena bracteata*	bigbract verbena	0	0	0	0	6	0
HOJU	*Hordeum jubatum*	foxtail barley	0	0	1	0	0	13
MEOF	*Melilotus officinalis*	sweetclover	0	0	0	0	0	11
PHAR3	*Phalaris arundinacea*	reed canarygrass	0	0	0	0	0	9
MELU	*Medicago lupulina*	black medick	0	0	0	0	0	4
		Total	100	100	100	480	2085	2360

Data Tables for Herbaceous Composition and Production by Site

Fort Keogh 1 (Cottonwood Flats) Control Transect

Species	Scientific Name	Common Name	2012 Composition (%)	2013 Composition (%)	2014 Composition (%)	2012 Production (lbs/acre)	2013 Production (lbs/acre)	2014 Production (lbs/acre)
POPR	*Poa pratensis*	Kentucky bluegrass	43	29	23	223	432	324
THIN6	*Thinopyrum intermedium*	intermediate wheatgrass	32	9	4	169	142	60
AGCR	*Agropyron cristatum*	crested wheatgrass	16	0	1	85	0	14
ELCA4	*Elymus canadensis*	Canada wildrye	3	3	0	15	39	0
EPILO	*Epilobium*	willowherb	2	0	0	10	0	0
AMBRO	*Ambrosia*	ragweed	1	0	0	7	0	0
SYOC	*Symphoricarpos occidentalis*	western snowberry	1	0	0	7	3	0
BRIN2	*Bromus inermis*	smooth brome	0	1	10	2	21	136
BRAR5	*Bromus arvensis*	field brome	0	0	0	1	3	0
CALO	*Calamovilfa longifolia*	prairie sandreed	0	7	9	1	100	125
POBI7	*Potentilla biennis*	biennial cinquefoil	0	6	0	1	94	0
DAGL	*Dactylis glomerata*	orchardgrass	0	9	0	0	130	0
NECA2	*Nepeta cataria*	catnip	0	1	17	0	21	241
PASM	*Pascopyrum smithii*	western wheatgrass	0	24	15	0	359	207
POCO	*Poa compressa*	Canada bluegrass	0	10	0	0	148	0
TAOF	*Taraxacum officinale*	common dandelion	0	1	0	0	15	0
TRIFO	*Trifolium*	clover	0	0	0	0	3	0
ELAN	*Elaeagnus angustifolia*	Russian olive	0	0	9	0	0	131
COCA5	*Conyza canadensis*	Canadian horseweed	0	0	5	0	0	77
ASPR	*Asperugo procumbens*	German-madwort	0	0	3	0	0	43
VIOLA	*Viola*	violet	0	0	2	0	0	28
CIRSI	*Cirsium*	thistle	0	0	1	0	0	20
CYOF	*Cynoglossum officinale*	gypsyflower	0	0	0	0	0	6
MEOF	*Melilotus officinalis*	sweetclover	0	0	0	0	0	6
COAR4	*Convolvulus arvensis*	field bindweed	0	0	0	0	0	3
		Total	100	100	100	521.4	1509.1	1418.9

Data Tables for Herbaceous Composition and Production by Site

Fort Keogh 2 (East Yellowstone) Treatment Transects								
Species	**Scientific Name**	**Common Name**	**2012 Composition (%)**	**2013 Composition (%)**	**2014 Composition (%)**	**2012 Production (lbs/acre)**	**2013 Production (lbs/acre)**	**2014 Production (lbs/acre)**
PASM	*Pascopyrum smithii*	western wheatgrass	19	6	28	128	76	439
THIN6	*Thinopyrum intermedium*	intermediate wheatgrass	25	2	10	168	24	155
CHENO	*Chenopodium*	goosefoot	16	0	2	109	5	28
JUNCU	*Juncus*	rush	3	0	0	21	0	0
PHAR3	*Phalaris arundinacea*	reed canarygrass	6	0	3	42	0	43
BRIN2	*Bromus inermis*	smooth brome	9	13	6	58	161	87
AGCR	*Agropyron cristatum*	crested wheatgrass	2	6	1	13	68	12
COCA5	*Conyza canadensis*	Canadian horseweed	2	0	1	11	0	17
VEBR	*Verbena bracteata*	bigbract verbena	3	12	3	20	140	46
DESCU	*Descurainia*	tansymustard	4	8	0	27	97	0
GAURA	*Gaura*	beeblossom	3	0	0	17	0	0
EPILO	*Epilobium*	willowherb	2	0	0	16	0	0
NECA2	*Nepeta cataria*	catnip	2	6	3	16	69	43
LEPID	*Lepidium*	pepperweed	1	0	0	5	0	0
AMBRO	*Ambrosia*	ragweed	1	1	2	9	17	31
SALSO	*Salsola*	Russian thistle	1	0	1	4	0	16
CAREX	*Carex*	sedge	1	0	0	4	0	0
CENTA	*Centaurea*	knapweed	0	0	0	3	0	0
DISP	*Distichlis spicata*	saltgrass	0	0	0	1	0	0
MAVE2	*Marsilea vestita*	hairy waterclover	0	0	0	1	0	0
VALER	*Valeriana*	valerian	0	0	0	1	0	0
XANTH2	*Xanthium*	cocklebur	0	1	0	1	7	2
BRAR5	*Bromus arvensis*	field brome	0	0	0	0	0	2
EQUIS	*Equisetum*	horsetail	0	0	0	0	0	0
POPR	*Poa pratensis*	Kentucky bluegrass	0	0	0	1	2	0

Data Tables for Herbaceous Composition and Production by Site

Fort Keogh 2 (East Yellowstone) Treatment Transects *(continued)*

Species	Scientific Name	Common Name	2012 Composition (%)	2013 Composition (%)	2014 Composition (%)	2012 Production (lbs/acre)	2013 Production (lbs/acre)	2014 Production (lbs/acre)
SYOC	*Symphoricarpos occidentalis*	western snowberry	0	0	0	1	0	0
BRTE	*Bromus tectorum*	cheatgrass	0	0	0	0	3	0
CEBI2	*Centaurea biebersteinii*	spotted knapweed	0	0	0	0	4	0
CIRSI	*Cirsium*	thistle	0	1	0	0	7	5
ECCR	*Echinochloa crus-galli*	barnyardgrass	0	1	2	0	10	30
ELAN	*Elaeagnus angustifolia*	Russian olive	0	11	5	0	136	72
PACA6	*Panicum capillare*	witchgrass	0	20	1	0	248	23
POAV	*Polygonum aviculare*	prostrate knotweed	0	3	3	0	36	39
POCO	*Poa compressa*	Canada bluegrass	0	1	1	0	6	22
PODE3	*Populus deltoides*	eastern cottonwood	0	0	11	0	1	178
SIAL2	*Sisymbrium altissimum*	tall tumblemustard	0	6	2	0	77	30
TAMAR2	*Tamarix*	tamarisk	0	0	1	0	2	14
TRIFO	*Trifolium*	clover	0	2	0	0	19	0
MEOF	*Melilotus officinalis*	sweetclover	0	0	5	0	0	70
SALIX	*Salix*	willow	0	0	1	0	0	21
GALIU	*Galium*	bedstraw	0	0	1	0	0	15
POLYG4	*Polygonum*	knotweed	0	0	1	0	0	22
XAST	*Xanthium strumarium*	rough cocklebur	0	0	1	0	0	12
POPA15	*Potentilla paradoxa*	Paradox cinquefoil	0	0	1	0	0	8
OEBI	*Oenothera biennis*	common evening primrose	0	0	1	0	0	9
AF01		annual forb	0	0	0	0	0	7
COAR4	*Convolvulus arvensis*	field bindweed	0	0	1	0	0	9
ERCI	*Eragrostis cilianensis*	stinkgrass	0	0	0	0	0	5
MUHLE	*Muhlenbergia Schreb.*	muhly	0	0	1	0	0	8

Data Tables for Herbaceous Composition and Production by Site

Fort Keogh 2 (East Yellowstone) Treatment Transects *(continued)*								
Species	**Scientific Name**	**Common Name**	**2012 Composition (%)**	**2013 Composition (%)**	**2014 Composition (%)**	**2012 Production (lbs/acre)**	**2013 Production (lbs/acre)**	**2014 Production (lbs/acre)**
LACTU	*Lactuca*	lettuce	0	0	0	0	0	6
PHVI5	*Physalis virginiana*	Virginia groundcherry	0	0	0	0	0	6
PG01		perennial grass	0	0	0	0	0	3
TAOF	*Taraxacum officinale*	common dandelion	0	0	0	0	0	4
CYXA	*Cyclachaena xanthifolia*	giant sumpweed	0	0	0	0	0	4
HEAN3	*Helianthus annuus L.*	common sunflower	0	0	0	0	0	4
HOJU	*Hordeum jubatum*	foxtail barley	0	0	0	0	0	4
RUCR	*Rumex crispus*	curly dock	0	0	0	0	0	4
PLMA2	*Plantago major*	common plantain	0	0	0	0	0	3
		Total	100	100	100	677	1215	1558

Data Tables for Herbaceous Composition and Production by Site

Fort Keogh 2 (East Yellowstone) Control Transect

Species	Scientific Name	Common Name	2012 Composition (%)	2013 Composition (%)	2014 Composition (%)	2012 Production (lbs/acre)	2013 Production (lbs/acre)	2014 Production (lbs/acre)
BRIN2	*Bromus inermis*	smooth brome	27	16	16	174	154	178
CHENO	*Chenopodium*	goosefoot	17	8	6	109	81	62
POPR	*Poa pratensis*	Kentucky bluegrass	15	5	2	95	51	20
DISP	*Distichlis spicata*	saltgrass	13	0	0	81	0	0
PASM	*Pascopyrum smithii*	western wheatgrass	10	7	4	64	69	49
AGCR	*Agropyron cristatum*	crested wheatgrass	9	9	2	55	93	24
DESCU	*Descurainia*	tansymustard	4	0	0	27	0	0
JUNCU	*Juncus*	rush	2	0	0	14	0	0
BRAR5	*Bromus arvensis*	field brome	2	2	4	13	18	47
EQUIS	*Equisetum*	horsetail	1	1	1	6	14	9
AMBRO	*Ambrosia*	ragweed	0	1	9	3	14	100
CIRSI	*Cirsium*	thistle	0	2	0	0	16	0
ELTR7	*Elymus trachycaulus*	slender wheatgrass	0	8	0	0	77	0
PACA6	*Panicum capillare*	witchgrass	0	1	0	0	10	0
POAV	*Polygonum aviculare*	prostrate knotweed	0	3	0	0	28	0
POCO	*Poa compressa*	Canada bluegrass	0	5	0	0	47	0
SEVI4	*Setaria viridis*	green bristlegrass	0	2	0	0	16	0
SIAL2	*Sisymbrium altissimum*	tall tumblemustard	0	30	15	0	300	164
THIN6	*Thinopyrum intermedium*	intermediate wheatgrass	0	0	29	0	0	320
COCA5	*Conyza canadensis*	Canadian horseweed	0	0	5	0	0	51
CALO	*Calamovilfa longifolia*	prairie sandreed	0	0	3	0	0	31
XAST	*Xanthium strumarium*	rough cocklebur	0	0	3	0	0	29
NECA2	*Nepeta cataria*	catnip	0	0	1	0	0	16
CENTA	*Centaurea*	knapweed	0	0	0	0	0	4
GLLE3	*Glycyrrhiza lepidota*	American licorice	0	0	0	0	0	2
HOJU	*Hordeum jubatum*	foxtail barley	0	0	0	0	0	2

Data Tables for Herbaceous Composition and Production by Site

Fort Keogh 2 (East Yellowstone) Control Transect *(continued)*

Species	Scientific Name	Common Name	2012 Composition (%)	2013 Composition (%)	2014 Composition (%)	2012 Production (lbs/acre)	2013 Production (lbs/acre)	2014 Production (lbs/acre)
TAOF	*Taraxacum officinale*	common dandelion	0	0	0	0	0	2
		Total	100	100	100	640	986	1111

Data Tables for Herbaceous Composition and Production by Site

Lovell Treatment Transects								
Species	**Scientific Name**	**Common Name**	**2012 Composition (%)**	**2013 Compositio n (%)**	**2014 Composition (%)**	**2012 Production (lbs/acre)**	**2013 Production (lbs/acre)**	**2014 Production (lbs/acre)**
SYOC	*Symphoricarpos occidentalis*	western snowberry	32	19	23	479	204	410
POPR	*Poa pratensis*	Kentucky bluegrass	20	0	5	296	0	97
THIN6	*Thinopyrum intermedium*	intermediate wheatgrass	15	8	29	223	89	529
SPCR	*Sporobolus cryptandrus*	sand dropseed	5	6	2	74	61	28
ELTR7	*Elymus trachycaulus*	slender wheatgrass	6	11	0	85	121	0
CIRSI	*Cirsium*	thistle	2	3	1	27	30	9
GLLE3	*Glycyrrhiza lepidota*	American licorice	6	4	5	84	46	86
PHPR3	*Phleum pratense*	timothy	5	0	5	82	1	89
BRIN2	*Bromus inermis*	smooth brome	3	4	1	46	40	22
CARDA2	*Cardaria draba*	whitetop	2	0	8	32	0	145
MAIAN	*Maianthemum*	mayflower	3	0	0	46	0	0
ELCA4	*Elymus canadensis*	Canada wildrye	1	0	2	17	0	30
ASCLE	*Asclepias*	milkweed	0	0	0	3	1	0
MELIL	*Melilotus*	sweetclover	0	0	0	1	1	0
ELAN	*Elaeagnus angustifolia*	Russian olive	0	3	0	0	35	0
TAMAR2	*Tamarix*	tamarisk	0	0	0	1	1	0
ASSP	*Asclepias speciosa*	showy milkweed	0	1	3	0	6	48
ASTRA	*Astragalus*	milkvetch	0	7	1	0	70	27
BRTE	*Bromus tectorum*	cheatgrass	0	1	0	0	7	0
CADR	*Cardaria*	whitetop	0	11	0	0	119	0
CAREX	*Carex*	sedge	0	0	0	0	1	0
LITHO3	*Lithospermum*	stoneseed	0	1	0	0	6	0
PACA6	*Panicum capillare*	witchgrass	0	0	0	0	5	0
PASM	*Pascopyrum smithii*	western wheatgrass	0	14	0	0	149	0
POAN3	*Populus angustifolia*	narrowleaf cottonwood	0	6	0	0	59	0
PODE3	*Populus deltoides*	eastern cottonwood	0	2	4	0	17	69

Data Tables for Herbaceous Composition and Production by Site

Lovell Treatment Transects *(continued)*

Species	Scientific Name	Common Name	2012 Composition (%)	2013 Composition (%)	2014 Composition (%)	2012 Production (lbs/acre)	2013 Production (lbs/acre)	2014 Production (lbs/acre)
RHTR	*Rhus trilobata*	skunkbush sumac	0	0	0	0	1	0
DISP	*Distichlis spicata*	saltgrass	0	0	3	0	0	53
HOPU	*Hordeum pusillum*	little barley	0	0	0	0	0	6
SALIX	*Salix*	willow	0	0	8	0	0	137
SALSO	*Salsola*	Russian thistle	0	0	2	0	0	28
		Total	100	100	100	1496	1069	1813

Data Tables for Herbaceous Composition and Production by Site

Lovell Mulch Transects

Species	Scientific Name	Common Name	2012 Composition (%)	2013 Composition (%)	2014 Composition (%)	2012 Production (lbs/acre)	2013 Production (lbs/acre)	2014 Production (lbs/acre)
BRIN2	*Bromus inermis*	smooth brome	22	4	2	718	231	126
SPAI	*Sporobolus airoides*	alkali sacaton	11	0	0	366	0	0
THIN6	*Thinopyrum intermedium*	intermediate wheatgrass	17	0	22	552	0	1845
ALPR3	*Alopecurus pratensis*	meadow foxtail	15	0	0	501	0	0
CHENO	*Chenopodium*	goosefoot	13	6	1	444	412	105
GLLE3	*Glycyrrhiza lepidota*	American licorice	10	6	8	347	417	671
CIRSI	*Cirsium*	thistle	6	11	12	193	692	1028
SYOC	*Symphoricarpos occidentalis*	western snowberry	2	2	9	80	122	769
ASSP	*Asclepias speciosa*	showy milkweed	2	7	8	52	427	657
CADR	*Cardaria draba*	whitetop	1	2	0	18	137	14
SPSA3	*Sphaerophysa salsula*	alkali swainsonpea	1	0	0	18	0	0
COUM	*Comandra umbellata*	bastard toadflax	0	0	2	15	7	140
GRSQ	*Grindelia squarrosa*	curlycup gumweed	0	0	0	9	0	0
ASTRA	*Astragalus*	milkvetch	0	2	6	0	111	489
DISP	*Distichlis spicata*	saltgrass	0	0	0	0	12	14
ELAN	*Elaeagnus angustifolia*	Russian olive	0	7	0	0	428	0
ELTR7	*Elymus trachycaulus*	slender wheatgrass	0	6	0	0	397	0
JUNCU	*Juncus*	rush	0	0	0	0	5	0
PHPR3	*Phleum pratense*	timothy	0	41	18	0	2639	1496
SOMO	*Solidago mollis*	velvety goldenrod	0	0	0	0	11	0
SPCR	*Sporobolus cryptandrus*	sand dropseed	0	0	0	0	2	0
SPPE	*Spartina pectinata*	prairie cordgrass	0	0	0	0	2	0
TAMAR2	*Tamarix*	tamarisk	0	5	3	0	300	224
TRIFO	*Trifolium*	clover	0	1	0	0	95	0
XANTH2	*Xanthium*	cocklebur	0	0	0	0	2	0
ASCLE	*Asclepias*	milkweed	0	0	1	0	0	98

Data Tables for Herbaceous Composition and Production by Site

Lovell Mulch Transects *(continued)*

Species	Scientific Name	Common Name	2012 Composition (%)	2013 Composition (%)	2014 Composition (%)	2012 Production (lbs/acre)	2013 Production (lbs/acre)	2014 Production (lbs/acre)
CARDA2	*Cardaria*	whitetop	0	0	3	0	0	224
CAREX	*Carex*	sedge	0	0	0	0	0	14
EQUIS	*Equisetum*	horsetail	0	0	0	0	0	14
HOPU	*Hordeum pusillum*	little barley	0	0	0	0	0	28
RIBES	*Ribes*	currant	0	0	1	0	0	56
SALSO	*Salsola*	Russian thistle	0	0	3	0	0	252
		Total	100	100	100	3316	6449	6511

Data Tables for Herbaceous Composition and Production by Site

Lovell Control Transect

Species	Scientific Name	Common Name	2012 Composition (%)	2013 Composition (%)	2014 Composition (%)	2012 Production (lbs/acre)	2013 Production (lbs/acre)	2014 Production (lbs/acre)
ELTR7	*Elymus trachycaulus*	slender wheatgrass	46	49	0	617	701	0
BRIN2	*Bromus inermis*	smooth brome	12	17	0	158	249	0
POPR	*Poa pratensis*	Kentucky bluegrass	11	0	2	150	0	25
THIN6	*Thinopyrum intermedium*	intermediate wheatgrass	11	0	81	150	0	1267
GLLE3	*Glycyrrhiza lepidota*	American licorice	11	9	8	142	132	121
SYOC	*Symphoricarpos occidentalis*	western snowberry	5	9	3	62	135	44
ASCLE	*Asclepias*	milkweed	2	0	0	24	0	0
EQUIS	*Equisetum*	horsetail	1	1	1	13	14	16
MAIAN	*Maianthemum*	mayflower	1	0	0	13	0	0
SPAI	*Sporobolus airoides*	alkali sacaton	1	0	0	8	0	6
ASSP	*Asclepias speciosa*	showy milkweed	0	0	3	0	3	53
DISP	*Distichlis spicata*	saltgrass	0	2	0	0	29	0
ELAN	*Elaeagnus angustifolia*	Russian olive	0	3	0	0	49	0
ELCA4	*Elymus canadensis*	Canada wildrye	0	1	0	0	11	0
PASM	*Pascopyrum smithii*	western wheatgrass	0	4	0	0	57	0
POAN3	*Populus angustifolia*	narrowleaf cottonwood	0	0	0	0	6	0
SPCR	*Sporobolus cryptandrus*	sand dropseed	0	3	0	0	40	0
TRDU	*Tragopogon dubius*	yellow salsify	0	0	0	0	6	0
SALIX	*Salix*	willow	0	0	1	0	0	16
CHENO	*Chenopodium*	goosefoot	0	0	0	0	0	6
CARDA2	*Cardaria*	whitetop	0	0	0	0	0	3
		Total	100	100	100	1337	1431	1556

Data Tables for Herbaceous Composition and Production by Site

Sturgis Site 1 Treatment Transects

Species	Scientific Name	Common Name	2012 Composition (%)	2013 Composition (%)	2014 Composition (%)	2012 Production (lbs/acre)	2013 Production (lbs/acre)	2014 Production (lbs/acre)
THIN6	*Thinopyrum intermedium*	intermediate wheatgrass	31	28	32	675	788	986
BRIN2	*Bromus inermis*	smooth brome	44	16	11	938	448	325
SONU2	*Sorghastrum nutans*	Indiangrass	14	0	0	302	0	0
JUBA	*Juncus balticus*	mountain rush	3	2	5	57	63	161
COAR4	*Convolvulus arvensis*	field bindweed	2	2	1	41	63	45
POPR	*Poa pratensis*	Kentucky bluegrass	2	22	20	48	620	627
CIRSI	*Cirsium*	thistle	2	4	1	40	117	45
TRIFO	*Trifolium*	clover	1	0	0	15	5	0
AGST2	*Agrostis stolonifera*	creeping bentgrass	1	16	9	13	449	287
GLLE3	*Glycyrrhiza lepidota*	American licorice	0	0	0	7	0	0
SCIRP	*Scirpus*	bulrush	0	0	1	4	0	40
TAOF	*Taraxacum officinale*	common dandelion	0	3	1	6	93	21
AMBRO	*Ambrosia*	ragweed	0	1	2	2	16	49
CAREX	*Carex*	sedge	0	3	0	2	80	0
ELAN	*Elaeagnus angustifolia*	Russian olive	0	1	1	0	20	23
MELU	*Medicago lupulina*	black medick	0	2	0	0	54	10
MEOF	*Melilotus officinalis*	sweetclover	0	0	0	0	3	0
PACA6	*Panicum capillare*	witchgrass	0	1	1	0	20	31
PHPR3	*Phleum pratense*	timothy	0	1	11	0	18	336
SEVI4	*Setaria viridis*	green bristlegrass	0	0	2	0	0	54
AF01		annual forb	0	0	1	0	0	27
CICHO	*Cichorium*	chicory	0	0	0	0	0	5
NAVI4	*Nassella viridula*	green needlegrass	0	0	0	0	0	9
		Total	100	100	100	2150	2855	3082

Data Tables for Herbaceous Composition and Production by Site

Sturgis Site 2 Treatment Transect

Species	Scientific Name	Common Name	2012 Composition (%)	2013 Composition (%)	2014 Composition (%)	2012 Production (lbs/acre)	2013 Production (lbs/acre)	2014 Production (lbs/acre)
BRIN2	*Bromus inermis*	smooth brome	72	60	9	1979	1057	168
CAREX	*Carex*	sedge	17	7	24	454	126	446
POPR	*Poa pratensis*	Kentucky bluegrass	4	22	1	115	382	26
JUBA	*Juncus balticus*	mountain rush	2	0	18	55	7	329
EQLA	*Equisetum laevigatum*	smooth horsetail	2	0	0	49	7	7
AGST2	*Agrostis stolonifera*	creeping bentgrass	1	0	32	22	0	581
CRYPT	*Cryptantha*	cryptantha	0	0	0	11	0	0
GLLE3	*Glycyrrhiza lepidota*	American licorice	0	0	1	11	4	18
PHPR3	*Phleum pratense*	timothy	0	4	6	11	74	102
CIRSI	*Cirsium*	thistle	0	1	1	11	11	11
CYOF	*Cynoglossum officinale*	gypsyflower	0	1	0	6	11	0
SCIRP	*Scirpus*	bulrush	0	0	0	6	0	0
SYOC	*Symphoricarpos occidentalis*	western snowberry	0	0	0	6	0	0
ELAN	*Elaeagnus angustifolia*	Russian olive	0	2	1	0	28	11
MELU	*Medicago lupulina*	black medick	0	0	2	0	4	44
TAMAR2	*Tamarix*	tamarisk	0	0	0	0	7	0
TAOF	*Taraxacum officinale*	common dandelion	0	1	1	0	11	15
TRIFO	*Trifolium*	clover	0	1	1	0	25	11
AMBRO	*Ambrosia*	ragweed	0	0	2	0	0	33
SEVI4	*Setaria viridis*	green bristlegrass	0	0	1	0	0	26
		Total	100	100	100	2733	1750	1827

Data Tables for Herbaceous Composition and Production by Site

Sturgis Site 2 Control Transect

Species	Scientific Name	Common Name	2012 Composition (%)	2013 Composition (%)	2014 Composition (%)	2012 Production (lbs/acre)	2013 Production (lbs/acre)	2014 Production (lbs/acre)
BRIN2	*Bromus inermis*	smooth brome	43	30	12	1014	590	236
SPPE	*Spartina pectinata*	prairie cordgrass	28	21	5	671	423	89
ANGE	*Andropogon gerardii*	big bluestem	20	6	12	485	115	229
PAVI2	*Panicum virgatum*	switchgrass	3	0	0	67	0	0
CIRSI	*Cirsium*	thistle	2	5	12	48	107	229
AGST2	*Agrostis stolonifera*	creeping bentgrass	1	0	17	29	0	337
JUBA	*Juncus balticus*	mountain rush	1	1	6	14	20	116
LITHO3	*Lithospermum*	stoneseed	1	0	0	14	0	0
GLLE3	*Glycyrrhiza lepidota*	American licorice	0	0	1	10	8	12
POPR	*Poa pratensis*	Kentucky bluegrass	0	9	2	10	170	31
EQLA	*Equisetum laevigatum*	smooth horsetail	0	0	0	5	0	0
MOFI	*Monarda fistulosa*	wild bergamot	0	0	0	5	0	0
SYOC	*Symphoricarpos occidentalis*	western snowberry	0	0	0	5	0	0
TAOF	*Taraxacum officinale*	common dandelion	0	0	0	5	4	0
CRYPT	*Cryptantha*	cryptantha	0	1	0	0	20	4
CYOF	*Cynoglossum officinale*	gypsyflower	0	1	6	0	20	109
ELAN	*Elaeagnus angustifolia*	Russian olive	0	0	0	0	4	8
PHPR3	*Phleum pratense*	timothy	0	4	0	0	83	0
SONU2	*Sorghastrum nutans*	Indiangrass	0	2	25	0	396	492
TRIFO	*Trifolium*	clover	0	1	0	0	20	0
CAREX	*Carex*	sedge	0	0	1	0	0	27
MELU	*Medicago lupulina*	black medick	0	0	1	0	0	19
		Total	100	100	100	2380	1978	1938

Data Tables for Woody Species Density

2012 Woody Species Density by Size Class (plants/ha)

	Tamarix (TAMAR2)							*Elaeagnus angustifolia* (ELAN)						
Site	< 20 cm	20-100 cm	1-2 m	2-4 m	>4 m	Dead	**TAMAR2 Total**	<30 cm	30-180 cm	DBH 2.5-15 cm	DBH 15-25 cm	DBH >25 cm	Dead	**ELAN Total**
Allen Control	0	0	0	0	0	0	0	0	0	200	600	450	300	1550
Allen Treatment	0	0	0	0	0	0	0	0	0	167	467	333	50	1017
Arapooish Control	0	0	0	200	400	0	600	0	0	50	100	200	0	350
Arapooish Treatment	0	0	17	300	217	0	533	0	75	267	125	67	50	583
Ft. Keogh 1 Control	0	0	0	0	0	0	0	0	100	700	1500	100	200	2600
Ft. Keogh 1 Treatment	33	0	0	0	0	0	33	0	100	967	900	467	433	2867
Ft. Keogh 2 Control	0	50	300	150	250	0	750	0	0	400	100	50	0	550
Ft. Keogh 2 Treatment	6667	34000	0	1400	50	0	42117	0	50	1467	717	250	300	2783
Lovell Control	0	0	0	0	0	0	0	0	450	400	50	0	150	1050
Lovell Mulch	0	0	0	25	400	238	663	0	50	50	88	175	38	400
Lovell Treatment	0	17	0	0	0	117	133	0	83	117	50	33	100	383
Sturgis 1 Treatment	0	0	0	0	0	0	0	25	69	525	6	0	13	638
Sturgis 2 Control	0	0	0	0	0	0	0	0	100	175	75	75	0	425
Sturgis 2 Treatment	0	0	0	0	0	0	0	0	150	550	200	0	0	900

Other woody species encountered in 2012 include:

Multi-Stem
- *Salix*, willow (SALIX)
- *Rhus trilobata*, skunkbush sumac (RHTR)

Single-Stem
- *Fraxinus pennsylvanica*, green ash (FRPE)
- *Juniperus occidentalis*, western juniper (JUOC)
- *Populus deltoids*, eastern cottonwood (PODE3)
- *Shepherdia argentea*, silver buffaloberry (SHAR)

Data Tables for Woody Species Density

2013 Woody Species Density by Size Class (plants/ha)

	Tamarix (TAMAR2)							*Elaeagnus angustifolia* (ELAN)						
Site	< 20 cm	20-100 cm	1-2 m	2-4 m	>4 m	Dead	**TAMAR2 Total**	<30 cm	30-180 cm	DBH 2.5-15 cm	DBH 15-25 cm	DBH >25 cm	Dead	**ELAN Total**
Allen Control	0	0	0	0	0	0	0	0	0	250	350	200	100	900
Allen Treatment	0	0	0	0	0	0	0	33	0	0	0	0	0	33
Arapooish Control	0	50	50	150	0	0	250	0	0	100	50	100	0	250
Arapooish Treatment	0	0	0	0	0	0	0	3633	0	0	0	0	0	3633
Ft. Keogh 1 Control	0	0	0	0	0	0	0	0	0	600	200	0	100	900
Ft. Keogh 1 Treatment	0	0	0	0	0	0	0	99400	1133	0	0	0	0	100533
Ft. Keogh 2 Control	0	0	100	0	0	0	100	0	0	0	0	0	0	0
Ft. Keogh 2 Treatment	300	0	0	0	0	0	300	31283	33	0	0	0	0	31317
Lovell Control	0	0	0	0	0	0	0	100	500	0	0	0	500	1100
Lovell Mulch	0	50	450	0	0	0	500	0	1200	0	0	0	0	1200
Lovell Treatment	0	0	0	0	0	0	0	133	67	0	0	0	0	200
Sturgis 1 Treatment	0	0	0	0	0	0	0	12275	0	0	0	0	0	12275
Sturgis 2 Control	0	0	0	0	0	0	0	0	150	150	100	0	0	400
Sturgis 2 Treatment	0	0	0	0	0	0	0	13600	100	0	0	0	0	13700

Other woody species encountered in 2013 include:

Multi-Stem
- No multi stemmed species encountered

Single-Stem
- *Populus angustifolia*, narrowleaf cottonwood (POAN3)
- *Populus deltoids*, eastern cottonwood (PODE3)
- *Salix amygdaloides*, peachleaf willow (SAAM2)
- *Symphoricarpos occidentalis*, western snowberry (SYOC)

Data Tables for Woody Species Density

2014 Woody Species Density by Size Class (plants/ha)

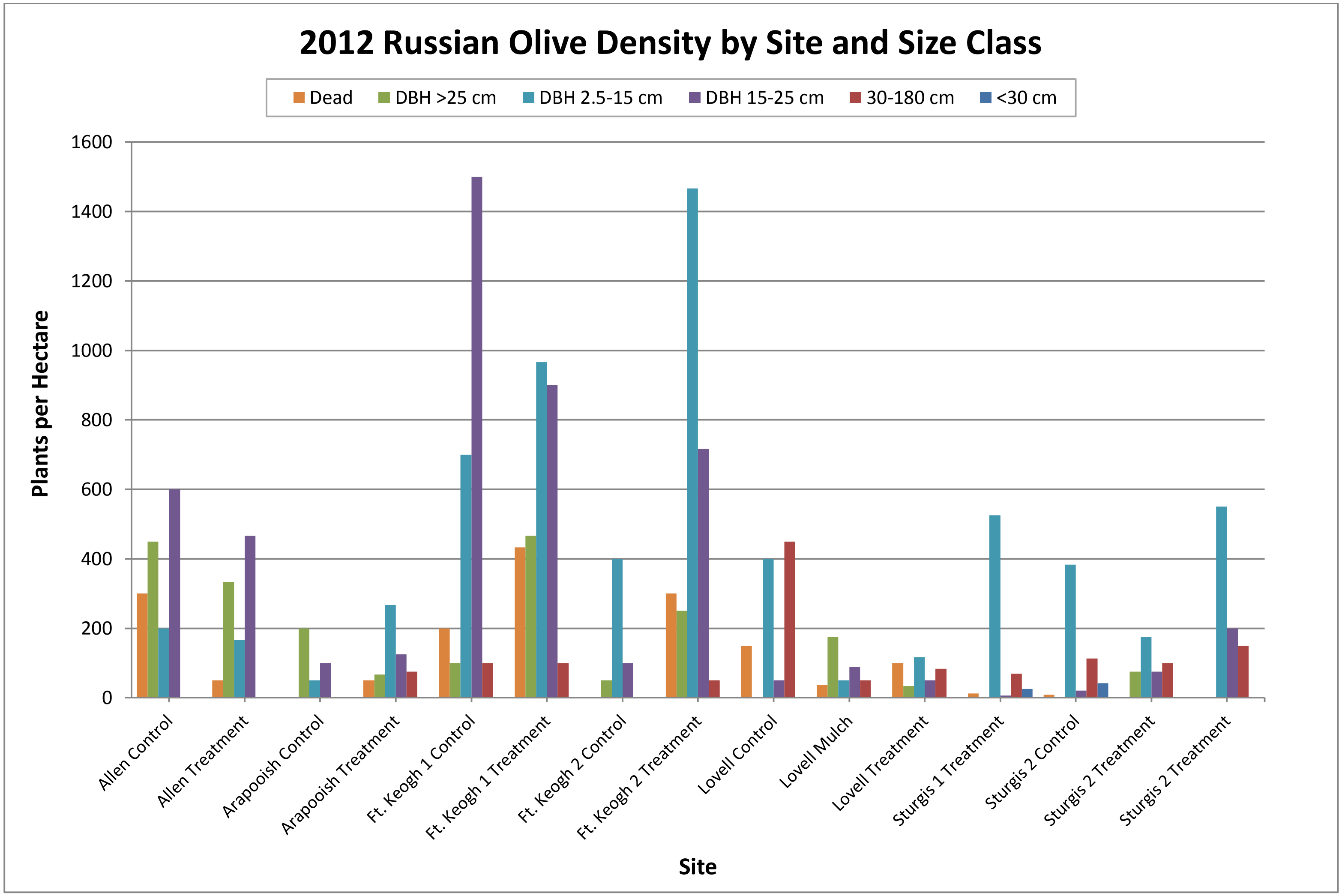
	Tamarix (TAMAR2)							*Elaeagnus angustifolia* (ELAN)						
Site	< 20 cm	20-100 cm	1-2 m	2-4 m	>4 m	Dead	**TAMAR2 Total**	<30 cm	30-180 cm	DBH 2.5-15 cm	DBH 15-25 cm	DBH >25 cm	Dead	**ELAN Total**
Allen Control	0	0	0	0	0	0	0	50	0	300	350	250	0	950
Allen Treatment	0	0	0	0	0	0	0	133	733	0	0	0	0	867
Arapooish Control	0	0	0	100	0	0	100	100	0	100	0	150	0	350
Arapooish Treatment	0	0	0	0	0	0	0	1017	367	0	0	0	0	1383
Ft. Keogh 1 Control	0	0	0	0	0	0	0	200	0	500	100	0	0	800
Ft. Keogh 1 Treatment	0	0	0	0	0	0	0	567	2433	0	0	0	0	3000
Ft. Keogh 2 Control	0	0	50	350	0	0	400	0	0	150	0	0	0	150
Ft. Keogh 2 Treatment	1533	0	0	0	0	0	1533	21950	2683	0	0	0	0	24633
Lovell Control	0	0	0	0	0	0	0	0	0	950	50	0	0	1000
Lovell Mulch	0	25	125	0	0	0	150	0	125	0	0	0	0	125
Lovell Treatment	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sturgis 1 Treatment	0	0	0	0	0	0	0	6400	375	0	0	0	0	6775
Sturgis 2 Control	0	0	0	0	0	0	0	0	0	450	100	0	0	550
Sturgis 2 Treatment	0	0	0	0	0	0	0	10350	50	0	0	0	0	10400

Other woody species encountered in 2014 include:

Multi-Stem
- *Salix*, willow (SALIX)

Single-Stem
- *Physalis virginiana*, Virginia groundcherry (PHVI5)
- *Populus deltoids*, eastern cottonwood (PODE3)
- *Symphoricarpos occidentalis*, western snowberry (SYOC)

Graph for Russian Olive Density



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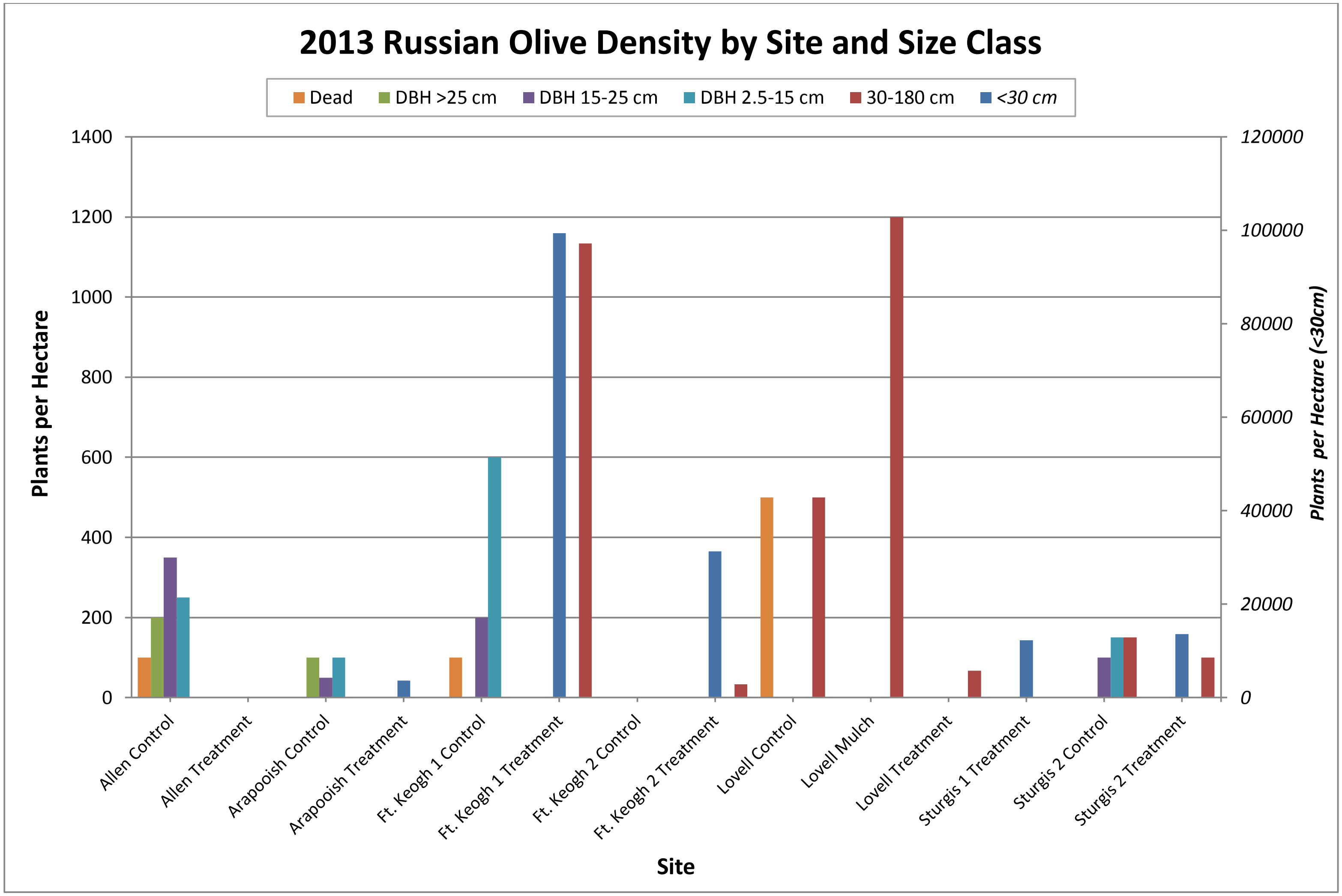
Graph for Russian Olive Density



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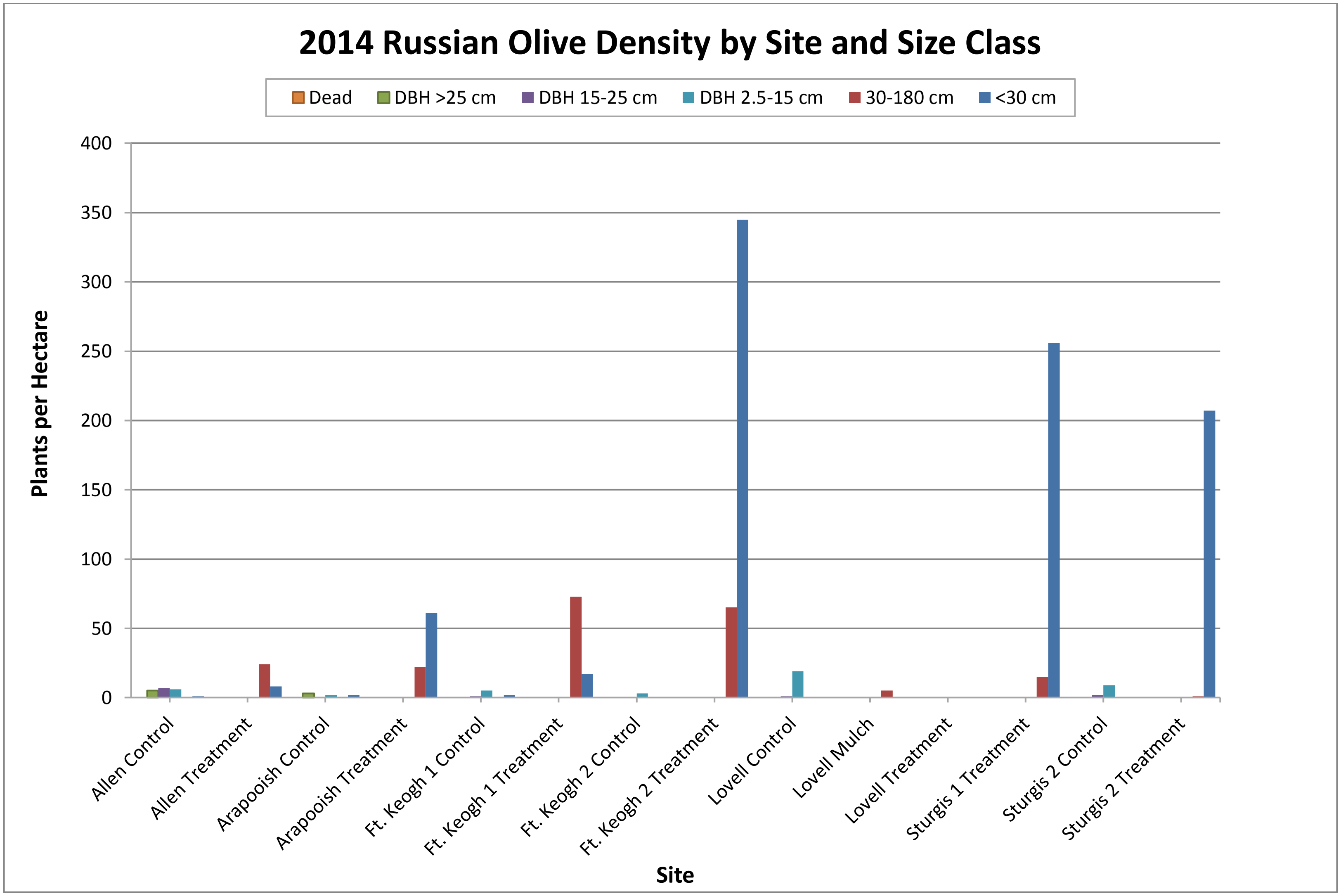
Graph for Russian Olive Density



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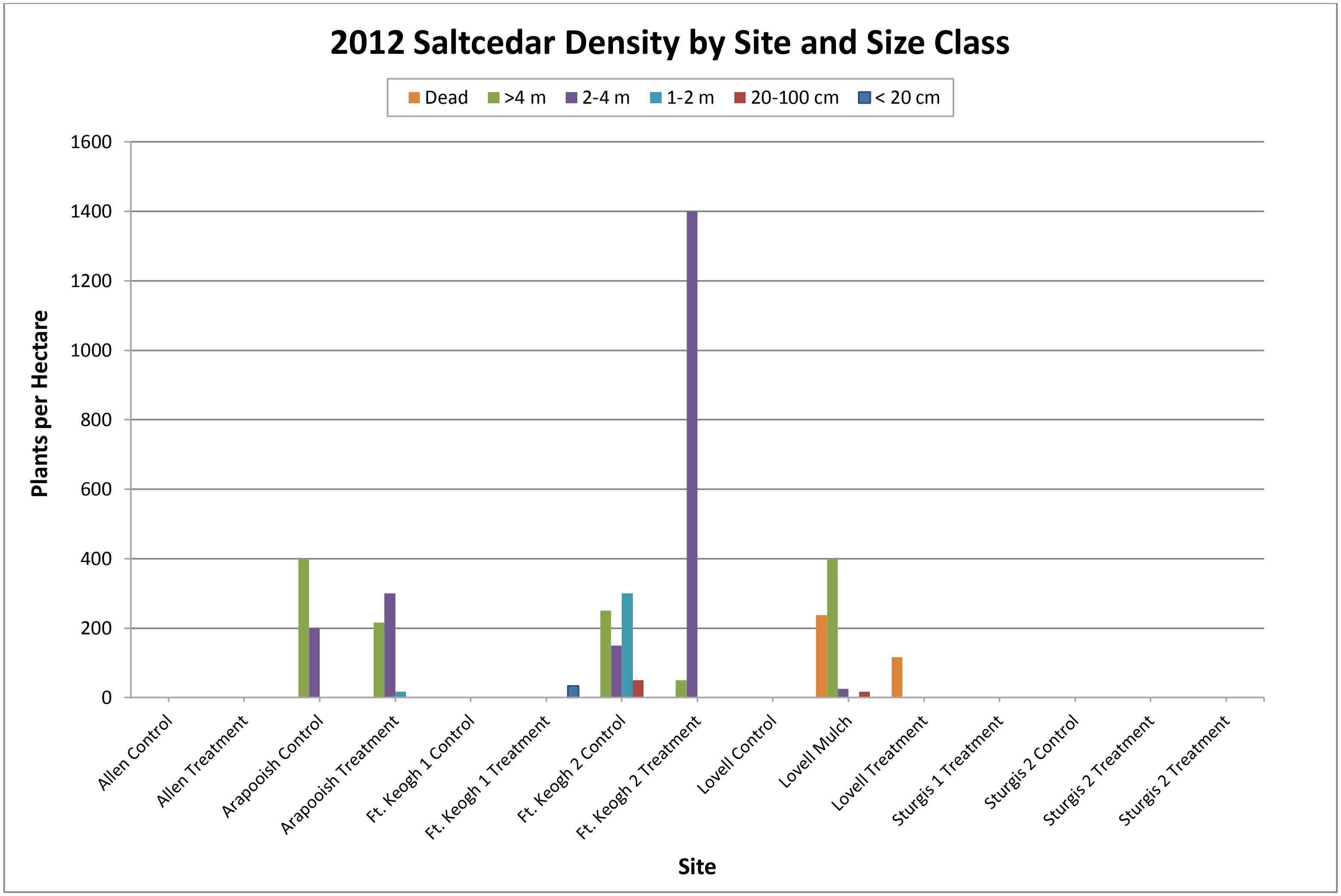
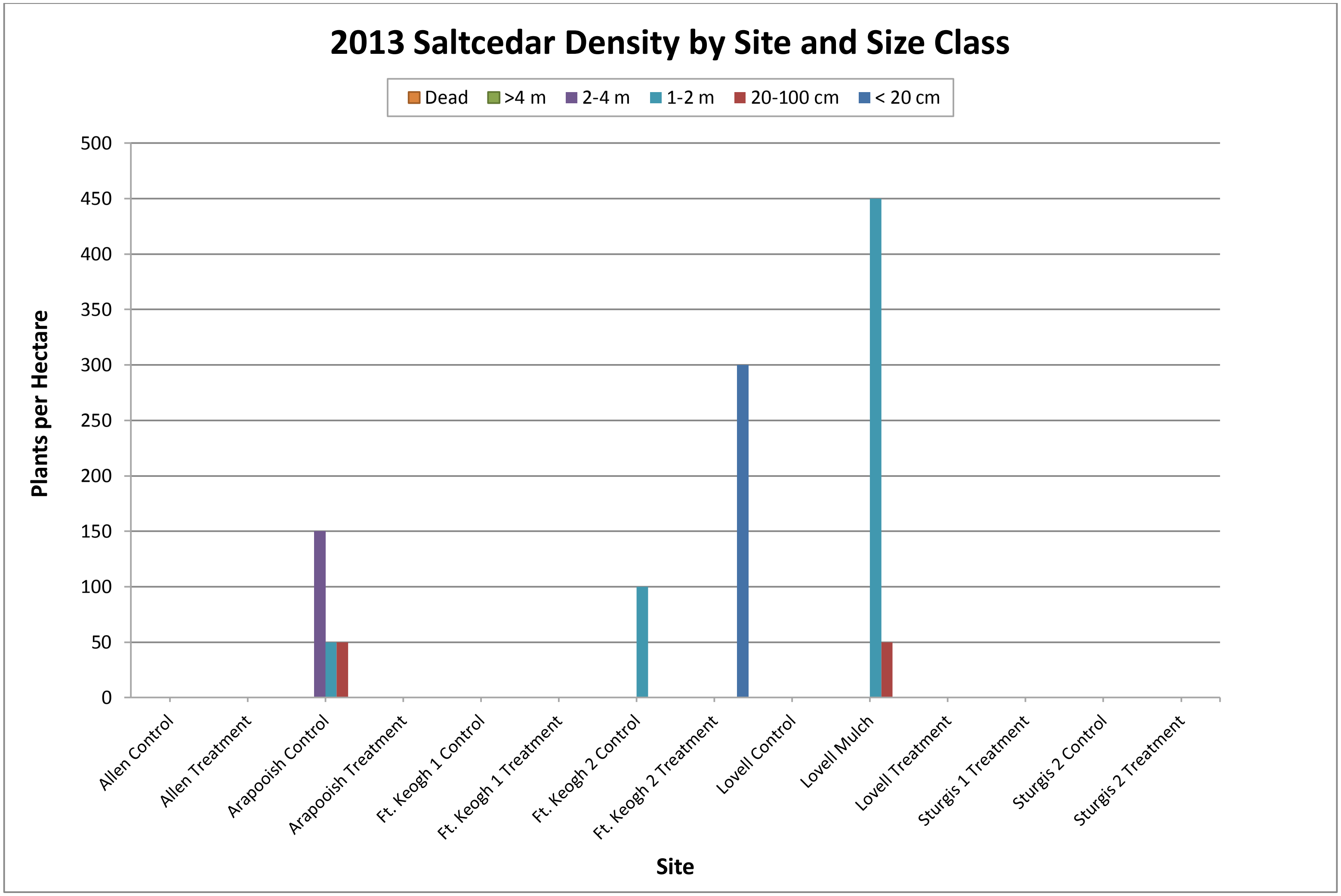
Graph for Saltcedar Density



Graph for Saltcedar Density



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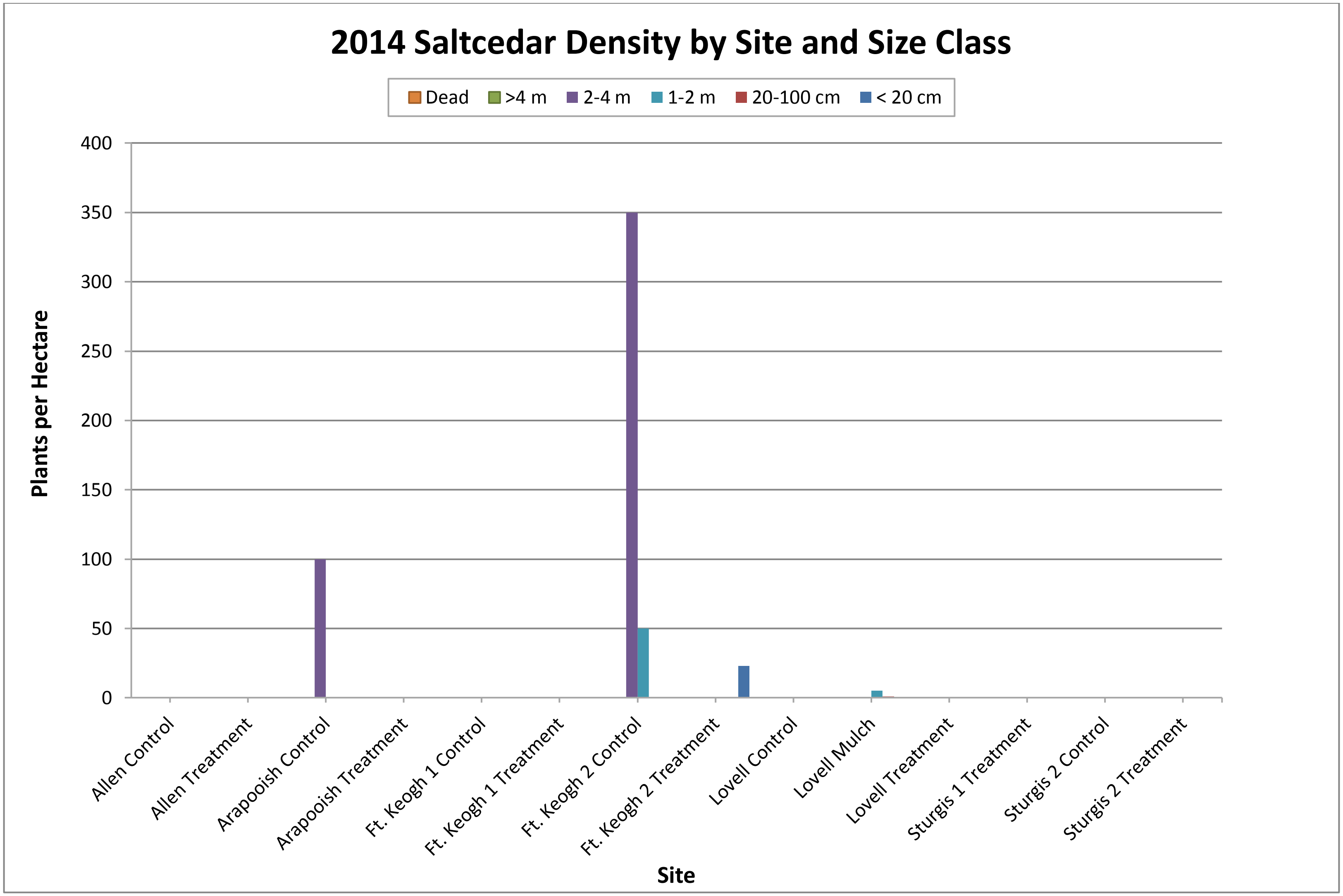
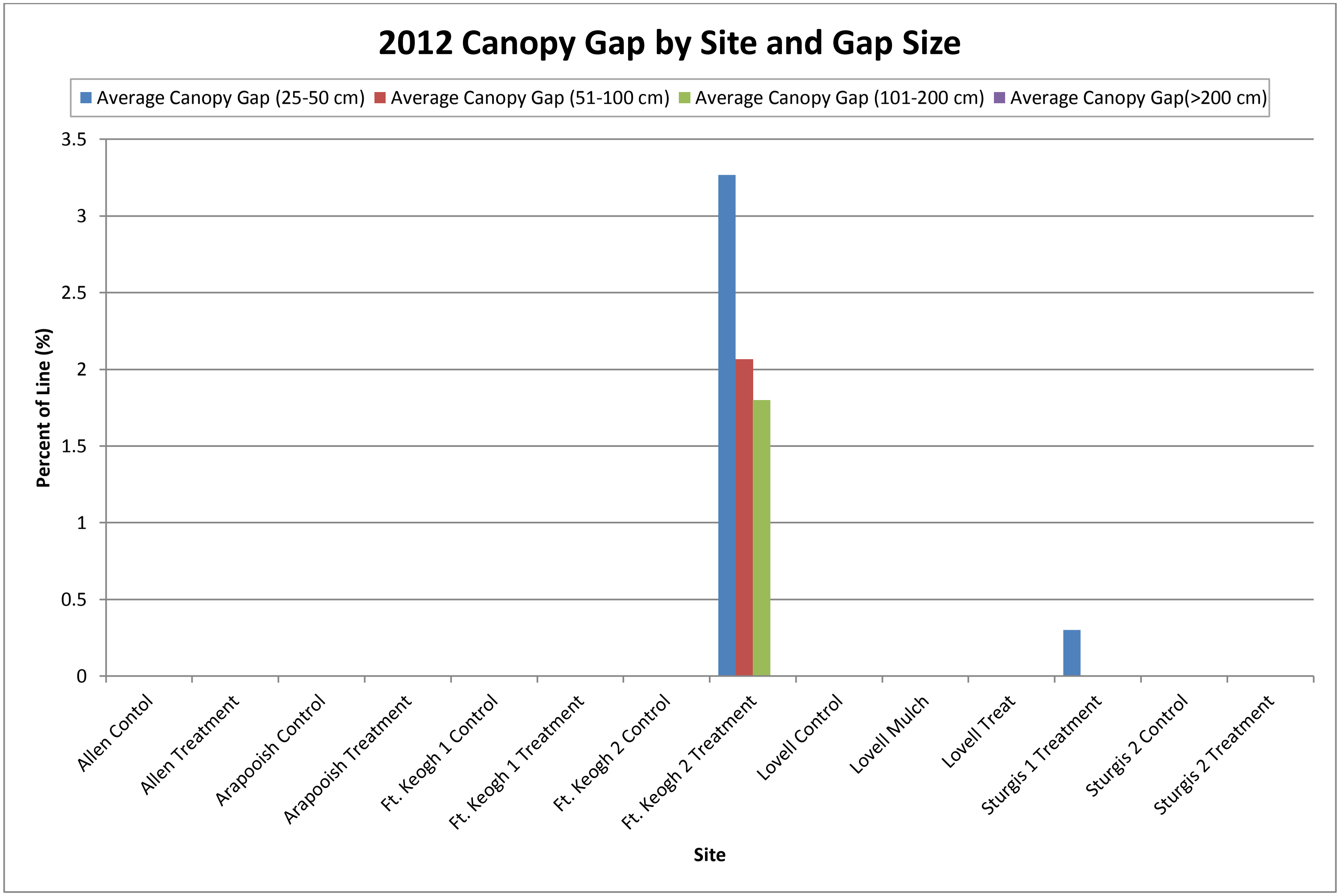
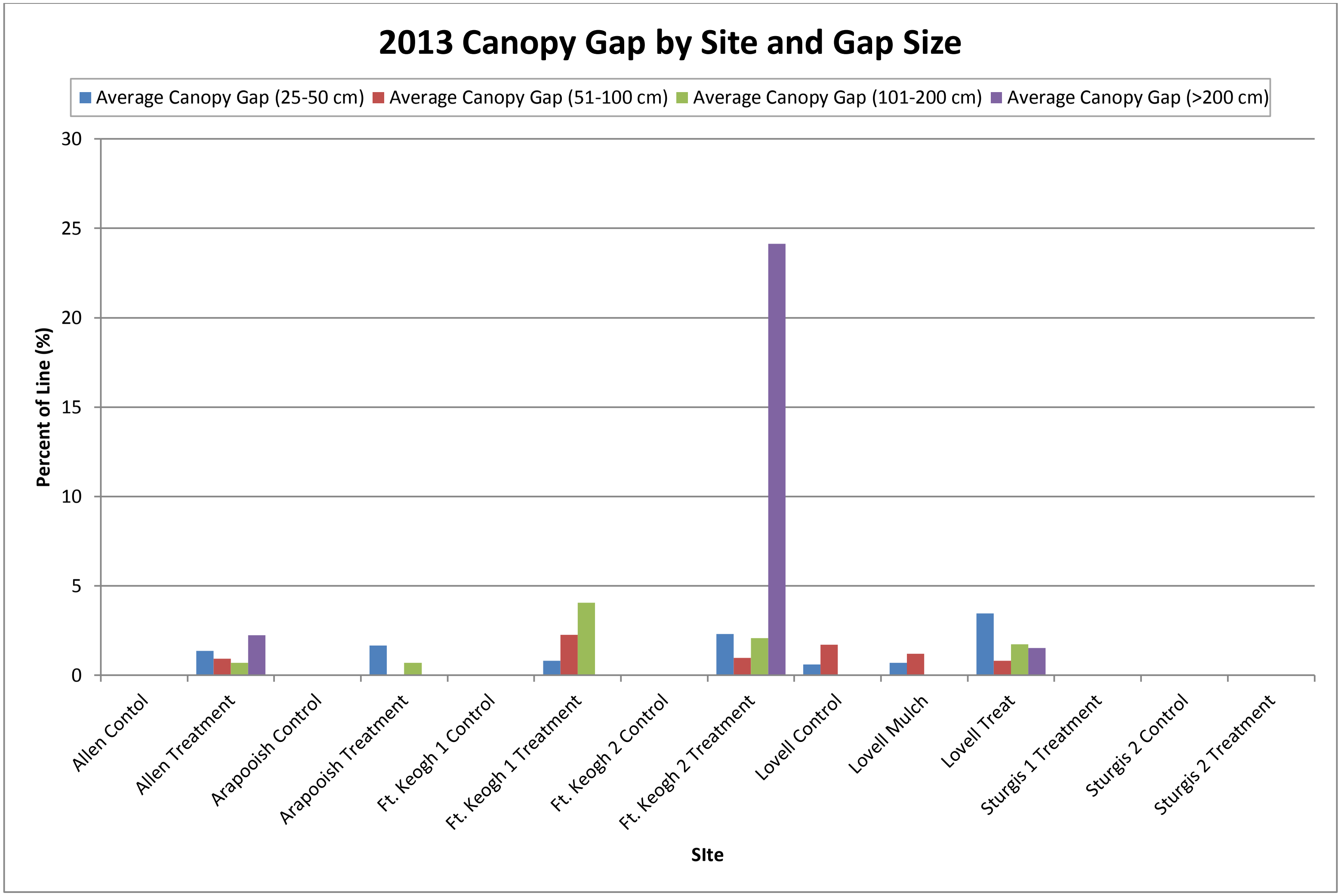
Graph for Saltcedar Density



Graphs for Canopy and Basal Gap by Site



Graphs for Canopy and Basal Gap by Site



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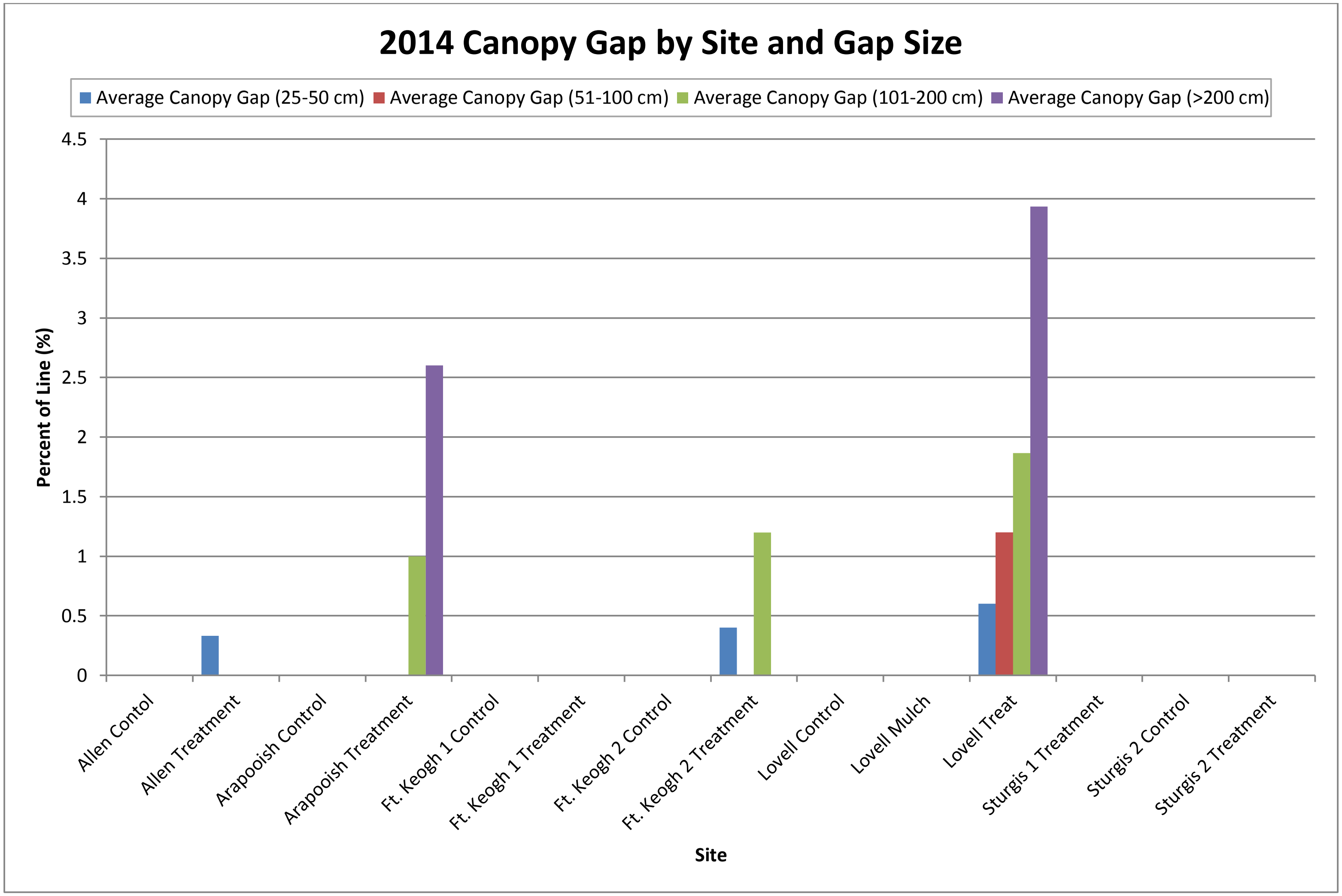
Graphs for Canopy and Basal Gap by Site



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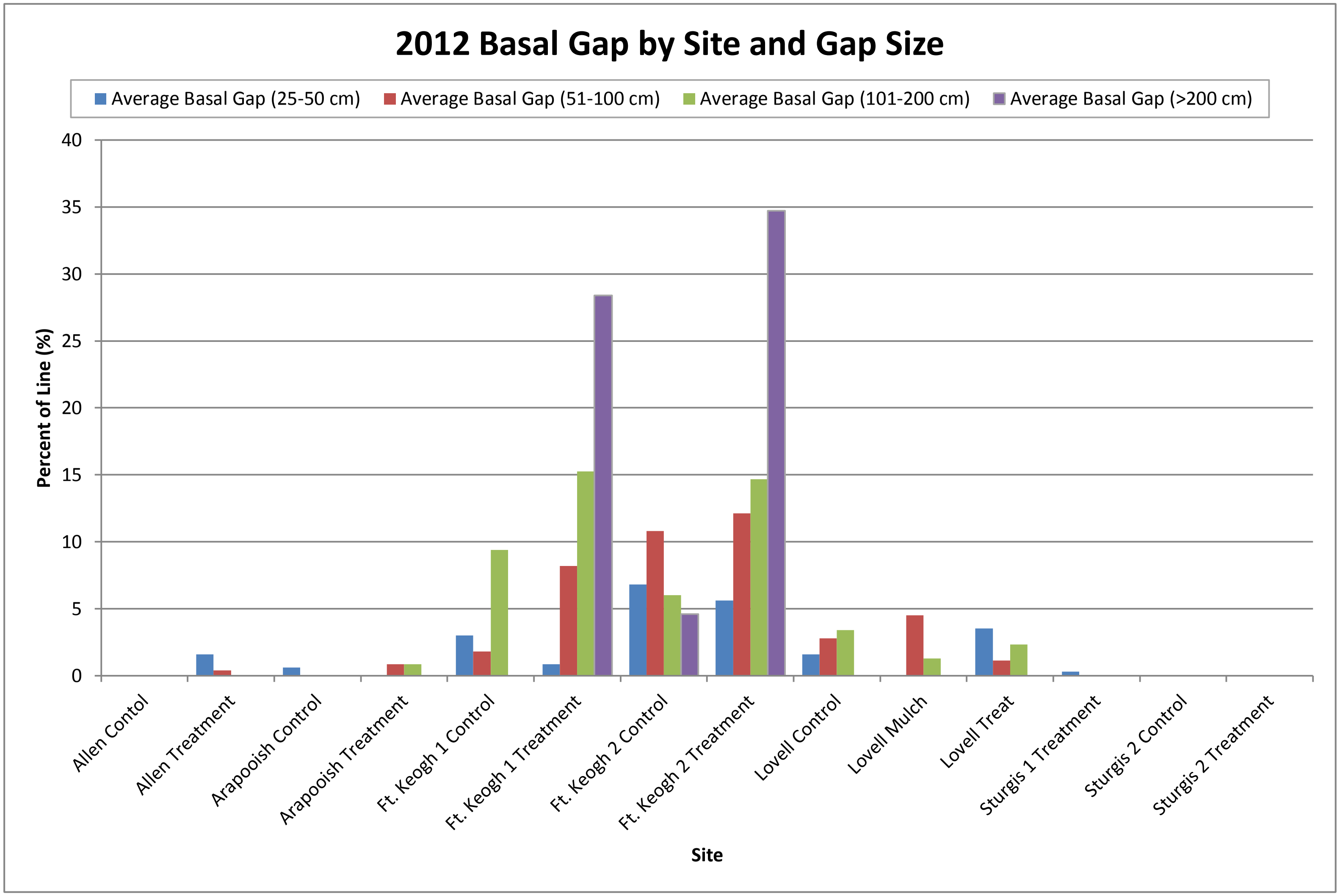
Graphs for Canopy and Basal Gap by Site



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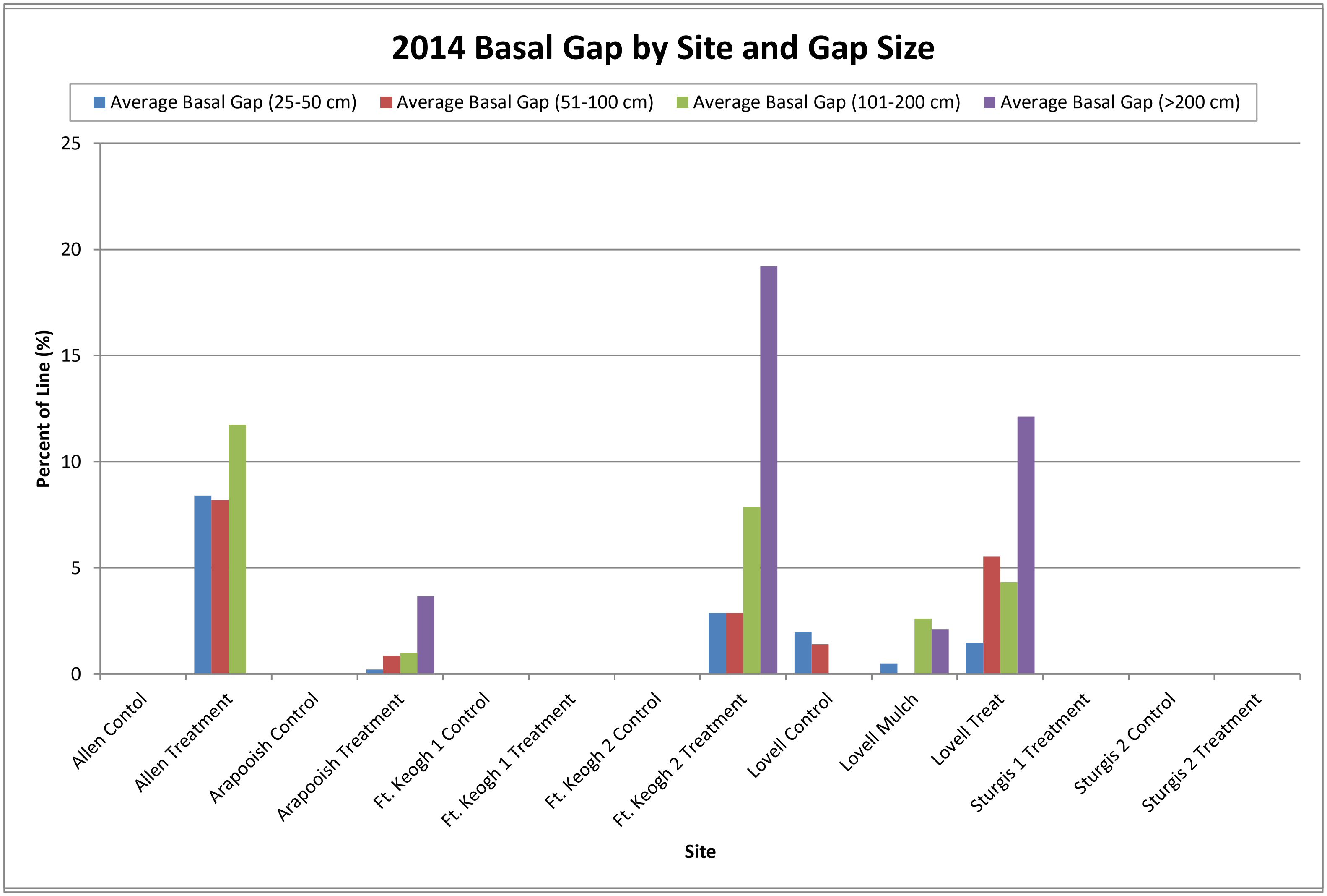
Graphs for Canopy and Basal Gap by Site



Synergy Resource Solutions, Inc. – 62

United States Department of Agriculture

NRCS

Natural Resources Conservation Service
724 Third Street West
Hardin, MT 59034
Phone: (406) 665-3442, ext. 101
Fax: (406) 665-1486

February 7th, 2012

Scott Bockness
MRWC CIG Project Leader
219 Linfield Hall
Montana State University - Dept. LRES
PO Box 173120
Bozeman, MT 59717-3120

VIA: Email scott.bockness@montana.edu

Dear Scott,

As requested, I have reviewed the eligibility file for Ellen T. Allen and Harry Allen regarding their participation in farm conservation programs. Both Ellen and Harry Allen have met USDA FY2011 eligibility requirements to participate in any 2008 Farm Bill Programs.

If you have any questions or concerns, please feel free to contact me at the number listed above, or by email at: seanna.sparks@mt.usda.gov.

Sincerely,

Seanna Sparks
District Conservationist
Hardin NRCS Field Office

Helping People Help the Land

An Equal Opportunity Provider and Employer

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IDENTIFICATION
SYNERGY RESOURCE SOLUTIONS

SYNERGY RESOURCE SOLUTIONS INC
HEIDI SMALZ
5393 HAMM RD
BELGRADE MT 59714

SOIL ANALYSIS REPORT

LAB NUMBER *241*	SAMPLE IDENTIFICATION	ORGANIC MATTER L.O.I. percent	RATE	PHOSPHORUS P1 (WEAK BRAY) 1:7 ppm	RATE	P2 (STRONG BRAY) 1:7 ppm	RATE	OLSEN BICARBONATE P ppm	RATE	POTASSIUM K ppm	RATE	MAGNESIUM Mg ppm	RATE	CALCIUM Ca ppm	RATE	SODIUM Na ppm	RATE	pH SOIL pH 1:1	BUFFER INDEX	CATION EXCHANGE CAPACITY C.E.C. meq/100g	PERCENT BASE SATURATION (COMPUTED) % K	% Mg	% Ca	% H	% Na
40641	1	2.6	M	4	VL	17	L	6	L	190	H	398	VH	2806	H	558	VH	8.2		20.3	2.4	16.3	69.3	0.0	12.0
40642	2	3.2	M	3	VL	19	L	9	L	345	VH	737	VH	3359	M	1095	VH	8.2		28.6	3.1	21.5	58.8	0.0	16.6
40643	3	3.1	M	8	L	35	M	12	M	360	VH	546	VH	3295	H	568	VH	7.9		24.4	3.8	18.6	67.5	0.0	10.1
40644	4	2.6	M	9	L	28	M	13	M	360	VH	577	VH	3511	M	833	VH	7.9		26.9	3.4	17.9	65.2	0.0	13.5
40645	5	2.2	L	8	L	34	M	6	L	284	VH	348	VH	3074	H			7.8		19.0	3.8	15.3	80.9	0.0	
40646	6	2.7	M	11	L	12	L	9	L	323	VH	566	VH	4232	H			7.8		26.7	3.1	17.7	79.2	0.0	
40647	7	0.8	VL	10	L	45	H	9	L	181	H	284	VH	2479	H			7.9		15.2	3.1	15.6	81.3	0.0	
40648	8	2.2	L	6	VL	27	M	8	L	273	VH	426	VH	3282	H	169	VH	7.8		21.4	3.3	16.6	76.7	0.0	3.4
40649	9	1.8	L	4	VL	23	M	6	L	241	VH	390	VH	3072	H			8.1		19.2	3.2	16.9	79.9	0.0	
40650	10	1.8	L	4	VL	21	M	5	VL	240	VH	501	VH	3130	H	138	VH	8.0		21.0	2.9	19.9	74.3	0.0	2.9

NEUTRAL AMMONIUM ACETATE (EXCHANGEABLE)

LAB NUMBER *241*	NITRATE-N (FIA) SURFACE ppm	lbs/A	depth (in)	SUBSOIL 1 ppm	lbs/A	depth (in)	SUBSOIL 2 ppm	lbs/A	depth (in)	Total lbs/A	SULFUR S ICAP ppm	RATE	ZINC Zn DTPA ppm	RATE	MANGANESE Mn DTPA ppm	RATE	IRON Fe DTPA ppm	RATE	COPPER Cu DTPA ppm	RATE	BORON B SORB. DTPA ppm	RATE	EXCESS LIME RATE	SOLUBLE SALTS 1:1 mmhos/cm	RATE
40641			0-8																						
40642			0-8																						
40643			0-8																						
40644			0-8																						
40645			0-8																						
40646			0-8																						
40647			0-8																						
40648			0-8																						
40649			0-8																						
40650			0-8																						

REV. 12/0

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BELGRADE MT 59714

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LAB NUMBER *241*	SAMPLE IDENTIFICATION	ORGANIC MATTER L.O.I. percent	RATE	PHOSPHORUS P1 (WEAK BRAY) 1:7 ppm	RATE	P2 (STRONG BRAY) 1:7 ppm	RATE	OLSEN BICARBONATE P ppm	RATE	POTASSIUM K ppm	RATE	MAGNESIUM Mg ppm	RATE	CALCIUM Ca ppm	RATE	SODIUM Na ppm	RATE	pH SOIL pH 1:1	BUFFER INDEX	CATION EXCHANGE CAPACITY C.E.C. meq/100g	PERCENT BASE SATURATION (COMPUTED) % K	% Mg	% Ca	% H	% Na
40651	11	1.8	L	2	VL	19	L	8	L	274	H	697	VH	3844	H	546	VH	8.1		28.1	2.5	20.7	68.4	0.0	8.4
40652	12	2.6	M	2	VL	8	L	6	L	236	H	527	VH	4121	H			8.0		25.6	2.4	17.2	80.4	0.0	
40653	13	4.2	H	4	VL	6	VL	13	M	230	H	195	M	4156	VH			7.9		23.0	2.6	7.1	90.3	0.0	
40654	14	6.6	VH	3	VL	5	VL	4	VL	152	L	402	M	13020	VH			7.7		68.8	0.6	4.9	94.5	0.0	
40655	15	4.5	H	3	VL	6	VL	4	VL	206	M	421	VH	5244	VH			7.7		30.3	1.7	11.6	86.7	0.0	
40656	16	1.2	VL	3	VL	25	M	9	L	248	H	621	VH	3969	H			7.8		25.7	2.5	20.1	77.4	0.0	
40657	17	1.1	VL	2	VL	29	M	7	L	276	H	715	VH	3850	H	168	H	7.8		26.6	2.7	22.4	72.2	0.0	2.7

NEUTRAL AMMONIUM ACETATE (EXCHANGEABLE)

LAB NUMBER *241*	NITRATE-N (FIA) SURFACE ppm	lbs/A	depth (in)	SUBSOIL 1 ppm	lbs/A	depth (in)	SUBSOIL 2 ppm	lbs/A	depth (in)	Total lbs/A	SULFUR S ICAP ppm	RATE	ZINC Zn DTPA ppm	RATE	MANGANESE Mn DTPA ppm	RATE	IRON Fe DTPA ppm	RATE	COPPER Cu DTPA ppm	RATE	BORON B SORB. DTPA ppm	RATE	EXCESS LIME RATE	SOLUBLE SALTS 1:1 mmhos/cm	RATE
40651			0-8																						
40652			0-8																						
40653			0-8																						
40654			0-8																						
40655			0-8																						
40656			0-8																						
40657			0-8																						

REV. 12/03

The above analytical results apply only to the sample(s) submitted. Samples are retained a maximum of 30 days.

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SOIL TEXTURE REPORT

Lab Number	Sample Identification	SAND	SILT	CLAY	SOIL TYPE
24140641	1	31%	56%	13%	SILT LOAM
24140642	2	27%	50%	23%	SILT LOAM
24140643	3	48%	36%	16%	LOAM
24140644	4	50%	35%	15%	LOAM
24140645	5	49%	42%	9%	LOAM
24140646	6	24%	52%	24%	SILT LOAM
24140647	7	66%	28%	6%	SANDY LOAM
24140648	8	57%	33%	10%	SANDY LOAM
24140649	9	60%	30%	10%	SANDY LOAM
24140650	10	47%	41%	12%	LOAM

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SOIL TEXTURE REPORT

Lab Number	Sample Identification	SAND	SILT	CLAY	SOIL TYPE
24140651	11	37%	43%	20%	LOAM
24140652	12	43%	31%	26%	LOAM
24140653	13	5%	90%	5%	SILT
24140654	14	50%	45%	5%	SANDY LOAM
24140655	15	40%	40%	20%	LOAM
24140656	16	35%	35%	30%	CLAY LOAM
24140657	17	47%	23%	30%	SANDY CLAY LOAM

Hazen Research, Inc.
4601 Indiana Street
Golden, CO 80403 USA
Tel: (303) 279-4501
Fax: (303) 278-1528

Date	August 18 2011
HRI Project	002-DGX
HRI Series No.	G316/11-1
Date Rec'd.	07/29/11
Cust. P.O.#	

CIPM - Montana State University
Scott Bockness
2220 St Johns Avenue, Apt. 24B
Billings, MT 59102

Sample Identification
Mulch

Reporting Basis >	As Rec'd	Dry	Air Dry
Proximate (%)			
Moisture	17.24	0.00	2.17
Ash	29.31	35.42	34.65
Volatile	45.02	54.39	53.21
Fixed C	8.43	10.19	9.97
Total	100.00	100.00	100.00
Sulfur	0.050	0.060	0.059
Btu/lb (HHV)	4307	5205	5092
Btu/lb (LHV)			
MMF Btu/lb	6302	8428	
MAF Btu/lb		8059	
Ultimate (%)			
Moisture			
Carbon			
Hydrogen			
Nitrogen			
Sulfur			
Ash			
Oxygen*			
Total			
Chlorine**			

Air Dry Loss (%) 15.40

Forms of Sulfur, as S, (%)

	As Rec'd	Dry
Sulfate		
Pyritic		
Organic		
Total	0.05	0.06

Water Soluble Alkalies (%)

Na2O	
K2O	

Lb. Alkali Oxide/MM Btu=	
Lb. Ash/MM Btu=	68.05
Lb. SO2/MM Btu=	0.23
Lb. Cl/MM Btu=	
As Rec'd. Sp.Gr.=	
Free Swelling Index=	
F-Factor(dry),DSCF/MM Btu=	

Report Prepared By:

Gerard H. Cunningham
Fuels Laboratory Supervisor

* Oxygen by Difference.
** Not usually reported as part of the ultimate analysis.

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Hazen Research, Inc.
4601 Indiana Street
Golden, CO 80403 USA
Tel: (303) 279-4501
Fax: (303) 278-1528

Date August 19 2011
HRI Project 002-DGX
HRI Series No. H30/11-1
Date Rec'd. 08/05/11
Cust. P.O.#

CIPM-MSU Bozeman
SCott Bockness
2220 St. Johns Avenue, Apt. 24B
Billings, MT 59102

Sample Identification
Dolph - Billings MT
Saltcedar
-

Reporting Basis >	As Rec'd	Dry	Air Dry
Proximate (%)			
Moisture	8.40	0.00	2.42
Ash	2.99	3.26	3.18
Volatile	79.46	86.75	84.65
Fixed C	9.15	9.99	9.75
Total	100.00	100.00	100.00
Sulfur	0.582	0.635	0.620
Btu/lb (HHV)	7248	7913	7721
Btu/lb (LHV)			
MMF Btu/lb	7484	8198	
MAF Btu/lb		8179	
Ultimate (%)			
Moisture			
Carbon			
Hydrogen			
Nitrogen			
Sulfur			
Ash			
Oxygen*			
Total			
Chlorine**			

Air Dry Loss (%) 6.13
Forms of Sulfur, as S, (%)

	As Rec'd	Dry
Sulfate		
Pyritic		
Organic		
Total	0.58	0.64

Water Soluble Alkalies (%)

Na2O
K2O

Lb. Alkali Oxide/MM Btu=	
Lb. Ash/MM Btu=	4.12
Lb. SO2/MM Btu=	1.61
Lb. Cl/MM Btu=	
As Rec'd. Sp.Gr.=	
Free Swelling Index=	
F-Factor(dry),DSCF/MM Btu=	

Report Prepared By:

Gerard H. Cunningham
Fuels Laboratory Supervisor

* Oxygen by Difference.
** Not usually reported as part of the ultimate analysis.

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HAZEN
Hazen Research, Inc.
4601 Indiana Street
Golden, CO 80403 USA
Tel: (303) 279-4501
Fax: (303) 278-1528

DATE September 12, 2011
PROJ. # 002-DGX
CTRL # G316/11
REC'D 07/29/11

CIPM-Montana State University
Scott Bockness
2220 St Johns Avenue, Apt. 24B
Billings, MT 59102

Control Number	Sample Identification	As Received Ash, %
G316/11-1	Mulch New Split Recheck	27.55

By:

Gerard H. Cunningham
Fuel Laboratory Manager

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Hazen Research, Inc.
4601 Indiana Street
Golden, CO 80403 USA
Tel: (303) 279-4501
Fax: (303) 278-1528

Date	February 15 2012
HRI Project	002-DXQ
HRI Series No.	A331/12-2
Date Rec'd.	01/27/12
Cust. P.O.#	

Montana State University
Scott Bockness
2220 St. Johns Ave., Apt 24B
Billings, MT 59102

Sample Identification
Saltcedar (chipped)

Reporting Basis >	As Rec'd	Dry	Air Dry
Proximate (%)			
Moisture	9.92	0.00	1.81
Ash	2.60	2.88	2.83
Volatile	74.82	83.06	81.56
Fixed C	12.66	14.06	13.80
Total	100.00	100.00	100.00
Sulfur	0.413	0.458	0.450
Btu/lb (HHV)	7454	8275	8125
Btu/lb (LHV)	6839		
MMF Btu/lb	7666	8540	
MAF Btu/lb		8521	
Ultimate (%)			
Moisture	9.92	0.00	1.81
Carbon	45.50	50.51	49.60
Hydrogen	5.53	6.14	6.03
Nitrogen	0.45	0.50	0.49
Sulfur	0.41	0.46	0.45
Ash	2.60	2.88	2.83
Oxygen*	35.59	39.51	38.79
Total	100.00	100.00	100.00
Chlorine**	0.039	0.043	0.042

Air Dry Loss (%) 8.26

Forms of Sulfur, as S, (%)

	As Rec'd	Dry
Sulfate		
Pyritic		
Organic		
Total	0.41	0.46

Water Soluble Alkalies (%)

Na2O
K2O

Lb. Alkali Oxide/MM Btu=	0.45
Lb. Ash/MM Btu=	3.48
Lb. SO2/MM Btu=	1.11
Lb. Cl/MM Btu=	0.05
As Rec'd. Sp.Gr.=	
Free Swelling Index=	
F-Factor(dry),DSCF/MM Btu=	9,884

Report Prepared By:

Gerard H. Cunningham
Fuels Laboratory Supervisor

* Oxygen by Difference.
** Not usually reported as part of the ultimate analysis.

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Hazen Research, Inc.
4601 Indiana Street
Golden, CO 80403 USA
Tel: (303) 279-4501
Fax: (303) 278-1528

Date February 15 2012
HRI Project 002-DXQ
HRI Series No. A331/12-1
Date Rec'd. 01/27/12
Cust. P.O.#

Montana State University
Scott Bockness
2220 St. Johns Ave., Apt 24B
Billings, MT 59102

Sample Identification
Russian Olive (chipped)

Reporting Basis >	As Rec'd	Dry	Air Dry
Proximate (%)			
Moisture	10.33	0.00	2.28
Ash	1.24	1.38	1.35
Volatile	73.81	82.32	80.44
Fixed C	14.62	16.30	15.93
Total	100.00	100.00	100.00
Sulfur	0.093	0.103	0.101
Btu/lb (HHV)	7471	8332	8142
Btu/lb (LHV)	6829		
MMF Btu/lb	7571	8457	
MAF Btu/lb		8448	
Ultimate (%)			
Moisture	10.33	0.00	2.28
Carbon	45.96	51.26	50.09
Hydrogen	5.78	6.44	6.29
Nitrogen	1.03	1.15	1.12
Sulfur	0.09	0.10	0.10
Ash	1.24	1.38	1.35
Oxygen*	35.57	39.67	38.77
Total	100.00	100.00	100.00
Chlorine**	<.005	0.005	0.005

Air Dry Loss (%) 8.24

Forms of Sulfur, as S, (%)	As Rec'd	Dry
Sulfate		
Pyritic		
Organic		
Total	0.09	0.10

Water Soluble Alkalies (%)

Na2O
K2O

Lb. Alkali Oxide/MM Btu= 0.13
Lb. Ash/MM Btu= 1.66
Lb. SO2/MM Btu= 0.25
Lb. Cl/MM Btu= 0.01
As Rec'd. Sp.Gr.=
Free Swelling Index=
F-Factor(dry),DSCF/MM Btu= 10,063

Report Prepared By:

Gerard H. Cunningham
Fuels Laboratory Supervisor

* Oxygen by Difference.
** Not usually reported as part of the ultimate analysis.

An Employee-Owned Company

Keystone Materials Testing
600 E 17th St S
Newton, IA 50208

ANALYTICAL REPORT

December 02, 2011

Page 1 of 1

Work Order: 91K0026

Report To

Scott Bockness
Center for Invasive Plant Management
2220 St. Johns Ave, Apt #24B
Billings, MT 59102

Project : Bio-Mass

Project Number: Hedges - MT

Analyte	Result		Method	Limits
ID:Russian Olive			Matrix:BioMass	Collected: 10/05/11 00:00
Ash	1.00	wt %	ASTM E1755	
Calorific Value	8012	BTU/lb	ASTM D240	
Moisture	2.97	wt %	ASTM E1755	
Volatile Matter	76.67	wt %	ASTM E1755	

End of Report

Keystone Materials Testing, Inc.

Jerry Dawson
Laboratory Manager

Phone 641-792-8451 600 East 17th Street South Newton, IA 50208 Fax 641-792-7989

Keystone Materials Testing
600 E 17th St S
Newton, IA 50208

ANALYTICAL REPORT

December 02, 2011

Work Order: **91K0027**

Report To

Scott Bockness
Center for Invasive Plant Management
2220 St. Johns Ave, Apt #24B
Billings, MT 59102

Project : Bio-Mass

Project Number: Yegen - MT

ID:Russian Olive — Matrix:BioMass — Collected: 10/05/11 00:00

Analyte	Result		Method	Limits
Ash	0.96	wt %	ASTM E1755	
Calorific Value	8098	BTU/lb	ASTM D240	
Moisture	3.53	wt %	ASTM E1755	
Volatile Matter	75.76	wt %	ASTM E1755	

End of Report

Keystone Materials Testing, Inc.

Jerry Dawson
Laboratory Manager

Keystone Materials Testing
600 E 17th St S
Newton, IA 50208

ANALYTICAL REPORT

December 02, 2011

Work Order: 91K0028

Report To

Scott Bockness
Center for Invasive Plant Management
2220 St. Johns Ave, Apt #24B
Billings, MT 59102

Project : Bio-Mass

Project Number: Pitts - S.D.

Analyte	Result		Method	Limits
ID:Phragmites			Matrix:BioMass	Collected: 10/18/11 00:00
Ash	5.20	wt %	ASTM E1755	
Calorific Value	6990	BTU/lb	ASTM D240	
Moisture	3.20	wt %	ASTM E1755	
Volatile Matter	75.88	wt %	ASTM E1755	

End of Report

Keystone Materials Testing, Inc.

Jerry Dawson
Laboratory Manager

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KMT Labs
600 E 17th St S
Newton, IA 50208

ANALYTICAL REPORT

June 11, 2010

Work Order: 90E0016

Report To

Les Puglia
Yankee Pellet Mills
177 Elm Street
Effingham, NH 03882

Project : Missouri River Watershed Coalition

PO : 4W2809

Analyte	Result		Method	Limits
ID:Tamarisk - Hot Springs			Matrix:BioMass	Collected: 04/01/10 00:00
Ash	2.1	%	E1755	
Moisture	5.0	%	E1755	
Triclopyr	210	mg/kg	GC/ECD	
Calorific Value	7319	BTU/lb	ASTM D240	
ID:Tamarisk - Edgemont			Matrix:BioMass	Collected: 04/01/10 00:00
Ash	2.6	%	E1755	
Moisture	5.0	%	E1755	
Triclopyr	2.83	mg/kg	GC/ECD	
Calorific Value	7530	BTU/lb	ASTM D240	
ID:Phragmites - Grand Island			Matrix:BioMass	Collected: 04/07/10 00:00
Ash	8.0	%	E1755	
Moisture	9.3	%	E1755	
Triclopyr	<0.0200	mg/kg	GC/ECD	
Calorific Value	6829	BTU/lb	ASTM D240	

End of Report

Keystone Materials Testing, Inc.

Jerry Dawson
Laboratory Manager

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Keystone Materials Testing
600 E 17th St S
Newton, IA 50208

ANALYTICAL REPORT

August 16, 2011

Work Order: 91H0002

Report To

Scott Bockness
Center for Invasive Plant Management
2220 St. Johns Ave, Apt #24B
Billings, MT 59102

Project : Bio-Mass

Project Number: Bumgarner - WY

Analyte	Result		Method	Limits
ID:Saltcedar - Aug 2009			Matrix:BioMass	Collected: 07/27/11 00:00
Ash	2.0	%	E1755	
Moisture	6.47	wt %	E1755	
Volatile Matter	74.20	wt %	E1755	
Calorific Value	7581	BTU/lb	ASTM D240	

End of Report

Keystone Materials Testing, Inc.

Jerry Dawson
Laboratory Manager

Keystone Materials Testing
600 E 17th St S
Newton, IA 50208

ANALYTICAL REPORT

August 16, 2011

Work Order: **91H0003**

Report To

Scott Bockness
Center for Invasive Plant Management
2220 St. Johns Ave, Apt #24B
Billings, MT 59102

Project : Bio-Mass

Project Number: Chalupa - WY

Analyte	Result		Method	Limits
ID:Saltcedar - Oct 2010			Matrix:BioMass	Collected: 07/27/11 00:00
Ash	2.8	%	E1755	
Moisture	8.05	wt %	E1755	
Volatile Matter	73.63	wt %	E1755	
Calorific Value	7420	BTU/lb	ASTM D240	

End of Report

Keystone Materials Testing, Inc.

Jerry Dawson
Laboratory Manager

Keystone Materials Testing
600 E 17th St S
Newton, IA 50208

ANALYTICAL REPORT

August 16, 2011

Work Order: 91H0004

Report To

Scott Bockness
Center for Invasive Plant Management
2220 St. Johns Ave, Apt #24B
Billings, MT 59102

Project : Bio-Mass

Project Number: WY

Analyte	Result		Method	Limits
ID:Russian Olive Mulch			Matrix:BioMass	Collected: 07/27/11 00:00
Ash	2.5	%	E1755	
Moisture	6.69	wt %	E1755	
Volatile Matter	75.47	wt %	E1755	
Calorific Value	6318	BTU/lb	ASTM D240	

End of Report

Keystone Materials Testing, Inc.

Jerry Dawson
Laboratory Manager

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Keystone Materials Testing
600 E 17th St S
Newton, IA 50208

ANALYTICAL REPORT

August 16, 2011

Page 1 of 1

Work Order: 91H0013

Report To

Scott Bockness
Center for Invasive Plant Management
2220 St. Johns Ave, Apt #24B
Billings, MT 59102

Project : Bio-Mass

Project Number: Dolph - Billings, MT

Analyte	Result		Method	Limits
ID:Dolph Sample - MT			Matrix:BioMass	Collected: 08/02/11 00:00
Ash	3.3	%	E1755	
Moisture	6.96	wt %	E1755	
Volatile Matter	75.91	wt %	E1755	
Calorific Value	7444	BTU/lb	ASTM D240	

End of Report

Keystone Materials Testing, Inc.

Jerry Dawson
Laboratory Manager

Keystone Materials Testing
600 E 17th St S
Newton, IA 50208

ANALYTICAL REPORT

August 16, 2011

Work Order: 91H0014

Report To

Scott Bockness
Center for Invasive Plant Management
2220 St. Johns Ave, Apt #24B
Billings, MT 59102

Project : Bio-Mass

Project Number: Blain - Billings, MT

Analyte	Result		Method	Limits
ID:Blain Sample - MT			Matrix:BioMass	Collected: 08/02/11 00:00
Ash	2.4	%	E1755	
Moisture	6.47	wt %	E1755	
Volatile Matter	76.96	wt %	E1755	
Calorific Value	7500	BTU/lb	ASTM D240	

End of Report

Keystone Materials Testing, Inc.

Jerry Dawson
Laboratory Manager

Summary of Invasive Species Biomass Testing, 2011–2012

Center for Invasive Species Management and Missouri River Watershed Coalition CIG Project

Prepared by Scott Bockness, Project Field Leader
Edited by Emily Rindos, Center for Invasive Species Management

Introduction

The purpose of Objective 2 is to investigate and demonstrate innovative bioenergy technologies that promote the use of Russian olive *(Elaeagnus angustifolia)* and saltcedar *(Tamarix* spp.) biomass as new raw materials or "feedstocks" for bioenergy generation. Russian olive and saltcedar are hugely problematic invaders that presently infest at least one million acres within the Missouri River Watershed region and are virtually untapped sources of biomass. The project proposes that the tons of mostly herbicide-treated biomass, much of which has simply been left in piles throughout the region, can be processed on location by producers and used as a new, free bioenergy source. The intent of this report is to provide initial documentation regarding the feasibility of Russian olive and saltcedar as potential feedstock sources for bioenergy applications.

Bioenergy Testing

As a preemptive and precautionary step prior to the start of the project, the MRWC began conducting tests on Russian olive and saltcedar in 2010 to determine that herbicide-treated biomass: (1) does not contain high levels of toxic residues; (2) can safely be used as a bioenergy source; and (3) has a heat value/energy content competitive with other vegetative materials currently used as fuel sources. The results indicated that calorific value (BTUs generated per pound of material) and ash content levels for both species fall within the "acceptable" BTU range for bioenergy generation.

In 2011 and 2012, additional samples were collected and sent for laboratory testing to determine calorific value and ash, volatile matter, and moisture content. The results were then compared with data from forestry species traditionally used in bioenergy applications. The first round of tests, conducted by Hazen Research, Inc. (Golden, Colo., www.hazenusa.com) and Keystone Materials Testing, Inc. (Newton, Iowa, www.kmtlabs.com), was completed in fall 2011.

In late 2011, the Project Field Leader solicited expert feedback on the test results from bioenergy experts from the government sector (Angela Farr, USDA Forest Service State and Private Forestry; Julie Kies, Department of Natural Resources Conservation Forestry Division), universities (Tom Javins, University of Montana; Dale Grant, Chadron State College), and the private and commercial sector (Adam Sherman, Biomass Energy Resource Center; Andrew Haden, Wisewood, Inc.; Tom Miles, T.R. Miles Technical Consulting, Inc.). Two of the experts recommended further testing, including additional ultimate and proximate testing for calorific values and ash, moisture, and volatile matter; elemental analysis to identify specific compounds within the plant materials; and ash fusion testing to identify the temperatures at which the materials can produce or influence the formation of slag or clinkers in a biomass conversion operation.

Results

The results of the tests conducted on the Russian olive and saltcedar biomass samples are included in Table 1. Comparisons were then drawn between the target species and thermal test data for seven forestry species currently used as biofuel sources (Table 2). Data comparisons indicate that Russian olive appears to be a more viable candidate species for bioenergy utilization than saltcedar, with an average calorific value of 90.2% of traditional forestry species, as well as a very low average ash level (1%). The average ash level of Russian olive is also low when compared to the average ash level of forestry species analyzed. The BTU values of saltcedar indicate a calculated average of 16% below the average BTU values found in the forest species currently used for biomass purposes. In addition, the ash content levels of saltcedar are somewhat higher than the majority of forest species listed in Table 2, which may be a limiting factor for some bioenergy uses.

In early 2012, upon recommendations from bioenergy experts, additional testing was conducted to accurately determine the overall potential of Russian olive and saltcedar as viable biomass feedstock materials. An additional set of ultimate and proximate tests were conducted on the Russian olive and saltcedar materials by Hazen Research, Inc. The elemental composition of Russian olive and saltcedar was also tested to further establish the fuel qualities of the invasive species material. In addition, the elemental composition of ash generated from burning the plant materials was tested to determine the ash fusion temperatures of the plant materials. Upon completion of the bioenergy testing, the project test data was then evaluated by T. R. Miles Technical Consulting, Inc., a biomass combustion analyst.

Ash fusion temperatures of woody biomass are important in that when plant material is burned in a biomass unit, if the material has a low ash fusion temperature (below 1800°F), the material tends to melt into solid "clinkers or slag", and reduces the efficiency of the system. According to the 2012 ash fusion test data, the ash fusion temperatures of Russian olive and saltcedar, (over 2700°F and 2141°F – 2185°F, respectively), are high, and when burned, it is unlikely to cause fouling or the formation of "clinkers" in a biomass system. Additionally, high levels of certain elements found in plants such as; sulfur or nitrogen can be problematic for certain bioenergy conversion forms. Sulfur can be corrosive to biomass conversion systems (pellet or wood stoves) and will damage the system over a period of time. High nitrogen levels (Russian olive 1.15% oven dry), under certain conditions can contribute to nitrogen oxide emissions. In many cases, elemental concerns such as: high nitrogen or sulfur levels, can be mitigated through either modification of the biomass system design, or by simply diluting/blending the biomass material (T. Miles).

Discussion

Extensive amounts of biomass information and analysis exists relating to forest species, but little information relating to woody invasive plant species bioenergy utilization has been documented. Current management and treatment practices for Russian olive and saltcedar are generally considered cost prohibitive by many landowners and managers, and require integrating herbicide treatments with mechanical cutting and removal efforts. Depending on plant density, management practices can generate fairly large amounts of biomass (estimated at 5–10 tons per acre). Historically, biomass has been stockpiled and removed using on-site prescribed burning. While prescribed burning may be cost effective, exploring the beneficial use of the material as a solid biomass feedstock is an innovative alternative approach, and may create an incentive to expand existing levels of management being dedicated to control these invasive species.

A report produced by T. R. Miles Technical Consulting, Inc., titled "Fuel Property Analysis and Bioenergy Potential of Saltcedar and Russian Olive Wood" is available on the project website and contains further analysis of the bioenergy test information generated from 2011 and 2012, in addition to an overview of existing bioenergy technologies.

Table 1. Thermal test data for Russian olive *(Elaeagnus angustifolia)* and saltcedar *(Tamarix* spp.)

Sample	Location of collection site	Test date	Laboratory[1]	Calorific value (BTU/#)[2]	Ash (%)[3]	Volatile matter (%)[4]	Moisture (%)[5]
Russian olive (Elaeagnus angustifolia)							
A	Yellowstone County, MT	12-02-11	Keystone	8,102	1.00	76.67	2.97
B	Yellowstone County, MT	12-02-11	Keystone	8,098	0.96	75.76	3.53
C	Yellowstone County, MT	02-15-12	Hazen	7,571	1.24	73.81	10.33
Russian olive mulch (mulched one year prior to collection and left outside)							
D	Goshen County, WY	08-16-11	Keystone	6,318	2.50	75.47	6.69
E[6]	Goshen County, WY	08-18-11	Hazen	6,302	29.31	45.02	17.24
		08-18-11	Hazen	6,527	29.73	44.74	17.95
		09-12-11	Hazen	—	27.55	—	—
Saltcedar (Tamarix spp.)							
F	Goshen County, WY	08-16-11	Keystone	7,581	2.00	74.20	6.47
		08-18-11	Hazen	7,453	1.57	76.61	8.59
G	Goshen County, WY	08-16-11	Keystone	7,420	2.80	73.63	8.05
		08-18-11	Hazen	7,427	1.97	74.30	10.18
H	Yellowstone County, MT	08-16-11	Keystone	7,500	2.40	76.96	6.47
		08-19-11	Hazen	7,517	2.84	78.60	8.13
		08-16-11	Hazen	7,561	2.27	76.64	8.32
I	Yellowstone County, MT	08-16-11	Keystone	7,444	3.30	75.91	6.96
		08-18-11	Hazen	7,484	2.99	79.46	8.40
		08-18-11	Hazen	7,564	2.48	76.23	8.61
J	Yellowstone County, MT	02-15-12	Hazen	7,666	2.60	74.82	9.92

[1] Samples were tested by two laboratories: Keystone Materials Testing, Inc. and Hazen Research, Inc.
[2] Calorific value: the BTU levels generated per pound of material.
[3] Ash (%): the amount of inorganic wmatter that remains after the material is burned.
[4] Volatile matter (%): the overall amount of material, exclusive of moisture, that generates gas and vapors from burning.
[5] Moisture (%): the amount of water contained in the material, which is critical for biomass conversion processing.
[6] Due to abnormally high levels of ash and volatile matter identified in the initial results from Hazen Research, Inc. for Russian olive sample E (taken from Goshen County, WY), it was determined that the material should be retested. Results of both retests indicated abnormally high levels of ash and therefore, lower levels of corresponding volatile matter. These results may be due to the fact that the sample material was mulched one year prior to collection, thus allowing the samples to decompose and become contaminated with high levels of debris.

Table 2. Thermal test data for seven forestry (conifer) species [7]

Species	Calorific value (BTU/#)	Ash (%)	Volatile matter (%)
Douglas fir	9,050	1.10	89.00
Ponderosa pine	9,028	1.70	79.90
White pine	8,900	0.10	78.00
Western red cedar	9,155	2.40	78.90
Grand fir	8,505	1.30	78.80
Lodgepole pine	8,800	0.50	73.50
Western spruce	8,740	3.80	69.60

[7] *Source:* R. Folk, University of Idaho College of Natural Resources. Source did not include moisture content data.

Missouri River Watershed Coalition Conservation Innovation Grant Project

Analysis of Fuel Properties and Bioenergy Potential for Saltcedar and Russian Olive Wood

May 2012

Prepared by:
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Prepared for:
Center for Invasive Plant Management
Montana State University - Bozeman
Land Resources & Environmental Sciences
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1.0 Executive Summary

Samples of saltcedar and Russian olive wood were tested for fuel properties. Heating value, moisture content and ash properties were compared with other biomass fuels. Potential energy uses were evaluated.

Fuels from the eradication of invasive species like saltcedar and Russian olive have high costs due to the methods of treatment. They would be more expensive than coal or natural gas but it could compete with oil or propane for rural heating.

Low moisture and ash content make the wood a good fuel for bioenergy. Inorganic ash components such as chlorine, sulfur, potassium or silica are low enough so that the fuels have a high ash fusion temperature and should not present problems in burners or boilers. While the ash content is low it is too high for making a high value residential wood pellet and it is too expensive to make a low value industrial or utility fuel. It would not be worth torrefying this wood to make an industrial fuel. It has been tested and marketed as a lump charcoal. Nutrients in the wood make it a good candidate for a soil amendment like biochar.

Opportunities should be sought where the cost of eradication could be shared with another process to lower the cost as a fuel. In that case it could be a good fuel for use in small heating boilers, such as schools or institutions, or as lump charcoal. If the cost of carbonization is acceptable it could be used on site as biochar to improve the fertility of soils in the Missouri river watershed.

2.0 Introduction

2.1 Background and Objectives

T. R. Miles, Technical Consultants Inc. was asked to evaluate the fuel properties of saltcedar (*Tamarix* spp.) and Russian olive (*Elaeagnus angustifolia*) wood. We have reviewed test results from samples of each species and compared them with typical biomass fuels. We have examined the components of the ash in each species for potential problems in thermal conversion. And, we have looked at the potential viability of using these woods for bioenergy.

2.2 Current Harvest Practices

Eradication of invasive species like saltcedar and Russian olive would seem to present opportunities for biomass energy. They may be suitable for direct use as chips, for conversion to densified fuels, for torrefaction, or for carbonization to charcoal or biochar. Unlike other forest residues the shrub-like invasive species require special treatments which increase harvesting costs so they are expensive compared with natural gas, coal or forest fuels. Table 2-1. Wood from invasive species could compete with fuel oil or propane.

Table 2-1. Delivered Cost of Fuel

Fuel	Unit	Net Heating Value[1] Btu/unit	Cost/unit	$/MMBtu
Natural Gas	Therm	82,000	$ 0.20	$2.44
Bituminous coal	Ton	26,000,000	$125.00	$4.81
Wyoming coal	Ton	22,000,000	$125.00	$5.68
Forest fuels	Oven dry ton	13,800,000	$60.00	$4.35
Invasive species	Oven dry ton	13,800,000	$300.00	$21.74
Fuel Oil #2	Gallon	115,000	$4.00	$34.78
Propane	Gallon	71,000	$2.50	$35.21

Woody biomass is typically harvested and piled for later chipping into whole tree chips for fuel or fiber. The growth characteristics of saltcedar and Russian olive are

[1] USFS 2004. Fuel Value Calculator, http://www.fpl.fs.fed.us/documnts/techline/fuel-value-calculator.pdf

somewhat different and have influenced the treatment methodology. Saltcedar is primarily a shrub that can grow to heights of 20’ but the stem diameters rarely exceed 3” so they would not lend themselves to any type of “log” form of decking. Figure 2-1. Russian olive, depending on age class can vary from young shrub-like forms to mature 40’ trees with up to 30” base diameters. Figure 2-2.

Management techniques used for control are driven primarily by site conditions, such as accessibility and plant densities, and treatment costs. A variety of management techniques are used in the control of these species in riparian areas. These include chemical, mechanical, or both mechanical and chemical methods. Effective saltcedar control has been achieved with hand herbicide applications (foliar and basal bark), generally with Triclopyr[2] and basal oil mixtures. Figure 2-1b. Triclopyr decomposes at 290 °C (554 °F). [3] It would decompose during combustion since most boilers and burners operate at 815 °C-1100 °C (1500 °F-2012 °F).

In many cases, the plants are left to naturally decompose. In some very dense patches they can be mechanically cut with the plant material piled or hauled away, and then the regrowth is treated with herbicides. Russian olive is generally mechanically cut by small-scale forestry type “feller buncher” skid steers with the material being slash-piled. Cut stumps of the trees are treated with herbicide/oil mixtures, and usually require one or two additional herbicide treatments in the following years to suppress regrowth. A review of potential harvest systems for saltcedar and Russian olive shows how various methods could be employed to prepare fuels.[4]

The riparian sites where invasive species grow are relatively easy to access and in most cases the slash piles, when left to air dry to reduce the moisture content and eliminate fuel quality reduction from leaves, could be chipped and hauled directly to a biomass plant.[5] The advantages of piling appear to be that the leaves fall off and the moisture dries. These techniques have been used for preparing Western juniper as fuel for

[2] U.S. Forest Service. 1996.Triclopyr Herbicide Information Profile. November http://www.fs.fed.us/r6/nr/fid/pubsweb/tri.pdf

[3] Pesticide Residues in Smoke. Undated manuscript from MRWC.

[4] Dykstra, Dennis P. 2010. Extraction and utilization of salt cedar and Russian olive biomass. Chapter 6 in: Shafroth, Patrick B.; Brown, Curtis A.; Merritt, David M. (eds.), Salt cedar and Russian Olive Control Demonstration Act Science Assessment. Fort Collins, CO: US Geological Survey, Scientific Investigations Report 2009-5247. pp. 103-116.

[5] S. Bockness, 2012.

biomass plants in Nevada and California in commercial quantities greater than 60,000 tons per year.

Figure 2-1. Saltcedar

A. Saltcedar Untreated (MRWC)

B. Saltcedar Basal Bark Treatment (MRWC)

Figure 2-2. Russian Olive

A. Russian Olive Untreated (MRWC)

B. Russian Olive Brush pile (MRWC)

3.0 Wood Fuel Properties

Fuel samples from MRWC were sent to Hazen Laboratories for analysis.[6] Fuel properties for saltcedar and Russian olive are similar to other woody biomass species in moisture content, heating value, combustion properties and ash.

3.1 Heating Value

Heating values for saltcedar and Russian olive wood are compared with pine hog fuel and Douglas fir mill waste in Table 3-1. Oven dry (o.d.) heating values are similar for most species on a weight basis. Wood chips are typically delivered at 45% to 50% moisture content, wet basis (MC50) and are sold either by weight (per ton) or volume (per Unit of 200 ft3). At 50% MC saltcedar and Russian olive would have a gross heating value (GHV) of 4,138-4,166 Btu/lb. compared with Douglas Fir at 4,390 Btu/lb. In the arid conditions of the Missouri river watershed the harvested fuel is more likely to be air dried to 20% moisture content (MC20), wet basis. The heating value of the saltcedar and Russian olive wood at 20% MC is 6,620-6,665 Btu/lb.

Table 3-1. Wood Fuel Properties.

Species	HHV Btu/lb od	GHV Btu/lb MC20	GHV Btu/lb MC50	Ash % od
Saltcedar	8,275	6,620	4,138	2.88
Russian Olive	8,332	6,665	4,166	1.38
Ponderosa Pine (hog fuel)	8,821	7,056	4,410	2.37
Douglas Fir (mill waste)	8,779	7,023	4,390	0.41
Higher Heating Value (HHV) and Gross Heating Value (GHV) = HHV (1-MCwb/100)				

3.2 Moisture Content

Saltcedar samples collected by MRWC are characterized by low levels of moisture (6%-10% MC wet basis). [7] Living wood often contains 40-50% MC. If cut and

[6] Hazen Research, Inc. 4601 Indiana Street, Golden, Colorado 80403, U.S.A. www.hazenusa.com

left in a dry environment the wood can reach its equilibrium moisture content (EMC). The arid environment and harvesting practices apparently combine to dry the wood to below 20% MC.

Russian olive samples also contained very low moisture. Even mulched samples collected from the ground were dry. If the wood can be harvested and chipped at less than 20% MC then it would make a very good fuel. Low moisture means that less heat is required to evaporate the water during combustion. Fuel of this quality could be burned directly in small boilers, or it could be cofired with coal in large utility boilers.

3.3 Combustion Properties

Combustion properties of Russian olive and saltcedar samples are compared with hog fuel from ponderosa pine and Douglas fir saw mill waste in Table 3-2. Nitrogen is high in the Russian olive (1.15% o.d.) wood so that nitrogen oxide emissions could be a concern in large boilers unless it is diluted with low nitrogen fuels or treated by nitrogen reduction methods.

Sulfur is also high in saltcedar. Table 3-1. Clemons and Stark noted high concentrations of sulfur and calcium in saltcedar compared with pine.[8] Sulfur volatilizes during combustion but it can also react with calcium in the fuel. It is notable that a high concentration of sulfur was retained in the ash sample which was prepared at relatively low temperatures (<600°C, <1112 °F) in the laboratory. Table 3-3. Biochar made from saltcedar should retain the sulfur to be available for plants if it is used as a soil amendment.

[7] S. Bockness. 2012. Summary of MRWC CIG Invasive Species Biomass Testing 2011. February 20.

[8] Clemons and N. Stark, 2007, Use of salt cedar and Utah juniper as fillers in wood-plastic composites: Madison, Wis., U.S. Forest Service, Forest Products Laboratory Research Paper FPL-RP-641, 17 p.

Table 3-2. Proximate and Ultimate Analysis[9]

Fuel	Russian Olive MT		Saltcedar MT		Pine E OR		Douglas Fir OR	
Type	Chips 1/2012		Chips 1/2012		Hog Fuel		Mill Waste	
	As Rec'd	Dry	As Rec'd	Dry	As Rec'd	Dry	As Rec'd	Dry
Proximate Analysis								
Fixed Carbon	14.62	16.30	12.66	14.06	14.03	22.51	6.47	17.48
Volatile Matter	73.81	82.32	74.82	83.06	46.26	74.22	30.38	82.11
Ash	1.24	1.38	2.60	2.88	2.04	3.27	0.15	0.41
Moisture	10.33		9.92		37.67	--	63.00	--
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Ultimate Analysis								
Carbon	45.96	51.26	45.50	50.51	33.38	53.56	18.95	51.23
Hydrogen	5.78	6.44	5.53	6.14	4.00	6.42	2.21	5.98
Oxygen	35.57	39.67	35.59	39.51	22.71	36.43	15.66	42.29
Nitrogen	1.03	1.15	0.45	0.50	0.18	0.29	0.02	0.06
Sulfur	0.09	0.1	0.41	0.46	0.02	0.03	0.01	0.03
Ash	1.24	1.38	2.60	2.88	2.04	3.27	0.15	0.41
Moisture	10.33		9.92		37.67	--	63.00	--
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
HHV, Btu/lb	7,471	8,332	7,454	8,275	5,498	8,821	3,248	8,779
Chlorine %	0.005	0.005	0.039	0.043			0.07	0.19

3.4 Ash

Ash content in the MRWC samples ranged from 1% oven dry basis (o.d.) for Russian olive to 3.3% for saltcedar.[10] Saltcedar samples contained low levels of ash (2%-3.3% dry basis) which would indicate that the wood came from a clean harvest area or had lost most of its leaves before chipping. These ash levels are low compared with Utah juniper (14% ash) or mesquite (6% ash).[11] They are more similar to pine hog fuel that contains wood and bark. Solid wood in most species contains about 0.5% ash. The bark contains 3% ash. Ash is usually higher in bark because the nutrients concentrate in the cambium layer beneath the bark. Dirt from harvest and wind-blown sand adhere to bark. High ash in saltcedar may also be due to the water soluble extractives contained in the

[9] Salt cedar and Russian olive sampled by MRWC. Pine hog fuel from an Eastern Oregon sawmill and Douglas fir from a western Oregon sawmill sampled by T.R. Miles.

[10] S. Bockness. 2012. Summary of MRWC CIG Invasive Species Biomass Testing 2011. February 20

[11] Utah juniper and mesquite samples from Arizona by T.R. Miles.

wood.[12] These water soluble nutrients volatilize during combustion and can react with each other, or with silica or chlorine, from the fuel.[13] In recent years ratios of these elements have been found to be good indicators of melting or fouling behavior in boilers.[14] Saltcedar would have a higher fouling factor than Russian olive due to the high alkali and sulfur. The ash contains low silica relative to the potassium which would suggest formation of a potassium-silica melt if there were an ash accumulation in a furnace. The potassium is likely to stay in the bottom ash rather than volatilize and deposit in the boiler. Even though Clemons found salt crystals in the wood the concentration of chlorine in the MRWC sample is low so the potential for corrosion from hydrochloric acid or alkali salts formed during combustion should be low.

The Russian olive samples had very low ash contents (1%-2.7% d.b.) and consequently they would have low concentrations of volatile alkali. The boiler fouling potential for Russian olive should be very low. It had a slightly higher concentration of phosphorous and silica than saltcedar but a lower concentration of sodium or potassium. Chlorine levels were very low. Volatile potassium should stay in the bottom ash during combustion. In general Russian olive would appear to be a very clean fuel.

Table 3-4 shows the ash fusion temperatures for both species. In this test the samples are ashed at a low temperature (<600ºC, 1112 ºF) in a crucible. The ash is formed into cones. The cones are observed while they are heated in reducing – air starved – and oxidizing – excess air – environments to simulate the conditions on the grate of a furnace. The Russian olive has high ash fusion temperatures (>2700ºF). Saltcedar had the lowest ash fusion temperatures (2141ºF -2185ºF) under reducing conditions. Temperatures on the grate in biomass furnaces are often between 1500 ºF and 1800ºF except when the fuel is very dry or there is a high concentration of charcoal so sintering or melting is not likely to occur.

[12] C. Clemons and N. Stark, 2007, Use of salt cedar and Utah juniper as fillers in wood-plastic composites: Madison, Wis., U.S. Forest Service, Forest Products Laboratory Research Paper FPL-RP-641, 17 p. When investigating the use of salt cedar for a filler in wood-plastic composites Clemons and Stark found that salt cedar had about 9% water soluble extractives at room temperature compared with 3.4 % for pine. They demonstrated substantial reduction of soluble nutrients (S, Ca, Na, K, Mg, P) during water extraction.

[13] T.R. Miles, et. al. 1995. Alkali Deposits Found in Biomass Power Plant: A Preliminary Investigation of Their Extent and Nature. National Renewable Energy Laboratory Subcontract TZ-1-1 1226-1, Golden CO.

[14] P. Sommersacher, T. Brunner, I. Obernberger, 2012. Fuel Indexes: A Novel Method for the Evaluation of Relevant Combustion Properties of New Biomass Fuels. Energy and Fuels, 2012, 26 (1), pp 380–390 DOI: 10.1021/ef201282y

Test burns with saltcedar pellets in stoves showed nothing unusual; however it often takes long term burning for ash related problems to appear, even at the high temperatures (1000°C, 1832°F) associated with combustion in pellet stoves.[15]

Table 3-3. Comparison of Ash Properties

Fuel	Russian Olive MT	Saltcedar MT	Pine Hog Fuel E OR	Douglas Fir Mill Waste OR
Elemental Composition				
SiO_2	23.66	7.51	42.59	15.17
Al_2O_3	2.06	1.66	11.23	3.96
TiO_2	0.13	0.08	1.28	0.27
Fe_2O_3	0.96	0.53	9.04	6.58
CaO	19.3	27.2	14.54	11.90
MgO	7.81	6.91	3.28	4.59
Na_2O	1.3	4.46	2.10	23.50
K_2O	6.47	8.47	6.39	7.00
SO_3	2.6	36.1	1.72	2.93
P_2O_5	9.26	3.3	2.00	2.87
SrO			0.06	
BaO			0.12	
MnO			0.34	
CL	0.1	0.31		
CO2	11.7	6.1		18.92
Undetermined	14.65	-2.63	5.31	2.31
TOTAL	100.00	100.00	100.00	100.00
Alkali, Lb./MMBtu	0.13	0.45	0.31	0.14

Table 3-4. Ash Fusion Temperatures

Fuel	Russian Olive MT		Saltcedar MT	
Ash Fusion Temperatures	Reducing °F	Oxidizing °F	Reducing °F	Oxidizing °F
Initial Temperature	2700	2700	2141	2489
Softening Temperature	2700	2700	2155	2496
Hemispherical Temperature	2700	2700	2170	2499
Fluid Temperature	2700	2700	2185	2505

[15] S. Bockness www.weedcenter.org/MRWC

4.0 Bioenergy Uses

4.1 Boilers

Wood boilers are more expensive to install, own and operate than oil boilers. Fuel savings must pay for the higher costs. The amount of fuel oil replaced depends on the heating value of the fuel and the efficiency of the wood boiler. Table 4-1 shows the amount of fuel oil displaced at typical efficiencies by wood with the heating values in Table 3-1. Boiler conversion efficiency (CE) can be expected to vary from 35% to 70% of the energy in the fuel in wood boilers. Recovered heat is calculated using the equation Recovered Heating Value (RHV) = Gross Heating Value (GHV) x % Conversion Efficiency (CE).[16] A ton of dry (20% MC) saltcedar or Russian olive wood could replace 79 gallons of fuel oil at 70% conversion efficiency. At $4/gallon for fuel oil the value of the wood heat ($316/ton) would be similar to the cost of harvest. Wood must be delivered at half the cost ($156/ton) to replace fuel oil at $4 if it is burned in a low efficiency, outdoor wood boiler.

Table 4-1. Fuel Oil Replacement by Wood

Fuel, boiler	Conversion Efficiency CE	Energy in Fuel HHV Btu	Heat Delivered RHV Btu	Gal Fuel Oil	$/gal, $/ton
Fuel Oil, Btu/gal	85%	138,500	117,300	1	$4.00
[a] Wood chip boiler, 20% MC, Btu/lb, MMBtu/ton, gal/ton	70%	6,600	9,240,000	79	$316
[b] Low efficiency wood boiler, 20% MC, Btu/lb, MMBtu/ton, gal/ton	35%	6,600	4,620,000	39	$156

Notes:

[a] Typical conversion efficiency 70%. Recovered Heating Value (RHV) = Gross Heating Value (GHV) x % Conversion Efficiency (CE).

[b] Typical outdoor wood boiler (OWB) efficiency 35% to 40%

[16] Briggs, David, 1994. Forest Products Measurements and Conversion factors: with Special Emphasis on the U.S. Pacific Northwest, University of Washington Institute of Forest Resources, AR-10, Seattle, Washington 98195 Chapter 8.

Figure 4-1. Small Boilers

A. Small Institutional Boiler with typical efficiency of 70%. (Messersmith Mfg.)

B. Combustion in a Small Chip Boiler (Hurst Boiler)

There are many suppliers of small scale wood heating equipment.[17] Some companies that specialize in small scale boilers have developed prefabricated boilers in containers that can be used for schools and small institutions. These boilers can burn wood chips as long as they do not exceed 35% MC wb. These small boilers often supply 500,000 Btu to 3 million Btuh and consume 100-800 tons of fuel per year. At a wood

[17] David Peterson and Scott Haase. 2009. Market Assessment of Biomass Gasification and Combustion Technology for Small- and Medium-Scale Applications. Technical Report NREL/TP-7A2-46190 July 2009, National Renewable Energy Laboratory 1617 Cole Boulevard, Golden, Colorado 80401-3393 www.nrel.gov

recovery rate of 4 tons per acre a single boiler would be supplied from 100 treated acres per year.

Small boilers are often used where fuel oil or propane prices are high (e.g. $2.50/gallon propane or $35/MMBtu). If air dried wood could be delivered and converted in a boiler for $200/ton then a school or small commercial facility would realize a significant savings in fuel costs.

4.2 **Pellets**

Tests conducted by the MRWC have shown that pellets can be made from clean Russian olive and saltcedar.[18] Pellets were made in the small machine shown in Figure 4.2.

Figure 4-2. Pellets

A. MRWC Experimental Pellet Machine

B. Typical Douglas Fir Pellet

While MRWC samples were relatively dry (<8%-10% MC) [19], wood for making pellets must be uniformly less than 8% MC. A dryer would be required to make a fuel product like the pellets shown in Figure 4-2B. Commercial pellet production would require a dryer that is typically sized for 1-6 dry tons per hour.

[18] S. Bockness www.weedcenter.org/MRWC

[19] S. Bockness. 2012. Summary of MRWC CIG Invasive Species Biomass Testing 2011. February 2012.

Standards for residential and commercial densified fuels are shown in Table 4-2. While Russian olive may meet moisture and ash requirements of the Pellet Fuels Institute "Standard" or "Utility" grades it would not qualify for the higher value "Premium" grade that is sold for residential use at $250-$300/ton ($18-$22/MMBtu). Given the potential variability of ash content at harvest it is not likely that even a standard grade pellet could be guaranteed. Beneficiation techniques have been developed to reduce foreign matter from whole tree chips to less than 2%.[20] As yet there are no commercial systems and the extra cost of cleaning may be too high for the intended market. A Russian olive or saltcedar pellet may be suitable for small scale or industrial boilers that can burn fuel with 6% ash fuel. A "Utility" pellet (<6% ash) would sell in bulk for $160-$180/ton ($12-$13/MMBtu).

Table 4-2. Residential/Commercial Densified Fuel Standards

	Residential/Commercial Densified Fuel Standards See Notes 1 - 3		
Fuel Property	PFI Premium	PFI Standard	PFI Utility
Normative Information - Mandatory			
Bulk Density, lb./cubic foot	40.0 - 46.0	38.0 - 46.0	38.0 - 46.0
Diameter, inches	0.230 - 0.285	0.230 - 0.285	0.230 - 0.285
Diameter, mm	5.84 - 7.25	5.84 - 7.25	5.84 - 7.25
Pellet Durability Index	≥ 96.5	≥ 95.0	≥ 95.0
Fines, % (at the mill gate)	≤ 0.50	≤ 1.0	≤ 1.0
Inorganic Ash, %	≤ 1.0	≤ 2.0	≤ 6.0
Length, % greater than 1.50 inches	≤ 1.0	≤ 1.0	≤ 1.0
Moisture, %	≤ 8.0	≤ 10.0	≤ 10.0
Chloride, ppm	≤ 300	≤ 300	≤ 300
Heating Value	NA	NA	NA
Informative Only - Not Mandatory			
Ash Fusion	NA	NA	NA

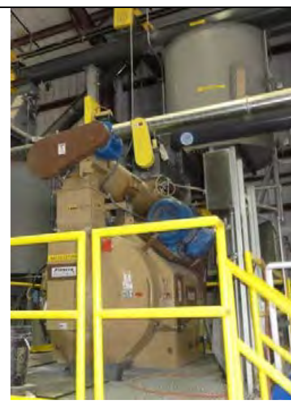
Source: Pellet Fuels Institute, www.pelletheat.org

[20] Forest Concepts, LLC., 3320 W. Valley Hwy. N., Ste. D110, Auburn, WA 98001 www.forestconcepts.com

A mobile pellet mill was considered in the original plan for the MRWC bioenergy project. Mobile operation does not seem to be a practical conversion method of making a good quality pellet because of the requirements for material handling, sizing, and drying. Modular or prefabricated plants are available at the small scale.[21] A 1,000 lb/hr plant would produce about 500-600 tpy on a single shift and cost $500,000. A 1 tph system would produce about 1,200 tpy on a single shift, or 2,400 tpy on a two shift basis, and cost $1,000,000. A 4-6 tph pellet mill, like the one shown in Figure 4-3, would produce more than 30,000 tons per year and cost about $7 million. Operating costs for pellet mills are from $60-$100/ton not including the cost of packaging and raw materials. Cost for pellets at plants in the Northwest and Mountain regions are $147-175 FOB.[22] Residential pellets retail for $250-$300 ton.[23] If harvest costs are $300/ton and processing costs are $60 to $100/ton, then pellets from invasive species would cost $360-$400/ton FOB. They would not compete with bulk or retail pellets unless harvest costs are offset by funding from other sources.

Figure 4-3. Industrial Pellet Mill

A. Pellet Mill Dryer 4 TPH 30,000 tpy



B. Pellet Mill 4 TPH 400 HP

[21] A typical supplier for small pellet mills is ExFactory www.exfactory.com

[22] March 2012 Market Update, Pellet Fuels Institute Newsletter 2011-2012 Issue #4www.pelletheat.org

[23] Commercial markups are about 35% for wood pellets.

4.3 Torrefied Wood

Torrefaction is a method to prepare fuel for industrial use.[24] It is an industrial process that requires drying and heating biomass to 285^{0}C (545^{0}F) in the absence of air. Moisture is evaporated. Some of the volatile carbon, such as the hemicellulose, is also driven off. About 30% of the volatiles including moisture and carbon are lost, which equal about 10% of the weight of the raw wood. The remaining carbon is partially charred and has a heating content of about 11,000 Btu/lb compared with dry wood at 8,300 Btu/lb. Torrefied wood is reported to be easy to grind and densify. Torrefied pellets could be transported and co-fired in a coal boiler. Production costs have not been validated and a value has not been established for torrefied wood because there are few commercial facilities.

Coal plants consume fuel at the rate of about 11 MMBtu/MWh. A 100 MWe coal plant requires 1100 MMBtuh fuel. If it cofired torrefied wood at 20% it would need 220 million Btuh or 10 tons of torrified pellets per hour at 22 MMBtu/ton. That would require about 90,000 tons of wood from the eradication programs and an investment of $20 million for a plant to make the torrefied wood. Utilities buy fuel on a "burner tip" basis. Coal at $124/ton delivered from Wyoming costs $4-$6/MMBtu. It is not likely that the useful value of the torrefied pellet would be greater than $10/MMBtu or about $220/ton delivered to a coal plant, which is less than the cost to harvest the wood.

Figure 4-4. Torrified Wood Pellets

Source: T.R. Miles. Technical Consultants, Inc.

[24] S. J. Sokhansanj, J. Peng, X.Bi Lim.2010.Optimum Torrefaction and pelletization of biomass feedstock . TCS 2010 Symposium on Thermal and Catalytic Sciences for Biofuels and Biobased Products, Iowa State University, Ames, Iowa September 21-13, 2010

4.4 Charcoal

Saltcedar has been used to make a good quality lump charcoal in small scale experiments.[25] Table 4-3, Figure 4-5. It has been sold in small quantities in New Mexico for about $0.70/lb ($7/10 lb bag, or $1,400/ton). Lump charcoal technologies are most advanced in Brazil. Current high technology kilns can produce about 1400 tons of charcoal per month from 50,000 tons of wood per year at a plant cost of about $2 million.[26] Afterburners prevent pollution. Markets for lump charcoal would have to be determined. Although the value of lump charcoal is high there are many producers. Much of the lump charcoal in the U.S. is supplied from Mexico.

Table 4-3. Properties of Charcoal

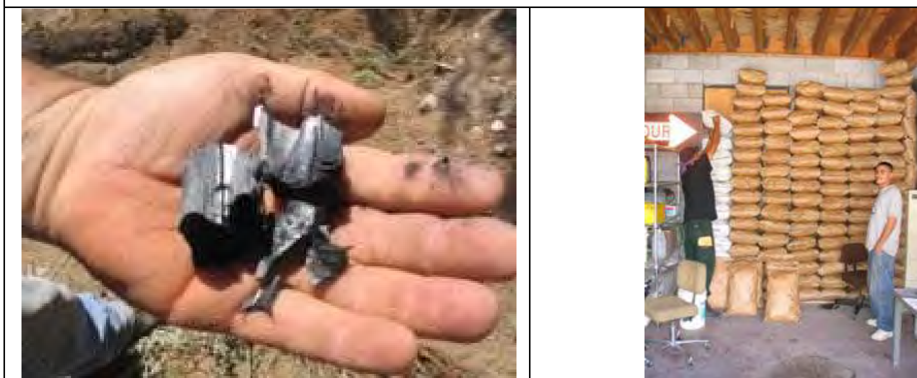
Fuel, boiler	Saltcedar	Mesquite	Ponderosa	Oak Encino
Heating Value Bt/lb	12,674	13,152	13,180	13,633
Fixed Carbon, %	73.17	76.12	70.46	80.83
Volatile Matter	20.76	18.17	26.02	14.28
Ash	2.78	2.97	1.30	2.63
Drying Loss	3.29	2.74	2.22	2.26

Source: www.scizeri-nm.org/ZERI/_PDF/chartfinalmad.pdf

[25] Dykstra, op. cit. and Sustainable Communities Zero Emissions Research & Initiatives, New Mexico http://www.scizeri-nm.org/ZERI/_PDF/chartfinalmad.pdf

[26] R. Miranda, A. Pimental. T. Miles, 2011. Review of Power Cogeneration Technologies for Charcoaling and their Potential Application in Sub-Saharan Africa. Report to the World Bank. May.

Figure 4-5. Saltcedar Lump Charcoal



A. Kiln charred saltcedar. (Sustainable Communities/ZERI, New Mexico)

B. Bagged charcoal for sale. (www.scizeri-nm.org/ZERI/charcoal.asp)

4.5 **Biochar**

Forest residues and chips from eradication programs can be converted to bulk charcoal in pyrolysis kilns to produce biochar. Biochar is defined by the International Biochar Initiative as solid material obtained from the carbonization of biomass. It is "1) added to soils with the intention to improve soil functions; and 2) produced in order to reduce emissions from biomass (that would otherwise naturally degrade to greenhouse gases) by converting a portion of that biomass into a stable carbon fraction that has carbon sequestration value."[27]

During pyrolysis biomass is heated in a retort to 400^{0}C-600^{0}C (752^{0}F-1112^{0}F).[28] Heat is applied externally in the absence of air, like in torrefaction, so that the carbon does not ignite. Low temperature pyrolysis is suited to wood like saltcedar because the nitrogen, sulfur or extractive components will be largely retained in the charcoal and will eventually be made available to plants through the action of micro-organisms that inhabit the charcoal when it is placed in the soil. Bark, leaves, sand, or clay that is picked up during harvest will just add nutrients to the biochar.

[27] International Biochar Institute www.biochar-international.org

[28] M. Garcia Perez, 2011. Methods for Producing Biochar and Advanced Biofuels in Washington State. Washington Department of Ecology Publication Number 11-01-017.

The technology of using charcoal in soils with low carbon content has existed since 1000 BCE but the current use of biochar in soil is recent and markets and applications are just now emerging. Standards for production and best practices for use are being developed. Biochar markets can be identified in agricultural crop production, horticultural crop production, turf management, and stormwater and erosion control. Biochar has been demonstrated as a suitable substitute for vermiculite in specialty horticultural crops. Current values for biochar range from $0.10/lb, or $200/ton, for agricultural uses to $1.00/lb, or $2,000/ton, for green roof and stormwater applications. The average sale is for about $0.40/lb or $800/ton.

Current use is limited by production. There are several small scale and pilot systems producing as little as one half ton per day or 125 tons per year. There are no large scale production facilities. There have been some small mobile demonstrations for production of biochar and bio-oil.[29] [30] Small plants are in commercial operation in Colorado and Idaho.[31] These systems have limited production but may be suitable for a small eradication program.

If the cost to carbonize wood from the eradication program is $60/ton then at 4 tons per acre the marginal cost of carbonization would be $240/acre. Approximately 1.2 tons of biochar could be produced from 4 tons of wood that could be used as amendment to improve the fertility of low carbon, or poor quality, soils and to sequester carbon. If the cost of eradication is added at $1200/acre then the total cost of eradication, soil improvement and carbon sequestration would be $1,440/acre. Table 4-4.

[29] D. Dumroese et. al. 2010. Can portable pyrolysis units make biomass utilization affordable while using bio-char to enhance soil productivity and sequester carbon? www.treesearch.fs.fed.us/pubs/37322

[30] Biochar Products, Halfway, OR www.biocharproducts.com

[31] Biochar Solutions, Carbondale, CO. www.biocharsolutions.com

Table 4-4. Cost of Treatment Including Biochar

Cost of Treatment	**$/ton**	**Tons/acre**	**$/acre**
Wood	$300	4	$1200
Carbonization	$60	4	$240
Total cost	$360		$1440
Biochar	$1200	1.2	$1440
$/ton **$CO_2$** [32]	$480	3	$1440

If biochar is produced for sale the total cost would be $1,200/ton or $0.60/lb ($1,440/1.2 ton biochar/acre) which is probably higher than the value of most applications. Carbonization of 4 tons of wood will produce approximately 20 MMBtu. If the char is valued at $0.40/lb and the heat was used in a boiler or greenhouse furnace the heat would cost about $24/MMBtu.[33] Combined heat and biochar could obtain savings when fuel oil is $4/gallon (or propane is $2.50/gal) and there are suitable markets for the char. Figure 4-6.

[32] Assume 2.5 tons of CO2 sequestered by 1 ton of biochar.

[33] Total cost $1,440/acre less biochar value of $960 ($0.40 x 1.2 tons/acre) = $480/acre/20 MMBtu= $24/MMBtu.

Figure 4-6. Biochar

	
A. Biochar furnace (right) converts wood to biochar and heat for a greenhouse heater (left). Est. value $35/MMBtu (Whitfield Biochar Furnace)	B. Biochar replaces vermiculite (left) in growing media for tree seedlings. Est. value $800/ton (Calforest Nurseries)

5.0 Conclusions and Recommendations

Bioenergy solutions for the eradication of saltcedar and Russian olive are likely dependent on the cost of production, the logistics of supply, and the value of markets rather than on their physical or chemical characteristics.

The potential to supply small heating boilers should be investigated. A tree service chipper might be sufficient to supply enough fuel for a small boiler to replace fuel oil or propane.

Wood from Russian olive or saltcedar is not likely to be competitive as a pellet fuel unless as is reduced and production costs are offset by funding from other sources.

Since large boilers rarely burn a single fuel these relatively clean fuels could be combined with other biomass or coal but the delivered cost of wood must be acceptable to the utility. If there is an opportunity to burn wood from an eradication program in a nearby boiler, then wood from saltcedar and Russian olive should be test burned for extended periods in large quantities. The large scale and high processing costs of torrefaction are not likely to make it a competitive process for saltcedar and Russian olive.

The potential to carbonize these fuels for use as a soil amendment should be investigated. Carbonization offers a means of improving poor quality soils and sequestering carbon. If suitable markets can be found for biochar and heat then combined heat and biochar could potentially recover the costs of treatment and provide heat savings.

Appendix A. List of Abbreviations and Acronyms

BDT Bone Dry Ton
BTU British Thermal Unit (MBtu, thousand Btu ; MMBtu, million Btu)
CE Conversion Efficiency (fuel to heat)
CHP Combined Heat and Power
Cord 80 ft3 of solid wood
DB Dry Basis (wet weight –dry weight/dry weight)
EMC Equilibrium moisture content
FOB Purchased at seller's premises. Buyer pays shipping costs
GHV Gross Heating Value (also Higher Heating Value)
Gpy Gallons per year
HHV Higher Heating Value
KBtu Thousand Btu
KWe Kilowatts, electric
KWt Kilowatts, thermal
MC Moisture Content (e.g. MC20 20 % moisture)
MMBtu Million Btu
MRWC Missouri River Watershed Coalition
MWe Megawatts per hour electrical capacity
MWh Megawatt hour, 1000 kilowatt hours
NHV Net Heating Value
OD Oven Dry (weight)
ODT Oven Dry Ton
O&M Operating and Maintenance
OWB Outdoor Wood Boiler
PV Present Value
RHV Recovered Heating Value
Therm Heating unit for natural gas = 100,000 Btu
Unit A shipping volume of 200 ft3
USFS United States Forest Service
WB Wet basis (wet weight-dry weight/wet weight)

Allen Control

Big Horn County, Montana

	2012	2013	2014
Start of Transect			
End of Transect			

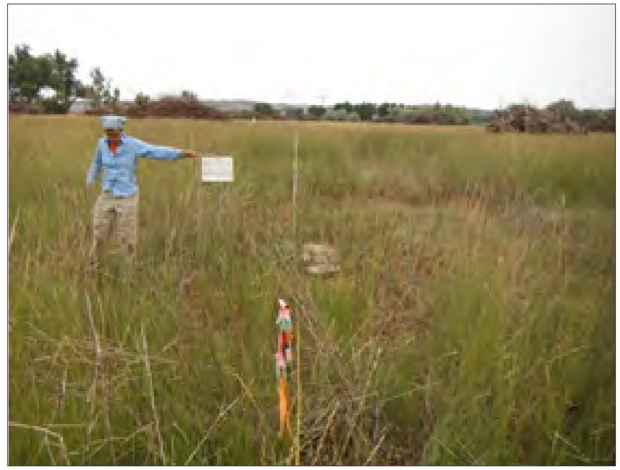
Allen Treatment 1

Big Horn County, Montana

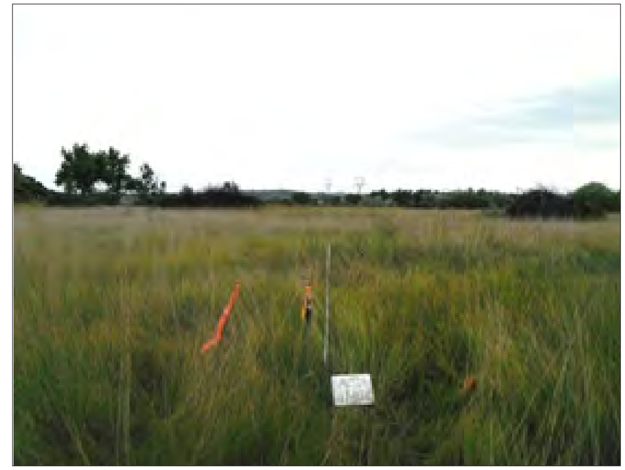
Start of Transect

2012

2013



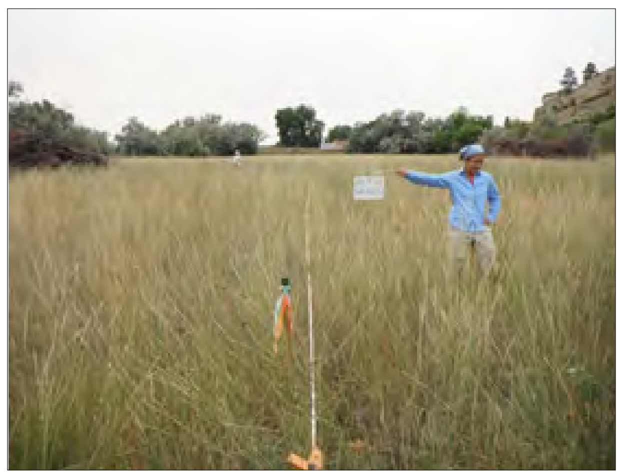
2014



End of Transect

2012

2013



2014

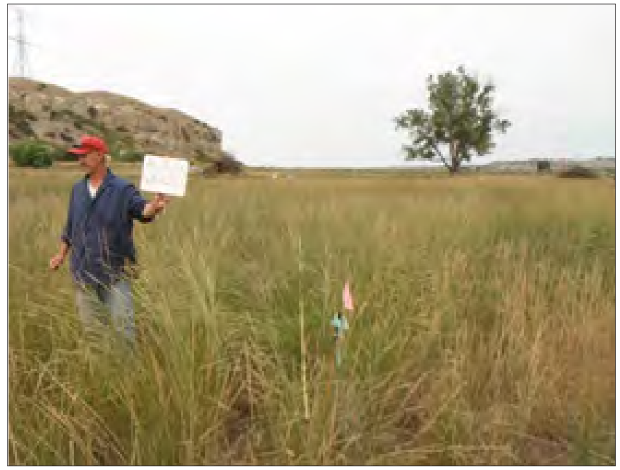
Allen Treatment 2

Big Horn County, Montana

Start of Transect

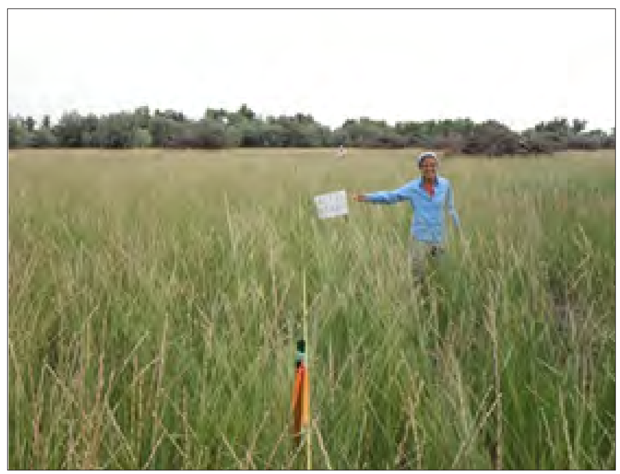
2012

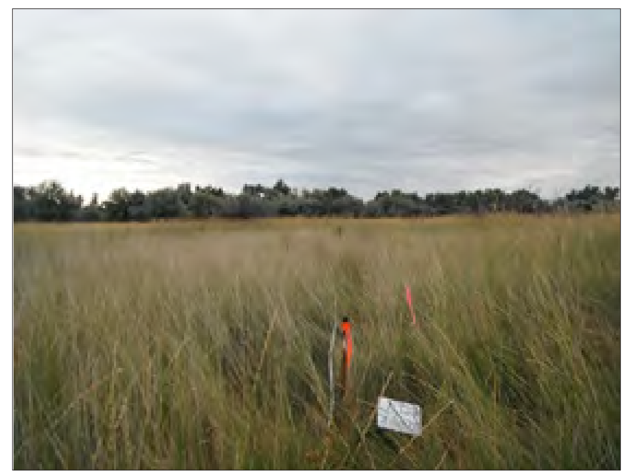
2013



2014

End of Transect





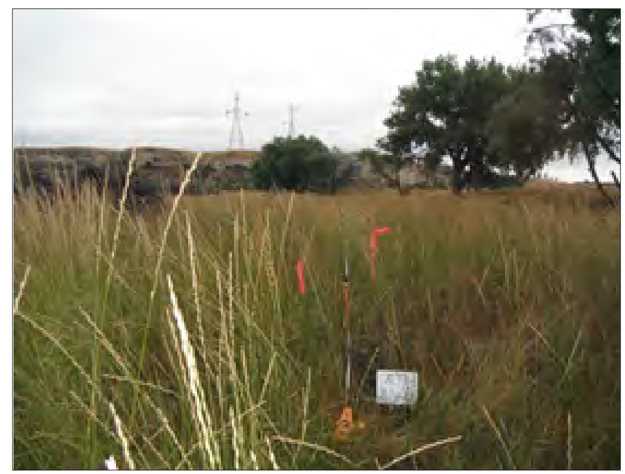
Allen Treatment 3

Big Horn County, Montana

2012 | **2013** | **2014**

Start of Transect

End of Transect



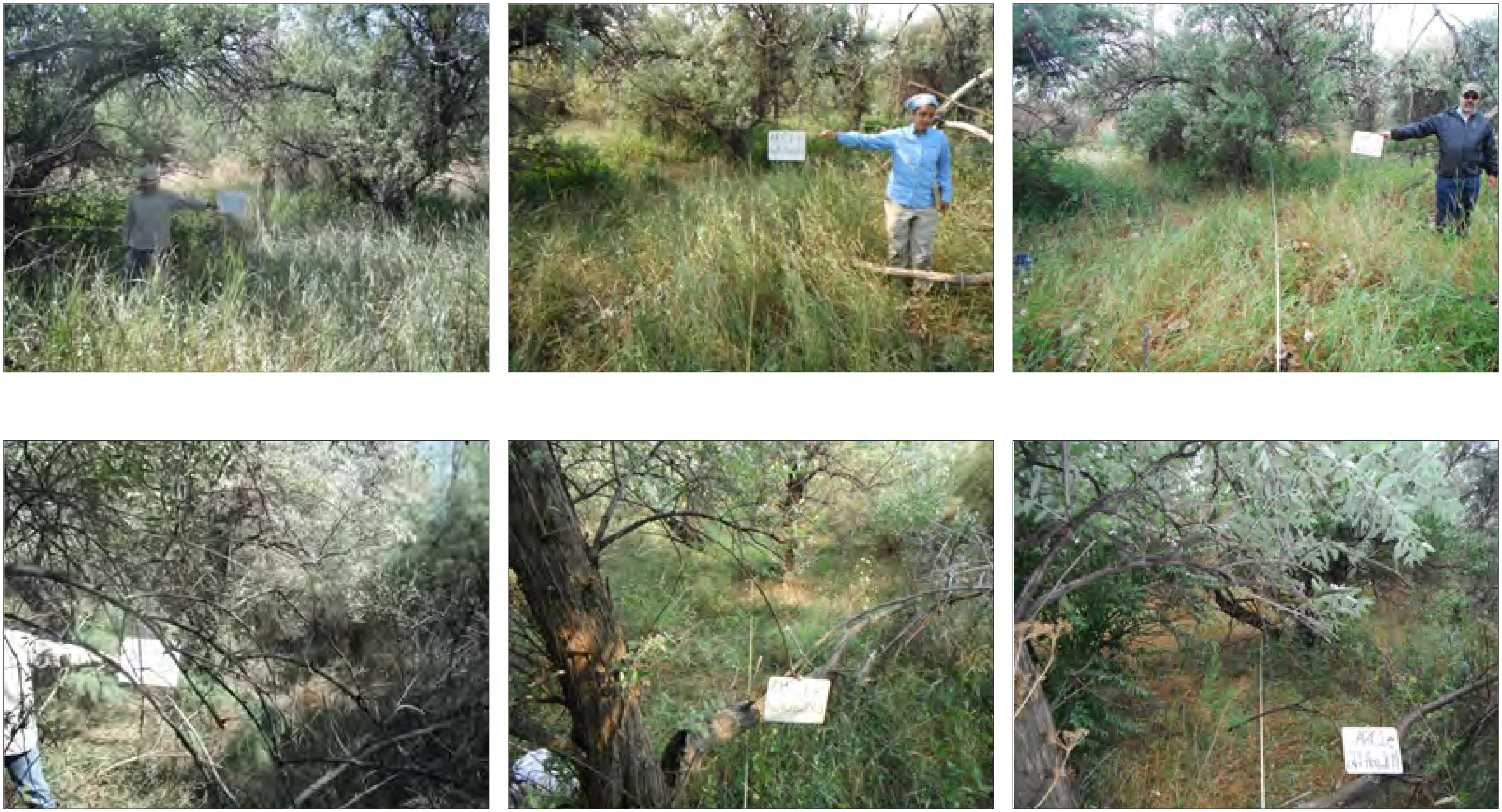
Arapooish Control

Hardin, Montana

2012 | 2013 | 2014

Start of Transect

End of Transect

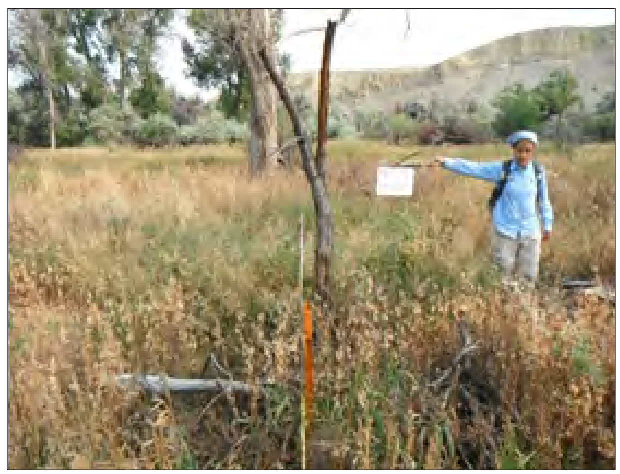


Arapooish Treatment 1
Hardin, Montana

2012 | **2013** | **2014**

Start of Transect

End of Transect



Arapooish Treatment 2

Hardin, Montana

2012 **2013** **2014**

Start of Transect

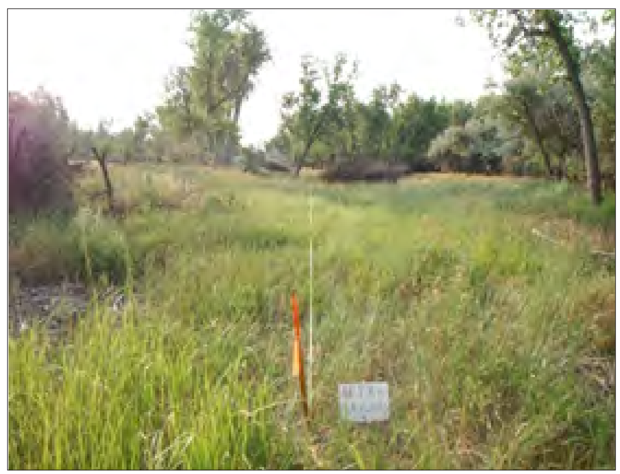
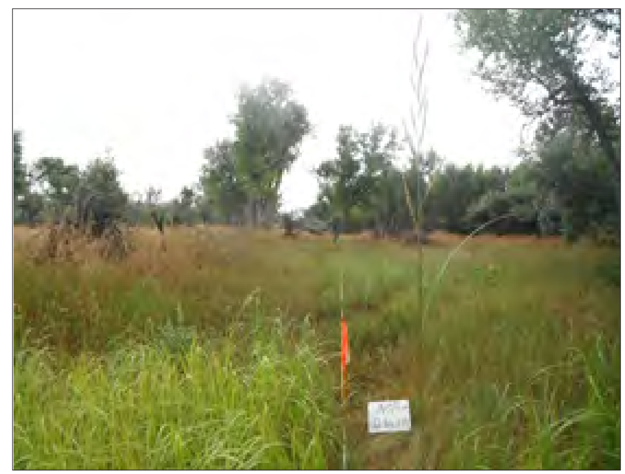


End of Transect



Arapooish Treatment 3

Hardin, Montana

	2012	2013	2014
Start of Transect			
End of Transect			

Ft. Keogh 1 (Cottonwood Flats) Control

Miles City, Montana

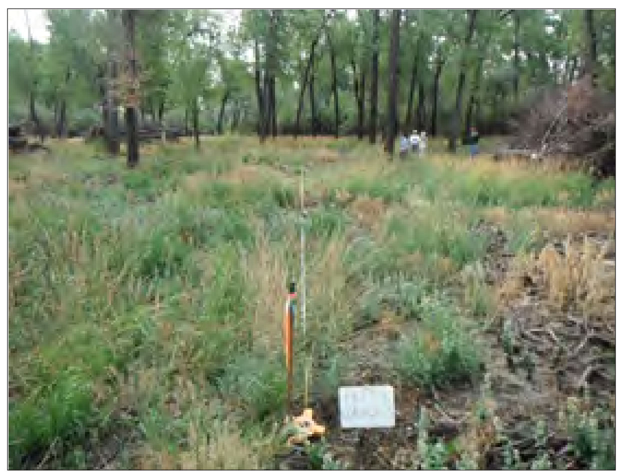
2012 | **2013** | **2014**

Start of Transect

End of Transect

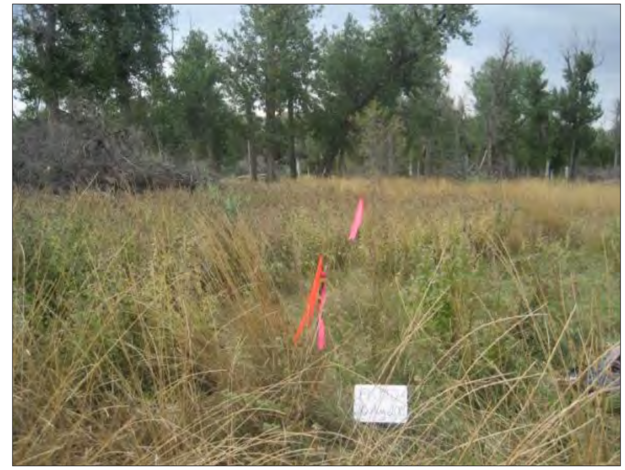
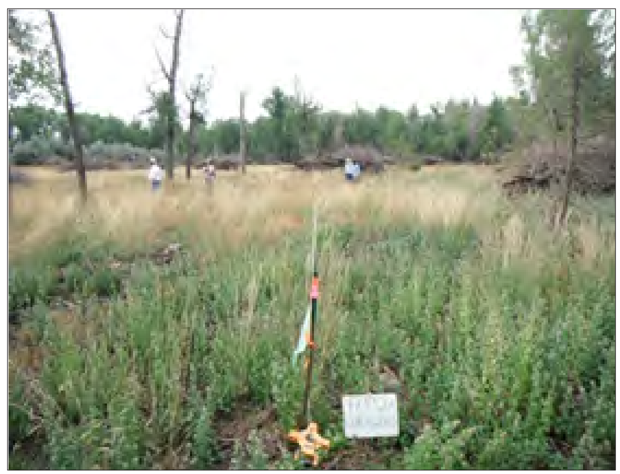
Ft. Keogh 1 (Cottonwood Flats) Treatment 1

Miles City, Montana

	2012	2013	2014
Start of Transect			
End of Transect			

Ft. Keogh 1 (Cottonwood Flats) Treatment 2

Miles City, Montana

	2012	2013	2014
Start of Transect			
End of Transect			

Ft. Keogh 1 (Cottonwood Flats) Treatment 3

Miles City, Montana

Start of Transect

2012

2013

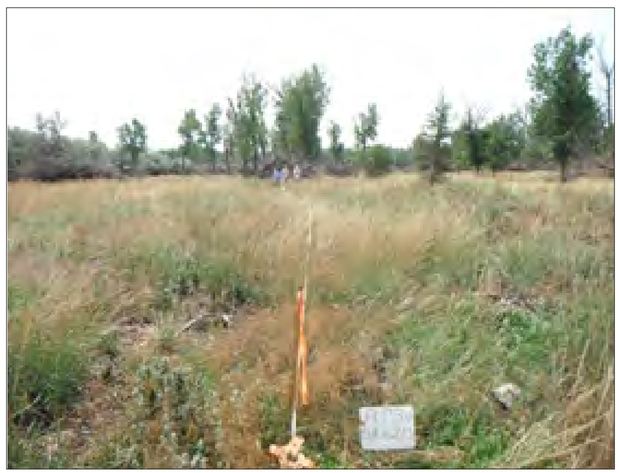
2014

No photo

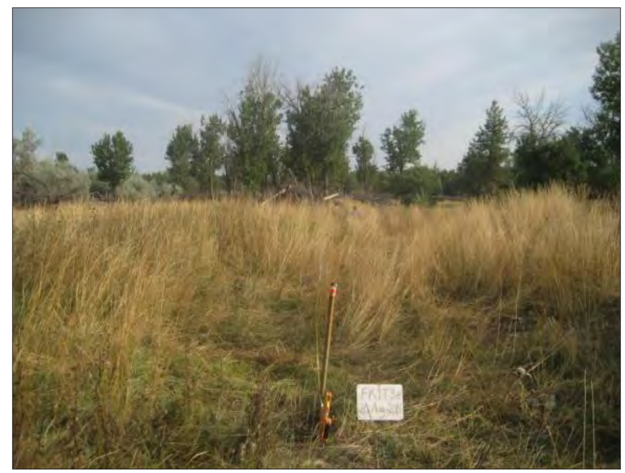
End of Transect

2012

2013



2014



Ft. Keogh 2 (East Yellowstone) Control

Miles City, Montana

2012 | **2013** | **2014**

Start of Transect

End of Transect

Ft. Keogh 2 (East Yellowstone) Treatment 1

Miles City, Montana

Start of Transect

2012

2013

2014

End of Transect

2012

2013

2014

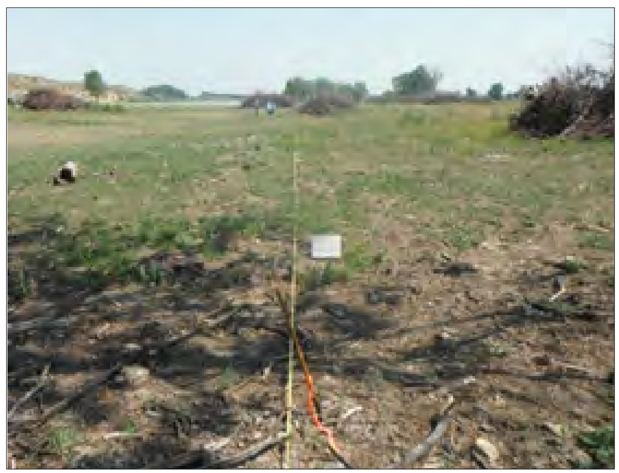
Ft. Keogh 2 (East Yellowstone) Treatment 2

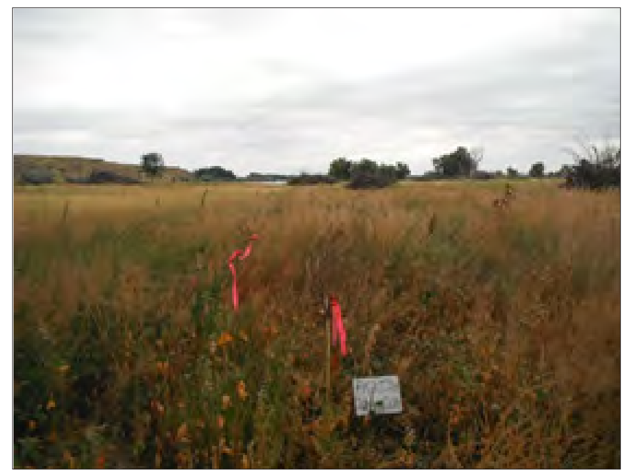
Miles City, Montana

2012 | **2013** | **2014**

Start of Transect

End of Transect





Ft. Keogh 2 (East Yellowstone) Treatment 3

Miles City, Montana

	2012	2013	2014
Start of Transect			
End of Transect			

Lovell (Classroom) Control

Lovell, Wyoming

	2012	2013	2014
Start of Transect			
End of Transect			

Lovell (Classroom) Mulch 1

Lovell, Wyoming

Start of Transect

2012

2013

2014

End of Transect

2012

2013

2014

Lovell (Classroom) Mulch 2

Lovell, Wyoming

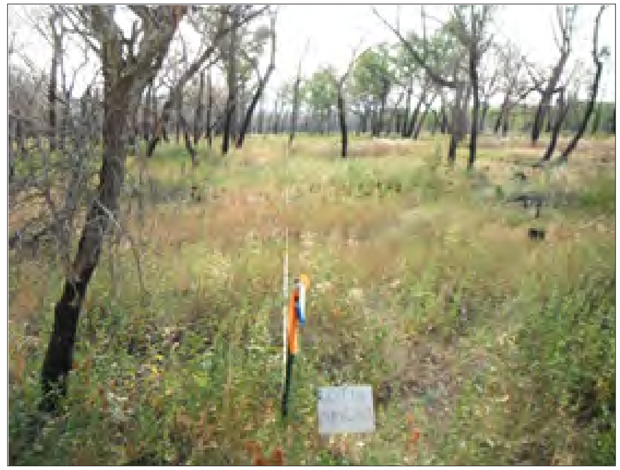
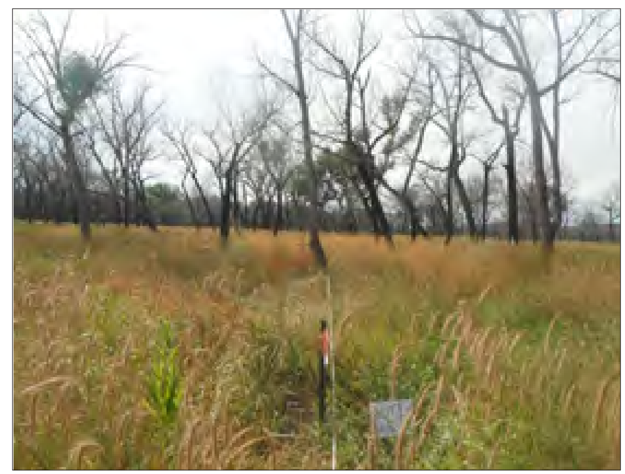
2012	2013	2014

Start of Transect

End of Transect

Lovell (Classroom) Treatment 1

Lovell, Wyoming

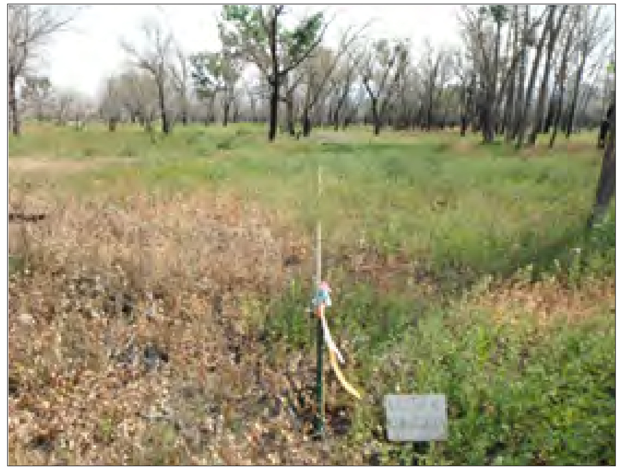
	2012	2013	2014
Start of Transect			
End of Transect			

Lovell (Classroom) Treatment 2

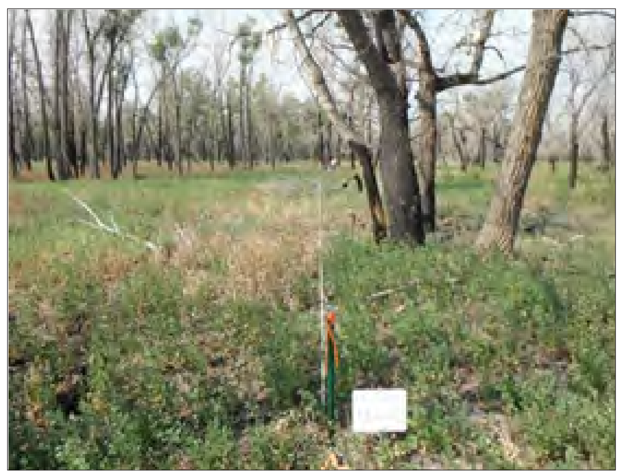
Lovell, Wyoming

2012 | **2013** | **2014**

Start of Transcect



End of Transect

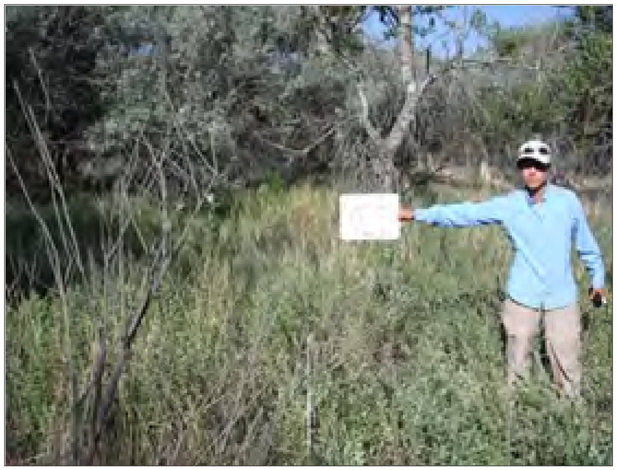


Lovell (Classroom) Treatment 3

Lovell, Wyoming

2012 | **2013** | **2014**

Start of Transect



End of Transect

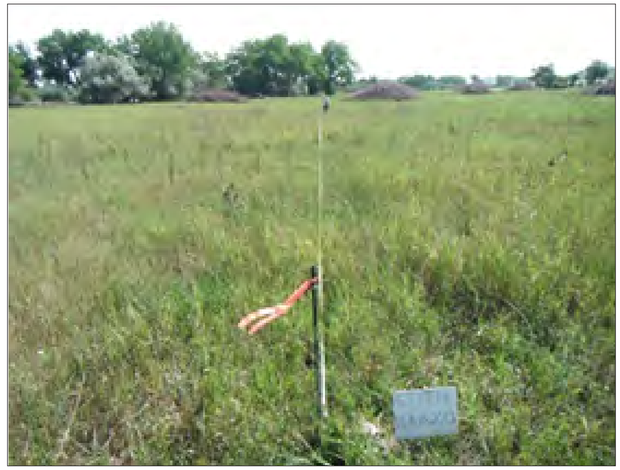
Sturgis School Site 1 Treatment 1

Sturgis, South Dakota

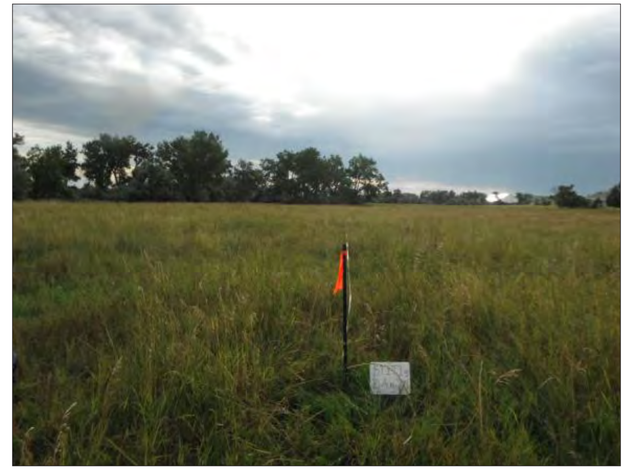
Start of Transect

2012

2013



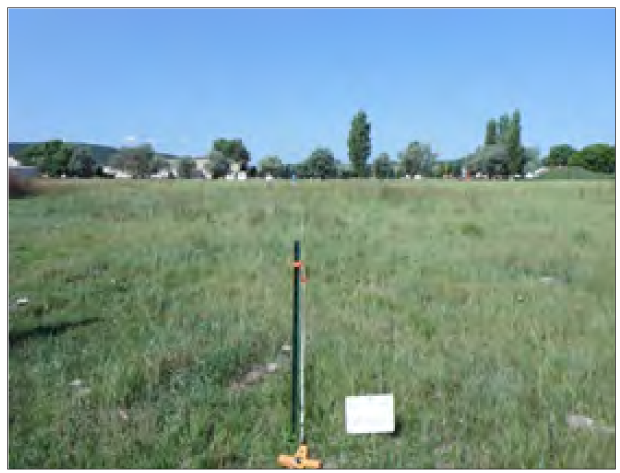
2014



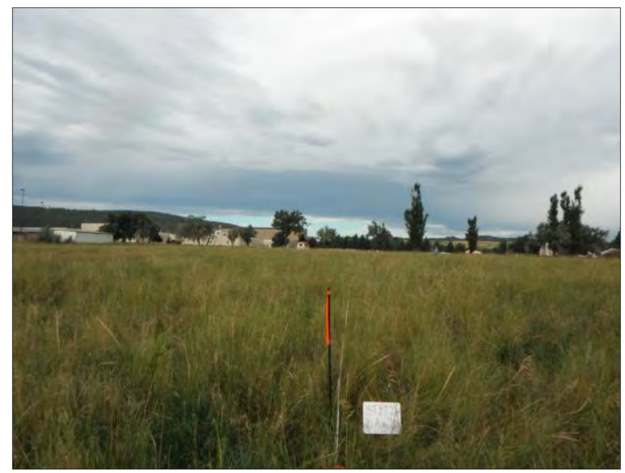
End of Transect

2012

2013



2014

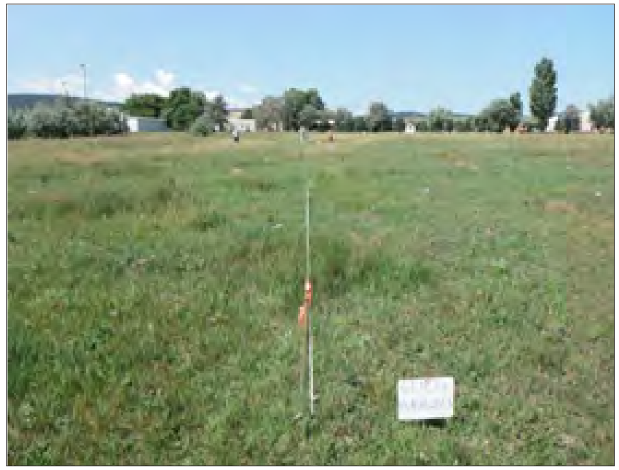


Sturgis School Site 1 Treatment 2

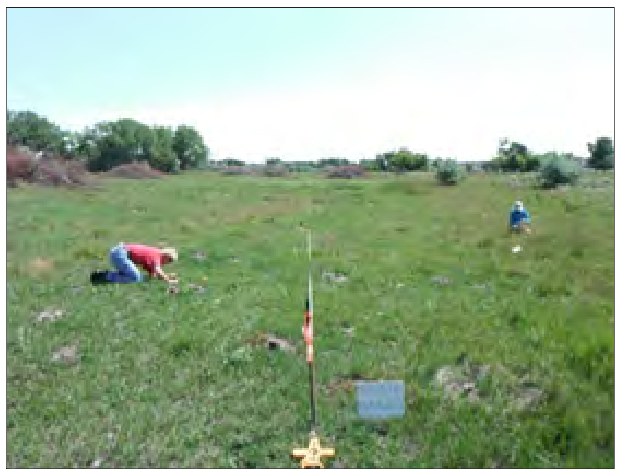
Sturgis, South Dakota

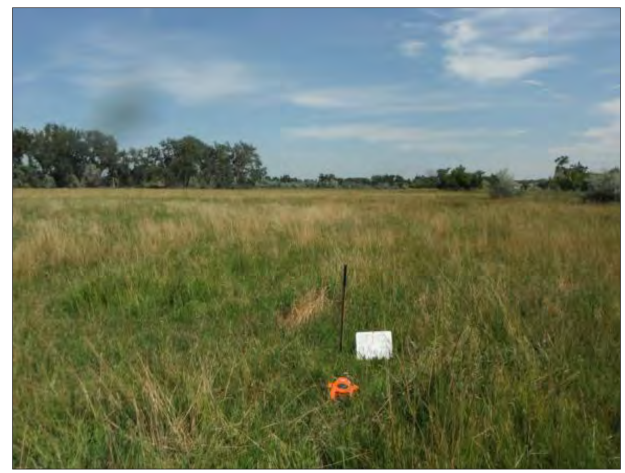
	2012	2013	2014

Start of Transect



End of Transect



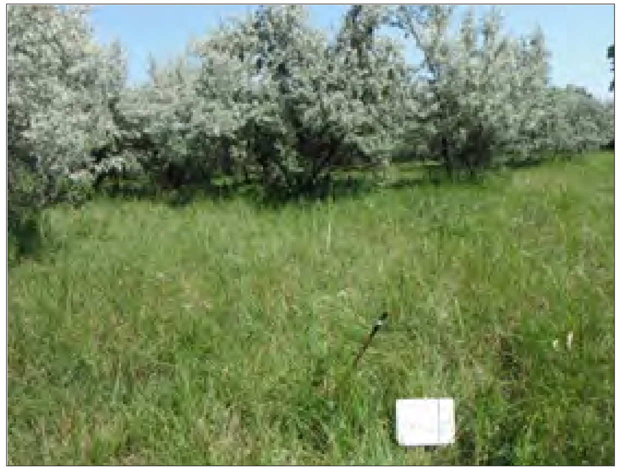


Sturgis School Site 2 Control

Sturgis, South Dakota

2012 **2013** **2014**

Start of Transect



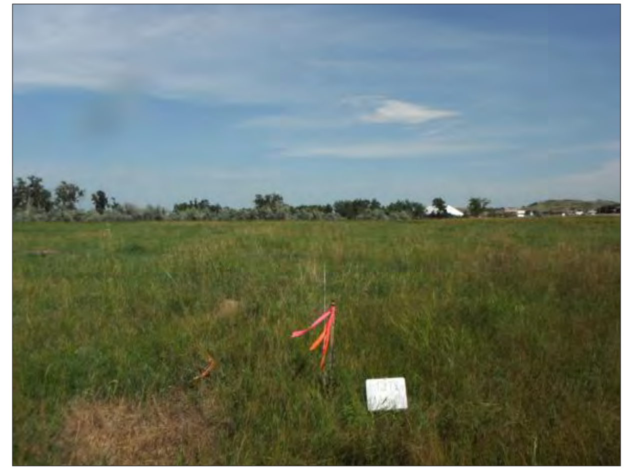
End of Transect

Sturgis School Site 2 Treatment 1

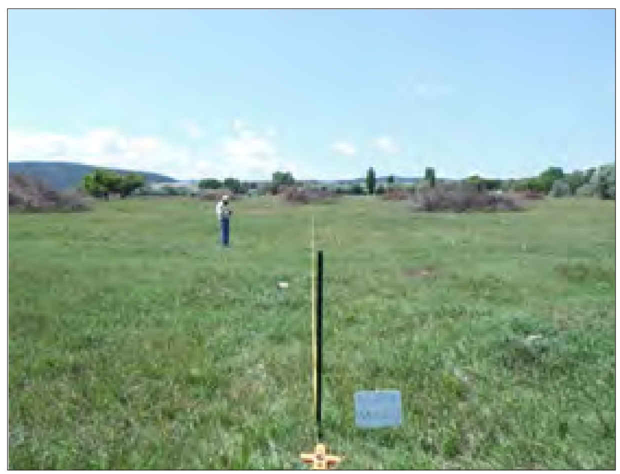
Sturgis, South Dakota

2012 | **2013** | **2014**

Start of Transect



End of Transect



Appendix M. Technology Transfer Summary Table

From the start of the project in September 2010 to October 2014, the project team as well as Montana State University staff and Missouri River Watershed Coalition Executive Committee members conducted approximately 70 CIG project-related technology transfer and outreach activities. These events reached nearly 5,000 regional and national stakeholders—producers and private citizens, tribes, conservation organizations, educators, university colleagues, congressional delegations, and local, state and federal agency personnel.

Date	Activity / location	Description	Audience	Participants
2010				
Sept. 30	North American Weed Management Association Annual Conference, *Pueblo, CO*	Formal presentation	Association members	250
Dec. 1	Western Weed Coordinating Committee Annual Meeting, *Las Vegas, NV*	Formal presentation	Committee members	50
Dec. 9	Montana Governor's Weed Advisory Committee Meeting, *Helena, MT*	Formal presentation	Committee members	15
2011				
Jan. 12	Montana Weed Control Association Annual Conference, *Great Falls, MT*	Formal presentation	Association members, commercial vendors	250
Feb. 17	Association of South Dakota County Weed and Pest Boards Annual Conference, *Huron, SD*	Formal presentation	Association members, commercial vendors,	200
March 9	Missouri River Natural Resources Conference, *Nebraska City, NE*	Formal presentation	State and federal government agency staff	250
March 14–17	Meetings with federal agencies and Congressional delegations, *Washington, DC*	Formal presentations	Senators, Congressmen, and staff (SD, MT, NE), NRCS, FICMNEW, USFS State & Private Forestry	20
April 7	Yellowtail Coordinated Resource Management Group Meeting, *Lovell, WY*	Formal presentation	Group members and interested stakeholders	30
April 27	Missouri River Watershed Coalition Semi-Annual Meeting, *Bozeman, MT*	Project update	Coalition members	35
May 24–26	Tour of potential project site locations for Wyoming and South Dakota stakeholders, *Various locations in SD and WY*	Presentation and tour	Producers, private landowners, local and state government agencies	25
June 30	Montana Noxious Weed Summit Advisory Council Meeting, *Helena, MT*	Project update	Council members, local, state, and federal government agencies	20
July 1	Meeting with ecoTECH Energy Group, *Butte, MT*	Discussion on developing alternative energy facilities in MT and utilizing wood biomass materials for energy generation	ecoTECH staff	5
Aug. 10–12	Montanans for Responsible Energy Development 2011 Meeting, *Colstrip, MT*	Discussion on promotion of Montana's energy development potential	Local and state government agency staff, industry representatives, area landowners	100

Date	Activity / location	Description	Audience	Participants
Aug. 11	Private meetings with Congressional staff and Montana Department of Commerce staff, *Colstrip, MT*	Discussion on project objectives and potential environmental and economic benefits of using invasive plant biomass for bioenergy	Staff of Senators Max Baucus (MT) and Jon Tester (MT), MT Department of Commerce staff, state government staff, area landowners	15
Sept. 13–14	South Dakota Weed and Pest Control Commission, Meeting and tour, *Sturgis, SD*	Discussion on partnership opportunities and tour of Russian olive- and phragmites-infested sites	Commission members, interested stakeholders	60
Oct. 11	Missouri River Watershed Coalition Semi-Annual Meeting, *Miles City, MT*	Project update	Coalition members	50
Oct. 13	Yellowtail Coordinated Resource Management Group Meeting, *Lovell, WY*	Project update and discussion on future plans	Group members, interagency and private partnership members	30
Oct. 20	Montana Weed Control Association Coordinators Fall Meeting, *Red Lodge, MT*	Project update	Association members, state and county weed managers	50
Nov. 5	Nevada Weed Management Association Annual Meeting, *Sparks, NV*	Formal presentation	Association members, state and county weed managers	150
Nov. 9	Wyoming Weed and Pest Council Annual Meeting, *Gillette, WY*	Formal presentation	Council members, state and county weed managers	60
Nov. 17	Montana Association of Conservation Districts Annual Meeting, *Helena, MT*	Formal presentation	Association members, conservation district supervisors and administrators	40
Nov. 30	Western Weed Coordinating Committee Annual Meeting, *Las Vegas, NV*	Project update	Committee members	50
Dec. 8	Yellowstone County Conservation District Monthly Meeting, *Billings, MT*	Formal presentation	Conservation District supervisors and staff	15
2012				
Jan. 11	Montana Weed Control Association Annual Conference, *Great Falls, MT*	Project update	State and county weed managers, commercial vendors	250
Feb. 2	Idaho Weed Management Conference, *Boise, ID*	Formal presentation	State and county weed managers, commercial vendors	200
Feb. 22	South Dakota Invasive Species Management Association Annual Meeting, *Rapid City, SD*	Formal presentation	Local, state and federal government agency staff, commercial vendors, landowners	40
Feb. 23	South Dakota Weed and Pest Association Annual Conference, *Rapid City, SD*	Formal presentation and informational booth	Local, state and federal government agency staff, commercial vendors, landowners	150
March 15	Regional Society of American Foresters Annual Meeting, *Dillon, MT*	Formal presentation	State and federal foresters, commercial forest contractors	30
March 15	Missouri River Natural Resource Committee Conference and BiOp Forum, *Pierre, SD*	Formal presentation	State and federal government agency staff	150
March 17	Meeting with USDA-ARS, *Sidney, MT*	Project update	USDS-ARS staff	25
May 4	Yellowstone River Conservation District Council Monthly Meeting, *Billings, MT*	Project update	Council members, area NRCS staff, state government agency staff	20

Date	Activity / location	Description	Audience	Participants
June 13	Missouri River Watershed Coalition Semi-Annual Meeting, *Sturgis, SD*	Project update	Coalition members, guests	50
July 11	Big Horn County Conservation District Monthly Meeting, *Hardin, MT*	Project update and discussion on local EQIP activities	Council members, MT NRCS staff	10
Aug. 16	Meeting with Montana Dam Owners, and Montana Department of Natural Resources and Conservation, *Billings, MT*	Project update and discussion on weed control methods for reservoir areas	MT DNRC staff, local landowners	25
Sept. 12	Yellowstone River Conservation District Council Monthly Meeting, *Billings, MT*	Project update and discussion on NRCS's Russian Olive Special Initiative projects	Council members and staff, MT NRCS staff, state government agency staff	15
Nov. 15	Missouri River Watershed Coalition Semi-Annual Meeting, *Bozeman, MT*	Project update	Coalition members, guests	40
2013				
Jan. 9	Yellowstone River Conservation District Council Monthly Meeting, *Billings, MT*	Project update	Council members, MT NRCS and FWP staff	10
Jan. 14	Montana Noxious Weed Trust Fund Council Meeting, *Great Falls, MT*	Discussion of Montana weed plan and priorities	Council members, MDA staff, guests	25
Jan. 16	Montana Weed Control Association Annual Meeting, *Great Falls, MT*	Project update	Local, state, and federal government staff	60
Feb. 12	Montana Association of Counties, Public Lands Committee Meeting, *Helena, MT*	Project update and discussion on Montana's weed issues	Council members, local and state government agency staff, landowners	50
Feb. 15	Montana Governor's Noxious Weed Advisory Council Meeting, *Helena, MT*	Discussion on Montana's aquatic weed plan	Council members, MDA and FWP staff	15
Feb. 21	Yellowstone River Conservation District Council Monthly Meeting, *Billings, MT*	Discussion on NRCS's Russian Olive Special Initiative projects	Council members, MT NRCS and FWP staff	10
March 12	Meeting with Montana State University Extension leaders, *Bozeman, MT*	Informal presentation on CISM's projects, including the CIG project	Extension leaders	3
March 26	Montana Weed Control Association, Spring Coordinator's Meeting, *Miles City, MT*	Project update and discussion on Montana's weed issues	County weed officials, MDA and MDOT staff	40
April 26	North American Invasive Species Network Annual Board of Director's Meeting, *Niagara Falls, ON, Canada*	Formal presentation	Board members, guests	25
June 19	Montana Ag-Tech High School Teachers Annual Meeting, *Alder, MT*	Formal presentation	High school teachers	75
July 19	Missouri River Watershed Coalition Semi-Annual Meeting, *Bozeman, MT*	Project update	Coalition members and guests	35
July 25–26	South Dakota Invasive Species Management Association Watershed Tour, *Spearfish, SD*	Project update and tour of project phragmites treatment site	Association members, local and state government agency staff, landowners	50
Aug. 8	Hot Springs County Range Tour, *Hot Springs, WY*	Project update and site visits	Local, state and federal government agency staff, area landowners	60
Aug. 13–15	Project site tour and Missouri River Watershed Coalition outreach filming project with Wild Dakota Outdoor TV, *Lovell, WY*	Project site tour and data collection demonstration; filming for invasive species outreach PSAs	MRWC Executive Committee, state and county land managers	15
Aug. 20	Meeting with Native Indian Alliance and BIA Weed Program Managers, *Pryor, MT*	Outreach event on event saltcedar and general weed education	Tribal weed management, BIA and FWP staff	10

Date	Activity / location	Description	Audience	Participants
Sept. 23	MSU Dept. of Land Resources and Environmental Sciences 2013 Seminar Series, *Bozeman, MT*	Formal presentation	Faculty, staff, and students	50
Sept. 24	Montana Association of Counties, Public Lands Committee Meeting, *Helena, MT*	Project update and discussion on public land issues	Committee members, state and federal government agency staff, landowners	60
Oct. 16	Montana Governor's Noxious Weed Advisory Council Meeting, *Helena, MT*	Discussion on MT's weed plan and program priorities	Council members, MDA staff	20
Oct. 28–30	North American Invasive Species Management Association Annual Conference, *Jackson Hole, WY*	Project update and discussion on regional approach to all-taxa invasive species management	Local, state and federal government agency and NGO staff, commercial vendors	75
Nov. 17–21	Western Weed Coordinating Committee Annual Meeting, *Las Vegas, NV*	Project update and discussion on regional weed management activities	Committee members, state and federal government agency staff	20
2014				
Jan. 14–17	Montana Weed Control Association Annual Meeting, *Great Falls, MT*	Project update	Association members, local, state and federal government agency staff, commercial vendors	80
Feb. 9	Society of Range Management Annual Conference, *Orlando, FL*	Poster presentation	Society members	200
Feb. 10–14	Northern Rockies Invasive Plant Council Symposium, *Spokane, WA*	Formal presentation and discussion on regional Russian olive research activities	Local, state and federal government agency and NGO staff, university and private researchers	100
Feb. 18–20	Tamarisk Coalition Annual Conference, *Grand Junction, CO*	Formal presentation and discussion on regional weed management needs	Local, state and federal government agency staff, commercial vendors	40
March 24–25	Montana Weed Control Association Board of Directors Meeting, *Bozeman, MT*	Project update and discussion on Montana's legislative weed issues	Board members, local and state government agency staff, commercial vendors	25
April 22	MT NRCS State Conservationist's Special Meeting, *Bozeman, MT*	Formal presentation	MT NRCS staff	15
May 20	NRCS Eastern and Central District State Meeting and Site Visits, *Miles City, MT*	Project update and site visits	MT NRCS area office and field staff	40
Aug. 24	Belle Fourche Conservation Partnership Meeting, *Belle Fourche, SD*	Project update and discussion on Russian olive noxious weed listing	Local, state and federal government agency staff, area stakeholders	40
Sept. 18	NRCS Washington Office Private Meeting, *Washington, DC*	Formal presentation	NRCS-CIG staff, FICMNEW members	10
Sept. 18	Meeting with staff of Sen. Jon Tester (MT), *Washington, DC*	Formal presentation	Sen. Tester's Legislative Correspondent	6
Oct. 1	Meeting with Montana Dept. of Agriculture Director, *Helena, MT*	Formal presentation	MDA staff	6
Oct. 24	CIG project summary webinar, *Bozeman, MT*	Formal presentation	State and university partners, county weed coordinators, interested stakeholders	8
Oct. 27	CIG project summary webinar, *Bozeman, MT*	Formal presentation	MRWC members, NRCS-CIG staff	15
Oct. 29	Greater Yellowstone Coordinating Committee, Invasive Species Subcommittee Annual Meeting, *Bozeman, MT*	Formal presentation	Committee members, weed managers, guests	20

Abbreviations Key

Bureau of Indian Affairs (BIA)
Conservation Innovation Grant (CIG)
Federal Interagency for the Management of Noxious and Exotic Weeds (FICMNEW)
Missouri River Watershed Coalition (MRWC)
Montana Department of Agriculture (MDA)
Montana Department of Fish Wildlife and Parks (FWP)
Montana Department of Natural Resources and Conservation (DNRC)
Montana Department of Transportation (MDOT)
USDA Agricultural Research Service (ARS)
USDA Natural Resources and Conservation Service (NRCS)
US Department of Agriculture (USDA)
US Forest Service (USFS)

CONSERVATION INNOVATION GRANT PROJECT FACT SHEET

Montana State University • Missouri River Watershed Coalition

Treatment and Control

Objective 1: Foster the adoption of innovative conservation approaches to invasive riparian plant management by establishing and monitoring herbicide treatment and control sites infested with Russian olive *(Eleagnus angustifolia)* and saltcedar *(Tamarix* spp.) for short- and long-term ecological changes, riparian systems function, environmental protection, and natural resource enhancement.

Purpose

Russian olive and saltcedar cause many documented ecological problems in riparian areas, and are projected to cause billions of dollars in economic losses over the next 50 years. While numerous removal techniques exist, not all result in the desired long-term effects. The goal of Objective 1 was to foster the adoption of innovative conservation approaches to invasive riparian plant management by establishing and monitoring Russian olive and saltcedar management sites throughout the Missouri River Watershed region.

Methods

Nine sites infested with Russian olive and saltcedar were selected in three states (MT, WY, and SD). The sites were stratified by river geomorphology and land use, and included a range of infestation sizes, ages, and densities. Detailed baseline monitoring was conducted at each site using permanent transects. Data were collected on three groups of resource attributes: vegetation (biotic), soils, and hydrology.

Round one treatments were conducted in summer 2012, consisting of mechanical cut-stump treatments of Russian olive and immediate follow-up application of triclopyr ester herbicide and a basal oil mixture. Individual saltcedar plants were treated with triclopyr ester or amine herbicide and basal oil mixtures. Follow-up treatments were conducted in 2013 and 2014.

Post-treatment monitoring activities included brief site visits and photo documentation. Information collected allowed the project team to determine short-term changes in each site's vegetation community. Monitoring data also allowed the team to determine which treatment methods provided the best short-term management results, and how those results varied by initial site condition and land use. Monitoring will be repeated in future years by state and federal agency partners to evaluate long-term riparian system function and to document long-term plant community changes in both treated and untreated areas.

Results/Discussion

Monitoring efforts over three years demonstrated the effectiveness of cut-stump and basal bark treatments for Russian olive and saltcedar control. In contrast, mulching treatments without follow-up herbicide treatments were considerably less effective in their control of Russian olive and saltcedar and had high levels of seedling and sapling regeneration or re-establishment. Changes in perennial grass abundance/production and the response of undesirable non-native herbaceous and woody species varied on treatment sites according to their site potential. Site potential factors that had the greatest influence on plant community response were: historical and post-treatment management such as grazing, historical and post-treatment disturbances such as flooding and wildfire, and pre-treatment species composition. Project results illustrate the importance of site specific, adaptive management approaches for noxious weed control.

CONSERVATION INNOVATION GRANT PROJECT FACT SHEET

Montana State University • Missouri River Watershed Coalition

Bioenergy Applications

Objective 2: Investigate and demonstrate the use of innovative bioenergy technologies that promote the utilization of Russian olive *(Elaeagnus angustifolia)* and saltcedar *(Tamarix* spp.) biomass as a fuel source.

Purpose

Russian olive and saltcedar are hugely problematic invaders that presently infest more than one million acres within the Missouri River Watershed region and are virtually untapped sources of biomass. This project proposed that the tons of mostly herbicide-treated biomass, much of which had simply been left in piles, could be processed on location or shipped to nearby processing facilities by producers and used as a new bioenergy source.

The primary goal of Objective 2 was to investigate and demonstrate innovative bioenergy technologies that promote the use of Russian olive and saltcedar biomass as new raw materials or "feedstocks" for bioenergy generation.

In early 2010, prior to the start of the project, the Center for Invasive Species Management and Missouri River Watershed Coalition conducted preliminary feasibility tests on samples of herbicide-treated and untreated Russian olive and saltcedar biomass. This action was taken to ensure that the material could be safely used as a bioenergy source, and had a heat value competitive with other vegetative materials currently used as fuel sources.

Methods

Russian olive and saltcedar samples were collected from five sites in Montana and Wyoming in 2010 and 2011. The samples were sent to two independent laboratories, which conducted feasibility tests to determine BTU levels generated per pound of material, ash content, volatile matter content, and moisture content. The test results were then compared to data from forestry species traditionally used in bioenergy applications. Additional samples were tested in 2012 to determine whether elemental composition of the plant material would negatively impact its potential value for use in bioenergy applications. Test results were sent to Tom Miles, an independent consultant, for further assessment.

Results/Discussion

Laboratory feasibility tests demonstrated that Russian olive and saltcedar biomass materials could be safely used as a bioenergy source, and that their BTU (calorific values) and ash content levels were competitive with other woody biomass feedstocks. Results showed that both species fall within the "acceptable" range for bioenergy generation. Miles found that while the elemental composition of Russian olive and saltcedar biomass may be less desirable for production as standalone raw material, they could be blended with other woody species commonly used in bioenergy applications. In addition, the plant materials could be processed in biochar form and used as soil amendments in a variety of restoration practices. Miles' analyses of the costs associated with harvesting and transporting the biomass to a limited number of regional biofuels facilities indicate that, currently, woody biomass cannot compete with low-cost, traditional fossil fuel-based energy sources (coal and gas), which are abundant in the region.

CONSERVATION INNOVATION GRANT PROJECT FACT SHEET

Montana State University • Missouri River Watershed Coalition

Technology Transfer

Objective 3: Utilize the Center for Invasive Species Management / Montana State University and Missouri River Watershed Coalition's management and communications infrastructure and networks to coordinate the project and transfer project findings, products, and technologies to a broad range of regional stakeholders.

Purpose

Project engagement and timely dissemination of information to Missouri River Watershed Coalition (MRWC) members, landowners, academic colleagues, government agencies, and the concerned public were key components of this project.

Methods

The Center for Invasive Species Management at Montana State University (CISM/MSU) led all aspects of project administration and kept the project on track, on time, well documented, and within budget. CISM/MSU also fostered critical citizen engagement throughout the process and educated landowners and the public about the problems invasive species pose to the region, as well as potential innovative conservation and management strategies to combat those problems. The MRWC facilitated many opportunities for landowners, agricultural producers, and the public to directly and indirectly take action (and responsibility) for the control of invasive species on their properties, which is crucial for sustainable, long-term conservation and management of riparian areas throughout the Missouri River Watershed region.

Project team leaders and a multitude of project partners initiated a wide range of opportunities for local, state, and federal interest groups and regional stakeholders to engage in the project using a wide variety of outreach and technology transfer activities including: dozens of formal presentations, field demonstrations, project site tours, interactive webinars, listserv communications, and personal, one-on-one, interactions.

In addition and of greatest importance for Objective 3 success, a comprehensive project website, www.weedcenter.org/cig, was developed, hosted, and maintained by CISM/MSU as the key mechanism to disseminate information about the project to all interested parties. The website was regularly updated with project information, reports, publications, photos, educational materials, and other pertinent resources throughout the duration of the project, and now serves as an archive for all project materials and deliverables.

Deliverables

- Weekly listserv communications
- 50+ formal project presentations and posters at professional meetings, conferences, MRWC meetings, and landowner group events
- 10 field demonstrations and tours
- 4 interactive project webinars
- Dozens of printed materials: briefings, handouts, fact sheets, articles, reports, and publications
- Video project targeting sportsmen with Wild Dakota Outdoor TV (South Dakota)
- Media interviews
- Comprehensive project website.

CONSERVATION INNOVATION GRANT

Montana State University • Missouri River Watershed Coalition

Innovative Conservation Approaches to Invasive Plant Management in the Missouri River Watershed: From Invasive Species Prevention and Control, to Biomass Utilization and Bioenergy Generation

Purpose

Russian olive *(Elaeagnus angustifolia)* and saltcedar *(Tamarix* spp.) were introduced to the US in the 1800s. They escaped cultivation and are now established in more than one million acres of floodplains and riparian areas. Both species cause many documented ecological problems in riparian areas, and are projected to cause billions of dollars in economic losses over the next 50 years. While there are numerous techniques for removing these species, not all result in desired long-term effects, and there is little published information to guide treatment and restoration efforts in the upper Missouri River Watershed. Moreover, historically, little or no effort has been dedicated to the feasibility of utilizing these species as biomass for bioenergy development.

In 2010, the Center for Invasive Species Management (CISM) at Montana State University (MSU) was awarded a national CIG grant to develop innovative ideas for managing Russian olive and saltcedar throughout the Missouri River Watershed region. The four-year project had three primary objectives:

1. Foster the adoption of innovative conservation approaches to invasive riparian plant management by monitoring mechanical and herbicide treatment and control sites infested with Russian olive and saltcedar for short- and long-term ecological changes, riparian system health and function, environmental protection, and natural resource enhancement.
2. Investigate and demonstrate the use of innovative bioenergy technologies that promote the utilization of invasive plant biomass as a fuel source.
3. Utilize MSU's and the Coalition's management and communications infrastructure and networks to coordinate all components of the project, and transfer project findings, products, and technologies to a broad range of regional stakeholders, including the private sector and NRCS.

Funding: USDA–NRCS National Conservation Innovation Grant award: $1 million; State match (Montana and Wyoming): $1 million

States Involved: Montana, South Dakota, Wyoming, Nebraska, North Dakota, Colorado, Kansas

Partners: Montana State University / Center for Invasive Species Management • Missouri River Watershed Coalition • Private landowners and producers • Private sector/industry • Local, state, and federal governments

Timeline: Sept. 2010 – Sept. 2014 *(2011 field activities postponed due to flooding event)*

Figure 1. Russian olive and saltcedar treatments drastically altered plant community characteristics following treatments. The reduction in Russian olive cover resulted in a release of pasture grasses, which responded to the treatments with increased canopy cover and productivity.

Top: Aerial imagery of a site near Hardin, MT prior to Russian olive treatment activities in 2012.

Bottom: The same site in August 2014, after treatment and follow-up treatment activities.




From left: A Russian olive site near Hardin, MT in August 2012, prior to treatments; The same site in August 2014, after two cycles of treatments; Survey sampling at a project site near Lovell, WY; Project tour participants at a site near Lovell, WY.

Objective 1: Treatment and Control

Methods

Nine sites infested with Russian olive and saltcedar were selected in three states (MT, WY, and SD). The sites were stratified by river geomorphology and land use, and included a range of infestation sizes, ages, and densities. Detailed baseline monitoring was conducted at each site using permanent transects. Data were collected on vegetation (biotic) and soil attributes.

Round one treatments were conducted in 2012; consisting of mechanical cut-stump treatments of Russian olive and immediate follow-up application of triclopyr ester herbicide and a basal oil mixture. Individual saltcedar plants were treated with triclopyr ester or amine herbicide and basal oil mixtures. Follow-up treatments were conducted in 2013 and 2014. Post-treatment monitoring activities included photo documentation and detailed monitoring of plant community and soil attributes, which illustrated changes in site vegetation communities. Monitoring will be repeated in future years by state and federal agency partners to evaluate long-term treatment efficacy and vegetation community changes.

Results/Discussion

Monitoring efforts over three years demonstrated the effectiveness of cut-stump and basal bark treatments for Russian olive and saltcedar control (Figure 1). In contrast, mulching treatments without follow-up herbicide treatments were considerably less effective in their control of Russian olive and saltcedar and had high levels of seedling and sapling regeneration or reestablishment. Changes in perennial grass abundance/production and the response of undesirable non-native herbaceous and woody species varied on treatment sites according to their site potential. For example, one site showed a 73% (or 4,029 lbs/acre) increase in grass production following an 81% reduction in Russian olive aerial cover. Site potential factors that had the greatest influence on plant community response were: historical and post-treatment management such as grazing, historical and post-treatment disturbances such as flooding and wildfire, and pre-treatment species composition. Project results illustrate the importance of site specific, adaptive management approaches for noxious weed control.

Objective 2: Bioenergy Applications

Methods

Russian olive and saltcedar samples were collected from five sites in Montana and Wyoming in 2010 and 2011. The samples were sent to two independent laboratories, which conducted fuel quality tests to determine BTU levels generated per pound of material, ash content, volatile matter content, and moisture content. The test results were then compared to data from forestry species traditionally used in bioenergy applications.

Additional samples were tested in 2012 to determine whether elemental composition of the plant material would negatively impact its potential value for use in bioenergy applications. Test results were sent to Tom Miles, an independent consultant, for further assessment.

Results/Discussion

Laboratory feasibility tests demonstrated that Russian olive and saltcedar biomass materials could be safely used as a bioenergy source, and that their BTU (calorific values) and ash content levels were competitive with other woody biomass feedstocks. Results showed that both species fall within the "acceptable" range for bioenergy generation. Miles found that while the elemental composition of Russian olive and saltcedar biomass may be less desirable for production as standalone raw material, they could be blended with other woody species commonly used in bioenergy applications. In addition, the plant materials could be processed in biochar form and potentially be used as soil amendments in a variety of restoration practices. Miles' analyses of the costs associated with harvesting and transporting the biomass to a limited number of regional biofuels facilities indicate that, currently, woody biomass cannot compete with low-cost, traditional fossil fuel-based energy sources (coal and gas), which are abundant in the region.

Objective 3: Technology Transfer

The project team and partners fostered citizen and stakeholder engagement in the project, and conducted dozens of outreach and technology transfer activities to a wide array of audiences, including: formal presentations, field demonstrations, site tours, interactive webinars, and personal interactions.

A comprehensive project website, www.weedcenter.org/cig, was developed and hosted by CISM/MSU to disseminate information about the project to landowners, government agencies, and the concerned public in a timely manner. The website was regularly updated with project information, reports and publications, photos, and educational materials throughout the duration of the project, and now serves as an archive for all project materials.

Project Team

Tracy Sterling (PI), Scott Bockness, Liz Galli-Noble, Emily Rindos, and Kitty Weiss, *Montana State University • MRWC Executive Committee • Synergy Resource Solutions, Inc.*

MONTANA STATE UNIVERSITY   Missouri River Watershed Coalition   Center for Invasive Plant Management

October 2014

Monitoring the Long-term Treatment Efficacy of Saltcedar (*Tamarix spp.)* and Russian olive (*Eleagnus angustifolia L.)*

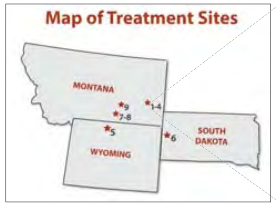
Scott Bockness[1], Amy Ganguli[2], Jack Alexander[3], Gary Horton Jr[3]

[1] Montana State University–Bozeman, [2] New Mexico State University, [3] Synergy Resource Solutions, Inc.

Abstract

Saltcedar *(Tamarix spp.)* and Russian olive *(Elaeagnus angustifolia* L.) are native Eurasian species introduced to North America as ornamentals in the 19th century. Subsequent escape from cultivation led to establishment on over one million acres of riparian habitat. Both species disrupt riparian ecosystem structure through competition and replacement of native plant species, degradation of native wildlife habitat, and moisture sequestration. Efforts to eliminate these target species have been unsuccessful, as initial treatments are often followed by secondary invasions of undesirable plant species.

Numerous methodologies employed for species removal have provided little information on desirable long-term results following treatment and removal. Synergy Resource Solutions, Inc. monitored treatment and control sites to determine pre-treatment conditions and post-treatment infestations of saltcedar and Russian olive invasions. Continued employment of methods utilized for baseline monitoring will demonstrate the long-term efficacy of different treatment methods and the influence of initial site conditions on results.



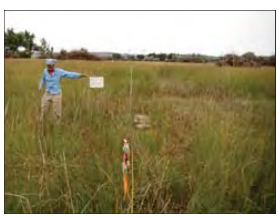
Site	Location	Target Species
1	Miles City, Montana	Russian olive
2	Miles City, Montana	Saltcedar
3	Miles City, Montana	Russian olive
4	Miles City, Montana	Saltcedar
5	Lovell, Wyoming	Russian olive/saltcedar
6	Sturgis, South Dakota	Russian olive
7	Hardin, Montana	Russian olive
8	Hardin, Montana	Saltcedar
9	Big Horn County, Montana	Russian olive

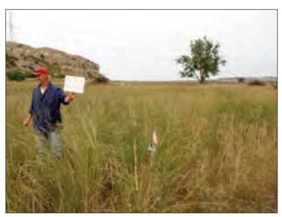
Site Selection: A total of nine sites, each approximately 14 acres in size, have been selected. All sites are infested with saltcedar, Russian olive or both. These sites encompass a range of saltcedar and Russian olive infestation, varying in size, age, and density. Each site contained three treatment plots and one control plot. At each plot a 50 m or 25 m transect line was established and used to assess change in vegetative communities before and after treatment.

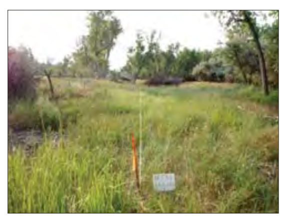
Allen Treatment 1 / Allen Treatment 2 / Arapooish Treatment 3

Pre-Treatment

Post-Treatment







Results

Site	Saltcedar (Plants/ha) < 20 cm	20-100 cm	1-2 m	2-4 m	>4 m	Dead	Russian olive (Plants/ha) <30 cm	30-180 cm	DBH 2.5-15 cm	DBH 15-25 cm	DBH >25 cm	Dead
Allen Treatment 1 Pre	0	0	0	0	0	0	0	0	150	400	200	50
Allen Treatment 1 Post	0	0	0	0	0	0	0	0	0	0	0	0
Allen Treatment 2 Pre	0	0	0	0	0	0	0	0	0	550	450	50
Allen Treatment 2 Post	0	0	0	0	0	0	0	0	0	0	0	0
Arapooish Treatment 3 Pre	0	0	50	600	250	0	0	200	300	100	50	0
Arapooish Treatment 3 Post	0	0	0	0	0	0	10900	0	0	0	0	0

Background

In August 2010, the Missouri River Watershed Coalition (MRWC) and the Center for Invasive Species Management at Montana State University received a Conservation Innovation Grant (CIG) from the USDA Natural Resource Conservation Service (NRCS). The three-year project will provide knowledge and benefits to producers and land managers throughout the Missouri River Watershed area and will serve as a pilot project for the western region and potentially the nation.

At 2,540 miles in length, the Missouri River is the longest river in the United States. The Missouri River Basin covers a geographic area of 529,350 square miles and includes six states (Colorado, Montana, Nebraska, North Dakota, South Dakota, and Wyoming). Russian olive and saltcedar are displacing the native plant community structure along the Watershed's riparian areas and have greatly impacted wildlife habitat, livestock production, and the conservation of native species in the region.

Objective

Foster the adoption of innovative conservation approaches to invasive riparian plant management by monitoring mechanical and herbicide treatment and control sites infested with Russian olive and saltcedar for short- and long-term ecological changes, riparian system health and function, environmental protection, and natural resource enhancement.

Methodology

Site Selection - A total of nine sites infested with Russian olive and saltcedar were selected throughout the Missouri River Watershed region. The sites are stratified by river geomorphology and land use, and include a range of infestation sizes, ages, and densities.

Initial Monitoring - Prior to the treatments, detailed baseline monitoring was conducted at each site using permanent transects, including both treatment and control areas within each project site. Data was collected on three groups of resource attributes: vegetation (biotic), soils, and hydrology. Data collected included canopy, basal, and litter cover, canopy and basal gap, plant height, soil stability, woody plant density, downed woody material, and weed survey.

Treatments -

Cut-stump treatment of Russian olive consisted of mechanical cutting at the base of the tree with a variety of excavator-type apparatuses and hand cutting with chainsaws. An immediate follow-up of triclopyr ester herbicide and a basal oil mixture* was applied to the exposed stump area.

Basal bark treatment of saltcedar consisted of the application of a triclopyr ester or amine herbicide and basal oil mixtures to the individual plants. The herbicide mixture* was applied to all live stems emerging from the ground up to a height of 18 inches.

Lovell Mulch Site - mechanical mulching (no herbicide)

*herbicide rate: 27% triclopyr + 73% basal bark oil

Excavator-type apparatus used to cut down and move trees

Follow-up Monitoring - Activities (post-treatment) include brief site visits and photo documentation to provide additional supporting project site information and replication of pre-treatment vegetation, soils, and hydrology data collection methods.

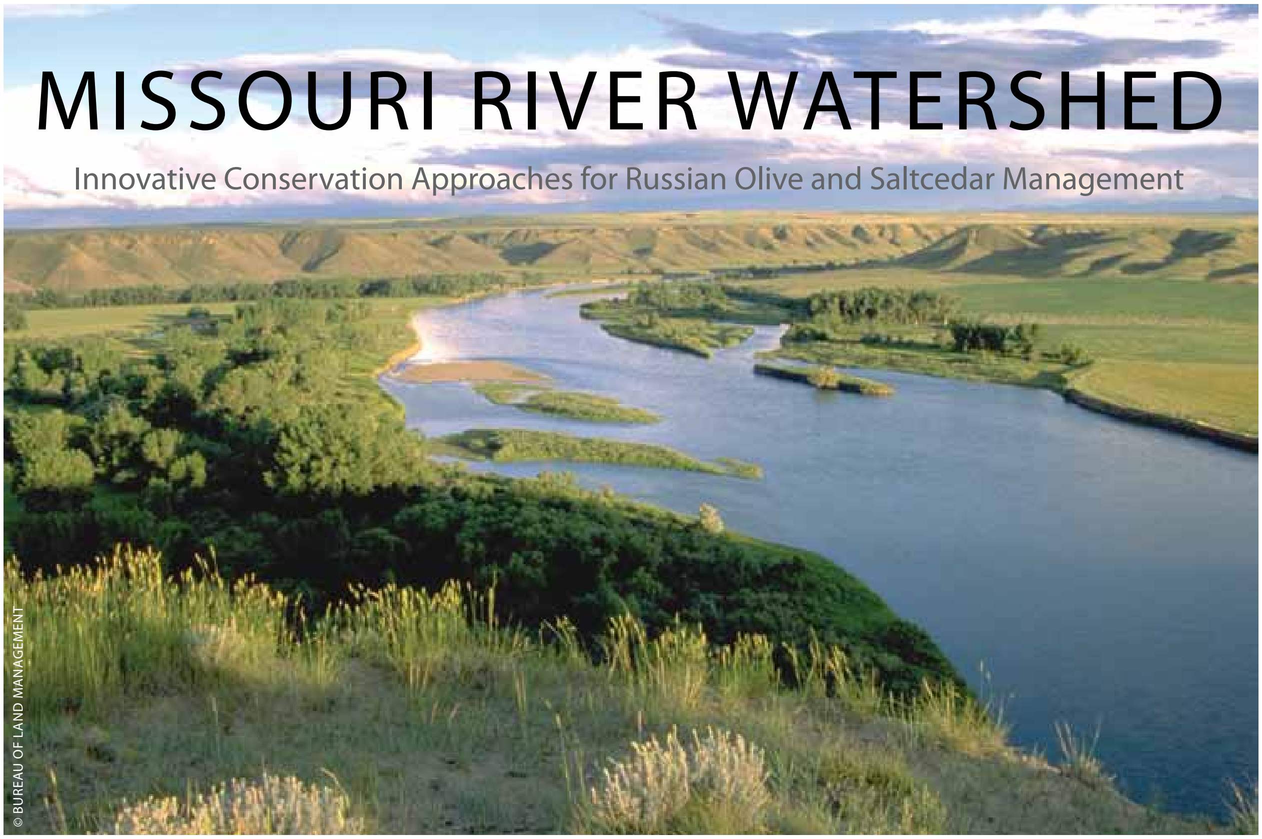
Data Analysis - Species composition by weight, vegetative production, multi-level cover (canopy and basal), soil aggregate stability, percent cover of herbaceous, shrub, and tree species, and woody plant density were investigated.

Discussion

First year monitoring efforts illustrated the effectiveness of the cut-stump and basal bark treatments for Russian olive and saltcedar control whereas the mulching treatments, without follow-up herbicide treatments, had high levels of seedling and sapling establishment of each species. Changes in perennial grass production and the response of undesirable species (e.g., noxious weeds) varied according to the initial species composition. However, the availability of perennial grasses to livestock and wildlife increased at all sites. Continued monitoring efforts of Russian olive, saltcedar, and noxious weed recruitment will allow for the implementation of follow-up treatments in this adaptive management framework.

MISSOURI RIVER WATERSHED

Innovative Conservation Approaches for Russian Olive and Saltcedar Management



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BY CELESTINE DUNCAN

THE MISSOURI RIVER FLOWS 2,540 MILES FROM ITS HEADWATERS IN SOUTHWESTERN MONTANA to its confluence with the Mississippi River north of St. Louis. The watershed covers more than 529,000 square miles in portions of ten states, supporting a multitude of uses including agriculture, wildlife habitat, drinking water, industry, and power generation.

In 2005, the Missouri River Watershed Coalition (MRWC) was organized to help protect the watershed from invasive plants including saltcedar (*Tamarix* spp.) and Russian olive (*Elaeagnus angustifolia*). The mission of the Coalition is to maintain productive, biologically diverse riparian habitat to meet the economic and ecological needs of the Missouri River Watershed region.

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MISSOURI RIVER WATERSHED COALITION includes Colorado, Montana, Nebraska, North Dakota, South Dakota, Kansas, and Wyoming.

The MRWC teamed up with the Center for Invasive Species Management (CISM) in 2010 and received a $1 million Conservation Innovation Grant (CIG) from the USDA Natural Resource Conservation Service, and additional state matches of $750,000 from Montana and $250,000 from Wyoming.

Scott Bockness, CIG Project Field Leader for the Coalition is tasked with

["WATERSHED" continued on page 6]

["WATERSHED" continued from page 5]

developing solutions to regional invasive plant issues within the watershed through this riparian investigation. "The objective of this project is to investigate methods to help mitigate the impacts of Russian olive and saltcedar and explore their potential use as bioenergy products," Bockness explains. "We believe our results will help producers and land managers with Russian olive and saltcedar management projects and serve as a model for other large-scale invasive plant projects in the West."

MANAGEMENT STUDY AREAS

RUSSIAN OLIVE- AND SALTCEDAR-INFESTED SITES were selected in six locations within three of the Missouri River Watershed Coalition states (Table 1). Sites include both regulated (dammed) and unregulated (free flowing) river watersheds with different saltcedar and Russian olive invasion patterns in terms of age, infestation size and density. Land use on the study areas range from livestock production to conservation areas.

"Our objective for the field studies is to determine which management methods provide the most effective control of saltcedar and Russian olive, in addition to evaluating the plant community response to herbicide treatments," explains Bockness.

Herbicide treatments on Russian olive and saltcedar included Garlon® 4 Ultra as a foliar application to young trees, and as a basal cut stump or basal bark treatment depending on the size of the target tree. Herbicides were applied in fall and early winter of 2012 at all sites except Lovell, Wyoming, which was treated spring 2013 (Table 1). Data collected at the Wyoming site will compare basal cut stump herbicide treatments to mastication and herbicide treatment that is part of an on-going Coordinated Resource Management Project.

Long-term monitoring data collected pre- and post-treatment from the study includes cover and relative abundance of Russian olive and saltcedar, desirable native and non-native species, and other invasive species that may colonize the site after treatment. Bockness explains, "These data will allow us to measure plant community changes over time for each treatment method under different land uses and hydrologic conditions. We will

> "WE BELIEVE OUR RESULTS WILL HELP PRODUCERS AND LAND MANAGERS WITH RUSSIAN OLIVE AND SALTCEDAR MANAGEMENT PROJECTS AND SERVE AS A MODEL FOR OTHER LARGE-SCALE INVASIVE PLANT PROJECTS IN THE WEST."
>
> **SCOTT BOCKNESS,** MISSOURI RIVER WATERSHED COALITION

TABLE 1. Herbicide rate, application method, acres treated and location of treatment sites within the Missouri River Watershed Coalition states.

Site Number and Location		Target	Acres Treated	Treatment Date	Herbicide Rate and Application Method
1	Miles City, MT	Russian olive	14	10/30 to 12/30/2012	Garlon 4 Ultra 33%/67% basal oil (v/v) mixture – basal cut stump
		Saltcedar	3	9/1 to 9/30/2012	Garlon 4 Ultra 27%/73% basal oil (v/v) mixture – basal bark
2		Russian olive	15	10/30 to 12/30/2012	Garlon 4 Ultra 33%/67% basal oil (v/v) mixture – basal cut stump
		Saltcedar	3	9/1 to 9/30/2012	Garlon 4 Ultra 27%/73% basal oil (v/v) mixture – basal bark
3	Lovell, WY	Russian olive	14	2/28 to 3/5/2013	Garlon® 4 Ultra 33%/67% basal oil (v/v) mixture – basal cut stump
		Saltcedar	7	2012	Mastication of trees followed by herbicide application
4	Sturgis, SD	Russian olive	7	9/1 to 12/30/2012	Garlon 4 Ultra 33%/67% basal oil (v/v) mixture – basal cut stump
5	Hardin, MT	Russian olive	14	10 to 12/2012	Garlon 4 Ultra 27%/73% basal oil (v/v) mixture – basal bark
		Saltcedar	11	9/1 to 9/30/2012	
6	Big Horn County, MT	Russian olive	14	9/1 to 12/30/2012	Garlon 4 Ultra 33% /67% basal oil (v/v) mixture – basal cut stump

SCENES FROM THE FIELD. **Russian olive** (bottom left) and **saltcedar** (top left) infest more than one million acres in the Missouri River Watershed. • Garlon 4 Ultra was applied to Russian olive and saltcedar trees as a **basal cut stump treatment** (top center) or basal bark treatment. • **Vegetation surveys** were conducted at all project sites prior to treatment (top right). • **Big Horn County study area** (site 6) pre-treatment, September 2012 (bottom left) and post-treatment, March 2013 (bottom right) for Russian olive and saltcedar.

also be able to evaluate the efficacy of basal bark and basal cut stump treatments for controlling saltcedar and Russian olive."

Local, state, and federal agencies including the NRCS have committed resources to mitigating the impacts of saltcedar and Russian olive throughout the region. Work conducted in the watershed prior to 2012 show excellent efficacy with Garlon® 4 Ultra on both Russian olive and saltcedar, and results from the current study will help land managers adapt conservation practices to improve long-term control of these invasive plants and improve ecosystem function.

BIOENERGY PRODUCTION

EXPLORING THE FEASIBILITY OF CONVERTING invasive Russian olive and saltcedar to fuel is a key component of the project. Bockness explains, "We have at least one million acres infested with these invasive trees in the Missouri River Basin, and each acre produces from 5 to 10 tons of wood biomass that could be a great source of bioenergy. Current management includes cutting, stockpiling and burning the trees since other economical alternatives haven't been explored."

Russian olive and saltcedar samples were collected in July and August 2011 from five sites in Montana and Wyoming. Tests were conducted on the samples to determine British Thermal Unit (BTU) levels generated per pound of material, as well as ash content, volatile matter content, and moisture content. Test results were compared to data from forestry species traditionally used in bioenergy applications (Table 2).

Comparisons of the data indicate that while the BTU levels of both Russian olive and saltcedar are relatively close to those of forest materials, the ash content level of saltcedar is considerably higher than the desired levels for use in commercial wood pellet markets. Unlike other forest residues, these shrub-like invasive species require special (and more expensive) treatments to harvest, making them an expensive fuel source compared with natural gas, coal or forest fuels.

["WATERSHED" continued on page 8]

["WATERSHED" continued from page 7]

TABLE 2. Wood from invasive tree species could compete with fuel oil or propane (based on delivered cost of fuel).

Fuel (Unit)	Net Heating Value BTU/unit	Cost/unit	Cost/Million Metric BTU
Natural Gas (Therm)	82,000	$0.20	$2.44
Bituminous coal (Ton)	26,000,000	$125.00	$4.81
Wyoming coal (Ton)	22,000,000	$125.00	$5.68
Forest fuels (Oven dry ton)	13,800,000	$60.00	$4.35
Invasive trees (Oven dry ton)	13,800,000	$300.00	$21.74
Fuel Oil #2 (Gallon)	115,000	$4.00	$34.78
Propane (Gallon)	71,000	$2.50	$35.21


SCOTT BOCKNESS


SCOTT BOCKNESS

BIOFUELS. The project is looking at the feasibility of invasive Russian olive and saltcedar as a source of biofuel. **Invasive trees** are cut, stockpiled and burned on site (top). • **Wood pellets** generated from Russian olive (left).

> "ONE OF OUR BIGGEST PROBLEMS IS THE COST OF TRANSPORTING BIOMASS; WE NEED A FACILITY WITHIN ABOUT 100 MILES OF OUR REMOVAL SITE TO BE ECONOMICALLY FEASIBLE."
>
> **SCOTT BOCKNESS,** MISSOURI RIVER WATERSHED COALITION

LEARN MORE

Missouri River Watershed Coalition

PROJECT OBJECTIVES include measuring short- and long-term ecological changes, riparian system health and function, and natural resource protection on Russian olive and saltcedar infested sites treated with manual removal alone and in combination with herbicides; investigating and demonstrating the use of innovative bioenergy technologies that promote the utilization of invasive plant biomass as a fuel source; and transferring project findings, products, and technologies to a broad range of regional stakeholders.

OTHER PROJECT COMPONENTS include: project-specific website and webinars, on-site demonstration on Russian olive and saltcedar removal, regional presentations, publications, and a Wild Dakota television production on invasive plants.

PROJECT PARTNERS represent private landowners and producers; private sector and industry; and local, state and federal governments. MRWC is led by Andrew Canham (President) from **South Dakota** and Karie Decker (Vice President) from **University of Nebraska**; and comprised of reprentatives from **Montana** (Dave Burch), **Nebraska** (Mitch Coffin), **Wyoming** (Slade Franklin), **Kansas** (Scott Marsh), **South Dakota** (Ron Moehring), **Colorado** (Steve Ryder), and **North Dakota** (Rachel Seifert-Spilde) **Departments of Agriculture**, as well as with the **Center for Invasive Species Management–Montana State University** (Liz Galli-Noble–Director, CIG Principal Investigator and Scott Bockness –CIG Project Field Leader).

LEARN MORE about MRWC from: Scott Bockness at scott.bockness@montana.edu, or visit the MRWC website at weedcenter.org/mrwc/cig/

Natural Resource Conservation Service – Conservation Initiative Grant (CIG) Program

THE PURPOSE of the NRCS–CIG program is to stimulate the development and adoption of innovative conservation approaches and technologies, while leveraging federal investment in environmental enhancement and protection of riparian areas in conjunction with agricultural production. CIG projects are expected to lead to the transfer of conservation technologies, management systems, and innovative approaches (such as market-based systems) into NRCS policy, technical manuals, guides and references, or to the private sector.

READ MORE about the CIG grant program: http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/cig/

["WATERSHED" continued from page 8]

"The ash content is too high for making a high value residential wood pellet, but there may be a potential to supply facility-scale heating boilers with biomass," says Bockness. "One of our biggest problems is the cost of transporting biomass; we need a facility within about 100 miles of our removal site to be economically feasible."

The University of Nebraska-Lincoln and the Center for Invasive Species Management at Montana State University are working together to pursue funding for assessing the feasibility of installing biomass facilities in local schools or hospitals and integrating Russian olive and saltcedar removal with other fuel reduction projects on forest lands.

THE MRWC PROJECT HAS UNITED university, county, state, and federal agencies in a collaborative effort to manage invasive plants over a wide geographic area encompassing seven of the ten watershed states. "We believe that results from this project will help develop science-based conservation approaches for managing Russian olive and saltcedar in the Missouri River Watershed," says Bockness. "Increased knowledge related to the removal of invasive species and the vegetative response to the treatments will be critical to understanding secondary weed invasion and to facilitate ecosystem recovery methods. In addition, determining the feasibility of biomass generated from invasive species could be an innovative catalyst in supporting regional woody biomass alternative energy program developments."

Active ingredients for herbicide products mentioned in this article: Garlon 4 Ultra (triclopyr).

FARM&RANCH GUIDE

MRWC, CIG working to tackle Russian olive threat along Missouri River

MARCH 12, 2013 3:30 AM • BY MATT MULLALLY • FARM & RANCH GUIDE

A riparian area near the Big Horn River in southeastern Mont. is overtaken by several Russian olive trees. Over the past 50 years, the non-native tree has become a big threat along waterways, displacing native trees and plants. (Photo courtesy of Scott Bockness.)

Just how big a threat is Russian olive to the riparian ecosystems along the Missouri River and its tributaries?

If you ask Scott Bockness, Missouri River Watershed Coalition CIG project leader, he'll give you quite a history lesson.

The trees have become a large-scale threat in the seven states that make up the river's watershed. They've displaced many native species of trees and plants and have caused significant harm to the economic and ecological stability of the region.

"Forty years when they were planted we just didn't know what was going to happen,'' he said. "They (the trees) were not managed and now there is just a massive blowout."

In 2010, the MRWC and the Center for Invasive Species Management at Montana State University received a $1 million Conservation Innovation Grant (CIG) from the USDA Natural Resource Conservation Service (NRCS). The states of Montana and Wyoming also provided funds.

The project will provide knowledge and benefits to producers and land managers throughout the Missouri River Watershed area and will serve as a pilot project for the western region and potentially the nation.

In a nutshell, Bockness said the project is to monitor different sites in riparian areas in the MRWS. Project officials are completing a vegetative inventory in these areas to determine how removal of Russian olives and future followup treatments are affecting that vegetation. And is it creating other threats?

Five sites are located in Montana, three more in Wyoming and one in South Dakota.

Bockness said after the removal of Russian olives there is usually a 10 to 15 percent change of regrowth. It requires follow up treatment over the next few years. However, in their place populations of terrestrial noxious weeds are cropping up.

Old science determined that the seed viability of Russian olives was three to for years. However, new findings are seeing that seed viability can stretch to 10 or 20 years.

So, it's a battle that continues.

"This is not an easy thing to accomplish,'' Bockness said to control these invasive spcies. "I tell people, if you are in it, you have to be in it for the long haul."

The goals of the project is to adopt innovative methods to invasive riparian plant management and monitor herbicide treatment at control sites infested with Russian olive and saltcedar.

This is a riparian area after Russian olive trees were removed. A Conservation Innovation Grant (CIG) from the USDA Natural Resource Conservation Service (NRCS) was awarded to the MRWC and Center of Invasive Species at Montana State University to develop methods to successfully control the spread and damage from Russian olives, saltcedar and other invasive species along the Missouri River watershed. (Photo by Scott Bockness).

Develop an innovative technology that can transform this invasive plant in a biomass fuel source as well as communicate the project findings and developed technologies to region stakeholders.

Liz Galli-Noble, Director of the Center for Invasive Species Management at Montana State University, said educating the public about this threat is also vital.

“It’s (Russian olive) not a bad species,’’ she said, adding the trees are highly regarded for their ability to grow rapidly in poor soils and provide good windbreaks as well as wildlife habitat for pheasants and other animals.

“However, the minute it starts to diplace other species, it’s a threat,’’ she said.

And years ago when seeds from the trees were transported from the dryland areas where the trees were no threat to riparian zones, it was only a matter of time before the Russian olives became interspersed among other trees and vegetation.

First or second generation landowners only remember riparian areas filled with cottonwoods and willows 50 or 60 years ago. Today, it’s a different scene.

“It doesn’t look like that at all,’’ she said.

The Russian olives and other invasive species have choked out many of those native species. Unfortunately, the next generation of landowners never saw the way it was. To many, the Russian olive has always been part of the scenery near waterways.

In reality, it’s been an unwelcome guest.

About the MRWC

The Missouri River Watershed Coalition, a seven-state organization, was established to protect riparian ecosystems along the river and its tributaries, is also working to mitigate the damage of Russian olives and other invasive species along the river. The coalition is comprised of Montana, Wyoming, North Dakota, South Dakota, Nebraska, Kansas and Colorado.

The Missouri River is the longest river in the US. At 2,540 miles in length, it drains about one-sixth of the North American continent. From its headwaters in the northern Rocky Mountains, the Missouri River and its tributaries flow through the western states of Montana, Wyoming, Colorado, North Dakota, South Dakota, Nebraska, and Kansas. These states rely heavily upon the Missouri River headwaters system for economic and ecological stability.

The rivers, streams, reservoirs, and ponds of the watershed support and provide for agriculture, livestock, recreation, tourism, wildlife habitat, irrigation, drinking water, industry, and power generation.

Riparian weed wars different, more urgent

By **LORETTA SORENSEN**


GOOD 'N' BAD: Riparian areas produce great grazing but seem to harbor the greatest potential for invasive species, according to weed watchers.

RIPARIAN areas contain the best and worst for landowners.

Andrew Canham says there's a growing need to raise both landowner and general public awareness about the amount and increasing number of new invasive species in riparian areas. Canham is Missouri River Watershed Coalition president and a rancher from Miller, S.D. He's also co-owner of MidDakota Vegetation Management.

"For ranchers, riparian areas represent some of the most fertile and productive areas of grazing units," Canham says. "For wildlife, fish and aquatic species, they offer plant diversity needed for survival. Healthy riparian areas protect the watershed during flooding events and play a vital role in determining property values. If managed correctly, riparian areas can address all these needs."

However, unwanted vegetation also thrives and spreads quickly in riparian areas. Characteristics conducive to invasive weeds include seasonal high-water events and influxes of wildlife traffic, recreational activities and livestock feeding.

"Non-native species commonly found invading riparian areas across South Dakota include leafy spurge and Canadian thistle," Canham says. "However, new species are being identified. Some have been around awhile. Houndstongue, yellow toadflax and tansy are showing up more and more. Salt cedar and phragmites were recently targeted for detrimental effects and rapid advancement in riparian areas. Even escaped Russian olive is causing havoc."

Russian olive doesn't dominate upland areas but quickly crowds out productive native vegetation in riparian settings.

Get a grasp of area's potential

Regardless of location, to successfully manage a riparian area, landowners should become familiar with their area's condition and what it should look like.

"Know the difference between what you see and what you should see," Canham advises. "Without an idea of the area's potential, you won't know how to attain that potential.

"Start by learning to identify a few of the most desired plant species and recognize some of the most detrimental species. It's critical to identify infestations early and stop them before they become widespread. It's cheapest and most effective to quickly address an invasive non-native plant explosion."

Canham points to education as a key component of informing landowners, managers and everyone spending time outdoors to take notice of vegetative surroundings. If unknown plants are spotted, they should quickly be reported to proper sources, such as range scientists or weed-control organizations.

"Even if you're uncertain of a weed's identity, we need an effective system for checking what's being found and confirming or putting to rest the possibility of the next detrimental weed becoming established and spreading," Canham says. "To make weed reporting as easy and accessible as possible, MRWC is currently working on EDDMAPS, an early detection and distributing mapping system, to provide an extensive network across the entire Missouri River Watershed."

EDDMAPS was developed by the University of Georgia Center for Invasive Species and Ecosystem Health. In addition to online reporting, iPhone and Android applications are becoming available to assist with field reporting.

Canham says some of the greatest resources in this battle to protect wetlands are public awareness of the threats and knowledge of how to help.

The Missouri River Watershed Coalition received a Conservation Innovation Grant from the Natural Resources Conservation Service for a study to help determine if some troublesome plants could be used for projects such as biomass for fuel or other innovative technologies. The study focuses on controlling invasive species, developing and marketing bioenergy projects, and facilitating a management and communications infrastructure and network.

Canham advises controlling invasive plants by combining herbicides, grazing and a weed management plan.

"Grazing during the growing season followed by fall herbicide application many times reduces seed production and is an opportune time for perennial herbicide application," he says. "The future holds many challenges. We live in a very global society. Because non-native species are so aggressive and prolific, we need to evaluate management strategies and make use of all available resources. Invasive species will only get worse."

For more information, email Liz Galli-Noble with MRWC at *Elizabeth.gallinoble@montana.edu*; Scott Bockness with the Conservation Innovation Grant project at *scott.bockness@montana.edu*; or Chuck Bargeron with EDDMAPS at *cbargero@uga.edu*. For summer internships and job opportunities in weed or watershed management, call Canham with MidDakota Vegetation Management at 605-530-8089.

Sorensen writes from Yankton, S.D.

New project brings together a broad range of stakeholders for invasive plant management

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The Missouri River Watershed Coalition has been funded by the Natural Resource and Conservation Service (NRCS) through the Conservation Innovation Grant program to conduct a riparian invasive plant species in the upper Missouri River watershed. The purpose of this project is to: (1) foster the adoption of innovative conservation approaches to invasive riparian plant management by monitoring herbicide treatment and control sites for short and long-term ecological changes, riparian system function, environmental protection, and natural resource enhancement; (2) investigate and demonstrate the use of innovative bioenergy technologies that promote the utilization of invasive plant biomass as a fuel source; and (3) utilize the MRWC's management and communications infrastructure and network to coordinate all components of the project, and to transfer project findings, products and technologies to a broad range of regional stakeholders, including the private sector and NRCS.

The MRWC has established project locations in Montana, South Dakota, and Wyoming that are designed to conduct management activities of Russian olive, saltcedar, and to a small degree phragmites in the region. Detailed vegetation sampling and surveys will be conducted on the project sites for the purpose of evaluating the efficacy of the management activities and to measure vegetative community response to the treatments. The information gathered from monitoring the treatment sites will provide valuable insight related to developing science-based effective management strategies for future projects. Additionally the project team has facilitated the necessary testing to validate the potential of Russian olive and saltcedar as biomass feedstock materials for bioenergy production purposes. Although the testing has established that the biomass generated from Russian olive and saltcedar is a high quality fuel, the use of biomass as an energy source is very limited in the region. The project will continue to investigate the various bioenergy technologies available, along with promoting the use of the invasive plant materials for future regional bioenergy opportunities.

MSU, partners in six states consider converting invasive plants to fuel

OCTOBER 6, 2010 • BY EVELYN BOSWELL • MSU NEWS SERVICE

Russian olives are so plentiful in the headwater states of the Missouri River Basin that MSU and partners in six states are investigating the possibility of turning them into biofuel. These Russian olives are located near Bozeman. (MSU photo by Kelly Gorham).

BOZEMAN – Invasive plants make life tougher for farmers and ranchers who live in the six headwater states of the Missouri River Basin, so why not turn the plants into fuel and make some money at the same time?
Russian olive and saltcedar alone could supply biomass far into the future, according to weed experts throughout the region.

Converting invasive plants to fuel is an intriguing idea that's being investigated by partners in a regional project headed by the Center for Invasive Plant Management (CIPM) at Montana State University and the Missouri River Watershed Coalition, said project director Liz Galli-Noble, also CIPM director.

The center and MSU were recently awarded $1 million from the Natural Resources Conservation Service, Conservation Innovation Grant program, to develop innovative ideas for managing invasive plants and work with public and private partners in Montana, North Dakota, South Dakota, Wyoming Colorado and Nebraska. Out of 230 grant proposals submitted and 61 grants awarded for conservation work, MSU's tied for the largest.

Invasive plants can be ornamental plants that escaped from the garden, fast-growing non-native plants that were intentionally brought to the region to stabilize soils or river banks, or strange-looking weeds that continuously spread from other states and countries. But Galli-Noble said they all can cause very serious ecological and economic problems in the western United States. She added that their prevention and control are crucial management issues in the Missouri River Watershed.

Dense invasive plant infestations choke river systems; restrict access for irrigation, wildlife and recreation; reduce water quality and quantity; and degrade or eliminate habitat for wildlife and livestock.

The six states in the upper Missouri watershed contain hundreds of thousands of tons of invasive plant biomass, Galli-Noble estimated. The entire river is 2,540 miles long and drains about one-sixth of the North American continent. More than a million acres in the western United States are infested with Russian olive *(Elaeagnus angustifolia)* and saltcedar *(Tamarix* spp.) alone.

"It's a huge supply of currently unwanted and untapped biomass," Galli-Noble said.

Scott Bockness of Billings, vice president of the Missouri River Watershed Coalition and weed coordinator for Yellowstone County, added that Russian olive and saltcedar -- the focus of the pilot project -- displace cottonwoods, willows and other native trees that grow along streams. Invasive plants push out native forbs and deciduous trees at alarming rates.

"There really isn't a place on the Yellowstone corridor where it's not a problem. It's massive," he said.

The Yellowstone River feeds into the Missouri River. It's a major contributor to the entire ecological system, Bockness said.

Slade Franklin, state weed coordinator for Wyoming and member of the Missouri River Watershed Coalition executive committee, said Russian olive and saltcedar, as well as Canada thistle (Cirsium arvense)and white top (Lepidium draba), have invaded the riparian areas along several Missouri River tributaries in Wyoming. In addition to trees, invasive plants have pushed out "some pretty valuable grasses and forage for wildlife, also for agriculture communities."

Russian olive invades every county in Wyoming, Franklin said. He noted that the infestation is particularly significant in the Bighorn Basin of northern Wyoming.

The regional endeavor is a three-part project, with a major component focusing on the feasibility of turning saltcedar and Russian olive into biofuel. Organizers said it will include setting up demonstration sites and conducting workshops that show how existing technology can use Russian olive and saltcedar biomass as a feedstock for pelletization, bio-brick production, gasification and other bioenergy production.

The second focus of the project is determining the effectiveness of existing strategies used in the six-state region for controlling invasive plants and restoring desired native plant communities. The project will monitor short-term and long-term ecological changes, riparian system health and function, and natural resource enhancement on selected treatment and control sites.

"There is great potential to incorporate students and other university resources into the project over our three-year time frame," Galli-Noble said.

Bockness said many agencies and groups already use various strategies to control invasive plants, but the six-state project is unique. Little work has been done prior to implementing management to quantify the effectiveness or understand the ecological impacts of those strategies, he said.

"Converting invasive plants to fuel is also a unique concept for the Missouri River Watershed, as far as we know," he said.

Galli-Noble said companies already use crop residues as feedstock for biofuel production, so it seems logical that invasive plant biomass feedstock can be used in much the same way. Bockness added that early BTU testing indicates that fuel made from invasive weeds is a viable product.

If the idea works, Galli-Noble said it could spread across the West and the rest of the nation and benefit local, state, federal and private landowners and managers. Besides providing an income to offset the costs of controlling invasive plants, she added that this innovative technology has the potential to develop community-based jobs, produce an effective energy source, improve the quality and reduce the cost of grazing land restoration, enhance fish and wildlife habitat, reduce the threat of wildfire, and promote long-term conservation strategies on high-value riparian lands.

A third key component of the three-year project is transferring these innovative conservation technologies and riparian land management approaches to a broad range stakeholders throughout the region, including the private sector, Galli-Noble said. All project information will be disseminated through CIPM and coalition communication networks, field demonstrations and workshops, and publications.

For more information, visit the coalition Website at http://www.weedcenter.org/mrwc/index.html

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