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EXECUTIVE SUMMARY

Thunder Basin Phase II Watershed Management Plan
Level I Watershed Study
Lance and Lightning Creek

Submitted to:
Wyoming Water Development Commission

Prepared by:
Olsson Associates

In Association With:
ESCO Associates, Inc.
Wester Wetstein Associates
Steady Stream Hydrology, Inc.

September 2011

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Lance and Lightning Creek

WWDC Contract Number 05SC0294198

September 14, 2011

I hereby certify that this report was prepared by us or under our direct supervision and that we are duly Licensed Professional Geologists and Engineers under the laws of the State of Wyoming.

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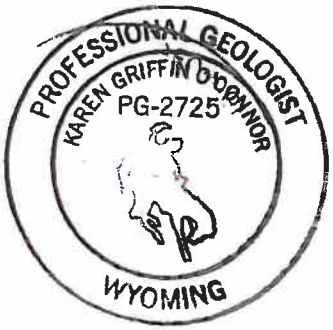

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ES-1.0 Introduction

Olsson Associates (Olsson) prepared the Thunder Basin Phase II, Lance and Lightning Creek (L&LC) Watershed Management Plan for the Wyoming Water Development Commission in accordance with Contract No. 055C0293618. The plan was prepared in association with ESCO Associates (ESCO) of Boulder, Colorado, Steady Stream Hydrology, Inc. of Sheridan, Wyoming, and Wester Westein & Associates of Laramie, Wyoming. The plan was prepared on behalf of the watershed landowners and the project sponsors including the Thunder Basin Grazing Association (TBGA), the Thunder Basin Grasslands Prairie Ecosystem Association (TBGPEA), and the two conservation districts that are represented in the Thunder Basin L&LC Watershed (Converse and Niobrara).

ES-1.1 Purpose and Scope

The purpose of this Watershed Management Plan is to describe Thunder Basin L&LC watershed in its current condition, to suggest resolutions for any water related issues and provide insight into opportunities identified. As illustrated in Figure ES-1, the current study is directly south of a Level I study completed by the same team in 2009 (Olsson, 2009). Both Level I watershed studies include an extensive inventory and description of the watershed with scientific information on geology, hydrology, soils, climate, plant communities, wildlife habitat, infrastructure, and the geomorphic characteristics of the watershed stream system. The information gathered is intended to be used to develop proposed watershed improvements. Specific to this study, the project sponsors have requested an evaluation of surface and groundwater availability, the potential to develop upland livestock and wildlife water resources, and the potential to develop and enhance additional irrigation systems and water storage. Proposed projects are listed in the report and include cost estimates as well as information on project financing opportunities and project permitting considerations.

ES-1.2 Overview of Study Area Key Issues

Thunder Basin L&LC watershed lies in the northeast portion of Wyoming and includes Lance and Lightning Creeks which are the primary tributaries to the Cheyenne River System. The watershed is located in central and east Converse and central Niobrara counties (Figure ES-1). The watershed encompasses approximately 1,572,390 acres of primarily grassland. The area has a robust livestock industry as well as mining and oil and gas development. For approximately ten years starting in 2000, the area has been abnormally dry and the drought conditions have exacerbated the need for additional water development and distribution.

The TBGA and TBGPEA, in conjunction with the two conservation districts (Converse and Niobrara), the BLM, NRCS, WWDC and other government agencies, have been promoting watershed improvement projects and best management practices across the area. With the extended drought conditions and the prospect of additional project support through the WWDC, the TBGA, TBGPEA, and the conservation districts decided to promote the completion of this Level I study in order to provide a comprehensive, multidisciplinary watershed management plan that will identify and begin to address the key issues facing the area. The intent was to produce a watershed management plan that would take into account the landowners' requests for future project improvements and also provide a comprehensive understanding of the current conditions of the watershed so that projects that will benefit a multitude of landowners and recreational visitors could be coordinated across the area.

In order to solicit landowner involvement and input, this project began with a series of bimonthly project meetings where information was solicited on specific project initiatives such as irrigation system upgrades, upland water development (wells), surface water storage, stream, rangeland enhancements as well as funding opportunities. Project meeting information request forms were

sent to landowners across the project area. Responses from the request for information were compiled into a project database.

Thirty-nine, approximately 10 percent, of the landowners across Thunder Basin L&LC watershed responded to the request for information. Twenty-one landowners had no specific projects for evaluation; however, they asked to be kept informed of the project status. Three of the landowners had ranches outside of the watershed boundary. Based on their response, the WWDC and project sponsors decided to expand the areal extent of the project by including portions of Hat and Angostura Reservoir watersheds that are contiguous with Lance and Lightning Creek east to the South Dakota and Nebraska borders.

Of the remaining eighteen responses, four requested irrigation system evaluations, nine requested information on well development opportunities, eleven requested information on water storage sites and three were interested in stream and rangeland enhancements. Landowners that requested evaluation and granted site access were visited by the project team. Specific issues raised at project meetings, during the site visits, and in written responses included:

- *Irrigation Systems* – Less than 1 percent of Thunder Basin L&LC is irrigated and spreader dike systems are used as the standard for water distribution. There were several requests to upgrade spreader dike systems.
- *Groundwater Well Development* – Additional stock and wildlife water supplies are needed throughout the basin to enhance range conditions and habitat restoration. Solar wells were requested with pipelines, as needed, to encourage rotational grazing and reduce the distance cattle and wildlife must travel to water.
- *Water Storage Sites* – Most ranchers are interested in either rehabilitating existing small stock watering ponds or installing new small structures. There were a few ranchers that were interested in medium to large reservoirs, however, it was suggested that before any additional investigation be done on the larger structures that a water rights evaluation be completed.
- *Rangeland/Riparian Conservation* – Questions arose about what grasses would perform best in specific soil types with minimal precipitation and the increased frequency of grass fires.

With these specific key issues identified, the project team began a comprehensive evaluation of the watershed. The first stage of the study involved compiling a description and inventory of Thunder Basin L&LC watershed.

ES-2.0 Conclusions and Recommendations

This section provides a summary of the conclusions and recommendations presented throughout this report. The conclusions pertain to the watershed inventory and current conditions of the watershed. The recommendations include the proposed watershed improvements projects, environmental permitting and financing.

ES-2.1 Conclusions

Natural Environment

The Lightning and Lance Creek watersheds lie within the Powder River Basin, a geologic structural basin that is part of the Missouri Plateau of the Great Plains (Trimble, 1980). A structural basin is a geologic feature that is formed by rock strata dipping at various angles to a

centralized area. The rock layers in the Powder River Basin were tilted from uplift of several structural features in the region, including the Big Horn Mountains and Casper Arch on the west, the Black Hills to the east, and the Hartville Uplift and Laramie Mountains to the south. To the north, the basin gently slopes upward towards the Miles City Arch, although the surface terrain in this area cannot be distinguished from the rest of the Missouri Plateau (Keefer, 1974). The region is characterized by rolling uplands dissected by tributaries of the Missouri River system. The Lightning and Lance Creek watersheds exist along the southern edge of the basin.

The study area watersheds consist of a dissected, rolling upland plain with low to moderate relief. The north to northeast oriented dissecting valleys originate along the southern edge of the study area in the uplands of the Hartville Uplift area. Buttes, mesas, hills, and ridges are present throughout the region, especially along the southern boundary of the Lightning watershed and throughout much of the southern and eastern portions of the Lance Creek watershed. Elevations range from 5,622 feet in the southwest area of the Lightning watershed to 3,693 feet in the far northeast corner of the Lance Creek watershed (Map 2, Ground Elevation Map). The present-day landforms have been shaped mostly by water action, even though modern-day precipitation is low and is greatly exceeded by evaporation. The incised drainages crossing the study area are mostly ephemeral or intermittent, and do not provide permanent sources of water along the entire drainage reaches. Runoff from surface precipitation can in places be augmented by groundwater-fed springs and seeps from shallow aquifers, particularly in the upper reaches of tributary drainages in the Lance Creek watershed (BLM, 2003).

Climate - The climate of the Thunder Basin L&LC watershed can be classified as semiarid, steppe in the Köppen climate classification system with precipitation averaging 16 inches annually. In October 2010, most of the watershed was experiencing abnormally dry conditions, classified as drought intensity D0 (on a scale of D0 to D4). Of the 7 weather stations used to monitor climatic conditions in the L&LC watersheds, only one (Redbird 1 NW) is still operational. At this station, the average annual precipitation is 15.9 inches per year.

Vegetation and Land Cover - The bulk of upland vegetation is comprised of plant communities in which grasses are predominant, both biologically, and visually. These grasslands appear mostly in the form of mid-grass prairie in the eastern portion of the Study Area. In the uplands of the west and southwest portions, the grass component is joined by a substantial presence of big sagebrush (*Artemisia tridentata*, mostly subspecies *wyomingensis*). Shrub abundance varies both in responses to substrates and climate but also in response to range condition. Stress can encourage the establishment of shrubs as grass competition is lessened.

Periodic declines in moisture delivery are responsible for conditions of moderate to severe vegetative stress, depending on how long the precipitation stays below average. Through periods of near average or greater moisture availability, mid-grasses are visually and physically dominant. Shortgrass cover, primarily blue grama (*Bouteloua gracilis*) is visually minimized during these times but upon return of severe moisture stress and the decline of mid-grass cover, the shortgrass cover can become visually dominant.

Based on current state and transition model information presented in the NRCS Ecological Site Descriptions (ESDs), most ecological sites of the Study Area can be expected to come to experience greater shrub cover as the effects of stress compound. This research suggests that grazing effects are likely not responsible for the presence of sagebrush in all cases. Extended drought is also an effective stressor. Some evidence also supports the view that sagebrush

(and even abundant sagebrush) is a natural plant community component and not a vestige of stress, with abundance proportional to precipitation and snow cover (WGFD 2009).

Soils - Soil surveys have been completed by the NRCS throughout the L&LC watershed. Soil Survey data is incorporated in the GIS dataset included electronically with this report. Soils within the study area watersheds have developed in residual material and alluvium in a climatic regime characterized by cold winters, warm summers, and low-to moderate precipitation. The upland soils are derived from both residual material (derived from flat-lying, interbedded sandstone, siltstone, and shale) and stream alluvium. Valley soils have developed in unconsolidated stream sediments including silt, sand, and gravel. Soils in the study area watershed are generally low in organic matter and are alkaline (Lowry et al. 1986). Textures range from clay loams to sandy loams with varying amounts of gravel or coarser materials. Slopes range from nearly level to very steep with deeper soils found in the less steeply sloped areas. These soils support little crop agriculture except in irrigated valleys of perennial streams. Across the L&LC watershed the predominant land use is rangeland and the vegetation developed on the soils is predominantly grass and shrubs, with limited areas of irrigated pastures along Lance Creek below its confluence with the Lightning Creek drainage.

Geology - The surficial geology of the Thunder Basin L&LC watershed can generally be divided into three unique categories: 1) Bedrock, residuum, and mined areas; 2) Alluvial valley deposits; and 3) Upland deposits. Across the two watersheds, the bedrock units are youngest (Tertiary) on the west and southeast fringes of the study area, with the oldest formations (Cretaceous, Jurassic, and Paleozoic) exposed in the upland areas of the Lance Creek watershed. Within the Lightning and the northwest corner of the Lance Creek watersheds, the four shallow bedrock units from youngest to oldest (west to east) include:

- Tertiary Wasatch Formation
- Tertiary Fort Union Formation; Lebo member
- Tertiary Fort Union Formation; Tullock member
- Cretaceous Lance Formation

In the northern half of the Thunder Basin L&LC watershed, two older Cretaceous formations, the Fox Hills and the Pierre, join the Lance Formation as the primary bedrock units beneath the surficial deposits. Near the eastern boundary of the Thunder Basin L&LC watershed, older Cretaceous and Jurassic formations are exposed in a structural upwarp (anticline) of the bedrock. Exposures of the Cretaceous and Jurassic bedrock units are also found in isolated areas in the southern half of the Thunder Basin L&LC watershed. In the southern half of the Thunder Basin L&LC watershed, the shallow bedrock is comprised of the Tertiary-age Arikaree and White River Formations.

The geologic materials at the land surface primarily consist of residuum, alluvial (water-transported) and eolian (wind-transported) deposits. The alluvial deposits mantling the watershed drainages are critical to the watershed since they can potentially be used to identify a location for groundwater development and in some areas, indicate a location with baseflow to surface drainages. Five distinct southwest-northeast oriented alluvium-filled valleys cross and converge in the northeast corner of the Lightning watershed. Three well-defined alluvial valleys with axes approximately in a north south orientation cross the Lance Creek watershed and one additional east-west oriented alluvial valley drains the northwest corner of the Lance Creek watershed. Most of the upland areas in the Lightning watershed are comprised of residuum overlying shallow bedrock combined with eolian deposits, alluvium, and slopewash. In the

Lance Creek watershed, the upland areas consist of residuum, slopewash, and colluvium especially in areas of steeper topography

Structural Features - Thunder Basin L&LC watershed lies within the Powder River Basin, a northwest-southeast trending structural basin that formed approximately 60 million years ago during the Laramide Orogeny. The tectonic events of the Laramide Orogeny affected the outcrop patterns which thus influenced soil development, aquifer characteristics, groundwater flow patterns, oil, gas, coal, and methane deposits, as well as the topographic relief of the region. The Thunder Basin L&LC watershed is flanked on the south and east by an extensive anticlinal structure known as the Hartville Uplift. This area of upwarp in the bedrock separates the Powder River Basin from the Denver Basin to the south. At least three mapped faults cross the south central portion of the Thunder Basin L&LC watershed including the Lance Creek thrust fault that exhibits influence on the orientation of the Lance Creek alluvial valley (Johnson and Micale, 2008). The types of faults found in the study area can also exhibit influence on aquifer characteristics, and thus the potential for groundwater development in the watershed.

Slope Stability - Landslides of significant size or scale have not been mapped in the study area watersheds. The lack of WSGS mapped landslides within the study area does not relieve project sponsors from evaluating the hazards of slope instability on specific sites prior to project implementation. Small, localized slope failures can occur along the banks of active channels. Slope instability increases after material saturation and watershed improvement projects should include site-specific geological hazard analyses.

Seismotectonics - Earthquakes can and have occurred in eastern Wyoming. There have been 29 historic earthquakes recorded in Converse County with magnitudes of 3.0 or greater and eight greater than 3.0 in Niobrara County. The strongest measured earthquake within the region was a magnitude 5.5 event that occurred southwest of Casper on October 18, 1984. Watershed improvement projects that involve significant disturbance or construction efforts should include site-specific geologic hazard analyses including a seismotectonic evaluation.

Groundwater - Groundwater in the Thunder Basin L&LC flows within the pore spaces of shallow alluvial sediments and bedrock units. Alluvial aquifers occur in the alluvial valleys located along the major drainages as well as floodplains, stream terraces, and alluvial fans and are composed of unconsolidated deposits of silt, sand, and gravel. The thickness of alluvial deposits is not known throughout the watersheds because of the inherent variability in alluvial depositional environments and the lack of geologic borehole information. Yields for alluvial aquifer wells range from 1 to 370 gallons per minute (gpm). The bedrock aquifers are part of the Northern Great Plains aquifer system and in the Thunder Basin L&LC, the aquifer system includes specifically the Tertiary aquifers exposed at the surface, as well as the deeper regional aquifers within older sedimentary rocks. Lower Cretaceous and Paleozoic rocks are not recommended as groundwater resources since they too deep and would be too costly to complete and maintain for livestock/wildlife and irrigation purposes. Bedrock wells can produce up to 500 gpm. Wells completed in the Wasatch and Lance Formations have been noted to contain high concentrations of dissolved solids. Springs occur where the groundwater table intersects the ground surface. 18 springs were identified in the Lance Creek watershed and 8 in the Lightning watershed, although there are likely many more developed and undeveloped springs in the watershed, particularly in the isolated area of clinker deposits in the northwest corner of the Lance Creek watershed. Additional mapping of springs throughout the study area would provide a more comprehensive understanding of the existing water resources in the Thunder Basin L&LC watershed.

Surface Water Hydrology - The Thunder Basin watershed is comprised of two main watersheds: the Lance Creek and Lightning Creek watersheds. In addition, a portion of the Angostura Reservoir watershed between the Lance Creek watershed and the eastern Wyoming state line were included in the study area. Within the study area, portions of fourteen streams are considered to be perennial. The larger tributaries are considered to be intermittent streams, and the remaining tributaries are considered to be ephemeral streams. Within the study area, there are no active and one historic USGS streamflow gaging station. There are four additional sites that have historic peak flow data and five observation sites. The one USGS stream gage with historic daily or monthly flow data is 06386000, Lance Creek near Riverview, Wyoming. This station reveals that the majority of flow occurs between April and September. Peak flow data shows that peaks most often occur in June.

Stream Geomorphology - A Rosgen Level I classification was completed across the main tributaries of the L&LC watersheds. The results are summarized as follows: The majority of the stream channels in the L&LC watersheds are classified as C channels (low gradient, meandering, point-bar, riffle/pool, alluvial channels with broad, well defined floodplains), B (moderately entrenched, moderate gradient, riffle dominated channel, with infrequently spaced pools, very stable plan and profile with stable banks) and E (low gradient, meandering riffle/pool stream with low width/depth ratio and little deposition. Very efficient and stable. High meander width ratio). Within the Angostura Reservoir Watershed, the majority of channels are Type B, C, G (Entrenched "gully" step/pool and low width/depth ratio on moderate gradients) and A (steep, entrenched, cascading, step/pool streams. High energy/debris transport associated with depositional soils. Very stable if bedrock or boulder dominated channel). The majority of channel classifications in the Hat Creek Watershed were B, C, and E.

Land Uses and Management Activities

Land Ownership - The majority of land (83%) the L&LC watersheds is privately owned. The remainder of the land is split about evenly between Federal (9%) and State (8%) ownership. Land ownership will play an important role in project implementation in that permitting and financing options depends heavily on land ownership and intended beneficial use.

Range Conditions – Bureau of Land Management (BLM) grazing allotments encompass approximately 18 percent (~283,000 acres) of the land within the Study Area. The BLM-administered allotments typically include intermingled private, state, and federally-administered lands used for grazing and are not currently administered through grazing agreements with Grazing Associations. U.S. Forest Service (USFS) grazing allotments encompass approximately 7.5 percent (~118,000 acres) of the land within the Study Area. These grazing allotments are administered by the Forest Service through grazing agreements with the Thunder Basin Grazing Association. Management of the rangeland in these areas is detailed in guidelines set forth by the BLM, USDA, and USFS.

Distribution of water sources are critical to the implementation of a functional grazing management system. Evaluation of range condition can be used to identify areas that will benefit, over time, from a plan to adjust exposure to grazing to the benefit of more nutritious and productive species. However, such plans inevitably require that reliable livestock and wildlife water is available. The alternative water resource improvements presented in this report will achieve their highest and their most durable positive effects in conjunction with well-reasoned range management planning that directs and times livestock activities in accordance with range plant health.

Oil and Gas Production – Exploration and production of oil and natural gas has been commonplace in Wyoming for at least 125 years. Over this time, extraction of these commodities has become an important part of the Wyoming economy. The largest oil field potential in the study area is situated primarily in the Lightning watershed, where approximately 160,000 acres have been designated as "High" potential areas for oil and gas according to the U.S. Department of Interior's former Bureau of Mines. Smaller, more isolated oil and gas fields are found throughout the Lance Creek watershed, with the largest productive zones found near the town of Lance Creek. Over the last decade (2000-2010), the Powder River Basin witnessed a substantial increase in the number of Coal Bed Methane (CBM) wells. Significant amounts of water are produced during CBM extraction. However, the amount of water discharged to the land surface during CBM production within the study area is expected to be limited since the areas of production in the basin are beyond the L&LC watershed boundary. Potential exists for an increase in CBM production based on the mapped potential for coal deposits in the study area.

Mining and Mineral Resources – The Powder River Basin is one of the most prolific coal-producing regions in the world. Much of the active mining in the Powder River Basin occurs just north of the L&LC watershed along the drainages of the Cheyenne River. Powder River Basin coal is highly sought because of its low-sulphur, sub-bituminous composition and high heat content that requires little preparation for use as a power plant fuel. Although no active coal mines exist in the study area, data from the Wyoming Geographic Information Science Center indicates that nearly 40,000 acres of land, primarily in the Lightning watershed and the northwest corner of the Lance Creek watershed have "High" potential for coal production. The remainder of the Lightning watershed and the northwest half of the Lance Creek watershed are designated as having "Moderate" potential for coal development. Little potential exists for coal development in the remainder of the Lance Creek watershed.

Other Minerals – Both the Lightning and Lance Creek watersheds contain isolated areas of potential uranium development. Potential deposits in the Lightning watershed can be found near the western watershed boundary in an area where the Wasatch Formation is mapped as the primary bedrock unit. Potential areas for uranium in the Lance Creek watershed can be found about 10 miles northeast of the town of Lance Creek in an area underlain by Cretaceous bedrock units.

Transportation and Energy Infrastructure – Highway 18-85 and Highway 59 are the main north/south routes with Highway 18-20 serving as the east/west route. Highway 270 provides a route north from Manville to Lance Creek (the center of the study area) and east to Highway 18-85. Due to the high coal production rates to the north of the study area, the rail lines in the area have an extremely high volume of rail traffic.

Watershed Inventory

Irrigation Inventory – There are approximately 14,913 acres of irrigated land (<0.1% of total area) in the L&LC watershed. Evaluation of irrigated lands using a variety of map and soil survey resources and satellite imagery reveals that almost all of the irrigated lands in the Thunder Basin L&LC watershed are located in the overbanks and flanking terraces along the streams and rivers. The Thunder Basin L&LC watershed can be described as having severe limitations that reduce the choice of plants or require special conservation practices in order to achieve success with irrigation. Crops in the study area are primarily irrigated using surface water (flood irrigation) and very limited amounts of groundwater is utilized for crops. Grass hay accounts for 87% of the actively irrigated crops in the Thunder Basin L&LC watershed.

Groundwater – Approximately 1,962 wells that are fully adjudicated/in good standing are found in the Thunder Basin L&LC watershed. Groundwater is used primarily for livestock/wildlife watering with minor amounts used for irrigation purposes. The reason for this has to do with the depth and yield of the aquifers in Thunder Basin. Groundwater is a viable resource for livestock/wildlife watering and should be expanded in areas where watering opportunities are scarce.

Water Storage Inventory – Although no natural lakes of significant size exist in the study area, there are 62 dams within the L&LC watersheds. The combined storage behind the identified dams is 13,483 acre-feet. The study area contains approximately 2,048 stock watering ponds. There are 290 breached dam locations within the L&LC watersheds with a median pond size of 0.7 acres and a median estimated volume of 3.6 acre-feet. The total estimated volume that could be achieved by rehabilitation of the dams was 1,946 acre-feet. Rehabilitation of the breached dams within the L&LC watersheds could provide viable livestock/wildlife watering opportunities.

Water Quality – Water quality was evaluated in the L&LC watersheds by the USGS. The water quality criteria most often exceeded in samples collected in the study area were sulfate, specific conductance, and manganese. Exceeding the criteria does not necessarily indicate that water is unsuitable for livestock watering or agriculture. It does suggest that livestock and less tolerant plants might not be as productive as they would be with lower levels of the constituents.

Economic Analysis and Project Financing

- An economic analysis on the watershed rehabilitation plans proposed in this report was completed that included an indirect benefits analysis, ability to pay analysis and an evaluation of WWDC financing guidelines. Based on this analysis the livestock watering (upland well development) improvement projects appear to be the most economically beneficial based purely upon a rate of return on the investment.
- Project financing sources include federal, state, local and non-profit agencies. The primary sources of funding for the improvements presented in this report include the WWDC, NRCS and BLM. Numerous other opportunities are presented and should be pursued should the projects move to the next phase of implementation.

ES-2.2 Recommendations

Irrigation Systems

- Three irrigation rehabilitation plans are proposed as requested by ranchers/landowners in the Thunder Basin L&LC watershed (Figure ES-1 and Table ES-1). Rehabilitation plans focus on rehabilitation/replacement of existing structures, enhanced delivery of water, reduction in annual operation and maintenance costs, improvement in ditch management and efficiency, and economic practicality and physical feasibility. Additional improvements could be made across the watershed using the plans and cost estimates provided in this report as a guide for conceptual design, cost, and financing opportunities.
- The recommendations include regarding ditches, head gate replacements, and construction of spreader dikes. The cost estimates for the projects range from $6,000 to construct improved berms along Lightning Creek to $10,000 to install a centrifugal pump along Lance Creek.

- Recommended improvements include projects at three ranches. The individual projects can be implemented individually or as a complete package based on the preferences and financial ability of the owner. The most likely sources of funding for these projects are the WWDC Small Water Project Program and NRCS programs through the local Conservation District.

Surface Water Storage

- An evaluation of water available for storage projects was completed based on the existing datasets accessible for such an analysis. It is recommended that if any of the proposed Account III storage projects is undertaken that StateMod or similar water rights accounting model be developed so that the water rights can be appropriately exercised and potential water availability can be more accurately estimated.
- Due to the lack of streamflow and watershed yield data, temporary stream gages or some means by which drainage yield information be collected should be installed at sites for which storage projects are desired.
- Four WWDC Account III multipurpose storage sites were identified in the Thunder Basin L&LC watershed (Figure ES-3). The Lightning Creek 2 site is estimated to be the most expensive.
- Storage evaluation requests were completed on ten different ranches and fourteen projects are recommended for further study and/or implementation (Figure ES-4 and Table ES-2). Most of the projects consist of constructing small dams to capture and store water. Two of the projects entail rehabilitating existing storage structures by excavating accumulated sediment.
- Livestock/wildlife watering opportunities were evaluated based on the assumption that cattle will graze up to a mile from a water source. Using this criterion, an analysis of the watershed was conducted to identify locations where additional water storage for livestock watering could be beneficial.
- Supplemental storage at existing breached dam locations is a potential option to address the areas underserved with the existing network of stock wells and functional stock ponds. The breached dams located outside of a mile radius totaled 120. The estimated volumes that could be gained from rehabilitating the structures ranged from 0.3 to 100 acre-feet. Site visits need to be made to ascertain the actual improvements needed. The most likely source of funding for breached dam rehabilitation is the WWDC Small Water Project Program, the Wyoming Wildlife and Natural Resource Trust, or the Bureau of Land Management Range Improvement Planning and Development Program.
- For expansion of existing reservoirs, each of the 62 dams identified in the National Inventory of Dams was evaluated to determine whether each dam has enough watershed area to yield a minimum of 1,000 acre-feet of available water based on the averages described in the preceding paragraph. None of the dams had sufficient watershed area to generate an additional 1,000 acre-feet of available water during a normal year.

Groundwater Development

- One of the best options to enhance rangeland and riparian habitat is to ensure that there are adequate watering opportunities in the upland areas of the watershed. Currently drainage ways are often the location of the water that is

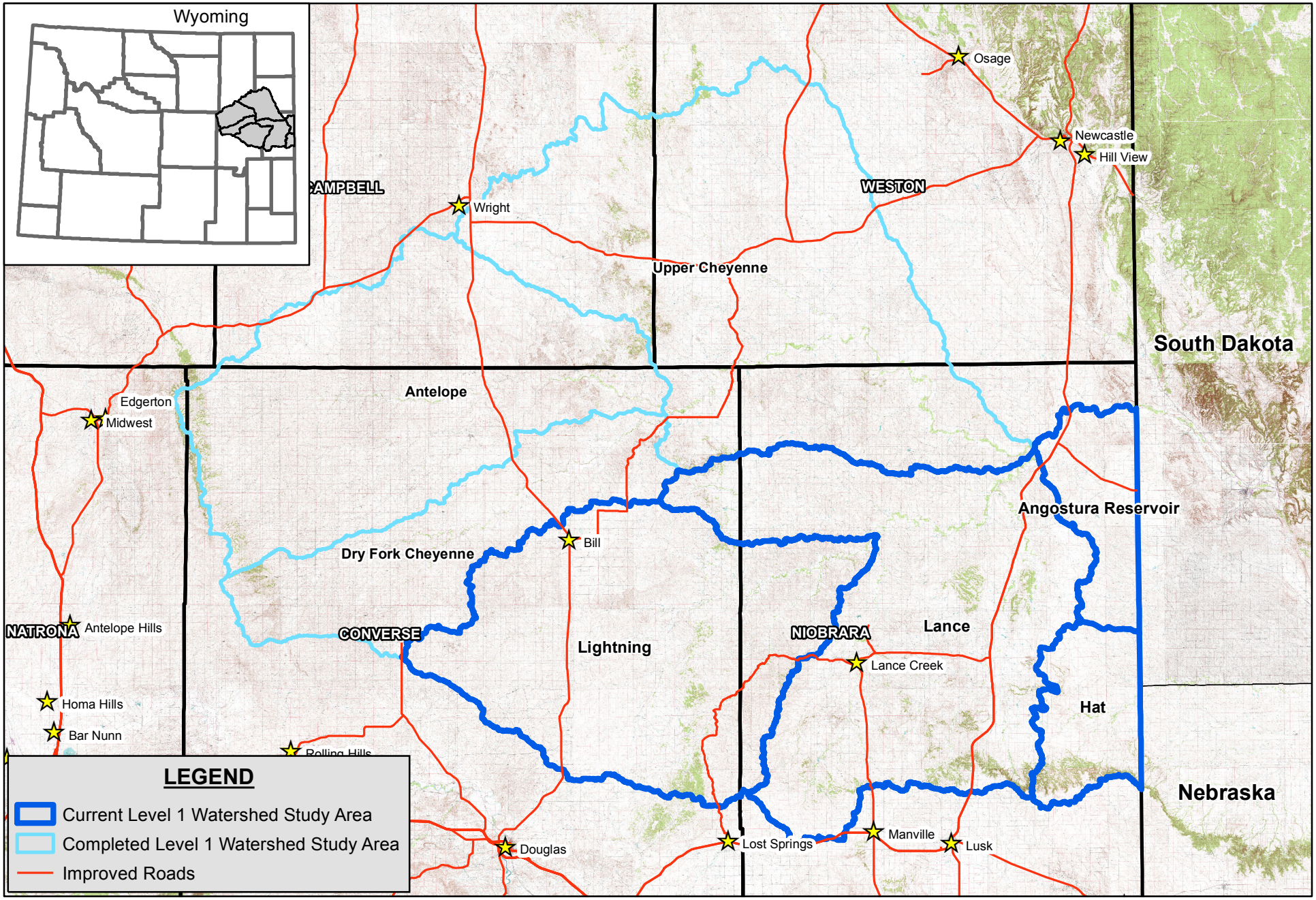
available and therefore livestock pressure in these portions of the landscape is disproportionately great. For this reason, 18 upland water development projects in underserved areas are recommended on nine ranches (Figure ES-5 and Table ES-3). These projects include the combinations of the following elements: installation of shallow to moderately deep groundwater wells, solar powered pumps, stock tanks, piping and fencing to maximize water distribution for livestock and wildlife. The projects range in cost from $6,500 to nearly $100,000.

- Additional upland water development improvements could be made across the Thunder Basin L&LC watershed using the plans and cost estimates provided in this report as a guide for conceptual design, cost, and financing opportunities.
- Development of deep aquifer irrigation wells is not deemed feasible for this area unless significant advances in technology for installation and long-term pumping are realized.

Other Management Practices

- Control of noxious weeds including Russian olive, salt cedar and Canada thistle, to name a few, should continue to be implemented to promote overall health of the rangeland. Efforts should be concentrated in areas of large infestations in both rangeland and riparian areas.
- Continued implementation of the grazing management plans developed for the Thunder Basin L&LC watershed is recommended. These plans provide methods for pasture rotation and riparian habitat protection that will continue to add to the value and health of the watershed.
- Based on the geomorphologic evaluation completed, it is recommended that channel restoration and stabilization efforts should be coordinated as the proposed projects are implemented. For example, in areas where the stream is entrenched and a diversion structure is planned, a series of cross vane type structures could be constructed to provide an increase in head elevation for the diversion point and as part of the headgate repair/replacement an in-channel diversion structure will be needed. Additionally, the large storage structures will require additional evaluations to ensure stream stability after project implementation. These more detailed geomorphologic evaluations (i.e., Level II Rosgen Classifications) can be implemented as part of the Level II feasibility studies that could be completed during the next phase of project implementation should the projects go forward.
- Two wetland development projects were proposed in conjunction with a proposed well and small reservoir project. In both cases, the amount of water available will limit the extent of wetland which can be constructed. One wetland would be created by overflow from a proposed well and stock tank. The extent of wetland that could be maintained by this hydrology may range up to 0.25 acres. The second proposed wetland area is a fringe wetland that would be maintained by an impoundment of an ephemeral creek. The wetland would be constructed in coordination with the construction of a new pond. However, due to the small size of the pond, at most 0.1 acre of wetland is likely to develop.

Figures



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PROJECT: 010-1333	LOCATION MAP Thunder Basin L&LC Watershed Management Plan Level I Watershed Study Converse and Niobrara Counties	FIGURE ES-1
DRAWN BY: RD		
DATE: September 12, 2011		

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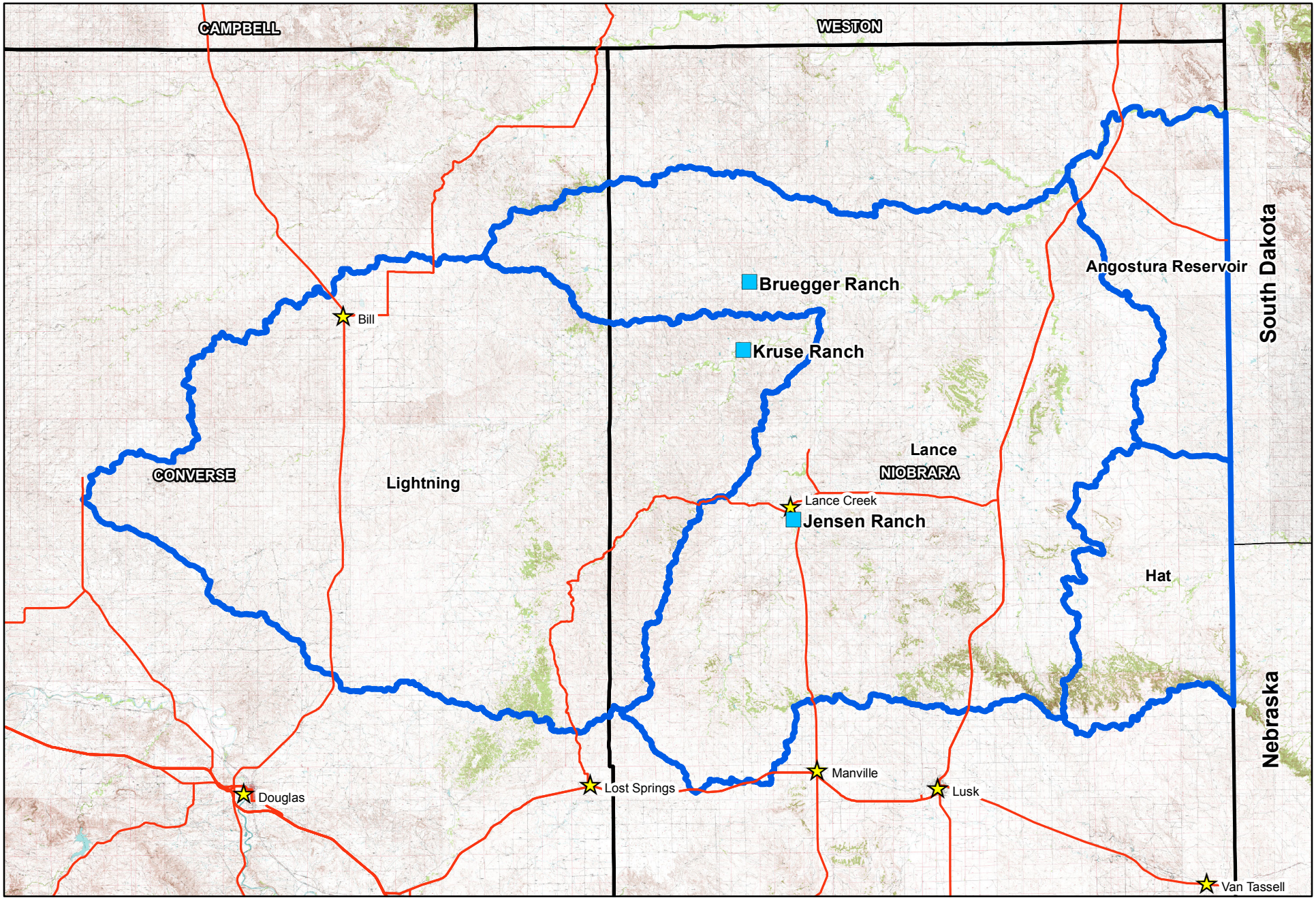

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PROJECT: 010-1333

DRAWN BY: RD

DATE: September 12, 2011

PROPOSED IRRIGATION IMPROVEMENTS
Thunder Basin L&LC Watershed Management Plan
Level I Watershed Study
Converse and Niobrara Counties

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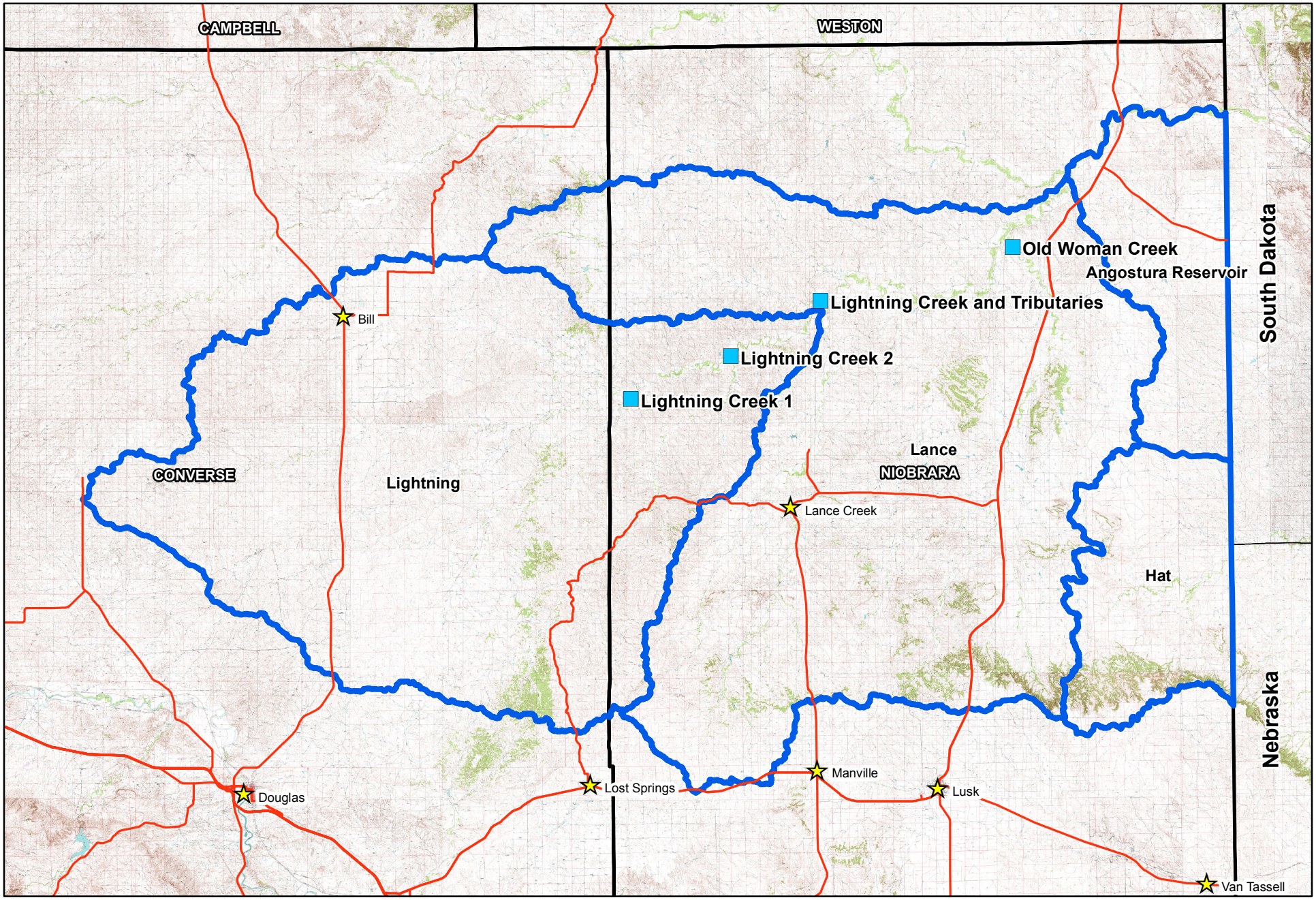
FIGURE
ES-2



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PROJECT: 010-1333	SURFACE WATER IMPROVEMENTS - ACCOUNT III SITES Thunder Basin L&LC Watershed Management Plan Level I Watershed Study Converse and Niobrara Counties	FIGURE ES-3
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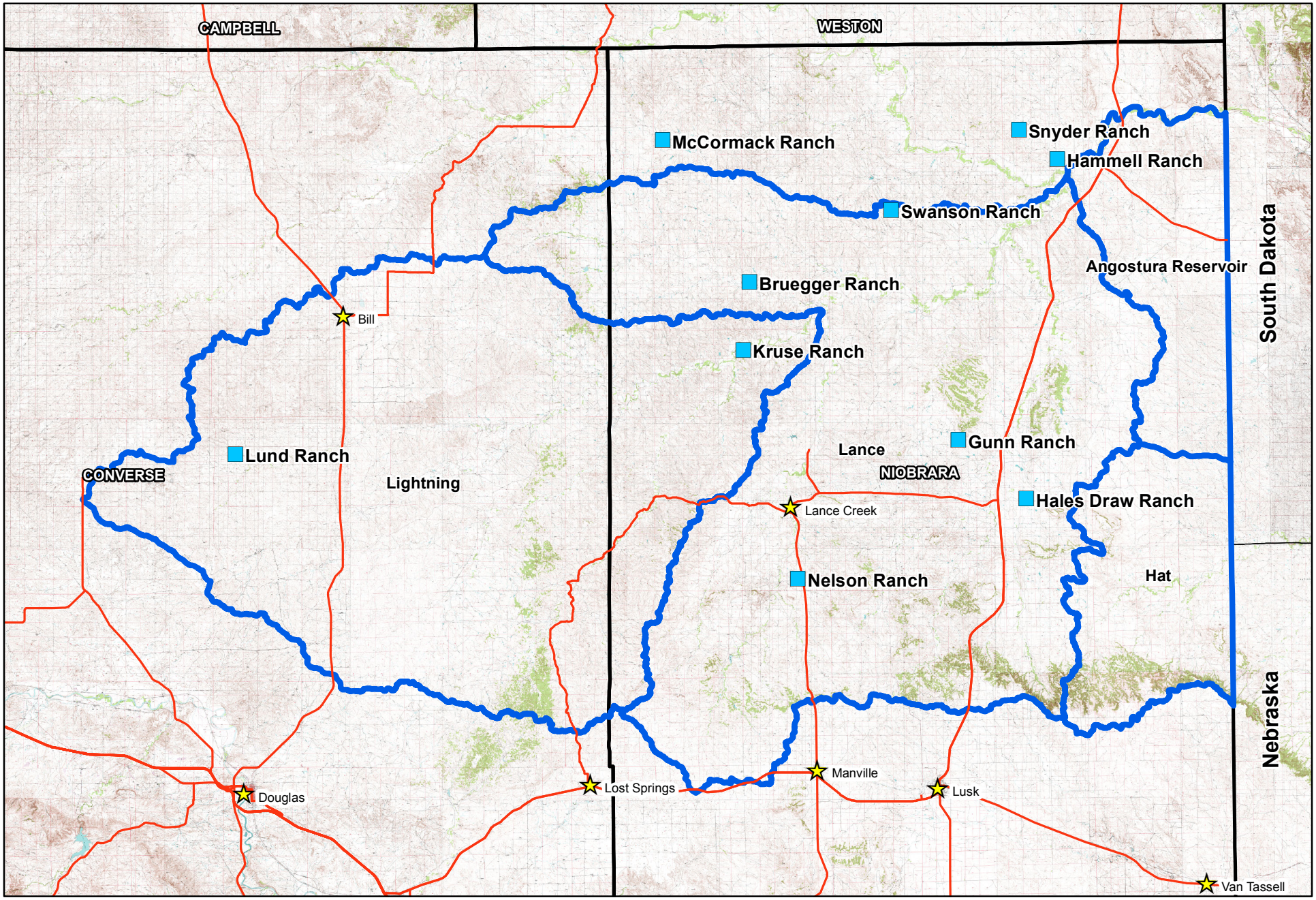

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PROJECT: 010-1333	PROPOSED SURFACE WATER IMPROVEMENT PROJECTS Thunder Basin L&LC Watershed Management Plan Level I Watershed Study Converse and Niobrara Counties
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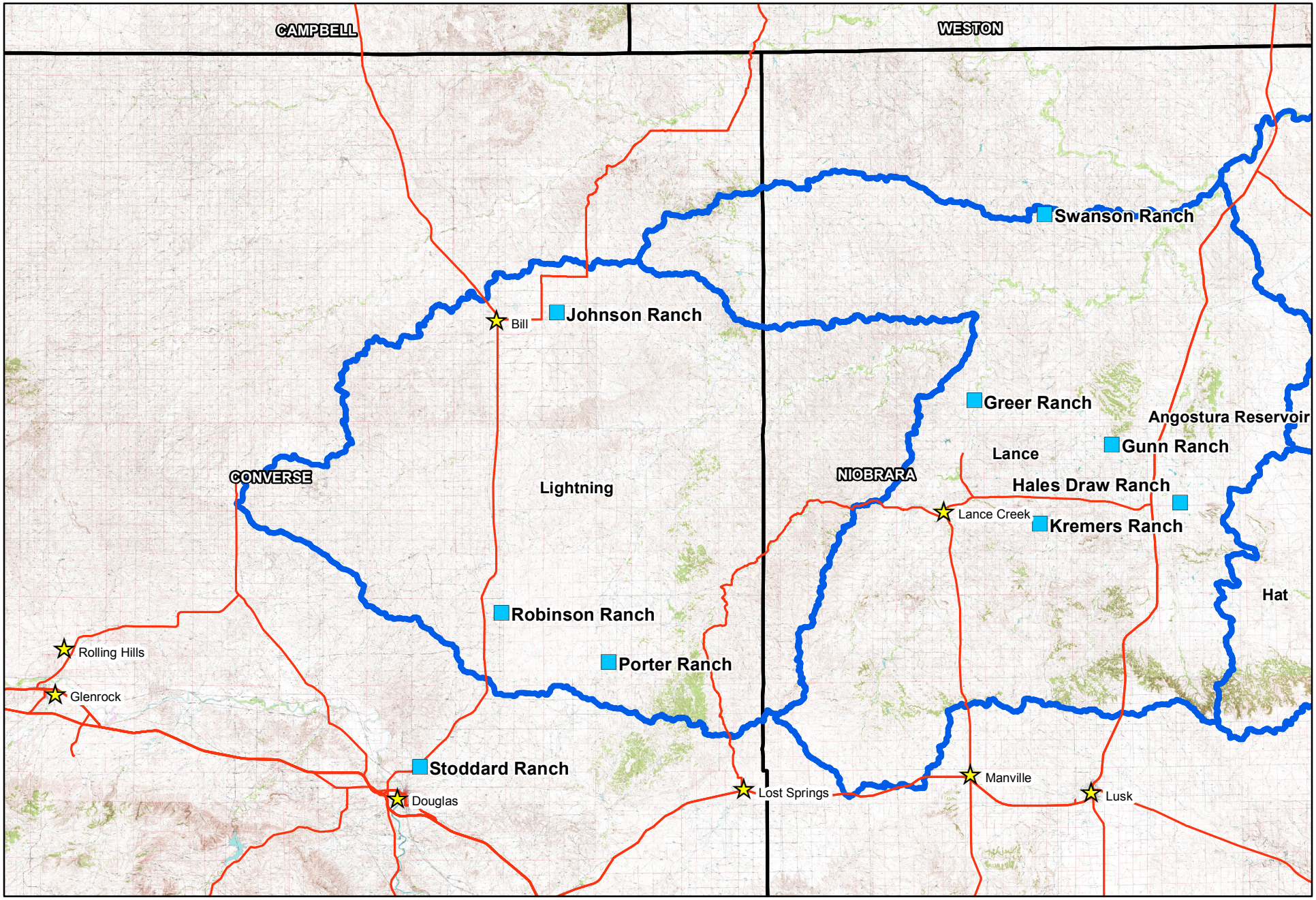
FIGURE
ES-4



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PROJECT: 010-1333	PROPOSED GROUNDWATER DEVELOPMENT IMPROVEMENTS Thunder Basin L&LC Watershed Management Plan Level I Watershed Study Converse and Niobrara Counties	FIGURE ES-5
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Tables

Table ES-1 Irrigation System Rehabilitation Plans

Project Number	Ranch Name	Description	Units	Quantity	Unit Cost	Total Cost
1	Bruegger	Construct spreader dikes	Foot	300	$30/ft	$9,000
2	Jensen	Install centrifugal pump	Each	1	10,000	$10,000
3	Kruse	Improve berms on N side of Lightning Creek for hay fields	Foot	600	$10/ft	$6,000

Table ES-2 Potential Surface Water Development Projects

Project Number	Ranch Name	Project Description	Estimated Cost
1	Bruegger	Pond rehabilitation – removal of sediment (maximum volume removed)	$4,500,000
2	Gunn Ranch	New dam and outlet structure	$24,300
3	Hales Draw	New dam and outlet structure	$92,600
4	Hammell	Relocation of existing dam plus outlet structure	$28,600
5	Kruse	Rebuild dam plus outlet structure	$97,100
6	Kruse	Pond rehabilitation – removal of sediment	$528,500
7	Kruse	New dam and outlet structure	$187,100
8	Lund	New dam on realigned road and outlet structure	$458,700
9	McCormack	New dam and outlet structure	$17,000
10	McCormack	New dam and outlet structure	$50,700
11	McCormack	New dam and outlet structure	$29,400
12	Nelson	New dam and outlet structure	$26,800
13	Snyder	New dam and outlet structure	$49,900
14	Swanson	New dam and outlet structure	$1,073,000

Table ES-3 Upland Water Well Development Projects

Project Number	Ranch Name	Water Well	Solar Power	Pipeline Length (feet)	Pasture Fencing	Storage Tank	Stock Tanks	Site Prep	Estimated Cost
1	Greer	0	1	0	0	0	0	0	$6,500
2	Gunn	1	1	0	0	1	1	1	$22,500
3	Hales Draw	1	1	0	0	0	1	1	$12,660
4	Johnson North	0	0	13107	0	1	3	0	$44,214
5	Johnson South	1	1	10548	0	0	3	1	$41,996
6	Kremers A	1	1	3158	0	0	1	1	$20,236
7	Kremers B	0	0	15370	0	1	6	0	$42,760
8	Kremers C	1	1	1965	0	0	1	1	$17,850
9	Kremers D	0	1	13633	0	1	4	0	$45,386
10	Kremers E	0	1	9844	0	0	3	0	$31,408
11	Porter	1	1	0	0	1	1	1	$20,120
12	Robinson East	1	1	0	0	1	1	1	$44,900
13	Robinson West	1	1	0	0	1	1	1	$44,900
14	Robinson South	1	1	0	0	1	1	1	$44,900
15	Stoddard A	1	1	0	0	1	1	1	$44,900
16	Stoddard B	1	1	0	0	1	1	1	$44,900
17	Stoddard C	1	1	0	0	1	1	1	$44,900
18	Swanson	1	1	0	0	0	0	1	$12,460