Chapter 4: Drainage and Routing Assessment

The purpose of this chapter is to describe the results of an assessment of the drainages selected for evaluation in this project. The grant calls for review of three to six sites that may be suitable for passive infiltration. Given the basic project concept, to introduce water into one or more drainages in Lincoln County along which the water can then infiltrate into the ground, the sites have been interpreted to mean streams. This seems to be consistent with language in the grant which appears to use site and drainage interchangeably.

For this prefeasibility assessment we investigated 10 streams (or drainages). Within each, the number of specific locations where water may infiltrate into the underlying aquifer system varies. Some streams appear to have more, and some fewer, losing reaches that have good potential for aquifer recharge. Given the current lack of hydrologic investigations for the vast majority of the potential project area Chapter 4 relies on anecdotal information, limited reconnaissance, GIS assessment, and the few available reports. It is largely qualitative in nature, supplemented with the very limited amount of quantitative information that is either available, or can be generated using GIS tools.

The first part of Chapter 4, Sections 4.1 through 4.3, focuses on a geographic assessment sub-divided into three major sub-regions of the County: (1) upper Crab Creek and its tributaries in eastern Lincoln County, (2) the tributaries draining out of central Lincoln County into Crab Creek, and (3) the Wilson Creek drainage in northwestern Lincoln County. For specific stream drainages we evaluate conditions to the extent we can, given available GIS coverage, information, and reconnaissance, as follows:

1. Physical characteristics, including drainage area size, channel size, headwater conditions, numbers of lakes, surface water flows, and related properties.

2. Land use and conveyance issues, including distance from potential water source(s), the nature of the route to deliver water, and channel conditions as they might pertain to conveying water through the drainage.

3. Habitat and recreational issues especially as they might be influenced by a stream hydration project.

Groundwater and water rights for the three sub-regions are assessed for each sub-region as a whole, and not-stream-by-stream. Later portions of Chapter 4 summarize:

1. General land ownership issues identified for the region in general, and several drainages in particular (Section 4.4).

2. A ranking of the assessed drainages for subsequent evaluation in the feasibility phase of the project (Section 4.5).

3. An initial evaluation of the primary preferred route currently identified in our ranking (Sections 4.6 and 4.7).

4. Section 4 concludes with a preliminary conceptual groundwater flow model that explores the possible fate of groundwater that has the potential to be recharged by a future project.

This is a very preliminary, or prefeasibility, assessment of conditions within these drainages. The observations and interpretations provided here are preliminary and should be confirmed and verified through further study and monitoring. These preliminary results are not suitable for design-level evaluation and no express or implied warranty is provided. Significant additional hydrologic analysis and measurement is recommended at the feasibility level of study.

4.1 Eastern Lincoln County

This portion of Lincoln County is drained by upper Crab Creek and two major tributaries, Bluestem Creek and Rock Creek (Figure 32). Surface conditions in these drainages are explored individually. Basic groundwater conditions are explored in a single assessment for the eastern Lincoln County area. Most of this assessment is based largely on anecdotal information, interview with area residents, and field reconnaissance in 2010. The hydrogeologic review is based on materials prepared by the Columbia Basin GWMA.

4.1.1 Upper Crab Creek

Physical Characteristics: Crab Creek is the trunk stream into which almost all surface drainages in Lincoln County flow. For this study upper Crab Creek is defined as that portion of the stream that flows generally north-south from the area near Reardan, Washington to the area west of Sprague, Washington (Figure 33). The area west of Sprague where Crab Creek turns west is sometimes referred to as Horseshoe Bend. Upper Crab Creek rises near Highway 2, west of Reardan.

The Crab Creek channel generally is well-defined where it crosses Highway 2. For several miles downstream of Highway 2 the stream generally occupies a broad, relatively flat valley floor where it commonly is restricted to an artificial channel. In some reaches of this broad valley floor the actual channel may be actively farmed because surface water is rarely present, and as a result the channel is obscured. Near the mouth of Bluestem Creek the Crab Creek channel becomes more confined, being restricted to a narrower, rock walled canyon. Below the mouth of Bluestem Creek, the stream channel is more commonly rock-floored and surface flows are more commonly observed than upstream.

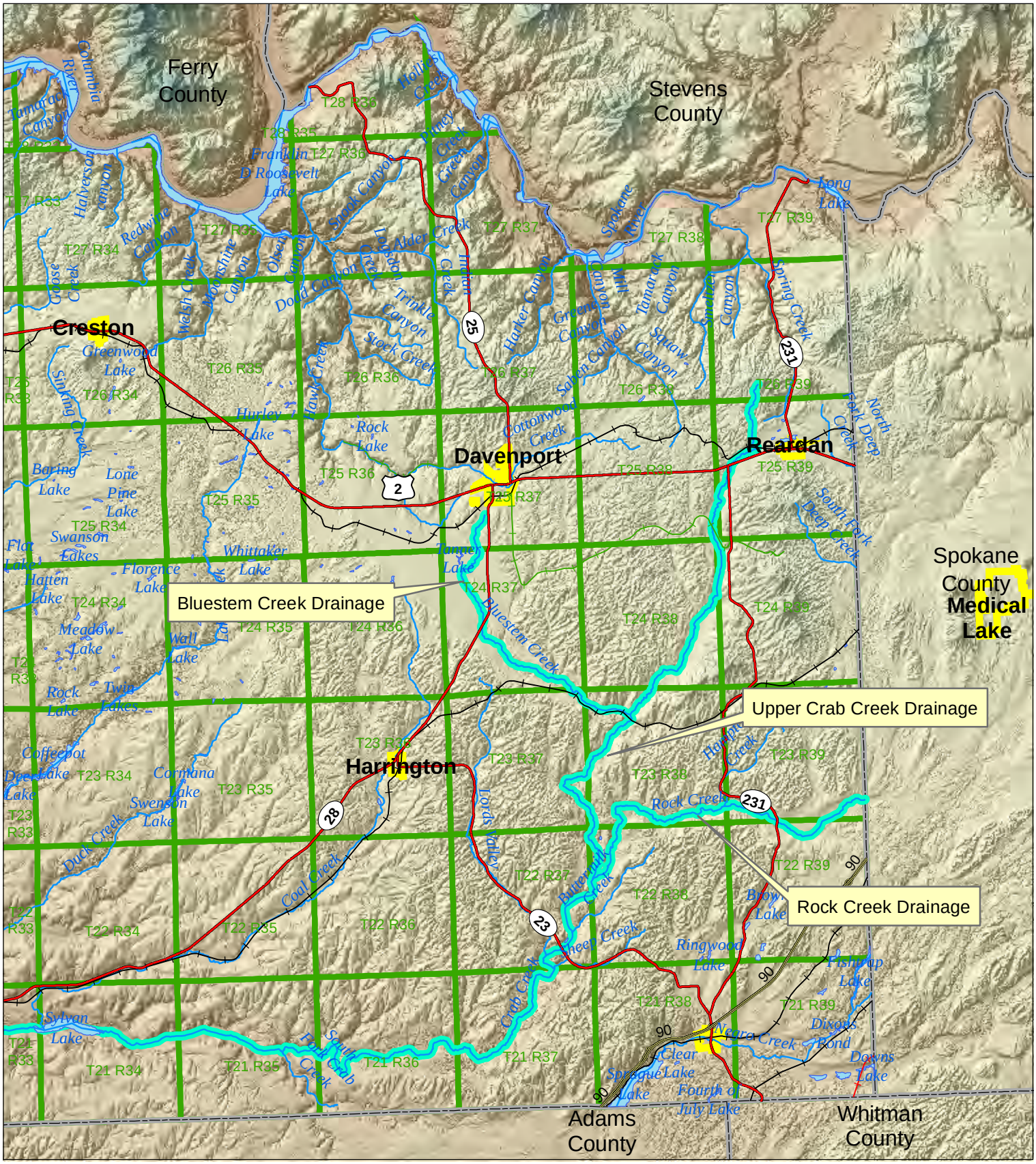

Figure 32
Map showing the locations of the Upper Crab, Bluestem, & Rock Creek drainages in eastern Lincoln County

Legend

- US
- State
- Active RR
- Abandoned RR
- Rails to Trails
- Rivers & Streams
- Water Bodies
- County Boundary
- Incorporated Area
- Township

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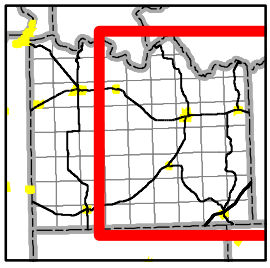

This is not a survey. Actual relationships and distances between features may be different from those depicted on this map. Accurate measurements are required in order to verify these relationships and distances.

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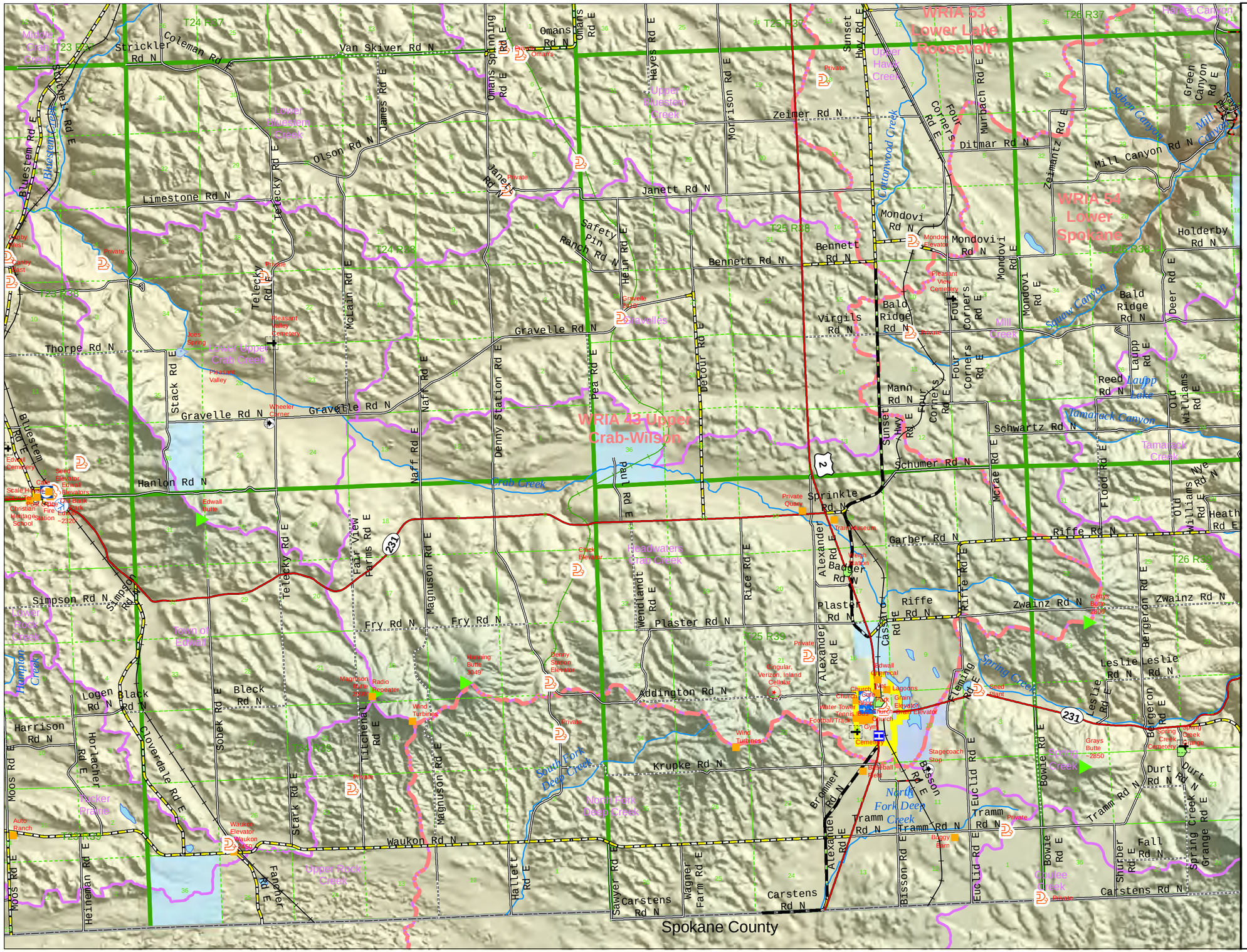
Figure 33
Geographic setting of upper Crab Creek



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Lincoln County, WA

The creek, when and where it is flowing, usually occupies a channel approximately 5 to 20 feet across and less than 5 feet deep. Locally this channel may be incised into a much deeper ravine 10 or more feet deep. Anecdotal evidence suggests there are reaches of the stream where it only flows seasonally, during the winter and spring, when surface runoff is abundant, and/or following extremely rare large storms. These intermittent flow reaches tend to be those where the coulee is floored by alluvial gravel and sand, and the stream likely is feeding a shallow groundwater system in the alluvial sediment. The fate of this groundwater is not known; some may be recharging underlying CRB aquifers, and some may be flowing through a localized alluvial aquifer before emerging further downstream on Crab Creek, providing base flow.

Land Use and Conveyance: Land uses along the reaches of upper Crab Creek above the mouth of Bluestem Creek largely are devoted to a mix of small irrigated fields, dryland farming, and grazing. From the area near the mouth of Bluestem Creek to near where Highway 23 crosses Crab Creek land uses near the creek generally are devoted to grazing, and habitat conservation. Down-stream of Highway 23 land uses return predominantly to a mix of irrigated farming, dryland farming, and grazing. Over 95% of the upper Crab Creek is privately owned, with the remaining owned by the Department of Natural Resources (DNR).

A potential rehydration system delivery location is northwest of Reardan, at the head of Squaw Creek. This is 30 miles from a possible intake at the confluence of Hawk Creek and Lake Roosevelt, although it is much closer to the upper end of the Spokane Arm of Lake Roosevelt at Porcupine Creek or Squaw Creek in Mill Canyon (less than 15 miles). Such a route up Mill Canyon would likely follow county road rights-of-way to potential discharge area near Highway 2 to 3 miles west of Reardan. This route could be shortened if permission to cross private lands was secured. From its headwaters near Reardan to the Horseshoe Bend area approximately 12 road crossings are present, including those of Highway 23 and Highway 2. If water is delivered to Crab Creek as part of a future project, some of these stream crossings, especially those associated with graveled county roads may require improvements.

The dominance of private land holdings when coupled with presence of farmed fields and artificially channelized reaches intermittently along upper Crab Creek will need to be considered if water is delivered to the stream as part of a future project. With this, landowner acceptance of a stream flow augmentation project will be important on this stream.

Habitat and Recreation: Almost all of the upper Crab Creek area is privately owned. Therefore, public recreational opportunities likely will be limited, and require the cooperation of private landowners. There is a potential for habitat improvement projects on upper Crab Creek, but again, given the dominance of private land holdings, such projects would require the active participation of individual landowners.

4.1.2 Bluestem Creek

Physical Characteristics: Bluestem Creek (Figure 34) rises just south of the City of Davenport, and flows southeast into Crab Creek west of Edwall. It has a drainage area of approximately 70 square miles, and the stream is approximately 15 miles long. The upper portion of the stream, from its headwaters to several miles below the Highway 28 crossing, generally occupies a broad, generally flat valley. The channel generally is less than a few feet across and a few feet deep. Below the Highway 28 crossing, the valley generally narrows and steepens, being incised into a basalt scabland coulee. There are several very small lakes along its length, generally no more than a few acres in size. Anecdotal observations suggest water generally flows in the stream most of the year.

Land Use and Conveyance: Along most of its length land uses are devoted primarily to grazing. In addition to the Highway 28 crossing, there are five additional stream crossings on the creek, generally associated with graveled county roads. Improvements may be necessary on one or more of these if a recharge project delivers additional quantities of water to the stream. The headwaters of Bluestem Creek are approximately 20 miles from a likely water intake location on Lake Roosevelt near the mouth of Hawk Creek. One hundred percent of the Bluestem Creek stream channel is privately owned.

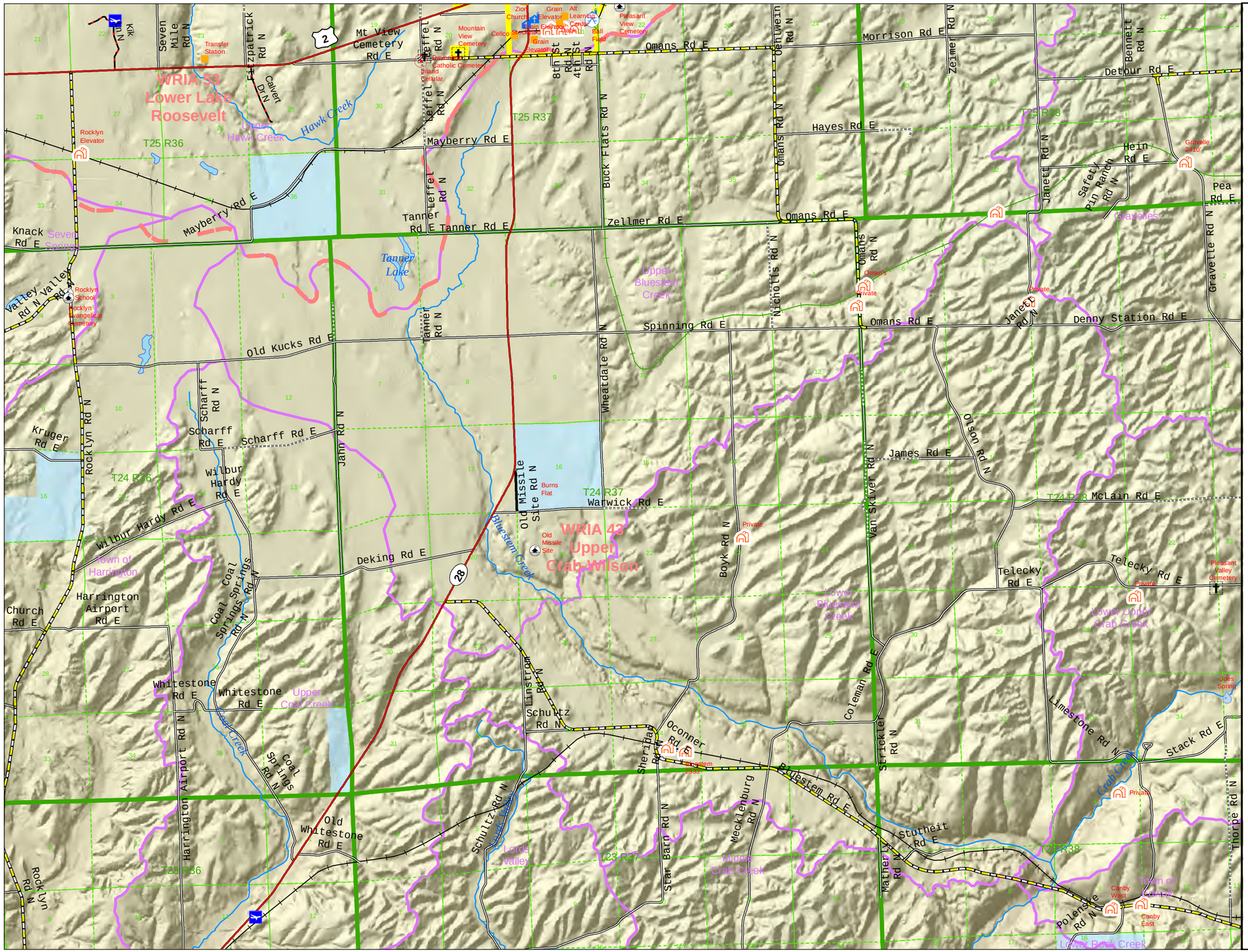
To deliver water to Bluestem Creek for a potential project a delivery route could follow county road rights-of-way up the Hawk Creek Valley, before crossing Highway 2 just west of Davenport. Once across the highway the route probably would be across private ground to a potential discharge location, also likely on private ground.

Habitat and Recreation: Because all of the Bluestem Creek area is privately owned, public recreational opportunities likely will be limited, and require the cooperation of private landowners. There is potential for habitat improvement projects on Bluestem Creek, but again, given the dominance of private land holdings, such projects would require the active participation of individual landowners.

4.1.3 Rock Creek

Rock Creek (Figure 35) is located on the eastern side of the study area and rises in Tucker and Malloy Prairies, just southwest of the City of Medical Lake in Spokane County. Clear Lake and West Medical Lake are two of the larger water bodies in the region. Rock Creek drains an area of 115 square miles and flows for 25 miles in a southwestern direction before entering Crab Creek south of Edwall. Any likely delivery location on the Rock Creek in Lincoln County is over 40 miles from the confluence of Hawk Creek and Lake Roosevelt. Given this distance Rock Creek is not assessed further for this prefeasibility study.

Figure 34
Geographic setting of Bluestem Creek



Legend

- Camping
- Boat Launch
- Camping/Boat Launch
- Fishing
- Park
- Trailhead
- Misc.
- Airport
- Bank
- Cafe
- Cell Tower
- Cemetery
- Church
- Fire Station
- Golf Course
- Grain Elevator
- Hospital
- Motel
- Public Building
- Spring
- Summit
- Waterfall
- History
- US
- State
- Co. Asphalt
- Co. Concrete
- Co. BST
- Co. MagChloride
- Co. Gravel
- Co. Dirt
- Private Road
- Active RR
- Abandoned RR
- Rails to Trails
- Rivers & Streams
- LCWater Bodies
- County Boundary
- Incorporated Area
- Township
- Section
- Watershed
- Sub-Watershed
- Odessa Sub-Area
- Dept of Natural Resources
- Dept of Fish and Wildlife
- Bureau of Land Mgmt
- National Park Service

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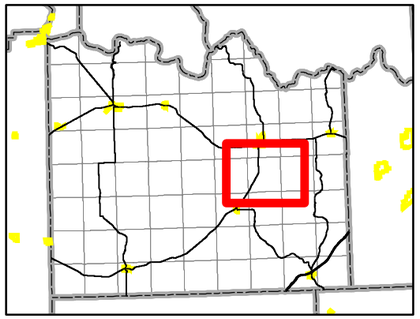

This is not a survey. Actual relationships and distances between features may be different from those depicted on this map. Accurate measurements are required in order to verify these relationships and distances.

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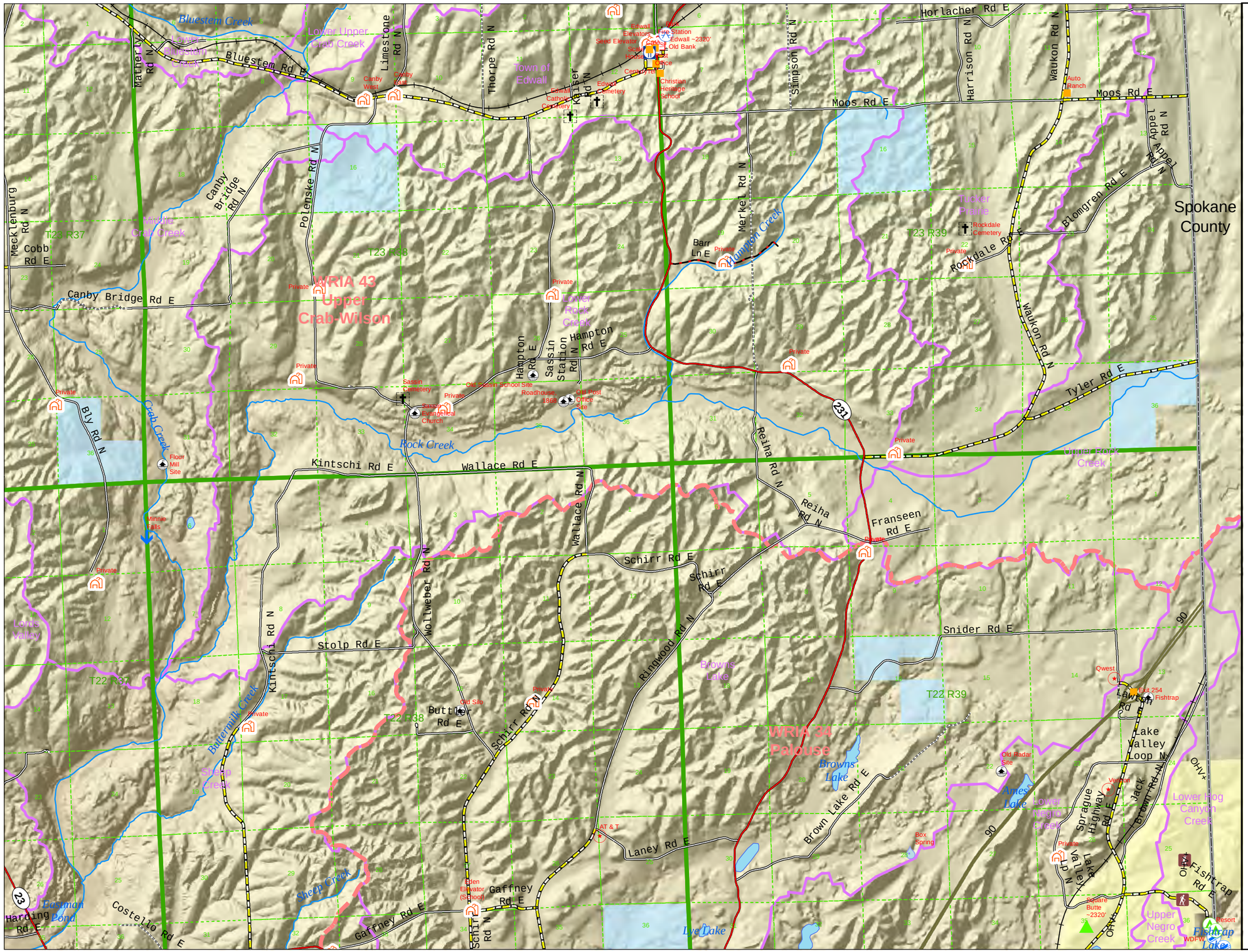
Lincoln County, WA

Figure 35
Geographic setting of Rock Creek



Legend

- Camping
- Boat Launch
- Camping/Boat Launch
- Fishing
- Park
- Trailhead
- Misc.
- Airport
- Bank
- Cafe
- Cell Tower
- Cemetery
- Church
- Fire Station
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- Co. MagChloride
- Co. Gravel
- Co. Dirt
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- County Boundary
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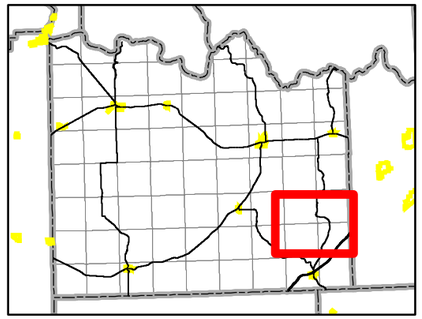

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Lincoln County, WA

4.1.4 Eastern Lincoln County Hydrogeology

The Priest Rapids Member and Roza Member are both present at, or near the top, of basalt in the eastern Lincoln County area. Both are deeply incised and cross-cut by coulees, and both generally dip downwards to the south-southeast (Figures 15 and 16). Given the lack of down dip continuity in these units, water present in interflow zones in up dip areas will discharge into canyons that incise through them in down dip areas.

The only Frenchman Springs Member unit with any significant presence in the eastern Lincoln County area is the Sentinel Gap where it is found in the lower reaches of the eastern Lincoln County drainages (Figure 19). In this area, groundwater in Sentinel Gap interflow zones likely will move down dip, predominantly to the southwest. In reaches where Crab Creek is incised into the unit, groundwater could discharge into the creek. Conversely, in areas were the unit extends uninterrupted beneath Crab Creek, groundwater in it could be moving beneath the creek and southwest into northern Adams County.

The uppermost Grande Ronde unit in the eastern Lincoln County area, the Sentinel Bluffs Member, underlies essentially the entire area. Mapped distributions show it present within 200 feet of the bedrock bottoms of large reaches of upper Crab Creek system near and north of Highway 23 (Figure 22). If recharged in the upper Crab Creek area, strike and dip of the unit suggests the predominant interflow zone orientation, and groundwater movement within such zones will be to the south-southwest. In these directions Sentinel Bluffs Member interflow zones are not incised into by Crab Creek or its tributaries. The absence of incision would allow groundwater moving down dip in these interflow zones to likely move into adjacent areas of northern Adams County.

Of the other Grande Ronde units present beneath eastern Lincoln County, the Wapshilla Ridge Member is only found within a few hundred feet of the top of basalt on the northern highlands bordering the northernmost edge of the CRBG. The other three members mapped in the area, the Umtanum Member, Ortley Member, and Grouse Creek Member, all pinch out beneath the southeastern part of the county. These units thicken down dip to the south-southwest. Given the depth of the Grande Ronde units underlying the Sentinel Bluffs Member, it seems likely that recharge pathways into them would be torturous and slow. For water moving into these deeper units, these recharge pathways would likely include (1) some cross-strata movement of groundwater into interflow zones in up dip areas where dense flow interiors are thin, or truncated; (2) down dip movement of water into multiple interflow zones as unit pinch-outs are encountered where the number of units increase. Water in these deeper Grande Ronde units likely would move generally to the south-southwest, down dip.

Groundwater is reported on water well reports for some wells that penetrate to the top of pre-basalt basement in eastern Lincoln County and adjacent portions of Spokane County. At this time our working hypothesis is that this groundwater is found in paleodrainages incised

into the pre-basalt rock prior to the emplacement of the CRBG. The source of recharge for this portion of the aquifer system is not generally known, but it might range from (1) water moving cross-strata through the basalt where it is thin to (2) water getting underneath the basalt where it pinches out completely against pre-basalt outcrops. However, given that the top of pre-basalt rock generally lies hundreds, if not several thousand feet beneath Crab Creek and its tributaries in the eastern Lincoln County area, we generally are not concerned with it for the purposes of this prefeasibility assessment.

It is possible that feeder dikes for the Priest Rapids Member cross-cut the eastern Lincoln County area south of Reardan. Roza Member dikes may be present beneath the area where Crab Creek turns west. If present, regional mapping would suggest they have a general northwest-southwest trending orientation. At this time we do not have any direct evidence for the presence of these features in this area. However, if they are present, they would be generally oriented perpendicular to likely preferred south-southwest oriented down dip flow paths in the CRBG. If this is the case these dikes may disrupt the general flow path of CRBG groundwater in the units they cross cut. Such disruptions, if found to be present, could include slowing of groundwater flow velocity, deflection of movement paths, and possibly even blockage of groundwater movement on at least a local scale. At this time we do not know if these dikes significantly impact the groundwater flow system beneath eastern Lincoln County.

4.2 Central Lincoln County

Central Lincoln County is occupied by a series of more-or-less parallel northeast to southwest flowing stream drainages that empty into Crab Creek near and west of Odessa. The headwaters of these drainages lie near and south of Highway 2. Fairly chaotic topography with poorly developed stream channels is common in the upper reaches of many of these streams. These streams are, from east to west, Coal Creek, Duck Creek, Lake Creek, Marlin Hollow, and Canniwai Creek (Figure 36). The assessment of these streams is based largely on anecdotal information, interviews with area residents, and field reconnaissance in 2010.

4.2.1 Coal Creek

Physical Characteristics: Coal Creek (Figure 37) rises in an area of uneroded loess hills and chaotic scabland topography southwest of the headwaters of Bluestem Creek and north of Harrington. The 35 mile long channel flows into Crab Creek approximately five miles east of Odessa, at Sylvan Lake. Naturally occurring lakes typically are not shown or seen on aerial photographs or maps of the Coal Creek drainage. The drainage area is approximately 105 square miles.

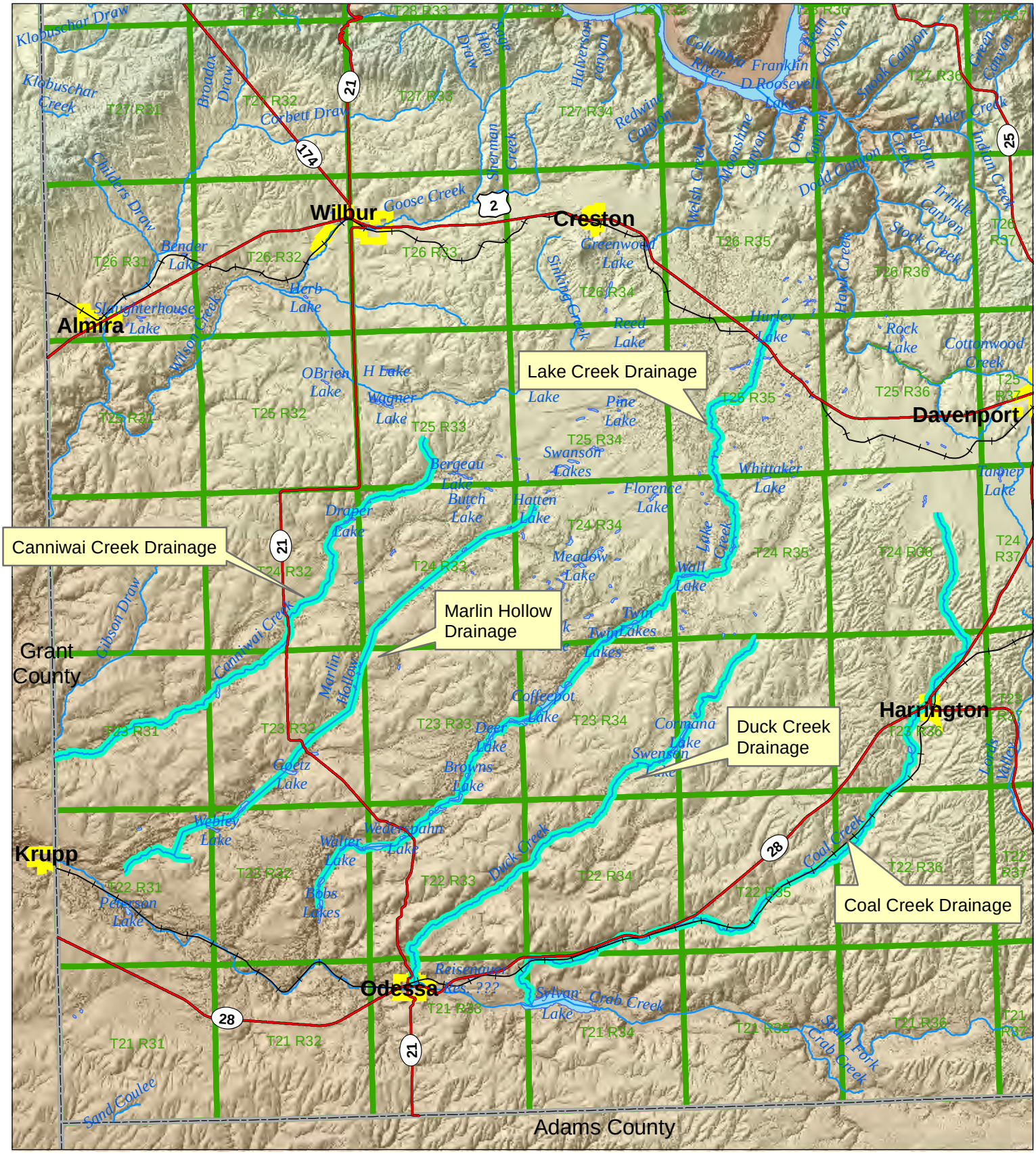

Figure 36
Map showing the locations of the Coal, Duck, Lake, Marlin Hollow, & Canniwai Creek drainages in central Lincoln County.

Legend

- US
- State
- Active RR
- Abandoned RR
- Rails to Trails
- Rivers & Streams
- Water Bodies
- County Boundary
- Incorporated Area
- Township

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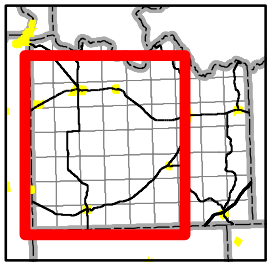

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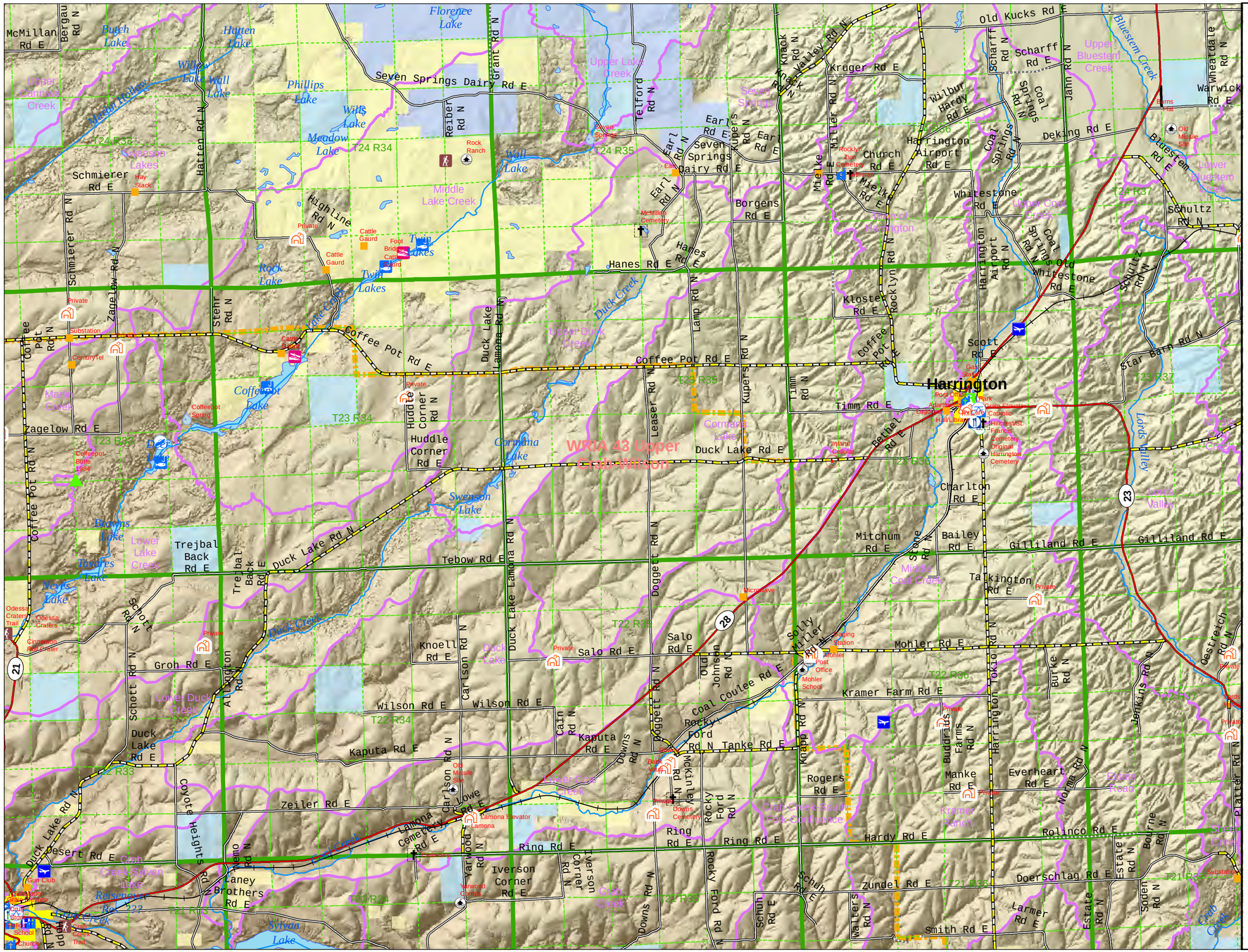
Figure 37
Geographic setting of Coal Creek



Legend

- Camping
- Boat Launch
- Camping/Boat Launch
- Fishing
- Park
- Trailhead
- Misc.
- Airport
- Bank
- Cafe
- Cell Tower
- Cemetery
- Church
- Fire Station
- Golf Course
- Grain Elevator
- Hospital
- Motel
- Public Building
- Spring
- Summit
- Waterfall
- History

- US
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- Co. Asphalt
- Co. Concrete
- Co. BST
- Co. MagChloride
- Co. Gravel
- Co. Dirt
- Active RR
- Abandoned RR
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- Incorporated Area
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- Watershed
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- Odessa Sub-Area
- Dept of Natural Resources
- Dept of Fish and Wildlife
- Bureau of Land Mgmt
- National Park Service

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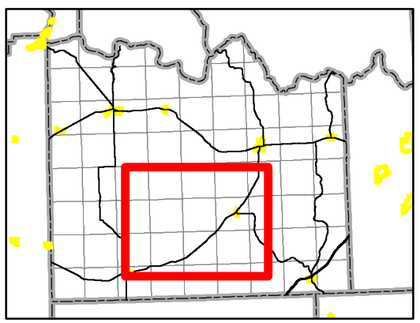

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Lincoln County, WA

In its uppermost reaches the stream channel may be difficult to ascertain when water is not present. Within a few miles below its headwaters though Coal Creek takes on a recognizable channel as it flows down a fairly wide, gently sloped valley to and beyond Harrington. Where it flows through Harrington it occupies a channelized course that is several tens of feet wide and approximately 10 feet deep. Below Harrington, Coal Creek flows down a valley that is narrower than above, but not generally as deeply incised or bedrock floored like many of the streams in the Crab Creek system. While basalt bluffs are present along portions of the creek, the stark scablands common to so many of the drainages in the area are not as strikingly developed. Throughout much of this reach of the stream, the creek is channelized.

The stream does not appear to have a significant history of depleted flow or losses, although it is generally small. During field reconnaissance, crude visual flow estimates in it suggest flows of less than 1 cubic feet per second (cfs) to no more than 2 or 3 cfs are normal in the winter and spring. These could be higher though in the event of a rapid snow melt or rainstorm event. Flows are difficult to ascertain, or even observe, in the summer when the channel is overgrown with grasses and shrubs.

Land Use and Conveyance: Above Harrington land use along the creek is dominated by grazing. This continues below the town as well. The lower reach of the stream includes some cropping in its last few miles. There appear to be 10 stream crossings along the creek from its headwaters above Harrington to its mouth at Sylvan Lake on Crab Creek. Many of these, especially at and below Harrington are relatively large and may not require significant improvement. Unlike other streams assessed in this study, Coal Creek does flow through a town. Approximately 85% of the Coal Creek channel is on private property; the remainder is on land owned by the Bureau of Land Management (BLM).

A potential rehydration project delivery area is approximately 3 miles south of Highway 2, on this streams headwaters near Old Kuchs Road E. This area is on private property approximately 27 miles from Lake Roosevelt, and direct access to it likely would be over a combination of public road rights-of-way and crossing of privately owned land. Much of this delivery route would be up the Hawk Creek valley before crossing Highway 2 and going south to a discharge location. Given that this stream flows through a town, enhanced flow through Harrington may present challenges. If stream flow is augmented as part of a rehydration project, project managers will need to evaluate operations to prevent flooding in the town as a result of increased flows associated with rain events, snow melt events, or ice damming events.

Habitat and Recreation: Because most of this stream flows across privately owned land devoted to grazing, other farming, and residential/town development, we suspect habitat and recreational opportunities along it will be limited. At this time, and at this level of

assessment, we therefore do not see significant opportunity for habitat or recreational benefit.

4.2.2 Duck Creek

Physical Characteristics: Duck Creek (Figure 38) is bounded by Lake Creek to the west and Coal Creek to the east. Its headwaters lay in an area of shallowly eroded scabland and surrounding loess hills, approximately 6 to 8 miles west-northwest of Harrington in the northern portion of T23N R35E. The creek drains approximately 115 square miles and is approximately 21 miles long. Duck Creek joins Crab Creek in the town of Odessa.

The upper drainage is a fairly broad, flat valley which contains several lakes, with Cormana Lake and Swenson Lake being the largest. The drainage is poorly developed above Cormona Lake, being a broad rather chaotic scabland topography, especially north of Hanes Road. Downstream from Swenson Lake to the Duck Lake Road crossing the stream generally has a well developed channel and commonly occupies a small, bedrock canyon or coulee. Land uses in this reach focus primarily on stock grazing. From near the Duck Lake Road crossing to the stream's confluence with Crab Creek, the valley floor is relatively flat and the stream flows through a number of channelized reaches where irrigated farming is common on the valley floor.

Our limited reconnaissance suggests water is only intermittently present in the upper portion of the drainage and that Cormona and Swenson Lakes do not commonly contain water. Below these lakes though the creek may see flows of a few cfs or less through much of the year in the scabland topography that dominates it above the Duck Lake Road crossing in T22N R34E. Downstream of this crossing surface flows generally are absent in the summer and the creek rarely experiences surface flows in its lower reaches near Odessa. Landowners we talked to during our limited reconnaissance and prefeasibility assessment work indicate the creek as seen diminished surface flows over the past few decades.

Land Use and Conveyance: Except for some BLM ground adjacent to the uppermost reach of the stream, the bulk of the land along this creek is privately owned. Along much of its length above the Duck Lake Road crossing the land along the creek is undeveloped or used for grazing. Below that crossing some irrigated farming is done. All the Duck Creek stream channel is on privately owned ground.

If a rehydration project were to deliver water to the upper reach of this stream, that delivery area would be in area between Hanes Road and Coffee Pot Road, in T23N R35E. However, this general area is approximately 38 miles from Lake Roosevelt near the town of Lincoln. A delivery route to this area would need to follow multiple rights-of-way and cross many areas of privately owned land.

Habitat and Recreation: A recharge project delivering water to Duck Creek could result in filling of Cormona and Swenson Lakes, and more flow through the scablands downstream of these lakes. This could have habitat and recreational benefits for water fowl and possibly even fisheries. However, given that this drainage lies almost entirely on privately owned land these landowners will need to agree that such outcomes are acceptable to them as owners and users of that land.

4.2.3 Lake Creek

In addition to reconnaissance done for this project, LCCD assessed basic steam flow and related conditions in this drainage in 1998 and 1999 (LCCD, 2000). That report supplements the anecdotal information, area resident interviews, and field reconnaissance done for this project in the Lake Creek drainage.

Physical Characteristics: The Lake Creek drainage area (Figure 39) covers approximately 175 square miles and numerous lakes are located along the creek. Lake Creek is about 40 miles in length and enters Crab Creek about four miles west of Odessa. The headwaters of Lake Creek lie on either side of Highway 2 between Creston and Davenport, 1 to 2 miles east of Telford Road. Most maps show that the headwaters of Lake Creek lie at a feature known as Hurley Lake, located approximately 1 mile north of Highway 2. In recent years Hurley Lake has been dry, or at best, a wetland.

The upper reaches of Lake Creek, north of Seven Springs Dairy Road, is a rocky scabland within which a poorly to moderately developed drainage exists. In this upper reach, the channel also is broken up in to a series of artificial ponds built to enhance wetlands and related habitat. South of Seven Springs Dairy Road, to the area below Delzer Falls, the stream, when it is flowing, occupies a fairly well developed channel flowing down the bottom of a well defined scabland coulee incised into bedrock. Through this reach Lake Creek connects the numerous lakes that give this drainage its name. From upstream to its confluence with Crab Creek these lakes include Wall, Upper Twin, Lower Twin, Coffee Pot, Deer, Browns, Tavares, Neves, Pacific, and Bobs. In addition, when water is present numerous un-named lakes, wetlands, and ponds are present along the full length of Lake Creek.

In 2010, and for much of the previous 20 years or more, the lower three Lake Creek lakes (Bobs, Pacific, and Neves) were dry. The next two major lakes above Neves Lake have been decreasing in volume in recent years, and in 2010 were almost completely dry (Figure 40). Local residents report that Deer Lake in 2010 was likely at about two-thirds of its normal volume, with lake levels being approximately 15 to 20 feet below historical normal levels seen 20 or more years ago. Coffee Pot Lake was observed to be within a few feet of normal levels during our 2010 reconnaissance and both Twin Lakes were observed to be at or above such levels. During 2010 reconnaissance Lake Creek was observed to be flowing through much of its length in the area above Seven Springs Dairy Road into Coffee Pot Lake. When

we observed them these flows were visually estimated to range from less than 1 cfs to approximately 3 or 4 cfs. Below Coffee Pot Lake the creek was not observed to be flowing in 2010, with all locations visited being dry.

Land Use and Conveyance: Land uses along most of Lake Creek are devoted to habitat conservation and grazing. Much of the habitat conservation ground is located in the upper drainage above Twin Lakes where significant reaches of the stream valley are owned by the Washington Department of Fish and Wildlife (WDFW) and the U.S. Bureau of Land Management (BLM). Both agencies have built structures in these reaches to restore pond, stream, wetland, and riparian habitat. Between Wall Lake and Seven Springs Diary Road and downstream of Coffee Pot Lake land ownership in along Lake Creek is predominantly private and grazing is the primary land use. The only significant areas devoted to cropping on the creek occur locally in the upper reaches, where stock growers raise hay, and in the lower part of the drainage below Delzer Falls, where the bottomlands along the creek are partially cropped and the stream is channelized for flood control. In addition to Highway 2, the stream is crossed by seven roads of various sizes and several flow control structures have recently been built on the BLM ground. Depending on the size of a pilot test, and later full size operations, some of these structures may require reconstruction. Private and public land ownership on the stream channel, from the headwaters to the mouth, is approximately 44.5% and 55.5, respectively. Approximately three-quarters of the public ownership is held by the BLM.

A likely delivery location for Lake Creek is in the upper basin at Hurley Lake, or just south of nearby Highway 2. These locations lie 12 to 15 miles south of Lake Roosevelt near the town of Lincoln. To reach these locations a delivery route would likely be up Welch Creek Canyon following the county road right-of-way to the Miles-Creston Road. From there, a delivery route might be on county road rights-of-way, across private land, and across public lands to reach Hurley Lake and or a location on the creek south of Highway 2. Given that most of the lands on the upper portion of the creek are public lands, it seems likely that a discharge point into Lake Creek would be on these lands.

Habitat and Recreation: Habitat and recreation potential in the Lake Creek drainage would be high if a rehydration project were implemented in it. The basic reasons for this are three-fold, as follows. First, recently completed habitat projects have resulted in increased water storage and flow on the upper creek. Delivering more water to the creek could expand the benefits already seen from these projects. Second, successful delivery of water to the lower drainage will likely see restoration of currently dry lakes and the creek connecting them. Third, because much of the stream flows across public lands, a flow enhanced stream and associated lakes could be more accessible than those on private property.

Figure 38
Geographic setting of Duck Creek

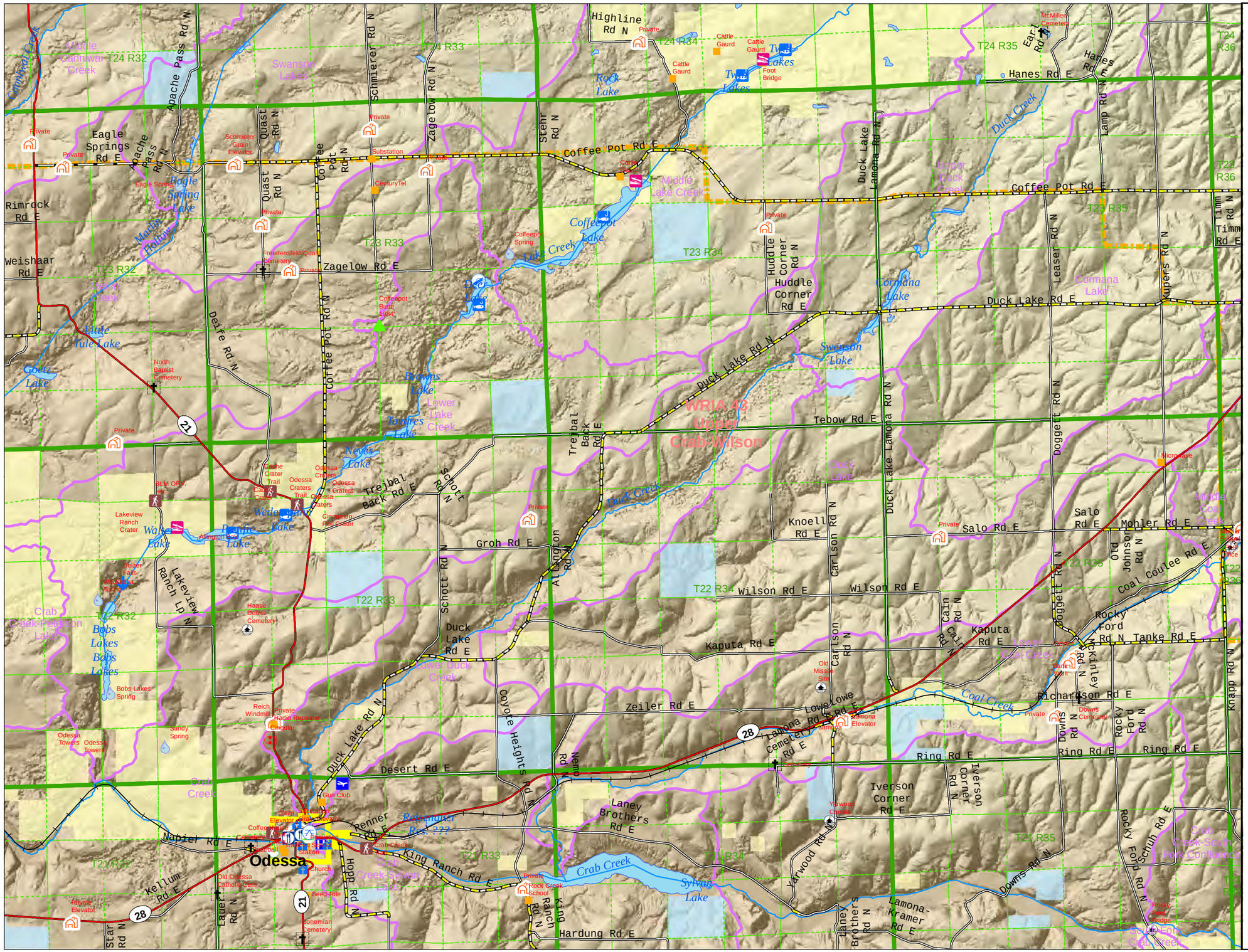
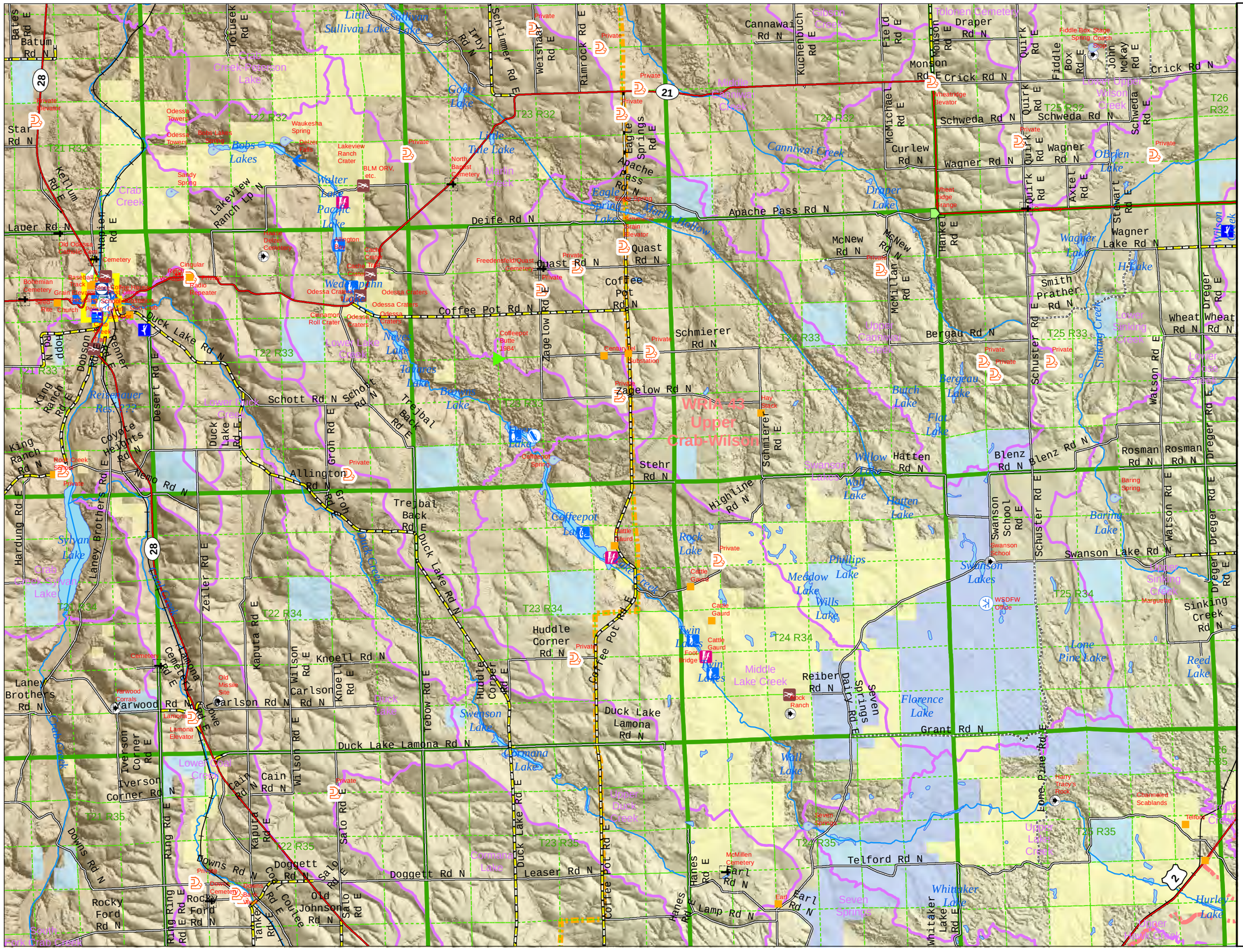

Highline Rd N
Hanes Rd E
Coffee Pot Rd E
Duck Lake Rd E
Duck Lake Rd N
Tebow Rd E
Zagelow Rd E
Zeiler Rd E
Salo Rd E
Mohler Rd E
Wilson Rd E
Kaputa Rd E
Coal Coulee Rd E
Rocky Ford Rd N
Tanke Rd E
Richardson Rd E
Ring Rd E
Desert Rd E
Napier Rd E
Kellum Rd E
King Ranch Rd E
Hardung Rd E
Groh Rd E
Trejbal Back Rd E
Eagle Springs Rd E
Rimrock Rd E
Weishaar Rd E
Apache Pass Rd N
Quast Rd N
Schmierer Rd N
Zagelow Rd N
Stehr Rd N
Huddle Corner Rd N
Leaser Rd N
Kuipers Rd N
Doggett Rd N
Knoell Rd E
Carlson Rd N
Cain Rd N
Old Johnson Rd N
Lakeview Ranch Ln N
Schott Rd N
Allington Rd N
Coyote Heights Rd N
Nemo Rd N
Renner Rd E
Hopp Rd N
Lauer Rd N
Star Rd N
Yarwood Rd N
Laney Brothers Rd E
Lamona-Kramer Rd E
Iverson Corner Rd E
Downs Rd N
Schuh Rd E
Knapp Rd N
Duck Creek
Coal Creek
Crab Creek
Odessa
WRIA 43 Upper Crab-Wilson
Swanson Lakes
Rock Lake
Twin Lakes
Coffeepot Lake
Middle Lake Creek
Cornana Lake
Swanson Lake
Duck Lake
Browns Lake
Lower Lake Creek
Neves Lake
Weide Sand Lake
Pacific Lake
Walker Lake
Bobs Lakes
Sylvan Lake
Eagle Spring Lake
Little Tule Lake
Goetz Lake
Upper Duck Creek
Middle Coal Creek
Lower Coal Creek
Crab Creek-South Fork Confluence
Crab Creek-Wilson Lake
Crab Creek-Fred Son Lake
Cattle Gaurd
Foot Bridge
Substation
CenturyTel
Schmierer Grain Elevator
Freedensfeld/Quast Cemetery
Coffeepot Spring
Coffeepot Butte 1984
North Baptist Cemetery
McMillen Cemetery
Haass Delzer Cemetery
Old Missouri Site
Lamona Elevator
Lamona Cemetery
Downs Cemetery
Yarwood Cemetery
Rock Creek School
Old Odessa Catholic Cem
Bohemian Cemetery
Gun Club
Seed-Rite
Radio Repeater
Reich Windmill
Sandy Spring
Bobs Lakes Spring
Lakeview Ranch Crater
Odessa Craters Trail
Odessa Craters
Cache Crater Trail
Microwave
Private
Substation
Church
Elevator
Hospital
Cemetery
Bridge
Rock Creek Bridge
Rock Creek Ford
Odessa Towers
Delzer Falls
Crab Creek
Sylvan Lake
Coffee Pot Rd N
Pot Rd N
Deife Rd N
Trejbal Back Rd E
Tebow Rd E
Duck Lake Rd N
Duck Lake Rd E
Lamona Rd E
Lowe Lowe Rd E
Salo Rd E
Wilson Rd E
Kaputa Rd E
Zeiler Rd E
Ring Rd E
Desert Rd E
Napier

Figure 39
Geographic setting of Lake Creek


Lake Creek
Upper Crab-Wilson
WRIA 43
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Duck Lake Lamona Rd N
Swanson Lake Rd N
Schweda Rd N
Wagner Rd N
Apache Pass Rd N
Deife Rd N
Lauer Rd N
Quick Lake Rd N
Schott Rd N
Zagelow Rd N
Schmierer Rd N
Stehr Rd N
Highline Rd N
Crick Rd N
Monson Rd N
Draper Rd N
Cannawai Rd N
Curlew Rd N
McNew Rd N
Bergau Rd N
Blenz Rd N
Hatten Rd N
Rosman Rd N
Grant Rd N
Telford Rd N
Leaser Rd N
Doggett Rd N
Downs Rd N
Allington Rd N
Nemo Rd N
Star Rd N
Batum Rd N
Kellum Rd E
Lakeview Ranch Lp N
Renner Rd E
Dobson Rd E
Desert Rd E
Duck Lake Rd E
Zeiler Rd E
Laney Brothers Rd N
Yarwood Rd N
Carlson Rd N
Knoell Rd N
Wilson Rd E
Kaputa Rd E
Cain Rd N
Iverson Corner Rd N
Ring Rd E
Rocky Ford Rd N
Old Johnson Rd N
Salo Rd E
Tebow Rd E
Huddle Corner Rd N
Coffee Pot Rd E
Zagelow Rd E
Quast Rd N
Eagle Springs Rd E
Apache Pass Rd E
Raimrock Rd E
Weishaar Rd E
Schlimmer Rd E
Irby Rd N
Totusek Rd E
Kuchenbuch Rd E
Field Rd E
Monson Rd E
Quirk Rd E
Fiddle Box Rd E
John McKay Rd E
McMichael Rd E
Axtel Rd E
Stewart Rd E
Hanke Rd E
McMillan Rd E
Schuster Rd E
Watson Rd E
Dreger Rd E
Swanson School Rd E
Lone Pine Rd E
Daisy Rd E
Seven Springs Rd E
Hanes Rd E
Lamp Rd N
Whitaker Lake Rd E
Sinking Creek Rd N
Wheat Rd N
Smith Prather Rd N
Cannawai Creek
Crab Creek
Sullivan Lake
Goose Lake
Little Title Lake
Bobs Lakes
Walter Lake
Pacific Lake
Wedekindt Lake
Coffee Pot Lake
Coffeepot Lake
Rock Lake
Meadow Lake
Phillips Lake
Wills Lake
Swanson Lakes
Middle Lake Creek
Florence Lake
Wall Lake
Whitaker Lake
Hatten Lake
Flat Lake
Butch Lake
Bergau Lake
Draper Lake
Wagner Lake
O'Brien Lake
Baring Lake
Lone Pine Lake
Reed Lake
Hurley Lake
Sinking Creek
Upper Sinking Creek
Lower Sinking Creek
Upper Lake Creek
Lower Lake Creek
Duck Lake
Lamona Lake
Swanson Lake
Rock Ranch
Channeled Scablands
Harry Travis Rock
Seven Springs
Telford
Earl
McMillen Cemetery
Cemetery
Church
Fire Station
Grain Elevator
Hospital
Public Building
Private
Cattle Gaurd
Footbridge
Hay Stack
Wheatridge Elevator
Fiddle Box Stage Spring Coach Stop
Lamona Elevator
Harwood Corrals
Old Missile Site
Lamona
Odessa Craters
Odessa Tower
Waukesha Spring
Lakeview Ranch Crater
BLM ORV, etc.
North Baptist Cemetery
Freedenfield/Quast Cemetery
Coffeepot Butte 1984
Cinnamon Roll Crater
Cinnamon Roll Creek
Roll Creek Spring
Coffeepot Spring
Baring Spring
Marguerite
WSDFW Office
Swanson School
Bohemian Cemetery
Baseball Back Stop
Grain Elevator
Fire Church
Radio Repeater
Circular
Cemetery
Dobson Cemetery
Downs Cemetery
Rocky Ford Cemetery
Old Johnson Cemetery
Sandy Spring
Deizer Falls
Lake Creek Falls
Cattle Gaurd
Private
Elevator
Grain Elevator
Hay Stack
Wheatridge Elevator
Wheat Ridge Range
Fiddle Box Stage Spring Coach Stop
Pioneer Cemetery
Eagle Springs
Apache Pass
Middle Lake Creek
Upper Lake Creek
Lower Lake Creek
Upper Sinking Creek
Lower Sinking Creek
Lower Sal Creek
Sylvan Lake
Crab Creek Sylvan Lake
Reinemeyer Res. 1974
Coyote Heights Rd N
King Ranch Rd N
Hardung Rd E
Laney Brothers Rd E
Brothers Rd E
Lamona Rd E
Cemetery Rd E
Tankers Rd E
Ring Rd E Rd E
Rocky Ford Rd E
Salo Rd E
Kaputa Rd E
Iverson Corner Rd E
Downs Rd N
Doggett Rd N
Leaser Rd N
Duck Lake Rd E
Huddle Corner Rd E
Coffee Pot Rd E
Tebow Rd E
Knoell Rd E
Carlson Rd E
Wilson Rd E
Cain Rd E
Salo Rd E
Zeiler Rd E
Groh Rd E
Trejbal Back Rd E
Dobson Rd E
Renner Rd E
Schmierer Rd E
Hanes Rd E
Daisy Rd E
Seven Springs Rd E
Lone Pine Rd E
Whitaker Lake Rd E
Watson Rd E
Dreger Rd E
Schuster Rd E
Swanson School Rd E
Stewart Rd E
Axtel Rd E
Quirk Rd E
Fiddle Box Rd E
John McKay Rd E
Schweda Rd E
Hanke Rd E
McMillan Rd E
McNew Rd N
Curlew Rd N
Monson Rd E
Draper Rd N
Cannawai Rd N
Kuchenbuch Rd E
Field Rd E
Weishaar Rd E
Raimrock Rd E
Schlimmer Rd E
Irby Rd N
Totusek Rd E
Bates Rd E
Batum Rd N
Star Rd N
Kellum Rd E
Lakeview Ranch Lp N
Renner Rd E
Dobson Rd E
Desert Rd E
Duck Lake Rd E
Zeiler Rd E
Laney Brothers Rd N
Yarwood Rd N
Carlson Rd N
Knoell Rd N
Wilson Rd E
Kaputa Rd E
Cain Rd N
Iverson Corner Rd N
Ring Rd E
Rocky Ford Rd N
Old Johnson Rd N
Salo Rd E
Tebow Rd E
Huddle Corner Rd N
Coffee Pot Rd E
Zagelow Rd E
Quast Rd N
Eagle Springs Rd E
Apache Pass Rd E
Raimrock Rd E
Weishaar Rd E
Schlimmer Rd E
Irby Rd N
Totusek Rd E
Kuchenbuch Rd E
Field Rd E
Monson Rd E
Quirk Rd E
Fiddle Box Rd E
John McKay Rd E
McMichael Rd E
Axtel Rd E
Stewart Rd E
Hanke Rd E
McMillan Rd E
Schuster Rd E
Watson Rd E
Dreger Rd E
Swanson School Rd E
Lone Pine Rd E
Daisy Rd E
Seven Springs Rd E
Hanes Rd E
Lamp Rd N
Whitaker Lake Rd E
Sinking Creek Rd N
Wheat Rd N
Smith Prather Rd N
Cannawai Creek
Crab Creek
Sullivan Lake
Goose Lake
Little Title Lake
Bobs Lakes
Walter Lake
Pacific Lake
Wedekindt Lake
Coffee Pot Lake
Coffeepot Lake
Rock Lake
Meadow Lake
Phillips Lake
Wills Lake
Swanson Lakes
Middle Lake Creek
Florence Lake
Wall Lake
Whitaker Lake
Hatten Lake
Flat Lake
Butch Lake
Bergau Lake
Draper Lake
Wagner Lake
O'Brien Lake
Baring Lake
Lone Pine Lake
Reed Lake
Hurley Lake
Sinking Creek
Upper Sinking Creek
Lower Sinking Creek
Upper Lake Creek
Lower Lake Creek
Duck Lake
Lamona Lake
Swanson Lake
Rock Ranch
Channeled Scablands
Harry Travis Rock
Seven Springs
Telford
Earl
McMillen Cemetery
Cemetery
Church
Fire Station
Grain Elevator
Hospital
Public Building
Private
Cattle Gaurd
Footbridge
Hay Stack
Wheatridge Elevator
Wheat Ridge Range

Figure 40. Photograph of the almost completely dry bed of Taveres Lake, lower Lake Creek drainage.

4.2.4 Marlin Hollow

Physical Characteristics: The headwaters of Marlin Hollow (Figure 41) lie in the area between Willow Lake and Swanson Lakes. The drainage area is approximately 130 square miles and the stream is approximately 25 miles in length. Marlin Hollow enters Crab Creek about two miles southeast of Krupp/Marlin, on the western boundary of Lincoln County.

In the upper half of the drainage, essentially above Eagle Springs Lake, there generally is no well defined channel. Rather, in its upper reaches the stream valley is essentially a series of interconnected topographic lows and eroded scablands. In its lower reaches, where the stream channel is better defined, Marlin Hollow includes numerous lakes throughout its lower reaches. From upstream down, these lakes include Eagle Spring Lake, Little Tule Lake, Goetz Lake, Sullivan Lake, Little Sullivan Lake, and Webley Lake. Generally a moderately to well defined channel in a bedrock scabland coulee connects these lakes. In 2009, and again in 2010, most of these lakes were observed to be dry, or significantly below historical high water levels suggested by observable high water lines seen in the lakes (Figure 42). Throughout the investigation, during our reconnaissance of the area, water was not observed in the portions of the Marlin Hollow stream channel we visited.

Land Use and Conveyance: Land uses along the majority of Marlin Hollow are devoted to grazing and almost all of the land in the stream valley is privately owned. Public lands owned and/or administered by WDFW are found in the valley in its upper reaches around Swanson Lakes. Approximately 80% of the stream is privately owned, with the remaining 20% owned predominantly by the DNR, primarily around Swanson Lakes.

A potential rehydration project delivery location might be in upper Marlin Hollow in the vicinity of Swanson Lakes, about 20 miles from Lake Roosevelt. Like Lake Creek a likely delivery route could follow Welch Creek from Lincoln to the Miles Creston Road. At that point two basic routes might be used. One would be to follow a route into upper Lake Creek along existing county road rights-of-way before turning southwest and heading across undeveloped private and public lands to the Swanson Lakes area. The other would be to follow the Miles-Creston Road to the vicinity of Creston before crossing Highway 2 and following other county roads southwards to the vicinity of Swanson Lakes. This later course is longer than the other route, but likely would involve the use of more existing rights-of way.

Habitat and Recreation: A recharge project delivering water to Marlin Hollow could result in filling of a number of lakes, from Swanson Lakes in its headwaters to the series of lakes seen in its lower reaches. In addition, a project likely would result in more flow through the scablands occupied by Marlin Hollow. This could have habitat and recreational benefits for water fowl and possibly even fisheries. However, given that this drainage is predominantly on privately owned land these landowners will need to agree that such outcomes are acceptable to them as owners and users of that land.

4.2.5 Canniwai Creek

Physical Characteristics: Canniwai Creek (Figure 43) has its headwaters in the chaotic terrain south of Creston and Highway 2 and west of the headwaters of Marlin Hollow. Given the chaotic nature of this topography a specific headwaters location is difficult to define, although Bergeau Lakes seems to generally occupy the headwaters area. The stream flows into Crab Creek between the towns of Krupp and Wilson Creek, in Grant County. The drainage area is approximately 135 square miles and its length is 30 miles.

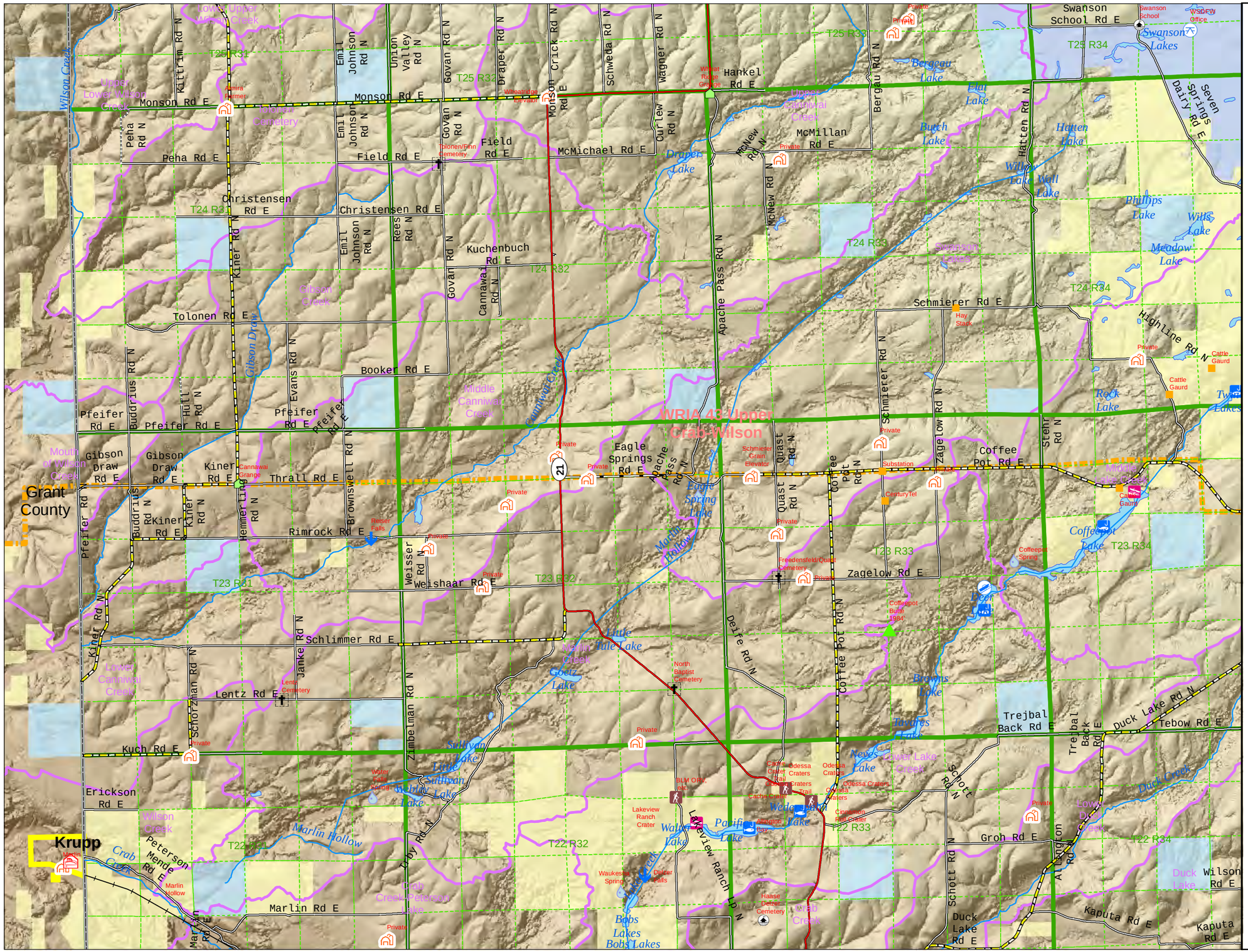
In its headwaters reach, between Bergeau Lake and Draper Lake, the stream occupies a well defined scabland tract, but the actual channel is less well defined. Below Draper Lake the stream channel is usually well defined, although it is fairly narrow (less than 10 feet across and 3 feet deep). From this area downstream to the mouth, the creek follows a well defined scabland coulee. Below Draper Lake, to the western county line, there are no mapped lakes on the creek. Throughout the investigation, during reconnaissance of the area, water was not observed in the portions of the Marlin Hollow stream channel we visited.

Land Use and Conveyance: Land uses in the lower portion of the drainage, below Draper Lake, alternate between areas of cropping and pasturage and those dominated by bedrock scabland and grazing. This drainage generally has more defined cropping activity than the other streams considered. Most of the land, approximately 96%, along the stream is privately owned. There are six or seven road crossings along the creek, most of which appear to be in need of some improvement if water were to be introduced to the drainage. Canniwai Creek has a history of lost stream flow.

A likely rehydration project delivery location is above Flat Lake or Bergeau Lake, just south of where Sinking Creek also rises. This is 26 miles from a likely water intake location on Lake Roosevelt, with much of the conveyance route over open ground, rather than along roadways (a potentially adverse issue). Land ownership issues could be difficult for getting water to the delivery point. The distance from Lake Roosevelt to its headwaters and the lack of a well developed upper drainage channel also present challenges to a future project. It has positive issues related to hydrogeology and water rights, recreation, and habitat.

Habitat and Recreation: A recharge project delivering water to Canniwai Creek would only fill lakes in its upper reaches, above Draper Lake. Below Draper Lake, with no lakes to fill, a recharge project would simply enhance flows in the normally dry modern creek channel. This could have habitat and recreational benefits for water fowl and possibly even fisheries. However, given that this drainage lies almost entirely on privately owned land these landowners will need to agree that such outcomes are acceptable to them as owners and users of that land.

Figure 41
Geographic setting of Marlin Hollow

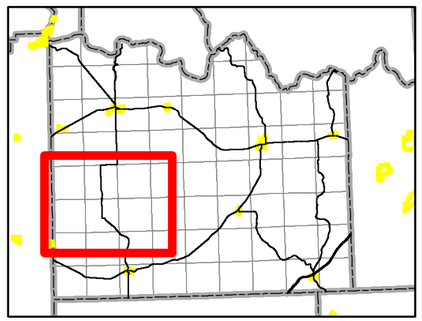


Legend

- Camping
- Boat Launch
- Camping/Boat Launch
- Fishing
- Park
- Trailhead
- Misc.
- Airport
- Bank
- Cafe
- Cell Tower
- Cemetery
- Church
- Fire Station
- Golf Course
- Grain Elevator
- Hospital
- Motel
- Public Building
- Spring
- Summit
- Waterfall
- History

- US
- State
- Co. Asphalt
- Co. Concrete
- Co. BST
- Co. MagChloride
- Co. Gravel
- Co. Dirt
- Active RR
- Abandoned RR
- Rails to Trails
- Rivers & Streams
- LCWater Bodies
- County Boundary
- Incorporated Area
- Township
- Section
- Watershed
- Sub-Watershed
- Odessa Sub-Area
- Dept of Natural Resources
- Dept of Fish and Wildlife
- Bureau of Land Mgmt
- National Park Service

N
W E
S



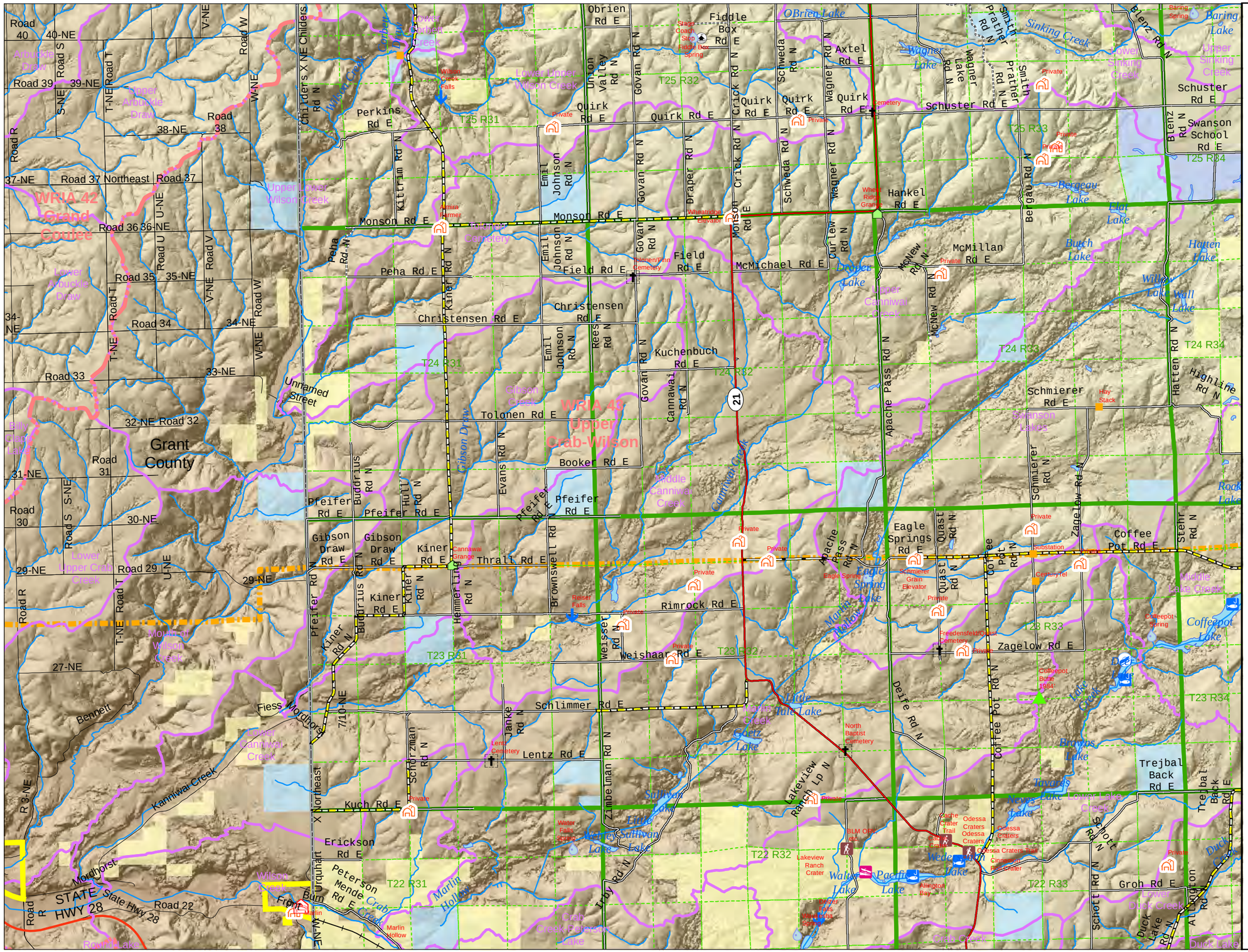
0 2.5 5 10
Miles

This is not a survey. Actual relationships and distances between features may be different from those depicted on this map. Accurate measurements are required in order to verify these relationships and distances.

Lincoln County, WA

Figure 42. Photograph of Lower Sullivan Lake in the lower Marlin Hollow drainage.
This lake is one of several lakes in that drainage showing water level declines in recent years.

Figure 43
Geographic setting of Canniwai Creek


WRIA 42 Grand Coulee
WRIA 45 Upper Crab-Wilson
Grant County
Canniwai Creek
Kanniwai Creek
Apache Pass Rd N
Hankel Rd E
Monson Rd E
Quirk Rd E
Schuster Rd E
Field Rd E
McMichael Rd E
Christensen Rd E
Kuchenbuch Rd E
Tolonen Rd E
Booker Rd E
Pfeifer Rd E
Thrall Rd E
Rimrock Rd E
Weishaar Rd E
Schlimmer Rd E
Lentz Rd E
Kuch Rd E
Erickson Rd E
Peterson Rd E
Schmierer Rd E
Zagelow Rd E
Coffee Pot Rd E
Eagle Springs Rd E
Trejbal Back Rd E
Groh Rd E
Schuster Rd E
Swanson School Rd E
STATE HWY 28
State Hwy 28
Road 22
Road 37 Northeast
Road 32
Road 33
Road 34
Road 35
Road 36
Road 37
Road 38
Road 39
Road 40
Road 30
Road 31
Road 29
Road 27
Road 21
Road 31
Road 30
Road 29
Road 27
Road 21
Road 22
Road 32
Road 33
Road 34
Road 35
Road 36
Road 37
Road 38
Road 39
Road 40

4.2.6 Central Lincoln County Hydrogeology

The Priest Rapids and Roza both are present at, or very close to top of basalt in the upper reaches of the central County drainages (Figures 15 and 16). However, these units are completely eroded through in the middle to lower reaches the central Lincoln County drainages. In addition, in the case of the Priest Rapids Member, this unit is completely absent in the southern part of this area. Based on the northwest-southeast strike and southwest dip of these units, water moving through interflow zones will move predominantly to the southwest. Given unit distribution, if water is introduced into these units in the upper stream reaches, much of it will discharge into the canyons to the southwest where the units are fully incised through.

Two Frenchman Springs units, the Sentinel Gap and Sand Hollow, are present only in the lower reaches of the central County drainages. Based on unit distribution, it would be necessary to deliver water into the lower reaches of these drainages in order to get water into the interflow zones of these two Frenchman Springs units. If that were to occur, any recharged groundwater would predominantly flow southwest until the units are truncated in the Crab Creek coulee near and west of Odessa. Therefore, if interflow zones in these units were successfully recharged, they would likely discharge into the Crab Creek valley.

The uppermost Grande Ronde unit in the County, the Sentinel Bluffs Member, underlies almost the entire area (Figure 22). Mapped distributions show it present within 200 feet of the bedrock bottoms of large reaches of all the drainages in central Lincoln County. Areas where the Sentinel Bluffs Member is at or near the base of these central County drainages include: (1) Canniwai Creek from the mouth upstream as far northeast as Highway 21, (2) from the mouth to above Highway 21 on Marlin Hollow, and (3) from the mouth to upstream of Twin Lakes on Lake Creek. Based on this distribution long reaches of these drainages might be candidates for recharge to the Sentinel Bluffs Member. If recharged, Sentinel Bluffs strike and dip suggests the predominant interflow orientation, and groundwater movement within the unit will be to the southwest. The top of the Sentinel Bluffs Member is exposed in Crab Creek near and west of Odessa. This area is down dip of potential recharge areas along many of the central County drainages. Given that, one could expect some discharge from the shallowest interflow zone(s) of the Sentinel Bluffs into the Crab Creek drainage. However, because of the depth of incision into the top of the Sentinel Bluffs Member generally is less than 100 feet and because its regional dip is to the south-southwest, one should expect that the multiple interflow zones present deeper in the unit would carry recharged water in that direction. In such cases, groundwater movement would be to the southwest into eastern Grant County and northwestern Adams County.

Of the other Grande Ronde units present beneath central Lincoln County, the Wapshilla Ridge Member is only found within a few hundred feet of the top of basalt on the northern highlands bordering the northernmost edge of the CRBG. The other three members mapped in the area, the Umtanum Member, Ortley Member, and Grouse Creek Member, all pinch

out beneath the southern part of the county. These units thicken down dip to the south-southwest. Given the depth of the Grande Ronde units underlying the Sentinel Bluffs Member, it seems likely that recharge pathways into them would be torturous and slow. For water moving into these deeper units, these recharge pathways would likely include: (1) some cross-strata movement of groundwater into interflow zones in up dip areas where dense flow interiors are thin, or truncated and (2) down dip movement of water into multiple interflow zones as new units are encountered in down dip areas. Water in these deeper Grande Ronde units likely would move generally to the south-southwest, down dip.

Groundwater is reported in water wells that penetrate to the top of pre-basalt basement in eastern Lincoln County and adjacent portions of Spokane County. Generally, this groundwater seems to be associated with paleodrainages incised into the pre-basalt rock prior to the emplacement of the CRBG. However, beneath the central Lincoln County drainages pre-basalt basement is only encountered in the highlands near Lake Roosevelt before dipping into the Columbia Basin to the south where it is several thousand feet deep. Given this depth it is unlikely if significant volumes of recharge water would reach it as it would have to migrate into, through, and between multiple CRBG interflow zones in the Grande Ronde to reach to top of the pre-basalt basement.

It is likely that feeder dikes for the Roza Member may be present beneath the central Lincoln County drainage area. Based on the few outcrops of feeder dikes and near vent facies observed during our field reconnaissance such a dike system would generally be northwest-southeast oriented and trend from the area around Sylvan Lake (on Crab Creek east of Odessa) to the area around Taveres Lake (on Lake Creek north of Odessa). Such an orientation is generally perpendicular to likely preferred south-southwest oriented down dip flow paths in the CRBG. If a well developed dike system proves to be present, it may disrupt the general flow path of CRBG groundwater in the units cross cut by it. Such disruptions, if found to be present, could include slowing of groundwater flow velocity, deflection of movement paths, and possibly even blockage of groundwater movement on at least a local scale. At this time we suspect, but do not know if, these dikes significantly impact the groundwater flow system beneath central Lincoln County.

4.3 Western Lincoln County

Western Lincoln County is drained by Wilson Creek and its two main tributaries, Goose Creek and Sinking Creek (Figure 44). The following summary of western Lincoln County drainages is generally shorter than the preceding sections because the Wilson Creek drainage is not considered suitable for feasibility and possible subsequent pilot scale testing. The reason for this is two-fold. One is a complex and contentious history of competing groundwater and surface water rights and the other is our assessment that the western Lincoln County drainages are too far west for the basic goal of recharging groundwater in the area targeted by this project.

4.3.1 Goose Creek

Goose Creek rises about 5 miles to the northwest of Creston, Washington. The contributing drainage area is 90 square miles and Goose Creek is about 18.5 miles long. It passes through the town of Wilbur, Washington before converging with Sinking Creek to form Wilson Creek. The creek has a well defined channel that is 5 to 15 feet across and up to 5 feet deep along much of its course. There are no natural lakes found on Goose Creek.

The Creek generally flows year round. Most road crossings appear to be large enough to handle additional flow. Because the Creek appears to flow most of the year, it does not appear to be experiencing significant losses due to water infiltrating into the underlying aquifer system.

Land ownership along the entire course of the creek is in private hands. If Goose Creek where to become a target for a rehydration project, one possible water delivery location is found at the head of Halverson Canyon, which is 12 miles from Lake Roosevelt. An alternate delivery location at the head of Sherman Creek, a tributary of Goose Creek, and reached via Jump Canyon is only approximately 2 miles from Lake Roosevelt. However, an extremely steep grade and evidence of flash flooding in Jump Canyon lead us to defer further prefeasibility phase consideration of this route.

4.3.2 Sinking Creek

Sinking Creek rises just south of the town of Creston in a headwater area that is approximately 11 miles from a potential intake on Lake Roosevelt near the town of Lincoln. Sinking Creek drains an 81 square mile area and flows for a length of 21 miles before converging with Goose Creek to form Wilson Creek. However, much of the upper 10 to 15 several miles of this stream does not have a well defined channel, and in its upper two to four miles the much of the channel is plowed over and farmed. Where a channel can be found, it is a few feet to 20 feet wide and generally less than 5 feet deep.

Historically Sinking Creek flowed year-round and several lakes were found along its course, including Baring Lake, Wagner Lake, and Herb Lake. However, beginning in the 1980's (or even earlier) stream flows diminished, Sinking Creek ceased to flow year round, and the lakes experienced declines. Currently, Sinking Creek only flows in the winter and spring when there is abundant runoff.

Almost the entire Sinking Creek channel (99%) is in private hands. If Sinking Creek where to become a target for a rehydration project, one possible water delivery location is found just southwest of Creston, approximately 11 miles from Lake Roosevelt via Redwine Canyon. However, given the farming currently seen in this headwater area, water may need to be carried 4 to 5 miles further south before it is discharged to a more well defined channel.

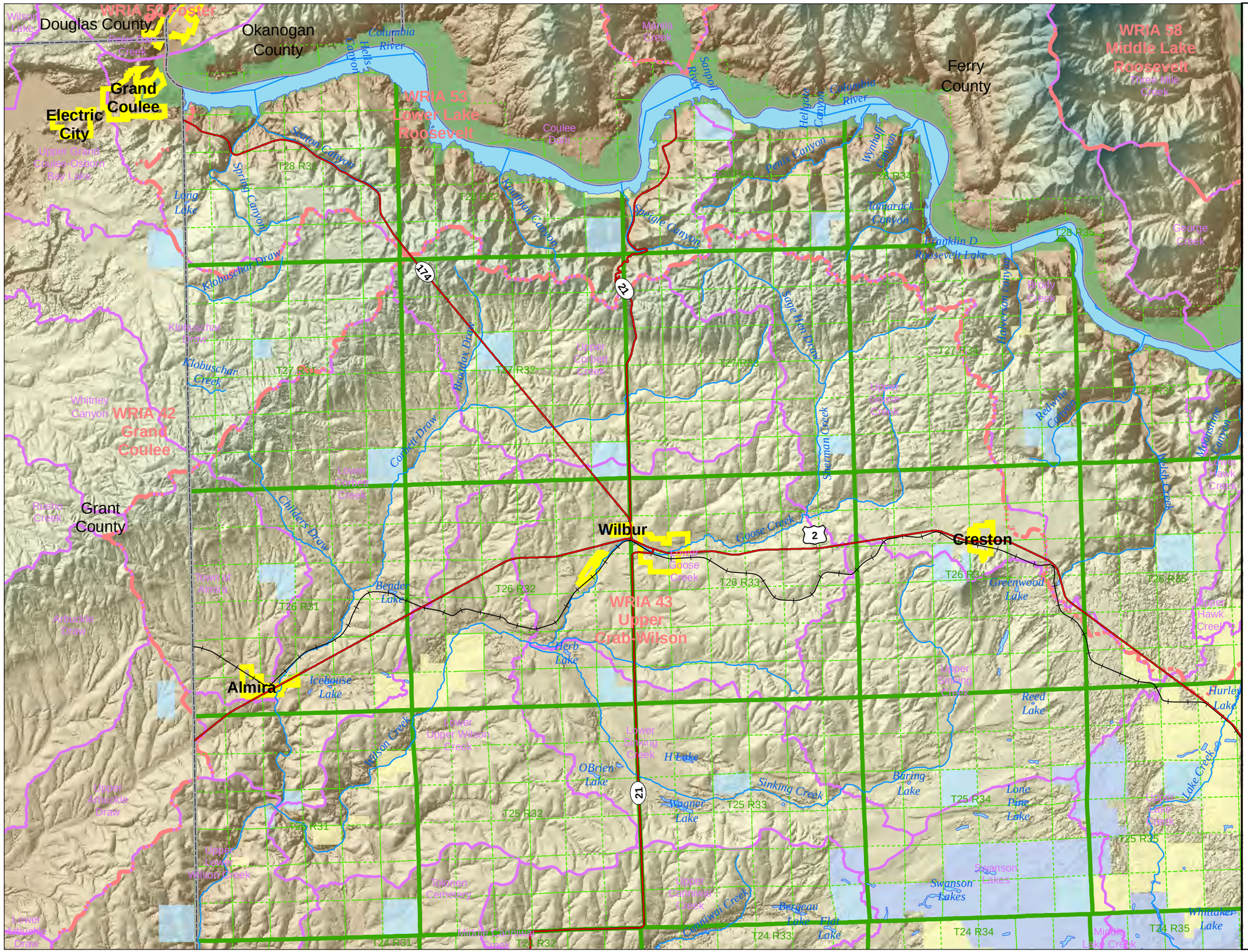
4.3.3 Wilson Creek

For the purpose of this prefeasibility assessment the main channel for Wilson Creek begins at the confluence of Sinking Creek and Goose Creek, approximately 3 miles southwest of Wilbur, Washington. From there it flows in a southwesterly direction for 38 miles before entering Crab Creek at the town of Wilson Creek in Grant County. The drainage area encompasses 440 square miles and it is the westernmost stream considered in the Prefeasibility Assessment. Wilson Creek generally occupies a channel a few feet to several tens of feet wide and a few feet deep which is located on the floor of a well defined coulee. No natural lakes are found along Wilson Creek before it exits Lincoln County.

The majority of the stream channel, approximately 88%, with the exception of a reach just below the confluence of Goose and Sinking Creeks lies on private land. These public lands are owned by the BLM.

A likely potential rehydration project delivery location would be approximately one mile south of Highway 2 where Gavon Road crosses the creek. This location is approximately 26 miles from Lake Roosevelt near the town of Lincoln.

Figure 44
Geographic setting of the western Lincoln County Drainages



Legend

- US
- State
- Active RR
- Abandoned RR
- Rails to Trails
- Rivers & Streams
- LCWater Bodies
- County Boundary
- Incorporated Area
- Township
- Section
- Watershed
- Sub-Watershed
- Odessa Sub-Area
- Dept of Natural Resources
- Dept of Fish and Wildlife
- Bureau of Land Mgmt
- National Park Service

N
W E
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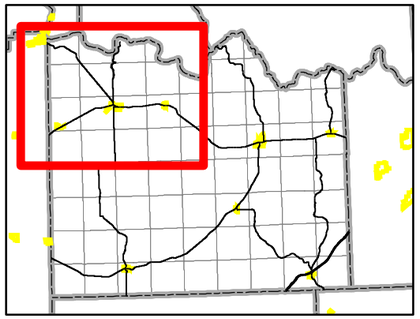


0 2.5 5 10 15 20

Miles

This is not a survey. Actual relationships and distances between features may be different from those depicted on this map. Accurate measurements are required in order to verify these relationships and distances.

Lincoln County, WA

4.3.4 Western Lincoln County Hydrogeology

Like in the central and eastern portions of Lincoln County the Priest Rapids Member and Roza Member are both present at, or very close to, the top of basalt in the upper reaches of this drainage area (Figures 15 and 16). However, below the confluence of Goose Creek and Sinking Creek, they are absent. Based on northwest-southeast strike and southwest dip, water moving through interflow zones in these units will move predominantly to the southwest. Given unit distribution, if water is introduced into these units in their upper stream reaches, much of it likely will discharge into canyons to the southwest where these units are incised through.

The Sentinel Gap, Sand Hollow, and Ginkgo, all Frenchman Springs Member units, only are present in the lower portions of the Wilson Creek drainage in westernmost Lincoln County. Based on this distribution, water in this drainage would have to flow into the westernmost part of the County to recharge interflow zones in these units. Furthermore, once these units receive recharge, GWMA's maps for northeastern Grant County show these units are dissected by the Crab Creek coulee to the southwest. Given that distribution, interflow zones in these Frenchman Springs units which are recharged in western Lincoln County likely would discharge into Crab Creek in adjacent Grant County.

The uppermost Grande Ronde unit in the County, the Sentinel Bluffs Member, is found within 200 feet of the bottom of large reaches of all the drainages in western Lincoln County. If the Sentinel Bluffs is successfully recharged, strike and dip suggests the predominant interflow orientation, and groundwater movement within such zones will be to the south-southwest. GWMA maps show the top of the Sentinel Bluffs exposed in Crab Creek in Grant County near and west of Marlin. This area is down dip of potential recharge areas along many of the western County drainages. Given that, one could expect some discharge from the shallowest interflow zone(s) of the Sentinel Bluffs into the Crab Creek drainage. However, because of the depth of incision into the top of the Sentinel Bluffs Member generally is less than 100 feet and because its regional dip is to the south-southwest, one should expect that the multiple interflow zones present deeper in the unit would carry recharged water in that direction. In such cases, groundwater movement would be to the southwest into north-central Grant County.

The deeper Grande Ronde units present in Lincoln County, the Grouse Creek Member and Wapshilla Ridge Member are only found within a few hundred feet of the top of basalt on the northern highlands bordering the northernmost edge of the CRBG. Given these mapped distributions, it seems likely that recharge pathways into these deeper units will be torturous, if present at all, and recharge timing will be slow. If water can get into these units as a result of recharge along the upper reaches of this drainage, it would move generally to the south-southwest.

Groundwater is reported in water wells that penetrate to the top of pre-basalt basement in eastern Lincoln County and adjacent portions of Spokane County, and northernmost Lincoln County. Generally, this groundwater seems to be associated with paleodrainages incised into the pre-basalt rock prior to the emplacement of the CRBG. However, beneath the western Lincoln County drainages pre-basalt basement is only encountered in the highlands near Lake Roosevelt before dipping into the Columbia Basin to the south where it is several thousand feet deep. Given this depth, it is unlikely that significant volumes of recharge water would reach it because the water would need to migrate into, through, and between multiple CRBG interflow zones in the Grande Ronde to reach to top of the pre-basalt basement.

Based on our current understanding of feeder dike distribution in the CRBG, it seems likely that the western Lincoln County drainages lie west, and down dip, of the main projected Roza and Priest Rapids dike systems. Based on that, we suspect that these dikes will have little to no impact on groundwater flow in this portion of Lincoln County.

4.4 Land Ownership Issues

A potential rehydration project would move water in a pipeline uphill from Lake Roosevelt, over the drainage divide south of the Lake, and down the generally southerly flowing drainages targeted in Lincoln County. Such a route will cross ground owned by both public entities and private individuals. These owners will have different issues and concerns that will need to be addressed in order to gain access to a proposed route. The purpose of this section is to summarize the range of issues identified during the prefeasibility assessment that need to be addressed for a rehydration project. To prepare this list of issues, GSI staff met with landowners and government entity stakeholders to describe the proposed project and learn what their issues and concerns might be concerning potential routes across their ground. A current list of interviewed landowners and stakeholders was compiled and a list of comments and concerns was prepared.

4.4.1 Private Landowners

Among the private landowners interviewed there were a variety of interests represented: stock raising, irrigated and dry land farming, and recreation. The most common concerns associated with the reintroduction of water to the area and re-establishment of flowing streams and refilling of now dry lakes focused on questions regarding the physical transmission of the water. These concerns included:

1. The need for repairing roads and stream crossing. If flows are increased in these streams there are a number of stream crossing that will need to be upgraded to handle these increased flows without erosion damage.

2. Rebuilding fences and regulating riparian corridors. The question of whether or not fencing off of creek/water bodies was of concern to landowners who run cattle/livestock on their lands. If fencing is required, some landowners raised questions of property value should their livestock not be able to navigate property that may be essentially cut into halves should a creek return to flowing. If riparian areas are to be fenced off will more regulations from state and federal entities follow?

3. Loss of usable pasture/tillable ground. With some uncertainty of where recharge water is likely to go, some landowners are concerned about the potential for loss of pasture and hay ground due to flooding and high water.

4. Dam rebuilds. There are a number of small dams along many of these streams associated with past irrigation practices. Will any of these be rebuilt, and if so, how will they be operated and regulated.

5. Increased traffic with public access. Several landowners are concerned about increased traffic through their properties if the presence of water attracts waterfowl, fish and wildlife.

6. Water quality. With the objective of recharging groundwater comes a concern about the quality of recharged water. Many local residents expressed a concern for making sure that local groundwater quality is not degraded by a rehydration project.

7. Sedimentation. With increased stream flow there is the increased potential for erosion of stream banks and downstream deposition of that eroded sediment. Several residents who own land on currently flowing reaches raised this concern and emphasized the need to manage enhanced stream flow to minimize this potential issue.

In addition to these issues, there was an often repeated concern about the involvement of the Department of Ecology. For example, would Ecology allow the transfer of water rights from some areas that may become flooded or wet year round to areas that had previously not been covered by a water right? Also, would Ecology allow the use of surface water rights previously idled due to lack of source; and would DOE issue new water rights from renewed surface water sources?

The full list of issues we heard in the course of our interviews with private landowners and other interested parties associated with the periodic rehydration of one or more streams is as follow:

- Fence construction adjacent to stream courses or lakes to protect water quality will become an issue.
- Loss of pasture/hay ground due to flooding and high water.

- Road rebuilds.
- Dam rebuilds.
- Increase in bad/noxious plants/weeds.
- Increased public access followed by abuse of private property, littering, tearing up the land.
- Piping water through or around hay/pasture ground.
- Fencing off riparian areas – do not want to invite more reasons to regulate or give Ecology any extra help in getting their foot in the door.
- Lake Creek system – landowners in favor of water returning to the lakes. Irrigation wells have decreased capacity – related to the decrease of water in the lakes.
- Cattle owners don't want to see their access to water cut off.
- Could the project provide the potential for damming water and generating power?
- Can the project recoup some of the initial pumping costs out of Lake Roosevelt?
- What is the potential for job enhancement should the project move forward?
- Will landowners near Lake Roosevelt cooperate?
- Will the tribes cooperate? Have issues with the tribes concerning withdrawals from Lake Roosevelt been resolved?
- Would the project help move fertile soil to higher ground in favor of lower ground for submersion?
- How will project be paid for if water continues to be pumped?
- One landowner reported he felt the passive rehydration would help increase cattle supporting capacity of the land.
- Is there an existing RCW that allows public access to lakes that have a public road nearby? If water comes back, will the landowner have to allow public access to his land?
- Can landowners who have existing surface water rights drill a shallow/hydraulically connected well near stream to remove existing point of withdrawal from the stream?
- Has injecting water into the basalt system been discussed as part of this project, or an extension of this project?

As the feasibility of a specific drainage is targeted for future work, issues specific to it, including some or all of those listed above, will need to be resolved. We propose that these be specifically addressed in the feasibility phase.

4.4.2 Public Entities

The three primary public land managers in the drainages being assessed are the U.S. Bureau of Land Management (BLM), the Washington Department of Fish and Wildlife (WDFW), and the Washington Department of Natural Resources (DNR).

At this stage of the project, the conceptual and prefeasibility stage, the WDFW and DNR field representatives we talked to about the project expressed little major concern about the prospect of revitalized stream flows in the area. The primary concern they had was related to flooding of shrub-steppe habitat ground. Because the project as currently conceived only envisions flooding of now dry lakes, the staff we discussed the project with appeared to be generally supportive, and from their perspective had no regulatory issues associated with the project were identified. Given that, if a pilot project is undertaken, WDFW and DNR will need to be consulted as part of the SEPA process.

In June 2010, project staff met with BLM staff to discuss the project concept. BLM staff indicated they are generally receptive to a project that revitalizes lost stream flow and lake capacity, but reported that there will be NEPA requirements that have to be met before the project could proceed on BLM ground. At a minimum, a right-of-way (ROW) authorization will need to be obtained (see BLM ROW program – Title 43 of the Code of Federal Regulations, Parts 2800 and 2880). A ROW authorization would come from the local BLM office whose jurisdiction includes the project area. A pre-application meeting with BLM will provide an opportunity to discuss the project in detail and allow both BLM and the applicant to go over the processing requirements, as well as to address any questions or concerns regarding the project, and the fees involved. A processing fee is required for a ROW application. BLM also charges a monitoring fee and rent. However, it is possible that this project may fall under an exemption, waiver, or reduction in the processing and monitoring fees as the project is part of a state and local agency (DOE funded and LCCD managed) where the land will be used for governmental purposes and the land resources will continue to serve the public interest. If the project proceeds to the feasibility phase the ROW authorization process will be further pursued with the BLM.

4.5 Drainage Rankings

The ten streams were evaluated according to six criteria using a qualitative ranking of one, two, or three. For each of the six criteria a three meant the ranking was generally favorable to further evaluation in the feasibility phase, a one meant the ranking was generally unfavorable, and a two was neutral. The six criteria are as follows:

- Available Information: Relatively more is known about the stream based on the number of field visits and availability of prior studies.
- Landowners/Stream Channel Issues: Lower likelihood of adverse issues associated with landowners along the stream and number of anticipated culvert issues along the re-watered channel.
- Conveyance Distance /Issues: Distance from Lake Roosevelt I shorter and/or it is easier to convey water to head of stream along public rights of way. (<15 miles is Positive, > 25 miles is Negative).
- Hydrogeology Benefits: Higher likelihood of hydrologic benefit to the underlying aquifer.
- Recreation and Habitat Benefits: Higher likelihood of recreational and /or habitat benefits from routing water down the channel. Related to presence or absence of de-watered lakes, etc.
- Water Rights: These were looked at from the perspective of potential conflict to the extent we can currently identify them. This is not an analysis of water rights that could be serviced or are needed for the project to proceed.

The following summarizes our current ranking of each stream using the six criteria and based on the discussions in Sections 4.1 through 4.4. Table 6 presents a tabulation of our rankings.

Table 6. Color-Coded Rankings of the Drainages Assessed in this Report

Green is favorable for the proposed project, red is not favorable for the proposed project, and yellow is neutral.

Drainage	Available Info	Landowner/ Stream Channel Issues	Hydro-geology	Con-veyance Distance/ Issues	Recreation and Habitat	Water Rights	Total Ranking
Upper Crab Creek	2	3	3	1	2	2	13
Bluestem Creek	2	1	2	1	1	2	9
Rock Creek	1	1	1	1	1	1	5
Coal Creek	2	1	2	1	1	2	9
Duck Creek	2	2	3	1	2	2	12
Lake Creek	3	2	3	2	3	2	15
Marlin Hollow	2	3	3	1	2	2	13
Canniwai Creek	2	2	3	1	2	2	12
Wilson Creek	3	1	1	1	2	1	9
Goose Creek	3	1	1	1	2	1	9
Sinking Creek	3	1	1	1	2	1	9

Upper Crab Creek:

- Available information: WRIA 42 general information; rank = 2
- Landowner/stream channel issues: Predominantly private land ownership; generally well defined, relatively large (>10 cfs) channel; rank = 3
- Hydrogeology: History of channel losses suggests recharge potential; CRBG groundwater movement generally towards Odessa Groundwater Management Subarea; rank = 3
- Conveyance Distance/Issues: Long distance to source (15 to 30 miles) depending on route; rank = 1
- Recreation/Habitat: Mostly private ground, but with well defined scabland coulees; trout fishery present in reaches; rank = 2
- Water Rights: no issues currently defined; rank =2
- Total = 13

Bluestem Creek:

- Available information: WRIA 42 general information; rank = 2
- Landowner/stream channel issues: Predominantly private land ownership; upper reaches poorly defined; channel in lower reaches generally small (<2 to 5 cfs); rank = 1
- Hydrogeology: Little anecdotal information found; Unknown history of channel loss, but reconnaissance suggests small; CRBG groundwater movement generally towards Odessa Groundwater Management Subarea; rank = 2
- Conveyance Distance/Issues: Long distance to source (20 miles); rank = 1
- Recreation/Habitat: Mostly private ground; no history of dried lakes; well defined scabland coulees; rank = 1
- Water Rights: no issues currently defined; rank =2
- Total = 9

Rock Creek:

Not evaluated further because of long distance (>30 miles) from source water to headwaters area. Ranked one (1) for all categories.

Coal Creek:

- Available information: WRIA 42 general information; rank = 2
- Landowner/stream channel issues: Predominantly private land ownership; generally well defined, small to medium (< 5 cfs) channel; creek flows through a town results in a flood control concern; rank = 1
- Hydrogeology: No anecdotal history of channel losses found, suggests small recharge potential; if recharge occurs CRBG groundwater movement generally towards Odessa Groundwater Management Subarea; rank = 2
- Conveyance Distance/Issues: Long distance to source (>20 miles) from poorly defined headwater area; rank = 1
- Recreation/Habitat: Mostly private ground, significant areas of active agriculture; rank = 1
- Water Rights: no issues currently defined; rank =2
- Total = 9

Duck Creek:

- Available information: WRIA 42 general information; rank = 2
- Landowner/stream channel issues: Predominantly private land ownership; upper reaches poorly defined, but with stream channel and lake losses suggested throughout drainage; Generally small to moderate channel size (< 5 cfs) channel; rank = 2
- Hydrogeology: History of channel and lake losses suggests recharge potential; CRBG groundwater movement generally towards Odessa Groundwater Management Subarea; rank = 3
- Conveyance Distance/Issues: Long distance to source (>30 miles); rank = 1
- Recreation/Habitat: Mostly private ground, but with several lakes and well defined scabland coulees; rank = 2
- Water Rights: no issues currently defined; rank =2
- General: Given the distance to its headwaters, and the lack of a well defined drainage in its upper valley, Duck Creek probably is not favorable for a pilot project
- Total = 12

Lake Creek:

- Available information: WRIA 42 general information, and LCCD Lake Creek study; rank = 3
- Landowner/stream channel issues: Mix of public and private land ownership, with private owners concerned about stream access and erosion issues; generally have a well defined, moderate sized channel (5 to >10 cfs) and numerous lakes, many of which have dried up; rank = 2
- Hydrogeology: History of channel and lake losses suggests recharge potential; Numerous lakes provide potential water storage and recharge potential; CRBG groundwater movement generally towards Odessa Groundwater Management Subarea; rank = 3
- Conveyance Distance/Issues: for the project areas, moderate distance to source (12 to 15 miles) depending on route; some private land access issues to address; rank = 2
- Recreation/Habitat: abundant public ground and lakes; formerly an active trout fishery throughout the system; rank = 3
- Water Rights: no issues currently defined; rank =2
- Total = 15

Marlin Hollow:

- Available information: WRIA 42 general information; rank = 2
- Landowner/stream channel issues: Headwaters publically owned, remaining drainage predominantly private land ownership; lakes are drying/decreasing; generally well defined, moderate (5 cfs) channel; rank = 3
- Hydrogeology: History of channel losses and diminished lakes suggests recharge potential; CRBG groundwater movement generally towards Odessa Groundwater Management Subarea; rank = 3
- Conveyance Distance/Issues: Long distance to source (20 miles); upper reaches poorly defined; might potentially be linked to a Lake Creek delivery system if ever developed; rank = 1
- Recreation/Habitat: With upper reaches in public ownership, and presences of lakes there is potential for improvement; rank = 2
- Water Rights: no issues currently defined; rank =2
- General comment: Potential issues with this stream are related to conveyance of water to the headwaters over open ground. It has positive issues related to channel conveyance, recreation, and habitat.
- Total = 13

Canniwai Creek:

- Available information: WRIA 42 general information; rank = 2
- Landowner/stream channel issues: Predominantly private land ownership, with significant channelized reaches and construction adjacent to creek; small to moderate channel size (2 to 5 cfs) with few lakes; rank = 2
- Hydrogeology: History of channel losses suggests recharge potential; CRBG groundwater movement generally towards Odessa Groundwater Management Subarea; rank = 3
- Conveyance Distance/Issues: Long distance to source (>20 miles); upper reaches poorly defined; might potentially be linked to a Lake Creek delivery system if ever developed; rank = 1
- Recreation/Habitat: predominantly private ownership with some scabland; rank = 2
- Water Rights: no issues currently defined; rank =2

- Potential issues with this stream are related to conveyance of water to the headwaters over open ground (similar to Bluestem and Canniwai). It has positive issues related to channel conveyance, recreation, and habitat.
- Total = 12

Wilson, Goose, and Sinking Creeks:

Given water rights concerns discussed earlier in this prefeasibility assessment these drainages were not favorably ranked. The following rankings apply to each of these three western Lincoln County drainages.

- Available information: Early Sinking Creek evaluations provide a fair amount of useful information; rank = 3
- Landowner/stream channel issues: Predominantly private with numerous existing water rights concerns; channels are small to moderate in size; rank = 1
- Hydrogeology: Recharge potential suggested by early water rights work, but overall location suggests minimal recharge potential for Odessa Groundwater Management Subarea to the south; rank = 1
- Conveyance Distance/Issues: Generally short distances to source, but via steep gradient canyons; rank = 1
- Recreation/Habitat outcomes: Predominantly private land, but with some lakes and stream access; rank = 2
- Water Rights: Previous contentious issues, especially with regards to groundwater and surface water continuity; rank = 1
- General comment: These creeks may be too far to the west to have a significant hydrogeologic connection or provide benefit to areas along Crab Creek in the Odessa Groundwater Management Subarea
- Total = 9

Table 6 summarizes how well each stream meets the respective criteria. In the matrix, Green indicates relatively higher positive characteristics, ranking of 3. Yellow indicates neutral or a mix of positive and negative characteristics, ranking of 2. Red indicates relatively lower or negative characteristics or issues that may count as fatal flaws for the purposes of this selection process, ranking of 1. Because significant information is missing for many streams and criteria, the matrix is highly subjective and qualitative. Additional information and research may alter these preliminary ratings.

The qualitative evaluation based on the six criteria described above, and shown in Table 6, ranks the drainages in the following order, from most acceptable to least acceptable:

1. Lake Creek – 15

2. Marlin Hollow and upper Crab Creek – 13

3. Duck Creek and Canniwai Creek – 12

4. Bluestem Creek, Coal Creek, Wilson Creek, Goose Creek, Sinking Creek – 9

5. Rock Creek – 5

Based on these rankings we recommend that Lake Creek be the initial focus of subsequent work during the feasibility phase of the project. In addition, we recommend that Marlin Hollow and Canniwai Creek be further evaluated in the feasibility phase because of generally high rankings, including their proximity to Lake Creek. If a Lake Creek pilot project is undertaken, the proximity of these other two creeks may facilitate expansion of a delivery system into these additional drainages.

Upper Crab Creek and Duck Creek, also ranked highly, are not recommended for further evaluation at this time because of distance to source water (over 15 miles). With respect to the 5 drainages with a ranking of 9, all offer some positive aspects, but each also has one or more negative aspects that lead us to remove them from further consideration for a potential pilot project. Conveyance from the source to Bluestem Creek and Coal Creek is long and both creeks are relatively small. In addition, Coal Creek flows through a town. Wilson Creek, Goose Creek, and Sinking Creek have several favorable aspects, but the history of water rights disputes and their location far to the west and not directly up gradient of the Odessa Groundwater Management Subarea all argue against their use in a pilot project.

This qualitative review suggests that based on our current state of knowledge, Lake Creek is the best choice for a possible Pilot Study. Based on that, the following sections make a very preliminary assessment of the pipeline infrastructure requirements and the potential fate of water delivered to the Lake Creek system as part of a pilot project. It cannot be over emphasized that this is a rough, concept-level estimate of potential Lake Creek water balance. The hydrologic estimates included in the model are preliminary and should be confirmed and verified through further study. These preliminary results are not suitable for design-level evaluation and no express or implied warranty is provided. Significant additional hydrologic analysis and measurement are recommended at the feasibility level of study.

4.6 Pipeline Infrastructure Assessment – Lake Creek

This section addresses potential pilot project infrastructure needs for the pipeline that could deliver water to the Lincoln County Passive Rehydration Project using the Lake Creek drainage. The assumptions made in this section are preliminary in nature and should be verified as further information is available during the feasibility study and design phase. A potential future fully built out system may deliver water to the Lake Creek system, as well as to other drainage systems in Lincoln County.

The proposed system outlined here consists of a pump station sited along the shore of Lake Roosevelt in Lincoln, WA. The pump station and pipeline would convey flow approximately 14.5 miles up and out of Redwine Canyon to a location south of State Route 2. The pilot study would provide approximately 10 to 20 cubic feet per second (cfs) to the Lake Creek system with the anticipated full project providing 100 cfs to be divided between multiple drainages in the area. The preliminary pipeline route is shown on Figure 45, and a preliminary pump station layout is shown on Figure 46. For the purpose of scoping a potential feasibility evaluation, this section reviews pump station and pipeline system hydraulics, pipeline route, and a preliminary discussion on the pipeline design.

4.6.1 Pipeline – System Hydraulics, Pipeline Route, and Pipeline Design

For a 10 cfs pilot project, a 24-inch-diameter pipeline is proposed. The pilot project could be expanded to the full 100 cfs future flow by adding a 48-inch-diameter pipeline parallel to the pilot project pipeline. Conversely, depending on the project funding, a single 60-inch-diameter pipeline could be built which would handle the full build out flows and the pilot project flows (100 cfs). There are three proposed pipeline routes shown on Figure 45: Moonshine Canyon Pipeline Route, Hawk Creek Pipeline Route, and Lincoln Pipeline Route. Each route and the hydraulics will be discussed further below. A summary table of pipeline headloss is presented after the route discussion in Table 7.

The Moonshine Canyon Pipeline Route is approximately 62,000 feet (11.75 miles) long. The static elevation difference between Lake Roosevelt and the highest point is 1,160 feet. The route generally follows existing roads (Copenhaver Road, Miles Creston Road, Telford Road), which may be either gravel or pavement, depending on the location. This route is the shortest and has the lowest total dynamic head of the three routes considered. However, as shown in Figure 47 the route is through a very steep canyon with minimal clearances for construction. This route should be further reviewed during the feasibility study, but is not currently the preferred route.

The Hawk Creek Pipeline Route is approximately 74,000 feet (14 miles) long. The static elevation difference between Lake Roosevelt and the highest point is 1,260 feet. The route generally follows existing roads (Hawk Creek Road N, Miles Creston Road, Telford Road), which may be either gravel or pavement, depending on the location. This route is the

second shortest, but has the highest total dynamic head of the three routes considered. The pipeline route appears feasible from the aerial photography available. However, this appears to be a shallow portion of Lake Roosevelt, with the Hawk Creek Campground website indicating that water access and usage is seasonal here. With the high head and potential for water access issues, this is not the preferred location and is not recommended for further study.

The Lincoln Pipeline Route from Lake Roosevelt to the Lake Creek system is approximately 14.5 miles long and has approximately 1,160-feet of elevation change. In general, the route follows existing roads (Redwine Canyon Road, Welch Creek Road, Miles Creston Road, Telford Road), which may be either gravel or pavement, depending on the location. This route has a more gradual elevation climb, and a wider access area for construction, as shown in Figure 48. There is a substantial culvert crossing along Redwine Canyon Road, shown in Figure 49. While this pipeline route is the longest, it is only slightly higher in total dynamic head, and is the preferred route in this prefeasibility report because of accessibility and potential access to Lake Roosevelt.

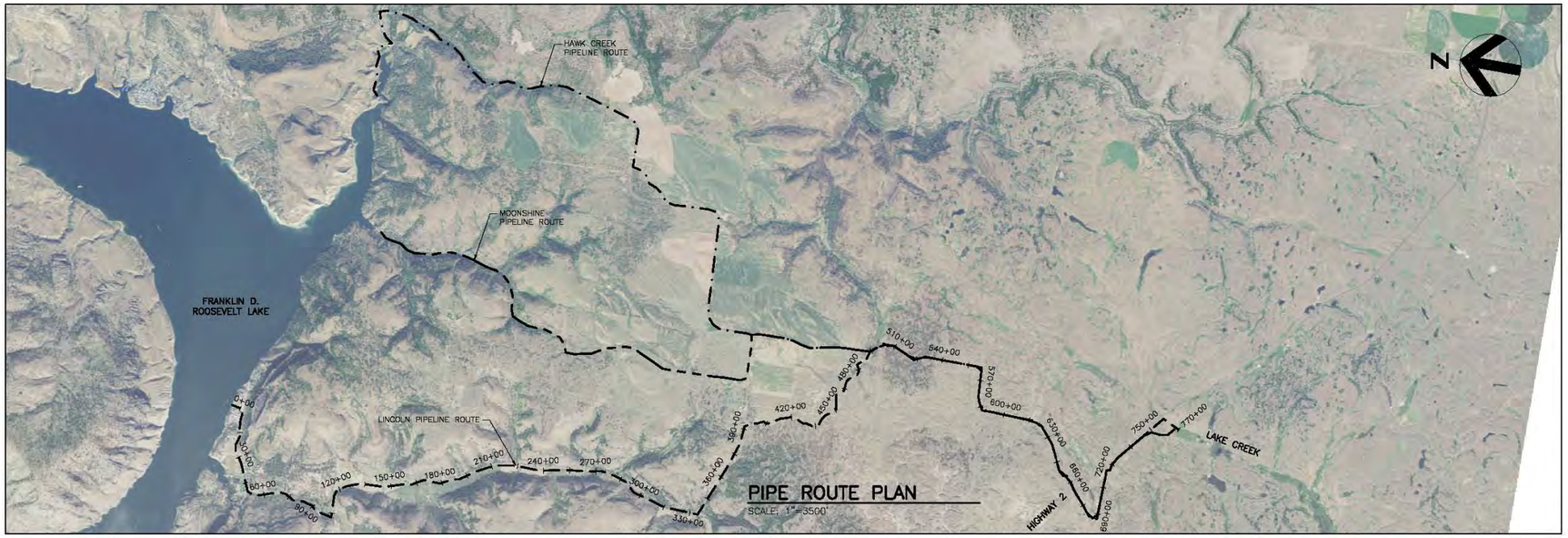
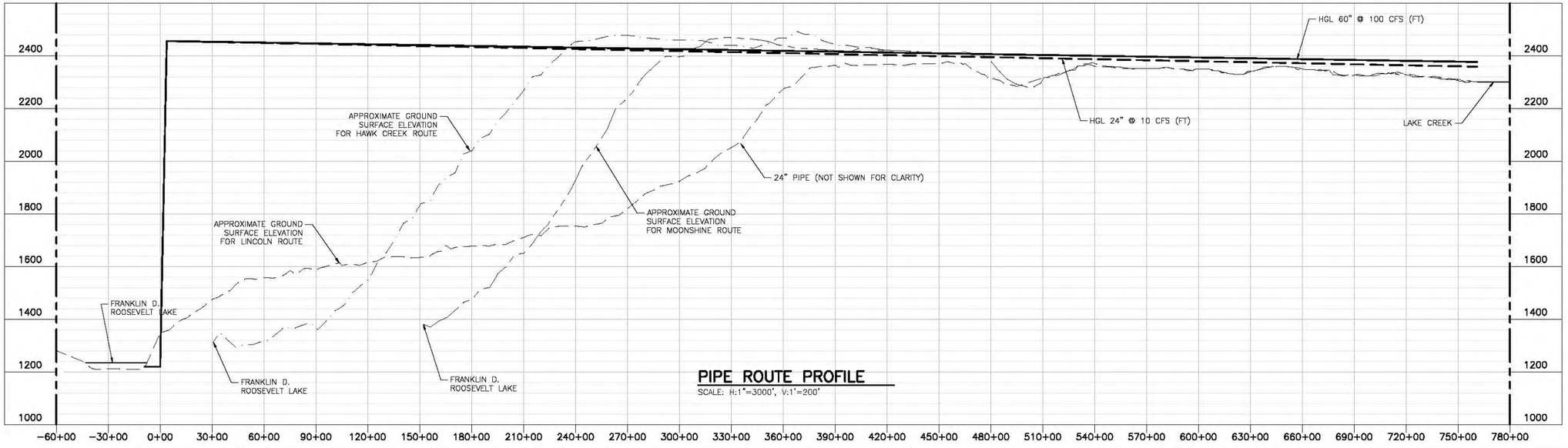


Figure 45. Possible routes for a potential pipeline for delivering water from Lake Roosevelt to the upper Lake Creek drainage. These routes assume water would be piped to the Telford area south of Highway 2.



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ISSUE	DATE	DESCRIPTION

PROJECT MANAGER	A. MEILLEUR
DESIGNED	B. BARTLE
DRAWN	M. NAGAMATSU
CHECKED	B. BARTLE
PROJECT NUMBER	00000000013198

DRAFT

LINCOLN COUNTY CONSERVATION DISTRICT

LAKE CREEK PROPOSED PIPE ROUTE HYDRAULIC GRADE SCHEMATIC

0 1" 2"

FILENAME	00F001.dwg
SCALE	H:1"=3000', V:1"=200'

SHEET **F001**

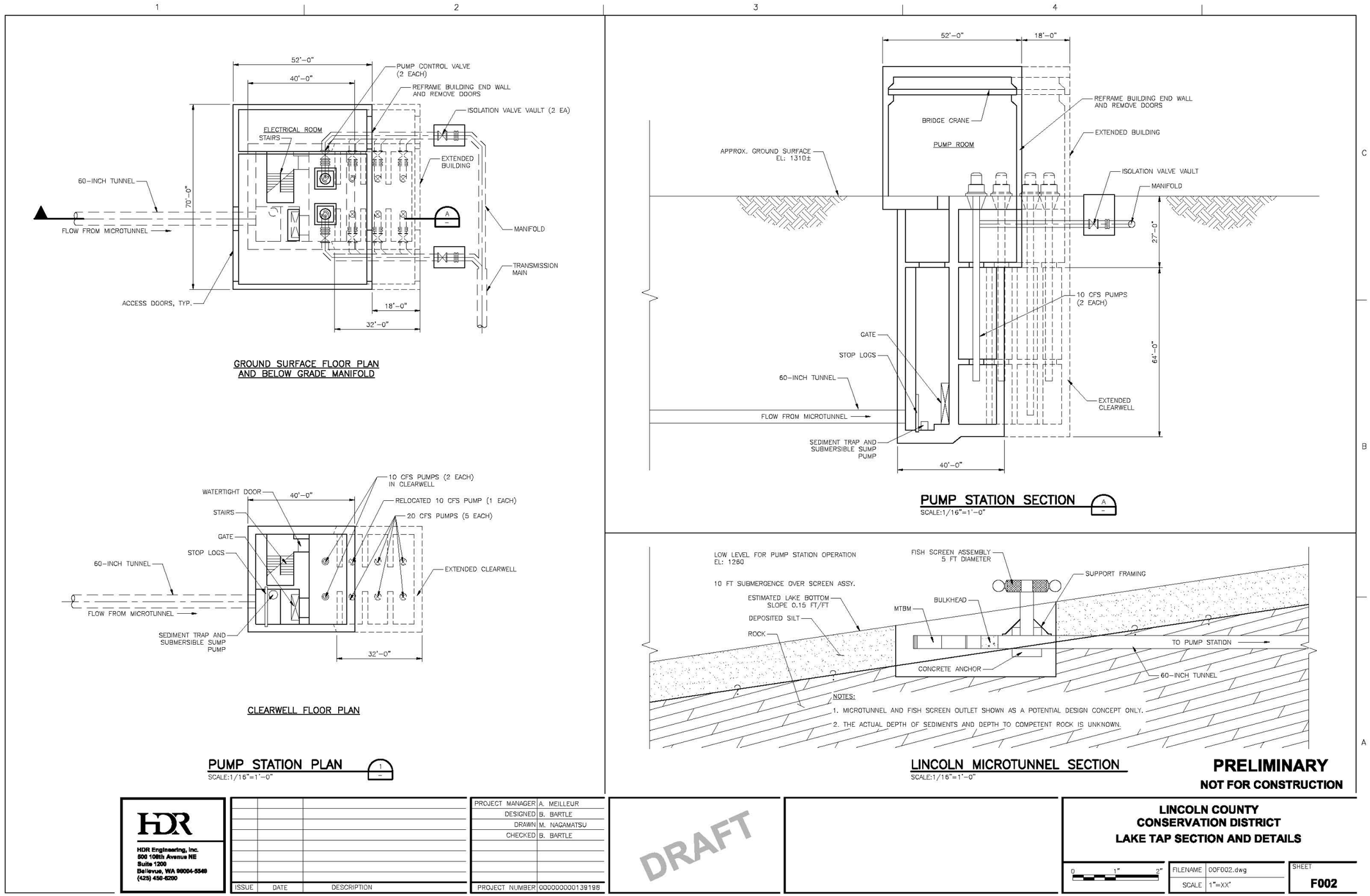

Figure 46. Potential pumping station configurations for a pump station(s) on Lake Roosevelt.

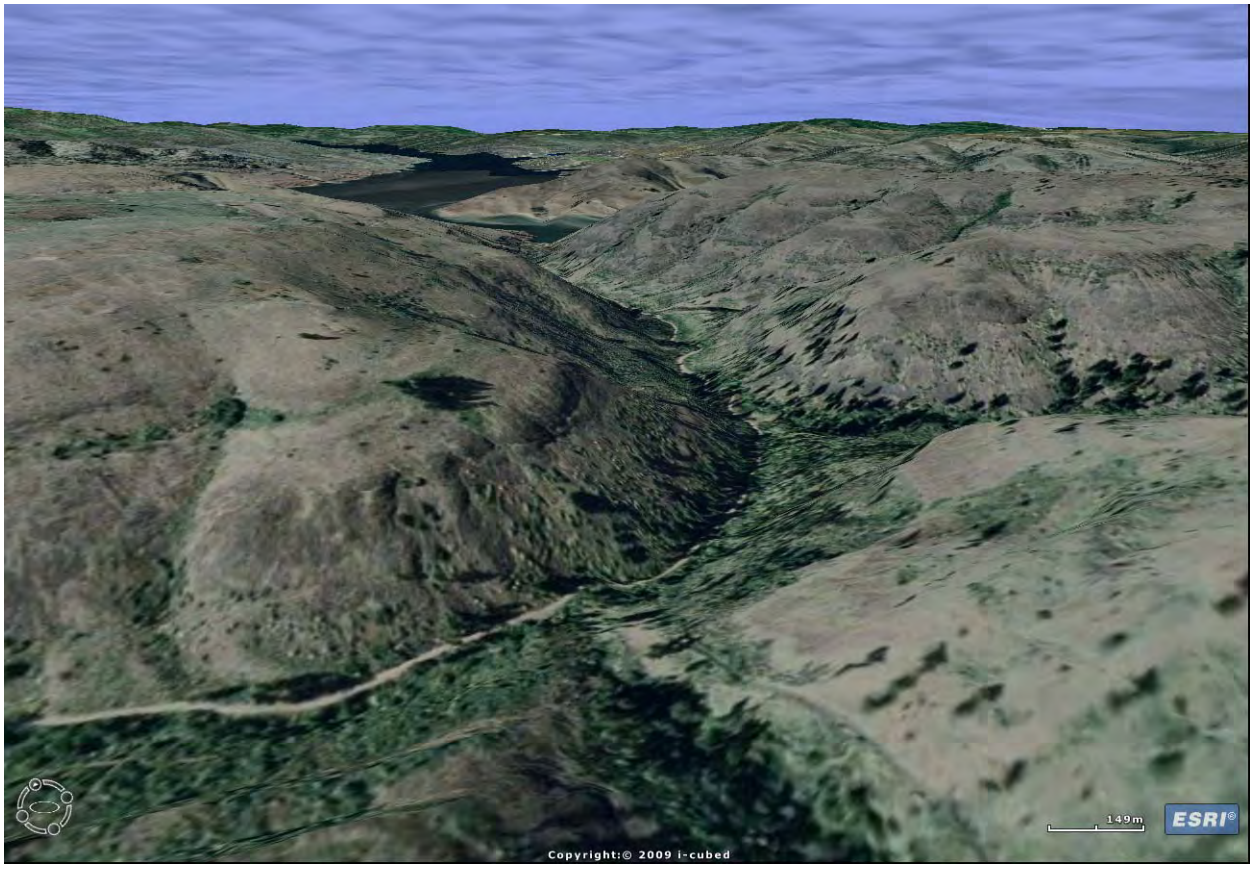

Figure 47. The geographic setting of the Moonshine Canyon Route along Copenhaver Road. This view is to the north down the canyon.

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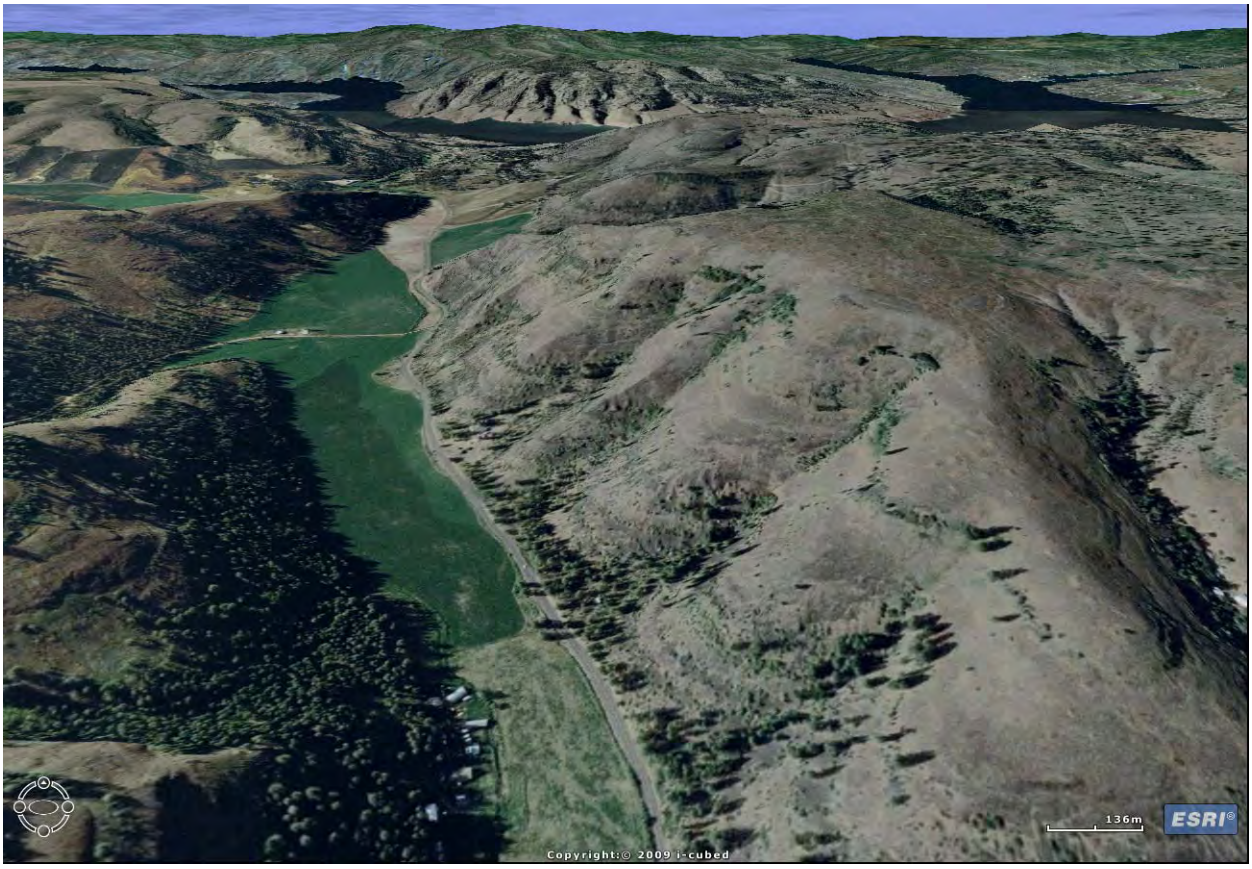

Figure 48. The geographic setting of the Welch Creek Road route. This view is to the north down the canyon.

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Figure 49. Culverts along the Welch Creek Road route on Redwine Canyon Road.

Table 7 summarizes the hydraulic conditions used to evaluate alternative routes. Hydraulic considerations should be further reviewed during the feasibility phase. The 24-inch pipeline for the 10-20 cfs pilot project would have a velocity of approximately 3.2 feet per second regardless of the alternative. Adding the 48-inch pipeline for the full build out of 100 cfs would give an equivalent pipe diameter of 57 inches, and a velocity of 5.6 feet per second. As discussed above, a 60-inch pipeline could be built to handle both the pilot and future flows. The velocity in this larger diameter line during the pilot project would be 0.51 feet per second; at final build out, the velocity would be 5.1 feet per second.

Table 7. Summary of Potential Pipeline Route Hydraulics

	Moonshine Pipeline Route	Hawk Creek Pipeline Route	Lincoln Pipeline Route
Pipeline length (ft)	62,000	74,000	77,000
Start elevation (ft)	1,320	1,240	1,200
Highest elevation (ft)	2,480	2,500	2,360
Total static head (ft)	1,160	1,260	1,160
10-cfs Pilot Study – 24-inch Pipeline			
Pipeline headloss (ft)	81.5	97.3	100.6
Velocity (ft/sec)	3.2	3.2	3.2
Total dynamic head (ft)	1,242	1,357	1,261
100-cfs Full Buildout – 57-inch Equivalent Pipeline			
Pipeline headloss (ft)	85.8	102.4	106
Velocity (ft/sec)	5.6	5.6	5.6
Total dynamic head (ft)	1,246	1,362	1,266
100-cfs Full Buildout – 60-inch Pipeline			
Pipeline headloss (ft)	66.9	79.8	82.6
Velocity (ft/sec) Pilot/Full Build	0.50/5.1	0.50/5.1	0.50/5.1
Total dynamic head (ft)	1,226	1,340	1,243

The Lake Creek system technically begins on the north side of State Route 2; however, based on field reconnaissance, there does not appear to be a culvert or other crossing of State Route 2. Therefore, all proposed routes assume a trenchless crossing of the highway, and nearby railroad tracks, and discharge on the south side of the highway, as shown in Figure 45.

As shown in Figure 45, the Lincoln Pipeline Route grade is steep for the first seven miles; it then flattens out for the remainder of the route. With the approximate 1,160-feet of static head and approximately 100-feet of dynamic head loss, the pipeline pressure is close to 565 psi in the first section of pipe. This pressure will require the use of steel pipe. The second half has a much more moderate 200' grade change resulting in a pipe pressure less than 100 psi. For this second segment, any pipe material (steel, ductile iron, PVC, or HDPE) could be used. For the purpose of this report, the entire pipeline route is assumed to be steel. The steel pipe thicknesses used are presented in Table 8.

Table 8. Steel Pipe Thicknesses

Pipeline Diameter (inches)	Segment 1 (7 miles at 565 psi) (inches)	Segment 2 (7.5 miles at 90 psi) (inches)
24	0.300	0.200
48	0.560	0.200
60	0.700	0.250

4.6.2 Pump Station

There are several components to the proposed pump station addressed here, including site, layout, and the intake structure.

Pump Station Location

During field reconnaissance several proposed pump station sites were reviewed. At this time, the preferred location for a pump station is at, or near, an abandoned lumber mill site in Lincoln, Washington. The mill structures have been mostly been demolished and removed from the site, except for the burner structure and some foundation fragments, as seen in Figure 50.

Figure 50. Photograph of the old Lincoln lumber mill site. This is one of several potential location on Lake Roosevelt where water might be pumped for the possible project. Lake Roosevelt lies just beyond the kiln and in the front of the hills in the background.

A significant consideration for the pump station siting is available power. During the field visit, three phase power lines were observed all the way to Lincoln. However, the availability, quantity, and quality of this line are not known at this time and should be investigated further in the feasibility and design phases.

Pump Station Layout

A proposed pump station site needs to accommodate both the pilot study size facilities and the future full build out condition. A preliminary plan and section of the pump station is included in Figure 46. This figure shows both the pilot study pump station and future growth plan for the pump station at a later date.

For the pilot study, two 10 cfs pumps are assumed. These pumps would provide redundancy during the pilot study, and also could be run in parallel in the future to increase flows to 15-17 cfs. For the full build out phase, four 20 cfs pumps would be added to increase the total pump station to 100 cfs capacity. Between the different sized pumps, any flow rate between 10 and 100 cfs could be achieved (in 10 cfs increments). This allows the future operators the flexibility to provide different flow rates at different seasons and/or to different creek systems. Redundant pumps and backup power are not included for the facility as it is likely not critical that the pump station provide 100 cfs at all times.

During the feasibility study, further review of the pump station should include determining if portions of the pump station should be built at the full-build out size during the pilot study. For some features, such as the wet well, it may be more cost effective to construct in one project than trying to accommodate future expansion.

Other appurtenances for the pump station, such as meters, valving, surge tanks are not shown at this time and need to be further reviewed during the feasibility study.

Intake Structure and Fish Screen

A challenging aspect of the project will be the pump station intake located in Lake Roosevelt. The water level in Lake Roosevelt varies by season from a low of 1,217-feet to a high of 1,290-feet. As the project progresses, further discussions are needed to determine if the intake structure needs to accommodate the full 80-feet of lake variation or if the pump station would only operate during a portion of the year. The wide variation may require a deep tunnel into the reservoir for the intake. Two options to be considered in the feasibility phase are a lake tap and microtunneling into the reservoir. Each has benefits and drawbacks which must be examined. For the purpose of this prefeasibility report, microtunneling is the preferred option.

The Columbia River and Lake Roosevelt are known fishing habitats and recreation areas. Also, there is a fish farm near the potential intake site in Lincoln in Welsh Creek Cove. A fish

screen will be required on the pump station intake, and is shown on Figure 46; however more detailed analysis and design are required. While most portions of the project can be scaled down for the pilot study, the intake structure and fish screen probably should be built to the full-build out condition. Mobilizing a contractor for a lake tap or microtunnel is costly, and the work is quite difficult. There would likely be a cost savings by constructing one intake at a larger size rather than two smaller projects.

4.7 Fate of Water – Surface Hydrology: The Lake Creek Drainage

This section presents a preliminary analysis of the possible fate of water delivered to the Lake Creek system, the drainage currently ranked as the most favorable one for a potential pilot rehydration project. We have selected Lake Creek for this preliminary analysis because the information collected to-date places it at the top of our recommended list of target drainages for a potential pilot project. The preliminary assessment looks at both potential surface water conditions and groundwater conditions that might result from a future pilot rehydration pilot project.

The primary purpose for this water balance analysis is to provide a rough idea of the potential effect of the pilot study on Lake Creek flows and water levels. In addition, it can inform future decision makers regarding characterization and background data collection needs, monitoring design, and implementation of a potential pilot project. If the pilot project is implemented this model will be refined, or more likely upgraded, using characterization, monitoring, and operations data so it can be used to support project management and operations decisions. The analysis provides an indication that the addition of water to the upstream end of Lake Creek may result in additional water in the lakes near the downstream end of the basin, and recharge to the underlying CRB aquifer.

4.7.1 Available Flow Data and Weather Data

There is no continuous stream gage data available on or near Lake Creek. Spot data was gathered at eleven locations throughout the basin, every other month and once a quarter, from August 1998 to July 1999. This data was collected and presented by Lincoln County Conservation District (LCCD) for a water reuse feasibility study (LCCD, 2000). The Washington Department of Ecology also collected spot data at a single location just upstream of Coffeepot Lake, once a month, from January 1996 to July 1996. The available flow data used in this analysis are summarized in Table 9.

Table 9. Measured (Bold) and Estimated (Italics) Flows in Lake Creek, 1998–1999 Used to Develop Water Budget

Date	Inlet to Upper Twin Lakes (cfs)	Inlet to Coffee Pot Lake (cfs)	Highway 21 crossing above Pacific Lake (cfs)	Upstream of Confluence with Crab Creek (cfs)
Aug-98	**0.5**	*0*	**0**	**0**
Sep-98	*0.5*	*0*	*0*	*0*
Oct-98	**0.86**	*0*	**0**	**0**
Nov-98	**0.87**	**0.037**	**0**	**0**
Dec-98	**2.5**	*5*	*3*	*0*
Jan-99	**14.4**	*20*	*15*	*0*
Feg-99	**40**	**44.6**	**33.4**	**0**
Mar-99	**34.0**	*38*	*25*	*0*
Apr-99	**13.7**	**16.6**	**17.2**	**18.1**
May-99	*5*	**6.61**	**8.58**	**5.36**
Jun-99	**2.24**	**0**	**0**	**0**
Jul-99	**0.639**	**0**	**0**	**0**

Besides the two sets of spot gage data, there is an anecdotal account of water levels and flows during spring 1996 until present. A local resident reported that in the spring of 1996 Pacific Lake filled for the last time and that by the end of 1997 it was dry. The anecdotal data also says that the stream above Coffee Pot Lake usually has less than 1 to 5 cfs of flow in it most of the year, but below Coffee Pot Lake the creek is ephemeral.

There is a long-term record of precipitation and evaporation-transpiration from the Reclamation Agrimet site at Odessa, Washington, which is near the downstream end of the watershed. This record has daily data from 1984 to present.

4.7.2 Basin Areas and Lake Geometry

The Lake Creek drainage basin was sub-divided into four sub-basins (Figure 51), and the drainage area for each sub-basin was found using USGS quad maps in GIS and the USGS's Watershed Boundary Database. The surface area for lakes along Lake Creek was found using the Water Bodies layer of USGS's National Hydrography Database (NHD). The estimated depth for each major lake was obtained from the text of the water reuse feasibility study performed by LCCD. Additional information on lakes was obtained from (Dion et al., 1976).

In order to have enough, complete data to develop a water balance and estimate runoff losses and seepage, the spot data reported in Table 9 was assumed to be the average flow for that month, and flows were interpolated for the missing months from August 1998 to July 1999. Estimated flows are shown highlighted in Table 10.

Table 10. Estimate of Seepage Rates for Lake Creek Sub-basin using Spot Data from August 1988 to July 1999

Location	Estimated Baseflow	Estimated Seepage Loss
Above and within upper Twin Lake	-0.5 cfs	
Above and within Coffee Pot Lake	-0.4 cfs	3.0 cfs
Above and within Pacific Lake		8.4 cfs
Above Crab Creek confluence		3.6 cfs

Examination of the measured and estimated flow in Table 10, in combination with the anecdotal data, allows a few generalizations about the basin.

- Lake Creek, as it leaves the most upstream sub-basin above Upper Twin Lakes, has flow year-round.
- Flow is seen to increase earlier in the year in the upstream reaches compared with downstream reaches.
- Seepage or another similar process depletes Lake Creek flow to zero in the downstream reaches for parts of the year.

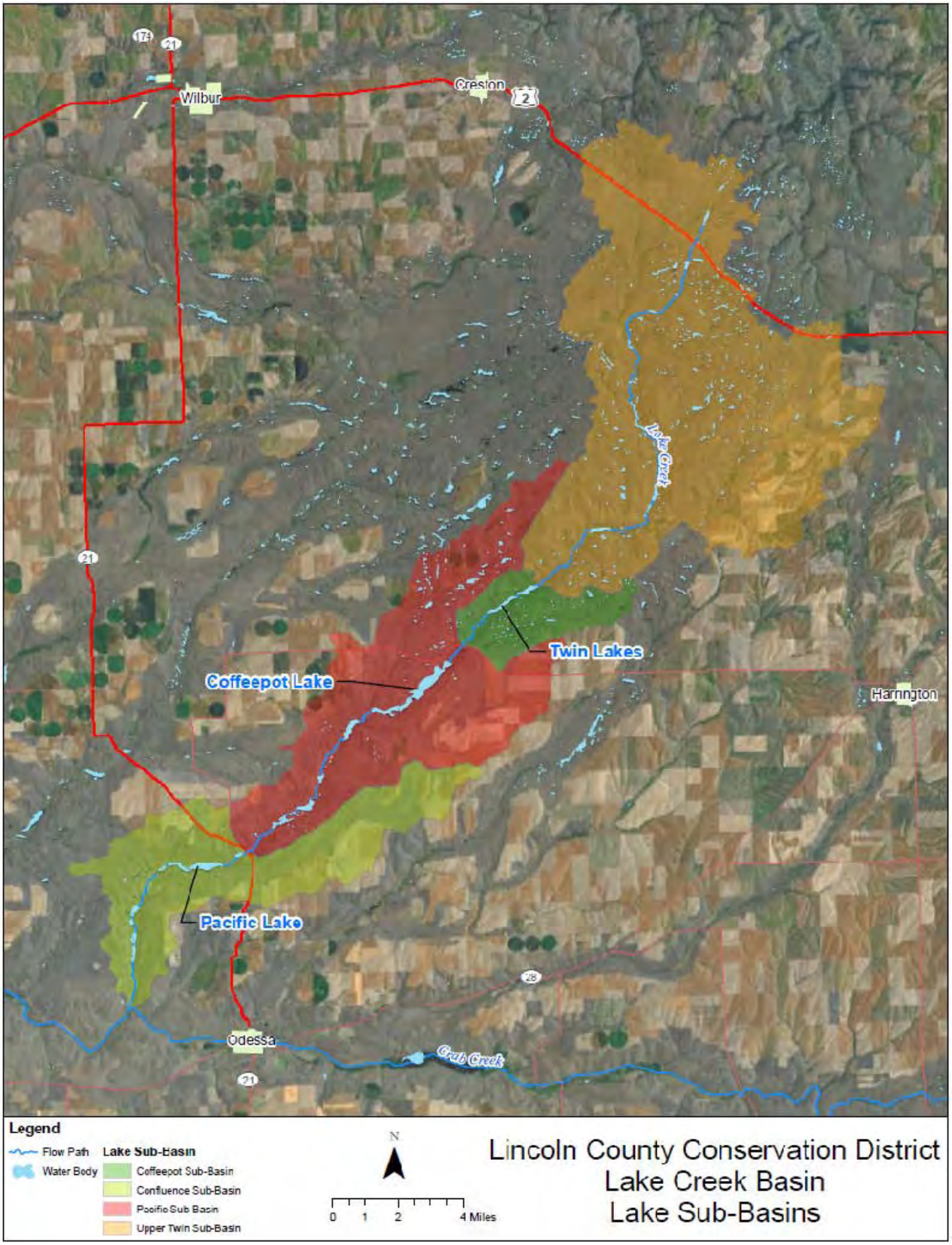

Figure 51. Map of the Lake Creek sub-basin showing the main lakes in the drainage.

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4.7.3 Development of Water Balance

Using the limited available and estimated data to predict the possible effects of adding water to Lake Creek was a three step process, as follows:

1. Estimate runoff loss coefficient in the basin.
2. Estimate the average seepage rate for each sub-basin. Use the available data with the calculated runoff loss and seepage rates to create a water balance model to predict how the basin functions long-term. Adjust the seepage estimates so the long-term model agrees with the historically measured/observed function of the basin.
3. Use the model to estimate the effects of adding pilot program flows to Lake Creek.

Runoff Losses

The runoff loss was calculated for the sub-basin above Upper Twin Lake.

Rloss = (PxA)+Qin -Qout -S

Where:

Rloss is runoff loss

P is precipitation

A is sub-basin area

Qin is inflow from upstream (assumed to be zero, because upper Twin Lakes sub-basin is the most upstream in the Lake Creek basin

Qout is outflow into Upper Twin Lake (estimated from Table 9)

S is seepage

The seepage in the Upper Twin Sub-Basin is assumed to be negative, indicating that base flow discharges into the creek, as opposed to seepage from the creek into the underlying groundwater, which would be positive. Anecdotal reports suggest that there is usually flow in the creek upstream from Coffeepot Lake and the smallest spot measurement was 0.5 cfs. Therefore, the seepage in the runoff loss equation, for Upper Twin Sub-Basin, is held at a constant flow of -0.5 cfs.

The runoff loss was calculated on a monthly basis for August 1998 to July 1999. The total loss for the year is divided by the total annual inflow, and subtracted from one, to get the runoff loss coefficient (Closs) of 85%. A runoff loss of 85% means that 15% of the precipitation on the basin contributes to flow in the stream, prior to losses from seepage or reservoir evaporation. This value was subsequently reduced, as described below.

$$closs = 1 - \frac{\sum Rloss}{\sum P \times A}$$

Calculating Seepage Rates

The runoff loss calculated for Upper Twin Lakes Sub-Basin was applied to the drainage areas of the other three sub-basins. The sub-basin equation for each of these basins was then solved for seepage.

$$S = closs\ (P \times A) + Qin - Qout$$

Where:

S is seepage (+ infiltration, -discharge)

P is precipitation

A is sub-basin area

Qin is inflow from the sub-basin upstream, Table 9

Qout is outflow into the sub-basin downstream, Table 9

Closs is runoff loss coefficient (initially 0.85)

The seepage is calculated on a monthly basis for each sub-basin from August 1998 to July 1999. The seepage is allowed to be positive or negative. These monthly values were summed for an average annual seepage rate.

Water Balance Model

A simple water balance model was developed using the four sub-basins and three lakes. A map of the area with the sub-basins and lakes used in the water balance model is provided in Figure 51. The order that the water balance calculates water flow through the basin is shown in Figure 52.

Because of the scarcity of data available for the basin, several assumptions were made to complete the water balance analysis.

- Runoff loss coefficient is the percent of the precipitation falling on the basin, which results in flow into the creek. This percentage is constant throughout the entire basin and throughout the duration of the water balance model.
- Each sub-basin has a seepage rate that is constant throughout the duration of the model.
- For the water balance, water can only flow out of a lake if the lake is near its maximum volume.

The water balance model was run on a monthly time step from January 1985 through August 2010. The water balance model applies the runoff loss coefficient to the sub-basins and the seepage rates to the lakes. This is discussed in greater detail below.

4.7.4 Sub-Basin Analysis

The equation used for flow through the sub-basins is:

= Qin + closs (P x A)

Qout

The maximum volume for each lake was found by using the surface area found in USGS Water Bodies NHD and the depth provided in the LCCD's reuse feasibility study. The water balance first calculates a change in storage within the lake using weather data, seepage rate, and inflow, see Figure 53. The outflow from the lake to the next sub-basin is not used in this equation.

The change in lake volume is then compared to the existing lake volume and the maximum lake volume using the logic diagramed in Figure 54. This logic sequence decides the volume of the lake and the flow out of the lake for each time step. The flow out of the lake is then used as inflow to the next downstream sub-basin. This step helps approximate the process of the lakes filling during wet periods and draining during dry periods.

Long-Term Modeling Results - Runoff Loss Coefficient Results

The long-term modeling results for the prefeasibility estimate yielded the following:

- Runoff Loss Coefficient: The best runoff loss coefficient found using the Upper Twin sub-basin data was 0.896. That means that only about 10.4% of the precipitation falling on the basin on an annual basis results in runoff. The other 89.6% accounts for things like ET, sublimation of snow, and deep infiltration.

- Seepage Loss Results: The seepage rates found using the spot gage data are summarized in Table 11. The calculation resulted in a net baseflow into the creek upstream of Coffeepot Lake and a net loss to groundwater downstream of Coffeepot Lake. This result is supported by the anecdotal reports that the creek above Coffeepot Lake always has some flow in it, and that below Coffeepot Lake the creek is ephemeral.
- Water Balance Seepage Loss: The water balance model used the initial runoff loss and seepage rates calculated from the 1998-1999 spot data. The model was run with the precipitation and evaporation data for the period 1985 through 2010. The water balance model was calibrated to agree with the anecdotal information that Pacific Lake has not filled since 1999. The resulting estimated seepage losses are shown in Table 12. This is approximately a 27% increase in seepage in the downstream reaches, compared with the originally estimated seepage losses from the spot data.
- Predictive Results: Using these long term seepage losses, the outflow from the Lake Creek sub-basin into Crab Creek is estimated as shown in Figure 55. The estimated storage in each modeled lake is shown in Figures 56 through 58.

Table 11. Estimate of Seepage Rates for Lake Creek Sub-basin Based on Long-Term Water Balance Model, January 1985 to August 2010

Location	Estimated Baseflow	Estimated Seepage Loss
Above and within upper Twin Lake	-0.5 cfs	
Above and within Coffee Pot Lake	-1.0 cfs	5.5 cfs
Above and within Pacific Lake		12 cfs
Above Crab Creek confluence		3.0 cfs

Table 12. Summary of Predictive Results for when Water Is and Is Not Added to Lake Creek

Added inflow for 10 months per year (cfs)	Predicted # of years out of 26 Pacific Lake would fill	Predicted average annual flow from Lake Creek into Crab Creek (cfs)	Predicted increase in groundwater seepage (cfs)
0	5	1.4	0
5	16	3.0	2.4
10	24	5.5	3.8
15	26	8.4	4.6

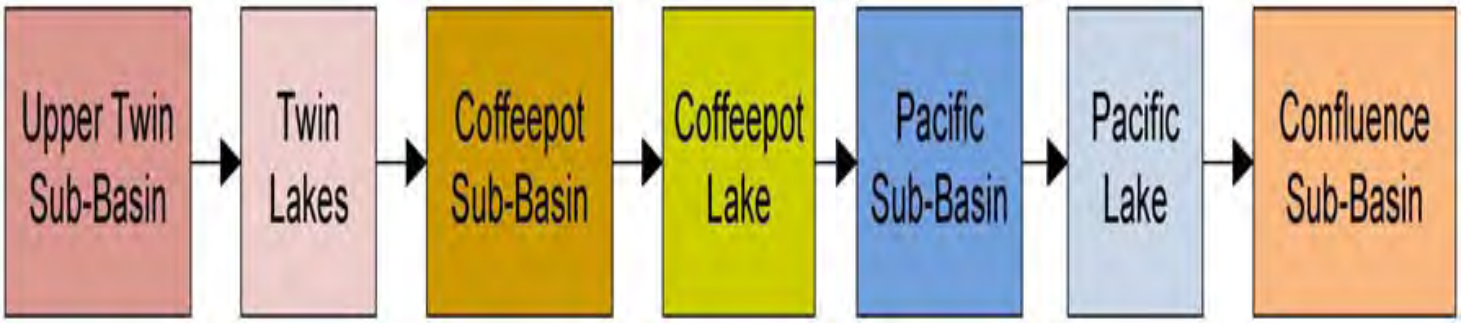

Figure 52. The order water flows through the four subdivisions of the Lake Creek sub-basin modeled for this effort. Each box represents an equation or a set of equations used in the water balance model.

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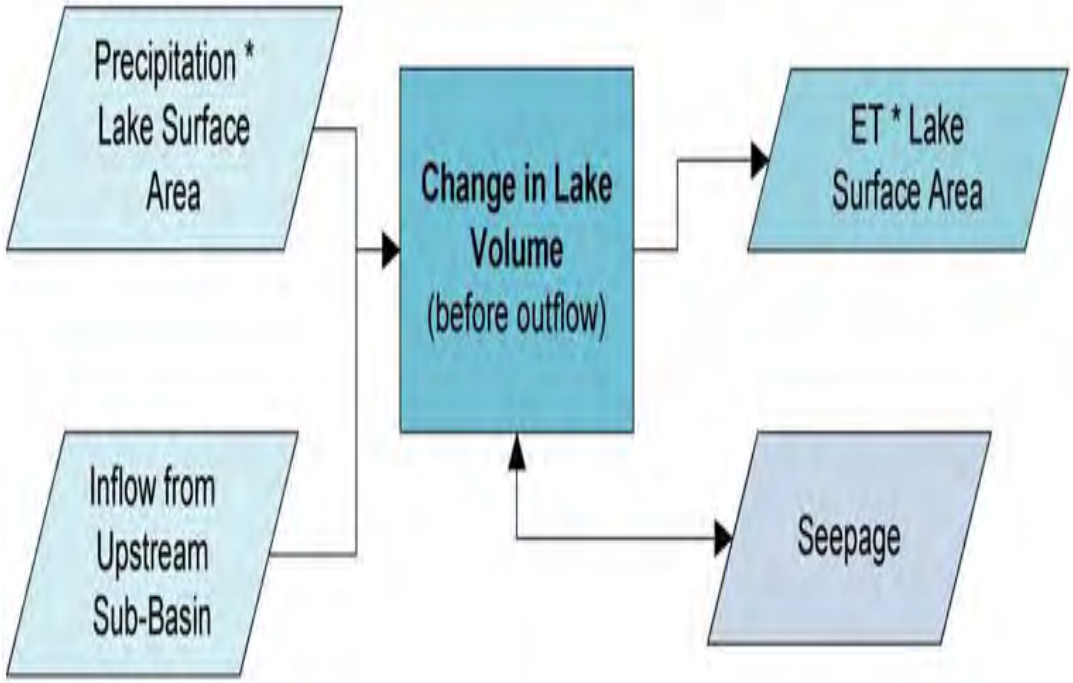

Figure 53. Diagram showing the relationship between the parameters used to calculate changes in lake volume.

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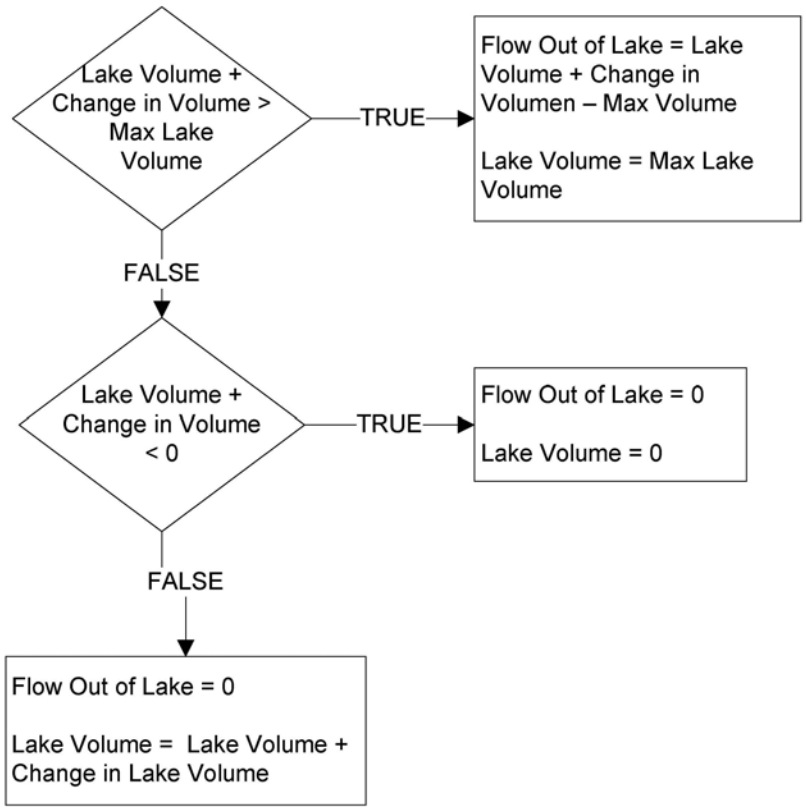

Figure 54. Diagram showing the logic used for calculating lake volume and the flow out of a lake for each time step in the water balance model.

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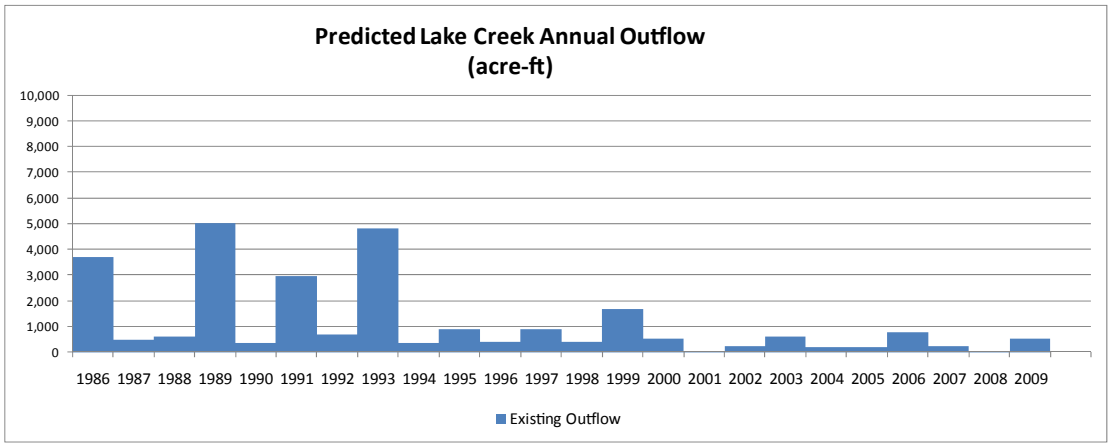

Figure 55. Graph showing predicted annual flow in Lake Creek at its confluence with Crab Creek. Predicted flow is from the long-term water balance model.

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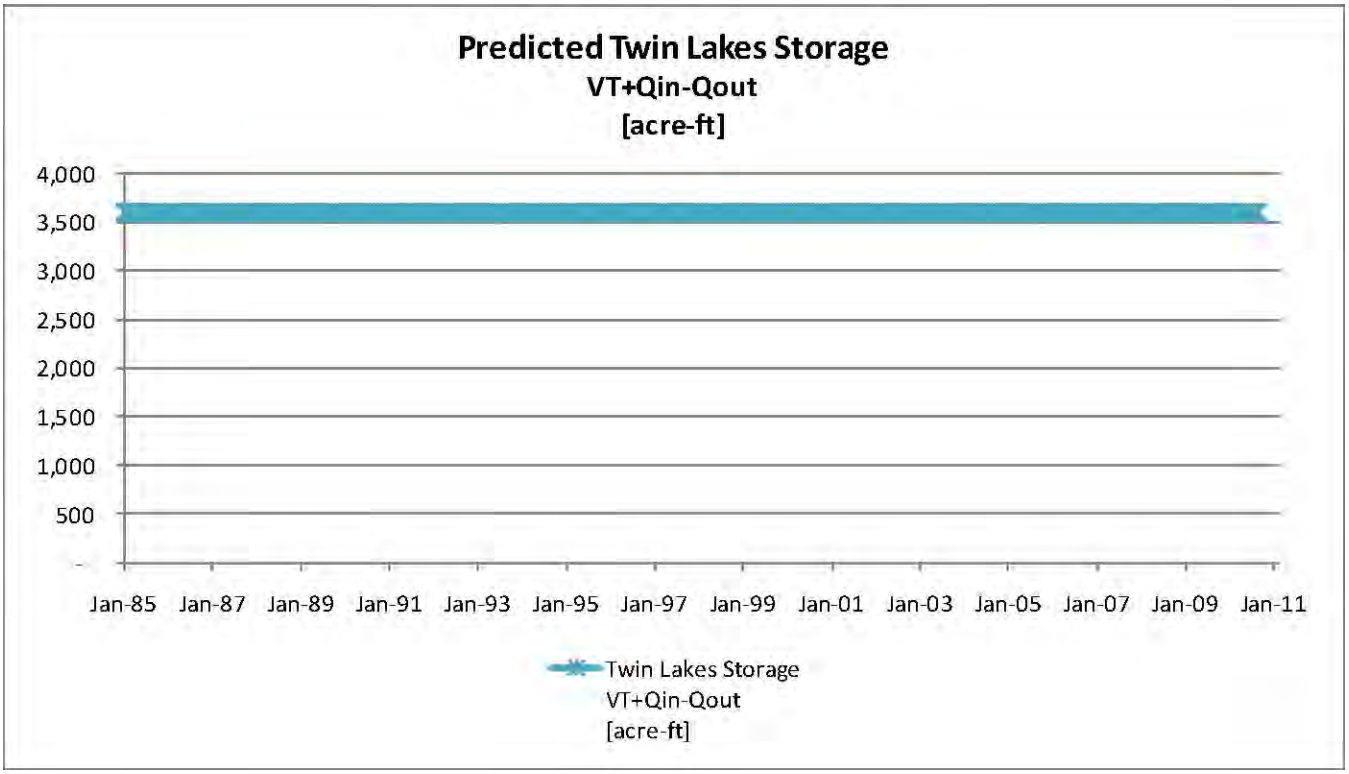

Figure 56. Graph showing predicted volume in Twin Lakes derived from the long-term water balance model.

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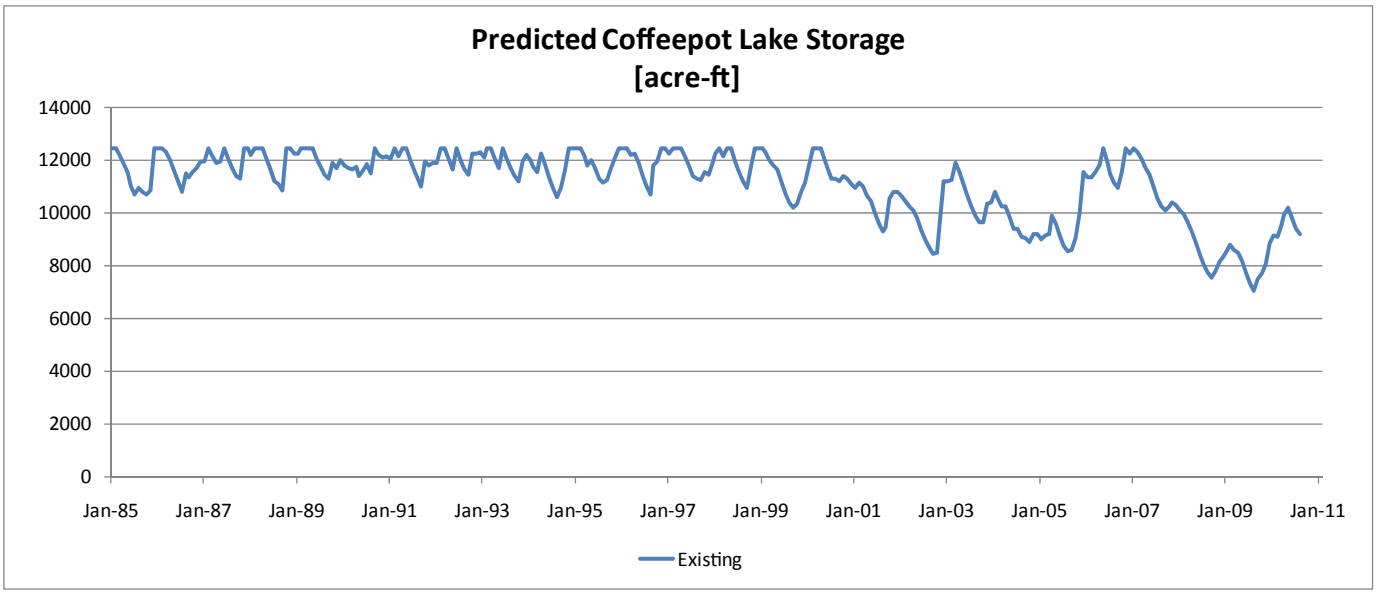

Figure 57. Graph showing predicted volume in coffee Pot Lake derived from the long-term water balance model.

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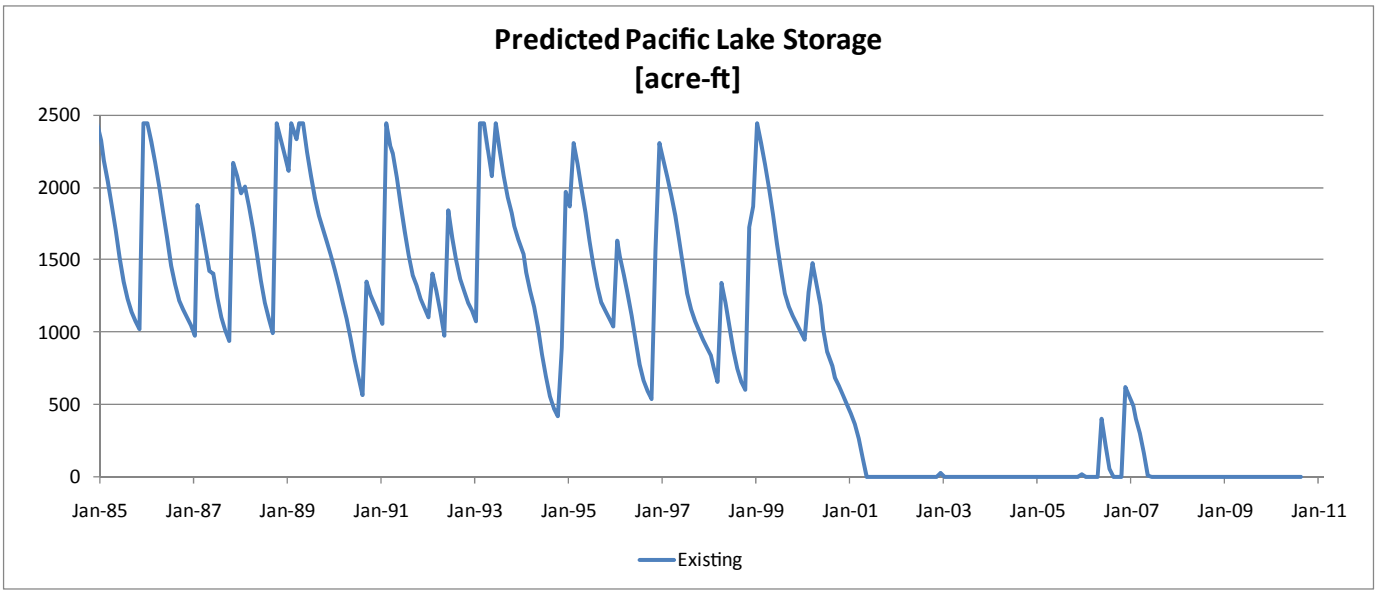

Figure 58. Simulated historical volume in Pacific Lake derived from the long-term water balance model.

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4.7.5 Water Balance Conclusions

The Lake Creek water balance model suggests that the Lake Creek basin loses approximately 19 cfs to seepage, when there is water available. The average inflow to the basin from precipitation runoff is estimated to be about 14 cfs. Although based on a very small amount of measured data, if the assumptions are close to being correct, these numbers suggest that the water balance of Lake Creek could be altered from being a net losing stream (with losses greater than gains and frequent zero outflow), to a flowing stream, with the addition of as little as 5 to 10 cfs of supply.

The Lake Creek water balance model provides the foundation of a predictive method to estimate the effect on Lake Creek water balance of a proposed rehydration project. By adjusting the inflow to the Upper Twin sub-basin, the model can predict the water levels in the lakes and the flow out of the basin into Crab Creek. A summary of the number of years Pacific Lake is predicted to fill during the water balance simulation and the average additional seepage and flow in Lake Creek at the confluence with Crab Creek is summarized in Table 12. The predicted effect on Pacific Lake of adding as little as 10 cfs of additional water to the stream has the potential of causing a dramatic impact to lake storage. The predictive model indicates that Pacific Lake could fill in nearly every year with an added 10 to 15 cfs of inflow and that this would also produce significant increases in the volume of water entering the groundwater basin contributing to Crab Creek and the Odessa Groundwater Management Subarea. The model-predicted storage in Pacific Lake, assuming a constant 10 cfs of supplementation, is compared with the existing conditions model-predicted Pacific Lake contents in Figure 59.

4.8 Conceptual Groundwater Model

As is suggested in the previous section, there appears to be capacity for stream losses into the aquifer system underlying the Lake Creek drainage. This certainly is suggested by the anecdotal history of the drainage, especially below Coffee Pot Lake. The purpose of this section of the prefeasibility report is to present a conceptual groundwater flow model that explores the potential fate of water seeping from stream channel and lake beds, once it enters the basalt aquifer system underlying the Lake Creek drainage. If the proposed project moves forward this conceptual model will provide a basis for proposing a groundwater monitoring program for the project, and as this data is collected it will be refined to such time as it can be used as the basis for a numerical model that will have utility in predicting future project performance.

Basic assumptions made in this conceptual groundwater model are as follows:

- Within the Lake Creek drainage we assume that vertical leakage into and through the basalt is effective to depths of 200 to 300 feet. Below those depths vertical leakage is

assumed to be negligible and groundwater flow is predominantly within interflow zones and parallel to bedding dip.

- Regional groundwater flow direction is from north-northeast to the south-southwest, down dip.
- Vertical leakage into the basalt aquifer system is negligible above Coffee Pot Lake, as indicated by generally unchanged long-term water levels in Twin Lakes in the upper reach of the drainage.
- Seepage losses become progressively greater below Coffee Pot Lake, as evidenced by each lake downstream appearing to be dryer. Deer Lake has lost approximately one-third of its volume, Browns Lake approximately one-half, Taveres Lake over 90%, and lakes below there from Neves Lake to Bob's Lake, including Pacific Lake, are completely dry.
- The fold mapped at the narrows on Coffee Pot Lake and the Roza Dike identified at Taveres Lake are interpreted to contribute to these observed hydrologic conditions with them impeding vertical leakage and lateral flow away from the upper portion of the drainage system.

Groundwater systems within the shallowest units, those completely eroded through in the middle to lower reaches of these drainages, would be fairly localized. Based on northwest-southeast strike and southwest dip, water moving through these interflow zones will move predominantly to southwest. Given unit distribution, if water is introduced into these units in the upper stream reaches, much of it will discharge into the canyons to the southwest where the units are fully incised through, including Crab Creek (Figure 60). Generally, these shallowest units would correspond to the Wanapum Basalt.

The uppermost Grande Ronde unit in the County, the Sentinel Bluffs Member, does underlie almost the entire area (Figure 22). Mapped distributions show it present within 200 feet of the bedrock bottoms of large reaches of all the drainages in central Lincoln County (Figure 22, 61). This system includes reaches as far northeast as Highway 21 on Cannawai Creek, above Highway 21 on Marlin Hollow, and upstream from the mouth of Lake Creek to Twin Lakes. Based on the strike and dip of the unit, groundwater (naturally occurring and artificially recharged) movement within it will be predominantly down dip in interflow zones, to the southwest (Figure 61). However, the presence of at least one Roza Dike between Deer Lake (still contains water) and Pacific Lake (dry) may influence this flow path (Figures 61, 62). If this dike system is a significant barrier to groundwater movement, the best recharge opportunities for the Sentinel Bluffs would be southwest of it, down dip of the dike system. In Lake Creek that would be the area downstream of Deer Lake.

GWMA maps show the top of the Sentinel Bluffs Member exposed in Crab Creek near and west of Odessa in down dip areas. Given that, one could expect some discharge from the Sentinel Bluffs into the Crab Creek drainage (Figure 61). In addition though, given the depth of incision into the top of the Sentinel Bluffs (generally less than 100 feet), and its regional dip to the south-southwest, one should expect the multiple interflow zones present within it to carry recharged water in that direction, assuming other barriers do not exist. If recharged groundwater can flow unimpeded to the south-southwest, it would flow into eastern Grant County and the northwestern of Adams County (Figure 61).

The deeper Grande Ronde units present in Lincoln County, the Grouse Creek Member and Wapshilla Ridge Member, are only found within a few hundred feet of the top of basalt on the northern highlands bordering the northernmost edge of the CRBG. Given these mapped distributions, it seems likely that recharge pathways into these deeper units will be torturous and recharge timing slow. The most likely pathways for such water would be along the up-dip edges of sub-units, where water moving down dip along an interflow zone splits as a new unit intervenes (Figurer 31). If water can get into these units as a result of recharge along the upper reaches of this drainage, it would move generally to the south-southwest. Generally though, given the current project concept to deliver water down the Lake Creek system, we would speculate that recharge of these deeper Grande Ronde units by a potential recharge project would be limited.

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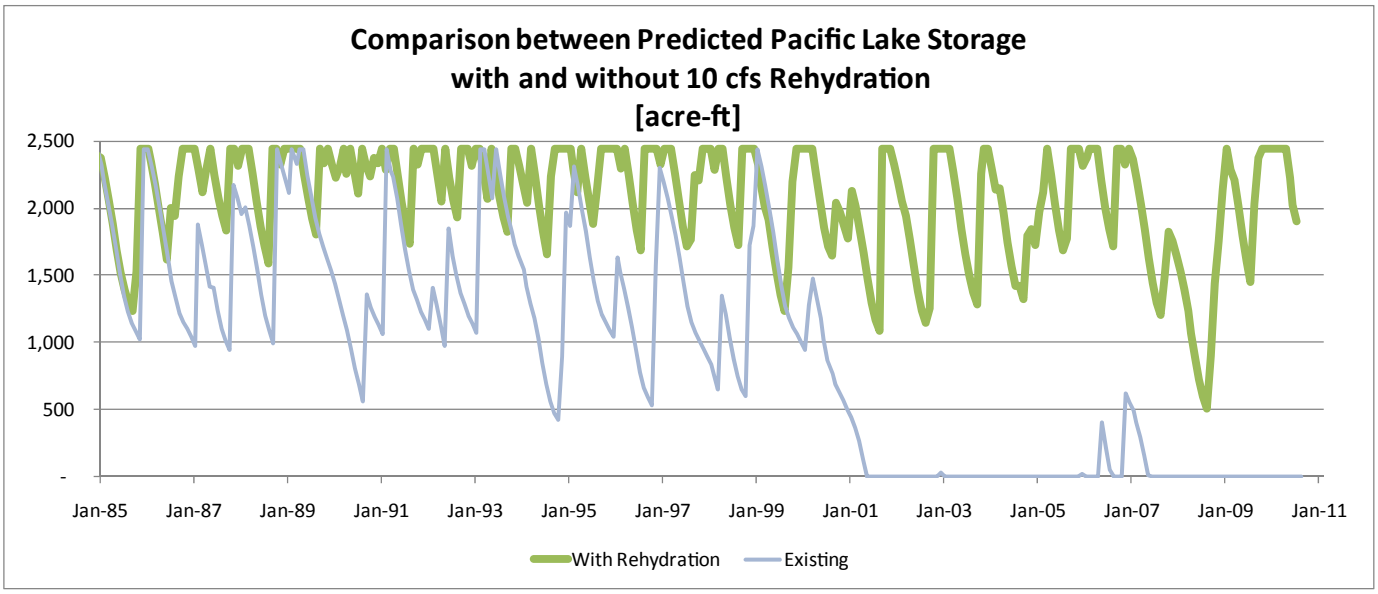

Figure 59. Predicted water volume in Pacific Lake with and without artificial rehydration. The graphs are derived from the long-term water balance model.

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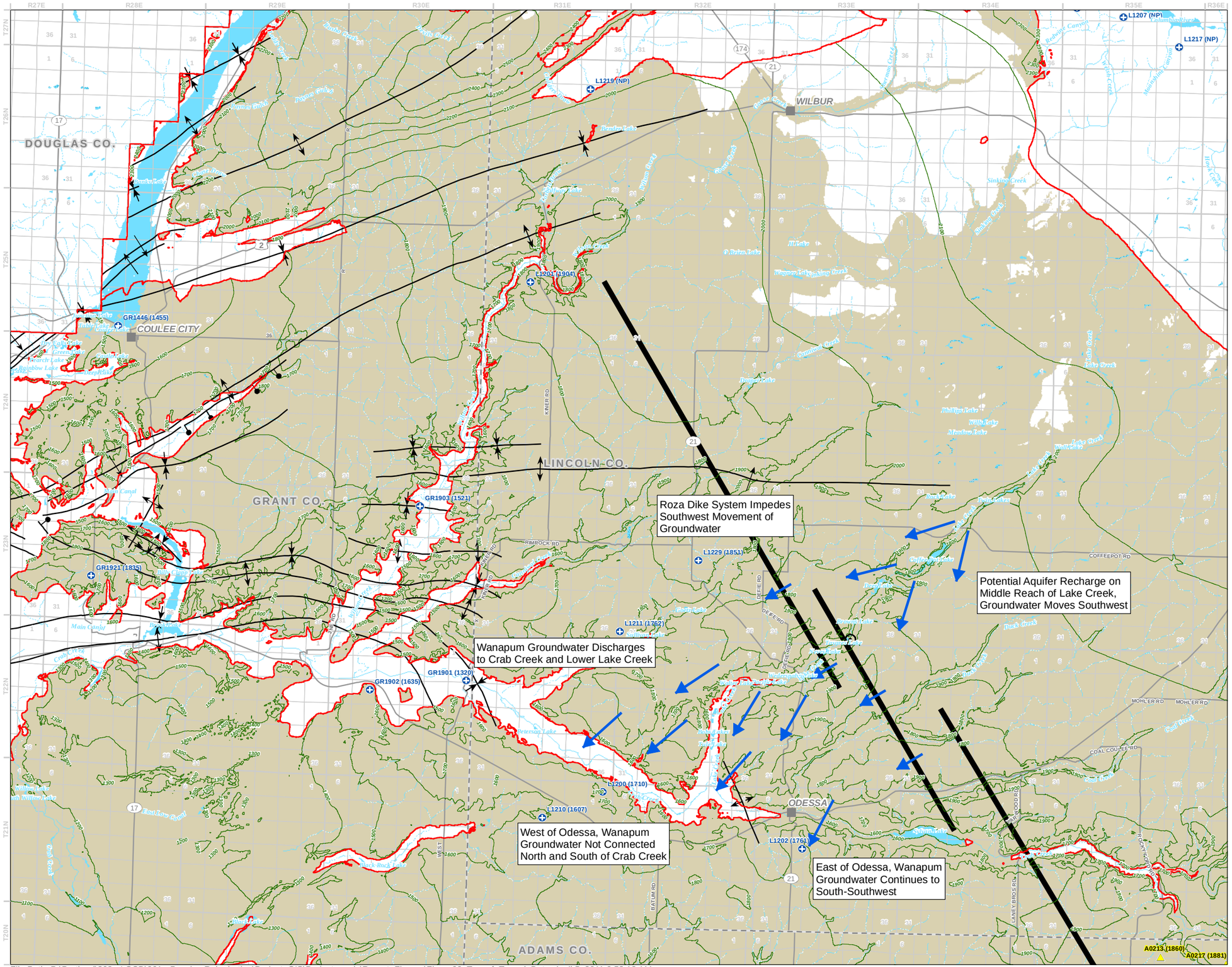

FIGURE 60

Structure Contour Map of the Top of the Roza Member (Tr) and Conceptual Comments on Potential Groundwater Movement in the Unit with Recharge Along Lake Creek

Lincoln County, Washington

LEGEND

- Inferred Direction of Groundwater Movement in the Wanapum Basalt
- Areas Where Top of Tr is Within 200 feet of the Top of Basalt
- Tr Pinchouts
- Top of Tr - 100 foot Contours
- Control Wells
- Geophysics Wells (Completed)

Existing Geologic Structure

- High-Angle Fault
- Anticline
- Monocline
- Syncline
- Inferred Positions of Roza Dikes
- Vents

Existing Features

- Cities
- Counties
- Highways and Major Roads
- Perrenial Watercourse
- Intermittent Watercourse
- Perennial Waterbody
- Intermittent Waterbody

N

0 2 4 6 Miles

MAP NOTES:
Date: April 5, 2011
Data Sources: Franklin Conservation District, WA DNR, USGS, ESRI

GSI Water Solutions, Inc.

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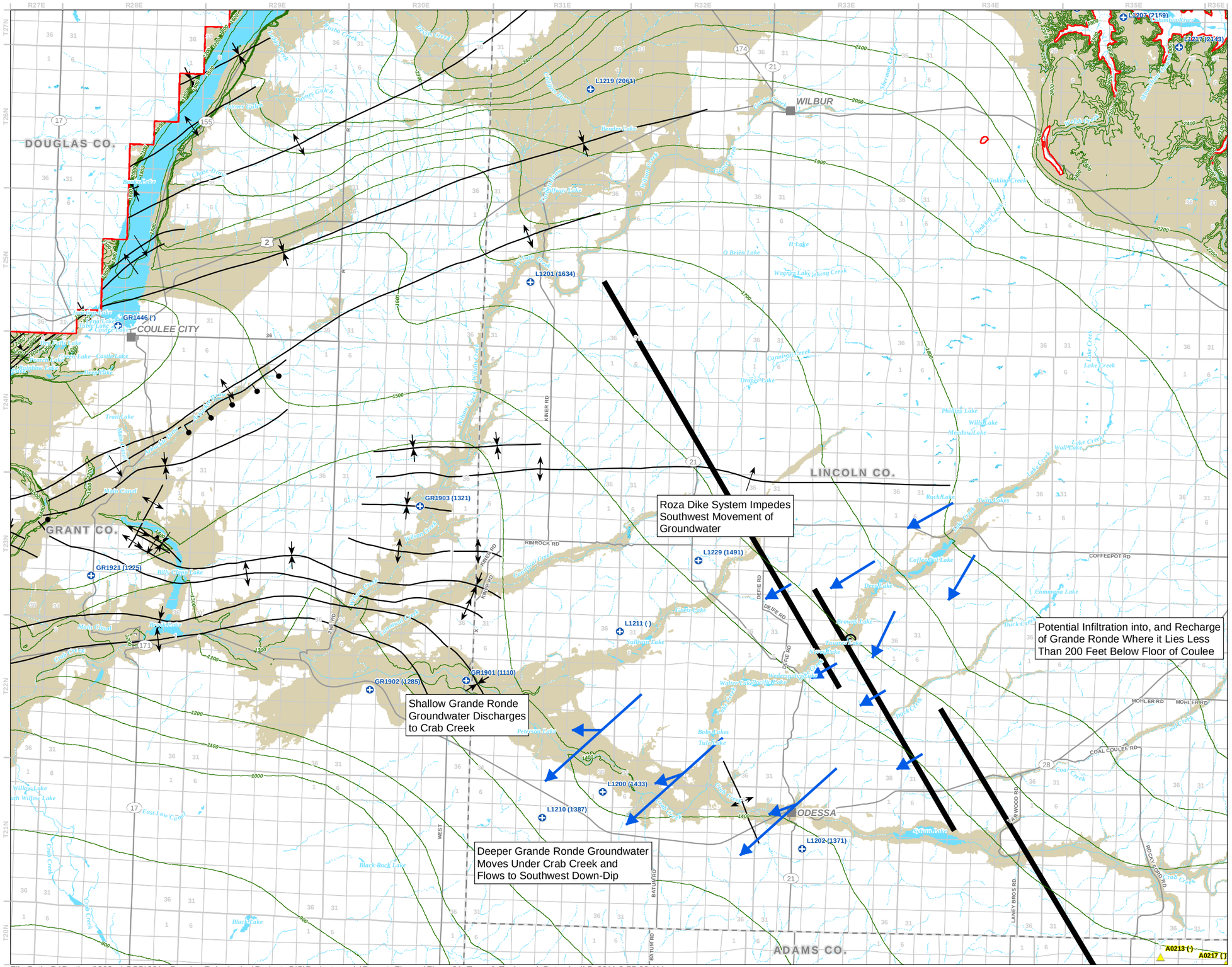

FIGURE 61

Structure Contour Map of the Top of the Sentinel Bluffs Member (Tgsb) and Conceptual Comments on Potential Groundwater Movement in the Unit with Recharge Along Lake Creek

Lincoln County, Washington

LEGEND

- Inferred Direction of Groundwater Movement in the Upper Grande Ronde Basalt
- Areas Where Top of Tgsb is Within 200 feet of the Top of Basalt
- Tgsb Pinchouts
- Top of Tgsb - 100 foot Contours
- Control Wells
- Geophysics Wells (Completed)

Existing Geologic Structure

- High-Angle Fault
- Anticline
- Monocline
- Syncline
- Inferred Positions of Roza Dikes
- Vents

Existing Features

- Cities
- Counties
- Highways and Major Roads
- Perrenial Watercourse
- Intermittent Watercourse
- Perennial Waterbody
- Intermittent Waterbody

N

0 2 4 6 Miles

MAP NOTES:

Date: April 5, 2011

Data Sources: Franklin Conservation District, WA DNR, USGS, ESRI

GSI Water Solutions, Inc.

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