OTTER CREEK MINE

ENVIRONMENTAL BASELINE REPORT 325A

ALLUVIAL VALLEY FLOOR IDENTIFICATION AND ANALYSIS

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July 2012
September 2014

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1.0 INTRODUCTION

Otter Creek Coal, LLC (OCC) intends to conduct coal mining and reclamation operations adjacent to the valley of Otter Creek, a permanent stream in a semi-arid region of Montana. Otter Creek has three intermittent tributaries within and adjacent to the Otter Creek coal tracts – Home Creek, Threemile Creek and Tenmile Creek, all of which flow to Otter Creek from the east. In addition, within the area of interest, there are three named and several unnamed ephemeral Otter Creek tributaries. The purpose of this Report is to present the information required under ARM 17.24.325 to enable the Montana Department of Environmental Quality (MDEQ) to make a determination as to the presence or absence of an alluvial valley floor (AVF) in the adjacent reaches of Otter Creek and its tributary drainages, and in the event of an affirmative determination, assess significance, confirm the essential hydrologic functions and assess the mine plan with respect to protection of those hydrologic functions.

1.1 REGIONAL SETTING

The Otter Creek drainage basin has a watershed area of approximately 700 square miles lying entirely within Montana. It is a tributary to the Tongue River with the confluence at Ashland in Rosebud County. The Tongue River arises in the Big Horn Mountains of Wyoming, has a total watershed area of about 5400 square miles, and enters the Yellowstone River at Miles City, Montana.

The lower reach of Otter Creek, generally below the Indian Creek confluence, is a permanent stream, although flow has been observed to cease during extended periods of drought. Based on long-term records at the USGS gauging station at the Highway 212 crossing just east of Ashland (USGS 063307740), the daily average and median flows are 4.7 and 2.7 cfs respectively, with a range of daily instantaneous flows from zero to 425 cfs. Flows higher than about 50 cfs are associated with infrequent flood events. Median and average daily specific conductivity (SC) are nearly identical at 2700 and 2740 uS/cm, and sodium adsorption ratio (SAR) typically is about 6.0 with a maximum of 6.7.

The Otter Creek drainage area comprises about 13 percent of the total Tongue River drainage area, but its relative contribution is much less due to the mountain headwaters of the Tongue River and regulation of flows by Tongue River Reservoir. At the USGS gauging station at Brandenburg Bridge (USGS 06307830) downstream of Ashland, average and median daily discharges for the period of record are 402 and 260 cfs respectively. Hence, daily average and median Otter Creek flows are 1.2 and 1.0 percent of Tongue River flows, respectively.

Otter Creek is located in the North-Central part of the Powder River Basin, an elongate geologically structural, sedimentary and physiographic basin that extends nearly north to south from southeastern Montana into northeastern Wyoming. In Montana, the axis of the Powder River Basin synclinal feature trends northeasterly and is traced approximately by the Tongue River. During Late Cretaceous (72-65 MYa) and Tertiary Paleocene-Eocene (65-33.7 MYa) periods, as much as 8,000 feet of sediments were deposited into the Powder River Basin. These sediments were derived from weathering, erosion and transport from exposed landmasses located to the east in central North Dakota and South Dakota (Black Hills Uplift), and the actively uplifting Big Horn Mountains to the west (Curry 1971).

Surface geology of the Otter Creek drainage basin is dominated by the Tertiary Fort Union Formation, with Quaternary unconsolidated deposits common in valleys, ephemeral drainages, and on lower slopes. The Late Paleocene-Early Eocene age (50-57 MYa) Wasatch Formation conformably overlies the Paleocene Fort Union Formation. It crops out to the south in the headwaters region of Otter Creek and along some high ridges to the west and south in Wyoming.

Early Tertiary, Paleocene age (58-65 MYa) strata assigned to the Fort Union Formation are the uppermost and youngest sediments exposed in the Otter Creek drainage basin. In descending order, the Fort Union Formation includes the Tongue River, the Lebo Shale, and Tullock members. Throughout most of the basin area, the upper two-thirds of the Tongue River Member, approximately 1,400 feet, has been removed by erosion. Sediments in the Tongue River Member consist of interbedded claystone and sandstone further interbedded with shale, claystone, and carbonaceous shale and laterally continuous thick to moderately thick coal beds.

In the project area, about 500 feet of the lower part of the Tongue River Member is all that remains, from approximately 150 feet above the Knobloch Coal to the base of the member, which includes the Flowers-Goodale Coal (Roberts) and Kendrick (Terret) seam, and the underlying shale (Wheaton et al. 2008). The base of the Tongue River Member and older underlying units are not exposed in the Otter Creek drainage basin.

Locally, and also over extensive areas along the exposed outcrops of many Fort Union Formation coal beds, the seams have caught fire and burned in place resulting in baking and fusing of the overlying strata forming a natural brick-like material, reddish-brown to orange-red in color referred to as scoria, clinker, or burn. These materials are particularly extensive on either side of Otter Creek and north of Threemile Creek.

The climate is continental, having cold winters and warm summers with a growing season extending from April to September in most years. Average high temperatures range from about 32 degrees F in January to around 88 degrees F in July. Average low temperatures are around 7 degrees F in January and about 56 degrees F in July. Monthly precipitation varies from about 0.5 inches in January and February to around 2.50 inches in May and June, with annual average values around 14 inches. Total snowfall generally is greatest in December and January, when it is around 6 inches. The total annual snowfall is about 34 inches.

Monthly and annual precipitation records are components used in analyzing and interpreting hydrologic and agricultural production data. The nearest NWS station with long-term precipitation records is located at Sonnette, Montana, about 20 miles to the southeast. Monthly precipitation from 1972 forward is shown on Table 1-1.

Soils reflect the variability of parent materials, and are predominantly of silt loam to silty clay loam texture, with some areas of clay loam and sandy loam.

In upland areas vegetation is dominated by mixed prairie grasses and forbs with areas of big sagebrush dominance and some go-back areas dominated by introduced pasture grasses on gentler slopes. Ponderosa pine forest and savannah dominate on upper slopes and ridges where well drained sandy and scoria derived soils occur, particularly on north- and east-facing slopes. Upland drainage bottoms typically are characterized by juniper growth in upper reaches, and low shrubs and herbaceous cover in lower reaches.

The flood plains of Otter Creek and its major tributaries are utilized for hay production, consisting primarily of crested wheatgrass, smooth brome and alfalfa, to provide winter feed and support the predominant land use of cattle ranching. Cropland other than hay has not been identified in the project area, and cropping of uplands is nearly nonexistent, limited to deeper soils on lower slopes and benches near the flood plains. The predominant land type in upland areas is undeveloped rangeland. Besides low shrubs – primarily snowberry and rose – woody plant growth along Otter Creek is limited almost exclusively to box elder; near absence of cottonwood likely reflects saline conditions in soils and shallow groundwater.

1.2 PREVIOUS INVESTIGATIONS

There has been interest in developing coal reserves at Otter Creek since the 1970's, and as a consequence there have been numerous geologic and hydrologic investigations in the Otter Creek area. From a hydrologic standpoint, the most relevant are Cannon (1985), Lambing and Ferriera (1986), and McLymonds (1984). None of these investigations addressed the alluvial valley floor criteria, although Cannon (1985) alludes to the "shallow alluvial aquifer that provides subirrigation," and McLymonds (1984) mentions use of Otter Creek water for "irrigating alfalfa fields" "during spring floods".

The Office of Surface Mining Reclamation and Enforcement (1985) (OSMRE) published reconnaissance maps to aid in identification of alluvial valley floors in the Powder River

Basin of Montana and Wyoming. This mapping showed potential alluvial valley floors in Otter Creek and its tributaries Tenmile Creek, Threemile Creek, Home Creek and East Fork Otter Creek. As described below, this mapping was used as a basis for initial mapping of the AVF study area with respect to soils and vegetation.

1.3 PROJECT OVERVIEW

In November 2009, Ark Land Company (Ark), an affiliate of Arch Coal Inc. (Arch), entered into a coal lease agreement with Great Northern Properties (GNP) covering coal resources on alternate sections in the Otter Creek Tracts in Powder River County, Montana. The coal reserve area is in the "checkerboard" created by railroad land grants in the late 1800's. In April 2010, Ark, for fair market value, obtained State of Montana coal interests on the intervening sections. These coal lease interests comprise approximately 17,900 contiguous acres containing an estimated 1.5 billion tons of surface mineable coal. Otter Creek Coal, LLC, a subsidiary of Arch was formed to develop the Otter Creek coal tracts.

Plate 1 shows the location of the Otter Creek coal tracts relative to the town of Ashland, and major highways and public roads. Mining will begin on Tract 2, east of Otter Creek and between Tenmile and Threemile Creeks as shown. Initial mine development will involve opening of a mobile equipment box cut east of and generally parallel to Otter Creek, leaving a band of in-place coal between the box cut and the Otter Creek alluvium in the south and the Knobloch coal burn line (clinker) in the north. Once the box cut is established, mining will transition to north-south dragline cuts progressing eastward toward a final pit closure near the Custer National Forest (CNF) boundary.

The alluvial valley floor investigation study area (Plate 1) generally encompasses the reach of Otter Creek from the Tenmile Creek road crossing to the mouth, and including the lower reaches of the tributaries entering Otter Creek within that reach. For purposes of soils and vegetation mapping, the potential AVF mapping by OSMRE (1985) was used as a starting point, with an approximate 500-foot buffer area to ensure inclusion of all potential AVF areas. Mapping was extended up Tenmile, Threemile, Home and East Fork Otter Creeks to the CNF boundary. Also, Otter Creek was mapped for a short distance upstream from the

Tenmile Creek road crossing. In short, the AVF study area is liberally overdrawn to assure inclusion of any potential AVF areas within the area of interest.

Referring to Plate 1, it is important to note that the projected mining area does not extend into the Otter Creek AVF study area, and that a buffer area of at least 500 feet is maintained between the mining area and the floodplains and terrace complex of Otter Creek and Threemile creek. The only mining related disturbance within the Otter Creek flood plain will be two transportation corridors for the main access road and conveyor line to the rail loop and associated facilities west of Otter Creek.

1.4 REGULATORY BACKGROUND

"Alluvial valley floor" is defined at 82-4-203(3) MCA:

(a) "Alluvial valley floor" means the **unconsolidated stream-laid deposits holding streams** where water availability is sufficient for **subirrigation** or **flood irrigation agricultural activities**.

(b) The term does not include **upland areas** that are generally overlain by a thin veneer of colluvial deposits composed chiefly of debris from sheet erosion and deposits by unconcentrated runoff or slope wash, together with talus, other mass movement accumulation, and windblown deposits (emphasis added; emphasized terms are defined at ARM 17.24.301).

Additional definitions referencing "alluvial valley floor" and related terms include the following from ARM 17.24.301:

(8) "Agricultural activities or farming" means, with respect to alluvial valley floors, use of any tract of land for the production of plant or domestic animal life where the use is enhanced or facilitated by subirrigation or flood irrigation associated with alluvial valley floors. These uses include, but are not limited to, the pasturing, grazing, or watering of livestock, and the cropping, cultivation, or harvesting of plants whose production is aided by the availability of water from subirrigation or flood irrigation. Those uses do not include

agricultural practices which do not benefit from the availability of water from subirrigation or flood irrigation.

(17) "Arid and semiarid area" means, in the context of alluvial valley floors, an area experiencing water deficits, where water use by native vegetation equals or exceeds that supplied by precipitation.

(39) "Ephemeral drainageway" is defined in 82-4-203, MCA, as "a drainageway that flows only in response to precipitation in the immediate watershed or in response to the melting of a cover of snow or ice and is always above the local water table."

(40) "Essential hydrologic functions" means, with respect to an alluvial valley floor, the collecting, storing, regulating, and making the natural flow of surface or ground water, or both, usefully available for agricultural activities by reason of the valley floor's topographic position, the landscape, and the physical properties of its underlying materials. A combination of these functions provides a water supply during extended periods of low precipitation.

(a) The role of the valley floor in collecting water includes accumulating runoff and discharge from aquifers in sufficient amounts to make the water available at the alluvial valley floor greater than the amount available from direct precipitation.

(b) The role of the alluvial valley floor in storing water involves limiting the rate of discharge of surface water, holding moisture in soils, and holding ground water in porous materials.

(c) The role of the alluvial valley floor in regulating the natural flow of surface water results from the valley geomorphic characteristics and physical configuration of the channel flood plain and adjacent low terraces.

(d) The role of the alluvial valley floor in regulating the natural flow of ground water results from the properties of the aquifers which control inflow and outflow.

(e) The role of the alluvial valley floor in making water usefully available for agricultural activities results from the existence of flood plains and terraces where surface and ground water can be provided in sufficient quantities to support the growth of agriculturally useful plants, from the presence of earth materials suitable for growth of agriculturally useful plants, from the temporal and physical distribution of water making it accessible to plants throughout the critical phases of the growth cycle either by flood irrigation or by subirrigation from the natural control of alluvial valley floors in limiting destructive extremes of stream discharge, and from the erosional stability of earth materials suitable for the growth of agriculturally useful plants.

(44) "Flood irrigation" means, with respect to alluvial valley floors, supplying water to plants by natural overflow or the diversion of flows, so that the irrigated surface is largely covered by a sheet of water.

(61) "Intermittent stream" means a stream or reach of a stream that is below the local water table for at least some part of the water year, and obtains its flow from both surface runoff and ground water discharge.

(69) "Materially damage the quantity or quality of water" means, with respect to alluvial valley floors, to degrade or reduce by strip or underground coal mining or reclamation operations, the water quantity or quality supplied to the alluvial valley floor to the extent that resulting changes would significantly decrease the capability of the alluvial valley floor to support agricultural activities. The term "material damage" may be applied to values other than those associated with alluvial valley floors.

(84) "Perennial stream" means a stream or reach of a stream that flows continuously during all of the water year as a result of ground water discharge or surface runoff. The term does not include intermittent streams or ephemeral streams.

(118) "Subirrigation" means, with respect to alluvial valley floors, the supplying of water to plants from a sub-surface zone where water is available and suitable for use by vegetation. Subirrigation may be identified by:

(a) diurnal fluctuation of the water table, due to the differences in nighttime and daytime evapotranspiration rates;

(b) increasing soil moisture from a portion of the root zone down to the saturated zone, due to capillary action;
(c) mottling of the soils in the root zones;
(d) existence of an important part of the root zone within the capillary fringe or water table of an alluvial aquifer; or
(e) an increase in streamflow or a rise in ground water levels, shortly after the first killing frost on the valley floor.

(132) "Unconsolidated streamlaid deposits holding streams" means, with respect to alluvial valley floors, all flood plains and terraces located in the lower portions of valleys which contain perennial or other streams with channels.

(134) "Undeveloped rangeland" means, for purposes of alluvial valley floors, lands that have not been agronomically altered by farming, seeding, interseeding, or other means, to increase production over the native condition and that are not intensively managed as irrigated or subirrigated pastures.

(136) "Upland areas" means, with respect to alluvial valley floors, those geomorphic features located outside the floodplain and terrace complex, such as isolated higher terraces, alluvial fans, pediment surfaces, landslide deposits, and surfaces covered with residuum, mud flows or debris flows, as well as highland areas underlain by bedrock and covered by residual weathered material or material deposited by sheetwash, rillwash, or wind.

1.5 DISCUSSION OF AVF DEFINITIONS AND CRITERIA

Taken together, these definitions establish the criteria for determining the presence or absence of an AVF, and, if present, delineating the AVF for regulatory purposes under the Montana strip and underground Reclamation Act (MSUMRA). From them, a listing of objective criteria can be constructed to include or exclude determination as an AVF:

- “Unconsolidated streamlaid deposits holding streams” is defined, but the definition – “all flood plains and terraces located in the lower portions of valleys which contain perennial or other streams with channels” – is general and descriptive.

"Unconsolidated streamlaid deposits" means deposition materials resulting from the action of a river or stream, or "fluvial" deposits. "Fluvial" means "of or pertaining to rivers; growing or living in a stream or river; produced by the action of a stream or river" (Bates and Jackson, 1984). A meandering stream channel is typical of the active depositional environment of low gradient streams. All of the foregoing means that a low gradient meandering channel with associated deposition materials may be diagnostic of "unconsolidated streamlaid deposits."

- The term "stream" is not defined, but "permanent stream" and "intermittent stream" are defined. If there is no "stream" there is no AVF.
- "Flood Irrigation" may involve "natural overflow or the diversion of flows, so that the irrigated surface is largely covered by a sheet of water." In order for the irrigated surface to be "largely covered by a sheet of water," the surface must be nearly level, with a slope gradient no greater than that of the floodplain.
  - The University of Missouri Extension (Cromwell et al. 1993) recommends furrow slopes in the range of 0.1 to 0.5 percent for flood irrigation.
  - In California, border or flood irrigation designs for alfalfa usually have slopes from 0.1 to 0.2 percent (Hanson and Putnam 2004).
- "Subirrigation" requires that groundwater be "available and suitable for use by vegetation." It may be identified by several criteria, including "existence of an important part of the root zone within the capillary fringe or water table of an alluvial aquifer." Because an alluvial aquifer typically is unconfined, the groundwater surface will be nearly level, and for subirrigation of a crop to be present the field surface must also be level or nearly so, with a slope no greater than the longitudinal slope of the floodplain.
- Also, "subirrigation" requires that available groundwater be "suitable for use by vegetation." This requires shallow groundwater quality not limiting to production of agricultural plants. If groundwater quality limits production of agricultural plants, it is not suitable.
- "Upland areas" are excluded by the AVF definition, limiting AVF consideration to the "floodplain and terrace complex." "Isolated higher terraces, alluvial fans, pediment surfaces, landslide deposits" etc. are "upland areas" and are excluded.

Conversely, “unconsolidated streamlaid deposits” are those “located in the lower portions of valleys.”

- “Floodplain” is not defined under ARM 17.4.303, but several definitions were offered in the 2010 MDEQ “Guideline for Reclamation of Drainage basins and Channels Disturbed by Surface Coal Mining,” Appendix A (emphasis added):
    - A level area near a river channel, constructed by the river in the present climate and **overflowed** during moderate flow events (Leopold, 1994).
    - The flat area adjoining a river channel constructed by the river in the present climate and **overflowed** at times of high discharge. The floodplain under construction is **flooded** frequently and at a relatively consistent recurrence interval of 1.5 years in the annual flood series, or 2 years out of 3 on the average. The valley level corresponding to the bankfull stage (Dunne and Leopold, 1978).
    - The nearly level plain that borders a stream and is **subject to inundation under flood-stage conditions** unless protected artificially. It is usually a constructional landform built of sediment deposited during overflow and lateral migration of the streams (Soil Survey Staff, NRCS, 1997).
    - That portion of a river valley, adjacent to the river channel, which is built of sediments during the present regimen of the stream and **which is covered with water when the river overflows its banks at flood stage** (Dictionary of Geologic Terms, 1976).
    - Relatively flat area found alongside the stream channel that is prone to flooding **and receives alluvium deposits from these inundation events** (Pidwirny, 1999). A flat or nearly flat surface that may be submerged by flood waters (Merriam-Webster, 1991).
    - The area a river covers with water when it spreads out during a **flood** (American Rivers, 1997).
- Although none of these definitions use the term “valley floor”, it is clear that the floodplain is a “constructional landform built of sediment deposited during overflow and lateral migration of the streams” (NRCS definition), or synonymously, “alluvial

streamlaid deposits." The floodplain and alluvial valley floor are therefore one and the same

- "Terrace" is not defined in the rules or the guidelines; it is necessary to distinguish between terraces included in the "floodplain and terrace complex," also stated as "floodplains and terraces located in the lower portions of valleys," and "isolated higher terraces" because the latter are excluded. The following definitions are helpful:
  - *Fluvial terraces* are the remnants of earlier floodplains that existed at a time when either a stream or river was flowing at a higher elevation before its channel downcut to create a new floodplain at a lower elevation (Fairbridge, 1968).
  - *Stream terraces* form when streams carve downward into their floodplains, leaving discontinuous remnants of older floodplain surfaces as step-like benches along the sides of the valley (usgs.gov).
- A definition of "floodplain and terrace complex" could not be found. However, in a discussion of Osage County Hydrology (O'Connor 1955), the following statement may provide guidance in that it distinguishes between low terraces in the flood plain and higher terraces:
  - "Quaternary deposits in Osage County consist chiefly of fluvial deposits. In addition to the alluvium and low terraces (flood-plain complex) which comprise the modern flood plains of the present streams there are a series of successively older and higher terraces and terrace remnants along the principal valleys."
- Based on the foregoing, the "floodplain and terrace complex" is the floodplain defined by the meander belt, which may include multiple low terrace levels due to active erosion and deposition processes. Higher fluvial terraces representing earlier floodplains do not hold "streams," or are isolated from the floodplain, and are therefore excluded from AVF consideration under the definition of "upland areas," as are alluvial fans formed at the mouths of tributary drainages.
- "Agricultural activities or farming" enhanced or facilitated by flood irrigation or subirrigation must be present. Notwithstanding agronomic alteration "by farming,

seeding, interseeding, or other means, to increase production over the native condition," rangeland "not intensively managed as irrigated or subirrigated pastures" is "undeveloped rangeland" excluded from AVF analysis requirements (ARM 17.24.325(3)(a)(ii)(A); 17.24.301(134)).

- "Essential hydrologic functions" require that the natural flow of surface or ground water, or both, be made "usefully available for agricultural activities." "Essential hydrologic functions" have numerous and varied components, depending on the combination of geomorphic, hydrologic, and soils components that in combination must provide in sufficient quality and quantity to "agriculturally useful plants" "a water supply during extended periods of low precipitation." "[W]ater available at the alluvial valley floor" must be "greater than the amount available from direct precipitation." The implication is that agricultural production must exceed production levels resulting from direct precipitation alone, and must be maintained through "extended periods of low precipitation
- "Essential hydrologic functions" also include the requirement that there must be "earth materials suitable for growth of agriculturally useful plants." Hence, soils must be of suitable depth and quality to support "agricultural activities or farming."

The foregoing analysis of the applicable definitions contained in 82-4-203(3) MCA and ARM 17.24.301 provides a blueprint for identifying and delineating an AVF. Concisely stated, an AVF:

- must consist of fluvial deposits holding a stream characterized by a meandering channel;
- is confined to the floodplain largely defined by the meander belt;
- must be sufficiently level for flood irrigation and/or subirrigation:
  - for flood irrigation, must experience regular inundation by natural overflow or diversion, with surface water quality not limiting to agricultural plants;
  - for subirrigation, must have shallow groundwater such that roots extend into the capillary zone with groundwater quality not limiting to agricultural plants;
- must have soils of suitable texture, depth and quality for production of crops;
- must be managed for crops or irrigated or subirrigated pasture; and

- must provide water suitable for use by vegetation in excess of that available from direct precipitation.

Each of the foregoing criteria is an essential component of an alluvial valley floor under the Montana Strip and Underground Mine Reclamation Act and the associated rules, the absence of any one of which precludes a determination that an AVF exists.

2.0 ALLUVIAL VALLEY FLOOR DELINEATION: PHASE 1, MACRO APPLICATION OF AVF CRITERIA

This section presents the information required under ARM 17.24.325(2)(a) to enable initial identification and delineation of potential alluvial valley floors in the reach of Otter Creek adjacent to prospective surface coal mining operations at Otter Creek Mine, within the AVF study area described in Section 1.0 and identified on Plate 1. The information presented in this section is a combination of publically available reconnaissance level mapping and data plus site specific information gathered and compiled during environmental baseline studies. The objectives are to:

- eliminate from further consideration areas which clearly do not meet one or more AVF criteria;
- delineate the potential AVF within the study area;
- provide information for application of statutory exclusions (ARM 17.24.325(3)(a)) if applicable; and
- identify issues to be investigated with respect to special application requirements (ARM 17.24.325(d)) and essential hydrologic function (ARM17.24.325(e)).

2.1 GEOLOGY

2.1.1 Alluvial Streamlaid Deposits

Geologic maps of the Otter Creek have been published by the Montana Bureau of Mines and Geology (MBMG) (Lame Deer and Birney quadrangles; MBMG Open Files 428 and 431 respectively) from which Plate 2, Geologic Map, has been compiled. It is clear from examination of Plate 2 that delineation of "alluvial streamlaid deposits," or quaternary alluvium, is somewhat subjective. The MBMG interpretation includes some lower slopes that are well outside of the meander belt and are more accurately categorized as colluvium or slope wash, although some of these marginal deposits may overlie alluvium. Notwithstanding mapping inconsistencies, Otter Creek, Tenmile Creek, Threemile Creek, Home Creek and East Fork Otter Creek all appear to include "alluvial streamlaid deposits holding streams."

East of Otter Creek, MBMG shows alluvium extending upstream in two unnamed tributaries in Tract 2. In Sections 22 and 23 (T.4S, R.45E), within a relatively small watershed (640 acres), there is an area mapped as alluvium showing a relatively straight drainageway with no floodplain development, and significant steeper areas are included. Except in the extreme lower reach immediately adjacent to the Otter creek floodplain, this mapping is clearly in error, and there is no potential AVF.

Also, MBMG has mapped a significant area of alluvium in the drainage containing Fortune Spring in Sections 24, 25 and 26 (T.4S, R.45E). Although this drainage is not named on USGS maps, for discussion purposes it will be referred to here as "Fortune Coulee." The upper reaches in Sections 24 and 25 clearly do not contain significant streamlaid deposits as there is little if any floodplain development. In the lower reach (Section 26) there is a narrow meander belt, but the channel is deeply incised (erosional rather than depositional) and floodplain development is minimal. Because alluvial "streamlaid deposits holding a stream" cannot be ruled out, this reach of Fortune Coulee requires further examination.

Also, MBMG shows alluvium extending well upstream in Chromo, Gene and Newell Creeks west of Otter Creek. These drainages are similar in that there is little if any floodplain development above the mouths adjacent to the Otter Creek floodplain, and what little meander is present appears to be incised (erosional) rather than fluvial. Field observation confirms that these drainages are ephemeral, and the presence of alluvial streamlaid deposits is unlikely.

2.1.2 Alluvium – Bedrock Communication

Hydrologically, in addition to the alluvium, the bedrock units of significant interest are the Knobloch coal, clinker (Knobloch burn) and underburden sandstone. Plate 3, Geologic Cross-Sections, shows the vertical and horizontal relationships between these units in the project area. In the vicinity of Tract 2, the Knobloch coal and the clinker are in direct communication with the alluvium. The underburden sandstone underlies the alluvium adjacent to Tract 2, but based on the structural trend appears to subcrop downstream in the vicinity of well cross-sections AVF1 and AVF2.

In addition to alluvium, clinker undoubtedly plays a role in shallow groundwater hydrology in the study area. Clinker outcrops are shown on Plates 2 and 3; highly permeable clinker is in contact with the alluvium in the vicinity of the Threemile Creek confluence approximately one mile upstream and downstream. Groundwater flow between the units may occur where they are in direct contact resulting in inflow, or outflow, from the alluvium depending on pressure gradients.

2.2 TOPOGRAPHY AND GEOMORPHOLOGY

As discussed above in Section 1.5, "alluvial streamlaid deposits" are defined by the depositional environment characteristic of a low gradient meandering stream. From this it may be inferred that the gradient and the degree of meander can be used to classify a steam reach as depositional or erosional. Depositional zones are characterized by channel meanders, or sinuosity. The meander ratio or sinuosity index (SI) is the ratio of actual length along a meandering river to the straight distance. It is an indication of quantification of meandering. Obviously, for a straight river course this ratio is equal to unity. A ratio varying from 1 to 1.5 defines the river course as sinuous and from 1.5 to 4 as meandering (Khatsuria, 2010).

The drainages in the AVF study area fall into three groups:

- Lower Otter Creek (below the Tenmile Creek confluence) is a permanent stream with a down-valley gradient of 0.29 percent, a channel gradient of 0.10 percent and a SI of 2.81. The low gradient and high SI are diagnostic of a depositional stream and a constructional floodplain landform, or "alluvial streamlaid deposits." The Otter Creek watershed encompasses 711 square miles.
- The lower reaches of the major east side tributary drainages – Tenmile, Threemile, Home and East Fork Otter Creeks – are classified as intermittent although Threemile and Home Creeks have significant ephemeral reaches. Channel gradients range from 0.32 to 0.41 percent, and SI ranges from 1.71 to 2.23. With the SI above 1.5, all are characterized as meandering, although the floodplains are narrow and range from minimally to moderately developed. Drainage areas range from 43 to 59 square miles, or an order of magnitude smaller than Otter Creek, and gradients are three to

four times greater than the Otter Creek gradient, exhibiting both erosional and depositional zones. With respect to AVF characteristics, all are considered marginal, with some reaches exhibiting meander characteristic of alluvial streamlaid deposits.

- The smaller drainages – Fortune Coulee and Chromo, Gene and Newell Creeks – have drainage areas ranging from 3.2 to 5.0 square miles, or an order of magnitude smaller still compared to the major east side tributary drainages. Gradients range from 0.51 to 1.02 percent, with SI ranging from 1.23 to 1.39, or less than the "meandering" threshold of 1.5. All of these are erosional in nature with little if any floodplain development, and correspondingly little if any alluvial streamlaid deposits.

Plate 4, Topography and Geomorphology, shows the floodplains of Otter Creek and its major tributaries and mapped terraces within the AVF study area. In the area of the Otter Creek coal tracts, including the adjacent reach of Otter Creek and lower Tenmile, Threemile and Home Creeks, the topographic interval is five feet from aerial mapping completed by Olympus under contract with OCC. In the remaining area the topographic interval is 20 feet from USGS mapping.

Geomorphic characteristics of the drainages in the AVF study area, including down-valley gradient, channel gradient, down-valley distance, channel distance and sinuosity index, are also summarized on Plate 4, with end points of the measured reaches indicated.

Field examination has classified three local "terrace levels" which are identified on Plate 4. Terrace Level 1 (T1) is the Otter Creek floodplain, or the lowest ground elevation above the creek channel, generally defined by the meander belt. Mapped higher T2 terraces are low terraces both within the meander belt and along the valley margins, and may be fluvial terrace remnants or alluvial fan formations. The highest terrace levels, classified T3, are most often associated with truncated alluvial fan formations at the mouths of tributary drainages and lie outside of the meander belt.

Discerning fluvial terraces from alluvial fans is difficult. It is suspected that fluvial terrace remnants are ancient and have been largely eroded away or masked by alluvial fan formation at the mouths of tributary drainages. Demarcation of the Otter Creek floodplain (T1) is facilitated by T1 and T2 terraces along the valley margins where they occur. Fluvial terraces are not evident on Tenmile, Threemile, Home and East Fork Otter Creeks.

As discussed in Section 1.0, an alluvial valley floor must be within the essentially level depositional landform characterized by a meandering stream and its floodplain. Mapping of the floodplain ("Terrace 1") is straightforward in some areas where it is bounded by terrace escarpments or bedrock-based landforms. In other areas where there is a gradual transition to terrace formations or lower slope colluvium, mapping is more subjective. In addition, narrow tributary drainages pose additional challenges, particularly where the floodplain is deeply channeled. The procedure used for floodplain delineation is described in more detail in subsection 2.9 – AVF Identification and Delineation. The floodplain outline is shown on succeeding maps to identify the "AVF zone," within which cropland areas meet the AVF criteria of occasional flood irrigation by natural overflow and/or shallow groundwater.

Channel cross-sections and photographs at surface water monitoring sites are included in Appendix A. This information is presented for reference and to illustrate channel geometry and vegetation condition. Banks of Otter Creek are generally well vegetated, although there are areas of localized degradation due to livestock and at trail crossings. See also Baseline Report 304K – Fish and Wildlife – Appendix D, Aquatic Biology Assessment. Channel vegetation in tributary drainageways is variable with lower gradient reaches well vegetated and steeper reaches often deeply channeled.

2.3 HYDROLOGY

Plate 5 shows the hydrologic monitoring network for the Otter creek coal tracts. Surface water monitoring stations and monitor well locations are shown. The USGS gauging station at the Highway 212 crossing just east of Ashland (USGS 063307740) has been in operation since 1972 and provides a long-term record of Otter Creek discharge and water quality.

2.3.1 Surface Water

The Otter Creek drainage basin is shown on Plate 6. The total basin area is about 711 square miles, of which 465 square miles, or 66 percent, is above the Tenmile Creek confluence. The prospective Otter Creek mine area of 3477 acres is less than one percent of the Otter Creek drainage area. Otter Creek and major tributaries in the AVF study area are shown.

2.3.1.1 Surface Water Flow

Long-term flow data for USGS 063307740 on lower Otter Creek east of Ashland are summarized on Tables 2-1A and 2-1B, which show monthly averages by year and daily averages by month respectively from October 1972 through September 2013. Monthly mean discharge ranged from a high 13 cfs in March to 1 cfs in September. Highest monthly mean discharges occurred in March 1975 (106.5 cfs), May 2011 (60.2 cfs) and May 1978 (53.1 cfs); these were the only months with mean flows exceeding 50 cfs during the 39-year period of record. Mean monthly flows of zero were recorded in August and September 1992; mean monthly flow fell below 1.0 cfs in late summer of 21 of the 41 years of record, or about half the time.

Mean daily flow ranged from a high of 13.4 cfs in March to 1.1 cfs in September, with a second lower peak of 8.6 cfs in May. Annual mean and median daily flows were 4.75 and 3.00 cfs respectively.

Annual peak flows reported by USGS are presented in Table 2-2. From 1973 to 2014, annual peak flow is reported for 32 years and ranged from two to 650 cfs, with a mean of 115 cfs. Median annual peak flow was 39 cfs. Floods exceeding 100 cfs occurred in 11 out of 32 years, or about once every three years on average. Peak flow exceeded 300 cfs six times, or once in five years. The single event exceeding 500 cfs occurred in March, 2014.

Appendix B includes current USGS preliminary data for 2014 (Table B-1) and a summary of the 2013 water year (Table B-2). The USGS estimates the peak flow on March 1, 2014 at 650 cfs; this event was preceded by frozen conditions and ice jams so it likely is conservative. On Table C-2, average annual runoff for the period of record is stated to be 3440 acre feet, or 0.09 inches over the watershed area.

Based on the foregoing and observations since 2011, it is likely that Otter Creek will overtop its banks in some places and flood low-lying fields at least once each three years on average, with sufficient stage to inundate the floodplain at least once every five years or so. Peak flows occurred most often in March, followed by February and May.

Hydrographs for four surface water stations on Otter Creek established for environmental baseline studies are presented in Appendix C. These are discussed below in conjunction with alluvial well hydrographs.

Significance of surface water flows is addressed below in the Flood Irrigation subsection.

2.3.1.2 Surface Water Quality

This discussion of surface water quality is limited to the agriculturally significant parameters of specific conductivity (SC) (uS/cm @ 25F) as a measure of salinity and sodium adsorption ratio (SAR). Surface water quality with respect to a full suite of analytical parameters is addressed in detail in Baseline Report 304E – Hydrology. Plants vary in their salt tolerance; high salinity may have adverse osmotic and toxic effects. SAR is a measure of exchangeable sodium relative to other cations, chiefly calcium and magnesium. Elevated SAR causes adherence of sodium ions to clay particles. The result is dispersion of clay particles in the soil, which reduces usefulness for agriculture by adversely affecting soil structure and limiting infiltration.

At USGS 063307740 a ten-year record (2003-2013) shows daily average SC ranging from a low of 2214 in March to a peak of 2997 in April (Table 2-3A). From the April peak, SC declined steadily through the growing season to 2370 in October, increasing to 2840 in November. (Water quality data were not reported for the winter months of December, January and February, presumably due to freezing conditions.) Average annual SC was 2700 with a nearly identical median value of 2740.

During the same period of record, SAR (Table 2-3B) followed the same pattern, with a low of 5.38 in March, a high of 6.42 in April, and a similar decline during the growing season. Average and median annual SAR were 6.00 and 6.06, respectively.

Surface water quality data from environmental baseline studies conducted in the project area several miles upstream are summarized in Table 2-4. Ranges of SC in Otter Creek were 3290 to 4990, with an average from 3601 to 4128 at individual stations, which is somewhat higher than reported by USGS. Similarly, SAR ranged from 4.82 to 8.54, with station averages ranging from 6.56 to 8.54.

At Home Creek station SW-1 near the Tract 1 boundary, water was present four of 13 quarterly sampling events, SC ranged from 40 to 580 with SAR less than 1.0, indicating surface runoff and ephemeral flow conditions. At SW-1A located downstream at the highway crossing, water was present in 10 of 13 quarters, with SC from 3580 to 4227 and SAR from 7.08 to 9.66, indicating groundwater connection and intermittent flow conditions.

On Threemile Creek, SW-11 is located near the CNF boundary, with water present 9 of 13 quarters. SC ranged from 3150 to 3990, and SAR from 4.85 to 6.88. This reach is intermittent with groundwater connection. Downstream at SW-3, water was present during 4 of 13 sampling events, SC ranged from 281 to 1070, and SAR averaged less than 1.0, indicating surface runoff dominance and ephemeral flow conditions.

On Tenmile Creek, station SW-23, water was present nearly half the time – 6 of 13 sampling events - and SC and SAR averaged 3454 and 5.73 respectively, indicating groundwater connection and intermittent flow conditions.

At Fortune Coulee, water was present for 5 of 13 sampling events; average SC and SAR were 349 and 0.71 respectively. Flow is ephemeral at station SW-18 near the mouth of Fortune Coulee.

Surface water quality and its significance with respect to flood irrigation is addressed below in the Flood Irrigation subsection.

2.3.2 Groundwater

With respect to AVF assessment, this subsection focuses on the depth and quality of water in the alluvium of Otter Creek and its major tributaries in the study area as the primary unit of interest. Table 2-5 summarizes installation and monitoring data for wells in the alluvium of Otter Creek, Home Creek, Threemile Creek and Tenmile Creek. Wells are ordered downstream to upstream. Detailed well construction and monitoring information can be found in Baseline Report 304E – Hydrology.

The alluvium receives groundwater and surface water from upstream and from the Knobloch coal in the study area. Also, there is interaction with the clinker where it is in contact with the alluvium. These flux relationships will be addressed in detail in a later section dealing with water balance.

2.3.2.1 Groundwater Flow

Potentiometric surfaces are shown on Plate 7. In the alluvium, groundwater is shallow and gradients parallel the floodplain surfaces. In the area of Tract 2 where the Knobloch coal subcrops in the alluvium the two units are in communication such that the potentiometric surfaces coincide.

Immediately downstream at the burn line in the vicinity of the Section 15-22 (T.4S, R.45E) section line near well A6, the alluvium is in communication with the clinker. The clinker is extremely porous and holds a large amount of water with a nearly flat water table at approximately elevation 3025 to 3026 feet in wells C-1, C-2 and C-3 (well C-4 is very close to the Knobloch coal burn line and has a water elevation of about 3038 compared to nearby well K-5 with a water elevation of 3043.) This means that the clinker would drain water from the alluvium where the alluvial water table is above approximately elevation 3025, and conversely, drain water to the alluvium below this elevation. That intersection point is at approximately the mouth of Threemile Creek. Base of Knobloch coal elevations near the western boundary of Tract 1 (approximately 3010) suggest that the base of the clinker is above the Otter Creek floodplain elevation from the vicinity of Willow Crossing (Section 33, T.3S, R.45E) downstream, and hence there is no communication between the two units. It is also likely that the underburden sandstone subcrops in this reach, based on the top elevation of 3037 in B-1-U.

2.3.2.2 Groundwater Depth

The hydrologic monitoring network includes six alluvial cross-sections with designations AVF1 through AVF6; the "AVF" identifier indicates the specific purpose of AVF investigation. In addition, there are nine individual wells completed in alluvium in Otter creek and its major tributaries. Appendix C includes hydrographs for wells completed in the alluvium. Following is a brief discussion of water levels in the alluvium. Monitor wells and surface water stations are shown on Plate 5, Hydrologic Monitoring Locations; please refer also to Plate 3, Geologic Cross-Sections.

Otter Creek

Based on well log data, depth of alluvium in Otter Creek ranges from approximately 30 to 60 feet, generally decreasing downsteam as the valley bottom becomes wider and less constricted. Underlying bedrock varies, but typically consists of siltstone and/or claystone, with coal at AVF3 and AVF4. Depth to groundwater is typically less than 8 feet except at well A9.

Well A9

Well A9 was installed near the Highway 212 crossing and the USGS Ashland gauging station July 7, 2014, to document alluvial groundwater depth and quality at this location, and to serve as a downstream station for future monitoring. Flowing sands were encountered at 50 feet and the well was not completed to bedrock. Depth to water at the time of well installation was 12 feet.

USGS Observation Well OC83-06 is an historic observation well that was installed in the Otter Creek alluvium in the NE ¼ SE ¼ of Section 11 (T.3S, R.44E) just south of Highway

212, near the present location of well A9. This well is inactive and not part of the monitoring program; the depth to water on June 9, 1983 was recorded as 15 feet.

AVF1 Well Cross-Section

The AVF1 well cross-section consists of three wells and is located on Otter Creek downstream of Home Creek, just above the mouth of East Fork Otter Creek. Water levels are 6-8 feet below the floodplain surface and are quite stable, varying seasonally by about two feet. Local terrace levels T2 and T3 are 20 feet or more above the floodplain and appear to be associated with fan formations at the mouths of East Fork Otter Creek on the east and an unnamed ephemeral drainage on the west. These terrace levels are outside of the floodplain and clearly above any groundwater influence.

AVF2 Well Cross-Section

The AVF2 well cross-section consists of six wells in the Otter Creek alluvium downstream of Threemile Creek and just above the mouth of Home Creek. Water levels range from 2-7 feet below the floodplain elevation, and vary seasonally by two to three feet. Well AVF2-6 is located on a local T-1 terrace about six feet above the floodplain, which appears to be associated with a fan formation at the mouth of Home Creek, and the water level is at or above the floodplain elevation. At this location there is a slight east to west gradient across the Otter Creek alluvium. The cross-gradient at this location appears to be associated with a recharge from the clinker to the east and draining of groundwater from the alluvium into clinker to the west (Cross-Section A, Plate 3).

Well A8

Well A8 was installed on June 5, 2014, to monitor alluvial groundwater quality downstream of the Threemile Creek confluence. Depth to water on that date was 2.3 feet.

Well A1, SW-2

Well A1 is located in Section 9 (T.4S, R.45E) about one-half mile above the Threemile creek confluence near surface water station SW-2. Depth to clinker is 15 feet, which likely does not represent the full depth of alluvium due to location near the edge of the floodplain. The water level is about 8 feet below the floodplain surface. There is a low T2 terrace indicated which appears to be associated with an alluvial fan formation at the mouth of an unnamed ephemeral drainage on the west side.

Comparison of the well A1 water level with the stage recording at SW-2 shows that despite seasonal fluctuation in surface water, the groundwater elevation shows only minimal response. Also, the groundwater level is approximately one foot below the surface water baseflow level, suggesting that there is muted groundwater-surface water connection and that this is a losing reach, with alluvial water draining to the adjacent clinker (Cross-Section B, Plate 3).

AVF3 Well Cross-Section

The alluvial well cross-section at AVF3 in Section 15 (T.4S, R.45E) is very near the burn line demarcating communication of the alluvium with clinker and the Knobloch coal, which underlies 59 feet of alluvium at this location. The ground water level is 6-11 feet below the floodplain elevation; there are no higher terrace levels noted at this location. Water levels vary by approximately two feet seasonally and up to four feet between wells. Examination of water levels shown on Cross-Section C on Plate 3 suggests that water is draining from the alluvium to clinker on the west, and to the clinker from both the alluvium and the Knobloch coal on the east.

Well A6, SW-16

Well A6 is about one-half mile upstream from cross-section AVF3. Alluvial depth of 23 feet over sandstone likely does not reflect the maximum depth to bedrock in the middle of the valley. The water level varies by 1-2 feet seasonally, and is 5-7 feet below the floodplain surface. There is a T2 Terrace level noted at this location about three feet above the floodplain. Comparison with the SW-16 hydrograph shows that there is a muted seasonal relationship, and that the groundwater level is at the same level as the baseflow stage of Otter Creek.

AVF4 Well Cross-Section

The AVF4 alluvial well cross-section consists of four wells located in Section 27 (T.4S, R.45E) near the mouth of Fortune Coulee (Cross-Section D, Plate 3). The alluvium is 33 feet thick over bedrock of coal (Upper Knobloch). Water levels vary by about a foot seasonally and laterally, and lie about 4-5 feet below the floodplain elevation. There is a T2 terrace about four feet and a T3 terrace level about 7 feet above the floodplain, the latter of which appears to be associated with a fan at the mouth of Fortune Coulee.

Well A7

Well A7 is about one-half mile above the AVF4 cross-section. The water level varies by about two feet seasonally and lies about 6-7 feet below the floodplain surface. There is a T2 terrace about six feet above the floodplain on the west side that appears to be associated with an alluvial fan at the mouth of Gene Creek.

Well A3, SW-22

Well A3 is located in Section 2 (T.5S, R.45E) just above the mouth of Tenmile Creek near the Tenmile Creek road crossing where SW-22 is located. The groundwater level is 3-5 feet below the floodplain surface and fluctuates by about two feet seasonally, peaking with the spring surface water peak. The surface water level lies slightly above the groundwater elevation, although the two intersect at times. No higher terrace levels are noted at this location.

At nine of ten locations monitored during baseline studies, the groundwater level is eight feet or less below the floodplain surface indicating the potential for subirrigation on the Otter Creek floodplain. The sole exception is well A9 near the US 212 highway crossing and the USGS Ashland gauging station. Based on the water level difference, depth to groundwater appears to increase slightly to more than eight feet in this reach. From the vicinity of well cross-section AVF3 downstream to a point between AVF2 and AVF1 geologic cross-sections and water levels suggest a dynamic equilibrium between water levels in the alluvium and adjacent clinker units.

Home Creek

Home Creek has a total drainage area of 59 square miles. The reach within the study area, from the northern boundary of Tract 1 to a short distance above the mouth is a deeply channeled ephemeral stream with a narrow floodplain defined by an irregular meander belt that is likely to be dominated by erosional rather than depositional processes. The valley is considerably broader and is flanked by colluvium and fan deposits at the mouths of ephemeral side drainages, primarily on the south side, with numerous spreader dikes to capture and infiltrate runoff in hayfields on gentle slopes.

AVF5 Cross-Section, SW-24

The AVF5 alluvial well cross-section (Plate 3) about one mile above the mouth of Home Creek consists of five wells. Water levels are consistent in all five wells at 16-17 feet below the floodplain elevation. Well logs indicate that the alluvium consists largely of clinker gravels and is underlain by siltstone and claystone bedrock. Home Creek at SW-24 is ephemeral, flowing only in response to major snow melt and rainfall events.

Well A2

Well A2 is in upper Home Creek near in Section 26 (T.3S, R.45E). The well log shows 75 feet of unconsolidated material consisting largely of clinker gravel over sandstone bedrock. The groundwater level is approximately 47-52 feet below the surface.

Based on the foregoing, groundwater levels in the Home creek valley bottom are far too deep to support subirrigation farming.

Threemile Creek

Threemile Creek has a total drainage area of 51 square miles. The lower reach from the CNF boundary to its confluence with Otter Creek separates Tracts 1 and 2. Threemile Creek is intermittent in the upper portion of this reach in Section 12 (T.4S, R.45E), but is ephemeral downstream to the mouth. It has a narrow meander belt and floodplain.

AVF6 Cross-Section

Alluvial well cross-section AVF6 (Plate 3) is located on lower Threemile Creek about one-half mile above the mouth. It consists of five wells; the depth of alluvium is 30 feet consisting primarily of clinker gravel over siltstone and claystone bedrock. Water levels are 13-15 feet below the surface.

Well A5

Well A5 is located near the CNF boundary in Section 12 (T.4S, R.45E). The bedrock is siltstone with 26 feet of alluvium. The water level varies from less than one to four feet below the surface, with the shallowest depth coinciding with spring runoff.

The reach of Threemile Creek in Section 12 (T.4S, R.45E) has shallow groundwater with subirrigation potential. Near the mouth groundwater is deeper, precluding subirrigation.

Tenmile Creek

Tenmile Creek has a drainage area of 43 square miles. In the lower reach between the CNF boundary and the mouth, it has a fairly well developed floodplain and meander belt.

The single monitor well on Tenmile Creek is well A4 near the CNF boundary. Well A4 has 68.5 feet of alluvium over claystone bedrock. The depth to water is 4-5 feet below the floodplain, indicating a potential for subirrigation.

Based on the foregoing data review, the floodplains of Otter Creek and specific tributary reaches are characterized by groundwater depth from two to eight feet. Plate 8 shows areas with the groundwater level at a depth of eight feet or less based on the difference between the ground surface and groundwater elevations from the potentiometric surface (Plate 7). These areas are seen as having the greatest potential for subirrigated agriculture, which is addressed below in more detail in the Subirrigation subsection.

2.3.2.3 Groundwater Quality

Quality of shallow groundwater is of particular interest with respect to suitability for subirrigation farming, which is addressed in more detail below in the Subirrigation subsection. This discussion summarizes alluvial groundwater quality in alluvial monitoring wells.

Table 2-5 includes average SC and SAR for alluvial wells in the study area; SC and SAR data for wells completed in alluvium are tabulated in Appendix F. In the Otter Creek alluvium, average SC ranged from a low of 1709 at AVF1 to 5598 at A6, with an overall average of 3760. Similarly, SAR ranged from 5.27 to 9.31 in the same wells, with an overall average of 6.84. Examination of the data suggests that relative to well A3 (SC = 3273) near the Tenmile Creek Road crossing, SC increases substantially in the reach between AVF4 and AVF3. This is the reach where the Knobloch coal subcrops. Proceeding downstream, SC declines to a minimum at AVF1. Well A1 is located on the east flank of the floodplain at the clinker contact with alluvium; relatively low SC (2474) at this location suggests that lower SC may be related to groundwater contribution from clinker. At AVF1, lower SC may also be related to inflow from Home Creek; SC at AVF5 is 1547. Also, the underburden sandstone appears to subcrop in this reach. At A9 near US Hwy 212, SC of 3560 is near the average.

As noted above, SC in lower Home Creek alluvium is relatively low, while upper Home Creek (well A2) is in the range typical of Otter Creek alluvium with SC of 3053. In Threemile Creek, a similar but less extreme differential exists with SC of 3546 at upstream well A5 and 2941 at AVF6. Home Creek, and to a lesser degree Threemile Creek, are flanked by clinker deposits, which may account for lower SC at the downstream locations. In Tenmile Creek alluvium, SC of 3028 at well A4 is similar to upper Home Creek alluvium.

Although SC and SAR of alluvial groundwater vary spatially, probably due to local contributions from coal and clinker subcrops, it is reasonable to say that in Otter Creek, Tenmile Creek and upper Threemile Creek where alluvial groundwater is sufficiently shallow for subirrigation, SC typically exceeds 3000 uS/cm, and SAR typically exceeds 5.0, up to a factor of about 2.

2.4 SOILS

Soils information for the AVF Study Area was derived from existing soils maps and data published by the Natural Resources Conservation Service (NRCS), as well as field data collected as part of the soils baseline inventory of the OCC project area. NRCS data were extracted from the Powder River and Rosebud County soil surveys, published online by the NRCS (NRCS 2013a, NRCS 2013b). A soils map of the AVF Study Area (NRCS mapping) is included as Plate 9. Complete soils baseline information for the permit area is contained in Baseline Report 304L. Included are profile descriptions, field data, laboratory analysis and NRCS series descriptions.

2.4.1 Soil Occurrence

Soils within the AVF Study Area are dominated by sandy and silty loam soils on uplands with finely textured silty and clayey soils found in the floodplains. Upland soils on slopes and ridges formed in a mixture of residuum and colluvium of sedimentary materials, while upland soils in swales and drainages consist of stratified horizons with variable textures and thicknesses. In contrast, the floodplains are dominated by fine-textured soils formed in alluvial deposits from a mixture of sedimentary parent materials on swales and low terraces. Soils within the floodplain include relatively productive soils such as the Haverson, Havre and Heldt soil series, which are also the most prevalent soils in agricultural fields. Tables 2-6A, 2-6B and 2-6C summarize soil acreages for the AVF study area, floodplains and crop fields, respectively.

As noted above in Section 1.5, areas meeting AVF criteria must consist of level or nearly level slopes. There are seven soil series' which include mapping units characterized by slopes of 0-2 percent; these are summarized below with information excerpted from NRCS mapping unit descriptions (Baseline Report 304L, Soils, Appendix D).

The **Farland** series consists of very deep, well drained soils that formed in stratified alluvium from mixed mineralogy on terraces, valley foot slopes and fans on uplands. Slope gradients commonly average between 1 and 6 percent, but range from 0 to 20 percent.

- Drainage: Well drained. Runoff is slow or medium.
- Permeability is moderate or moderately slow.

The **Fort Collins** series consists of very deep, well drained soils that formed in mixed eolian sediments and alluvium. Fort Collins soils are on terraces, hills, plains, and alluvial fans and have slopes of 0 to 10 percent.

- Drainage: Well drained. Runoff is medium.
- Permeability is moderate.

The **Haverson** series consists of very deep, well drained soils that formed in alluvium from mixed sources. Haverson soils are on floodplains and low terraces and have slopes of 0 to 9 percent.

- Drainage: Well drained. Runoff is negligible to medium depending on slope.
- Moderate permeability.

The **Havre** series consists of very deep, well drained soils that formed in stratified, calcareous, loamy alluvium. Slopes are 0 to 6 percent. These soils are on floodplains, alluvial fans and stream terraces.

- Drainage: Well drained.
- Moderate permeability.

The **Heldt** series consists of very deep, moderately well drained, moderately slow to slowly permeable soils that formed in fine textured, sedimentary alluvium on fans, remnant terraces, hillslopes and piedmonts. Slopes range from 0 to 25 percent.

- Drainage: Well or moderately well drained. Slow or very slow runoff.
- Slow to moderately slow permeability.

Hesper soils are on upland plains and terraces and formed in uniform calcareous silt loam. (Slope range not specified; mapping units 0-8 percent in AVF study area.)

- Drainage: Well drained.
- The B horizon is moderately permeable.

McRae soils are on terraces of rivers and streams, alluvial fans in valleys, and footslopes in the uplands. They formed in calcareous loam alluvium from soils developed over sedimentary rocks. (Slope range not specified; mapping units 0-8 percent in AVF study area)

- Drainage: Well-drained.
- Moderate permeability. Slow to medium runoff.

These soil series descriptions are helpful and potentially diagnostic in identifying potential alluvial valley floors. Among other criteria, classification of soils includes parent material, landscape position and agricultural use. Also, soil mapping units are categorized based on slope. Within the AVF study area, all of the soil series are potentially derived from alluvial parent material and can be used for irrigated or dryland agriculture. However, only the Haverson and Havre soil series are commonly located on floodplain landforms. The NRCS mapped these alluvium derived floodplain soils as the Havre series (0-2 percent slopes, occasionally flooded) in Rosebud County and as Haverson soils (no slope range or drainage class provided) in Powder River County. Based on the series descriptions and baseline soils data, these two soils are typical of potential AVF areas. The Haverson and Havre series soils are designated as Probable AVF Soils on Plate 9.

Five additional series are described as occurring on terraces, fans, footslopes etc. with some mapping units described as having 0-2 percent slopes. These are the Farland, Fort Collins, Heldt, Hesper and McRae series. While all of these are described as being associated with alluvial parent material, none is commonly located on floodplains. Farland and McRae mapping units are typically associated with higher terraces, fans and colluvium on lower slopes located above the floodplain. However, on occasion Fort Collins, Heldt and Hesper mapping units may be inundated on lower terraces and therefore are indicated as Possible AVF Soils on Plate 9.

Also highlighted on the map are terrace escarpments. Where they occur, these escarpments form a discreet floodplain boundary and as such aid in AVF mapping.

2.4.2 Soil Characteristics

Soil characteristics were evaluated to identify differences in soil properties between floodplain and non-floodplain (i.e. AVF Soils and non-AVF) soils. Eight soil sample locations were located in or near crop fields in the Otter Creek floodplain, and six samples were in or near crop fields located out of the floodplain. Selected data are presented in Table 2-7. (Complete soils data are contained in Baseline Report 304L.) The following observations are notable:

- At all of the floodplain sample sites, groundwater was encountered in the soil profile.
- At two of the non-floodplain sites, moisture was noted near the bottom of the profile, indicating interception of the capillary fringe, but groundwater was not encountered.
- At seven of eight floodplain sites, the average EC in the soil profile was 9.3 mmhos/cm, exceeding the conventional saline soil threshold of 4.0 mmhos/cm. The highest individual value observed was 31.5 mmhos/cm.
- Outside of the floodplain, but within the AVF study area, average EC at two of five sites exceeded the 4.0 mmhos/cm threshold, with the average for all non-floodplain sites of 4.7 mmhos/cm. The highest individual EC value was 16 mmhos/cm.
- At non-floodplain sites, elevated EC, when encountered, was at or near the bottom of the profile. Both sites where moisture was noted had associated high EC.
- SAR followed a similar pattern, with values exceeding 15 encountered in six of eight floodplain profiles, and just one of six non-floodplain profiles.

Data summaries of the grouped soil samples illustrate that soil salinity is much higher in floodplain soils than non-floodplain soils. Floodplain soils also exhibited shallow groundwater in combination with high salinity.

The soils of the Otter Creek floodplain and associated tributaries are finely textured soils with few coarse fragments. However, the presence of scattered sand and gravel lenses at various depths within the soil profiles are evidence of the meandering nature of the Otter Creek stream channel.

Floodplain versus upland soils exhibit differences in physical and chemical properties that promote variable vegetation patterns and land use practices. Non-floodplain soils are typically coarse to loamy textured soils with low to moderate water holding capacity and low to moderate soil salinity. These soils do not support wide-spread agricultural use, with the exception of a few grass dominated fields occasionally harvested for hay. Floodplain soils are mostly silty or clayey soils with high salinity throughout the soil profile. The lower percolation rates and high capillary action of these soils, coupled with shallow groundwater, contribute to the high salinity concentrations.

2.5 VEGETATION

Plate 10 - Vegetation shows hay crop fields within the area of stream laid deposits. Farmed Hay Cropland occupies 2868 acres (40 percent) of the Otter Creek AVF Study Area. Sixty-one vegetation plots were sampled in the baseline study area (Tract 2 and the Facilities Area) on floodplains and terraces along Otter Creek (Plate 10). Nearly all sites were on very gentle slopes of 0-5 percent gradient; aspect was variable. The predominant ecological sites were saline lowland (Heldt silty clay loam – Saline and Haverson silty clay – Saline soils), clayey (Heldt silty clay loam soils) and silty (McRae silt loam).

Plant species dominance is shown below based on mean percent canopy cover rounded to the nearest percent. Hay is the only crop grown on the valley bottom; hay fields are typically dominated by introduced pasture grasses, with alfalfa variable among fields. Dominant hay species are crested wheatgrass (*Agropyron cristatum*), smooth brome (*Bromus inermis*), alfalfa (*Medicago sativa*) and quackgrass (*Agropyron repens*). Vegetative cover data for the 61 sites is included in Appendix G as Table G-1 (plots located within the Otter Creek floodplain) and Table G-2 (plots outside the floodplain). The following table summarizes the mean cover and constancy data in Table G-3 – Summary.

HAY CROPLAND Within (W, n=44) and Outside (O, n=17) the Otter Creek Floodplain								
GRAMINOIDS			**FORBS**			**WOODY PLANTS**		
Class/Species	% Cover		Class/Species	% Cover		Class/Species	% Cover	
	W	O		W	O		W	O
Perennial	96	80	Perennial	12	25	Shrub	<1	<1
Annual	<1	<1	Annual/Biennial	3	6	Tree	-	-
Agropyron cristatum	36	53	*Medicago sativa*	11	21			
Bromus inermis	23	22	*Atriplex heterosperma*	2	<1			
Agropyron repens	18	1	*Taraxacum laevigatum*	1	<1			
Agropyron elongatum	6	-	*Melilotus officinalis*	<1	5			
Agropyron smithii	4	<1	*Cirsium arvense*	1	<1			
Poa pratensis	3	4	*Convolvulus arvensis*	<1	2			
Agropyron intermedium	2	-						
Elymus junceus	1	-						
Hordeum jubatum	1	-						
Distichlis stricta	-	1						

These data show that hay crop species dominance differed between sample sites within and outside of the Otter Creek floodplain. Crested wheatgrass cover was greater outside of the floodplain – 53 vs. 36 percent. Conversely quackgrass was more dominant on the floodplain with an average cover value of 18 percent vs. just one percent outside of the floodplain. Smooth brome cover did not differ. Alfalfa cover outside the floodplain was roughly twice – 21 vs. 11 percent – that observed within the floodplain.

Most hay fields in the area are best characterized as mixed alfalfa-grass hay. Higher alfalfa dominance in fields outside the floodplain suggests saline conditions on the floodplain are less conducive to growing alfalfa. Dominance of quackgrass in some fields no doubt has been a result of saline conditions not suitable for conventional hay crop species.

2.6 LAND USE

Land use in the study area is cattle ranching. Farming is limited to the valley bottoms, and consists exclusively of hay crops for winter feeding of cattle. Hay fields occupy the floodplain of Otter Creek, and some areas of adjacent terraces, fans and lower slopes where soils are suitable and slopes are gentle, generally less than two percent. Hay fields are also present in the valley bottoms of Tenmile Creek, upper Threemile Creek and Home Creek. Typically, cattle are moved from summer pastures in the uplands to the valley bottoms in the fall and turned into hay fields for aftermath grazing. Cattle remain in the valley bottom feeding areas through the winter until they are moved to spring pastures, typically on lower slopes.

Landowner interviews were conducted in the fall of 2011, except where otherwise indicated, which provided information regarding irrigation practices and hay production. These are summarized below:

- Denson Ranch: Irrigation has never been implemented other than spring runoff. Spreader dikes collect runoff during spring snow melt, which is then used to flood hay meadows. Many of the dikes were built before the Densons acquired the land. There is an older diversion in Section 34 probably dating to the early 1900's that is not used any more, and another old ditch that started above the main ranch house. Hay production is typically 1-1.5 T/Ac, although 2011 was exceptional with production averaging 3.5 T/Ac. There usually is some second cutting producing 0.5 T/Ac where harvested. Hay is primarily alfalfa and crested wheatgrass.
- Thomas Ranch: There is an old diversion in Section 27, but flood irrigation is not used. Hay species are alfalfa and crested wheatgrass; production is stated to be 2 T/Ac. Second cutting is minimal, perhaps 25 bales on the entire place.
- Stevens Ranch: No irrigation practices are used now or in the past. Spring runoff is collected and distributed by spreader dikes. In Section 9 water from a side drainage is routed through a culvert under the road and dispersed by dikes at the edge of a terrace above Otter Creek. Production is 1-1.5 T/Ac of alfalfa and crested wheatgrass. There is no second cutting.

- Woods Ranch: Irrigation has never been used; spring runoff is collected in one field; all others depend on precipitation. Typical production is 1.5 T/Ac, although 2011 production was 3.5 T/Ac. Alfalfa and crested wheatgrass are the hay species grown. There is a second cutting.
- Trusler Ranch (Personal Communication, 2014): The Trusler ranch has perhaps the most elaborate system for managing Otter Creek floodwaters. In the northeast quarter of Section 19 (T. 3S, R.45E) a large shallow pond is developed between the creek and an old meander that fills during high flow periods. On the east side of this pond along the creek there is a dam, head gate and piping system to direct the ponded water to a ditch on the west side of the valley where it is then directed to a series of diked containment basins. Excess water is collected behind a retention dike in the northeast quarter of Section 13 (T. 3S, R.44E) where it is held to infiltrate on a large hay field. This dike also had a head gate for water release into the creek downstream.

Summarizing the foregoing, there is no active diversion of stream flow for flood irrigation during the growing season. Management of spring runoff using diversions and/or spreader dikes is practiced to varying extent. Typical hay species are alfalfa and crested wheatgrass. Production is 1-2 T/Ac, with 1-1.5 T/Ac noted on three of the four ranches. Production in 2011 was much higher – 3.5 T/Ac noted by two ranches. (There was heavy rainfall and consequent flooding on Otter Creek in the spring of 2011.) Three of four ranches noted either minimal or no second cutting. Rather than harvest a second cutting, it appears in most cases re-growth after harvest is left in the fields for fall grazing.

Land use features including hay fields, runoff management diversions and dikes, and ranch boundaries are shown on Plate 11, Land Use. Fields benefitting from managed inflow from tributaries are indicated, as is the floodplain.

Based on compilation of long-term annual production data, NRCS (NRCS 2012) has determined representative values for total irrigated and non-irrigated hay production for pertinent soils in the AVF study area (Table 2-8). Hay cropland can be expected to produce 3 to 7 irrigated tons per acre and 1 to 2 non-irrigated tons per acre, depending on the soil and crop combination. Specifically, for Haverson soils which dominate the Otter Creek floodplain, the NRCS-predicted non-irrigated yields of alfalfa and grass hay are 1.8 and 1.5 T/A, respectively. Non-irrigated yields predicted by NRCS are consistent with that reported during landowner interviews.

2.7 FLOOD IRRIGATION

As noted above, direct diversion of Otter Creek base flow during the growing season for flood irrigation is not practiced on Otter Creek. According to local ranchers, historic attempts to dam Otter Creek and divert the water for flood irrigation and/or enhance sub-irrigation were not successful due to consequent salt accumulations in soils that inhibited hay production. To date, no active diversions of Otter Creek base flow for flood irrigation have been identified in the Study Area, although two of the ranchers interviewed noted historic diversions that have not been used for many years.

Although three terrace levels have been identified (Plate 4), the valley bottom of Otter Creek shows limited terrace development. Hence, if irrigation water in sufficient quantity and of suitable quality were available, flood irrigation would not be limited by topography in most areas.

As noted above, NRCS provides irrigated and non-irrigated production data for several soils, which together dominate the Otter Creek valley bottom. These soils are considered to be potentially irrigable. Table 2-8 lists the mapping units, capability classes, and typical hay production (un-irrigated and irrigated) for these soils. The Special Use Pasture (hay cropland) type can be expected to produce 3 to 7 irrigated tons per acre and 1 to 2 non-irrigated tons per acre, depending on the soil and crop grown.

2.7.1 Otter Creek Stream Flow Water Quantity

Table 2-1A shows the range of monthly surface water flows from 1972 to 2013 in Otter Creek recorded at U.S. Geological Survey (USGS) stream gauging station 063307740 on lower Otter Creek east of Ashland. Peak flows (Table 2-2) most often occur in March and February in response to snow melt, and in May of some years in response to spring rainfall.

Highest average flows occurred in March (13 cubic feet per second (cfs)), followed by May (8.6 cfs) and June (6.8 cfs). In some years flows fell to zero in late summer and fall.

One cfs is equivalent to about 60 acre feet per month. According to the DNRC, (2010), approximately six inches of water applied by flood irrigation is required to increase alfalfa production by one ton per acre. Using this relationship, each cfs of water that could be diverted in theory could be used to irrigate 360 acres over a period of three months. Based solely on average water quantity, irrigation of limited acreage might be feasible from May to July in some years, and would not be practicable after July. Flows are not sufficiently consistent to plan for irrigation every year.

2.7.2 Otter Creek Stream Flow Water Quality

Quality of surface water is summarized on Tables 2-3A and 2-3B at USGS stream gauging station 063307740, and Table 2-4 in the project area. The ten-year record (2003-2013) shows daily average SC ranging from a low of 2214 in March to 2997 in April (Table 2-3A). Average annual SC was 2700 with a nearly identical median value of 2740. During the same period of record, SAR (Table 2-3B) followed the same pattern, with a low of 5.38 in March and a high of 6.42 in April, with average and median annual SAR of 6.00 and 6.06, respectively.

Surface water quality data from environmental baseline studies conducted in the project area several miles upstream are summarized in Table 2-4. Ranges of SC in Otter Creek were 3290 to 4990 with averages from 3601 to 4128 at individual stations, which is somewhat higher than reported by USGS. Similarly, SAR ranged from 4.82 to 8.54 with station averages ranging from 6.56 to 8.54. In general, SC and SAR typically exceed 3000 and 5.0 respectively, by up to a factor of 2.

Due to SC exceeding 3000 µmhos/cm and SAR averaging about 6.0, surface water is not considered suitable for flood irrigation, and such use would likely result in soil degradation due to salt accumulations and/or dispersion of clays in the predominantly silty clay loam soils.

According to USDA Agriculture Handbook 60 (USDA 1954), waters with SC values above 2250 µmhos/cm are seldom suitable for irrigation, and are usable only with more salt tolerant crops when water is used copiously and subsoil drainage is good. Water Quality for Agriculture published by the Food and Agriculture Organization of the United Nations (Ayers and Westcot 1985) lists slight to moderate water use restriction at SC in the range of 0.7 to 3.0 mmho/cm and severe restriction above 3.0. According to USDA Handbook 60, at very high SC (defined as >2250), effects of SAR are enhanced such that values from 3 to 7 are considered medium sodium hazard, and will present an appreciable problem in fine textured soils with high cation exchange capacity. Because the dominant textural class is silty clay loam, use of Otter Creek stream flow for flood irrigation is almost certain to result in poor tilth and low permeability characteristic of sodium-affected (alkali) soils.

In summary, notwithstanding theoretical availability of water in Otter Creek for limited irrigation in some years, water quality limitations of high salinity and moderately elevated SAR effectively preclude the practice. Recognizing the resourcefulness of ranchers in the area, the fact that flood irrigation using Otter Creek base stream flow is not practiced is sufficient demonstration that it is not feasible.

2.7.3 Natural Overflow

The definition of "Flood irrigation" includes "supplying water to plants by natural overflow"… "so that the irrigated surface is largely covered by a sheet of water." At Otter Creek, as noted above, several ranches noted the use of spreader dikes. Examination of aerial photographs and investigations on the ground identified numerous spreader dikes and several diversions of ephemeral tributaries directing snow melt and rainfall runoff to hay fields. Also, numerous retention dikes were noted along the banks of Otter Creek to hold runoff on fields and prevent it from running directly into the creek. Plate 11 shows runoff management facilities and hay fields in the study area. The Otter Creek ranchers have been very resourceful in managing and utilizing low salinity snow melt and rainfall runoff water to enhance soil moisture, and incidentally, flush salts from the root zone.

Runoff management facilities are in use for the length of Otter Creek where hay fields are present to a greater or lesser extent on most ranches and are visible from the Otter Creek road. These facilities are no doubt effective in retaining a major portion of good quality spring runoff such that it infiltrates into soils and alluvium rather than flowing down the creek. Such facilities are also present in upper Threemile and Home Creeks. Appendix D includes a collection of photos documenting spreader dikes, diversions and retention dikes in the project area.

There are four general types of runoff management facilities – side drainage diversions, spreader dikes, retention dikes, and floodwater diversion to containment dikes, which singly or in combination direct, capture and hold water on hay fields. Some of the fields receiving side-channel runoff are in the floodplain, some are out of the floodplain on terrace and fan formations, and some include areas of both. In order to constitute "flood irrigation," the irrigated surface must be "largely covered by a sheet of water" originating from natural overflow or the diversion of flows. Hence, for purposes of AVF identification, "flood irrigation" is necessarily limited to the floodplain formation composed of alluvial streamlaid deposits holding a stream where level topography is conducive to a land surface "largely covered by a sheet of water" whether by natural overflow from side drainages and/or Otter Creek floodwaters, with or without retention dikes, which prolong the time of inundation. As noted above, Otter Creek experiences peak flows exceeding 100 cfs in approximately one out of three years.

2.7.3.1 <u>Side Drainage Diversions</u>

Most of the Otter Creek tributaries have diversions near their mouths ranging from simple to elaborate to direct runoff water to hay fields in the Otter Creek valley. Some of the beneficiary fields are in the floodplain, while others are on higher terraces and fan areas:

- A diversion ditch above the mouth of Tenmile Creek directs runoff to a field on the fan/terrace north of the Denson ranch headquarters.
- Threemile Creek is an exception; a breached dike structure above the mouth appears to be an old impoundment rather than a diversion.

- Above the mouth of Home Creek on the Trusler ranch, there is an elaborate dike and ditch system diverting the entire flow to a large field along Otter Creek road. This field also is on a fan/terrace above the floodplain.
- Fortune Coulee: There are two dikes at the mouth of Fortune Coulee directing runoff to fields to the south and north on the Otter Creek floodplain.
- West Side Tributaries: Similarly, on the west side of Otter Creek, Chromo, Gene and Newell Creeks have spreader dikes or diversions above the mouth directing flow to hay fields both within and outside of the Otter Creek floodplain, as do at least three unnamed ephemeral tributaries.

Tributary diversions are also present on upper Home and Threemile Creeks. On Home Creek, there is a dike across a tributary drainage that serves to divert the entire flow onto a hay field with a series of down-slope spreader dikes. On Threemile Creek, overflow from a pond is routed to a hay field. In both cases, fields receiving diverted water are on fan/terrace/lower slope formations above the floodplain.

2.7.3.2 <u>Spreader Dikes</u>

Spreader dikes are ubiquitous in the study area, and have been built to intercept, detain and infiltrate runoff water, both on and off of the floodplains. There are numerous spreader dikes in hay fields on upper Home Creek on the Stevens ranch; nearly all are well above the narrow Home Creek floodplain on fan/lower slope landforms. On Threemile Creek in Section 12, there is a series of spreader dikes on the floodplain which serve to detain floodwater on several small hay fields.

Spreader dikes are located most often on fields situated on fans and lower slopes, which due to the absence of a stream would not otherwise flood. Dikes function to detain and infiltrate natural overflow and/or diverted ephemeral flow.

On the Otter Creek floodplain, most notably on the Denson and Thomas ranches, spreader dikes appear to be located in areas of concentrated flow from side drainages to detain and infiltrate runoff.

2.7.3.3 <u>Retention Dikes</u>

As noted above, the Otter Creek floodplain is by definition flood irrigated as a result of flooding expected to occur once in three years on average. Retention dikes are dikes constructed along the Otter Creek channel which prevent floodwaters, whether from Otter Creek flooding or inflow from side drainages, from flowing back into the creek. Use of retention dikes on Otter Creek varies between ranches; they are most prominent on the Denson, Thomas and Stevens operations. By retaining flood water on fields rather than allowing it to flow naturally back into the stream when floodwaters recede, retention dikes enhance natural flood irrigation.

2.7.3.4 <u>Floodwater Diversion and Containment Dikes</u>

The most elaborate flood irrigation system using Otter Creek floodwater is on the Trusler ranch. During high flow periods, Otter Creek floodwater is diverted to and collected in a large shallow pond. Using a system of piping, ditches and head gates, water is directed to hay fields on the valley floor with multiple containment dikes or cells where the water is held until it infiltrates. These containment dikes are constructed with gentle slopes negotiable by haying equipment such that no hay acreage is lost to dike construction

2.7.3.5 <u>March 2014 Flood Event</u>

Otter Creek experienced a major snow melt runoff in early March 2014. Appendix E includes a collection of photos taken on March 10, 2014, documenting flooding of the Otter Creek floodplain and retention of water by dikes. These photos are ordered upstream to downstream beginning at the Tenmile Creek road. According to USGS preliminary data (Appendix Table B-1) the peak flow of 650 cfs occurred on March 10, although by the afternoon of that day the flood waters had started to recede. Several of the photos show floodwater held on fields by retention dikes.

The March, 2014, snow melt runoff event is important for two reasons. It demonstrates inundation of fields on the floodplain, which provides low salinity runoff water to hay fields.

Also, it documents the effectiveness of diversions and dikes in distributing and retaining runoff on fields to promote infiltration to maximize soil moisture.

Also, infiltration of runoff water is likely to flush accumulated salts from the soil. This would explain why daily average SC at the Ashland USGS stream gauging station was at a low of 2214 in March, but peaked in April at 2997 (Table 2-3A). This is consistent with an initial flush of salts from March inundation. The steady decline through the growing season to 2430 in September suggests that flushing continues as infiltrated water migrates to the channel emerging as base flow as water levels decline through the summer months.

The matter of accumulation and flushing of salts will be examined in more detail in the discussion of essential hydrologic functions (Section 5.0).

2.8 SUBIRRIGATION

From the definition of "Alluvial valley floor," water **availability** must be sufficient for subirrigation or flood irrigation **agricultural activities**. "Subirrigation" means the supplying of water to plants from a sub-surface zone where water is **available** and **suitable for use by vegetation**. "Agricultural activities or farming" means use of any tract of land for the production of plant or domestic animal life where the use is **enhanced or facilitated** by subirrigation or flood irrigation associated with alluvial valley floors (emphasis added).

The key components of subirrigation are variable, interactive and not easily quantified with respect to enhancement or facilitation of production. The relevant components are:

- Depth to groundwater
- Rooting depth of species grown
- Quality of groundwater
- Salt tolerance of crop species grown
- Crop production

This discussion will address primarily the presence or absence of subirrigation based on depth to groundwater and rooting depth of crop species grown to aid in identification and

AVF delineation. Quality of groundwater will also be reviewed to make a preliminary assessment of whether available groundwater is "suitable for use by vegetation." Production is not addressed here, but is deferred to Section 4.0.

2.8.1 Availability of Groundwater

Depth to groundwater has been discussed in detail, and Plate 8 shows areas where the depth to groundwater is eight feet or less. Most of the Otter Creek floodplain and portions of the major tributary floodplains meet this criterion. Some wells show water levels as shallow as two to five feet.

The dominant hay species based on rancher interviews and vegetation sampling data are alfalfa, crested wheatgrass and smooth brome. Rooting depth characteristics of these species are discussed below:

- Alfalfa is a deep-rooted perennial crop that can survive for long periods between irrigations. Although individual taproots may exceed 20 feet in length, the active feeder roots are located closer to the soil surface with an effective rooting depth of about six feet and will deplete available water to a depth of four to six feet (Bauder, 1978). Based on the foregoing, deep taproots probably aid in long-term survival in the absence of irrigation, but have little bearing on production.
- Crested wheatgrass is an introduced long-lived cool season perennial pasture grass with a bunchgrass growth form. According to Oregon State University (Hannaway and Larson 2004), the root system is fibrous and finely branched with most roots extending to a depth of 3.3 feet, but roots can penetrate to a depth of eight feet.
- Smooth brome also is an introduced perennial cool season pasture grass. It is weakly rhizomatous. In a meadow in West Virginia smooth brome roots grew to a depth of 18 inches with most of the root biomass in the first three inches; however, roots as long as 9.4 feet have been reported (Howard 1996).

The University of California (2014) did not specify rooting depth for individual grass species, but reports that perennial pasture grasses will deplete available water to a depth of two to three feet, which is consistent with rooting depths reported for crested wheatgrass and smooth brome.

Based on the foregoing, there is strong overlap between the depth to groundwater and rooting depths of hay species, particularly when the capillary fringe above the water table is considered. Therefore, it can be concluded that areas mapped with a depth to groundwater of eight feet or less meet the criterion of water availability for subirrigation. This eight-foot criterion is further supported by field data discussed in Section 5.0.

2.8.2 Suitability of Groundwater for Agricultural Use

With few exceptions, SC in groundwater samples exceeds the unsuitability threshold 2250 uS/cm for irrigation water. Even though a few individual samples fall below this threshold, the range of 750 to 2250 is considered high salt hazard and usable for irrigation only under favorable management and drainage conditions; saline conditions will develop if leaching and drainage are inadequate (USDA Handbook 60).

In soil samples with shallow groundwater present, salinity levels are much higher, indicating concentration of salts. The concentration of salts in the soil solution is increased by the extraction of water by roots and by evaporation (USDA Handbook 60).

This situation is also described by FAO (1985). A salinity problem exists if salt accumulates in the crop root zone to a concentration that causes a loss in yield. In irrigated agriculture, many salinity problems are associated with or strongly influenced by a shallow water table (within two meters of the surface). Salts accumulate in this water table and frequently become an additional source of salt that moves upward into the crop root zone. Yield reductions occur when salts accumulate to such an extent that the crop is no longer able to extract sufficient water from the soil solution.

According to Maas (1990), alfalfa is moderately sensitive to salinity and the yield reduction threshold is 2.0 mmhos/cm. According to the same source, crested wheatgrass is moderately salt tolerant with a yield reduction threshold of 3.5 mmhos/cm. Smooth brome is also considered moderately salt tolerant, although a specific yield reduction threshold is not provided.

Smooth brome was not mentioned as a hay grass during rancher interviews, so it is likely that its co-dominance in some hay fields has resulted from invasion. This makes sense because smooth brome has the shallowest root system of the three dominant hay species.

Another species not mentioned by ranchers is quackgrass, which dominates in some fields, particularly where the water table is very shallow. Quackgrass also is an introduced cool season invader characterized by a strongly rhizomatous habit, shallow rooting and high salt tolerance (na.fs.fed.us/fhp/invasive_plants/weeds/quackgrass). It invades wet meadows, wetland borders and other low-lying wet areas of grasslands and prairies. It forms extensive rhizomes that enable it to compete strongly with cultivated crops, and native grasses and forbs in prairies and grasslands.

The strong presence of smooth brome and quackgrass suggests that shallow rooted and salt tolerant species are favored by the soil environment in shallow groundwater areas of the Otter Creek floodplain. It is also apparent that more deeply rooted and salt sensitive alfalfa is not favored in these same areas.

All of the foregoing suggests that shallow groundwater areas of the Otter Creek floodplain are not functionally subirrigated because groundwater is saline, the effect of which is magnified by concentration of salts in the root zone by withdrawal of water by plants. Although this concentration of salts confirms that shallow groundwater is being used by plants, it is likely to reduce yields and promote invasive grass species. The concentration of salts and crop yields will be examined in detail in Section 5.0.

2.9 ALLUVIAL VALLEY FLOOR IDENTIFICATION AND DELINEATION

The first step of alluvial valley floor identification in the valleys of Otter Creek and its major tributaries must consider multiple overlapping geologic, hydrologic, geomorphic and soils criteria in order to identify and delineate those areas with the required physical attributes.

Once that delineation is completed, the second step is to overlay land use information – crop (hay) fields – to identify and delineate flood irrigated and/or subirrigated agriculture. Third, and finally, production data must be applied to compare AVF and non-AVF production in order to assess the significance of productivity enhancement attributable to the AVF. Steps one and two are addressed here; productivity is addressed in Section 4.0.

2.9.1 Physical AVF Criteria

The Step 1 Physical AVF criteria are summarized as follows:

- Geology: Plate 2, Geologic Map, shows Quaternary Alluvium as delineated by MBMG. As noted in the discussion in Section 2.1, this delineation is generalized in that in includes lower slopes, terraces and several upland drainages lacking developed floodplains. Hence, this mapping covers a larger area than the floodplains of the major streams; conversely, any AVF areas will lie within this area mapped as Quaternary Alluvium.
- Surface Water Hydrology: Drainage basins and streams are shown on Plate 6. Otter Creek is the only perennial stream. Tenmile, Threemile, Home and East Fork Otter Creeks are intermittent, although floodplain development varies and some reaches are deeply channeled and/or ephemeral. Based on basin size and intermittent character, these major Otter Creek tributaries are considered to be "streams" within the meaning of the AVF definition, although some channeled ephemeral reaches may ultimately be excluded on that basis. The remaining smaller drainages – Fortune Coulee and Chromo, Gene and Newell Creeks - are ephemeral without floodplain development and do not meet the standard of alluvial "streamlaid deposits holding streams."
- Groundwater Hydrology: Shallow groundwater is documented in monitor wells in Otter Creek, Tenmile Creek, and the upper reach of Threemile Creek. With groundwater depth less than eight feet in much of the Otter Creek floodplain, roots can extend into the capillary fringe, rendering water available for subirrigation. Areas with depth to groundwater of eight feet or less are shown on Plate 8.
- Geomorphology: Plate 4, Topography and Geomorphology, shows the floodplains of Otter Creek and its major tributaries. The Otter Creek floodplain is clearly a depositional landform characterized by a highly sinuous channel with a sinuosity

index of 2.8. Tenmile, Threemile, Home and East Fork Otter Creeks meet the definition of meandering with SI greater than 1.5; floodplain development is variable with some reaches exhibiting a depositional landform.

- Soils: Mapping of soils by NRCS (Plate 9) confirms the dominant soils in the Otter Creek floodplain to be the Haverson (Powder River County) and Havre (Rosebud County) series, both of which are described as forming on alluvium with slopes less than two percent, and used for irrigated and non-irrigated agriculture. The Haverson soils also extend into the major tributaries. Mapping units of soils of several other series with a slope range of 0-2 percent are also present, some of which occur in the floodplain. In many areas, terrace escarpments define the limit of the floodplain.

2.9.2 Floodplain Mapping Procedure

Mapping of the floodplain, or "AVF zone," incorporated geologic, topographic, geomorphic, hydrologic and soils information using the following procedure:

- The floodplain limit was interpreted using topography and terrace mapping overlain on an aerial photograph. This mapping effort was most easily accomplished in the area of five-foot interval topographic mapping by Olympus in the reaches of Otter Creek and tributaries Tenmile, Threemile and Home Creeks within and adjacent to the Otter Creek coal tracts.
- The floodplain limit was superimposed on the shallow groundwater (< 8 feet) map. Confidence in the shallow groundwater map is highest in the area of five-foot topographic mapping where the density of monitoring wells is greatest, and downstream to the AVF1 cross-section. Within these zones on Otter Creek, Tenmile Creek and Upper Threemile Creek the fit was very good, with additional minor adjustments made.
- The floodplain limit as adjusted to match the shallow groundwater zone was then superimposed on the NRCS soils map with probable and possible alluvial soils highlighted. Again, the fit was very good in the higher confidence topography and shallow groundwater zones with a few additional minor corrections. Upstream of the Tenmile Creek road and downstream of well cross-section AVF1, the limit was

adjusted to coincide largely with floodplain soil mapping as the most objective criterion where USGS topographic mapping utilizes a 20-foot contour interval.

The application of multiple criteria in concert assures the most precise and objective mapping of the AVF zone. This is the zone where geologic, topographic, geomorphic and hydrologic conditions are conducive to natural overflow and/or shallow groundwater.

2.9.3 Flood Irrigated and/or Subirrigated Agriculture

The intersection of the AVF zone and crop fields is shown on Plate 12 – Alluvial Valley Floors Hay Cropland. Crop fields are derived from Plate 10 – Vegetation. Fields benefitting from side drainage inflow and floodwater diversion are indicated and ranch boundaries are shown (From Plate 11 – Land Use).

Plate 12 also includes grouping of fields by ranch, with acreages within and outside of the AVF. Production by ranch is addressed in Section 4.0 based on these plates.

2.9.4 Infrared Aerial Photography

Infrared (IR) aerial photography may be useful in reconnaissance level investigations to identify areas that may be alluvial valley floors. Plates 13A through 13E are a series of IR aerial photographs showing the AVF outline for comparison with moisture enhanced vegetation as indicated by brighter red hues.

3.0 STATUTORY EXCLUSIONS

The AVF study area (Plate 1) encompasses valley bottoms in the lower reach of the Otter Creek drainage from Tenmile Creek downstream to the mouth. ARM 17.24.325 states under what circumstances AVF investigations and protections are required:

(1) This rule applies to each applicant who conducts or intends to conduct coal mining and reclamation operations in, **adjacent** to or under a valley holding a stream in the arid or semi-arid regions.

"Adjacent area" is defined in 82-4-203, MCA, as "the area outside the permit area where a resource or resources, determined in the context in which the term is used, are or could reasonably be expected to be adversely affected by proposed mining operations, including probable impacts from underground workings."

Therefore, streams within the AVF study area that could not be reasonably expected to be adversely affected by mine operations at Otter Creek Mine are excluded from the "adjacent area," or are not "adjacent to," for purposes of AVF identification and investigation.

Also, there are statutory exclusions from the AVF investigation and protection requirements codified at 82-4-227(3)(b) MCA and addressed in ARM 17.24.325(3)(a). These provisions are quoted below:

82-4-227 MCA:
(3): The department may not approve an application for a strip- or underground-coal-mining permit or major revision unless the application affirmatively demonstrates that:
…
(b) the proposed strip- or underground-coal-mining operation would not:
(i) interrupt, discontinue, or preclude farming on alluvial valley floors that are irrigated or naturally subirrigated, **excluding undeveloped rangelands that are not significant to**

farming on alluvial valley floors and excluding land about which the department finds that if any farming will be interrupted, discontinued, or precluded, it is of such small acreage as to be of negligible impact on the farm's agricultural production (emphasis added)**;** or

(ii) materially damage the quantity or quality of water in surface water or underground water systems that supply the valley floors described in subsection (3)(b)(i).

ARM 17.24.325:

(3)(a)(i) Whenever an alluvial valley floor is identified pursuant to (2)(b), and the proposed coal mining operation may affect this alluvial valley floor or waters that supply the alluvial valley floor, the applicant may request the department, as a preliminary step in the permit application process, to separately determine the applicability of the statutory exclusions set forth in (ii). The department may make such a determination based on the available data, may require additional data collection and analyses in order to make the determination, or may require the applicant to submit a complete permit application and not make the determination until after the complete application is evaluated.

(ii) An applicant need not submit the information required in (3)(c)(ii)(B) and (C), and the department is not required to make the findings of (3)(f)(ii)(A) and (B) when the department determines that 1 of the following circumstances, heretofore called statutory exclusions, exist:

(A) the premining land type is undeveloped rangeland that is not significant to farming;

(B) any farming on the alluvial valley floor that would be affected by the coal mining operation is of such small acreage as to be of negligible impact on the farm's agricultural production. Negligible impact of the proposed operation on farming is based on the relative importance of the affected vegetation and water of the developed grazed or hayed alluvial valley floor area to the farm's production over the life of the mine; or

(C) the circumstances set forth in ARM 17.24.802(3) exist.

(iii) For the purposes of this section, a "farm" is 1 or more land units on which agricultural activities are conducted. Agricultural activities or farming are generally considered to occur on a combination of land units with acreage and boundaries in existence prior to August 3, 1977, or, if established after August 3, 1977, with those boundaries based on enhancement of the farm's agricultural productivity and not related to coal mining operations.

As confirmed in Section 2.0 above, the floodplain of Otter Creek within and adjacent to the Otter Creek coal tracts meets initial AVF screening criteria as do portions of some tributary drainages in the AVF study area (Plate 12). OCC proposes that tributary drainages be excluded from further AVF investigations and protection requirements either due to lack of adjacency, or as a result of exclusions authorized by 82-4-227(3)(b), MCA. This section presents the information supporting those exclusions.

3.1 TENMILE CREEK

Tenmile Creek lies along the south boundary of Tract 2 (Plate 1). It is intermittent in this reach. There are several hay fields portions of which overlap the narrow floodplain, and the floodplain has shallow groundwater (Plate 8). Floodplain hay fields in Tenmile Creek downstream of the CNF boundary comprise just 40 acres, or five percent of the Denson Ranch 773-acre hay acreage. Groundwater quality at well A4 near the CNF boundary is saline with SC of 2910 and SAR of 4.72.

Mining will not advance into the Tenmile Creek watershed because the Knobloch seam is separated into multiple splits in the southern portion of Tract 2, and the upper Knobloch is burned along the flanks of Tenmile Creek. Therefore, surface water drainage patterns will remain unaffected. Also, because at least 85 percent of the watershed area is to the east upstream of the AVF study area on the CNF, it is reasonable to conclude that a comparable percentage of alluvial groundwater and flood water during major runoff events originates upstream.

Tenmile Creek is not adjacent to currently projected or potential future coal mining operations at Otter Creek. Adverse effects are not reasonably expected. Any alluvial valley floor, or the waters that supply any alluvial valley floor, would not be affected. It should be excluded on that basis.

3.2 THREEMILE CREEK

Threemile Creek separates Tracts 1 and 2. It is intermittent in the upper portion (Section 12, T.4S, R.45E) and near the mouth; the intervening segment is ephemeral. The only cropland is in Section 12, where several small fields lie in the narrow floodplain, which has shallow groundwater and spreader dikes to intercept and retain runoff from snow melt and larger rainfall events. Groundwater quality at well A5 is saline, with SC of 3603 and SAR of 5.62.

The valley bottom of Threemile Creek is inside the permit area, but outside of the mining area. Because it lies between projected and potential future mining areas on Tracts 2 and 1 respectively and portions of its watershed area will be affected, Threemile Creek is in the adjacent area. Approximately 90 percent of the drainage area lies upstream to the east on the CNF, so inflow to Section 12 will be only minimally affected. There is a pond in Section 12 (Pond 4) with an overflow spillway that directs runoff to a hay field on a terrace outside the floodplain, bypassing the floodplain fields.

The probability of adverse effects on water supply to hay fields on the floodplain in Section 12 is remote since this reach is at the tract boundary and the water supply originates upstream on the CNF.

Threemile Creek should be excluded on three bases:

- The lower reach below Section 12 is undeveloped rangeland and qualifies for the statutory exclusion on this basis.
- Tarter Ranch hay fields are shown on Plate 14. The floodplain hayfields on Section 12 comprise 16 acres of the Tarter ranch hay acreage of 267acres, or 6 percent. This is such small acreage as to have negligible impact on Tarter Ranch hay production and qualifies for the statutory exclusion. Productivity of the Threemile Creek hay fields is addressed below in Section 4.0.
- Adverse effects are improbable and not reasonably expected to occur because the water supply originates upstream in the CNF.

3.3 HOME CREEK

Home Creek flows southwestward toward Otter creek across the northwest corner of Tract 1. It will not be mined; the Knobloch coal is burned and there is a wide band of clinker separating it from the coal on Tract 1. Groundwater is too deep for subirrigation to be a factor.

The reach of Home Creek in Tract 1 is ephemeral and therefore does not meet the definition of “stream” for purposes of AVF identification. The floodplain is narrow, the channel is deeply incised and the weak meander is likely erosional rather than depositional. Hayfields on this reach in some cases overlap the narrow floodplain, but are primarily situated on lower slopes and fans of ephemeral tributary drainages on the south flank. These fields have numerous spreader dikes to capture and infiltrate runoff water from the side drainages, and in some locations there are retention dikes along the lower boundaries to reduce loss of runoff water to the channel. Mining on Tract 1 will eventually cut off the upper reaches of these tributary drainages for drainage control; effects will be temporary and drainage will be restored when mining and reclamation are complete.

Downstream of Tract 3 near the mouth Home Creek is intermittent with a narrow meander belt. In the east half of Section 28 (T.3S, R.45E) upstream of the Otter Creek road, a hay field overlaps into the floodplain and shallow groundwater is mapped. The hayfield portion mapped in the floodplain is 10 acres, or 1.0 percent of the Trusler Ranch hayfield acreage, which is not significant. Any impact would have negligible impact on the farm’s agricultural production, and Home Creek qualifies for the statutory exclusion on this basis.

Between Otter Creek road and the Otter Creek confluence, there are no hay fields within the Home Creek meander belt, and the exclusion for undeveloped rangeland applies.

3.4 EAST FORK OTTER CREEK

There will be no mining within the East Fork Otter Creek watershed. There are no hay fields mapped in East Fork Otter Creek below the CNF boundary (Plate 11). Because hydrologic functions will not be impacted and adverse effects are not reasonably expected to occur, East Fork Otter Creek is not in the adjacent area.

3.5 FORTUNE COULEE

Because the lower portion of Fortune Coulee within Tract 2 is within the area slated for mining, it is mentioned here. Fortune Coulee is an ephemeral drainage. It does not meet the definition of a stream. The channel is deeply incised and is clearly erosional rather than depositional. There are no hay fields above the mouth, and the entire watershed is undeveloped rangeland. Therefore, it is not an AVF.

3.6 WEST SIDE TRIBUTARIES

Three named tributaries on the west side of Otter Creek are Chromo, Gene and Newell Creeks. Only Chromo Creek has a minor acreage of drainage bottom hay cropland near the mouth; otherwise all consist entirely of undeveloped rangeland. Chromo Creek and Gene Creek lie to the south of Tract 3, their watersheds will not be affected by future mining on that tract, and hence are not in the adjacent area.

Newell Creek and several smaller unnamed ephemeral drainages lie within Tract 3, and none meets AVF criteria:

- All are ephemeral and do not meet the definition of “stream” for AVF purposes.
- None has a developed meander belt; weak meander where it occurs is likely erosional rather than depositional.
- None has floodplain hay acreage above the mouth, and all consist solely of undeveloped rangeland.

Based on the foregoing, there are no potential AVF’s among the tributaries on the west side of that portion of Otter Creek in the AVF study area.

3.7 SUMMARY

Regulatory AVF criteria are addressed in detail in Section 1.0. These criteria are applied in Section 2.0 to identify and delineate the Otter Creek AVF. Those areas of tributaries

Tenmile, Threemile, Home and East Fork Otter Creeks with AFV characteristics are also delineated. In Section 3.0, exclusion criteria are applied to the tributary drainages to exclude those which:

- Are not part of the “adjacent area” (Tenmile Creek, East Fork Otter Creek, Chromo Creek, Gene Creek);
- Do not meet the criterion of “alluvial streamlaid deposits holding a stream” (upper Home Creek, Fortune Coulee, Chromo Creek, Gene Creek, Newell Creek);
- Do not support “subirrigation or flood irrigation agricultural activities” (upper Home Creek, East Fork Otter Creek, Fortune Coulee, Chromo Creek, Gene Creek, Newell Creek);
- Consist of undeveloped rangelands not significant to farming (lower Threemile Creek, Fortune Coulee, Chromo Creek, Gene Creek, Newell Creek) and/or
- Have such small hay acreage in the floodplain so as to be of negligible impact on a farm’s production (Tenmile Creek, upper Threemile Creek, upper and lower Home Creek).

All of the Otter Creek tributaries in the AVF study area meet one or more exclusion criteria, and more detailed studies and findings are not indicated.

4.0 AGRICULTURAL PRODUCTION

Hay production was examined using two data sets of bale count data:

- Farm Service Agency (FSA) reports by the Thomas and Denson ranches during the period 2006-2011 were reviewed and compiled.
- Bale counts had been planned for 2012, but due to dry conditions and consequent low production many if not most fields were not harvested. Available information for the Thomas and Denson ranches are included in the review of FSA data.
- Bale counts were completed in 2014 on nearly all fields in the AVF study area, including tributaries.

In each of these data compilations, data are grouped and compared based on location in the AVF versus not in the AVF. Within these groupings, fields receiving additional overflow from side drainages are identified and broken out for comparison.

4.1 FARM SERVICE AGENCY DATA – THOMAS AND DENSON RANCHES

4.1.1 Acknowledgements

Two ranches, operated by Thane Thomas and Ross and Dennis Denson, have participated in the USDA Farm Service Agency (FSA) Non-Insured Assistance Program. The investigators wish to thank both ranchers for granting permission to access their FSA records reporting annual hay production, and acknowledge their assistance in compiling the data presented in this report.

Also, the investigators wish to thank Mr. Mike Riley of the Powder River County FSA office in Broadus for his assistance in providing copies of reporting forms, aiding with verification of bale numbers, and generally providing information about the program. According to Mr. Riley, the Thomas and Denson ranches are the only ranches operating in the AVF study area that have filed production reports under this program. Mr. Thomas filed in 2008, 2010 and 2011. Mr. Denson filed in 2006, 2007, 2008, 2010 and 2011. Mr. Riley verified that neither ranch had filed reports for 2009 or 2012.

4.1.2 Methods

Under the FSA program, hay production is to be reported as numbers of bales harvested from individual fields and so indicated on tract maps on an aerial photo base. Average bale weight is also reported.

Not surprisingly, quality and consistency of reporting varied, with bale totals and weights only reported by Thomas in 2008 and Denson in 2011. In many cases, legibility was a problem due to the dark aerial photo base. Legibility problems were resolved by consulting with Mr. Riley at FSA by telephone. Also, some fields crossed tract boundaries and/or may have been combined or separated in different years' reporting. Copies of completed map sets are included as Appendix H.

4.1.3 Data Compilation

In order to compile the data, the following procedure was followed.

- Section maps were prepared from Plate 10 – Vegetation, which shows hay fields.
- Bale numbers from reporting maps for each year were plotted by field on the section maps. This was a tedious process that required some judgment to make sure all production was accounted for in as consistent a manner as possible. Fields were assigned AVF categories (in or out) using Plate 12.
- FSA field acreages were taken from the reporting forms.
- Individual field data were tabulated by section, with hay production in tons per acre (t/ac) calculated for each field.
- Individual field data were sorted by AVF category, excluding fields encompassing both categories.
- Total bale numbers from the section plots and total FSA field acreages for each section were compiled to calculate total hay production in tons per acre for each ranch. (Totals for tabulated field acreages and bale counts may not agree with section totals because tabulated data utilized only numbers that could confidently be assigned to individual fields.)

4.1.4 Disclaimer

This analysis utilizes data submitted by Mr. Thomas and Mr. Denson to FSA. The investigators had no role in collecting the field data and cannot attest to its accuracy. Although the data are felt to be reliable, inconsistencies in reporting and legibility problems created challenges in compilation, which have been resolved as consistently as possible. Despite the foregoing, the investigators are confident that the data analysis reasonably assesses hayland productivity for the ranches and years examined, and that the results are representative of the Otter Creek Valley within the AVF study area.

4.1.5 Confounding Factors

The compilation and analysis of hay production data considers gross production only in tons per acre. The FSA reporting forms also indicate the type of hay grown in each field; these types are noted in the tabulations. The hay types are:

- IGS – Intermixed Grasses
- AGM – Alfalfa-Grass Mix (25-60% Alfalfa)
- GMA – Grass-Alfalfa Mix (5-25% Alfalfa)
- ALF – Alfalfa
- WCR – Crested Wheatgrass
- RRW – Russian Wildrye

Possible differences in productivity for the different hay types are not considered, and may confound the results to some extent.

The reporting forms also include the date seeded. This information was not compiled or tabulated. For alfalfa and alfalfa-grass mixes, alfalfa dominance may decline with time, which may affect productivity.

This analysis did not consider potential effects of soil differences. Soils in the AVF study area are addressed in subsection 2.4.

In no single year were bale counts reported for all fields on either ranch. In some cases there was a notation that a field was not harvested, but for the most part this was not the case. For purposes of the analysis it was assumed that fields with no reported bale counts were not harvested, but the possibility that bale counts may have been combined with adjoining fields cannot be ruled out.

The data are reported from two neighboring ranches. In reviewing and compiling the data, it became apparent that reporting methodology may not have been consistent. To avoid possible confounding effects of reporting methodology, results are presented by individual ranch. This aspect is discussed in the results section below.

4.1.6 Thane Thomas Ranch

The Thane Thomas ranch operation includes hay cropland on the Otter Creek bottom in portions of Sections 15, 22 and 27, T4S, R45E. Table 4-1 shows hay production on the Thomas ranch by field for the years 2010 and 2011. In 2008, totals only were reported. Hay production for individual fields ranged from 0.69 to 2.72 t/ac in 2010 and 0.77 to 2.74 t/ac in 2011.

Table 4-2 shows these data sorted by AVF category. Averages for individual field data are tabulated below (tons per acre):

Thomas Ranch	**2008**	**2010**	**2011**	**Average**
AVF	-	1.58	1.65	1.62
Non-AVF	-	-	1.10	1.10
Total	1.55	1.58	1.62	1.58

In reviewing the Thomas data, it appeared that in at least some cases bale numbers may have been allocated to individual fields generally by acreage within a reporting tract, although there is no way to be certain. This is inferred because bale numbers were reported most often, but not always, in multiples of five or ten. This approach would dampen any differences between terrace levels.

From this data array, it can be inferred that hay production on the Thomas ranch portion of the Otter Creek valley bottom is typically in the range of 1.5 – 1.6 t/ac. The one field out of the AVF was harvested only in 2011, so the AVF vs. non-AVF (1.54 vs. 1.10 t/ac) comparison is questionable. What is most interesting is that three fields with side drainage inflow averaged 2.05 t/ac, or 27 percent more than the AVF average.

In 2012, Mr. Thomas harvested a total of just 180 bales at 1100 lbs/bale, (pers. comm., Oct 17, 2012) or 99 tons. This works out to 0.27 t/ac. He estimated ½ to ¾ bale (0.28 to 0.41 tons) per acre; it is likely that some fields were not harvested due to lack of production in a year with a very dry spring.

4.1.7 Ross and Dennis Denson Ranch

The Denson ranch includes hay fields in the Otter Creek bottom (portions Sections 27, 34 and 35, T.4S, R.45E and Sections 2 and 3, T.5S, R.45E), Tenmile Creek (Section 1, T.5S, R.45E), both in and out of the AVF study area, and upland fields west of Otter Creek. The Denson data appear to be quite good in the sense of accuracy and consistency from year to year, although there are some apparent anomalies. Table 4-3 shows hay production by field reported by Denson. In 2006, production ranged from 0.16 to 1.52 t/ac. Corresponding ranges for 2007, 2008 and 2010 were 0.26 to 4.29, 0.98 to 2.43, and 0.75 to 2.71 t/ac, respectively. In 2007, the low figure of 0.26 t/ac was from an upland field only a portion of which was harvested. The high figure of 4.29 t/ac seems unlikely, but there is no ambiguity on the report map.

Table 4-4 shows the individual field data sorted by AVF category. Upland fields west of Otter Creek are included for comparison purposes; fields along Tenmile Creek are separated as well. Averages are summarized in the following table (tons per acre):

Denson Ranch	**2006**	**2007**	**2008**	**2010**	**Average**
AVF	0.87	1.76	1.38	1.67	1.42
Non-AVF	1.29	1.74	1.76	1.88	1.67
Total OC	0.81	1.73	1.39	1.70	1.41
Tenmile	1.13	1.47	1.40	2.09	1.43
Upland	0.16	0.26	0.91	0.87	0.55

For five inflow fields within the floodplain, the overall average production was 1.78 t/ac, or 125 percent of the AVF average. On two inflow fields outside of the floodplain, average production was 1.93 t/ac, or 116 percent of the non-AVF average average.

Most fields in Section 1 on Tenmile Creek overlap floodplain and non-floodplain areas, so comparison was not possible. Production was not materially different from fields on Otter Creek.

In 2012, Denson (pers. comm., Oct. 19, 2012) reported total production of 500 bales at 1100 lb/bale, or 275 tons. Based on total hay cropland of 709 acres, this calculates to 0.39 t/ac. This is similar to the range reported by Thomas in this very dry year.

Several trends are apparent from the Denson ranch data:

- Total average production over all years was about 1.4 tons/acre.
- Within the AVF, production relative to non-AVF fields varied, but was slightly lower on average for the four years of data (1.42 vs. 1.67 t/ac).
- For fields with side-drainage inflow, average production was 12-25 percent higher in both AVF and non-AVF fields.
- Production on upland fields with shallower soils averaged 0.55 t/ac, or about 40 percent of that observed on alluvial soils as a whole.
- For the four years with field specific data production was lowest in 2006 and highest in 2007.
- Production on Tenmile Creek was similar to Otter Creek.

Total hay production figures for the Thomas and Denson ranches are shown on Table 4-5. This table includes all of the data reported by Thomas and Denson for the period 2006-2012, whether broken down by field or not. This analysis is useful because it examines six of seven years (There was no data for 2009.) On this table, data for Tenmile Creek and upland fields in Sections 3 and 4 (T.5S, R.45E) are presented separately from Otter Creek data. Also, in calculating total production for 2011 and 2012, acreage in Section 31 (T.5S, R.46E) is included because the bale counts are presented as totals. Considering all acreage and production on both ranches combined, annual production was as follows:

YEAR	TONS/AC
2006	0.73
2007	1.41
2008	1.35
2009	
2010	1.52
2011	1.72
2012	0.37

Average production for these six years was 1.18 tons/acre, ranging from 0.37 to 1.72 tons/acre in 2012 and 2011, respectively.

Figure 4-1 displays the relationship between overall combined hay production on the Thomas and Denson ranches compared to spring precipitation, defined as the period March through June. The relationship is very good, demonstrating hay yields in tons per acre to be a direct function of spring precipitation.

4.1.8 Discussion

Rancher interviews summarized in subsection 2.6 reported yields typically in the 1-2 t/ac range, with 1-1.5 t/ac reported most often. Data from both ranches calculate to average yields of about 1.5 t/ac (except in very dry years), which is consistent with rancher interviews and NRCS predicted yields for non-irrigated soils in the AVF study area (Table 2-8). This result suggests that benefit to hay crops from shallow groundwater in dry years, if any, is minimal. Further, yields varied substantially from year to year, supporting the conclusion that shallow groundwater is not a primary determinant of hay production in the valley floor.

Quality of groundwater is discussed in subsection 2.3.2.3, and suitability for subirrigation is addressed in subsection 2.8. Groundwater quality exceeds salinity thresholds for irrigation, and soils data suggest concentration of salts in the root zone due to the shallow water table. Very shallow groundwater may be detrimental in other ways. Alfalfa in particular does not do well on waterlogged soils, and lower terraces may be difficult to harvest due to soft ground conditions, particularly in wet years. Production data confirm that production on the AVF is neither substantially greater nor more consistent than production in fields outside of the AVF.

On both ranches, fields both in and out of the AVF receiving inflow of snow melt and/or precipitation runoff from ephemeral side drainages had 12 to 27 percent greater production than the average. This result suggests that yields are more likely a function of precipitation and seasonal flooding, depending on position and floodwater management.

4.1.9 Summary and Conclusions

This data set derived from FSA reports is far from ideal because it examines just two ranches occupying a relatively small part of the AVF study area, and data reporting was not consistent from year to year. However, these concerns are largely offset in that the data allow examination of AVF vs. non-AVF production in some years, and comparison over a seven-year period with varying rainfall. By examining each ranch separately, separating field specific data from general totals, and then considering the entire data base together, important trends can be discerned. Primary conclusions from this review of hay production on the Thomas and Denson ranches are:

- Hay production is consistent with information obtained during rancher interviews, and is also consistent with NRCS production figures for unirrigated soils.
- Hay production in the Otter Creek valley varies from year to year.

- Annual variability in hay production closely parallels variation in early growing season rainfall (March through June).
- In 2012, a very low rainfall year, hay production was less than 30 percent of the average reported over five prior years.
- Highest overall production was 1.72 tons/acre in 2011, which was also the wettest year. (Based on this result, reports of 2011 production in the 3.5 –tons/acre range may have been overly optimistic.)
- Hay production is not materially greater in the AVF compared to terraces outside the AVF.
- Hay production in fields receiving ephemeral inflow from side drainages was up to 27 percent higher than the average.

From the foregoing, shallow groundwater plays a minimal role in hay production, and it does not provide a usable water supply for hay crop growth during extended periods of low precipitation.

The essential hydrologic functions driving hay production appear to be:

- Sufficient early growing season rainfall.
- Overflow from Otter Creek into low-lying fields during seasonal flooding in some years.
- Ephemeral inflow from side drainages directed to specific fields by diversions and spreader dikes.
- Infiltration of rainfall and natural inflow into deep alluvial soils facilitated by the flat topography of the floodplain and higher terraces.

4.2 2014 BALE COUNTS

In 2014, a major effort was made to get bale counts as complete as possible for hay fields in the AVF study area, including Tenmile, Threemile and Home Creeks in addition to the Otter Creek valley bottom. Counts were completed by Dave Simpson of Simpson & Associates LLC, and Darrel Myran working for Hydrometrics, Inc. Between the two investigators, the effort consisted of visiting the study area approximately every other day beginning on June 22 and continuing through July. The last visit was on August 4, with a follow-up on August

28 to document any second cutting. There was no second cutting observed, and Trusler, Stevens, Denson and Thomas confirmed as much. A second follow-up visit September 15 again confirmed no evidence of second cutting.

Records at the Otter Creek meteorological station showed total precipitation of 7.78 inches from March through June, which is near the long-term average of 8.05 inches. This level of precipitation corresponds to predicted average production of about one ton per acre based on the graph in Figure 4-1.

In early March 2014, there was a snowmelt event that resulted in extreme flooding of the Otter Creek valley floor. According to Thane Thomas (personal communication), an 80-year resident told him that this was only the second time he could remember in his lifetime that Otter Creek had flooded to that extent. Photos taken on March 10 are included in Appendix E. This flood event would be expected to increase soil moisture on the flood plain above that available from precipitation alone.

4.2.1 Methods

Each investigator kept bale counts on section maps prepared from Plate 12 which identifies fields by number. Counts were maintained independently, although the investigators communicated after each visit to advise of swathing and baling activity, and to decide on the next field visit to minimize data loss due to bales being stacked before counting. Communication with ranchers during field visits yielded estimated bale weights and other pertinent information.

At the conclusion of bale counts, both investigators met to go through the data and prepare a master table and set of maps. In a very few cases where counts differed, they were resolved in favor of the higher number, on the theory that under-counting was more likely than over-counting.

The master table listed field numbers (Plate 12), the number of bales counted and comments. Fields not harvested were so noted. For each harvested field, acreage in the AVF, acreage outside of the AVF, total acreage, with bale counts and bale weights, were used to calculate tons per acre for each field.

Data were analyzed in several ways to glean as much information as possible from the data set. Analyses included:

- Analysis by ranch on Otter Creek– tabular and graphic
- Analysis by drainage – tabular and graphic
- Comparison of AVF fields to non- AVF fields (Otter Creek only)

4.2.2 Results

Plate 12 identifies 158 fields wholly or partly within the study area, and all of these fields were included in the counts. Exclusions from the bale count data base were made for several reasons:

- 25 fields were not harvested.
- Three fields on the Brian Creek Cattle Company ranch south of the Tenmile Creek road were excluded. These were partial fields and Brian Creek Cattle Company is outside the area of interest.
- Four small fields near the mouth were excluded because of overlap outside the study area, use of small square bales and/or location on the Tongue River floodplain.
- Exclusion of these 32 fields leaves a net of 126 fields in the study area. Of these, complete counts were obtained on 123 fields, or 98%. Of the three remaining fields, two had incomplete counts due to poor visibility and lack of access (O 126, Snodgrass) and stacking before counting (O 8W, Denson); one field (O 81, Stevens) had no count due to stacking before it could be counted.

4.2.2.1 <u>Otter Creek Production by Ranch</u>

There are seven ranch operations with hay cropland acreage on Otter Creek within the AVF study area; hay harvest occurred on six of these. Hay production on each ranch is examined based on 2014 bale counts. Ranches are arranged downstream from the Tenmile Creek road to the Tongue River confluence. Data tabulated by ranch are presented on Tables 4-6A to F.

Denson Ranch

Otter Creek hay harvest on the Denson ranch (Table 4-6A) occurred on 17 fields ranging in size from 4.2 to 125.3 acres. Of the total of 400 hay cropland acres harvested, 67 percent were within the AVF. A complete count was not obtained on one field (O 8W). Average production based on individual field counts was 1.12 t/ac; total production (total tons/total acres) was 1.40 t/ac. This disparity no doubt arises from over-representation of small fields with lower yields in the arithmetic average, and the weighted average is the more reliable figure. Graphic representation indicates essentially no difference in production between AVF and non-AVF fields, with the former perhaps 0.1 t/ac higher. Based on comparison of the arithmetic and weighted averages, the difference is skewed downward.

Average production on five fields receiving inflow from side drainages was 1.72 t/ac, or 122 percent of the overall average. Four of the five fields exceeded the average, and the highest producing field was among them at 2.29 t/ac, receiving runoff diverted from Chromo Creek.

Thomas Ranch

On the Thomas ranch (Table 4-6B), 34 fields ranging in size from 0.5 to 35.6 acres were harvested. Total hay cropland acreage harvested was 327 acres, 86 percent of which was within the AVF. Hay production ranged from 0.70 to 3.23 t/ac, with an arithmetic average of 1.67 t/ac. Overall production was 1.43 t/ac, indicating over-representation of smaller fields with higher production in the arithmetic average. The weighted average production is virtually identical to the corresponding figure for the Denson ranch. Graphic representation suggests higher production on the AVF fields by about 0.7 t/ac; the graph is skewed upward compared to overall production.

The Thomas ranch includes six fields that benefit to at least some extent from side drainage inflow. Average production for these five fields was 1.71 t/ac, or 120 percent of the overall average. Three of the six fields exceeded the average. The highest producing field was not an inflow field.

Stevens Ranch

On the Stevens ranch (Table 4-6C) portion of Otter Creek, 24 fields with acreage ranging from 1.0 to 46.9 acres were counted; one harvested field (O 81) was not counted because bales were stacked before a count could be obtained. Harvested acreage of 375 acres was 69 percent within the AVF. Hay production ranged from 0.31 to 2.27 t/ac with an arithmetic average of 1.24 t/ac and overall production of 1.32 t/ac. Graphic presentation of the data suggests greater production on AVF fields by about 0.7 t/ac, or about double that on non-AVF fields. This graph is no doubt skewed somewhat downward toward the non-AVF side; nonetheless, this positive difference between AVF and non-AVF fields was greatest among the ranches counted. During a conversation in the field, Mr. Stevens commented that this was the first time in several years that the floodplain fields produced more than the upper terrace fields.

Four fields on the Stevens ranch benefit from side drainage inflow, although the contributing watersheds on the east side of the highway are relatively small. Average production for these fields was just 1.17 t/ac, or 88 percent of the overall average. Two of the four fields exceeded the average. The highest producing field was not an inflow field.

Gaskill Ranch

In 2014, hay was not harvested on the Gaskill ranch portion of the Otter Creek valley bottom. Grazing of the hay fields continued through the summer.

Woods Ranch

On the Woods ranch (Table 4-6D), five fields ranging from 3.5 to 150.6 acres were harvested; 52 percent of the total hay cropland acreage of 315 acres was within the AVF. Production ranged from 1.27 to 2.35 t/ac with an arithmetic average of 1.65 t/ac. The overall average was 1.46 t/ac. The smallest field produced 2.3 t/ac, skewing the average upward. Graphic presentation of the data showed slightly higher production in the AVF, but essentially no difference with just five data points.

The single inflow field produced 1.55 t/ac, or 106 percent of the overall average. It was not the highest producing field.

Trusler Ranch

The Trusler ranch (Table 4-6E) has the largest Otter Creek hay acreage at 819 acres, with field size ranging from 6.0 to 134.0 acres, and 80 percent of the acreage within the AVF. Individual field production ranged from 0.58 to 2.31 t/ac with an arithmetic average of 1.39 t/ac. The overall average was nearly identical at 1.41 t/ac. Graphic presentation of the data indicates AVF fields producing about 0.2 t/acre less than non-AVF fields, or essentially no difference.

Two fields receiving inflow from adjacent side drainages averaged 1.81 t/ac, or 128 percent of the overall average. Similarly, two fields receiving irrigation water diverted from high flows in Otter Creek averaged 1.74 t/ac, or 123 percent of the average. One of the inflow fields was the highest producing at 2.31 t/ac.

Snodgrass

The Snodgrass property (Table 4-6F) lies north of Highway 212 nearly to the mouth in Section 11 (T.2S, R.44E), adjacent to the town of Ashland. It is not known if haying is done by the owner, or if it is leased to another party. Due to lack of access, the count for field O 126 was short due to limited visibility from the nearest public road. Bale weight was assumed to be 1400 lbs. Production on two counted fields totaling 67 acres was nearly identical at 1.09 and 1.07 t/ac with the former mostly in and the latter mostly out of the AVF. The overall average was 1.07 t/ac. Acreage within the AVF was 25 percent of the total.

Summary of Individual Ranch Otter Creek Production

Overall average production between ranches was remarkably similar, ranging from a low of 1.32 t/ac on the Stevens ranch to 1.46 t/ac on the Woods ranch. (Snodgrass was excluded due to the small sample.) The very narrow range of 0.14 t/ac could easily be attributed at least partly to bale weight estimates. Woods had the highest estimated bale weight at 1450 lbs;

coincidentally the Woods ranch had the highest average production. Conversely, Stevens (along with Denson) had the lowest bale weight estimate at 1200 lb.

This consistent result suggests strongly that hay production is reasonably uniform on Otter Creek within the study area. This is to be expected because soils in the valley bottom are reasonably consistent along this reach. Percentage of hay cropland within the AVF ranged from 67 percent on the Denson ranch to 86 percent on the Thomas ranch. Hence all five ranches had a majority of their Otter Creek hay cropland acreage within the AVF. Production on individual fields varied greatly, from 0.31 to 3.23 t/ac, reflecting a number of potential factors including variations in soils, surface water management, natural flooding, species composition and management practices.

4.2.2.2 <u>Production by Drainage</u>

Given the foregoing, it is reasonable to analyze hay production data for all fields on Otter Creek. Combining of ranches results in a large sample size which allows statistical analysis. Hay production in tributary drainages also is addressed in this subsection.

Table 4-7 shows the compilation of Otter Creek hay fields. There were 103 hay fields comprising 2302 acres in the Otter Creek portion of the study area harvested in 2014. The arithmetic average yield was 1.41 t/ac with a range of 0.31 to 3.23 t/ac. The overall average production was nearly identical at 1.39 t/ac. Graphic presentation showed a difference of about 0.3 t/ac between non-AVF and AVF fields, which may be estimated from the graph at 1.2 and 1.5 t/ac, respectively, or a difference of about 0.3 t/ac. This result indicates production on the AVF was about 125 percent of production outside of the AVF.

Seventeen inflow fields had average production of 1.58 t/ac, or 112 percent of the average; ten fields exceeded the average. Similarly, two fields irrigated by flood water diversion averaged 1.74 t/ac, or 125 percent of the overall average.

Sixty-one fields classified as AVF based on 80 percent or more within the AVF (green fill) and 27 fields considered outside the AVF (AVF acreage 20 percent or less; yellow fill) were analyzed using an unpaired t-test (graphpad.com/quickcalcs/ttest2). The respective means were 1.51 and 1.17 t/ac, and the two-tailed P value was 0.0129, indicating a significant difference. Hence, 2014 arithmetic average production on AVF fields vs. non-AVF fields with a difference of 0.34 t/ac was statistically significant. The 95 percent confidence interval of this difference was 0.07 to 0.61(plus or minus 0.27). The overall weighted averages for these two data sets were 1.45 and 1.22 t/ac, with a difference of 0.23 t/ac. This difference in weighted averages is the more reliable value.

Overall production differed slightly at 1.45 and 1.22 t/ac, respectively. Either way, in 2014 Otter Creek AVF fields produced 1.5 t/ac compared to 1.2 t/ac for non-AVF fields, consistent with the graphic interpretation.

Bale counts were also completed in fields in the Tenmile Creek, Threemile Creek and Home Creek portions of the study area; production data are shown on Table 4-8.

The Tenmile Creek portion of the study area is within the Denson ranch. Six fields comprising 84.5 acres averaged 1.07 t/ac; the overall average was 1.23 t/ac. Graphic presentation shows a declining trend with increasing AVF acreage of about 0.3 t/ac. Based on floodplain mapping, 35 percent, or 29.6 acres, of the Tenmile Creek hay cropland acreage is within the AVF. Tenmile Creek (starting approximately June 20) was harvested earliest which may account for slightly lower production compared to the Otter Creek portion of the Denson ranch.

Harvested hay cropland within the Threemile Creek portion of the study area was confined to Section 12 (T.4S, R.45E) on the Tarter ranch. Total hay cropland is 43.3 acres, 36 percent of which, or 15.5 acres, is within the floodplain. Average production for six harvested fields was 1.60 t/ac; overall production was 1.39 t/ac, or virtually identical to the Otter Creek average. Graphic presentation indicates that AVF fields produced perhaps 0.2 t/ac more than non-AVF fields. An inflow field on a terrace receiving overflow from a tributary pond produced 1.5t/ac.

As noted above in Section 3, the Section 12 AVF acreage of 15.5 acres constitutes six percent of the Tarter ranch hay cropland acreage. Assuming 0.2 t/ac incremental production on the AVF, the total incremental production would be 3.1 tons, or about one percent. Annual variation will be much greater.

Field H 1 on lower Home Creek is on a terrace/fan formation and is part of the Trusler Ranch. This field received inflow from Home Creek through an elaborate dike and ditch system that diverts the entire ephemeral flow to this field. In 2014, only a portion of this field was harvested, which did not include the floodplain portion along Home Creek. Production was 1.22 t/ac, which is comparable to non-AVF fields along Otter Creek.

Fields on the Upper portion of Home Creek comprising 173.1 acres are on the Stevens ranch. Of this total, 8.7 acres, or five percent, are on the narrow Home Creek flood plain. The upper Home Creek fields are located mostly on the south side of the drainage on lower slopes and fan formations at the mouths of ephemeral tributary coulees, and there is an elaborate system of diversion dikes and spreader dikes to direct, detain and infiltrate runoff water. Production in 2014 was 0.71 t/ac. Mr. Stevens noted that these fields produced less than normal in 2014.

4.3 OTTER CREEK HAY PRODUCTION SUMMARY

From the foregoing discussion and bale count data, the following observations are notable with respect to 2014 hay production:

- Average hay production on Otter Creek was about 1.4 t/ac.
- Hay production within the Otter Creek AVF was about 1.5 t/ac, compared to 1.2 t/ac on higher terraces outside of the AVF, a difference which based on analysis of the data using an unpaired t test was statistically significant.
- Production was remarkably consistent between ranches, ranging from 1.32 to 1.46 t/ac.
- Tenmile Creek production was 1.23 t/ac, or slightly less than the Otter Creek range. It is suspected this resulted from early harvest.
- Production on Threemile Creek was 1.39 t/ac, or equivalent to production on Otter Creek.

- On Home Creek, yield was equivalent to (Trusler) or less than (Stevens) upper terrace fields on Otter Creek.

Comparing 2014 production to FSA reported data analyzed in subsection 4.1, the following additional observations are relevant:

- 2014 yield on the Thomas ranch was slightly less than the average reported in 2008, 2009 and 2011 (1.62 t/ac).
- On the Denson ranch, 2014 production was equivalent to the 2006, 2007, 2008 and 2012 four-year average (1.41 t/ac).
- In three of four years, Otter Creek production on the Denson ranch was higher on non-AVF higher terraces, and the four-year averages were 1.67 and 1.42 t/ac, respectively.
- From all of the foregoing, it can be concluded that typical hay production on Otter Creek is in the range of 1.3 to 1.7 t/ac, except in very dry years. This level of production is consistent with the NRCS predicted yield of 1.5 t/ac on non-irrigated soils. Higher production on the AVF in 2014 is likely a result of spring flooding. FSA data for the Denson ranch indicate the opposite to be true in some years. Of the years examined, only 2007 had a peak flow (300 cfs) exceeding 100 cfs. This was also the year AVF production slightly exceeded non-AVF production.

4.4 IMPORTANCE OF THE OTTER CREEK AVF TO RANCHING OPERATIONS

Ranching operations at Otter Creek are typical cow-calf operations. Hay is harvested by each operation to feed cattle over winter, and hence an adequate hay crop is conducive to long-term sustainability. Although excess hay is typically held over in the event of a shortage the succeeding year, at times surplus hay may be sold.

Any economic impact of a hay shortage would result from a need to buy additional hay at market prices. Hay prices are hard to estimate due to difference in grade, and variability over time depending on availability. In the fall of 2014, asking prices for mixed alfalfa grass hay are in the range of $125 to $150 per ton. Winter prices in the event of shortage after a dry growing season typically exceed $200/ton.

Table 4-9 summarizes hay acreage and production on the ranches in the study area, including total and AVF acreages. Production values for Otter Creek are from the weighted averages of 1.45 and 1.22 t/ac respectively for AVF and non-AVF fields. Overall averages were used for Tenmile and Threemile Creeks. Denson is the only ranch with hay cropland outside of the study area; the Tenmile Creek average was used for Section 31, and the FSA upland average was used for Chromo Creek.

Although for the purpose of Table 4-9 the 2014 differential between AVF and non-AVF fields on Otter Creek was applied, it is not necessarily applicable from year to year. Annual production on and off the Otter Creek AVF will vary annually depending on spring rainfall, runoff and flooding.

5.0 ESSENTIAL HYDROLOGIC FUNCTIONS

As discussed in detail in Section 2.0, salinity (as measured by EC) of groundwater in the Otter Creek alluvium exceeds criteria for irrigation water. The first objective of this section is to examine the relationships between:

- Shallow groundwater depth;
- Shallow groundwater quality (salinity);
- Soil chemistry (salinity);
- Rooting depth of hay species; and
- Hay production.

This analysis is directed at determining whether hay fields over shallow groundwater in the Otter Creek floodplain constitute subirrigated farming.

The second objective is to examine the water balance in the reach of Otter Creek in the AVF study area.

5.1 DETAILED SHALLOW GROUNDWATER, SOILS, ROOTING DEPTH AND PRODUCTION STUDIES

Detailed investigations of shallow groundwater utilized shallow piezometers to document and monitor groundwater depth and quality in the floodplain and adjacent terraces at four cross-sections on Otter Creek adjacent to Tract 2. During piezometer installation, soil samples were taken to document soil chemistry and rooting depth. Finally clip plots were completed to document 2013 production of hay cropland vegetation at each site. Methods and results of these investigations are described in detail below.

5.1.1 Piezometers

In the summer of 2013, 15 shallow piezometers were installed in four arrays across the Otter Creek floodplain and adjacent low terraces in the reach adjacent to the mine plan area. Seven sites were within the floodplain and eight outside of the floodplain. The target unit was the fine-grained surface layer including soil and subsoil, as opposed to deeper sands and gravels of the alluvial aquifer. Objectives were to measure and monitor shallow groundwater depth and quality. Methods and results are described in Appendix I - AVF Piezometer Installation and Monitoring Report, Hydrometrics, Inc.

Initial results (August, 2013) showed that where groundwater depth was less than about 8 feet, SC exceeded the ranges observed in alluvial observation wells, ranging from about 6000 to over 9000 uS/cm, and that SC was inversely related to groundwater depth. At depths greater than eight feet, SC values were generally within the alluvial groundwater range below 6000. All sites within the floodplain had groundwater depths less than eight feet.

Water levels were lowest in late summer, typically rising by about three feet in March, coinciding with spring runoff. From March to April, SC declined sharply, in most cases to the observed groundwater range below 6000. But by May, SC values rebounded, with the highest observed value near 15000.

These results indicate:

- Late in the growing season, where groundwater is shallow, salts are concentrated, presumably as a result of water uptake by plants.
- SC decreases with increasing groundwater depth.
- Below a depth of about eight feet, SC is in the range observed in deeper observation wells, suggesting that water uptake by plants is minimal.
- Annual minimum shallow groundwater SC in April followed immediately after spring flooding, suggesting flushing of salts. Rebounding of SC in May coincides with onset of the growing season.
- Shallow groundwater levels vary annually by about three feet, with the lowest elevations in late summer and a peak coinciding with spring runoff, which occurred in early March, 2014.

At each cross-section, Otter Creek surface water elevations were recorded also for comparison with shallow groundwater levels. These are shown on the hydrographs for piezometers (in downstream order) AVF4-P2, AVF8-P3, AVF3-P1 and AVF7-P3. At three of the four locations, the stream elevation is consistently below the groundwater elevation, indicating groundwater contribution to base flow and a gaining reach. At AVF3-P1, however, the surface water level is higher than the groundwater elevation. This location is near the beginning of the alluvium – clinker interface, and this condition indicates a losing reach with alluvium in all probability losing water to the clinker, and loss of water from Otter Creek to the alluvium.

5.1.2 Soils and Rooting Depth

During piezometer installation at each site, soil samples were collected, described and analyzed in the laboratory with emphasis on documenting rooting depth, salinity as measured by EC, and SAR. Methods and results are described in Appendix J – Alluvial Valley Floor Detailed Soils Report Using Piezometer Transects, Westech Environmental Services, Inc.

Rooting depth observations indicated that plant roots generally did not extend to the late-season water table. However, with the groundwater levels three feet higher in the spring, roots would extend into the water table at all floodplain sites.

At all seven sites located within the floodplain, elevated EC (>4.0 mmho/cm) was observed in the root zone, compared to three of eight sites outside of the floodplain. Elevated SAR (>10.0) was observed in five of seven floodplain sites and five of eight non-floodplain sites. At floodplain sites, elevated SAR was generally associated with high EC in the root zone, but at non-floodplain sites it was most often (but not always) encountered in deeper soil horizons.

5.1.3 Vegetation Production

At each piezometer site, vegetation production was measured by clipping two 0.5-meter plots. Most sites were located in hay fields, and one additional hay field sample site was located on a higher terrace for comparison. Methods and results are described in detail in Appendix K – Baseline Monitoring of AVF Vegetation, Westech Environmental Services, Inc.

Average production at floodplain and non-floodplain sites was virtually identical – 2.08 and 2.09 t/ac respectively. Ranges were 1.71 to 3.06 t/ac on floodplain sites compared to 1.12 to 2.72 t/ac on non-floodplain sites. Standard deviations were also virtually identical at 0.52 and 0.53, respectively.

Because clipping measures vegetation production from the ground surface, production figures are greater than hay production because haying equipment cuts several inches above ground level. Hence production figures using the two methods are not directly comparable.

5.1.4 Discussion of Results of Piezometer Data

Plate 15 summarizes August 2013 piezometer and soils data with a location map and cross-sections. The charts on this plate show piezometer installation, water level and soils data for each site. From these cross-sections the following observations are evident:

- Water levels in nearby monitor wells accurately reflect shallow groundwater levels measured in piezometers.
- Water levels at each cross-section location are consistent between piezometers across the valley bottom width.
- At AVF3 (Cross-Section B), the water table is below the stream elevation. This location is just below the upstream limit of the alluvium – clinker interface as discussed above.

August 2013 data are summarized on Table 5-1 and presented graphically on Figure 5-1. Scatter charts are used to relate various data sets to groundwater depth below surface:

- Field SC is inversely related to groundwater depth at shallow depths, leveling out in the 4000 to 6000 range at about eight feet.
- Rooting depth is a function of groundwater depth to about eight feet, above which the pattern is scattered.
- Plotting production against groundwater depth yields no discernable pattern.

As noted above, groundwater levels were highest in March 2014, followed by minimum SC readings in April. In May, SC values increased, quite dramatically in some cases (Figure 5-2). The following are evident from plotting the data:

- May SC ranged from 3410 to 13290. Extreme high values were associated with very shallow groundwater, declining rapidly and leveling out in the 4000-6000 range at a depth of about five feet.
- The difference between April (low point) SC and May SC follows the same pattern. Differences ranged from 990 to 4990, with the greatest differences at shallow depth, leveling off in the1000- 2000 range at about the five-foot depth.

5.1.5 Conclusions from Shallow Piezometer Studies

Taking all of the data together, the following conclusions can be drawn with respect to agricultural productivity and hydrologic functions in the Otter Creek AVF during the period of study:

- There was no difference in production between locations on the AVF vs higher terraces based on 2013 clipping data. This result supports the conclusion that subirrigation on the Otter Creek floodplain does not materially enhance hay yields above that achieved from direct precipitation.
- Shallow groundwater areas of the AVF are characterized by elevated salinity in groundwater and soils. Dramatic increases in groundwater SC from April to May are consistent with concentration of salts as a result of water uptake by plants. At this time of year, roots extend into groundwater from less than two to 4 to 6 feet below the surface.
- Ground water elevation declined by about three feet through the growing season as a result of losses to evapotranspiration and drainage to the Otter Creek channel contributing to base flow.
- In late summer, salt concentrations in the root zone remained high due to residual from declining groundwater, water uptake from the capillary fringe, or both. At this time of year, roots did not extend appreciably into the water table, and elevated SC in groundwater was evident to a depth of about eight feet.

- Groundwater elevations gradually increased through the fall and winter, peaking in March coincident with spring snowmelt runoff and inundation of the floodplain.
- A sharp decrease in shallow groundwater SC coincided with the influx of fresh water snow melt flooding in March. This decrease corresponds with an annual April peak in SC in Otter Creek (Table 2-3A), consistent with flushing of salts from the root zone.
- As noted above, from April to May, SC in shallow groundwater rebounded to very high levels as the growing season got underway. This concentration of salts would greatly limit useful availability of shallow groundwater to plants, consequently limiting production, and precluding the ability of subirrigation to provide a "water supply during extended periods of low precipitation."

The essential hydrologic functions to maintain agricultural productivity on the Otter Creek AVF are direct precipitation and occasional flooding to flush salts from the root zone. The degree and effectiveness of flooding is variable depending on elevation above the stream channel, localized inflow from tributary drainages, and inflow and floodwater management facilities utilized by ranchers to direct, detain and infiltrate fresh water on hay fields. Although there may be variations from year to year depending on spring rainfall and runoff conditions, there is no consistent facilitation or enhancement of hay production attributable to the AVF.

5.2 WATER BALANCE

Water balance of the alluvium in the study area is instructive in identifying and understanding essential hydrologic functions. Table 5-2 shows the input and output components of the Otter Creek floodplain water balance within the study area for the four-month period March to June, which coincides with the hay growing season. Groundwater and surface water inputs are derived from data presented in Baseline Report 304E – Hydrology.

In reviewing the input data, the exact values are not as important as the magnitudes. Total groundwater input from all sources over the four-month period is estimated at 419 acre feet (af). Input from the Knobloch coal is 69 af, or16 percent of the groundwater total.

Surface water input is an order of magnitude greater, estimated at 2142 af, and output at the Ashland gauging station is essentially equivalent at 2071 af. Hence, surface water input and output essentially offset, and do not enter into the water balance as it applies to growth of agricultural plants on the AVF.

Over the 42-year period of record (Table 1-1), precipitation for the March to June period has ranged from 2.49 to 17.43 inches with an average of 8.0 inches. Eight inches of rainfall over the 3019-acres within the Otter Creek AVF equals 2013 acre feet, or about five times the groundwater input, and 30 times the Knobloch coal contribution.

Potential evaporation, which is assumed to represent evapotranspiration, is in the range of 3100 af, resulting in a deficit on the order of 900 af. Part or all of this deficit could be made up in some years by flooding, inflow and/or above average rainfall. One additional inch of rainfall is equivalent to about 250 af, and four inches would offset this deficit entirely.

This analysis reinforces the conclusion that agricultural production on the Otter Creek AVF is a function of spring precipitation combined with flooding and inflow rather than groundwater. The entire groundwater component could only account for a fraction of the potential evapotranspiration, and the Knobloch groundwater contribution is clearly immaterial.

6.0 PROTECTION OF ALLUVIAL FLOORS DURING AND AFTER MINING

This section addresses the requirements of ARM 17.24.325(3)(d)(v) that plans be provided showing how the operation will avoid, during mining and reclamation, interruption, discontinuance, or preclusion of farming on alluvial valley floors, and will not materially damage the quantity or quality in surface and groundwater systems that supply alluvial valley floors. Per ARM 17.24.810, operations at the Otter Creek Mine are designed and will be conducted to:

- preserve, throughout the mining and reclamation process, the essential hydrologic functions of portions of the Otter Creek valley floor not within the permit area;
- reestablish, throughout the mining and reclamation process, the essential hydrologic functions of the Otter Creek valley floor within an area of land affected; and
- ensure that the agricultural utility and the level of productivity of the Otter Creek valley floor in affected areas are reestablished to premining levels.

6.1 ESSENTIAL HYDROLOGIC FUNCTIONS

Survey and analysis data presented in Sections 2.0, 4.0 and 5.0 collectively demonstrate that agricultural productivity on the floodplains of Otter Creek and its tributaries varies annually in response to rainfall, occasional inundation of low lying fields resulting from snow melt and/or spring rainfall runoff, and in some cases inflow of ephemeral runoff from side drainages diverted away from Otter Creek and routed to fields by diversions and/or spreader dikes. Retention dikes along the margins of the Otter Creek stream channel retain inflow in the fields, whether from flooding or side drainage inflow, promoting infiltration with consequent enhancement of soil moisture and flushing of salts.

Salinity of Otter Creek base flow exceeds acceptability thresholds for irrigation water, so flood irrigation by stream diversion is not a factor.

Much of the Otter Creek floodplain has shallow groundwater at depths conducive to subirrigation, but like stream flow, salinity levels limit productive utilization by agricultural plants. Extraction of water by plant roots from shallow groundwater and the capillary zone has the effect of further concentrating salts in the root zone, exacerbating its limited usefulness to plants as the growing season progresses. Periodic flooding with fresh water from snow melt and/or spring rainfall has the effect of flushing salts from the root zone to the groundwater, and ultimately to the creek, where it emerges as base flow.

6.2 MINE PLAN COMPONENTS TO AVOID INTERRUPTION, DISCONTINUANCE, OR PRECLUSION OF FARMING

Features of the Otter Creek Mine plan to avoid impacts outside the permit area and minimize impacts within the permit area are based on avoidance, minimization and mitigation. Primary components are listed below:

- There will be no mining within the floodplains of Otter Creek and Threemile Creek.
- Adjacent reaches of Otter Creek and Threemile Creek (where cropland occurs) are included within the permit area.
- Mining will leave a barrier of in-place coal along Otter Creek and Threemile Creek to moderate backflow from alluvium to the pit during operations, and flow of water from re-saturated spoils to the alluvium during and after mining and reclamation.
- When reclamation is complete, sediment ponds will be reclaimed to appropriate size to restore flow while meeting Effluent Limitations for Western Alkaline Coal Mines contained in 40 CFR 434 Subpart H.
- The only surface disturbance in the Otter Creek valley floor will be two transportation corridors for the access road and overland conveyor. These facilities will affect neither surface water nor groundwater flow patterns; culverts will be sized appropriately to pass safely a 100-year flood.
- Soil salvaged from transportation corridors in the Otter Creek valley bottom will be stored separately and used to reclaim those corridors as part of the final reclamation plan.

6.3 IMPACTS OF MINING AND RECLAMATION ON ESSENTIAL HYDROLOGIC FUNCTIONS

Impacts of mining on essential hydrologic functions with respect to the Otter Creek valley floor outside of the permit area will be essentially zero. These functions are direct precipitation, occasional flooding of the valley floor in response to snow-melt and/or rainfall, and inflow of ephemeral runoff from Tenmile, Chromo, Newell, Gene and Home Creeks. Control of runoff from the mine area will affect less than one percent of the Otter Creek watershed area, and water yields are almost certainly disproportionately less than from higher elevation areas upstream to the south.

Within the permit area, impacts will be minimal, localized and temporary. Temporary localized water level declines in the alluvial aquifer in response to dewatering of the box cut along Otter Creek, if it occurs, will not affect agricultural productivity because hay production is not dependent on subirrigation, and there is no demonstration of facilitated or enhanced productivity or production through extended periods of low rainfall due to subirrigation. Alluvial water levels will return to normal within a short time as mining advances and the box cut is backfilled.

Inflow from tributary drainages within the area affected will be contained by sediment ponds during all but very infrequent large runoff events. The few fields receiving runoff from these watersheds would have potential yield reductions in some years, although farming would not be interrupted, discontinued or precluded. Re-establishment of flow after completion of reclamation will restore this function.

Surface water and groundwater in Otter Creek exceed salinity criteria for irrigation. Groundwater contributions after mining from re-saturated spoils will likely be of SC similar to the range observed in alluvium, and lower than observed in shallow piezometers. Inflow will be moderated by a barrier of in-place coal, and consequently will be of small volume compared to alluvial groundwater flux. These factors lead to the conclusion that effects on alluvial water quality, if any, will likely be imperceptible. Effects on groundwater are addressed in Exhibit 314C – Probable Hydrologic Consequences.

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