Funding for WRDS and the creation of this electronic document was provided by the Wyoming Water Development Commission (http://wwdc.state.wy.us)

SHELL VALLEY

Watershed Plan

Level I Study

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FINAL REPORT March 2010

SHELL VALLEY WATERSHED PLAN LEVEL I STUDY

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1.0 INTRODUCTION

This study was requested by Shell Valley Watershed Improvement District (SVWID) and granted by Wyoming Water Development Commission (WWDC) to assess the existing irrigation structures and canals, survey irrigation canal locations and structure locations, identify upland water development projects for livestock and wildlife stock, review existing information available for this watershed at different agencies, gather field information on the watershed and its hydrology, provide geomorphology of stream runs, locate potential reservoir sites, and determine if power generation was possible. This study's goal is to compile existing data and new data into one document.

Created in 1981, the goal of SVWID would be to provide a governing entity to Shell Valley as a whole, while lending assistance to the individual private irrigation companies. The SVWID is under the governing authority of the South Big Horn County Conservation District. The SVWID encompasses approximately 26,200 acres within their boundary. Of the 26,200 acres, approximately 15,159 acres of water rights exist under many different permits. Additional water rights exist within the watershed. The SVWID does have governing authority to level unequal per acre or acre-foot assessments for the irrigation companies within their boundary, if necessary. Otherwise stated, if certain areas will not benefit from a project they can be exempt from the additional assessments to fund the project. The members of the SVWID vote on all assessment increases.

Various agencies have studied this area extensively throughout the last 50 years. One of the problems for the District is the amount of information published under various agencies and no clearinghouse to handle this information. A goal of this study was to research the known agencies that had information and compile it into this report. This will provide SVWID with a one-stop reference document for their District.

2.0 EXISTING DATA REVIEW

Various sources were evaluated prior to analyzing and reporting data within the Shell Creek Watershed. Primary sources are noted in each section and cited in the Section 13.0 References. In general, the following types of information were reviewed for each discipline.

Table 2.0.1
General Data Sources
Shell Creek Watershed

Discipline	General Data Sources
Physical, Biological, and Cultural Sciences	• Natural Resources Conservation Service • PRISM Data for Precipitation • Published Technical Reports and Texts • South Big Horn County, Wyoming, Watershed Plan • U.S. Census Bureau • U. S. Department of Agriculture – Forest Service • U.S. Department of Interior – Bureau of Land Management • U.S. Geological Survey • Western Regional Climate Center • Wyoming Cultural Resource Information Summary Program • Wyoming Department of Environmental Quality • Wyoming Game & Fish • Wyoming Natural Diversity Database • Wyoming Water Resources Data System

3.0 WATERSHED DESCRIPTION AND INVENTORY

Watershed analysis was completed through a review of existing data listed in Section 2.0 supplemented with limited reconnaissance-level fieldwork. The Shell Creek Watershed is located within the Bighorn River Basin in north-central Wyoming. Shell Creek is the primary drainage within the watershed and runs from high-elevation sources in the Big Horn mountains to its confluence with the Bighorn River near Greybull, Wyoming. Vegetation is stratified between the high elevation mountains and the lower elevation foothills and floodplains. Primary vegetation community types are detailed in Section 4.1 and include Meadow tundra and conifer forests at high elevations; sagebrush, juniper, and mixed grass communities at mid-elevations; and saltbush and sagebrush communities at lower elevations. A variety of wildlife lives within the watershed and are described in Section 4.2

Land uses within the watershed are primarily agricultural with limited cultivation on stream terraces above Shell Creek and its major tributaries. Shell is the only town within the watershed. The estimated 2000 population for Big Horn County was approximately 11,461, of which approximately 4,648 people lived in or around the Shell Creek Watershed (including areas to the south and west that are outside the watershed but within the survey area)(U.S. Census Bureau www.census.gov). The largest economic sectors for individuals within this survey area are agriculture and education/social services. Approximately 20 percent of residents 16 and older are involved in agriculture, forestry, or mining, while another 20 percent are involved in education, health, and social service sectors. Other primary areas of employment are retail trade and construction.

Land ownership and administration within the watershed is a mixture of private lands, primarily located along Shell Creek and major tributaries, interspersed with public lands administered by the Bureau of Land Management (BLM) and the U.S. Forest Service (USFS). Lands administered by the BLM are typically located at lower elevations within the watershed and are managed from two offices; the Cody District manages lands north of U.S. Highway 14, while the Worland District manages lands south of U.S. Highway 14. Higher elevation lands, typically from the mouth of Shell Canyon to the upper ridgelines, are managed by the USFS from the Medicine Wheel-Paintrock District in Lovell. The percentage of land within each ownership/administration category is presented below in Table 3.0.1.

TABLE 3.0.1
Land Surface Ownership or Administration Acreage
Shell Creek Watershed

Ownership/Administration Category	Acreage	%
Bureau of Land Management (BLM) Cody and Worland Districts	153,035	42.2
United States Forest Service (USFS) Medicine Wheel-Paintrock District	139,590	38.6
Private	60,384	16.7
State of Wyoming	9,062	2.5
TOTAL	**362,071**	**100%**

Reservoir sites were assessed from existing data and reconnaissance surveys to determine which sites, if any, would be viable water storage locations. Sites were assessed relative to water availability, storage, distribution, construction costs and permitting constraints. Reservoir sites are described and compared in Section 11.0

Detailed descriptions of watershed, irrigation, and reservoir characteristics are presented in the following sections.

4.0 SHELL CREEK WATERSHED-BIOLOGICAL

4.1 VEGETATION

Vegetation within the watershed was primarily evaluated from existing data sources including:

- Wyoming Gap Data (WYGAP);
- USFS Range Condition data;
- BLM Range Condition data;
- USFS riparian data;
- BLM riparian data;
- Wyoming DEQ – Beneficial Use Reconnaissance Project (BURP) data;
- Wyoming Natural Diversity Database; and
- Scientific literature on range, forest, and riparian resources within the Bighorn Mountains and Shell Valley.

Supplementing the existing data is specific field data collected at potential reservoir sites and by riparian data collected at four points along Shell Creek and several of its tributaries. Dominant plant communities and biological assessments were the primary data collected to supplement the existing vegetation data. Ecological Site Descriptions (ESD's) were not available from the local NRCS office at the time of the report. ESDs provide a valuable resource for range management, and incorporation into the GIS model as soon as the information becomes available for the watershed is highly recommended.

Vegetation was evaluated to accomplish the following goals:

1. Describe the distribution and extent of vegetation types within the watershed to establish a baseline inventory for comparing future change.
2. Describe and evaluate range condition and trend on federal lands.
3. Describe and evaluate forest health and timber resources on federal lands.
4. Describe and evaluate riparian conditions.
5. Depict and describe regionally significant species and vegetation communities within the watershed.

4.1.1 LAND COVER TYPES

The Wyoming Gap Data (Gap Data) was used as the basis for locating and describing Land Cover types and vegetation communities within the watershed (USGS 1996). Gap Data is derived from satellite imagery, and subsequent ground verification, to create a seamless, statewide data inventory of cover types. Data resolution is 30 meters x 30 meters with an overall accuracy rate of approximately 80%. Aerial photo mapping and field verification of irrigated lands supplemented the Gap Data. Land Cover types are depicted on Figure 4.1.1.1 Primary Land Cover Types on the following page.

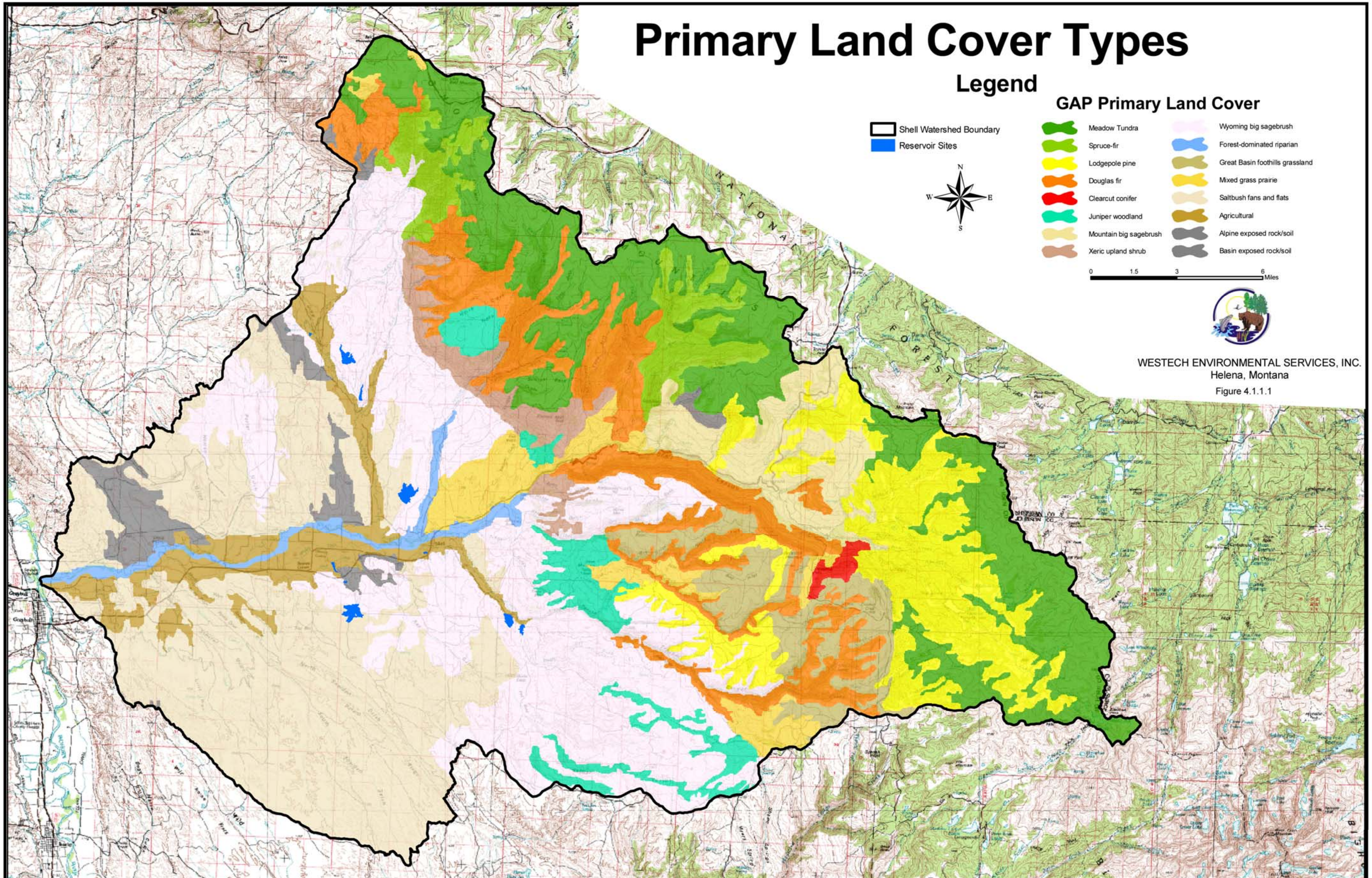
Vegetation within the watershed is distinctly stratified by the elevation change between the Bighorn Basin and the Bighorn Mountains. This transition typically occurs between 5,000 feet and 8,000 feet elevation depending upon aspect. For example, transition from Wyoming big sagebrush (*Artemisia tridentata* var. *wyomingensis*) community to a Douglas fir (*Pseudotsuga menziesii*) dominated community would occur at a lower elevation on a north-facing slope with cooler temperatures and greater soil moisture than on a relatively hotter, drier south-facing slope.

Land Cover types within the entire watershed are depicted in Table 4.1.1.1 along with the approximate total area occupied by each type and the elevation range within which the type typically occurs.

TABLE 4.1.1.1
Land Cover Types
Shell Creek Watershed

Land Cover Type	Acreage	Percent of Watershed
Basin exposed rock-soil	9,052	2.5
Clear cut conifer	1,031	0.3
Douglas fir	33,467	9.2
Agricultural	15,105	4.2
Forest dominated riparian	4,544	1.3
Great Basin foothills grassland	12,834	3.5
Juniper woodland	10,419	2.9
Lodge pole pine	31,116	8.6
Meadow tundra	50,232	13.9
Mixed grass prairie	11,597	3.2
Mountain big sagebrush	12,855	3.6
Saltbrush fans and flats	75,987	21.0
Spruce-fir	11,526	3.2
Wyoming big sagebrush	74,682	20.6
Xeric upland Shrub	7,624	2.1
TOTAL	**362,071**	**100**

The three dominant Land Cover types within the Shell Creek watershed are Saltbush fans and flats (75,987 acres or 21 percent of the watershed), Wyoming big sagebrush (74,682 acres or 20.6 percent of the watershed), and Meadow Tundra (50,232 acres or 13.9 percent of the watershed). These types also correspond to the general elevation gradient within the watershed.


Primary Land Cover Types
Legend
GAP Primary Land Cover
Shell Watershed Boundary
Reservoir Sites
Meadow Tundra
Spruce-fir
Lodgepole pine
Douglas fir
Clearcut conifer
Juniper woodland
Mountain big sagebrush
Xeric upland shrub
Wyoming big sagebrush
Forest-dominated riparian
Great Basin foothills grassland
Mixed grass prairie
Saltbush fans and flats
Agricultural
Alpine exposed rock/soil
Basin exposed rock/soil
0 1.5 3 6 Miles
WESTECH ENVIRONMENTAL SERVICES, INC.
Helena, Montana
Figure 4.1.1.1

Saltbush fans and flats occupy the lower elevations of the watershed. Saltbush fans and flats are comprised primarily of Gardner's saltbush (*Atriplex gardneri*) or Black greasewood (*Sarcobatus vermiculatus*) on poorly drained and saline soils. The Wyoming big sagebrush Land Cover type is the dominant type within the mid-elevation range of the watershed. Dominant species within this type include Wyoming big sagebrush, bluebunch wheatgrass (*Agropyron spicatum*), needle-and-thread (*Stipa comata*), and Idaho fescue (*Festuca idahoensis*). There is extensive intergrading between Saltbush fans and flats and Wyoming big sagebrush. Several areas are a mosaic of these two types with Wyoming big sagebrush occupying cooler aspects or better soils, and Saltbush fans and flats occupying warmer aspects or poorer soils. Local intergrading between cover types is typically not discernible with satellite imagery.

The upper elevations of the watershed are dominated by the Meadow tundra Land Cover type intermixed with Douglas fir and Lodge pole pine types. Dominant species within the Meadow Tundra type include timber danthonia (*Danthonia intermedia*), Idaho fescue, and alpine timothy (*Phleum alpinum*) (Collins 1984). The Douglas fir type typically occupies drier, south-facing slopes within the upper elevations of the watershed, while the Lodge pole pine type typically occurs on cooler level or north-facing slopes. Similar to intergrading among cover types at lower elevations, intergrading among these, and other types, creates a mosaic of habitat features that cannot be discerned from satellite imagery.

A more thorough description of each Land Cover type, excerpted from the WY-GAP database, is provided in Appendix A: Land Cover Descriptions & Site Parameters and Canopy Cover by Species.

4.1.2 RANGE CONDITION

Range condition is a rating system developed by the Natural Resource Conservation Service (NRCS) for determining grazing capacity and vegetation status. Range condition is often used as an indicator of ecological condition in addition to being a tool for assessing grazing management. Allowable species compositions can be found under the "range condition rating system" for different soil types. In general, the greater the amount of native perennial grasses within a soil mapping unit, the higher the range condition scores for the unit. Range condition is rated on a scale of Poor, Fair, Good, and Excellent. The modifiers "-"(Low) and "+" (High) are sometimes added to further describe a condition class.

Range condition was chosen as the measure of upland ecological condition within the watershed because 1) it is a measurable variable; 2) it has a developed and consistent methodology; 3) there is a long history of range condition's use in the scientific community; and 4) it is a consistent variable collected by all of the land management agencies within the watershed.

The range condition scores and apparent trends depicted in the following tables are not intended to quantitatively define range condition at all locations or times in the watershed. Rather, this data is presented as an indicator of ecological status within upland vegetation communities in the Shell Creek Watershed. Specific locations within the watershed would likely appear similar to the conditions assessed for this study, but could vary substantially depending upon soils, aspect, and land-management history.

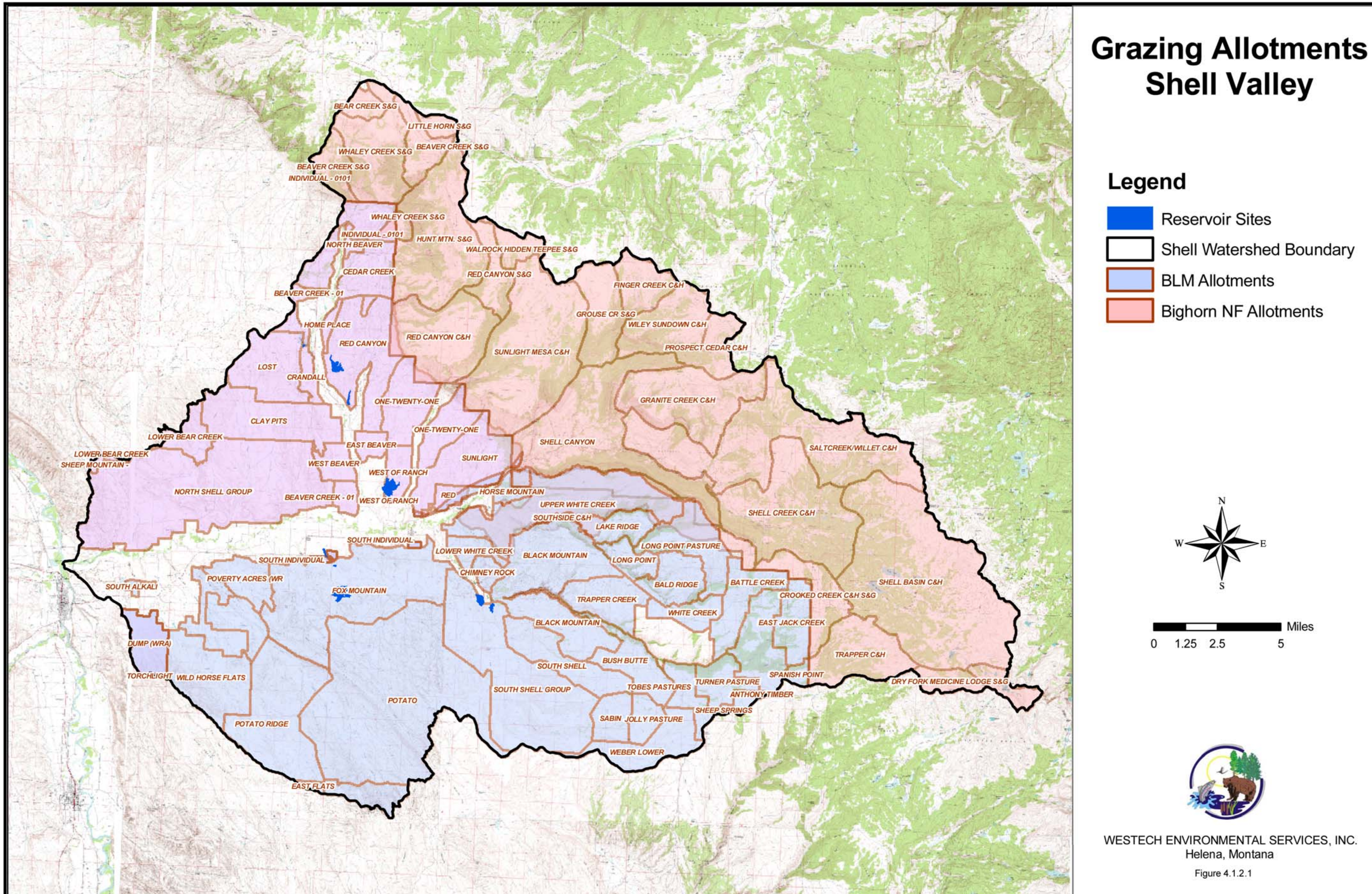
Transect data specific to many grazing allotments within the Big Horn National Forest, Medicine Wheel-Paintrock District (USFS) were reviewed and summarized. These data represent repeated measurements at permanent sample points throughout many portions of the Big Horn National Forest within the watershed. Sample transects are located in general clusters within each allotment and many allotments contain multiple clusters.

These data are presented in Table: Range Condition by Cluster Data located in Appendix A and summarized in Table 4.1.2.1. Figure 4.1.2.1 Grazing Allotments, page 8 shows the grazing allotments within the watershed by USFS or BLM district jurisdiction.

TABLE 4.1.2.1 USFS Cluster Transect Summary by Decade Shell Creek Watershed					
Sample Decade	**Number of Cluster Samples**	**Percent of Clusters within Range Condition Class**			
		Excellent	**Good**	**Fair**	**Poor**
1950 – 1960	20		25	35	40
1970	10		40	30	30
1980	36	11	58	31	
2005	2			100	

The percentage of cluster transects that were in Poor condition decreased from a high of 40 percent in the 1950-60s to zero in the 1980's and 2005 (note that only two clusters were sampled in 2005). Some of these areas improved to Fair condition, while many areas in Fair condition improved to Good condition as evidenced by: 1) the relatively stable number of clusters within the Fair condition class (clusters sampled in 2005 are something of an anomaly since only two sites were recorded); and 2) an increase of sample clusters in the Good condition class from 25 percent in the 1950 – 1960's to 58 percent in the 1980's.

Additional range data was compiled by resource specialists at the USFS; Bureau of Land Management - Cody District (BLM – Cody); and Bureau of Land Management - Worland District (BLM – Worland). Resource specialists completed an estimate of range condition, and in some cases trend, for most allotments within the Shell Creek Watershed. Specifically, these data represent an estimate of acreage by range condition class for most allotments within the watershed (Table 4.1.2.2, 4.1.2.3, and 4.1.2.4). Some allotments are not represented within these tables. Allotments that are partly located within the Shell Creek Watershed but that are primarily located in other watersheds were excluded from analysis, since general data for these allotments may not be representative of the small area within the Shell Creek Watershed. Furthermore, data were not compiled for all USFS allotments due to a lack of recent, representative samples.



Grazing Allotments
Shell Valley
Legend
Reservoir Sites
Shell Watershed Boundary
BLM Allotments
Bighorn NF Allotments
N
S
E
W
Miles
0 1.25 2.5 5
WESTECH ENVIRONMENTAL SERVICES, INC.
Helena, Montana
Figure 4.1.2.1
BEAR CREEK S&G
LITTLE HORN S&G
WHALEY CREEK S&G
BEAVER CREEK S&G
BEAVER CREEK S&G
INDIVIDUAL - 0101
WHALEY CREEK S&G
INDIVIDUAL - 0101
HUNT MTN. S&G
NORTH BEAVER
WALROCK HIDDEN TEEPEE S&G
CEDAR CREEK
RED CANYON S&G
BEAVER CREEK - 01
FINGER CREEK C&H
GROUSE CR S&G
WILEY SUNDOWN C&H
HOME PLACE
RED CANYON
RED CANYON C&H
SUNLIGHT MESA C&H
PROSPECT CEDAR C&H
LOST
CRANDALL
ONE-TWENTY-ONE
GRANITE CREEK C&H
CLAY PITS
ONE-TWENTY-ONE
LOWER BEAR CREEK
SHELL CANYON
EAST BEAVER
LOWER BEAR CREEK
SUNLIGHT
SALTCREEK/WILLET C&H
SHEEP MOUNTAIN -
WEST BEAVER
WEST OF RANCH
NORTH SHELL GROUP
HORSE MOUNTAIN
BEAVER CREEK - 01
WEST OF RANCH
RED
UPPER WHITE CREEK
SOUTHSIDE C&H
SHELL CREEK C&H
LAKE RIDGE
SOUTH INDIVIDUAL
LONG POINT PASTURE
LOWER WHITE CREEK
BLACK MOUNTAIN
SOUTH INDIVIDUAL
LONG POINT
CHIMNEY ROCK
POVERTY ACRES (WR
BALD RIDGE
BATTLE CREEK
SHELL BASIN C&H
SOUTH ALKALI
FOX MOUNTAIN
CROOKED CREEK C&H S&G
TRAPPER CREEK
WHITE CREEK
BLACK MOUNTAIN
EAST JACK CREEK
DUMP (WRA)
TRAPPER C&H
BUSH BUTTE
SOUTH SHELL
SPANISH POINT
TORCHLIGHT
WILD HORSE FLATS
TURNER PASTURE
DRY FORK MEDICINE LODGE S&G
SOUTH SHELL GROUP
TOBES PASTURES
ANTHONY TIMBER
POTATO
SHEEP SPRINGS
POTATO RIDGE
SABIN
JOLLY PASTURE
WEBER LOWER
EAST FLATS

TABLE 4.1.2.2 Estimated Range Condition and Approximate Acreage of Selected Allotments Information Provided By: USFS Big Horn District Shell Creek Watershed									
Allotment Name (Date of Data)	**Condition Class (Percent and Acres) by Allotment[1]**								**Approximate Allotment Acres in Watershed**
	Excellent		**Good**		**Fair**		**Poor**		
	Percent	**Acres**	**Percent**	**Acres**	**Percent**	**Acres**	**Percent**	**Acres**	
Bear Creek/Crystal Creek S & G (1981)	--	--	19	170	55	492	26	233	895
Beaver Creek (1981)	--	--	29	1,120	43	1,661	28	1,082	3,863
Finger Creek (1989)	--	--		0	68	1,686	32	794	2,480
Hunt Mountain S & G (1986)	--	--	22	2,958	65	8,741	13	1,748	13,447
Red Canyon C&H (1981)	--	--	40	3,513	60	5,269	--	--	8,782
Red Canyon S & G (1981)	--	--	20	582	80	2,327	--	--	2,909
Shell Canyon Big Game Winter Range (current observation)	--	--	100	12,870	--	--	--	--	12,870
Sunlight Mesa (1987)	19	3,825	54	10,871	26	5,234	1	201	20,132
Whaley Creek (1980)	27	1,686	62	3,873	3	187	8	500	6,246
Wiley/Sundown (1989)	--	--	--	--	96	4,191	4	175	4,366
TOTAL	**7**	**5,512**	**47**	**35,957**	**39**	**29,790**	**6**	**4,732**	**75,990**

[1] Condition data provided by the USFS Big Horn District Office, August 10, 2007. The condition class percent break down for all allotments is based on knowledge of the area, knowledge of ecological site potential, field inspections, and professional judgment by BLM range/watershed/wildlife specialist. Acreage represents that portion of the allotment that lies within the Shell Creek Watershed. Allotments with minimal area in the Shell Creek Watershed were not included since data for these allotments may not be indicative of the area within the Shell Creek Watershed. Allotments without percentage estimates provided by the USFS have not been included. Transect data for several of these omitted allotments are presented in Table Range Condition Cluster Data.

TABLE 4.1.2.3
Estimated Range Condition and Approximate Acreage Primary of Allotments
Information Provided by BLM Cody District
Shell Creek Watershed

Allotment Name	Condition Class (Percent and Acres) by Allotment[1]								Approximate Allotment Acres in Watershed
	Excellent		Good		Fair		Poor		
	Percent	Acres	Percent	Acres	Percent	Acres	Percent	Acres	
BEAVER CREEK – 01[2]	30	222	40	296	25	185	5	37	740
BEAVER CREEK – 01[3]	40	754	40	754	15	283	5	94	1,885
CEDAR CREEK	35	926	50	1,324	10	265	5	132	2,647
CLAY PITS[5]	20	1,159	40	2,319	30	1,739	10	580	5,797
CRANDALL	45	344	40	306	10	76	5	38	764
DUMP (WRA)	30	1,253	60	2,505	5	209	5	209	4,175
EAST BEAVER	40	315	40	315	10	79	10	79	788
HOME PLACE	30	118	50	197	15	59	5	20	393
INDIVIDUAL – 0101[4]	40	1,276	35	1,116	20	638	5	159	3,189
LOST	30	1,904	40	2,539	20	1,270	10	635	6,348
LOWER BEAR CREEK[5]	20	2,777	40	5,555	25	3,472	15	2,083	13,887
NORTH BEAVER	40	142	30	106	25	89	5	18	354
NORTH SHELL GROUP[5]	20	3,797	30	5,696	30	5,696	20	3,797	18,985
ONE-TWENTY-ONE	40	2,236	50	2,795	5	279	5	279	5,589
RED	40	439	45	494	10	110	5	55	1,098
RED CANYON	40	2,643	45	2,974	10	661	5	330	6,608
SHEEP MOUNTAIN	30	4,246	40	5,662	20	2,831	10	1,415	14,154
SOUTH INDIVIDUAL	20	93	30	139	40	186	10	46	464
SUNLIGHT	20	1,037	40	2,074	30	1,556	10	519	5,186
WEST BEAVER	40	498	40	498	15	187	5	62	1,246
WEST OF RANCH	60	815	25	340	10	136	5	68	1,358
TOTAL	**28**	**26,995**	**40**	**38,002**	**21**	**20,003**	**11**	**10,656**	**95,655**

[1] Condition data provided by the BLM Cody District Office, March 29, 2007. The condition class percent break down for all allotments is based on knowledge of the area, knowledge of ecological site potential, field inspections, and professional judgment by BLM range/watershed/wildlife specialist. Acreage represents that portion of the allotment that lies within the Shell Creek Watershed. Allotments with minimal area in the Shell Creek Watershed were not included since data for these allotments may not be indicative of the area within the Shell Creek Watershed.
[2] Allotment ID for this Allotment Name “Beaver Creek-01” at the BLM Office is 01017.
[3] Allotment ID for this Allotment Name “Beaver Creek-01” at the BLM Office is 01506.
[4] Allotment ID for this Allotment Name “Individual-0101” at the BLM Office is 01018.
[5] The identified allotments had a “static” trend identified by the BLM. The remaining allotments were identified as having an uptrend.

TABLE 4.1.2.4 Estimated Range Condition and Approximate Acreage of Primary Allotments Information Provided by BLM Worland District Shell Creek Watershed											
	Condition Class (Percent and Acres) by Allotment[1]										Approximate Allotment Acres in Watershed
	Excellent		Good		Fair		Poor		No Condition Class		
Allotment Name	Percent	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent	Acres	
Bald Ridge	45	1,152	30	768	3	77	--	--	22	563	2,561
Battle Creek	17	521	63	1,932	4	123	--	--	16	491	3,066
Black Mountain	33	3,206	49	4,760	7	680	2	194	9	874	9,714
Bush Butte	18	578	52	1,670	21	674	--	--	9	289	3,211
Chimney Rock	--	--	70	547	21	164	--	--	9	70	781
East Jack Creek	--	--	64	1,599	13	325	--	--	23	575	2,499
Fox Mountain	9	1,152	59	7,554	14	1,792	10	1,280	8	1,024	12,803
Jolly Pasture	3	40	45	594	40	528	--	--	12	159	1,321
Lake Ridge	1	19	65	1,242	3	57	--	--	31	592	1,911
Long Point	27	392	28	407	13	189	--	--	32	465	1,453
Long Point Pasture	26	1,011	40	1,555	--		--	--	34	1,322	3,887
Lower White Creek	2	23	75	851	23	261	--	--	--	--	1,135
Potato	18	4,116	55	12,575	16	3,658	6	1,372	5	1,143	22,864
Potato Ridge	--	--	44	3,764	34	2,908	--	--	22	1,882	8,554
Poverty Acres	10	216	36	779	37	801	2	43	15	325	2,164
Sabin	14	239	62	1,056	14	239	3	51	7	119	1,704
Sheep Springs	2	20	85	868	--	--	--	--	13	133	1,021
South Shell	37	1,370	61	2,259	--	--	--	--	2	74	3,703
South Shell Group	25	3,163	52	6,579	13	1,645	4	506	6	759	12,651
Tobes Pasture	37	492	24	319	3	40	--	--	36	479	1,331
Trapper Creek	1	31	82	2,555	5	156	--	--	12	374	3,116
Turner Pasture	24	486	39	789	--	--	--	--	37	749	2,023
Upper White Creek	9	765	52	4,422	20	1,701	1	85	18	1,531	8,504
White Creek	12	198	73	1,205	1	17	--	--	14	231	1,651
Wild Horse Flats	5	266	85	4,525	4	213	--	--	6	319	5,323
TOTAL	**16**	**20,534**	**55**	**69,189**	**14**	**18,003**	**3**	**3,583**	**12**	**15,439**	**126,749**

[1] Condition data provided by the BLM Worland District Office, April 20, 2007. The condition class percent break down for all allotments is based on knowledge of the area, knowledge of ecological site potential, field inspections, and professional judgment by BLM range/watershed/wildlife specialist. The BLM developed the information in 1985. Acreage represents that portion of the allotment that lies within the Shell Creek Watershed. Allotments with minimal area in the Shell Creek Watershed were not included since data for these allotments may not be indicative of the area within the Shell Creek Watershed.

In total, these data represent an estimate of the ecological condition of upland vegetation communities on approximately 282,955 acres or approximately 78 percent of the watershed. In general, these data are most applicable to conditions on federally administered land within the watershed. Range condition data for private lands within the watershed (60,384 acres or 16% of the watershed) were not available. Acreages of land surface ownership or administration are shown in Table 3.0.1.

Table 4.1.2.5 provides a summary of the condition class scores and acreages presented in the previous tables.

TABLE 4.1.2.5 Acreage with Range Condition Class Shell Creek Watershed				
	Acres within Condition Class			
Agency District	**Excellent**	**Good**	**Fair**	**Poor**
BLM -Worland	20,534	69,189	18,003	3,583
BLM – Cody	26,995	38,002	20,003	10,656
USFS – Medicine Wheel-Paintrock	5,512	35,957	29,790	4,732
TOTAL	**53,041**	**143,148**	**67,796**	**18,971**
PERCENT OF TOTAL	**19**	**51**	**24**	**7**

In summary, approximately 70 percent of upland vegetation communities on federally administered land within the watershed is in Good or Excellent condition. Approximately one-quarter of federally administered land is in Fair condition, while less than 10 percent is in Poor condition. Lands in Excellent and Good condition would typically contain a high percentage of native perennial grasses and palatable forbs and shrubs. Common species would include bluebunch wheatgrass, Idaho fescue, Nelson's needlegrass (*Stipa nelsonii*), and green needlegrass (*Stipa viridula*).

Areas in Fair condition would typically contain less native perennial grasses and palatable forbs and shrubs. Higher amounts of weedy species such as cheatgrass (*Bromus tectorum*), annual wheatgrass (*Agropyron triticeum*), and annual mustards such as flixweed tansymustard (*Descurainia sophia*) and tumble mustard (*Sisymbrium altissimum*) would be common.

Areas in Poor condition would typically be comprised primarily of weedy species such as those mentioned. Native perennial plants and other desirable species would only occur in limited amounts. Large amounts of bare soil would likely be present.

4.1.2.1 ECOLOGICAL SITE DESCRIPTIONS

An important asset to land management is Ecological Site Descriptions. The Natural Resources Conservation Service has developed a standard practice for creating Ecological Site Descriptions (ESD) for forestland and rangeland. (An) "Ecological site is defined as "a distinctive kind of land with specific characteristics that differs from other kinds of land in its ability to produce a distinctive kind and amount of vegetation". (http://esis.sc.egov.usda.gov/About.aspx) The ESD for a site is unique because it is dependent upon the site's physical geography, elevation, soils, annual moisture, weather conditions, plant life, and uses of the land. An ESD for a site is even impacted by the ESD's of surrounding sites.

ESD's provide a tool to identify the potential of a site to provide the maximum plant life based on the land use. An ESD for any given site has four key components: Site Characteristics, Plant Communities, Site Interpretations, and Supporting Information. Unfortunately, at this time, the ESD's have not been developed for the Shell Valley area. When the Ecological Site Descriptions for Shell Valley become available, they can be found online at http://esis.sc.egov.usda.gov/Welcome/pgReportLocation.aspx?type=ESD .

4.1.3 FORESTRY RESOURCES

The limited forestry resources that occur within the watershed range from forested riparian zones in the valley bottoms to mid- and high-elevation coniferous forests. Streams and larger riparian areas contain narrow-leaf cottonwood (*Populus angustifolia*), plains cottonwood (*Populus deltoides*), and aspen (*Populus tremuloides*). However, these vegetation communities occupy less than 5% of the watershed and thus provide minimal timber resources. The lower elevation uplands contain Rocky Mountain juniper (*Juniperus scopulorum*) growing in depressions and along some riparian zones. Middle and upper elevations in the watershed with sedimentary rock parent material generally have forests of Engleman spruce (*Picea englemannii*), Douglas fir (*Pseudotsuga menziesii*), and subalpine fir (*Abies lasiocarpa)*. Higher elevations generally contain granitic soils and are dominated by lodgepole pine (*Pinus contorta*), Engleman spruce, and Douglas fir (Despain, 1973).

Dave Sisk, Resource Specialist for the Unites States Forrest Service, Bighorn Ranger District provided information about the timber management activities in the Shell watershed. Timber management activities in the Shell watershed have primarily focused on an insect infestation south of Shell Creek between Post Creek to the west and Shell Creek campground to the east. The north-facing and heavily-timbered slope in this area has been devastated by a beetle infestation which has contributed to a high tree mortality rate. The infestation was first discovered in the lower portion of the canyon in 2004, despite the use of pheromone traps between the mouth of the canyon and the Shell Falls recreation area, the infestation spread along the full face of the slope from the mouth of the canyon to Shell Creek campground area.

In response to the high tree mortality in this area and the need to establish uneven aged stands to prevent future forest health hazards, the USFS has begun logging this area. The portion of the canyon below a tornado blow down area (near the confluence with Granite Creek) is currently being selectively logged using a helicopter to haul downed timber while the upper portion will use a combination of cable-haul logging and skidder-haul logging to access newly constructed logging roads. In both areas the upper 1/3 of the slope will not be logged due to difficult access, additional costs associated with steep terrain, and to preserve the aesthetic quality of the area. Due to the down slope proximity of Shell Creek, the logging plans have been developed to minimize the introduction of sediment and debris into the streams. Other timber activities in the watershed include the reestablishment of aspen through thinning and burning of encroaching conifers. Reduction of fuels for wildfires and structure protection will occur through thinning trees that surround summer homes to increase distance between tree crowns. Prescribed burns will be used to reduce fuels in small areas near Antelope Butte ski area and between Bald Mountain and Shell Falls (Dave Sisk, personal communication). Logging is scheduled to be completed by the spring of 2008 and all newly constructed roads will be removed and reclaimed to pre-logging conditions.

Relatively limited old-growth forest resources exist within the watershed. Most forest structural stages in the watershed occur within the one-inch to 9-inch plus tree diameter categories. Consequently, the majority of forest communities are comprised of trees within relatively small diameter classes. Similarly, of the more than 70,000 acres of forested cover types within the watershed (See Table 4.1.1.1), only 5,703 acres are comprised of stands greater than 200 years old (USDA 2000).

4.1.4 WETLAND AND RIPARIAN RESOURCES

Wetland and riparian resources within the Shell Watershed were evaluated using existing GIS data provided by Big Horn Conservation District, BLM (Cody and Worland Districts), USFS, and Wyoming Game and Fish Department. Additional correspondence with each of these offices provided data and insight on ecological conditions and current agency projects in the area. Many of the wetlands are either adjacent to or overlapping the riparian zones making these areas difficult to distinguish from GIS or monitoring databases. Therefore, wetlands and riparian zones are discussed simultaneously in this section.

The wetland resources in the watershed are widely varied from irrigation dependent slopes and depressions in the valley to sub-irrigated forested and wet meadow sites in the higher elevations. Numerous acres of herbaceous, shrub, and forested wetlands are also present along the streams and irrigation channels in the watershed. In addition, most of the natural ponds and constructed reservoirs in the watershed support a wetland fringe around the shore and larger wetlands at the inlet and outlet sites.

The riparian areas within the watershed range from narrow, densely forested communities in the higher elevations to broad, sparsely vegetated, and frequently flooded riparian zones in the lower elevations. The majority of streams in the Shell Creek watershed are buffered from uplands by some riparian vegetation, although the width and density of the riparian zone can vary greatly within proximal reaches. Variability in the vigor and size of riparian areas is influenced by factors such as surrounding land use, resource management, and to a lesser extent, flood frequency and intensity.

The dominant species found in the lower elevation riparian zones are narrow leaf cottonwood, a variety of sedges such as Nebraska sedge (*Carex nebraskensis*), beaked sedge (*Carex utriculata*), and other sedge species (*Carex spp*), several grass and forb species, and low shrubs such as snowberry (*Symphoricarpos albus*). In addition, many low-elevation riparian areas have been invaded by weedy species such as Canada thistle (*Cirsium arvense*), salt cedar (*Tamarix chinensis*) and Russian olive (*Elaeagnus angustifolia*).

The middle and upper elevation riparian zones contain a mix of species including a variety of willows such as alpine willow (*Salix arctica*), Booth's willow (*Salix boothii*), gray willow (*Salix glauca*), planeleaf willow (*Salix planifolia*), and wolf willow (*Salix wolfii*) (Jensen 1987). Forbs such as Lewis monkey flower (*Mimulus lewisii*) and grasses and sedges are also common. Narrowleaf cottonwood and Engleman spruce also occur in several middle and upper elevation forested riparian areas.

Introduced species appear to dominate vegetative communities in some riparian reaches. Reclamation efforts by Wyoming Department of Game and Fish are currently attempting to remove these species from public lands adjoining streams. Removal of invasive, high water uptake species (such as salt cedar and Russian olive) is anticipated to measurably increase stream flows (E. Smith, personal communication).

Data regarding wetland and riparian community types and observed Proper Function Conditions (PFC) (a measure of ecological health) were collected from the USFS and BLM-Cody and BLM-Worland Districts. Table 4.1.4.1 summarizes the acreages of each wetland and riparian type as well as the PFC for each of these types in the Shell Watershed. Riparian zones and wetlands are prevalent in the Shell Valley along perennial streams and irrigation canals, however the acreages and PFC data for these areas on private lands has not been determined or reported. PFC data has not been reported for the riparian/wetland areas on Bighorn National Forest lands, although qualitative descriptions of community types and adverse conditions are present in the USFS database.

TABLE 4.1.4.1
Summary of Wetland and Riparian Resources
Shell Creek Watershed

		Wetland Types						
Land Ownership	**Ecological Function Condition**	**Open Water (ac)**	**Herbaceous (ac)**	**Scrub/Shrub (ac)**	**Forested (ac)**	**Unknown Type (ac)**	**Ownership & Function Condition Totals**	**% of Total Wetland Acres**
USFS Medicine Wheel-Paintrock District	NA	296.4	3672.7	1524.6	4339.0	0.0	9832.7	97.2%
BLM Cody District	Proper Function	0.0	0.0	15.2	40.4	0.0	55.6	0.5%
	At Risk	0.0	0.5	36.4	21.3	0.0	58.2	0.6%
	NA		7.4	47.3	23.1	0.0	77.9	0.8%
BLM Worland District	Proper Function	0.0	0.4	0.0	3.3	41.7	45.4	0.4%
	At Risk	0.0	7.1	6.5	18.0	0.0	31.5	0.3%
	NA	0.0	0.0	0.0	0.0	15.9	15.9	0.2%
	Wetland Type Total	296.4	3688.1	1630.1	4445.0	57.6		
	% of Total	2.9%	36.5%	16.1%	43.9%	0.6%		
						Approximate Total Wetland Acres	**10,117**	

Over 10,000 acres, or 3% of the Shell Creek watershed, is comprised of wetlands and riparian areas that are monitored by the USFS and BLM. Approximately 97% of these are located on USFS land, 2% are located within the BLM-Cody District, and 1% on the BLM-Worland District of the BLM. Forested and herbaceous wetlands are the predominate wetland types monitored on public land followed by scrub/shrub and open water. A small percentage of wetlands (<1%) on BLM lands did not contain community type data and therefore were classified as Unknown Type wetlands.

Wetland ecological health or PFC data was available for about 66% of the wetlands monitored by the BLM. Of these wetlands with associated PFC data, approximately 53% were classified as "Proper Function" and 47% were classified as "At Risk". The BLM uses the following descriptions to classify the functioning condition of riparian/wetland areas (Prichard, 1998): *Proper Functioning Condition* sites are:

- riparian/wetland areas that contain adequate vegetation, landform, or debris to dissipate energies, thereby reducing erosion and improving water quality;
- filter sediment and aid floodplain development;
- improve flood-water retention and ground-water recharge;
- develop root masses that stabilize islands and banks against cutting action;
- restrict water percolation;
- develop diverse ponding characteristics to provide habitat and support greater biodiversity.

At Risk sites are riparian/wetland areas that are in functional condition but have an existing soil, water, or vegetation attribute that makes them susceptible to degradation.

Nonfunctional sites are riparian/wetland areas that are clearly not adequately performing one or more of the functions described under proper functioning condition.

Riparian conditions in the upper portion of the Shell Creek watershed are generally characterized as "fair" or "good", while conditions in the lower portion of the watershed have been described as "unstable" or "degraded". The habitat conditions of upper Shell Creek and associated tributaries include well-developed riparian areas, stable flows, low sedimentation, and relatively narrow channels with cobble/gravel streambeds (Welker, 2000).

4.1.5 SPECIAL STATUS SPECIES

The Wyoming Natural Diversity Database (WYNDD) does not record any known federally-listed Threatened or Endangered plant species in the watershed (WYNDD 2006). However, there are 21 Wyoming plant species of concern documented within the watershed including five regional endemics of the Big Horn Mountains/Pryor Mountains (WYNDD 2006). Wyoming plant species of concern known to occur within the watershed include those listed in Table 4.1.5.1.

TABLE 4.1.5.1
Special-Status Plant Species
Shell Creek Watershed

Scientific name	Common name	Regional Endemic	Wetland Species
Anemone narcissiflora ssp. zephyra	Zephyr Windflower		
Antennaria aromatica	Aromatic Pussytoes		
Arnica lonchophylla	Northern Arnica		
Cirsium foliosum	Leafy Thistle		
Cypripedium parviflorum var. pubescens	Large Yellow Lady's-slipper		Yes
Epipactis gigantean	Giant Helleborine		Yes
*Erigeron allocotus**	Bighorn Fleabane	X	
Eriophorum chamissonis	Russet Cotton-grass		Yes
Listera convallarioides	Broad-leaved Twayblade		
Pedicularis contorta var. ctenophora	Pink Coil-beaked Lousewort		
Pedicularis parryi ssp. mogollonica	Mogollon Lousewort		
Pedicularis pulchella	Mountain Lousewort		
*Penstemon caryi**	Cary's Beardtongue	X	
Penstemon laricifolius ssp. exilifolius	White Larch-leaf Beardtongue		
Physaria lanata	Woolly Twinpod		
*Pyrrocoma clementis var. villosa**	Hairy Tranquil Goldenweed	X	
Sambucus cerulea var. cerulea	Blue Elderberry		
Sporobolus neglectus	Small Dropseed		
Stanleya tomentosa var. tomentosa	Hairy prince's-plume		
*Sullivantia hapemanii var. hapemanii**	Hapeman's Sullivantia	X	Yes
*Symphyotrichum molle**	Soft Aster	X	

Three federally listed wildlife species have been documented within the watershed including the gray wolf (Canis lupus) [Threatened], black-footed ferret (*Mustela nigripes) [*Endangered], and the Canada lynx *(Lynx Canadensis)* [Threatened]. A variety of other rare or protected wildlife species also occur within the watershed as listed in Table 4.1.5.2.

TABLE 4.1.5.2 **Special-Status Wildlife Species** **Shell Creek Watershed**		
Scientific Name	**Common Name**	**Habitats**
BIRDS		
Haliaeetus leucocephalus	Bald eagle	Wooded areas usually along rivers, lakes, reservoirs. Sometimes in open country
Histrionicus histrionicus	Harlequin duck	Rapid mountain streams and rivers
Accipiter gentilis	Northern goshawk	Open montane conifer forest or aspen
Falco columbarius	Merlin	Open woodlands, grasslands, and shrublands sometimes in cities in winter
Centrocercus urophasianus	Greater sage grouse	Sagebrush basins and foothills, generally close to water
Coccyzus americanus	Yellow-billed cuckoo	Deciduous woods and thickets, usually along large streams
Athene cunicularia	Burrowing owl	Plains and basins, often associated with prairie dog towns
Aegolius funereus	Boreal owl	Subalpine conifer forest with snags for nesting cavities
Sphyrapicus thyroideus	Williamson's sapsucker	Old-growth conifer forest, especially a mixture of spruce and lodgepole pine
Picoides dorsalis	American Three-toed Woodpecker	Old-growth conifer forest, especially spruce-fir and ponderosa pine or recently burned forest
Myotis evotis	Long-eared myotis	Found in conifer forests, especially ponderosa pine. Forage over water holes and possible openings in conifer forest. Roosts: caves, buildings, mines.
MAMMALS		
Ovis canadensis	Bighorn sheep	Formerly wide-ranging, they have been re-introduced to several mountain ranges in the state.
Ochotona princeps obscura	Bighorn Mountain pika	High elevation talus slopes with nearby grass or forb cover.
Sylvilagus floridanus	Eastern cottontail	Nation-wide they are habitat generalists, but in Wyoming are restricted to riparian or brushy habitats.
Canis lupus	Gray wolf	Formerly thought to be extinct in Wyoming, reintroduction in the Yellowstone area has lead to a viable population in that portion of the state. The gray wolf occupies a variety of habitats in that area, often associated with ungulate herds, such as elk.
Martes americana	American marten (Bighorn Mountain population)	Martens prefer mature subalpine spruce-fir forests, but can less frequently be found in lodgepole, Douglas fir and cottonwood river bottoms.
Mustela nigripes	Black-footed ferret	Black-footed ferrets always occur in or near prairie dog colonies, generally on short or mixed-grass prairie.
Lynx canadensis	Canada lynx	Lynx are generally found in mature subalpine forest, usually spruce-fir, with significant winter snow accumulation that prohibits the invasion of generalist carnivores such as coyote and bobcat. They are usually found above 1,900 meters in areas where re
HERPTILES		
Rana pipiens	Northern leopard frog	Found near permanent water in areas up to about 9,000 feet. Lower elevation sites are usually swampy cattail marshes and higher ones tend to be beaver ponds.
Rana sylvatica	Wood frog (Bighorn Mountian wood frog)	Wood frogs are found in ponds, lakes, and slow-moving streams at higher elevations (e.g., usually over 8,500 feet above sea level), often in the vicinity of conifer forests.
FISH		
Oncorhynchus clarki bouvieri	Yellowstone cutthroat trout (Native populations)	Historically Yellowstone cutthroat trout lived in lakes, rivers and streams of the Yellowstone River drainage (including Yellowstone Lake). Also found in the Snake, Tongue, Bighorn, and Clarks Fork Drainages. May no longer occur in watershed.

4.2 WILDLIFE

Diverse wildlife habitats exist in the Shell Creek watershed due to the juxtaposition of Great Basin vegetation communities in the valley bottoms and valleys and alpine environments at higher elevations. In between these two extremes are Wyoming big sagebrush and juniper woodlands along the abrupt elevation transition between low and high elevation ecosystems. The lower watershed is typical of Great Basin ecosystems that support a diverse population of upland birds, waterfowl, raptors, and both large and small mammals. Species present in the lower watershed include: pronghorn antelope (*Antilocapra americana),* red-tailed hawk (*Buteo jamaicensis*), magpie (*Pica pica*), and white-tailed deer (*Odocoileus virginianus).* The upper watershed contains montane to alpine ecosystems that provide habitat for species such as elk (*Cervus canadensis)* and moose (*Alces alces*). The mosaic of diverse habitats throughout the watershed supports common species such as the common raven (*Corvus corax*), mule deer (*Odocoileus hemionus)*, and coyote (*Canis latrans)* as well as numerous other wildlife species (USDA 1999). Sensitive habitats such as crucial winter habitat and calving habitat are present for elk, mule deer, and moose and are shown in Figure 4.2.1 Shell Valley Wildlife Map, on the following page.

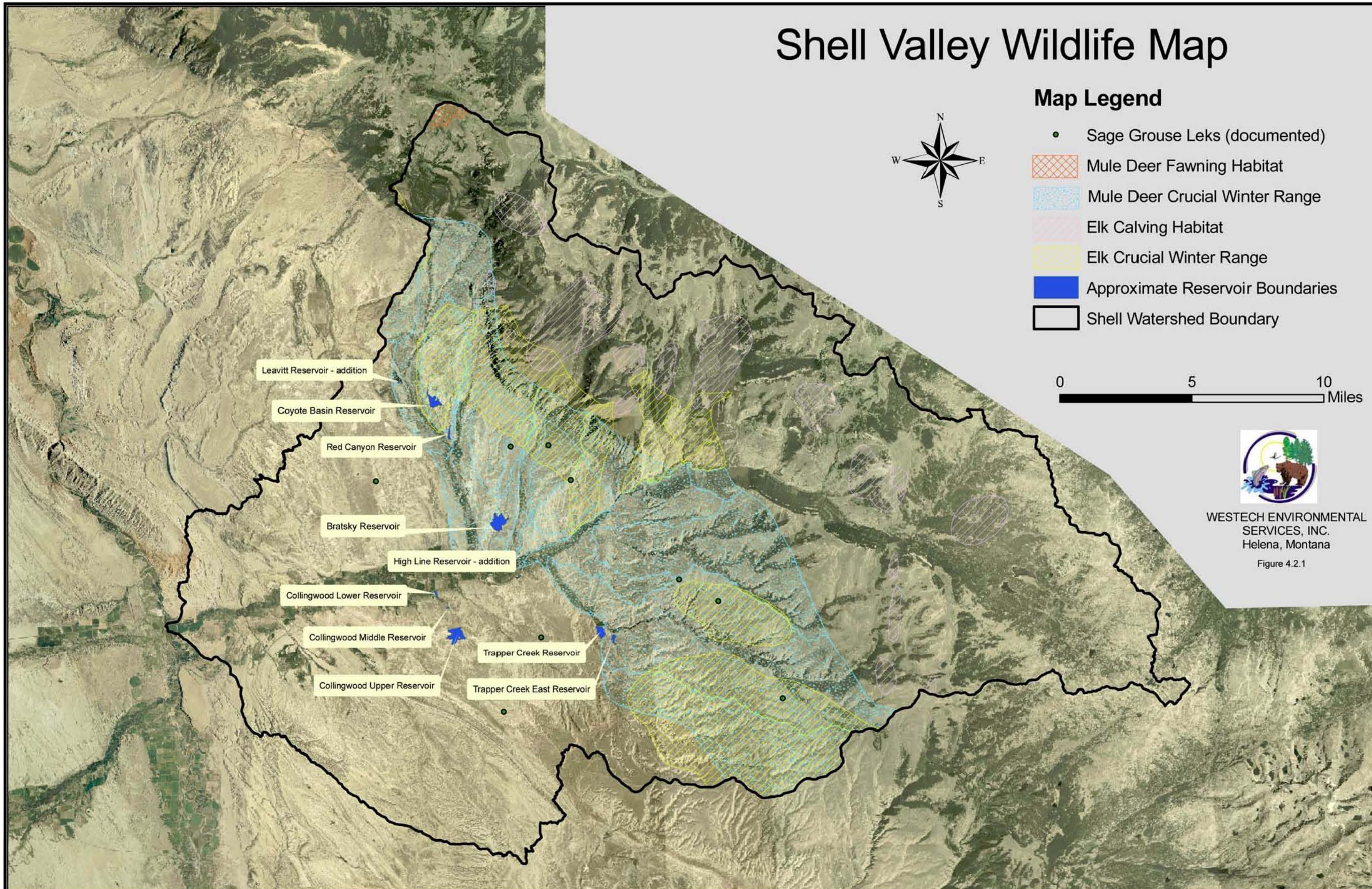
Mule deer are an adaptable species that occur throughout forests, open woodlands, sagebrush foothills, and dry basins of the Shell Valley. Mule deer are found year-round at elevations below 7000 ft and are present spring, summer, and fall in habitat above 7000 ft (Petty, 2000). According to Wyoming Game and Fish habitat data, critical mule deer habitat, primarily winter range, occupies over 100,000 acres of the watershed. This habitat is generally located in the mid-elevation Wyoming big sagebrush vegetation communities. A small area (approximately 550 acres) of mule deer fawning habitat is located at the uppermost elevations of the Beaver Creek drainage.

Elk winter-range habitat is located in mid-elevation sagebrush and forest habitats within the watershed and occupies approximately 50,500 acres. The elk and mule deer winter ranges share many similar attributes (i.e. elevation and vegetation community types) and often occupy overlapping geographic areas. The elk calving habitat is generally found in mid- to high- elevation forests and open meadows in the Bighorn Mountains. Elk calving areas documented by Wyoming Game and Fish are located in discrete non-contiguous areas that occupy a total of 17,800 acres in the Shell watershed.

Moose habitat is prevalent throughout the Bighorn Mountains and moose populations are managed to moderate browsing pressures on willows. The abundance of willows in the higher elevation forests and meadows enables moose to remain in the mountains throughout the year (Petty, 2000). Substantial winter range for moose has been identified in the Big Horn Mountains; however a very small area (i.e. < 8 acres) is located within the eastern boundary of the watershed.

Other notable large game species present in the Shell watershed includes pronghorn antelope, white-tailed deer, and bighorn sheep (*Ovis canadensis*). Antelope are generally located in the foothills at elevations below 5000 ft. Water is often the limiting factor in the basin and foothill habitats, although reservoirs and irrigation channels are allowing the antelope to expand their distribution during late-summer and fall. White-tailed deer populations are also expanding by utilizing the riparian habitats along perennial streams and irrigation distribution networks within the valley.

Native populations of bighorn sheep were historically present in the Shell Creek watershed, however, the populations have continued to decline despite reintroduction efforts between 1992 and 1994 in the Shell Canyon area. The three most common forms of death among bighorn sheep in the area are predation by mountain lions, pneumonia, and vehicle impacts. The resulting high mortality and low reproduction have prohibited a viable bighorn sheep population from establishing in Shell Canyon (Petty, 2000).


Shell Valley Wildlife Map
Map Legend
Sage Grouse Leks (documented)
Mule Deer Fawning Habitat
Mule Deer Crucial Winter Range
Elk Calving Habitat
Elk Crucial Winter Range
Approximate Reservoir Boundaries
Shell Watershed Boundary
0 5 10 Miles
N
S
E
W
WESTECH ENVIRONMENTAL SERVICES, INC.
Helena, Montana
Figure 4.2.1
Leavitt Reservoir - addition
Coyote Basin Reservoir
Red Canyon Reservoir
Bratsky Reservoir
High Line Reservoir - addition
Collingwood Lower Reservoir
Collingwood Middle Reservoir
Collingwood Upper Reservoir
Trapper Creek Reservoir
Trapper Creek East Reservoir

A total of 9 sage grouse leks have been identified and surveyed in the watershed between 1999 and 2005. There are 6 leks in the upper Shell Creek drainage and 3 leks in the lower portion, however one of these leks is considered inactive. Future monitoring of these leks is planned and will determine the viability of the species in the Shell Creek Watershed.

4.3 FISHERIES

Based on current and historical information of fish hatcheries and habitat, identified in the Basin Management Plan by author Mike Welker, the diversity of fish species within the Shell Creek watershed is dictated by elevation and stream gradients. Fish habitat within the Shell Creek watershed includes a total of 32 streams and 6 reservoirs/ponds identified as suitable fisheries in the Shell Basin Management Plan. Historical fish populations likely included Yellowstone cutthroat trout. However, genetically pure populations of this fish have not been identified in recent fish inventories. The populations of Yellowstone cutthroat present in the Shell watershed today are likely the progeny of Yellowstone Lake populations that were transplanted to this area in the early 1900's. Additional stocking of brook, rainbow, and brown trout populations during the 1930's and 1940's may have out-competed any remaining native Yellowstone cutthroat strains. Current fish stocking activity includes the release of rainbow trout at the Shell Creek Campground. (This statement has been confirmed through personal communication with Steve Yekel with Wyoming Game and Fish, April 9, 2007)

Standing water fisheries in the watershed includes 6 constructed ponds/reservoirs (Shell Creek Reservoir, Shell Ranger Station Pond, Brindle Creek Pond, Arden Lake, Adelaide Lake, and Leavitt Reservoir) and several alpine lakes in the Cloud Peak Wilderness area. These water bodies, with the exception of Leavitt Reservoir, are dominated by naturally reproducing brook trout (*Salvelinus fontinalis*) populations.

Native fish species present in the Shell Creek drainage include occasional reports of Sager (*Sander Canadensis*) and channel catfish (*Ictalurus punctatus*) migrating from the Big Horn River. Some populations of Yellowstone cutthroat trout are present in tributary streams such as Trapper Creek, Cedar Creek, and Beaver Creek. Wyoming Game and Fish Department is currently supporting native fish populations by implementing habitat improvement projects and stocking native species in several of these tributaries. Other native fish species found in the Shell watershed include: Flannelmouth Sucker (*Catostomus latipinnis*), Flathead Chub (*Platygobio gracilis*), and Mountain Sucker (*Catostomus platyrhynchus*).

The majority of game fish species within the watershed are introduced species, namely brook trout, rainbow trout (*Oncorhynchus mykiss*), and brown trout (*Salmo trutta)*. Brook trout occupy the high-elevation and high-gradient streams, while a mix of rainbow and brook trout exist in mid-elevation and mid-gradient sections of Shell Creek (approximately between Shell Campground and Shell Falls), and a mix of brown and rainbow trout are found in the lower elevation sections between the mouth of Shell Canyon and the confluence with the Big Horn river.

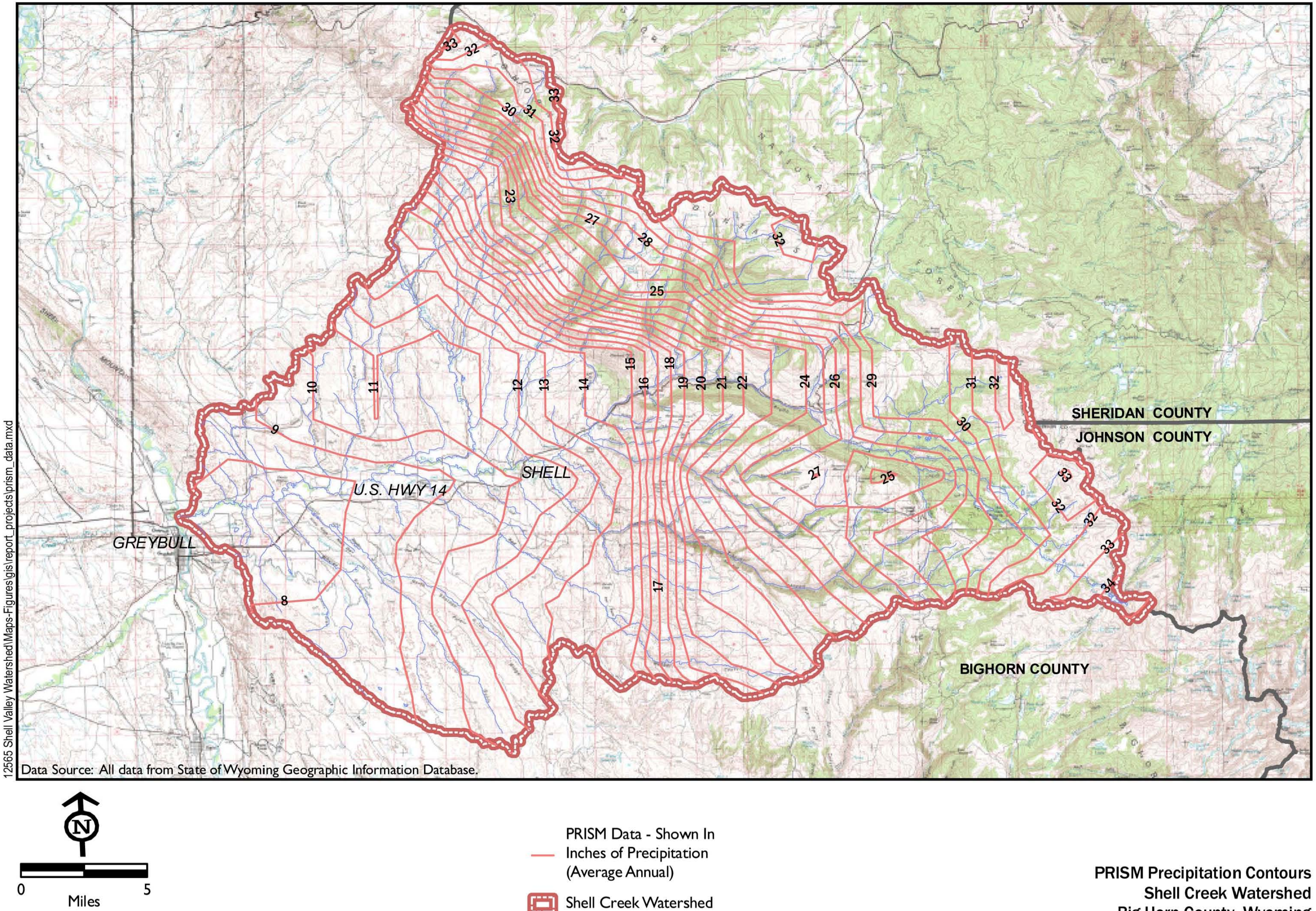
5.0 SHELL CREEK WATERSHED

5.1 CLIMATE

Climate in the Shell Creek watershed area is subject to extreme weather conditions due to the varied topographic setting of mountains, hills, canyons, valleys, and rolling flatlands. Elevations in the watershed range from about 3,900 feet in the western lowlands, to 11,000 feet in the eastern mountains. Climate summaries were obtained from the Western Regional Climate Center (WRCC 2007) for three stations in the watershed: Burgess Junction in the eastern mountains; Shell town in the central area; and Greybull town at the western mouth of the watershed.

Average annual precipitation in the mountains at Burgess Junction is 21.0 inches, with only 9.9 inches/year at Shell, and 6.9 inches/year at Greybull. Average monthly precipitation at these three stations is summarized in Table 5.1.1. Highest monthly precipitation in the mountains occurs in April; whereas, highest precipitation at the lower stations is in June. Highest monthly precipitation at all three stations generally occurs during April-May-June. Figure 5.1.1, on the following page, shows lines of equal precipitation in the Shell Creek watershed based on a GIS-based PRISM model from the Oregon Climate Service (2007).

Snowfall in the watershed varies significantly from the mountainous eastern side to the lowlands in the west. Average annual snowfall at Burgess Junction is 242 inches, while snowfall at Shell and Greybull averages only about 20 inches/year shown in Table 5.1.1. This snow-pack in the mountains provides a significant amount of surface water runoff in streams during the spring and early summer periods.



PRISM Data - Shown In Inches of Precipitation (Average Annual)

Shell Creek Watershed

Geomatrix

12565

PRISM Precipitation Contours
Shell Creek Watershed
Big Horn County, Wyoming
FIGURE 5.1.1

TABLE 5.1.1 Monthly Precipitation and Temperature Data Shell Creek Watershed													
Station Name	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
Average Total Precipitation (inches)													
Burgess Jnctn.	1.35	1.33	1.98	2.66	2.36	2.14	1.45	1.29	1.83	1.86	1.40	1.37	21.02
Shell Town	0.54	0.46	0.52	1.02	1.44	1.63	0.74	0.59	1.11	0.85	0.56	0.49	9.94
Greybull Town	0.35	0.28	0.31	0.68	1.16	1.22	0.53	0.47	0.77	0.49	0.35	0.30	6.90
Average Total Snowfall (inches)													
Burgess Jnctn.	30.0	29.7	39.2	36.2	15.2	4.1	0.1	0.2	8.0	21.8	27.3	31.2	242.8
Shell Town	6.0	3.3	2.2	0.4	0.4	0.0	0.0	0.0	0.2	0.6	1.7	5.2	20.1
Greybull Town	4.0	3.2	2.5	1.7	0.3	0.0	0.0	0.0	0.7	0.6	2.9	4.3	20.1
Average Maximum Temperature (^{o}Fahrenheit)													
Burgess Jnctn.	27.6	29.5	33.9	40.5	50.8	60.4	70.0	68.5	58.0	47.1	34.7	28.4	45.8
Shell Town	32.5	40.3	50.9	61.0	70.1	80.5	89.3	87.6	75.4	62.4	44.8	34.6	60.8
Greybull Town	30.2	38.6	51.6	61.9	72.7	81.5	90.4	88.7	75.5	62.3	44.8	32.8	60.9
Average Minimum Temperature (^{o}Fahrenheit)													
Burgess Jnctn.	5.8	6.1	10.2	17.8	28.0	34.9	40.5	38.7	31.4	22.8	12.6	6.7	21.3
Shell Town	6.1	12.5	21.5	29.7	37.3	47.1	53.6	50.2	39.6	29.4	17.3	7.5	29.3
Greybull Town	3.9	10.5	22.5	34.6	42.1	50.4	56.2	52.9	44.4	30.6	18.0	7.6	31.1

Note: Period of record for all stations is approximately 1960 – 2005.
Source: WRCC 2007.

A Snotel station (Site No. 751) monitored by the Natural Resources Conservation Service (NRCS 2007) is located in the mountainous portion of the Shell Creek watershed at an elevation of 9,580 feet (Figure 5.1.1). Graphs of Snotel data for the last 5 water years (2003–2007) showing snow water equivalent (yearly versus 30-year average) and precipitation (yearly versus 30-year average) are included in Appendix B. These graphs show that, with the exception of water year 2005 (October 2004 through September 2005), snow water equivalent and precipitation have generally been below the 30-year averages (1971–2000).

Temperature varies widely between the seasons, with the hottest months being July and August, and coldest months are December-January-February. Maximum and minimum monthly temperatures for stations at Burgess Junction, Shell, and Greybull are summarized in Table 5.1.1. Potential evaporation is >25 inches/year in most of the Shell Creek watershed, with lower rates of 17 to 21 inches/year in the mountains (Marston et al. 1990).

5.2 GEOLOGY

5.2.1 GEOLOGIC SETTING

The Shell Creek watershed is located in a diverse geologic setting. The physical forces of folding, faulting, glaciers, wind/water erosion, and sedimentation have shaped the landscape over many years. Big Horn County is located primarily in the Bighorn structural basin containing bedrock from Precambrian through Tertiary age. The mountainous areas consist primarily of sedimentary and igneous rocks that form the core of the mountains. Approximately 52 million years ago, a large inland freshwater lake covered most of Big Horn County, along with initiation of some volcanic activity. The Big Horn Mountains began to rise, with accompanying glacier formation that helped carve the mountainous canyons and valleys.

Figure 5.2.1, on the following page, is a stratigraphic column that shows primary lithologic rock units in the Shell Creek watershed area. Primary sedimentary units include the Paleozoic-age Flathead Sandstone, Bighorn Dolomite, Three Forks Shale, Jefferson and Madison Limestones, and Tensleep Sandstone. Mesozoic-age units include the Chugwater Sandstone, Sundance Sandstone/Shale, Morrison Siltstone/Sandstone, Cloverly Formation, Thermopolis and Mowry Shales, Claggett Shale, Parkman Sandstone, and Bearpaw Shale. Most geologic units in the mountains are steeply-dipping Paleozoic-age beds; whereas, the Cretaceous-age shales are dominant in the flatlands.

Appendix C contains surficial and bedrock geology maps from the Wyoming Ground Water Vulnerability Assessment Handbook (Hamerlinck and Arneson 1998). Appendix C also includes definitions of the geologic unit abbreviations.

5.2.2 SEISMIC CONDITIONS

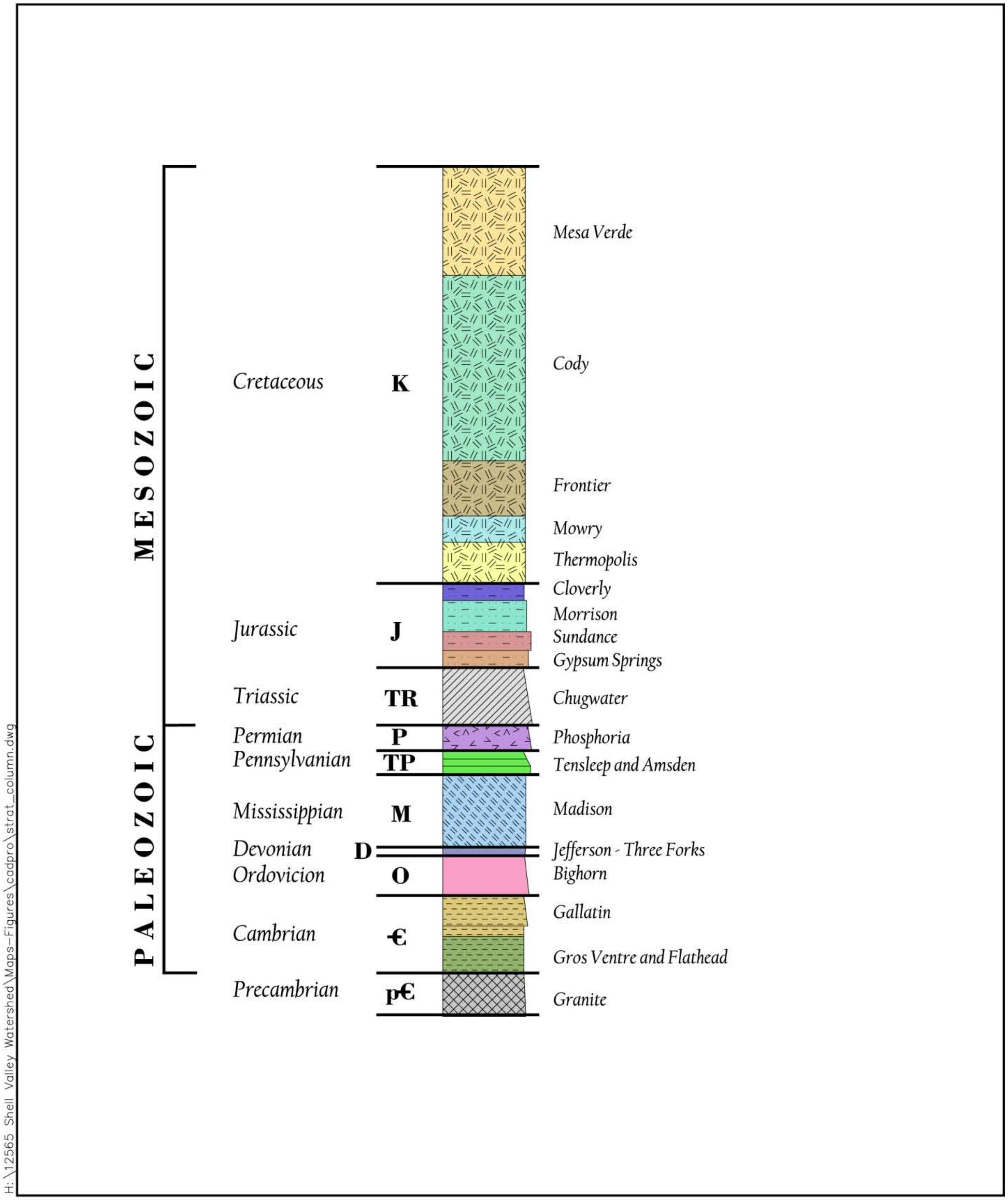
A basic seismic characterization was completed by Case et al. (2002) for Big Horn County. Four magnitude 2.5 and greater earthquakes have been recorded in this county. One of these was located 12 miles east-northeast of the town of Shell on September 2, 1962. The most recent earthquake in Big Horn County occurred on February 12, 1998 (magnitude 3.0), approximately 12 miles north-northeast of Hyattville. An earthquake database for Wyoming is included in the Wyoming Water Resources Data System (2007).

The Shell Creek watershed is located in Uniform Building Code (UBC) Seismic Zone 1, indicating that for a 2500-year earthquake, which has a 2 percent chance of occurring in the next 50 years, there could be a peak gravitational acceleration of 5 to 10 percent in Big Horn County (Case et al. 2002). Also, probability-based worst-case scenarios could result in some damage in the Greybull and Shell areas due to an Intensity VI earthquake (Case et al. 2002). In such an earthquake, only minor building damage may occur.

Appendix D contains an Information Pamphlet (No. 6 – Earthquakes in Wyoming) that shows a map of historical earthquake epicenters in Wyoming. Only three such epicenters are shown in Big Horn County along the southeastern side in the mountains or foothills. Another map in the Pamphlet shows known and suspected active faults in Wyoming, none of which are delineated in Big Horn County.

5.2.3 LANDSLIDES

Landslides occur where geologic materials are unstable, either naturally or man-caused due to disrupting the native material, such as road-cuts at the base of slopes. Additionally, landslides can affect water storage reservoirs by releasing soil and rock into the water body; increasing significantly sediment loading; and/or cause a wave of water to overtop the dam, possibly even breaching the dam. Landslides in Wyoming have been mapped and are presented by quadrangle for most mountainous and foothill areas in the Shell Creek watershed. A review of this information, which is available from the Wyoming



Not To Scale

Geomatrix 12565

Stratigraphic Column
Shell Creek Watershed
Big Horn County, Wyoming
FIGURE 5.2.1

Water Resources Data System (2007), shows that landslides occur in the study area, primarily along foothills of the mountains, including valley and canyon walls, but are not present in the western flatlands. Some of the common types of landslides in the area include: block slide, debris flow, rock slide, slump, and slump/flow complex.

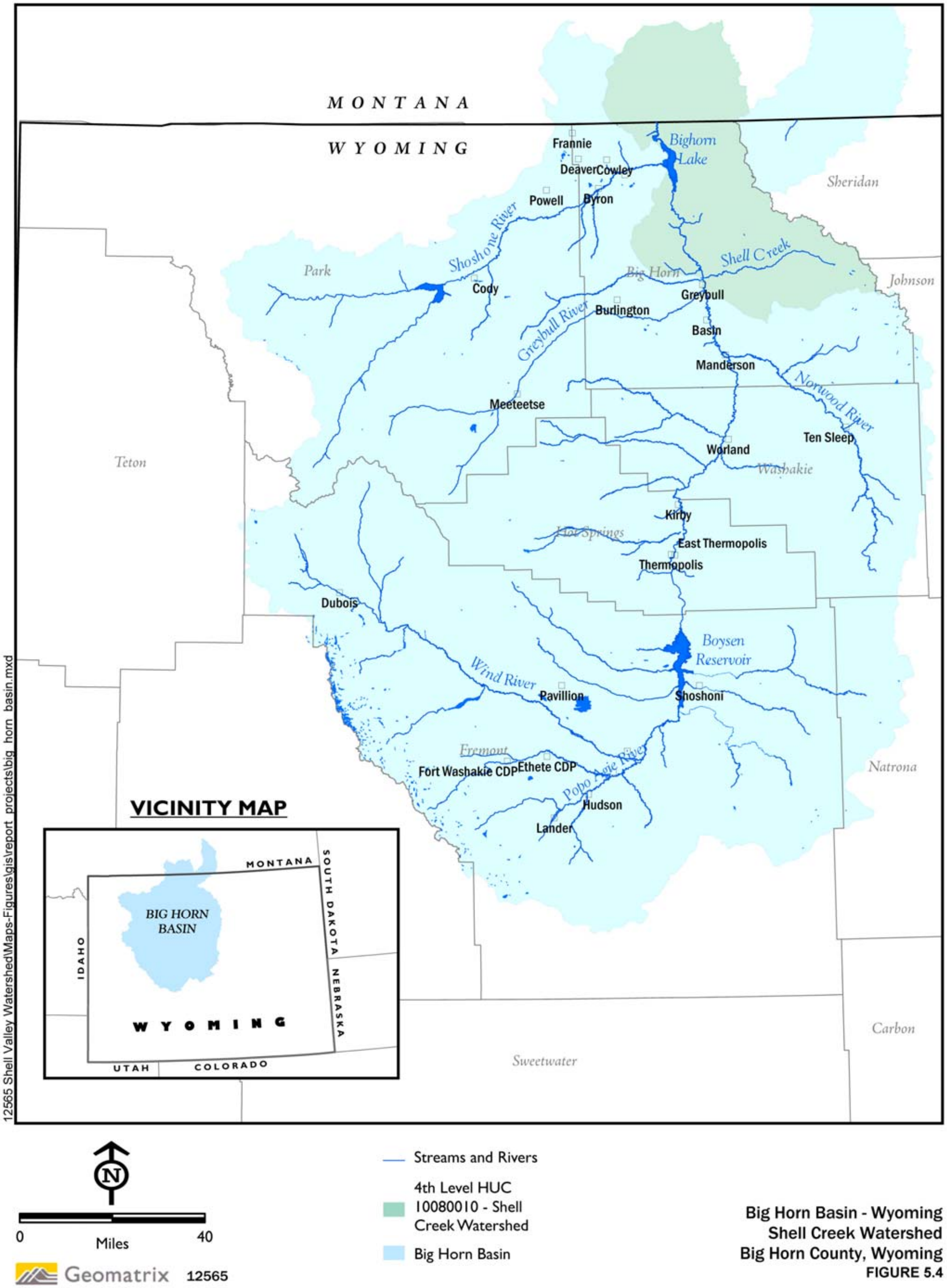
5.3 SOIL RESOURCES

Soils in Big Horn County are diverse and vary according to parent geologic material and the forces that have eroded and deposited these materials. A comprehensive soil survey has not been published for Big Horn County. However, a soils map for Big Horn County from the Wyoming Ground Water Vulnerability Assessment Handbook (Hamerlinck and Arneson 1998) is included in Appendix B. Additionally, soil information for portions of the Shell Creek watershed area, mostly along drainages and irrigated areas, is available from the NRCS (2007b) office in Greybull. Available soil data for these areas includes: dominant soil complex, soil map unit, erosion hazard, percent coarse fragments, organic matter, plasticity and expansion index, chemical soil properties, and engineering properties. Specific soil information for potential water storage reservoir sites is discussed later in this report. Further information can be found in the electronic GIS file.

Soils in the western rolling flatlands have surface organic layers of <5 inches; whereas, soils in the valleys and foothill slopes generally are deeper and higher in organic content. The low lying soils typically are poorly drained and susceptible to erosion. Some of these areas also have accumulations of salts which decrease vegetative production.

5.4 HYDROLOGY

The Shell Creek Valley incorporates surface water drainage from the west-central portion of the Big Horn Mountains, which lies along the eastern edge of the Big Horn Basin. The Shell Creek watershed covers an area of 370,000 acres or 580 square miles, and is located within the Big Horn/Wind hydrologic basin of Wyoming, see Figure 5.4 on the following page.



Big Horn Basin - Wyoming
Shell Creek Watershed
Big Horn County, Wyoming
FIGURE 5.4

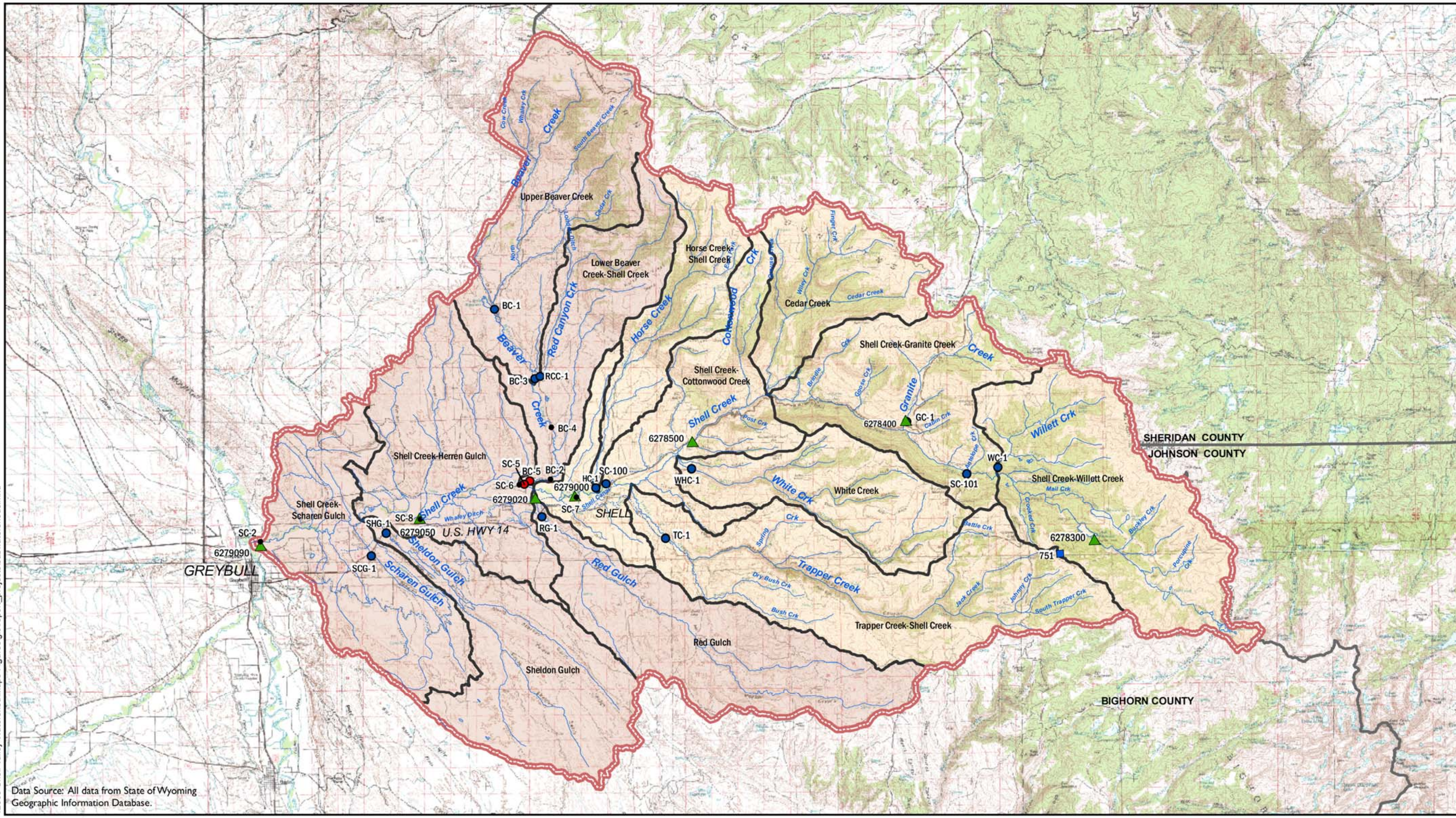
5.4.1 HYDROLOGIC UNITS

A hydrologic unit defines the area of land upstream from a specific point on the stream that contributes surface water runoff directly to this outlet point. The hydrologic unit code (HUC) is a system of identifying such hydrologic units, consisting of 2 to 12 digits based on the levels of classification. The 4th Level HUC for Shell Creek is sub-basin 10080010. This sub-basin is divided further into watersheds (5th Level HUCs) and sub-watersheds (6th Level HUCs). The Shell Creek drainage basin is comprised of two watersheds: HUC 1008001001 (Upper Shell Creek watershed) and HUC 1008001002 (Lower Shell Creek watershed), both of which are 5th Level HUCs. The 12-digit or 6th Level HUCs (sub-watersheds of Shell Creek Upper and Lower Watersheds) are listed in Table 5.4.1.1. and shown on Figure 5.4.1 on the following page.

TABLE 5.4.1.1.
Shell Creek Sub-Watersheds and Drainage Areas

HUC-12 Number and 6th Level HUC[1]	Sub-Watershed Name[2]	Drainage Area (acres)
100800100101	Upper Shell Creek	37,674
100800100102	Shell Creek - Granite Creek	27,409
100800100103	Cedar Creek	18,331
100800100104	Shell Creek - Cottonwood Creek	28,094
100800100105	White Creek	19,913
100800100106	Trapper Creek	42,250
100800100107	Horse Creek	15,549
100800100201	Red Gulch	30,721
100800100202	Shell Creek - Herren Gulch	32,006
100800100203	Upper Beaver Creek	32,912
100800100204	Beaver Creek - Red Canyon Creek	20,460
100800100205	Sheldon Gulch	29,046
100800100206	Shell Creek - Scharen Gulch	27,853

Notes:
[1] HUC-12 = 6th Level Hydrologic Unit Code (HUC) (sub-watershed-level designation).
[2] See Figure 5.4.1 for locations of sub-watersheds.



Surface Water Monitoring Sites

- South Big Horn Conservation District (SBHCD) Station
- U.S. Geological Survey (USGS) Station
- Supplemental WY Water Development Commision (WWDC) Station
- Snotel Monitoring Station (Precipitation and Snow)
- Upper Shell Valley (HUC 1008001001) - 5th Level
- Lower Shell Valley (HUC 1008001002) - 5th Level
- Shell Creek Watershed
- 6th Level HUC Boundaries and Names

0 Miles 6

Geomatrix 12565

Sub-Watersheds and Monitoring Stations
Shell Creek Watershed
Big Horn County, Wyoming
FIGURE 5.4.1

5.4.2 LAKES AND RESERVOIRS

Several lakes and reservoirs occur throughout the Shell Creek watershed. In the eastern mountainous region, the primary water bodies include: Shell Reservoir, Adelaide Lake, and Moraine Lake. These lakes receive cold, clear, high-quality water from precipitation in the mountains. They are used for fishing, recreation, wildlife, and irrigation storage. In the western flatlands, there are several man-made reservoirs including Leavitt Reservoir and some smaller unnamed reservoirs for irrigation and/or stock watering.

5.4.3 GROUNDWATER

Groundwater in the Shell Creek watershed is present in all geologic materials, from unconsolidated deposits (clay, silt, sand, and gravel) to sedimentary and igneous rocks. Groundwater is encountered in wells, springs, or as inflow to streams. Numerous springs occur throughout the watershed. Water in geologic formations is under either confined or unconfined conditions.

The most common water-bearing units in Big Horn County in descending order of use are: Quaternary-age alluvium; Mississippian-age Madison Limestone; Ordovician-age Bighorn Dolomite; Cambrian-age Flathead Sandstone; Pennsylvanian-age Tensleep Sandstone; Triassic-age Chugwater Sandstone; and Cretaceous-age Cloverly Formation (Hamerlinck and Arneson 1998). Highest yields from wells typically occur from deep unconfined aquifers where the water usually has the best quality characteristics. Domestic and stock watering wells, however, generally are completed in relatively shallow bedrock units and alluvial deposits.

Specific information about groundwater wells in Big Horn County and the watershed can be obtained from the Wyoming State Engineer's office at http://seo.state.wy.us. Appendix C contains a map from the Wyoming Ground Water Vulnerability Assessment Handbook (Hamerlinck and Arneson 1998) that shows registered groundwater wells in Big Horn County as of 1998.

5.4.4 WATER MONITORING

All surface water stations in the Shell Creek watershed that have been monitored by the U.S. Geological Survey (USGS), South Big Horn Conservation District (SBHCD), and Wyoming Water Commission (WWDC) are listed in Table 5.4.4.1 and shown on Figure 5.4.1. The table includes northing/easting locations.

TABLE 5.4.4.1
Surface Water Monitoring Stations in Shell Creek Watershed

Station ID[1]	Agency[2]	Location[3]		Description
		Easting	Northing	
6278300	USGS	308987.413009	4931113.30620	Shell Creek above Shell Reservoir
6278400	USGS	297717.905056	4938959.84506	Granite Creek at Hwy 14 culvert
6278500	USGS	284600.238876	4937932.04974	Shell Creek 3 miles upstream of Shell
6279000	USGS	277595.108957	4936777.00708	Shell Creek near bridge 1 mile d/s of Shell
6279020	USGS	274754.972656	4935144.57567	Red Gulch near culvert along County Lane
6279050	USGS	267583.376626	4934193.07431	Shell Creek at Porter Gulch
6279090	USGS	257745.338871	4932976.78639	Shell Creek near bridge at Greybull, WY
BC-2	SBHCD	275034.150924	4942457.01346	Beaver Creek 1.5 miles u/s of Shell Ck
BC-4	SBHCD	275950.982180	4939434.91783	Beaver Ck at culvert 3.5 miles u/s of Shell Ck
BC-5	SBHCD	274445.627892	4936184.41579	Beaver Ck at culvert 0.5 mile u/s of Shell Ck
SC-2	SBHCD	259594.548202	4933712.24225	Shell Ck at bridge near Greybull & USGS Stn. 6279090
SC-5	SBHCD	274093.719901	4935996.67835	Shell Creek near bridge along Beaver Ck road
SC-6	SBHCD	273808.162380	4936006.08621	Shell Creek below confluence of Beaver Ck
SC-7	SBHCD	277311.191934	4935062.97352	Shell Creek near bridge along County Rd 39
SC-8	SBHCD	267644.404486	4934119.70552	Shell Creek near bridge along Porter Gulch Rd
BC-1	WWDC	273024.617544	4945652.33462	Beaver Ck at culvert near Leavitt Reservoir
BC-3	WWDC	275753.011035	4936263.27397	Beaver Creek at culvert u/s of Red Canyon Creek confluence
GC-1	WWDC	297744.420589	4938828.78739	Granite Creek near Hwy 14 culvert; 0.25 mile u/s of Shell Creek
HC-1	WWDC	278469.853098	4935581.82506	Horse Creek at culvert along County Rd 31
RCC-1	WWDC	275294.336945	4942304.56208	Red Canyon Creek at culvert, 0.2 mile u/s of Beaver Creek
RG-1	WWDC	275219.105303	4934095.43220	Red Gulch at Hwy 14
SCG-1	WWDC	264489.534761	4931979.81664	Scharen Gulch at Hwy 14
SHG-1	WWDC	265469.843819	4933352.94897	Sheldon Gulch at Hwy 14
SC-100	WWDC	279622.426463	4935660.65443	Shell Ck at County Rd bridge near Shell
SC-101	WWDC	301278.468174	4935453.23872	Shell Creek at bridge near USFS campground
TC-1	WWDC	282607.483129	4932282.00524	Trapper Ck at bridge along Black Mountain Rd
WC-1	WWDC	303211.574718	4935759.48441	Willett Creek at trail bridge near Shell Ck
WHC-1	WWDC	284412.289228	4936485.94034	White Creek at culvert 0.5 mile u/s of Shell Ck

Notes: [1] See Figure 5.4.1 for station locations. [2] USGS = U.S. Geological Survey; SBHCD = South Big Horn Conservation District; WWDC = Wyoming Water Development Commission. [3] UTM coordinates, NAD83.

Over the last 9 years, the Wyoming DEQ has conducted a comprehensive water quality monitoring program for rivers, streams, lakes, and reservoirs throughout the state. An annual work plan is prepared each year to guide the targeted monitoring program and define monitoring objectives (Wyoming DEQ 2007a). No water bodies in the Shell Creek watershed, however, were included in the 2007 work plan.

The USGS has intermittently monitored five stations along Shell Creek, one site on Granite Creek, and one site on Red Gulch beginning as early as 1911. Table 5.4.4.2 summarizes the monitoring schedule implemented by the USGS for these seven stations. Currently, only two stations on Shell Creek (no. 6278300 – above Shell Reservoir; no. 6278500 – 3 mile upstream of Shell town site) are being monitored by the USGS (for continuous flow only). Some of the other stations were monitored by the USGS for water quality, biology, and/or annual peak discharge.

TABLE 5.4.4.2
Monitoring Schedule for USGS Surface Water Stations
Shell Creek Watershed

Station ID & Stream Name[1]	Drainage Area[2] (square miles)	USGS Period of Record[3]			
		Instantaneous, Daily, or Monthly Discharge	Annual Peak Discharge	Water Quality	Biology
6278300 Shell Creek	23.1	1956 - current	---	---	---
6278400 Granite Creek	11.1	---	1961-1974	1951; 1976; 1982	---
6278500 Shell Creek	145	1940 - current	---	---	---
6279000 Shell Creek	256	1911-1923	---	---	1973-1974
6279020 Red Gulch	47.8	---	1967; 1970-1981	---	---
6279050 Shell Creek	---	1983-1990	---	1983-1989	1989-1990
6279090 Shell Creek	560	1965-1986	---	1951; 1965-1986	1973-1978

Notes:
USGS = U.S. Geological Survey.
[1] See Figure 5.4.1 for station locations.
[2] Source: USGS National Water Information System (http://waterdata.usgs.gov/nwis)
[3] Source: USGS Water Resources Data Wyoming, various water years.

Beginning in 2002, the SBHCD initiated monitoring of Shell Creek at five stations, and Beaver Creek at three stations. This agency measures stream flow and some water quality parameters, including microbiological parameters of fecal coliform and ecoli bacteria. The SBHCD performs five consecutive weekly monitoring events three times each year according to a DEQ approved Sampling and Analysis Plan. Table 5.4.4.3 summarizes the monitoring schedule implemented by the SBHCD for the stations on Shell and Beaver creeks.

TABLE 5.4.4.3.
Monitoring Schedule for SBHCD Surface Water Stations
Shell Creek Watershed

Station No. & Stream Name[1]	Instantaneous Discharge		Water Quality [2]		Microbiological [3]	
	No. of Measurements	Period of Record[4]	No. of Measure-ments	Period of Record	No. of Measure-ments	Period of Record
BC-2 Beaver Creek	15	6/05 - 4/07	18	4/04 - 4/07	30	5/02 - 4/07
BC-4 Beaver Creek	16	6/05 - 4/07	18	4/04 - 4/07	31	5/02 - 4/07
BC-5 Beaver Creek	15	6/05 - 4/07	18	4/04 - 4/07	30	5/02 - 4/07
SC-2 Shell Creek	13	6/05 - 4/07	17	4/04 - 4/07	29	5/02 - 4/07
SC-5 Shell Creek	13	6/05 - 4/07	17	4/04 - 4/07	22	5/02 - 4/07
SC-6 Shell Creek	14	6/05 - 4/07	18	4/04 - 4/07	27	8/02 - 4/07
SC-7 Shell Creek	15	6/05 - 4/07	18	4/04 - 4/07	23	5/02 - 4/07
SC-8 Shell Creek	14	6/05 - 4/07	17	4/04 - 4/07	19	4/03 - 4/07

Notes:
[1] See Figure 5.4.1 for station locations.
[2] Field measurements of temperature, pH, conductivity, and dissolved oxygen, total dissolved solids, turbidity and salinity.
[3] Consists primarily of fecal coli form with some E. coli bacteria.
[4] 2005 data consist of one velocity measurement per station per collection date; no stream depths were reported.
Source: Data provided by South Big Horn Conservation District (SBHCD), Greybull, WY.

As part of this current watershed study, WWDC directed flow measurements of several streams throughout the Shell Creek watershed, including five stations on Shell Creek, three sites on Beaver Creek, and one site each for Horse Creek, Red Canyon Creek, Red Gulch, Sheldon Gulch, Scharen Gulch, Trapper Creek, White Creek, Granite Creek, and Willett Creek. Some of these sites have been monitored by the USGS and/or SBHCD. Table 5.4.4.4 summarizes the monitoring schedule completed for this WWDC study in 2006-2007. Monitoring included instantaneous flow measurements on a seasonal basis.

TABLE 5.4.4.4
Monitoring Schedule for WWDC Supplemental Surface Water Stations
Shell Creek Watershed

Station No. & Stream Name[1]	Instantaneous Discharge	
	No. of Measurements	Period of Record
Supplemental Sites Not Monitored by Others		
BC-1 Beaver Creek	2	Jul-Sep-06
BC-3 Beaver Creek	4	Jun-Jul-Sep-06; Jun-07
HC-1 Horse Creek	4	Jun-Jul-Sep-06; Jun-07
RG-1 Red Gulch	3	Jul-Sep-06; Jun-07
RCC-1 Red Canyon Creek	4	Jun-Jul-Sep-06; Jun-07
SHG-1 Sheldon Gulch	3	Jul-Sep-06; Jun-07
SCG-1 Scharen Gulch	3	Jul-Sep-06; Jun-07
SC-100 Shell Creek	4	Jun-Jul-Sep-06; Jun-07
SC-101 Shell Creek	2	Jul-Sep-06
TC-1 Trapper Creek	4	Jun-Jul-Sep-06; Jun-07
WC-1 Willett Creek	3	Jun-Jul-Sep-06
WHC-1 White Creek	1	Jul-06
Sites Monitored by WWDC and SBHCD or USGS[2]		
BC-5 Beaver Creek	4	Jun-Jul-Sep-06; Jun-07
GC-1 Granite Creek (same as USGS 6278400)	3	Jul-Sep-06; Jun-07
SC-2 Shell Creek	1	Sep-06
SC-5 Shell Creek	3	Jul-Sep-06; Jun-2007
SC-8 Shell Creek	1	Jun-07

Notes:
USGS = U.S. Geological Survey.
[1] See Figure D for station locations.
[2] WWDC = Wyoming Water Development Commission; SBHCD = South Big Horn Conservation District;
Source: Data obtained by Geomatrix Consultants, Helena, MT for the WWDC.

5.4.5 SURFACE WATER FLOW

Flow has been measured in several streams throughout the Shell Creek watershed by the USGS, SBHCD, and WWDC. Most measurements have been made on the main channel of Shell Creek, extending for over 40 stream miles from the town of Greybull to high elevations in the Big Horn Mountains above Shell Reservoir. Beaver Creek is the next most frequently measured stream in the watershed. Major irrigation diversion canals are located on both of these streams which affect flow during and for some time after the irrigation season.

The USGS currently maintains two continuous gauging stations on Shell Creek: no. 6278300 located just upstream from the Shell Reservoir; and no. 6278500 located approximately 3 miles upstream from the town of Shell (Figure 5.4.1). The USGS began monitoring at station no. 6278500 and station no. 6278300 in 1940 and 1956, respectively in Table 5.4.4.2. The USGS also monitored flows at station no. 6279090 (near Greybull town) from 1965 to 1986, and station no. 6279050 (at Porter Gulch) from 1983 to 1990 (See Table 5.4.4.2. and Figure 5.4.1).

Flow information for the two Shell Creek stations currently being monitored by the USGS is included in Appendix E. These results show that the mean annual flow for the upper Shell Creek station (above Shell Reservoir) is 33.2 cfs for the period 1957-2006, with highest and lowest mean annual flows of 50.2 cfs (1968) and 17.9 cfs (2001), respectively. Highest and lowest mean daily flows were 1,010 cfs (June 15, 1963) and 0.60 cfs (March 7, 1967), respectively, for this station. For the lower Shell Creek station (near town of Shell), mean annual flow is 119 cfs for the period 1941-2005, and the highest and lowest mean annual flows are 160 cfs (1968) and 77.3 cfs (1966), respectively. Highest and lowest mean daily flows for lower Shell Creek were 1,980 cfs (June 4, 1968) and 13 cfs (April 10, 1989), respectively.

Also included in Appendix E are hydrographs for the two Shell Creek stations discussed above (above Shell Reservoir; and near town of Shell) that show average daily flow for the period of record (POR). Also shown on these hydrographs are average daily flows for 1968 (representing a year with high flows), and for 1966 (representing a year with low flows). These graphs show that the greatest variability in flow occurs during the period of about May through July. During the other months, flows are relatively similar between the three conditions presented.

Appendix E includes a figure showing hydrographs for Shell Creek station no. 6278500 (upstream from irrigation diversion canals near town of Shell) and station no. 6279090 (near mouth of stream at Greybull town) for the period 1965 through 1970. By comparing these two hydrographs, it is shown that during the peak spring flow period, the lower station has higher flows, but that the upper station is close to the peak flow. Immediately after the peak flow reaches a low base-flow condition, the lower station flow becomes less than the upper station flow (early period of irrigation withdrawals). After about another month, however, the lower station flow becomes higher than the upper station flow, indicating return flow reaching Shell Creek from irrigation. This is also demonstrated on another figure included in Appendix E that graphically shows the ratio between the downstream (no. 627090) and upstream (no. 6278500) stations.

Flow measurements by SBHCD for five Shell Creek stations and three Beaver Creek stations from April 2004 through April 2007 are summarized in Table 5.4.5.1 on page 38. These data show that Beaver Creek usually gains in flow from the uppermost station (BC-4) to the middle station (BC-2), but then often loses flow down to the lowermost station (BC-5) due to natural seepage losses to alluvium in the lower basin and/or to irrigation withdrawals. Flow rates measured at the Beaver Creek stations ranged from 0.2 to 60.9 cfs.

The uppermost of the five Shell Creek stations (SC-7) measured by SBHCD is located between the confluences of Horse and Beaver creeks, approximately 1.5 miles downstream from the town of Shell. This station had flow rates ranging from 1.6 to 216 cfs. The lowermost Shell Creek station (SC-2) had measured flows ranging from 3.5 to 129 cfs. During the non-irrigation season, flows typically increase from upper to lower stations. Water withdrawals and return flows during the irrigation season, however, result in variable flows among the five Shell Creek stations monitored by SBHCD.

Stream flow measurements conducted in 2006-2007 as part of this study for the WWDC are summarized in Table 5.4.5.2 on page 39**.** These measurements were made in June, July, and/or September 2006, and in June 2007 on Shell Creek, Beaver Creek, and other tributaries of Shell Creek. Calculation sheets are presented in Appendix F. These data show that flows in Shell Creek and Beaver Creek ranged from 7 to 137 cfs and from 0.9 to 24 cfs, respectively. Flows in the other tributary channels ranged from no flow to 20 cfs, with the exception of Willett Creek which had a high flow measurement of 43 cfs. June 2007 flows generally were higher than June 2006 flows.

Peak flows were calculated by the USGS for Shell Creek stations no. 6278300 (above Shell Reservoir) and no. 6278500 (3 miles upstream of Shell town), one site on Granite Creek (no. 6278400), and one site on Red Gulch (no. 6279020). Results of these peak flow calculations for several storm return periods are presented in Table 5.4.5.3 on page 40. This table also includes other information for these four sites: drainage area, mean elevation, mean basin slope, mean annual precipitation, soil permeability, and soil hydrologic index.

TABLE 5.4.5.1 Stream Flow for SBHCD Measurements (2004-2007) Shell Creek Watershed								
Date	**Flow Measurements (cfs) by SBHCD[1]**							
	Beaver Creek Stations			**Shell Creek Stations**				
	BC-4	**BC-2**	**BC-5**	**SC-7**	**SC-5**	**SC-6**	**SC-8**	**SC-2**
04/8/04 [2]	NM	NM	0.7	11.1	11.8	48.1	17.6	37.6
06/21/04 [2]	1.4	2.9	0.45	1.6	37.7	36.7	85.9	27.8
06/15/05 [3]	33.1	60.9	23.7	106	NM	174	NM	NM
10/12/05 [3]	3.7	7.3	4.4	24.1	19.6	228	NM	NM
09/13/05 [3]	NM	NM	NM	NM	NM	NM	71.6	3.5
05/04/06	NM	NM	NM	NM	NM	NM	NM	8.3
05/10/06	4.8	0.2	0.6	3.8	2.9	7.0	5.1	5.4
05/15/06	17.5	11.5	14.8	64.3	74.8	22.8	122.2	128.9
05/22/06	45.6	NM	NM	101.5	NM	NM	105.5	NM
05/30/06	18.3	25.3	22.8	216.3	NM	NM	NM	NM
08/03/06	3.6	1.6	2.6	22.2	20.5	12.2	21.6	9.3
09/18/06	4.1	4.2	2.4	28.3	38.8	35.4	DD	63.6
09/27/06	4.9	3.1	4.6	7.7	8.9	12.0	28.6	42.7
10/04/06	4.1	11.7	10.1	8.8	8.9	18.1	34.7	43.7
10/13/06	9.3	7.7	8.1	20.9	22.4	25.6	41.2	63.0
10/19/06	8.4	8.4	10.0	11.3	8.3	17.2	39.1	59.3 *
03/27/07	1.7	1.3	1.6	49.6	53.9	DD	58.2	69.5
04/01/07	3.8	4.1	NM	53.6	53.7	DD	67.0	71.4
04/10/07	2.8	3.0	3.3	51.3	49.9	57.9	49.9	54.4

Notes:

[1] See **Figure 5.4.1** for station locations. cfs = cubic feet per second. NM = not measured. DD = data discrepancy.
SBHCD = South Big Horn Conservation District. Table columns are arranged such that upstream-to-downstream is left-to-right. * Measured 10-20-06.

[2] WWC Engineering 2005

[3] Data consisted of one depth and velocity measurement; discharge was calculated assuming these were representative average values.

TABLE 5.4.5.2 Stream Flow for WWDC Measurements (2006-2007) Shell Creek Watershed					
Station ID[1]	Stream Name	Stream Discharge Rate (cubic feet per second) Measured by WWDC[2]			
		June 19-20, 2006	July 25-28, 2006	Sept. 22-23, 2006	June 27-28, 2007
SC-2	Shell Creek - lower	NM	NM	57.45	NM
SC-8	Shell Creek	NM	NM	NM	136.54
SC-6	Shell Creek	NM	NM	NM	NM
SC-5	Shell Creek	NM	7.13	9.95	80.08
SC-7	Shell Creek	NM	NM	NM	NM
SC-100	Shell Creek	41.87	37.60	19.84	130.95
SC-101	Shell Creek - upper	NM	94.00	27.31	NM
BC-5	Beaver Creek - lower	6.90	2.56	6.70	23.53
BC-2	Beaver Creek	NM	NM	NM	NM
BC-4	Beaver Creek	NM	NM	NM	NM
BC-3	Beaver Creek	4.84	1.96	3.74	20.99
BC-1	Beaver Creek - upper	NM	0.86	3.24	NM
RCC-1	Red Canyon Creek	1.51	0.06	0.21	3.23
HC-1	Horse Creek	0.11	0.20	0.01	1.89
SCG-1	Scharen Gulch	NM	2.45	3.61	8.80
SHG-1	Sheldon Gulch	NM	1.26	4.92	19.84
RG-1	Red Gulch	NM	1.80	0.16	2.66
TC-1	Trapper Creek	12.16	8.45	10.31	14.80
WHC-1	White Creek	NM	Dry	NM	NM
GC-1	Granite Creek	NM	4.37	5.45	16.54
WC-1	Willett Creek	43.00	20.40	5.14	NM

Notes:
[1] See **Figure 5.4.1** for station locations.
[2] All flows measured by Geomatrix and/or Westech consulting staff for the Wyoming Water Development Commission (WWDC). NM = not measured.

TABLE 5.4.5.3 Hydrologic Characteristics of Selected Streams with Gaging Stations Shell Creek Watershed				
Parameter[1]	**USGS Surface Water Station and ID Number[2]**			
	Shell Creek above Reservoir – 6278300	**Shell Creek near Shell - 6278500**	**Granite Creek near Highway - 6278400**	**Red Gulch near Highway - 6279020**
Drainage Area (mile²)	23.1	145	11.1	47.8
Mean Elevation (feet)	10,020	8,800	9,040	5,460
Mean Basin Slope (feet/mile)	1,170	1,350	1,020	929
Mean Annual Precipitation (inches)	31.8	28.5	29.8	15.9
2-yr, 24-hr Precipitation (inches)	2.02	2.04	2.24	1.22
Mean Annual Runoff (acre-feet)	24,090	85,900		
Mean Annual Flow (cfs)	33.3	119		
Highest Annual Mean Flow (cfs)	50.2	160		
Lowest Annual Mean Flow (cfs)	17.9	77		
10% of Flows Exceeds (cfs)	91	--		
50% of Flows Exceeds (cfs)	5.7	--		
90% of Flows Exceeds (cfs)	2.0	--		
Mean Soil Permeability (inches/hour)	4.28	2.26	1.62	1.03
Mean Soil Hydrologic Index (no units)	3.14	3.23	3.16	3.19
Period of Record (year)	1957-2008	1941-2004	1961-1974	1967-1981
1.5-year Calculated Peak Flow (cfs)	636	1,190	228	134
2-year Calculated Peak Flow (cfs)	720	1,370	253	232
5-year Calculated Peak Flow (cfs)	932	1,810	313	730
10-year Calculated Peak Flow (cfs)	1,070	2,090	353	1,390
25-year Calculated Peak Flow (cfs)	1,260	2,430	403	2,840
50-year Calculated Peak Flow (cfs)	1,400	2,680	440	4,590
100-year Calculated Peak Flow (cfs)	1,540	2,930	478	7,170
200-year Calculated Peak Flow (cfs)	1,690	3,170	516	10,900
500-year Calculated Peak Flow (cfs)	1,890	3,490	567	18,300

Notes:
[1] cfs = cubic feet per second.
[2] See **Figure 5.4.1** for station locations. USGS – U.S. Geological Survey.
Source: Miller 2003.

Results of the calculations show that Shell Creek above the Shell Reservoir would have peak flows ranging from 636 cfs (1.5-year event) to 1,890 cfs (500-year event). Peak flows for Shell Creek near the town of Shell would increase to 1,190 cfs for the 1.5-year event, to 3,490 cfs for the 500-year event. Calculated peak flows for Granite Creek and Red Gulch would range from 228 and 134 cfs (1.5-year event) to 567 and 18,300 cfs for the 500-year event.

5.4.6 SURFACE WATER QUALITY

In 1996, the Wyoming DEQ began monitoring streams in the Shell Creek watershed for some chemicals, dissolved oxygen, and fecal coliform. Preliminary results showed an exceedance of fecal coliform levels. These non-pathogenic bacteria are found in the feces of humans and warm-blooded animals. Fecal coliform in a water body is an indicator of a water quality problem. Pathogenic organisms are bacteria, viruses, and parasites that cause disease and illness. Pathogenic organisms, along with fecal coliform, together generate Escherichia coli (e. coli) which can cause deadly infections.

In 1996, the Wyoming DEQ published the federally-mandated 303(d) List of Impaired Water Bodies, naming rivers, streams, lakes, and reservoirs that were impaired for one or more reasons. In the Big Horn Basin, fecal coliform was one of the predominant reasons for impairment. In 2002, Shell Creek and Granite Creek were listed as impaired due to fecal coliform which adversely affects contact recreation. Beaver Creek is listed as “threatened” because of fecal coliform measurements. Information about these water quality impairments can be found in Wyoming’s 2006 305(b) State Water Quality Assessment Report and 2006 303(d) List of Waters Requiring TMDLs (Wyoming DEQ 2007b).

Shell Creek and Granite Creek are classified as a Surface Water Class 2AB and are listed on Table A of the Wyoming Surface Water Classification List published by the Wyoming DEQ in June 21, 2001. According to the Wyoming DEQ Water Quality Rules and Regulations, Chapter 1, Section 27. E. coli Bacteria, Shell Creek and Granite Creek are identified as Primary Contact Recreation due to their listing in Table A of the Wyoming Surface Water Classification List.

Total coliform has no specific standard in Wyoming; however fecal coliform concentrations shall not exceed 200 maximum probable number per 100 milliliters (MPN/100 mL) (geometric mean of >4 samples collected during separate 24-hour periods for any 30-day period); nor shall fecal coliform concentrations exceed 400 MPN/100 mL (geometric mean of 3 samples collected within a 24-hour period) in any Wyoming surface water. E. coli human health standard in Wyoming = 126 maximum probably number per 100 milliliters (MPN/100 mL) (geometric mean of >4 samples collected during separate 24-hour periods for any 30-day period). Single sample maximum concentrations range from 235 MPN/100 mL (high use swimming areas) to 576 MPN/100 mL (infrequently used full body contact).

During the summer of 2000, the USGS conducted a synoptic study of Shell Creek (three sites), Granite Creek, Trapper Creek, and Beaver Creek (Clark and Gamper 2003). Samples were collected on the same day (July 18) from all sites for several constituents, including fecal coliform and E. coli. Results of this sampling event, which are summarized in Table 5.4.6.1, established these streams (except Trapper Creek) on the 2002 303(d) List. In 2001, the SBHCD received grants to provide for continued monitoring of Shell and Beaver creeks, including funding for field equipment, water testing, education seminars, reporting, and distribution of information to the public.

TABLE 5.4.6.1 Synoptic Water Quality Data from USGS (July 2000) Shell Valley Watershed						
Parameter[1]	Water Quality at Designated Stream Site[2] (Samples collected by USGS)[2]					
	Upper Shell Creek (SC-101)	Shell Creek Near Shell (USGS 6278500)	Shell Creek Near Greybull (USGS 6279090)	Granite Creek (USGS 6278400)	Trapper Creek Near Mouth	Beaver Creek Near Mouth (BC-5)
Sample Date	7-18-2000	7-18-2000	7-18-2000	7-18-2000	7-18-2000	7-18-2000
Sample Time (hour)	0845	1540	1430	1000	10000	1145
Flow (cfs)	90	113	27	11	8.1	14
Turbidity (NTU)	1.6	6.3	18	9.7	2.7	6.7
TSS (mg/L)	4	7	80	13	96	33
Water Temp. (^oC)	9.5	15.0	24.5	10.0	12.5	20.0
Barometric Pressure (mm of mercury)	580	655	667	589	652	655
pH (std. units)	7.4	8.4	8.4	8.4	8.0	8.2
Diss. Oxygen (mg/L)	8.4	9.5	8.1	7.8	9.1	7.7
SC (µS/cm)	35	188	1,540	241	646	659
Alkalinity (mg/L)	19	75	217	120	219	180
Bicarbonate (mg/L)	23	92	253	147	268	219
Fecal Coliform[3] (col/100 mL)	130	93	630	1,600	170	680
E. coli[4] (col/100 mL)	100	74	600	1,200	170	400

Notes: [1] cfs = cubic feet per second; NTU = nephelometric turbidity units; TSS = total suspended solids; mg/L = milligrams per liter; ^oC = degrees Celsius; mm = millimeters; µS/cm = microSiemens per centimeter; col = colonies; mL = milliliter. [2] See Figure 5.4.1 for station locations. USGS – U.S. Geological Survey. [3] Fecal coliform concentrations shall not exceed 200 MPN/100 mL (geometric mean of >4 samples collected during separate 24-hour periods for any 30-day period); nor shall fecal coliform concentrations exceed 400 MPN/100 mL (geometric mean of 3 samples collected within a 24-hour period) in any Wyoming surface water. [4] E. coli human health standard in Wyoming = 126 MPN/100 mL (geometric mean of >4 samples collected during separate 24-hour periods for any 30-day period). Single sample maximum concentrations range from 235 MPN/100 mL (high use swimming areas) to 576 MPN/100 mL (infrequently used full body contact). Source: Clark and Gamper 2003.

The USGS has been collecting and analyzing water samples in the Shell Creek watershed since 1951. Results of these samples, collected from Shell and Granite creeks, are presented in Appendix G

The following sections summarize water quality information for streams in the Shell Creek watershed.

5.4.6.1 SHELL CREEK

On July 18, 2000, the USGS (Clark and Gamper 2003) collected water samples on a single day from Shell Creek at three locations: upper Shell Creek at SC-101; middle Shell Creek near town of Shell (USGS station no. 6278500); and lower Shell Creek near the town of Greybull (SC-2 and USGS station 627090). Results of these samples are included in Table 5.4.6.1.1. On that day, flow at the upper, middle, and lower sites was 90, 113, and 27 cfs. Turbidity increased downstream, going from 1.6 to 6.3 to 18 nephelometric turbidity units (NTU), and total suspended solids went from 4 to 7 to 80 milligrams per liter (mg/L) at the upper, middle, and lower stations, respectively. Water temperature increased downstream, ranged from 9.5 degrees Celsius (^{o}C) at the upper site, to 15 ^{o}C at the middle site, to 24.5 ^{o}C at the lower site.

Also from the July 2000 USGS samples, pH remained relatively constant between 7.4 and 8.4 standard units (su), and dissolved oxygen ranged from 8.1 to 9.5 mg/L. Specific conductance (SC) increased significant downstream, starting at 35 microSiemens per centimeter (µS/cm), increasing to 188 µS/cm at the middle station, and finally at 1,540 µS/cm for the lower station. Alkalinity and bicarbonate concentrations also increased downstream.

In May 2001, the SBHCD collected water samples from Shell Creek at SC-2 (lower site near town of Greybull) and SC-7 (middle site near town of Shell). These samples were analyzed for general parameters, ions, and nutrients and shown in Table 5.4.6.1.1. A sample was also collected in September 2001 at Shell Creek station SC-2. Results of selected parameters for SC-2 and SC-7 are as follows, all of which show that there was a significant increase in concentrations from upstream to downstream locations:

TABLE 5.4.6.1.1

Shell Creek General Water Chemistry Data from SBHCD (2001) – Shell Creek Watershed

Date & Site	Ca	Mg	Na	K	TDS	TSS	pH	SC	Turb.	Carb.	F	Cl	$N0_3$	NO_2	O-P	SO_4	T-P	Hard.	Alk.
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	s.u.	µmhos/cm	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Shell Creek Station SC-7 (near town of Shell)																			
5/2/01	21	6.7	2.6	1.1	96	7	8.1	160	6.4	0	<0.1	<1.0	0.1	<0.1	<0.1	4.6	0.04	230	76
5/9/01	19	6	1.4	1.3	88*	18.2*	8.2	150	14.4	0	<0.1	<1.0	<0.1	<0.1	<0.1	4.1	0.08	77	69
5/16/01	9.8	2.4	<1	1	44*	15*	7.9	66	13.4	0	<0.1	<1.0	<0.1	<0.1	<0.1	1.8	0.05	34	30
5/22/01	17	5.2	2.9	<1	72*	2.8*	8.1	130	2.2	0	<0.1	<1.0	<0.1	<0.1	<0.1	3.7	0.05	64	62
5/30/01	9.7	2.9	2.2	<1	96	2.9	8.0	90	1.5	0	<0.1	<1.0	<0.1	<0.1	<0.1	2.5	<0.02	36	40
Ave.	**15.3**	**4.64**	**2.3**	**1.1**	**96**	**5.0**	**8.1**	**119**	**7.6**	**0**	**---**	**---**	**0.1**	**---**	**---**	**3.3**	**0.06**	**88**	**55**
Shell Creek Station SC-2 (at mouth near town of Greybull)																			
5/2/01	61	18	32	1.7	364	92	8.2	550	624	150	0.2	1.8	0.2	<0.1	<0.1	150	0.09	80	120
5/9/01	110	45	130	3.1	968*	9.5*	8.5	1,300	8.4	180	0.3	4.3	<0.1	<0.1	<0.1	540	0.02	460	170
5/16/01	34	7	10	1.2	168*	220	8.1	260	192	84	<0.1	<1.0	0.2	<0.1	<0.1	58	0.23	150	69
5/22/01	120	40	110	4.2	924*	34*	8.3	1,300	25	230	0.3	3.9	0.5	<0.1	<0.1	490	0.19	460	190
5/30/01	84	25	59	2.5	656	232	8.4	850	14	170	0.2	2.3	0.1	<0.1	<0.1	260	0.11	310	150
Ave.	**82**	**27**	**68**	**2.5**	**510**	**181**	**8.3**	**852**	**173**	**163**	**0.25**	**3.1**	**0.25**	**---**	**---**	**300**	**0.13**	**292**	**140**
Shell Creek Station SC-2 (at mouth near town of Greybull)																			
9/13/01	190	54	120	4	1,310	130	8.4	1,630	8	290	0.5	4.6	0.4	<0.1	<0.1	540	0.14	---	250

Notes: 1. SBHCD – South Big Horn Conservation District. See Figure 5.4.1 for station locations. 2. Ca – calcium; Mg – magnesium; Na – sodium; K – potassium; TDS – total dissolved solids; TSS – total suspended solids; SC – specific conductance; Turb. turbidity; Carb. – carbonate; F – fluoride; Cl – chloride; NO_3 – nitrate; NO_2 – nitrite; O-P – orthophosphate; SO_4 – sulfate; T-P – total phosphorus; Hard. – hardness; Alk. – alkalinity. 3. mg/L – milligrams per liter; s.u. – standard units; µmhos/cm – micromhos per centimeter; NTU – nephelometric turbidity units. * - value considered anomalous or unreliable and not used to calculate average. Source data sheet for station SC-7 listed the site as SC-1; it is assumed that this is close to a site farther upstream (SC-7) based on the chemistry results.
Source: SBHCD 2007b.

The SBHCD (2007b) measured field parameters at five Shell Creek locations from 2004 through 2007. These parameters consist of water temperature, pH, SC, total dissolved solids (TDS), dissolved oxygen (DO), and turbidity. Results of these samples are summarized in Table 5.4.6.1.2. These values also confirm that concentrations of most constituents increase from upstream to downstream locations.

TABLE 5.4.6.1.2

Shell Creek Field Parameters from SBHCD (2004-2007)

Shell Creek Watershed

Date	Field Measurements by SBHCD along Beaver Creek[1]					
	Temperature (°F)	pH (s.u.)	SC (µS/cm)	TDS (mg/l)	DO (mg/l)	Turbidity (NTU)
Shell Creek at SC-2 (lowest site near town of Greybull)						
4-8-04	75.2	7.80	3,923	2,550	7.17	NM
6-29-04	83.7	8.17	134	87	5.99	NM
9-13-05	53.2	NM	1,449	942	11.53	7
5-4-06	51.8	8.13	1,581	1,027	11.44	<0.01
5-10-06	53.7	7.84	1,926	1,252	11.14	100
5-15-06	63.6	7.61	628	413	8.63	100
5-22-06	52.7	6.16	429	278	9.31	20
5-30-06	60.9	7.66	613	398	8.54	<1000
8-3-06	77.7	8.16	1,482	963	8.56	23
9-18-06	54.5	7.54	1,249	811	9.94	923
9-27-06	54.4	7.90	1,433	932	10.47	107
10-4-06	53.8	8.13	1,450	943	14.62	15
10-13-06	51.5	8.11	1,292	839	12.39	29
10-20-06	47.8	8.43	1,204	865	14.71	9
3-27-07	54.5	8.30	846	550	2.57	16
4-1-07	48.2	8.14	810	526	1.03	46
4-10-07	46.9	8.02	858	552	11.23	12
Shell Creek at SC-8 (next lowest site near Porter Gulch bridge)						
4-8-04	67.6	NM	679	441	7.96	NM
6-29-04	91.6	7.99	129	84	5.66	NM
9-13-05	51.4	8.11	1,452	945	11.56	8
5-4-06	48.2	8.13	1,366	888	10.8	<0.01
5-10-06	51.9	7.94	1,293	841	12.62	<0.01
5-15-06	61.7	7.63	258	170	9.53	500
5-22-06	49.3	7.42	184	120	9.72	100
5-30-06	51.3	7.44	372	242	9.20	20
8-3-06	74.8	8.05	1,376	894	10.23	11
9-18-06	55.5	7.39	1,141	741	9.84	654
9-27-06	53.2	7.87	1,326	861	10.61	56
10-4-06	53.5	7.84	1,294	841	13.43	15
10-13-06	49.0	7.90	1,215	789	13.68	15
10-19-06	49.6	8.05	1,268	825	11.61	11
3-27-07	53.4	8.22	657	427	4.96	11
4-1-07	48.2	8.06	659	428	1.31	7
4-10-07	44.2	8.00	1,642	1,076	10.87	74
Shell Creek at SC-6 (downstream of Beaver Creek confluence)						
4-8-04	59.9	8.02	4,114	2,674	8.38	NM
6-21-04	70.0	8.49	4,437	2,884	5.78	NM
6-15-05	84.0	6.85	NM	NM	5.68	68
10-12-05	48.7	8.12	623	404	11.45	6
5-2-06	54.3	8.37	611	397	11.35	20
5-10-06	47.7	8.03	725	471	12.24	20
5-15-06	57.2	8.21	276	180	10.61	100
8-3-06	73.4	8.51	864	502	12.30	12
9-18-06	52.8	7.92	651	420	11.05	112
9-27-06	53.0	7.78	1,041	665	10.14	114

TABLE 5.4.6.1.2 Shell Creek Field Parameters from SBHCD (2004-2007) Shell Creek Watershed						
Date	Field Measurements by SBHCD along Beaver Creek[1]					
	Temperature (°F)	pH (s.u.)	SC (µS/cm)	TDS (mg/l)	DO (mg/l)	Turbidity (NTU)
10-4-06	50.6	7.79	858	565	12.03	38
10-13-06	46.4	7.77	930	621	12.60	31
10-19-06	47.9	7.92	1,033	681	12.04	21
3-27-07	48.4	8.16	469	303	2.56	6
4-1-07	45.1	8.04	484	310	1.94	3
4-10-07	43.9	7.70	479	311	11.23	4
Shell Creek at SC-5 (upstream of Beaver Creek confluence)						
4-8-04	61.2	7.73	NM	NM	7.79	NM
6-21-04	81.0	8.41	886	576	5.09	NM
10-12-05	48.7	8.05	621	404	11.25	NM
5-2-06	53.5	8.26	637	410	11.56	20
5-10-06	46.4	7.86	767	494	11.52	20
5-15-06	54.2	7.59	262	170	10.95	20
8-3-06	74.6	8.59	603	392	13.33	7
9-18-06	51.0	7.77	592	385	11.33	38
9-27-06	53.1	7.72	814	528	10.06	12
10-4-06	50.5	7.72	760	493	12.28	10
10-13-06	46.5	7.85	631	410	12.46	4
10-19-06	50.6	7.87	776	504	11.93	6
3-27-07	47.8	8.14	462	299	1.88	5
4-1-07	45.5	8.05	458	297	1.73	4
4-10-07	43.7	7.58	477	310	11.23	4
Shell Creek at SC-7 (below town of Shell)						
4-8-04	62.6	NM	636	NM	6.31	NM
6-21-04	63.3	NM	NM	NM	6.93	NM
6-15-05	86.7	4.34	NM	NM	5.78	7
10-12-05	46.2	8.15	478	310	11.06	4
5-2-06	45.4	8.51	432	280	10.82	<0.1
5-10-06	44.5	8.12	502	326	10.36	<0.01
5-15-06	46.8	7.40	205	133	11.16	20
5-22-06	44.5	8.45	102	66	11.49	20
5-30-06	45.3	5.86	195	126	11.22	<0.1
8-3-06	65.0	8.15	352	229	11.01	1
9-18-06	47.8	8.31	445	288	10.43	17
9-27-06	62.9	7.60	480	312	9.24	7
10-4-06	48.6	7.53	452	295	10.73	4
10-13-06	43.3	7.92	432	281	11.45	3
10-19-06	46.9	7.89	554	361	12.45	2
3-27-07	44.4	7.90	424	276	2.68	5
4-1-07	43.7	7.99	425	275	1.91	3
4-10-07	40.5	7.80	432	281	10.95	3

Notes:

[1] See Figure 5.4.1 for station locations. NM = not measured. SBHCD – South Big Horn Conservation District. °F = degrees Fahrenheit; s.u. = standard units; SC = specific conductance; µS/cm = microSiemens per centimeter; TDS = total dissolved solids; mg/l = milligrams per liter; NTU = nephelometric turbidity units. Source: SBHCD 2007b. WWC Engineering 2005.

The Wyoming DEQ also measured some field parameters (pH, SC, DO, temperature, and turbidity) on a nearly daily basis from July 9 through July 18, 2001 at lower Shell Creek near Greybull. These results are summarized in Table 5.4.6.1.3. During this time-span, turbidity started at 71.5 NTU on July 9, and gradually decreased to 9.4 NTU on July 18. The following ranges in parameter concentrations were measured:

- pH = 7.85 to 8.27 su
- SC = 1,185 to 1,956 µS/cm
- DO = 7.59 to 10.03 mg/L
- Turbidity = 9.4 to 71.5 NTU
- Temperature = 20.4 to 27.4 ^{o}C

TABLE 5.4.6.1.3
Shell Creek Microbiological Data and Field Parameters from WDEQ (2001)
Shell Creek Watershed

Parameter[1]	Measurement by WDEQ for Shell Creek at Greybull in 2001 [2]					Geometric Mean
	July 9	July 10	July 11	July 12	July 18	
Fecal Coliform Bacteria (CFU/100 ml)	1,160	320 & 650	440	440	240	444
pH (s.u.)	8.27	8.17	8.16	8.25	7.85	NR
SC (µS/cm)	1,185	1,381	1,496	1,521	1,956	NR
DO (mg/l)	7.59	9.56	9.75	10.03	NR	NR
Temp. (^{o}C)	23.1	26.9	26.8	27.4	20.4	NR
Turbidity (NTU)	71.5	20.16	20.13	14.5	9.4	NR

Notes: [1] CFU = colony forming units; ml = milliliters; s.u. = standard units; µS/cm = microSiemens per centimeter; mg/l = milligrams per liter; ^{o}C = degrees Celsius; NTU = nephelometric turbidity units. [2] WDEQ = Wyoming Department of Environmental Quality (2001) –Water Quality Division. NR – not reported.

For the microbiological parameters in the July 2000 USGS samples (See Table 5.4.6.1.), both fecal coliform and E. coli bacteria decreased from the upper to middle stations, and then increased down to the lower station. Fecal coliform went from 130 to 93 to 630 MPN/100 mL, and E. coli went from 100 to 74 to 600 MPN/100 mL.

Microbiological parameters consisting of fecal coliform, total coliform, and E. coli bacteria were measured in Shell Creek by the Wyoming DEQ in 2001 (see Table 5.4.6.1.3) and by the SBHCD in 2002-2007 Shown in Table 5.4.6.1.4. Results of samples collected in Shell Creek in 2001 show that fecal coliform ranged from 240 to 1,160 MPN/100 mL, with a geometric mean of 444 MPN/100 mL (see Table 5.4.6.1.3). Samples collected by SBHCD in 2002-2007 show a wide range in values for the microbiological parameters (see Table 5.4.6.1.4). Samples collected in April 2007 show relatively low values for total coliform and E. coli.

TABLE 5.4.6.1.4

Shell Creek Microbiological Data from SBHCD (2002-2007) – Shell Creek Watershed

Date	Shell Creek Monitoring Stations[1]													
	SC-2		SC-3		SC-4		SC-5		SC-6		SC-7		SC-8	
	Fecal Coliform[2]	E. coli[3]	Fecal Coliform[2]	E. coli[3]	Fecal Coliform[2]	E. coli[3]	Fecal Coliform[2]	E. coli[3]	Fecal Coliform[2]	E. coli[3]	Fecal Coliform[2]	E. coli[3]	Fecal Coliform[2]	E. coli[3]
5-28-02	NA	650	NA	240	NA	20	NA	7	NA	NA	NA	<7	NA	NA
6-7-02	NA	3,200	NA	145	NA	18	NA	9	NA	NA	NA	<9	NA	NA
7-10-02	340	NA	210	NA	36	NA	64	NA	NA	NA	<1	NA	NA	NA
8-6-02	130	140	520	550	NA	NA	NA	NA	560	490	NA	NA	NA	NA
8-13-02	NA	250	NA	510	NA	NA	NA	NA	NA	400	NA	NA	NA	NA
8-20-02	NA	470	NA	240	NA	NA	NA	NA	NA	270	NA	NA	NA	NA
8-27-02	NA	73	NA	380	NA	NA	NA	NA	NA	350	NA	NA	NA	NA
9-5-02	NA	200	NA	55	NA	NA	NA	NA	NA	140	NA	NA	NA	NA
10-1-02	NA	88	NA	96	NA	NA	NA	NA	NA	180	NA	NA	NA	NA
11-7-02	NA	120	NA	9	NA	NA	NA	NA	NA	40	NA	NA	NA	NA
4-8-03	NA	300	NA	NA	NA	NA	NA	270	NA	240	NA	150	NA	270
6-2-03	NA	NA	NA	NA	NA	NA	NA	210	NA	250	NA	160	NA	NA
6-4-03	NA	450	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	210
4-8-04	NA	210	NA	NA	NA	NA	NA	330	NA	210	NA	1,000	NA	NA
6-21-04	NA	NA	NA	NA	NA	NA	NA	78	NA	69	NA	96	NA	NA
6-29-04	NA	138	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	138
Date	Total Coliform[2]	E. coli[3]	Total Coliform[2]	E. coli[3]	Total Coliform[2]	E. coli[3]	Total Coliform[2]	E. coli[3]	Total Coliform[2]	E. coli[3]	Total Coliform[2]	E. coli[3]	Total Coliform[2]	E. coli[3]
6-15-05	NA	NA	NA	NA	NA	NA	NA	NA	410	1,120	816	86	NA	NA
9-13-05	>2,420	261	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	>2,420	159
10-12-05	NA	NA	NA	NA	NA	NA	866	172	1,203	146	613	57	NA	NA
5-2-06	727	141	NA	NA	NA	NA	>2,420	141	>2,420	136	387	53	980	146
5-10-06	>2,420	214	NA	NA	NA	NA	>2,420	214	1,986	141	461	64	1,120	146
5-15-06	>2,420	214	NA	NA	NA	NA	>2,420	275	>2,420	727	>2,420	113	1,553	236
5-22-06	NA	NA	NA	NA	NA	NA	>2,420	236	>2,420	236	>2,420	79	>2,420	1,046
5-30-06	>2,420	687	NA	NA	NA	NA	>2,420	228	>2,420	530	>2,420	66	>2,420	579
8-3-06	>2,420	326	NA	NA	NA	NA	>2,420	194	>2,420	816	727	43	>2,420	579
9-18-06	>2,420	159	NA	NA	NA	NA	>2,420	365	>2,420	345	1,120	365	>2,420	>2,420
9-27-06	>2,420	435	NA	NA	NA	NA	>2,420	>2,420	>2,420	1,732	921	99	>2,420	816
10-4-06	>2,420	365	NA	NA	NA	NA	>2,420	921	>2,420	770	>2,420	125	>2,420	1,300
10-13-06	>2,420	238	NA	NA	NA	NA	1,046	146	>2,420	291	579	54	>2,420	579
10-19-06	>2,420	276	NA	NA	NA	NA	>2,420	921	>2,420	579	579	35	>2,420	488
4-10-07	260	49	NA	NA	NA	NA	81	20	158	46	144	44	201	23

Notes: [1] SBHCD = South Big Horn Conservation District. NA = not analyzed. See **Figure 5.4.1** for station locations. [2] Total coliform has no specific standard in Wyoming; however fecal coliform concentrations shall not exceed 200 maximum probable number per 100 milliliters (MPN/100 mL) (geometric mean of >4 samples collected during separate 24-hour periods for any 30-day period); nor shall fecal coliform concentrations exceed 400 MPN/100 mL (geometric mean of 3 samples collected within a 24-hour period) in any Wyoming surface water. [3] E. coli human health standard in Wyoming = 126 maximum probably number per 100 milliliters (MPN/100 mL) (geometric mean of >4 samples collected during separate 24-hour periods for any 30-day period). Single sample maximum concentrations range from 235 MPN/100 mL (high use swimming areas) to 576 MPN/100 mL (infrequently used full body contact). Source: Mercer 2006. WWC Engineering 2005.

5.4.6.2 BEAVER CREEK

The SBHCD (2007b) measured field parameters at three Beaver Creek locations (BC-2, BC-4, and BC-5; Figure 5.4.1) from 2004 through 2007. These parameters consist of water temperature, pH, SC, total dissolved solids (TDS), dissolved oxygen (DO), and turbidity. Results of these samples show that concentrations of most constituents are within similar ranges for the three sites located within an overall reach length of about 3 miles along lower Beaver Creek (in Table 5.4.6.2.1). Turbidity values range from <0.1 to 1,000 NTU.

TABLE 5.4.6.2.1
Beaver Creek Field Parameters from SBHCD (2004-2007)
Shell Creek Watershed

Date	Field Measurements by SBHCD along Beaver Creek[1]					
	Temperature (°F)	pH (s.u.)	SC (µS/cm)	TDS (mg/l)	DO (mg/l)	Turbidity (NTU)
Beaver Creek at BC-5 (lowest station near mouth of stream)						
4-8-04	70.0	9.25	665	432	7.37	NM
6-21-04	62.4	7.81	1,287	837	6.35	NM
6-15-05	90.3	6.81	NM	NM	5.24	70
10-12-05	48.2	7.85	2,003	1,302	10.90	NM
5-2-06	54.5	8.28	1,045	679	12.59	20
5-10-06	47.6	7.74	1,380	896	12.15	20
5-15-06	58.2	7.60	749	487	8.75	800
5-22-06	50.9	7.32	309	201	9.52	1,000
5-30-06	51.5	6.12	732	476	9.33	100
8-3-06	68.9	8.11	1,432	929	10.14	14
9-18-06	49.9	7.48	1,567	1,017	10.01	434
9-27-06	52.7	7.92	1,342	871	9.68	172
10-4-06	50.3	7.89	1,189	772	11.05	86
10-13-06	45.7	7.81	1,368	887	11.83	81
10-19-06	45.3	8.01	1,290	839	12.11	45
3-27-07	49.8	7.96	1,879	1,222	2.58	18
4-1-07	46.4	8.17	1,399	910	1.85	14
4-10-07	44.2	8.00	1,642	1,076	10.87	74
Beaver Creek at BC-2 (1 mile upstream from mouth)						
4-8-04	63.9	8.35	588	382	7.93	NM
6-21-04	77.5	8.81	8,170	5,310	5.35	NM
6-15-05	74.1	7.10	NM	NM	6.57	71
10-12-05	48.0	7.81	2,441	1,588	10.85	NM
5-2-06	50.9	7.83	1,044	679	11.15	<0.01
5-10-06	45.3	7.56	1,839	1,195	10.88	<0.1
5-15-06	55.2	7.23	790	513	9.19	800
5-22-06	49.7	7.55	313	203	9.80	1,000
5-30-06	50.1	5.98	774	503	9.81	20
8-3-06	71.3	7.94	2,185	1,421	13.43	6
9-18-06	49.4	7.26	1,706	1,109	10.02	422
9-27-06	52.6	7.65	1,540	1,002	9.53	123
10-4-06	48.9	7.87	537	346	10.96	84
10-13-06	45.0	7.65	1,386	901	12.28	88
10-19-06	45.0	7.75	1,316	853	12.92	39
3-27-07	48.9	7.79	2,054	1,335	2.53	12
4-1-07	46.0	8.00	1,412	920	1.65	9
4-10-07	43.9	7.90	1,756	1,137	11.94	8
Beaver Creek at BC-4 (3 miles upstream from mouth)						
4-8-04	63.1	8.18	4,782	3,108	8.04	NM
6-21-04	75.9	7.97	1,333	866	5.71	NM

TABLE 5.4.6.2.1
Beaver Creek Field Parameters from SBHCD (2004-2007)
Shell Creek Watershed

Date	Field Measurements by SBHCD along Beaver Creek[1]					
	Temperature (°F)	pH (s.u.)	SC (µS/cm)	TDS (mg/l)	DO (mg/l)	Turbidity (NTU)
6-15-05	75.4	5.23	NM	NM	6.26	45
10-12-05	47.4	7.65	1,863	1,211	10.47	NM
5-2-06	50.4	8.19	943	613	95.80	<20
5-10-06	43.4	7.77	1,252	814	11.75	<0.1
5-15-06	51.6	7.36	554	360	9.94	1,000
5-22-06	48.8	7.75	317	207	10.31	800
5-30-06	47.8	5.90	686	446	10.46	20
8-3-06	72.2	8.13	1,678	1,094	9.65	8
9-18-06	48.3	7.53	1,691	1,100	10.57	659
9-27-06	53.0	7.51	1,781	1,161	9.90	334
10-4-06	48.9	7.80	1,556	1,011	11.21	227
10-13-06	43.7	7.68	1,213	786	12.04	78
10-19-06	45.8	7.76	1,128	733	11.94	34
3-24-07	47.1	7.81	1,851	1,205	2,27	11
4-1-07	46.8	8.00	1,231	799	1.51	6
4-10-07	42.6	7.95	1,554	1,007	11.06	4

Notes: [1] See Figure 5.4.1 for station locations. NM = not measured. SBHCD – South Big Horn Conservation District. °F = degrees Fahrenheit; s.u. = standard units; SC = specific conductance; µS/cm = microSiemens per centimeter; TDS = total dissolved solids; mg/l = milligrams per liter; NTU = nephelometric turbidity units.
Source: SBHCD 2007b. WWC Engineering 2005.

Microbiological parameters consisting of fecal coliform, total coliform, and E. coli bacteria were measured in Beaver Creek by the SBHCD in 2002-2007 (in Table 5.4.6.2.2). Results of these samples show a wide range in values for the microbiological parameters, ranging from 9 to 3,300 MPN/100 mL for E. coli, 45 to 400 MPN/100 mL for fecal coliform, and 141 to >2,420 MPN/100 mL for total coliform (see Table 5.4.6.2.2).

TABLE 5.4.6.2.2
Beaver Creek Microbiological Data from SBHCD (2002-2007)
Shell Creek Watershed

Date	Microbiological Data for SBHCD Beaver Creek Monitoring Stations[1] (Maximum Probable Number (MPN) per 100 ml)							
	BC-2		BC-3		BC-4		BC-5	
	Fecal Coliform[2]	E. coli[3]	Fecal Coliform[2]	E. coli[3]	Fecal Coliform[2]	E. coli[3]	Fecal Coliform[2]	E. coli[3]
5/28/02	NA	3,300	NA	140	NA	3,200	NA	350
6/7/02	NA	1,700	NA	82	NA	2,100	NA	445
7/10/02	140	NA	45	NA	73	NA	400	NA
7/24/02	NA	NA	NA	NA	NA	NA	NA	NA
7/25/02	NA	NA	NA	NA	160	140	NA	NA
8/6/02	120	120	NA	NA	150	160	310	290
8/13/02	NA	220	NA	NA	NA	160	NA	230
8/20/02	NA	18	NA	NA	NA	100	NA	9
8/27/02	NA	73	NA	NA	NA	410	NA	330
9/5/02	NA	140	NA	NA	NA	230	NA	230
10/1/02	NA	190	NA	NA	NA	54	NA	520
11/7/02	NA	84	NA	NA	NA	1,400	NA	51
4/8/03	NA	100	NA	NA	NA	20	NA	140
6/2/03	NA	290	NA	NA	NA	210	NA	240
4/8/04	NA	28	NA	NA	NA	73	NA	140
6/21/04	NA	65	NA	NA	NA	71	NA	96
Date	**Total Coliform[2]**	**E. coli[3]**	**Total Coliform[2]**	**E. coli[3]**	**Total Coliform[2]**	**E. coli[3]**	**Total Coliform[2]**	**E. coli[3]**
6/15/05	141	152	NA	NA	159	141	>2,420	345
10/12/05	>2,420	179	NA	NA	>2,420	196	>2,420	165
5-2-06	980	179	NA	NA	>2,420	214	>2,420	172
5-10-06	>2,420	172	NA	NA	1,733	121	1,203	141
5-15-06	>2,420	>2,420	NA	NA	>2,420	1,203	1,553	921
5-22-06	>2,420	727	NA	NA	>2,420	1,553	>2,420	1,120
5-30-06	>2,420	479	NA	NA	>2,420	659	>2,420	548
8-3-06	>2,420	461	NA	NA	>2,420	>2,420	>2,420	1,414
9-18-06	>2,420	>2,420	NA	NA	>2,420	1,733	>2,420	>2,420
9-27-06	>2,420	1,444	NA	NA	>2,420	548	>2,420	1,553
10-4-06	>2,420	435	NA	NA	>2,420	1,046	>2,420	>2,420
10-13-06	>2,420	649	NA	NA	>2,420	770	>2,420	816
10-19-06	>2,420	308	NA	NA	>2,420	548	>2,420	411
3-24-07	345	167	NA	NA	461	131	>2,420	>2,420
4-1-07	248	102	NA	NA	179	11	870	1,733
4-10-07	1,413	921	NA	NA	488	185	>2,420	>2,420

Notes:
[1] SBHCD = South Big Horn Conservation District. NA = not analyzed. See Figure 5.4.1 for station locations.
[2] Total coliform has no specific standard in Wyoming; however fecal coliform concentrations shall not exceed 200 maximum probable number per 100 milliliters (MPN/100 mL) (geometric mean of >4 samples collected during separate 24-hour periods for any 30-day period); nor shall fecal coliform concentrations exceed 400 MPN/100 mL (geometric mean of 3 samples collected within a 24-hour period) in any Wyoming surface water.
[3] E. coli human health standard in Wyoming = 126 maximum probable number per 100 milliliters (MPN/100 mL) (geometric mean of >4 samples collected during separate 24-hour periods for any 30-day period). Single sample maximum concentrations range from 235 MPN/100 mL (high use swimming areas) to 576 MPN/100 mL (infrequently used full body contact). Source: Mercer 2006. WCC Engineering 2005.

5.4.6.3 GRANITE CREEK

Samples for fecal coliform, total coliform, and/or E. coli bacteria were collected from Granite Creek by the Wyoming DEQ in 2004-2005, and by the USFS in 2001 (shown in Table 5.4.6.3.1). Results of these samples show the following ranges: fecal coliform = 210 to 650 MPN/100 mL; total coliform = 85 to 248 MPN/100 mL; and E. coli = 2 to 45 MPN/100 mL (see Table 5.4.6.3.1).

TABLE 5.4.6.3.1
Granite Creek Microbiological Data from WDEQ (2001) and USFS (2004-2005)
Shell Creek Watershed

Date of Measurement By WDEQ and USFS[1]	Fecal Coliform (MPN/100 mL)[2]	Total Coliform (MPN/100 mL)[2]	E. Coli (MPN/100 mL)[3]
8-6-2001	650	NM	NM
8-8-2001	210	NM	NM
8-9-2001	520	NM	NM
8-13-2001	400	NM	NM
8-14-2001	260	NM	NM
11-4-2004	NM	165.0	44.8
11-30-2004	NM	178.9	24.6
11-30-2004	NM	248.1	27.5
1-5-2005	NM	126.7	10.9
1-5-2005	NM	123.4	13.0
2-4-2005	NM	129.1	10.9
2-4-2005	NM	113.0	2.0
3-3-2005	NM	84.5	10.7
3-3-2005	NM	107.6	10.8
4-6-2005	NM	108.6	2.0
4-6-2005	NM	123.6	2.0

Notes:
[1] WDEQ = Wyoming Department of Environmental Quality; USFS = U.S. Forest Service. Samples collected near Highway 14 crossing of Granite Creek, approximately ½-mile from confluence with Shell Creek. WDEQ collected the samples in 2001. The USFS (Mercer 2006) collected the samples in 2004-2005.
[2] Total coliform has no specific standard in Wyoming; however fecal coliform concentrations shall not exceed 200 maximum probable number per 100 milliliters (MPN/100 mL) (geometric mean of >4 samples collected during separate 24-hour periods for any 30-day period); nor shall fecal coliform concentrations exceed 400 MPN/100 mL (geometric mean of 3 samples collected within a 24-hour period) in any Wyoming surface water. NM – not measured.
[3] E. coli human health standard in Wyoming = 126 maximum probably number per 100 milliliters (MPN/100 mL) (geometric mean of >4 samples collected during separate 24-hour periods for any 30-day period). Single sample maximum concentrations range from 235 MPN/100 mL (high use swimming areas) to 576 MPN/100 mL (infrequently used full body contact). NM – not measured. Source: Wyoming DEQ 2001. Mercer 2006.

5.5 STREAM MORPHOLOGY

Stream morphology describes the form or physical characteristics of the channel and immediate surroundings. Because of the relatively large Shell Creek watershed area, two levels of stream channel characterization and evaluation were employed: "Level I" is a broad morphological inventory, and refers to a general level of study that does not involve in-depth field work or measurements. It relies primarily on maps and published data. "Level II" stream inventory involves collection of field data sufficient to assign stream types to individual reaches. This study classified selected portions of the streams according to Rosgen's (1994, 1996) classification system.

5.5.1 LEVEL I STREAM DESCRIPTION AND CLASSIFICATION

Morphology of some major streams that characterize the Shell Creek watershed is described in this section using the Level I system. This methodology uses topographic maps, patterns of land use, and aerial photographs (ortho-photographs). Using the program Global Mapper®, in combination with the ortho-photographs, selected stream segments were defined by examining sinuosity, slope, and confinement.

The watershed can be divided into two very distinct regions: upper watershed in the Big Horn Mountains; and lower watershed in the Big Horn Basin. Most major streams in the watershed span both of these regions. The "basin" stream segments generally are formed in alluvium and weakly resistant bedrock, including shale and mudstone. These stream segments are somewhat confined to unconfined (i.e., erodible, low banks) with sinuous, low-gradient channel slopes (<1 percent). The "mountain" stream segments typically are formed in bedrock or in mass wasting or glacial deposits, and are generally confined in steeper and straighter channels (> 1.5 percent).

5.5.1.1 SHELL CREEK

Shell Creek is one of the major drainages on the west slope of the Big Horn Mountains, and in the eastern Big Horn Basin. It flows from Precambrian-age granitic basement rock in the core of the mountains, through Paleozoic-age limestone on the steeply dipping western mountain front, into the erodible Mesozoic-age mudstones and shale of the Big Horn basin to the west, and finally through its own well-developed alluvial floodplain to the Big Horn River near the town of Greybull. Shell Creek starts at an elevation of over 10,000 feet in the mountains, at Emerald Lake. It drains the formerly glaciated slopes of the upper watershed, flowing across very coarse-grained glacial moraines and drift.

There is a section of Shell Creek that flows through a steep canyon of highly resistant granite from stream mile 27 to 34. This segment includes the steepest portions of the stream channel, including Shell Creek Falls. Below this section, Shell Creek flows through the steeply dipping sandstone, limestone, and dolomite of the western mountain front. From the edge of the mountains, the stream flows mostly due west through successively younger geologic formations, mostly weakly indurate mudstone and shale, with some sandstone.

The floodplain of Shell Creek expands immediately west of the Shell Canyon section (where USGS stream gage no. 6278500 is located), to an average elevation of about 4200 feet at the town of Shell. The floodplain is approximately 1,400 feet wide in this area. Downstream from the town of Shell, the floodplain generally doubles in width. The channel and floodplain cut across several plunging anticlines and synclines, with many tributary streams and gulches following zones of geologic structural weakness perpendicular to the Shell Creek channel.

Numerous abandoned and highly sinuous channels are present in the lowermost reaches of the floodplain. These features are likely a result of natural migration of the river channel, and partly due to intensive cultivation of the floodplain and associated development of infrastructure. The lowermost half-mile of Shell Creek appears to have been straightened to facilitate bridge maintenance. The substrate in the channel west of the mountain front is mainly cobbles and gravel, becoming gravel and sand near the confluence with the Bighorn River.

5.5.1.2 BEAVER CREEK

Beaver Creek, including Red Canyon Creek, is the largest tributary to Shell Creek. This drainage is located north of Shell Creek, with the confluence located approximately 10 air miles from the mouth of Shell Creek near the town of Greybull. Beaver Creek spans both the basin and the mountains, and has a significant "transitional" reach between the two regions, where stream gradient is from 1 to 4 percent, and the channel is relatively confined, even where it is meandering. In the lower reaches, Beaver Creek is moderately meandering and sinuous. For the lowermost mile, Beaver Creek parallels Shell Creek in its floodplain. The channel has recently shifted across the floodplain and abandoned channels in several places. Some segments have been straightened for the purposes of floodplain cultivation. The substrate varies from gravel in the upper reaches, to sand and fine gravel near the confluence with Shell Creek.

5.5.1.3 TRAPPER CREEK

Trapper Creek is the second largest tributary to Shell Creek. Much of its drainage area is in the westerly dipping strata on the west slope of the Big Horn Mountains. It is deeply incised into the mountain front along most of its length, including the nearly 10-mile long Trapper Canyon. Where Trapper Creek leaves the mountain front, the gradient becomes flatter down to its confluence with Shell Creek. In the mountain portion, the stream is steep, has very low sinuosity, and has a cobble/gravel and bedrock substrate. In the basin portion, the stream flows through an alluvial floodplain and is relatively unconfined in a more sinuous pattern. Trapper Creek is located south of Shell Creek and joins this stream approximately 13 air miles from the mouth of Shell Creek.

5.5.1.4 WHITE CREEK

White Creek is almost entirely in the mountain portion, and as such is steep, confined, and has low sinuosity. The stream has incised a canyon along the western mountain front. An alluvial fan is present where White Creek exits the mountains, which extends for approximately 1 mile before joining Shell Creek. The substrate consists of boulders, cobbles, and gravel. Evidence of debris flows was observed at the mouth of the White Creek canyon.

5.5.1.5 CEDAR CREEK

Cedar Creek is the largest tributary to Shell Creek that lies entirely within the mountain region. It is steep, has very low sinuosity, and is highly confined. Its substrate is composed of boulders, cobbles, and gravel. The lower reaches of Cedar Creek flow through a canyon incised into Precambrian-age granite, while the uppermost reaches flow through the younger Paleozoic sedimentary units. Cedar Creek joins Shell Creek in the lower reach of Shell Canyon.

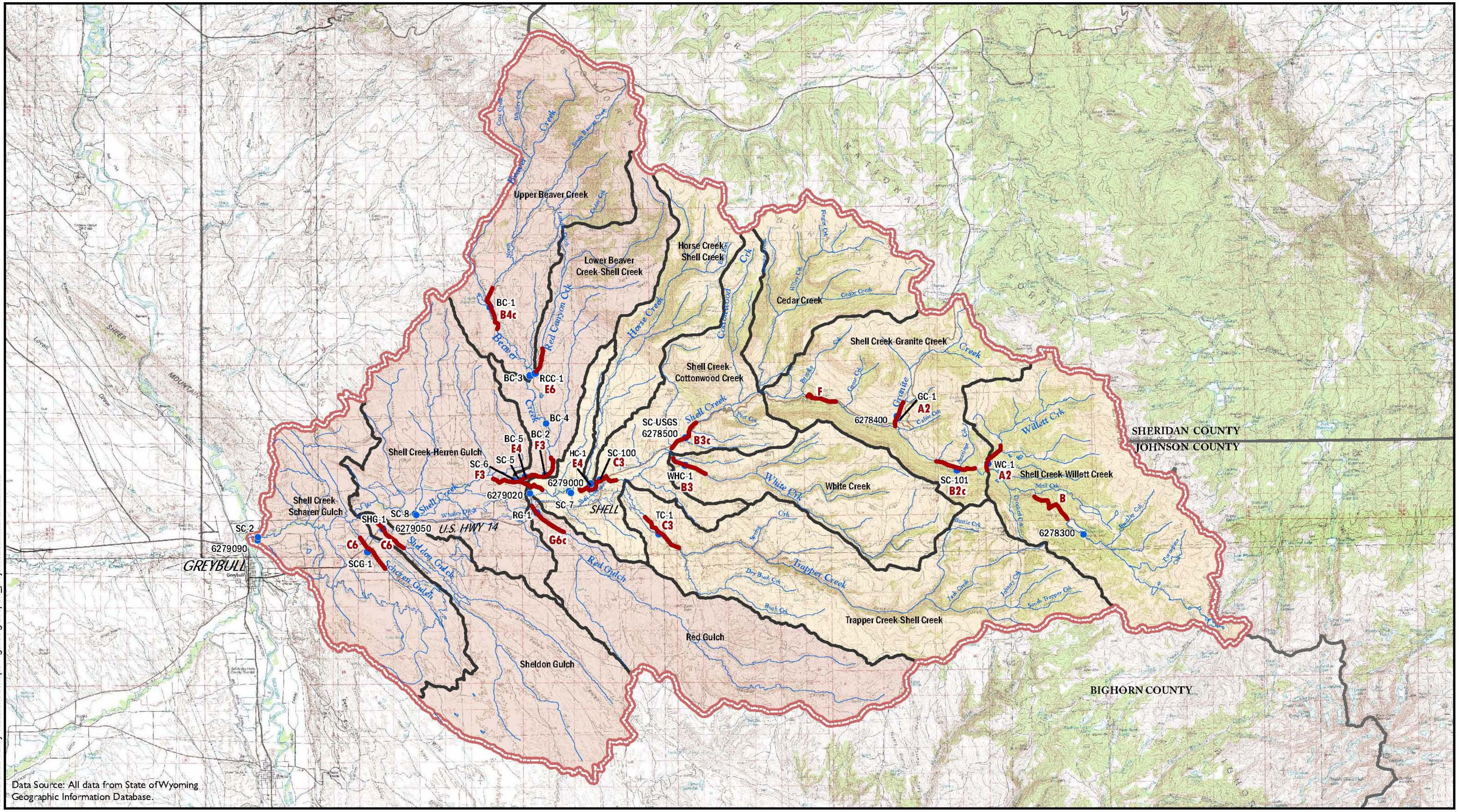
5.5.1.6 GRANITE CREEK

Granite Creek drains an area in the mountain portion of the watershed. It is a very steep stream, has a very low sinuosity, and is confined. It enters Shell Creek near the upper end of Shell Canyon. Its substrate consists of boulders and cobbles, with very little sediment smaller than gravel. Granite Creek is very stable, though it intercepts some debris flows from nearby hill slopes.

TABLE 5.5.2.1
Stream Channel Characteristics
Shell Creek Watershed

Stream Name	Segment ID No. [1]	Rosgen Classification[2]	Stream Mile[3]	Dominant Substrate	Bankfull Width / Depth (feet)[4]	Width / Depth Ratio	Flood-prone Width (feet)[5]	Entrenchment Ratio[6]	Sinuosity [7]	Channel Gradient (%)
Shell Creek	SC-5	F3	17.0	Cobbles, gravel	61 / 1.5	41	68	1.1	1.3	0.5
Shell Creek	SC-100	C3	22.0	Cobbles, gravel, bedrock	66 / 2.7	24	178	2.7	1.7	1.0
Shell Creek	SC-USGS	B3c	24.0	Cobbles, gravel	30 / 4.5	6.7	200	6.7	1.1	1.5
Shell Creek	SC-101	B2c	40.0	Cobbles, boulder	63 / 4.4	14	88	1.4	4.1	1.4
Beaver Creek	BC-5	E4	0.7	Gravel, sand	12 / 2.0	6.0	17	1.4	1.7	0.5
Beaver Creek	BC-2	F3	8.2	Cobbles, gravel	30 / 1.9	16	35	1.1	1.4	1.7
Beaver Creek	BC-1	B4c	13.8	Cobbles, gravel	13 / 1.5	8.7	22	1.7	1.5	1.3
Granite Creek	GC-1	A2	0,5	Boulders, cobbles	20 / 2.0	10	38	1.9	<1.2	6.5
Horse Creek	HC-1	E4	0.3	Cobbles, gravel	7 / 2.5	2.8	24	3.4	2.7	1.6
Red Canyon Creek	RCC-1	E6	0.4	Silt, clay	3 / 2.1	1.4	33	11	1.2	0.8
Red Gulch	RG-1	G6c*	0.6	Silt, clay	13 / 2.8	4.6	22	1.7	4.2	1.5
Scharen Gulch	SCG-1	C6*	1.3	Silt, clay	43 / 2.0	22	300	10.6	4.2	0.3
Sheldon Gulch	SHG-1	C6*	1.3	Silt, clay	22 / 2.0	11	180	8.3	>1.2	0.5
Trapper Creek	TC-1	C3	3.0	Cobbles, gravel	27 / 2.3	12	150	5.5	1.2	1.4
Willett Creek	WC-1	A2	0.1	Boulders, cobbles	36 / 2.9	12	50	1.4	<1.1	5.0
White Creek	WHC-1	B3	1.3	Cobbles, gravel	11 / 1.6	6.9	18	1.6	4.2	3.0

Notes: [1] See Figure 5.5.1 for stream segment location. Measurements and data were obtained in the field in 2006 by Geomatrix Consultants. [2] Classification based on Rosgen (1994, 1996) methodology. * - Indicates a stream classification applied to a non-natural stream. [3] Stream mile is distance from mouth of stream. [4] Bankfull Width = width of active channel that begins to spread onto the floodplain. Bankfull Depth = depth of active channel. [5] Flood-prone Width is measured at the elevation that corresponds to twice the maximum depth of bankfull channel. [6] Entrenchment Ratio = flood-prone width divided by bankfull width. [7] Sinuosity = ratio of stream length to valley length or ratio of valley slope to channel slope (estimated from Gobal Mapper). Sinuosity can be modified by bedrock control, roads, channel confinement, and vegetation. As channel gradient and dominant particle size decrease, there generally is a corresponding increase in sinuosity.



Surface Water Monitoring Sites

Upper Shell Valley (HUC 1008001001) - 5th Level

Lower Shell Valley (HUC 1008001002) - 5th Level

Shell Creek Watershed

6th Level HUC Boundaries and Names

Rosgen Stream Classification

0 Miles 6

AMEC Geomatrix 12565

Stream Morphology Classification
Shell Creek Watershed
Big Horn County, Wyoming

FIGURE 5.5.1

5.5.2 LEVEL II STREAM DESCRIPTION AND CLASSIFICATION

Additional details on stream type and potential behavior were developed under the Level II stream channel assessment. Segments of each stream that coincide with water quality sampling sites were examined. Bankfull width and depth, flood-prone width, sinuosity, and gradient were determined following the methods in Harrelson et al. (1994) and Rosgen (1994, 1996). Longitudinal surveys were conducted to determine local slope. Dominant substrate for each site was recorded based on visual evaluation of the stream bed.

Stream stations that were surveyed for channel characterization are shown on Figure 5.4.1. Table 5.5.2.1 summarizes channel characteristics for surveyed stream reaches within the Shell Creek watershed. Summary field forms are contained in Appendix H. This appendix includes figures showing Rosgen's (1996) stream classification types. Table 5.5.2.2 presents information about the erosion potential and sediment supply for the surveyed stream segments. Photographs of each surveyed site are included in Appendix I.

TABLE 5.5.2.2
Stream Sensitivity to Erosion and Sediment
Shell Creek Watershed

Stream Name	Segment ID No. [1]	Rosgen Classification[2]	Stream Mile[3]	Sensitivity to Disturbance[4]	Recovery Potential[4]	Sediment Supply[4]	Stream Bank Erosion Potential[4]
Shell Creek	SC-5	F3	17.0	Moderate	Poor	Very High	Very High
Shell Creek	SC-100	C3	22.0	Moderate	Good	Moderate	Moderate
Shell Creek	SC-USGS	B3c	24.0	Low	Excellent	Low	Low
Shell Creek	SC-101	B2c	40.0	Very Low	Excellent	Very Low	Very Low
Beaver Creek	BC-5	E4	0.7	Very High	Good	Moderate	High
Beaver Creek	BC-2	F3	8.2	Moderate	Poor	Very High	Very High
Beaver Creek	BC-1	B4c	13.8	Moderate	Excellent	Moderate	Low
Granite Creek	GC-1	A2	0,5	Very Low	Excellent	Very Low	Very Low
Horse Creek	HC-1	E4	0.3	Very High	Good	Moderate	High
Red Canyon Creek	RCC-1	E6	0.4	Very High	Good	Low	Moderate
Red Gulch	RG-1	G6c*	0.6	Moderate	Excellent	Very Low	Very Low
Scharen Gulch	SCG-1	C6*	1.3	Moderate	Excellent	Very Low	Very Low
Sheldon Gulch	SHG-1	C6*	1.3	Moderate	Excellent	Very Low	Very Low
Trapper Creek	TC-1	C3	3.0	Moderate	Good	Moderate	Moderate
Willett Creek	WC-1	A2	0.1	Very Low	Excellent	Very Low	Very Low
White Creek	WHC-1	B3	1.3	Moderate	Good	Very High	Low

Notes: [1] See Figure 5.4.1 for stream segment location. [2] Classification based on Rosgen (1994, 1996) methodology. * - Indicates a stream classification applied to a non-natural stream. [3] Stream mile is distance from mouth of stream. [4] These stream characteristics are based on field observations in 2006 by Geomatrix Consultants.

5.5.2.1 SHELL CREEK

Four sites on Shell Creek were examined (SC-5, SC-100, SC-USGS-6278500, & SC-101; Figure 5.4.1). Lowermost site SC-5 was characterized as Rosgen stream type F3, which is an entrenched meandering stream. This stream segment has a low gradient (0.5 percent) with a very high width/depth ratio (41). The channel exhibits riffle-pool morphology in this reach, and the substrate is cobble and gravel. Erosion potential and sediment supply are rated very high for this stream reach.

Site SC-100, located just upstream from the town of Shell, is partly underlain by bedrock, but also has substrate of cobbles and gravel. The Rosgen stream type is C3, which is a low gradient (1.0 percent), meandering, point bar stream with riffles and pools. It has a well-defined channel in a broad valley with inset terraces. A width/depth ratio of 24 is still relatively high. This type of stream is generally stable and moderately sensitive to disturbance.

Site SC-USGS-6278500 is located approximately 1 mile downstream from where Shell Creek exits Shell Canyon, and about 3 miles upstream from the town of Shell. The Rosgen stream type is B3c with cobbles and gravel, and a moderate gradient of about 1.5 percent. Width/depth ratio is relatively low at 6.4. This section of stream has significant stream power, being immediately downstream from the most confined reach of the canyon. The reach surveyed was nearly continuous rapids, with no pools, and very low sinuosity. Erosion potential and sediment supply at this location are low.

The uppermost site surveyed on Shell Creek (SC-101) is in the upper reaches of the watershed, near a USFS campground. The substrate consists of boulders and cobbles, and appears to be a lag deposit from glacier deposits. The site is at stream mile 40, and the Rosgen stream type is B2c. B-type streams are characterized by moderate relief, moderate entrenchment, with numerous rapids and occasional pools. Width/depth ratio and channel gradient are moderate at 14 and 1.4 percent, respectively.

5.5.2.2 BEAVER CREEK

Three locations on Beaver Creek were surveyed for channel characteristics (BC-5, BC-2, and BC-1; Figure 5.4.1). The lowermost stream reach at BC-5 is located close to the confluence with Shell Creek. Dominant substrate is gravel and sand, with some finer-grainded sediment. The measured slope (both from surveying and from maps) is low at 0.5 percent, and sinuosity is 1.7. Width/depth ratio is relatively low at 6.0. Based on overall morphology, this reach of Beaver Creek seems to best-fit a Rosgen stream type E4. E-type streams are laterally stable, with well vegetated banks and low sediment deposition. Notably, the morphology of Beaver Creek may be affected by some historic channelization and upstream water withdrawals. This stream reach as moderate sediment supply and high potential for bank erosion.

Beaver Creek site BC-2 was surveyed at stream mile 8.2. This stream reach has a much different character than downstream site BC-5. The substrate at BC-2 is much coarser, being composed of cobble and gravel. The slope is steeper at 1.7 percent. The Rosgen stream type is F3, which is an entrenched stream with low to moderate gradient and a high width/depth ratio (16). This stream type is considered to be unstable with high bank erosion rates. A comparison of the aerial photographs to the USGS topographic maps indicates substantial change in stream location has occurred in recent years.

At uppermost site BC-1 (stream mile 13.8), Beaver Creek is a moderately entrenched cobble and gravel stream channel. Based on overall morphology, the most applicable Rosgen stream type is B4c. The reach surveyed has an entrenchment ratio of 1.7, and a width/depth ratio of 8.7. Sinuosity is similar to the other Beaver Creek sites at 1.7, and gradient is moderate at 1.3. Erosion potential for this stream reach is low, and sediment supply is moderate.

Beaver Creek upstream of the mountain front are likely Rosgen type A to Aa+. These reaches were not surveyed, but the topographic maps and orthophotographs indicate a steep channel that is highly confined and in which bedrock is a common substrate. Therefore, a continuum of stream types can be visualized on Beaver Creek, from the steep, high energy reaches of the mountains, to the low gradient, meandering channels in the lower basin.

5.5.2.3 RED CANYON CREEK

Red Canyon Creek was surveyed at one location (RCC-1; Figure 5.4.1) within the basin region and just ½-mile upstream from the confluence with Beaver Creek. The floodplain in much of the lower valley of Red Canyon Creek is cultivated, and the stream appears to have been altered significantly from its natural state. The stream channel was completely vegetated, with very little flow, minimal sediment transport, and low stream bank erosion potential. The Rosgen stream classification is E6, although the sinuosity (1.2) is lower than the threshold for this stream type (1.5). The width/depth ratio is 1.4, and channel gradient is low at 0.8 percent. Possible alteration of the stream channel may be the reason that the stream does not fit easily into any one stream classification category.

5.5.2.4 GRANITE CREEK

Granite Creek was surveyed just upstream from where it is crossed by Highway 14 near a USFS picnic area. This is a steep (6.5 percent), mountain stream, classified as Rosgen stream type A2, with low sinuosity. The substrate is very coarse with boulders and cobbles, and very little sediment finer than gravel. This stream is very stable and not subject to incision or aggradations. Width/depth ratio is 10 and entrenchment ratio is 1.9.

5.5.2.5 WILLETT CREEK

The surveyed Willett Creek reach is where the Adelaide Trail crosses the stream near its confluence with Shell Creek. The Rosgen stream type is A2, and is very similar to the surveyed reach of Granite Creek. Willet Creek flows through glacial moraine deposits and has removed the fine material, leaving primarily boulder-sized substrate. For this reason, the stream is very stable, being unable to transport most of the bed and bank material. The stream gradient is steep (5.0 percent), being a series of cascades and with occasionally step-pools. Additionally, the sediment supply is limited because of the relatively high position in the watershed, and because of a low-gradient meadow area upstream, which serves as an area to trap and settle any sediment.

5.5.2.6 HORSE CREEK

Horse Creek is a large tributary on the north side of Shell creek that extends from the Bighorn Mountains into the basin. The survey was conducted at stream mile 0.3 where the stream is entrenched through a low gradient (1.6 percent) alluvial floodplain. Rosgen stream type is E4, with a width/depth ratio of 2.8, entrenchment ratio of 3.4, and sinuosity of 2.7. The channel has a gravel/cobble substrate and exhibits riffle/pool morphology. The stream is highly sensitive to disturbance, but has a good recovery potential.

5.5.2.7 TRAPPER CREEK

The reach surveyed on Trapper Creek was at a road crossing at stream mile 3.0. The Rosgen stream type is C3, a slightly entrenched, meandering channel (sinuosity of 1.2) at a gradient of 1.4 percent. This stream has moderate stability and sediment supply, gravel/cobble substrate, and a relatively broad floodplain. Upstream from the surveyed reach, however, there is evidence of multiple channels.

5.5.2.8 WHITE CREEK

White Creek was dry at the time it was surveyed. The reach examined was at stream mile 1.3, just above a section with multiple channels. Rosgen stream type for the survey reach is B3; however, some of its characteristics indicate a type D3 channel. There is a high sediment supply, as this reach is at the base of a canyon section. Channel sinuosity is 4.2, and has a cobble/gravel substrate. The banks in the surveyed reach are stable; however, the channel becomes unstable below this reach, as evidenced by recent bank erosion.

5.5.2.9 SCHAREN GULCH

The reach examined was just upstream from where Scharen Gulch crosses under Highway 14, 1.4 miles from its confluence with Shell Creek. Scharen Gulch drains a portion of the very arid lower watershed. It appears to be supplied primarily with return flow water from irrigated fields upstream. In response to this water source, a well-developed riparian zone has been established, with numerous cattails. Channel substrate is composed of silt, clay, and organic matter.

Although classified as a Rosgen type C6 stream, the classification system may not apply to this stream because it is not subject to natural seasonal flows. Other similarly sized drainages in this part of the watershed did not have discharge at the time of stream surveying. There is very little evidence for sediment transport in the channel; it is mostly low gradient (0.3 percent) flow through a stable channel surrounded by riparian vegetation and a wide floodplain. The banks are gentle, densely vegetated, and show no signs of disturbance. Width/depth and entrenchment ratios are high, and sinuosity is 4.2.

5.5.2.10 SHELDON GULCH

This stream in Sheldon Gulch is similar to Scharen Gulch; it is also likely is receiving irrigation return flow from upstream areas. The surveyed site is also located at the Highway 14 crossing where the gradient is 0.5 percent. The stream reach is densely vegetated (marshy) with a wide floodplain. Sheldon Gulch in this area is also classified as a Rosgen type C6 stream. Sheldon Gulch was probably an ephemeral stream, flowing only in response to heavy rain storms, before extensive irrigation was developed in its watershed.

5.5.2.11 RED GULCH

Like Scharen and Sheldon Gulches, Red Gulch probably is subject to return irrigation flows moving through a previously ephemeral stream channel. The channel was surveyed at about stream mile 0.6, just upstream from Highway 14. The gradient is steeper than Scharen and Sheldon Gulches at 1.5 percent, and the floodplain is narrower. The width/depth ratio is 4.6, and sinuosity is 4.2. The banks are densely vegetated and appear to be very stable with low sediment supply.

6.0 IRRIGATION

There are many irrigation canals and ditches, and many water rights permitted within the boundary of SVWID. SVWID comprises 26,200 acres and the permitted water rights, according to the State Engineer's Office, comprise approximately 15,159 acres. There are 105 different water rights permits covering the irrigated lands within SVWID's boundary; the majority of which are territorial or late 1800's water rights. Since the State of Wyoming ranks water rights on the idea of "first in time is first in right", the water rights in this area are senior water rights and very valuable. All water rights are allowed to receive 1 cfs per 70 acres. The senior water rights before March 1, 1945, are allowed to receive an additional 1 cfs per 70 acres when surplus water is available. As the amount of available water decreases, the surplus water right is eliminated first. Then water is then restricted based on the "first in time is first in right". The youngest water rights are the first to feel the impacts of water restrictions.

In the 1985 WWDC, Shell Valley Watershed Level II Study, HKM Associates performed a detailed analysis of all the water rights within the watershed. HKM included the analysis in Appendix D and E of their report. The tract numbers on the Irrigated Land Base and Water Right Maps, Appendix D of the 1985 report, provide a visual correlation to the information provided in Appendix E. The Shell Valley Water Rights and Irrigated Land Inventory, Appendix E, includes 67 pages of valuable information for the entire water shed.

Engineering Associates researched the State Engineer's Office for adjudicated water rights. The individual Certificates of Appropriation in the State Engineer's Office are still in the name of whichever landowner filed the Certificate. The State Engineer's Office does not require each successive landowner to update the Certificate of Appropriation when the new landowner purchases the property. Therefore, there is a legal disconnect between the State Engineer's Office and each county's assessor's office. Until these laws are changed by legislative action, each property owner should be responsible for verifying their water rights with the State Engineer's Office. The website is http://seo.state.wy.us/. Therefore, providing updated Certificates of Appropriation for the current landowners is beyond the purview of this study.

One hundred and five (105) original surface water right permits were determined to be within the SVWID boundary. Table 6.1 is a list of the irrigation water rights found within SVWID's boundary. A breakdown of water rights based on the Facility Name can be found in Appendix M.

A Water Right Permit Overview map is located in Appendix P. The map displays only 58 permits identified by the Wyoming State Water Plan, http://waterplan.state.wy.us/gis/gis.html.

Table 6.1 WYOMING STATE ENGINEER'S PERMITS WITHIN THE DISTRICT BOUNDARY*							
Permit Number	Source	Facility Name	Priority Date	Maximum Adjudicated Flow**	Adjudicated Flow	Adjudicated Acreage	Type
3965	Shell Creek	McDonald(Shell Canal)	Spring 1886	4.00 cfs	2 cfs	140.00	os
3966	Shell Creek	McDonald(Shell Canal)	Spring 1886	3.00 cfs	1.5 cfs	105.00	os
3971	Shell Creek	Beaver Ditch	Spring 1887	1.43 cfs	0.71 cfs	50.00	os
3972	Shell Creek	Allen & Hough Ditch	Spring 1887	3.14 cfs	1.57 cfs	110.00	os
3973	Shell Creek	Allen & Hough Ditch	Spring 1887	3.57 cfs	1.79 cfs	125.00	os
4001	Beaver Creek	Pense Ditch	Spring 1888	0.57 cfs	0.29 cfs	20.00	os
3977	Shell Creek	Whaley Ditch	Spring 1889	4.06 cfs	2.03 cfs	142.00	os
3967	Shell Creek	Odessa Ditch	1/10/1887	3.86 cfs	1.93 cfs	135.00	os
3968	Shell Creek	Odessa Ditch	1/10/1887	2.71 cfs	1.36 cfs	95.00	os
3969	Shell Creek	Odessa Ditch	1/10/1887	1.83 cfs	0.91 cfs	64.00	os
3970	Shell Creek	Odessa Ditch	1/10/1887	1.86 cfs	0.93 cfs	65.00	os
4016	Horse Creek	Austin Ditch	4/26/1887	1.00 cfs	0.5 cfs	35.00	os
3974	Shell Creek	Dunshee Ditch	4/15/1888	3.57 cfs	1.79 cfs	125.00	os
3975	Shell Creek	Dunshee Ditch	4/15/1888	13.49 cfs	6.74 cfs	472.00	os
3976	Shell Creek	Denny Ditch	5/8/1888	6.57 cfs	3.29 cfs	230.00	os
3999	Beaver Creek	Loveland Ditch	6/15/1888	0.43 cfs	0.21 cfs	15.00	os
365	Shell Creek	Porter Ditch	11/18/1892	32.00 cfs	16 cfs	1120.00	os
270	Beaver Creek	Beaver Ditch	5/5/1892	3.91 cfs	1.96 cfs	137.00	os
386	Beaver Creek	Trout Ditch	1/3/1893	1.69 cfs	0.84 cfs	59.00	os
430	Shell Creek	McDonald(Shell Canal)	3/7/1893	6.29 cfs	3.14 cfs	220.00	os
508	Shell Creek	Kershner Ditch	6/01/1893	2.46 cfs	1.23 cfs	86.00	os
510	Horse Creek	Kershner-Lapman Ditch	6/01/1893	1.37 cfs	0.69 cfs	48.00	os
42Enl.	Shell Creek	Enl. Whaley Ditch	6/17/1893	19.77 cfs	9.89 cfs	692.00	os
853	Beaver Creek	Anderson Ditch	11/20/1894	2.66 cfs	1.33 cfs	93.00	os
682	Beaver Creek	Kenyon Ditch	4/03/1894	0.43 cfs	0.21 cfs	15.00	os
686	South Fork Beaver Creek	London Ditch	4/07/1894	7.71 cfs	3.86 cfs	270.00	os
691	Beaver Creek	Crandall Ditch	9/04/1894	2.14 cfs	1.07 cfs	75.00	os
1075	Trapper Creek	Hatten Ditch	11/13/1895	1.71 cfs	0.86 cfs	60.00	os
1010	Shell Creek	Rath Ditch	7/5/1895	2.34 cfs	1.17 cfs	82.00	os
1039	Trapper Creek	Willard Ditch	8/16/1895	1.14 cfs	0.57 cfs	40.00	os
1341	Beaver Creek	Matthews Ditch	10/15/1896	2.63 cfs	1.31 cfs	92.00	os
1415	Beaver Creek	St. Jermain Ditch	1/15/1897	3.37 cfs	1.69 cfs	118.00	os
232 Enl	Beaver Creek	Kenyon Ditch	1/7/1897	1.03 cfs	0.51 cfs	36.00	os
1573	Horse Creek	Lampman No. 2 Ditch	9/13/1897	2.29 cfs	1.14 cfs	80.00	os
271Enl.	Shell Creek	Enl. McDonald (Shell Canal)	9/18/1897	15.34 cfs	7.67 cfs	537.00	os
1716	Trapper Creek	Highline Ditch	1/12/1898	6.03 cfs	3.01 cfs	211.00	os
322 Enl	Shell Creek	Porter Canal	1/21/1898	4.17 cfs	2.09 cfs	146.00	os
1807	Beaver Creek	Pense Ditch	3/28/1898	1.57 cfs	0.79 cfs	55.00	os
462Enl.	Shell Creek	Enl. Whaley Ditch	9/18/1899	12.4 cfs	6.2 cfs	434.00	os
2563	Trapper Creek	Jenks Ditch	4/20/1900	1.60 cfs	0.8 cfs	56.00	os
605 Enl	Shell Creek	Frieze Ditch, Beaver Enl	12/17/1900	17.21 cfs	8.6 cfs	602.30	os
2967	South Fork Beaver Creek	Davis Ditch	12/22/1900	3.26 cfs	1.63 cfs	114.00	os
3132	Trapper Creek	Sabin-Brown Ditch	4/22/1901	1.63 cfs	0.81 cfs	57.00	os
650Enl.	Shell Creek	Enl. Whaley Ditch	4/22/1901	7.69 cfs	3.84 cfs	269.00	os
3246	Shell Creek	Fender Ditch	6/10/1901	2.14 cfs	1.07 cfs	75.00	os
3648	Horse Creek	Bench Ditch	1/9/1902	0.37 cfs	0.19 cfs	13.00	os
3720	Trapper Creek	Cull No.1 Ditch	2/13/1902	1.40 cfs	0.7 cfs	49.00	os
3721	Shell Creek	Lynn Ditch	2/13/1902	12.2 cfs	6.1 cfs	427.00	os
3722	Red Gulch	M.E. Jackson Ditch	2/13/1902	0.86 cfs	0.43 cfs	30.00	os
5274	Shell Creek	Scharen Ditch	1/12/1903	1.57 cfs	0.79 cfs	55.00	os
5363	Hudson Falls	Hunt Ditch	3/17/1903	3.95 cfs	1.97 cfs	138.17	os
1274Enl.	Shell Creek	Enl. Denny Ditch	4/18/1904	0.71 cfs	0.36 cfs	25.00	os
1275 Enl	Shell Creek	Dunshee Ditch	4/18/1904	0.71 cfs	0.36 cfs	25.00	os
1244Enl.	Trapper Creek	Enl. Sabin-Brown Ditch	5/19/1904	0.26 cfs	0.13 cfs	9.00	os
6217	Beaver Creek	Arthur Mason Ditch	7/28/1904	1.06 cfs	0.53 cfs	37.00	os
1262 Enl	Trapper Creek	Hatten Ditch	8/8/1904	1.00 cfs	0.5 cfs	35.00	os
1330Enl.	Shell Creek	McDonald(Shell Canal)	1/6/1905	5.43 cfs	2.71 cfs	190.00	os
1348 Enl	Shell Creek	Freese Ditch	3/11/1905	1.54 cfs	0.77 cfs	54.00	os
1438 Enl.	Beaver Creek	Enl. Calvin Ditch	5/22/1905	1.09 cfs	0.54 cfs	38.00	os
1439Enl.	Shell Creek	Enl. McDonald (Shell Canal)	5/22/1905	5.43 cfs	2.71 cfs	190.00	os
6799	White Creek	Boylan Ditch	7/10/1905	6.06 cfs	3.03 cfs	212.00	os

Table 6.1 WYOMING STATE ENGINEER'S PERMITS WITHIN THE DISTRICT BOUNDARY*							
Permit Number	**Source**	**Facility Name**	**Priority Date**	**Maximum Adjudicated Flow****	**Adjudicated Flow**	**Adjudicated Acreage**	**Type**
1464 Enl	Shell Creek	Porter Canal	11/13/1905	1.54 cfs	0.77 cfs	54.00	os
1522Enl.	Trapper Creek	Enl. Highline Ditch	4/7/1906	1.86 cfs	0.93 cfs	65.00	os
1601 Enl	Beaver Creek	Beaver Ditch	8/6/1906	0.54 cfs	0.27 cfs	19.00	os
7438	Trapper Creek	Crain-Jenks Ditch	8/11/1906	1.20 cfs	0.6 cfs	42.00	os
1730	Shell Creek	Whaley Ditch	12/18/1906	4.29 cfs	2.14 cfs	150.00	os
1938 Enl	Shell Creek	McDonald(Shell Canal)	4/10/1907	0.57 cfs	0.29 cfs	20.00	os
8290	Shell Creek	Shell Canal	4/22/1907	25.03 cfs	12.51 cfs	876.00	os
1726Enl.	Shell Creek	Enl. Porter Ditch	4/22/1907	1.23 cfs	0.61 cfs	43.00	os
1808 Enl	Beaver Creek	Beaver Ditch	9/16/1907	2.20 cfs	1.1 cfs	77.00	os
1850	Beaver Creek	Pense Ditch	3/19/1908	0.40 cfs	0.2 cfs	14.00	os
8538	Rath Springs	Rath-Early Ditch	7/13/1908	0.91 cfs	0.46 cfs	32.00	os
8627	Shell Creek	Fletcher Ditch	9/4/1908	1.76 cfs	0.88 cfs	61.75	os
1962Enl.	Trapper Creek	Enl. Highline Ditch	10/9/1908	1.57 cfs	0.79 cfs	55.00	os
1964 Enl	Shell Creek	Freise Ditch	10/12/1908	0.51 cfs	0.26 cfs	18.00	os
2031Enl.	Shell Creek	Enl. Odessa Ditch	3/23/1909	1.26 cfs	0.63 cfs	44.00	os
2084Enl.	Shell Creek	Enl.Shell Canal	6/1/1909	68.7 cfs	34.35 cfs	2404.55	os
2446 Enl	Shell Creek	Lynn Ditch	4/6/1911	7.86 cfs	3.93 cfs	275.00	os
2469Enl.	Trapper Creek	Enl. Highline Ditch	5/5/1911	0.21 cfs	0.11 cfs	7.50	os
11335	South Fork Beaver Creek	Kimbrow No.1 Ditch	6/21/1912	0.34 cfs	0.17 cfs	12.00	os
2747Enl.	South Fork Beaver Creek	Enl. Davis Ditch	7/27/1912	3.46 cfs	1.73 cfs	121.00	os
12217	Cedar Creek	Howe Ditch	12/18/1912	0.76 cfs	0.38 cfs	26.70	os
13194	Beaver Creek	Ewen No. 1 Ditch	6/6/1913	0.62 cfs	0.31 cfs	21.80	os
13195	Beaver Creek	Ewen Ditch No. 2	6/6/1913	0.45 cfs	0.22 cfs	15.60	os
13196	Beaver Creek	Bond Ditch	6/20/1913	0.49 cfs	0.25 cfs	17.30	os
3192 Enl	Beaver Creek	Beaver Ditch	6/20/1913	1.27 cfs	0.63 cfs	44.40	os
13197	Red Canyon Creek	Leavitt Ditch	12/8/1913	0.93 cfs	0.47 cfs	32.70	os
3559 Enl	Beaver Creek	Anderson Ditch	11/12/1915	0.60 cfs	0.3 cfs	21.00	os
3558 Enl	Beaver Creek	Trone & Hurt Ditch	11/15/1915	1.91 cfs	0.96 cfs	67.00	os
14358	Horse Creek	Emerick Ditch	6/3/1916	0.29 cfs	0.14 cfs	10.00	os
3777 Enl	Shell Creek	Linn Ditch	2/14/1917	0.86 cfs	0.43 cfs	30.00	os
3786 Enl	Shell Creek	Dunshee Ditch	4/2/1917	0.62 cfs	0.31 cfs	21.70	os
16412	Shell Creek	Red Bluff Ditch	8/3/1922	2.14 cfs	1.07 cfs	75.00	os
17817	Horse Creek	Frank Gould No.2 Ditch	12/12/1930	0.86 cfs	0.43 cfs	30.00	os
4715Enl.	Horse Creek	Enl.Bench Ditch	3/5/1931	0.71 cfs	0.36 cfs	25.00	os
5312 Enl	Shell Creek	McDonald(Shell Canal)	5/24/1941	4.00 cfs	2 cfs	140.00	os
19680	Shell Creek	Flitner Ditch	6/3/1941	1.06 cfs	0.53 cfs	37.00	os
5420Enl.	Shell Creek	Enl.Whaley Ditch	4/19/1945	0.57 cfs	0.57 cfs	40.00	os
5472 Enl	Shell Creek	Whaley Ditch	7/26/1948	0.22 cfs	0.22 cfs	15.24	os
20877	Frenchy Draw	Cropsey Ditch	11/29/1951	0.13 cfs	0.13 cfs	9.00	os
5859Enl.	Shell Creek	Enl. Dunshee Ditch	6/19/1956	0.67 cfs	0.67 cfs	47.11	os
21842	Beaver Creek	Ewen No. 3 Ditch	6/24/1957	0.19 cfs	0.19 cfs	13.20	os
5986 Enl	Shell Creek	McDonald(Shell Canal)	6/23/1959	0.60 cfs	0.6 cfs	42.00	os
6091 Enl	Shell Creek	Shell Canal	1/18/1963	0.29 cfs	0.29 cfs	20.29	os
24240	Trapper Creek	Cassey Pipeline	10/15/1973	0.06 cfs	0.06 cfs	4.50	os
			Total	**412.45**	**207.60**	**14,531.81**	

17571	Spring Creek	Spring Creek Ditch	8/2/1922	None	None	115.00	ss
17878	Cottonwood Creek	Cottonwood Ditch	1/12/1931	None	None	513.00	ss
			Total	**None**	**None**	**628.00**	

Note: **SS** - Supplimental Supply   **OS** - Original Supply

* Water Right Permits located within the Shell Watershed, but outside of the boundary of the Shell Valley Improvement District were not calculated. A detailed list of Water Rights within the district was completed during the 1985 WWDC Shell Valley Water Shed Level II Study prepared by HKM Associates. The boundary of the Shell Valley Improvement District was provided by a board representative in June 2006.

**All water rights are entitled to 1 cfs/70 acres. Water rights before March 1, 1945 are allowed to use an additional 1 cfs/70 acres when water is available.

6.1 SUMMARY OF EXISTING ISSUES & PROBLEMS

Engineering Associates completed a thorough location survey and review of the irrigation systems including all structures, head gates, measuring devices, and ditch location of all irrigation ditches that could be located by our personnel. Many ditch riders spent time with our field surveyor to provide location information for parts of their system. The remainder of the field investigation was completed by our Surveyor.

Engineering Associates found the existing irrigation ditches and structures to be very old and minimal maintenance being performed. The ditches and structures have far outlived their useful design life and are in need of replacement. Generally, the irrigation ditches are not lined with any type of impervious material. Because the ditches are unlined, water is lost from seepage through the bottom and sidewalls. There were a few reaches that appeared to have high seepage losses due to the growth of cattails and wetland-type growth along the banks of the ditches. Engineering Associates completed flow tests along these reaches and it was found the water losses were within an acceptable range for an unlined, dirt canal. Seepage losses will be discussed in detail in Section 6.2.3.

6.2 IRRIGATION STRUCTURE SYSTEMS

6.2.1 FIELD SURVEY

The mapping of the irrigation system was completed using a RTK GPS equipment at sub-centimeter accuracy and included surveying the main canals, laterals, sub-laterals, some smaller private ditches, and system structures including flumes, siphons, tunnels, drop, checks, drop/checks, chutes, diversion boxes, head gates and pipes. This information was overlaid onto aerial photos and used to build a map in ArcGIS. Over 6,000 shots were surveyed and took over 6 months to complete due to the overgrowth of grass, covering head gates, and rough country that made accessibility difficult even with a four wheeler. Additional effort was made to be available at the convenience of the irrigation personnel.

Each survey shot included a point number, elevation, and descriptor. The point number and descriptor are used in the Structure Data Sheets and the Irrigation Inventory Maps to help the reader locate the structure or reach of canal in question. The descriptors are listed in the following tables. The descriptors communicate to the reader what type of structure or ditch section the reader is reviewing. The descriptors were used by the surveyor on board the GPS unit to allow for rapid information input in the field.

The following tables show the data dictionary acronyms that were used during surveying. These acronyms were placed on the Structure Data Sheets and in the Project Overview Map found in the Appendices. A sample structure data sheet and an irrigation inventory map are provided in Appendix K. Table 6.2.1.1 provides the descriptor for the Ditch Name. Table 6.2.1.2 provides the descriptor for Ditch Lining Type. There were only two types of linings found. A dirt lining is simply a trenched ditch that has not had any type of impervious liner constructed such as concrete, shot-crete or PVC. The lined canal type is where there was bentonite clay placed along the McDonald Ditch. EA was made aware of this lined section from the ditch rider. Table 6.2.1.3 provides the descriptor for the structure type. During surveying, one descriptor from each table is used to completely identify the structure or ditch. Examples of a complete descriptor and how to read them follows:

BVD-D-HG – This descriptor is read as Beaver Ditch; Dirt Ditch; Head Gate
SC-D-P – This descriptor is read as Shell Canal; Dirt Ditch; Pump
WHD-D-CUL-Iron – This descriptor is read as Whaley Ditch; Dirt Ditch; Culvert made out of Iron.
MCDLD-D-CS – This descriptor is read as McDonald Ditch; Dirt Ditch; Check Structure.

The data dictionary tables follow:

TABLE 6.2.1.1 Data Dictionary Ditch Name	
AMD	Arthur Mason Ditch
AND	Anderson Ditch
BED	Bench Ditch
BER	Bernie Ditch
BVD	Beaver Ditch
CALD	Calvin Ditch
CASPL	Casey Pipeline
CJD	Crain Jenks Ditch
CRD	Crandall Ditch
CULD	Cull Ditch
CWD	Cottonwood Ditch
DAVD	Davis Ditch
DED	Denny Ditch
DNSD	Dunshee Ditch
EMD	Emerirch Ditch
EWD	Ewen Ditch
FEND	Fender Ditch
FGD	Frank Gould Ditch
FLTD	Flitner Ditch
FRD	Friese Ditch
HATD	Hatten Ditch
HLD	High Line Ditch
HNTD	Hunt Ditch
HOWD	Howe Ditch
JKD	Jenks Ditch
KEND	Kenyon Ditch
KLD	Kerchner-Lampman Ditch
KMBD	Kimbro Ditch
KRSD	Kerschner Ditch
LAMD	Lampman Ditch
LAT1	Unnamed Lateral 1 (Not known to SEO Superintendent)
LAT2	Unnamed Lateral 2 (Not known to SEO Superintendent)
LAT3	Unnamed Lateral 3 (Not known to SEO Superintendent)
LAT4	Unnamed Lateral 4 (Not known to SEO Superintendent)
LAT5	Unnamed Lateral 5 (Not known to SEO Superintendent)
LOND	London Ditch
LYND	Lynn Ditch
MCDLD	McDonald Ditch
MEJDME	Jackson Ditch
MTHWD	Mathews Ditch
OD	Odessa Ditch
PC	Porter Canal
PEND	Pense Ditch
RED	Rath Early Ditch
SBD	Sabin Brown Ditch
SC	Shell Canal
SCN	Shell Canal North Branch
SHRD	Sharen Ditch
SJD	Saint Jermain Ditch
SPCRD	Spring Creek Ditch
TL	Thompson Lateral
TRD	Trout Ditch
WHD	Whaley Ditch
WILD	Willard Dtich

TABLE 6.2.1.2 Data Dictionary Ditch Lining Type	
D	Dirt
LC	Lined Canal

TABLE 6.2.1.3 Data Dictionary Structure Type	
BDG	Bridge
CH	Chute
CONC	Concrete
CS	Check Structure
CUL	Culvert
DRN	Drain
FL	Flume
HG	Head Gate
MD	Measuring Device
P	Pump
PL	Pipeline
PVC	Polyvinyl Chloride Pipe
RCP	Concrete Pipe
RG	Radial Gate
S	Structure
SPH	Siphon
SPL	Spill
STL	Steel Pipe
TB	Turn Out Box
TU	Tunnel
US	Undershot
V	Vent
VAL	Valve
WW	Waste Water Pick-Up

6.2.2 STRUCTURE ASSESSMENT

Engineering Associates visited the structures to provide a visual assessment of the physical condition and to take a photograph of each structure. It was impossible to take photos of all structures in the "dry" condition since irrigation water is in the ditches from early April until late October or snow is covering the ground. This area experiences only about 20 to 30 days when ditches are dried out and not filled in with snow. Another difficulty encountered during the structure inventory was that vegetation in and around the structures made obtaining a clear photograph of the structure sometimes difficult. Since many of the irrigation companies do not burn or mechanically clean their ditches each off-season, some of the photos show the structure and surrounding vegetation as well. Due to the vegetation, some of the smaller structures such as head gates are difficult to see in the photo. Where the structure is hard to see in the surrounding vegetation, we added text and an ellipse to the photo was added.

For each structure, we created a Structure Data Sheet. The Structure Data Sheet provides the Structure Name, Point No., Descriptor, Structure Description and Function, Structure Condition, and Structure Rating. The Structure Name is the type of structure such as a siphon, check structure, head gate, etc. The Point Number is the surveying point number from our RTK-GPS survey instrument. The Structure Description and Function states where the structure is located, which canal or lateral the structure is located, and the structure's use.

During the field investigation, the structure's condition was rated from poor to excellent. We also added a Structure Rating number from 1 through 10. Numbers 1, 2, and 3 are for structures in Poor condition. Numbers 4, 5, and 6 are for structures in Fair condition. Numbers 7, 8, and 9 are for structures in Good condition. And the number 10 is for structures in excellent condition.

The numbers were assigned to show how many years out the replacement should be such as a number 1 states the replacement should take place one year after this study, a number 8 states the replacement should take place within 8 years after this study. The structures rated a 10 do not necessarily need to be replaced in 10 years unless they are showing signs of deterioration. Due to the age of these ditches and their structures, and the minimal maintenance and replacement that has occurred over the last 60 to 80 years, the majority of structure conditions were poor and fair.

The rating criteria tends to be subjective depending on who (an irrigator or an engineer) is looking at the structure. Engineering Associates attempted to rate structures based on whether it is continuing to work as its intended use, what condition the concrete is in, does the structure appear to be installed correctly, were the proper materials used for the structure, and does there appear to be poor materials in the ditch such as old tin dams, wood, and pieces or parts of stray materials. As indicated earlier, these irrigation structures are old and have outlived their useful design life. It is the professional opinion of the council that conveyance systems need to be considered and prioritized by each ditch company. Each irrigation company is encouraged to understand their system and make adjustments to the priority list to meet the needs of the ditch company.

An example of the Structure Data Sheet is included in Appendix K. Due to the large quantity of structure data sheets, the completed structure data sheets are provided electronically in Word format on a CD included in Appendix K.

The rating numbers were used to provide SVWID and the private irrigation companies with a replacement schedule and construction costs for the next 10 years. This spreadsheet shows the Replacement Year, Structure Rating (taken from the Structure Data Sheets), Revised Structure Rating, Ditch Name, Structure Description, and Location of Structure in miles from head end of ditch, Survey Point Number, Replacement Construction Cost. The construction costs are further broke down to show each private irrigation company's in-kind contribution.

Most of the structures were rated 1 through 4 on the Structure Data Sheets which places a large financial burden on each private irrigation company in the next four years. Each irrigation company should review their list and determine how much money they are willing to spend and adjust their list accordingly

6.2.3 SEEPAGE ANALYSIS

The majority of the canals and ditches has no lining material and do seep throughout the irrigation season. Seepage is expected in dirt ditches and will increase when the ditch passes through a sandstone or gravel material.

The sponsor indicated that seepage loss was a concern for both the McDonald Ditch and Shell Canal. The McDonald Ditch and Shell Canal water is conveyed through the same ditch. This ditch is approximately 31 miles long and does not have any impermeable lining. Due to the length of this ditch and it being unlined, there will continue to be losses due to seepage and evaporation.

To determine the best measurement locations visible evidence such as surrounding an abundance of green vegetation (the native vegetation is high desert sagebrush), cattails on the down gradient side of the canal, surrounding visible geology such as visible sandstone, and standing water adjacent to the canal were taken into account. If the surrounding terrain was high desert, it was assumed there was negligible seepage. Flow measurements were taken using a Model 1215 Current Meter with the Model 3000 Current Velocity and Stream Discharge Indicator attached to it. Discharge measurements can be taken at many points in the cross section of the canal and totaled to equal the total discharge of that cross section. The number of measurement points depends on the width of the canal at that cross section.

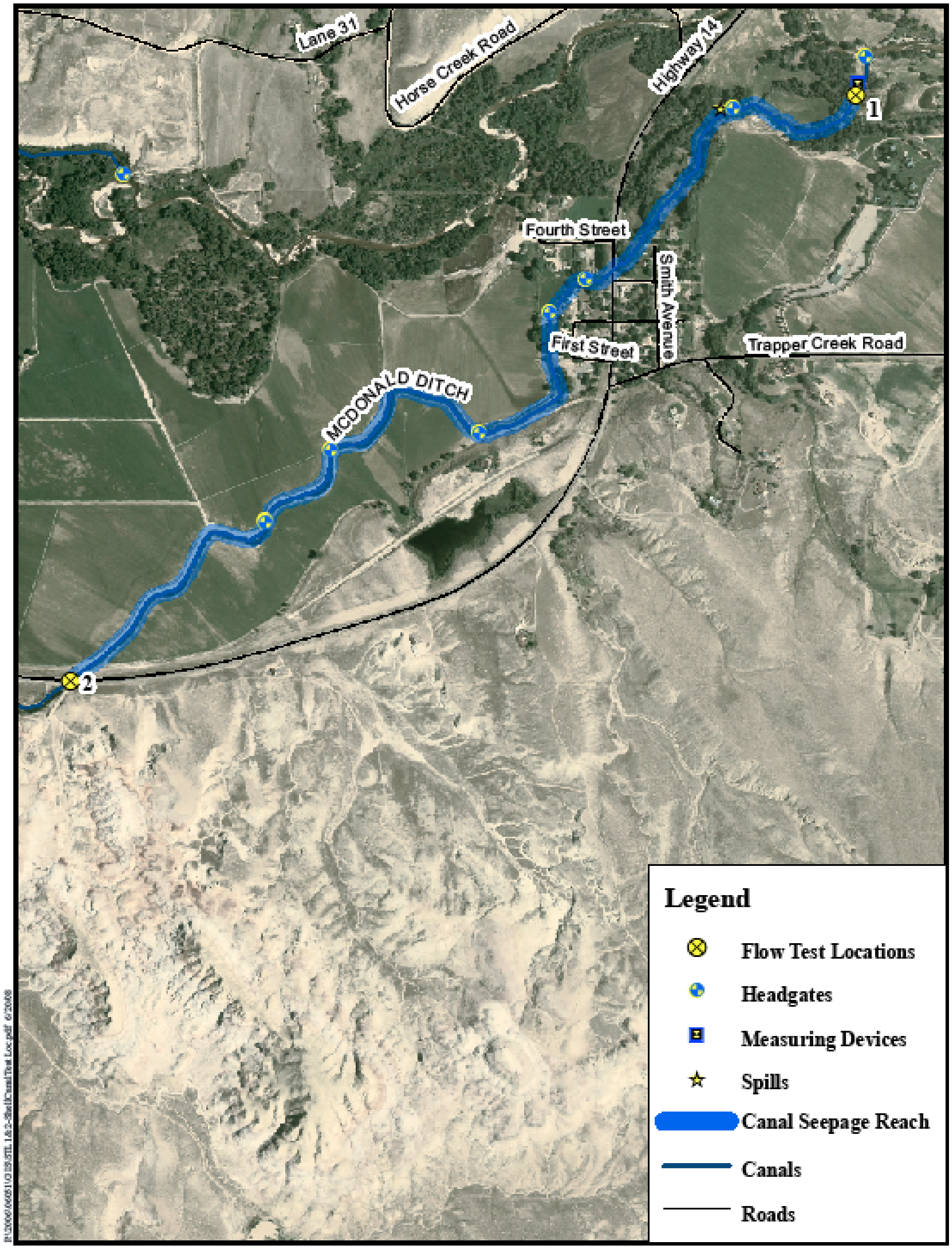
Depending upon the depth of the water, one of two methods was used. For depths greater than 2.5 feet, the Two Point Method was used. The Two Point Method consists of two velocity measurements for each partial area. The first velocity measurement was 20% the total depth from the bottom of the canal, and the second velocity measurement was 80% the total depth from the bottom of the canal. The 20% velocity and 80% velocity were averaged for each partial area. For depths 2.5 feet or less, the Six-Tenths Method was used. One velocity measurement for each partial area was taken at 60% the total depth from the bottom of the canal.

To calibrate the equipment, the first measurement cross section was taken at the McDonald Ditch/Shell Canal Parshall Flume just downstream of the radial gate at Shell Creek The Parshall Flume was measuring approximately 90 cfs and the current meter measured a discharge of 91.7 cfs. This measurement verified that the discharge equipment was calibrated to the field conditions.

Engineering Associates spent several days in July 2007 riding along the McDonald Ditch/Shell Canal access road to find locations that appeared to have water loss due to seepage. Measurements were taken at ten locations. Flow data is presented in Appendix L. The first location was at the Parshall Flume at the head end and the last location was at the downstream side of the siphon located upstream of the Shell Tunnel. After reviewing our data, we determined that there was not an unusually high seepage loss for unlined canals and stopped taking discharge measurements. One should note that if there are reaches of earthen canal in sandy and shale-type soils, the seepage rates will be higher. Figure 6.2.3.1 through Figure 6.2.3.4 show the measurement locations.

Several miles downstream of the 10th location, there is the bottom of a small drainage on the south side of Shell Canal that has cattails and standing water. At first glance, this reach of canal appears to be losing a large amount of water to seepage. However after further investigation, the canal both upstream and downstream was “brim-full” with irrigation water and the water at the bottom of the drainage is standing still and not flowing. This location is the low point in the drainage and while there is some seepage into the wetland area during charging of the canal in April, it does appear to find hydraulic equilibrium after the soils are completely saturated. Again, this reach of canal would need to be concrete lined to stop the seepage into the adjacent wetland.

Photo 6.2.3.1: Flow measurement of canal cross section



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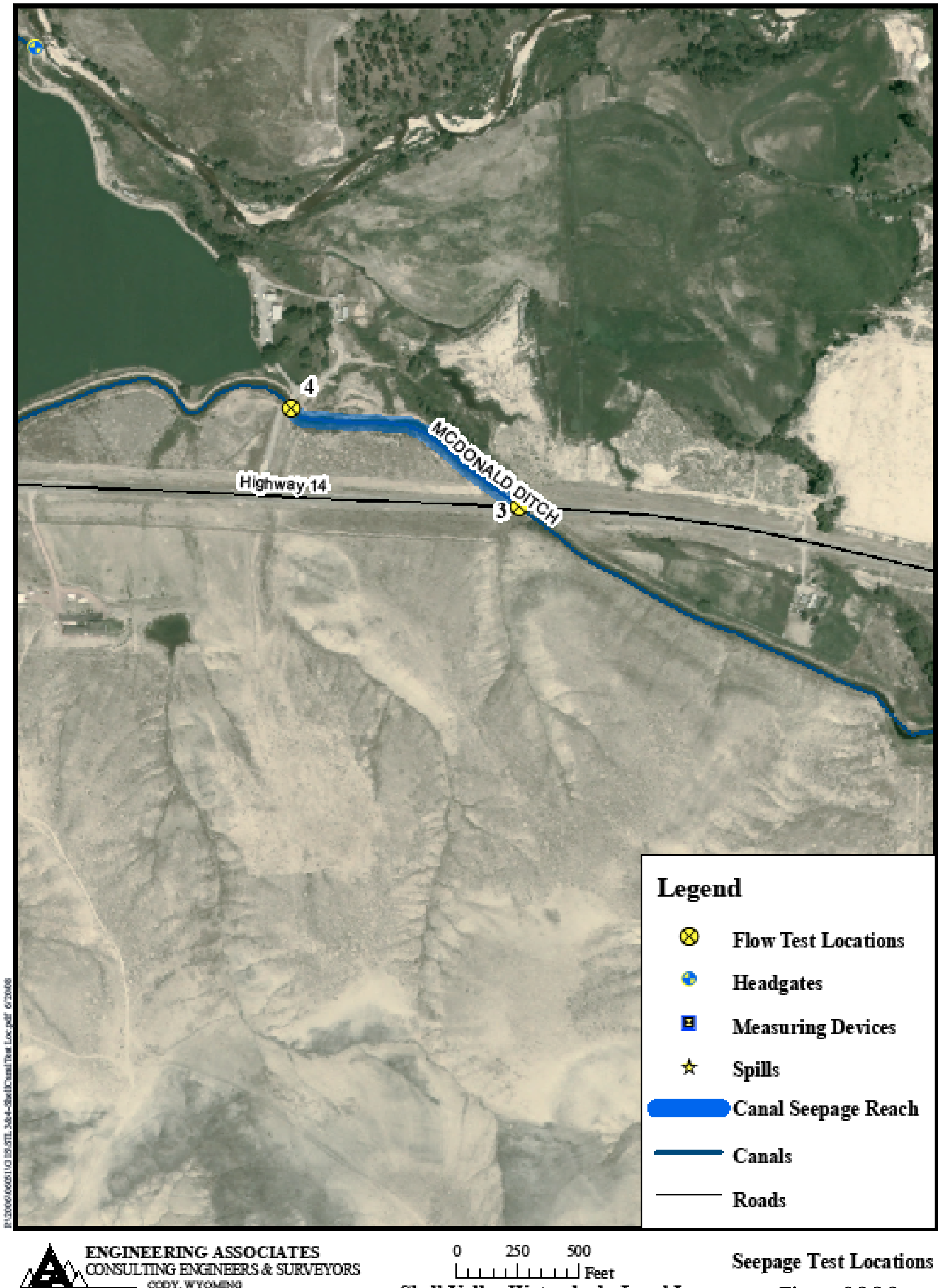
CONSULTING ENGINEERS & SURVEYORS
CODY, WYOMING

Shell Valley Watershed - Level I

Seepage Test Locations

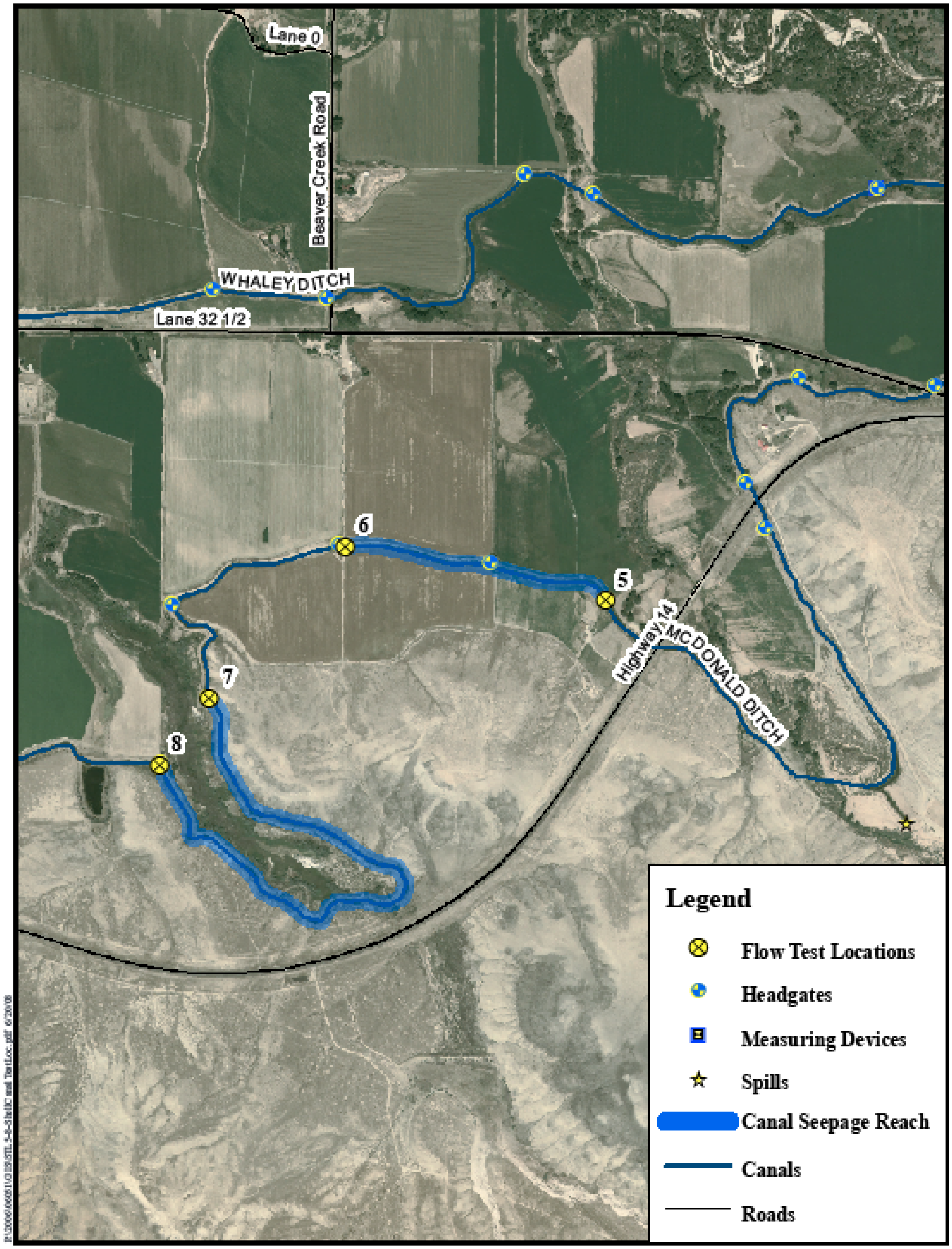
Figure 6.2.3.1



Shell Valley Watershed - Level I

Seepage Test Locations

Figure 6.3.2.2



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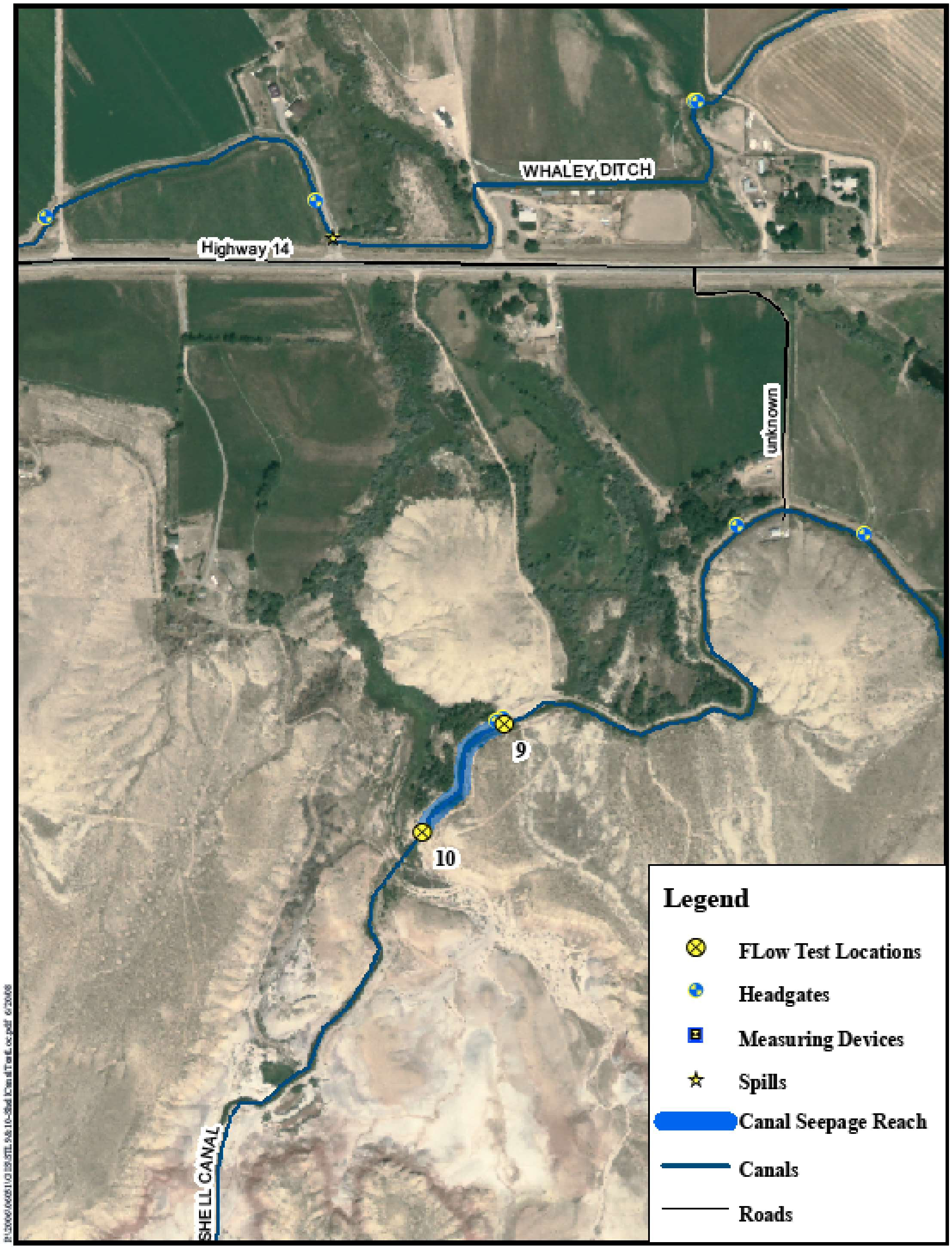
0 500 1,000 Feet

Shell Valley Watershed - Level I

Seepage Test Locations
Figure 6.3.2.3



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0 250 500 Feet

Shell Valley Watershed - Level I

Seepage Test Locations

Figure 6.3.2.4

Photo 6.2.3.1: Example of seepage area

A bentonite lining was placed between Locations 3 and 4. While lining the ditch with bentonite does retard water seepage, it will not stop water seepage. Also, if livestock punctures the liner during the off-season and it is not repaired, then water will find this puncture and seep out through the hole in the bentonite.

For an inexpensive and temporary repair, bentonite would be a viable alternative. However, to stop seepage completely, a concrete liner or pipe should be installed. This alternative is very costly and the ditch companies may want to use their money to replace aging structures.

Measurements of the Porter Ditch were anticipated however, after driving along the Porter Ditch, it was determined that the velocity was much too slow to get an accurate reading. Due to the slow velocity in the Porter Ditch, it is understandable why there is seepage loss. The Porter Ditch essentially acts as a small reservoir and will continue to experience seepage losses as well as evaporation losses. The best way to eliminate seepage losses and evaporation losses in the Porter Ditch is to install pipe. Any designs to install pipe in Porter Ditch will need to factor in the amount of moss buildup the ditch has historically experienced.

6.3 CONSTRUCTION COSTS FOR STRUCTURE REPLACEMENTS

Engineering Associates prepared 2010 construction costs and conceptual designs for a head gate, ramp flume, check structure, weir, and spill. These structures will be constructed of concrete and rebar. For estimation purposes, these estimates were prepared as contractor-bid estimates. The cost of constructing these individual structures falls under the Small Water Project Program. The conceptual designs are located in Appendix N. This program allows assessment districts to apply for these funds. Table 6.3.1 shows the total construction cost for each private irrigation company in 2010 costs. Construction Costs in Table 6.2.2 show the ten replacement groups.

The higher group rating indicates a lower replacement priority. The lower rating indicates a higher replacement priority. The replacement schedule will be highly dependent upon the desire of the private ditch companies to initiate improvements. Thus, it is possible for an active ditch company to initiate improvements on structures rated a 4 before another group initiates improvements on structures rated a 1.

Shell Canal has a substantial amount of structures rated as 5 and 8 which should be evaluated by ditch staff to determine which structures could be ranked a ranked a 6 or 9, respectively, to distribute improvements over time.

Table 6.3.1

2010 Construction Cost Totals for Rating Category

Irrigation Company	Rating 1	Rating 2	Rating 3	Rating 4	Rating 5	Rating 6	Rating 7	Rating 8	Rating 9	Rating 10	Total*
Arthur Mason Ditch		$ 11,564.36									$ 11,600
Beaver Ditch	$ 12,044.34	$ 12,044.34					$ 11,564.36	$ 11,564.36			$ 47,300
Calvin Ditch								$ 11,564.36			$ 11,600
Crain Jenks Ditch								$ 11,564.36			$ 11,600
Crandall Williams Ditch					$ 11,564.36						$ 11,600
Davis Ditch				$ 11,564.36							$ 11,600
Ewen Reservoir	$ 11,564.36										$ 11,600
Friese Ditch	$ 46,257.44				$ 19,287.63			$ 46,257.44			$ 111,900
Hatten Ditch					$ 12,044.34			$ 23,608.70			$ 35,700
High Line Ditch					$ 23,128.72			$ 30,851.99			$ 54,000
Howe Ditch	$ 11,564.36										$ 11,600
Kenyon Ditch		$ 11,564.36									$ 11,600
Kerschner Ditch								$ 92,514.88			$ 92,600
Leavitt Ditch				$ 11,564.36							$ 11,600
London ditch				$ 11,564.36							$ 11,600
Loveland Ditch	$ 11,564.36			$ 7,713.59							$ 19,300
McDonald Ditch	$ 11,564.36		$ 11,564.36	$ 11,564.36	$ 76,032.84	$ 50,120.25	$ 57,821.80	$ 92,514.88		$ 73,077.42	$ 384,300
Nathan Ditch								$ 11,564.36			$ 11,600
Pense Ditch		$ 11,564.36									$ 11,600
Porter Canal	$ 11,564.36				$ 66,025.05	$ 15,427.17	$ 23,128.72	$ 23,128.72	$ 11,564.36	$ 11,564.36	$ 162,500
Sabin Brown Ditch	$ 70,826.10			$ 23,128.72							$ 94,000
Shell Canal	$ 135,555.73	$ 86,637.24	$ 75,072.88	$ 75,072.88	$ 274,066.90	$ 88,497.27	$ 69,195.24	$ 172,701.74		$ 17,251.08	$ 994,100
Shell Canal North Bench	$ 11,564.36	$ 11,564.36			$ 46,066.52			$ 23,128.72			$ 92,400
Thompson Lateral		$ 11,564.36			$ 35,173.06			$ 23,608.70			$ 70,400
Trout Ditch								$ 11,564.36			$ 11,600
Whaley Ditch	$ 11,564.36	$ 40,379.80	$ 35,173.06	$ 23,128.72	$ 12,044.34	$ 23,140.76		$ 94,360.51		$ 11,564.36	$ 251,400

* Totals were rounded up to the hundred dollars.

Table 6.3.2 Structure Replacement Schedule & Construction Costs							
Rating	**Ditch Name**	**Structure Description**	**Miles from Beginning of Ditch**	**Point No.**	**2010 Total Construction Cost**	**Individual Ditch Company 2010 Cost**	**Ditch Company**
1	Ewen Reservoir	Head Gate	0.0	663	$ 11,564.36	$ 11,564.36	Ewen Reservoir
1	Beaver Ditch	Flume	0.2	571	$ 12,044.34	$ 12,044.34	Beaver Ditch
1	Friese Ditch	Head Gate	2.1	532	$ 11,564.36		
1	Friese Ditch	Head Gate	0.2	534	$ 11,564.36		
1	Friese Ditch	Head Gate	0.3	536	$ 11,564.36		
1	Friese Ditch	Head Gate	0.3	536	$ 11,564.36	$ 46,257.44	Friese Ditch
1	Howe Ditch	Head Gate	0.0	654	$ 11,564.36	$ 11,564.36	Howe Ditch
1	Loveland Ditch	Head Gate (Main)	0.0	662	$ 11,564.36	$ 11,564.36	Loveland Ditch
1	McDonald Ditch	Head Gate	0.3	3936	$ 11,564.36	$ 11,564.36	McDonald Ditch
1	Porter Canal	Head Gate	1.6	420	$ 11,564.36	$ 11,564.36	Porter Canal
1	Sabin Brown Ditch	Flume	0.3	583	$ 12,044.34		
1	Sabin Brown Ditch	Flume	0.7	610	$ 12,044.34		
1	Sabin Brown Ditch	Flume	0.9	618	$ 12,044.34		
1	Sabin Brown Ditch	Head Gate	1.1	628	$ 11,564.36		
1	Sabin Brown Ditch	Head Gate	1.3	634	$ 11,564.36		
1	Sabin Brown Ditch	Head Gate	1.4	640	$ 11,564.36	$ 70,826.10	Sabin Brown Ditch
1	Shell Canal	Spill	10.9	254	$ 19,287.63		
1	Shell Canal	Spill	18.2	265	$ 19,287.63		
1	Shell Canal	Head Gate 59	24.0	275	$ 11,564.36		
1	Shell Canal	Head Gate 65	27.4	284	$ 11,564.36		
1	Shell Canal	Spill	28.4	292	$ 19,287.63		
1	Shell Canal	Check Structure	29.7	339	$ 21,499.88		
1	Shell Canal	Check Structure	30.5	351	$ 21,499.88		
1	Shell Canal	Head Gate 91	30.5	351	$ 11,564.36	$ 135,555.73	Shell Canal
1	Shell Canal North Branch	Head Gate	0.4	376	$ 11,564.36	$ 11,564.36	Shell Canal North Bench
1	Whaley Ditch	Head Gate	7.6	510	$ 11,564.36	$ 11,564.36	Whaley Ditch
				Total Cost Rank 1	**$ 345,634.13**		

Table 6.3.2
Structure Replacement Schedule & Construction Costs

Rating	Ditch Name	Structure Description	Miles from Beginning of Ditch	Point No.	2010 Total Construction Cost	Individual Ditch Company 2010 Cost	Ditch Company
2	Arthur Mason Ditch	Head Gate (Main)	0.0	664	$ 11,564.36	$ 11,564.36	Arthur Mason Ditch
2	Beaver Ditch	Flume	0.3	574	$ 12,044.34		
2	Beaver Ditch	Head Gate	0.6	575	$ 11,564.36		
2	Beaver Ditch	Head Gate	0.8	576	$ 11,564.36		
2	Beaver Ditch	Head Gate	0.2	572-573	$ 11,564.36	$ 46,737.42	Beaver Ditch
2	Kenyon Ditch	Head Gate (Main)	0.0	665	$ 11,564.36	$ 11,564.36	Kenyon Ditch
2	Pense Ditch	Head Gate (Main)	0.0	553	$ 11,564.36	$ 11,564.36	Pense Ditch
2	Sabin Brown Ditch	Head Gate	0.0	579	$ 11,564.36		
2	Sabin Brown Ditch	Head Gate	0.1	586	$ 11,564.36		
2	Sabin Brown Ditch	Head Gate	0.7	609	$ 11,564.36		
2	Sabin Brown Ditch	Head Gate	1.1	627	$ 11,564.36	$ 46,257.44	Sabin Brown Ditch
2	Shell Canal	Head Gate 48	11.5	252	$ 11,564.36		
2	Shell Canal	Head Gate 54	21.8	261	$ 11,564.36		
2	Shell Canal	Head Gate 60	25.4	277	$ 11,564.36		
2	Shell Canal	Head Gate 61	26.1	279	$ 11,564.36		
2	Shell Canal	Head Gate 66	27.6	285	$ 11,564.36		
2	Shell Canal	Head Gate 67	27.7	286	$ 11,564.36		
2	Shell Canal	Check Structure	30.6	354	$ 17,251.08	$ 86,637.24	Shell Canal
2	Shell Canal North Branch	Head Gate	NA	377	$ 11,564.36	$ 11,564.36	Shell Canal North Branch
2	Thompson Lateral	Head Gate	4.3	518	$ 11,564.36	$ 11,564.36	Thompson Lateral
2	Whaley Ditch	Check Structure	0.9	460	$ 17,251.08		
2	Whaley Ditch	Head Gate	5.3	491	$ 11,564.36		
2	Whaley Ditch	Head Gate	7.6	508	$ 11,564.36	$ 40,379.80	Whaley Ditch
				Total Cost Rank 2	**$ 277,833.70**		

Table 6.3.2
Structure Replacement Schedule & Construction Costs

Rating	Ditch Name	Structure Description	Miles from Beginning of Ditch	Point No.	2010 Total Construction Cost	Individual Ditch Company 2010 Cost	Ditch Company
3	McDonald Ditch	Head Gate	1.5	204	$ 11,564.36	$ 11,564.36	McDonald Ditch
3	Shell Canal	Head Gate 52	19.6	263	$ 11,564.36		
3	Shell Canal	Head Gate 68	27.7	287	$ 11,564.36		
3	Shell Canal	Head Gate 70	28.2	289	$ 11,564.36		
3	Shell Canal	Head Gate 76	28.9	303	$ 11,564.36		
3	Shell Canal	Check Structure	29.8	341	$ 17,251.08		
3	Shell Canal	Head Gate 86	29.8	341	$ 11,564.36	$ 75,072.88	Shell Canal
3	Whaley Ditch	Flume	0.3	467	$ 12,044.34		
3	Whaley Ditch	Head Gate	4.7	488	$ 11,564.36		
3	Whaley Ditch	Head Gate	7.8	511	$ 11,564.36	$ 35,173.06	Whaley Ditch
				Total Cost Rank 3	**$ 121,810.30**		
4	Davis Ditch	Head Gate	0.0	659	$ 11,564.36	$ 11,564.36	Davis Ditch
4	Leavitt Ditch	Head Gate (Main)	0.0	656	$ 11,564.36	$ 11,564.36	Leavitt Ditch
4	London Ditch	Head Gate	0.0	660	$ 11,564.36	$ 11,564.36	London Ditch
4	McDonald Ditch	Head Gate	7.0	225	$ 11,564.36	$ 11,564.36	McDonald Ditch
4	Sabin Brown Ditch	Head Gate	0.6	604	$ 11,564.36		
4	Sabin Brown Ditch	Head Gate	0.9	619	$ 11,564.36	$ 23,128.72	Sabin Brown Ditch
4	Shell Canal	Head Gate	9.9	245	$ 11,564.36		
4	Shell Canal	Head Gate 63	27.1	281	$ 11,564.36		
4	Shell Canal	Check Structure	30.3	350	$ 17,251.08		
4	Shell Canal	Head Gate 90	30.3	350	$ 11,564.36		
4	Shell Canal	Head Gate 92	30.5	353	$ 11,564.36		
4	Shell Canal	Head Gate 89	30.3	349	$ 11,564.36	$ 75,072.88	Shell Canal
4	Whaley Ditch	Head Gate	2.0	449	$ 11,564.36		
4	Whaley Ditch	Head Gate	1.5	455	$ 11,564.36	$ 23,128.72	Whaley Ditch
				Total Cost Rank 4	**$ 167,587.76**		

Table 6.3.2 Structure Replacement Schedule & Construction Costs							
Rating	**Ditch Name**	**Structure Description**	**Miles from Beginning of Ditch**	**Point No.**	**2010 Total Construction Cost**	**Individual Ditch Company 2010 Cost**	**Ditch Company**
5	Crandall Williams Ditch	Head Gate (Main)	0.0	667	$ 11,564.36	$ 11,564.36	Crandall Williams Ditch
5	Friese Ditch	Spill	1.6	528-529	$ 19,287.63	$ 19,287.63	Friese Ditch
5	Hatten Ditch	Flume	NA	388	$ 12,044.34	$ 12,044.34	Hatten Ditch
5	High Line Ditch	Head Gate	NA	404	$ 11,564.36		
5	High Line Ditch	Head Gate	NA	408	$ 11,564.36	$ 23,128.72	High Line Ditch
5	McDonald Ditch	Head Gate	8.4	232	$ 11,564.36		
5	McDonald Ditch	Head Gate	8.5	234	$ 11,564.36		
5	McDonald Ditch	Head Gate	8.6	236	$ 11,564.36		
5	McDonald Ditch	Flume	8.6	238	$ 12,044.34		
5	McDonald Ditch	Check Structure	0.3	3935	$ 17,251.08		
5	McDonald Ditch	Flume	0.0	3943	$ 12,044.34	$ 76,032.84	McDonald Ditch
5	Porter Canal	Flume	0.3	417	$ 12,044.34		
5	Porter Canal	Head Gate	1.3	419	$ 11,564.36		
5	Porter Canal	Head Gate	2.9	427	$ 11,564.36		
5	Porter Canal	Spill	3.5	431	$ 19,287.63		
5	Porter Canal	Head Gate	5.1	438	$ 11,564.36	$ 66,025.05	Porter Canal
5	Shell Canal	Head Gate	9.5	242	$ 11,564.36		
5	Shell Canal	Head Gate	9.9	243	$ 11,564.36		
5	Shell Canal	Head Gate 49	12.0	250	$ 11,564.36		
5	Shell Canal	Head Gate 50	12.5	251	$ 11,564.36		
5	Shell Canal	Head Gate 53	21.5	262	$ 11,564.36		
5	Shell Canal	Head Gate 57	23.4	272	$ 11,564.36		
5	Shell Canal	Head Gate 58	23.9	274	$ 11,564.36		
5	Shell Canal	Head Gate 69	27.9	288	$ 11,564.36		
5	Shell Canal	Flume	28.5	298	$ 12,044.34		
5	Shell Canal	Head Gate 75	28.8	301	$ 11,564.36		
5	Shell Canal	Check Structure	29.6	337	$ 17,251.08		
5	Shell Canal	Head Gate 83	29.6	337	$ 11,564.36		
5	Shell Canal	Flume	29.6	338	$ 12,044.34		
5	Shell Canal	Head Gate 84	29.7	339	$ 11,564.36		
5	Shell Canal	Head Gate 85	29.8	340	$ 11,564.36		
5	Shell Canal	Flume	29.8	342	$ 12,044.34		
5	Shell Canal	Head Gate 87	29.9	343	$ 11,564.36		
5	Shell Canal	Head Gate 88	30.1	344	$ 11,564.36		
5	Shell Canal	Flume	30.1	345	$ 12,044.34		
5	Shell Canal	Flume	30.5	352	$ 12,044.34		
5	Shell Canal	Head Gate	30.8	357	$ 11,564.36		
5	Shell Canal	Head Gate 81	29.4	3952	$ 11,564.36		
5	Shell Canal	Head Gate 82	29.5	3953	$ 11,564.36	$ 274,066.90	Shell Canal
5	Shell Canal North Branch	Head Gate	0.3	373	$ 11,564.36		
5	Shell Canal North Branch	Check Structure	0.4	376	$ 17,251.08		
5	Shell Canal North Branch	Check Structure	NA	377	$ 17,251.08	$ 46,066.52	Shell Canal North Branch
5	Thompson Lateral	Head Gate 94	1.4	266	$ 11,564.36		
5	Thompson Lateral	Head Gate	4.4	519	$ 11,564.36		
5	Thompson Lateral	Flume	4.6	520	$ 12,044.34	$ 35,173.06	Thompson Lateral
5	Whaley Ditch	Flume	6.0	499	$ 12,044.34	$ 12,044.34	Whaley Ditch
				Total Cost Rank 5	**$ 575,433.77**		

Table 6.3.2
Structure Replacement Schedule & Construction Costs

Rating	Ditch Name	Structure Description	Miles from Beginning of Ditch	Point No.	2010 Total Construction Cost	Individual Ditch Company 2010 Cost	Ditch Company
6	McDonald Ditch	Head Gate	1.0	200	$ 11,564.36		
6	McDonald Ditch	Head Gate	3.8	211	$ 11,564.36		
6	McDonald Ditch	Head Gate	8.6	237	$ 11,564.36		
6	McDonald Ditch	Head Gate (Main Diversion)	0.0	3944	$ 7,713.59		
6	McDonald Ditch	Head Gate	7.6	227-229	$ 7,713.59	$ 50,120.25	McDonald Ditch
6	Porter Canal	Head Gate	2.0	422	$ 7,713.59		
6	Porter Canal	Head Gate	3.8	433	$ 7,713.59	$ 15,427.17	Porter Canal
6	Shell Canal	Head Gate (Thompson Lateral)	13.9	260	$ 7,713.59		
6	Shell Canal	Head Gate 56	22.4	268	$ 7,713.59		
6	Shell Canal	Head Gate 56	2.3	270	$ 7,713.59		
6	Shell Canal	Check Structure	25.4	278	$ 17,251.08		
6	Shell Canal	Head Gate 64	27.2	282	$ 7,713.59		
6	Shell Canal	Check Structure	27.4	284	$ 17,251.08		
6	Shell Canal	Head Gate 71	28.3	290	$ 7,713.59		
6	Shell Canal	Head Gate 74	28.7	300	$ 7,713.59		
6	Shell Canal	Head Gate	28.4	294-295	$ 7,713.59	$ 88,497.27	Shell Canal
6	Whaley Ditch	Head Gate	23.8	441	$ 7,713.59		
6	Whaley Ditch	Head Gate	1.3	457	$ 7,713.59		
6	Whaley Ditch	Head Gate	5.0	489	$ 7,713.59	$ 23,140.76	Whaley Ditch
				Total Cost Rank 6	**$ 177,185.45**		
7	Beaver Ditch	Head Gate (Main)	0.0	552	$ 11,564.36	$ 11,564.36	Beaver Ditch
7	McDonald Ditch	Head Gate	3.4	208	$ 11,564.36		
7	McDonald Ditch	Head Gate	5.1	218	$ 11,564.36		
7	McDonald Ditch	Head Gate	7.5	226	$ 11,564.36		
7	McDonald Ditch	Head Gate	8.0	231	$ 11,564.36		
7	McDonald Ditch	Head Gate	9.4	241	$ 11,564.36	$ 57,821.80	McDonald Ditch
7	Porter Canal	Head Gate	0	416	$ 11,564.36		
7	Porter Canal	Head Gate	1.8	421	$ 11,564.36	$ 23,128.72	Porter Canal
7	Shell Canal	Head Gate 51	13.0	256	$ 11,564.36		
7	Shell Canal	Check Structure	27.2	283	$ 17,251.08		
7	Shell Canal	Check Structure	27.6	285	$ 17,251.08		
7	Shell Canal	Head Gate 72	28.3	291	$ 11,564.36		
7	Shell Canal	Head Gate 80	29.4	3951	$ 11,564.36	$ 69,195.24	Shell Canal
				Total Cost Rank 7	**$ 161,710.12**		

Table 6.3.2 Structure Replacement Schedule & Construction Costs							
Rating	**Ditch Name**	**Structure Description**	**Miles from Beginning of Ditch**	**Point No.**	**2010 Total Construction Cost**	**Individual Ditch Company 2010 Cost**	**Ditch Company**
8	Beaver Ditch	Head Gate	0.8	577	$ 11,564.36	$ 11,564.36	Beaver Ditch
8	Calvin Ditch	Head Gate	0.0	653	$ 11,564.36	$ 11,564.36	Calvin Ditch
8	Crain Jenks Ditch	Head Gate	NA	381	$ 11,564.36	$ 11,564.36	Crain Jenks Ditch
8	Friese Ditch	Head Gate (Main)	0.0	533	$ 11,564.36		
8	Friese Ditch	Head Gate	0.4	539	$ 11,564.36		
8	Friese Ditch	Head Gate	0.6	540	$ 11,564.36		
8	Friese Ditch	Head Gate	0.7	541	$ 11,564.36	$ 46,257.44	Friese Ditch
8	Hatten Ditch	Head Gate	NA	387	$ 11,564.36		
8	Hatten Ditch	Flume	NA	392	$ 12,044.34	$ 23,608.70	Hatten Ditch
8	High Line Ditch	Head Gate	NA	407	$ 11,564.36		
8	High Line Ditch	Spill	NA	411	$ 19,287.63	$ 30,851.99	High Line Ditch
8	Kerschner Ditch	Head Gate (Main)	0.0	555	$ 11,564.36		
8	Kerschner Ditch	Head Gate	0.3	559	$ 11,564.36		
8	Kerschner Ditch	Head Gate	0.6	561	$ 11,564.36		
8	Kerschner Ditch	Head Gate	0.7	562	$ 11,564.36		
8	Kerschner Ditch	Head Gate	1.0	563	$ 11,564.36		
8	Kerschner Ditch	Head Gate	1.0	564	$ 11,564.36		
8	Kerschner Ditch	Head Gate	1.4	565	$ 11,564.36		
8	Kerschner Ditch	Head Gates (3)	1.9	568-570	$ 11,564.36	$ 92,514.88	Kerschner Ditch
8	McDonald Ditch	Head Gate 8	1.3	202	$ 11,564.36		
8	McDonald Ditch	Head Gate	1.5	205	$ 11,564.36		
8	McDonald Ditch	Head Gate	2.0	206	$ 11,564.36		
8	McDonald Ditch	Head Gate	3.6	209	$ 11,564.36		
8	McDonald Ditch	Head Gate	3.9	210	$ 11,564.36		
8	McDonald Ditch	Head Gate	5.4	219	$ 11,564.36		
8	McDonald Ditch	Head Gate	5.6	221	$ 11,564.36		
8	McDonald Ditch	Head Gate	5.8	222	$ 11,564.36	$ 92,514.88	McDonald Ditch
8	Nathan Ditch	Head Gate	NA	380	$ 11,564.36	$ 11,564.36	Nathan Ditch
8	Porter Canal	Head Gate	0.5	418	$ 11,564.36		
8	Porter Canal	Head Gate	3.7	432	$ 11,564.36	$ 23,128.72	Porter Canal

Table 6.3.2 Structure Replacement Schedule & Construction Costs							
Rating	**Ditch Name**	**Structure Description**	**Miles from Beginning of Ditch**	**Point No.**	**2010 Total Construction Cost**	**Individual Ditch Company 2010 Cost**	**Ditch Company**
8	Shell Canal	Check Structure	22.4	269	$ 17,251.08		
8	Shell Canal	Check Structure	22.9	271	$ 17,251.08		
8	Shell Canal	Check Structure	23.4	273	$ 17,251.08		
8	Shell Canal	Check Structure	24.0	276	$ 17,251.08		
8	Shell Canal	Head Gate 62	26.6	280	$ 11,564.36		
8	Shell Canal	Check Structure	26.6	280	$ 17,251.08		
8	Shell Canal	Check Structure	27.9	288	$ 17,251.08		
8	Shell Canal	Check Structure	28.4	293	$ 17,251.08		
8	Shell Canal	Head Gate 73	28.6	299	$ 11,564.36		
8	Shell Canal	Check Structure	28.8	301	$ 17,251.08		
8	Shell Canal	Head Gate	29.2	3948	$ 11,564.36	$ 172,701.74	Shell Canal
8	Shell Canal North Branch	Head Gate	NA	378	$ 11,564.36		
8	Shell Canal North Branch	Head Gate	NA	379	$ 11,564.36	$ 23,128.72	Shell Canal North Branch
8	Thompson Lateral	Head Gates (3)	3.6	362	$ 11,564.36		
8	Thompson Lateral	Flume	3.7	525	$ 12,044.34	$ 23,608.70	Thompson Lateral
8	Trout Ditch	Head Gate	0.0	655	$ 11,564.36	$ 11,564.36	Trout Ditch
8	Whaley Ditch	Head Gate	1.9	452	$ 11,564.36		
8	Whaley Ditch	Head Gate	1.8	453	$ 11,564.36		
8	Whaley Ditch	Check Structure	1.5	454	$ 17,251.08		
8	Whaley Ditch	Head Gate	0.9	461	$ 11,564.36		
8	Whaley Ditch	Head Gates (Main)	0.0	469	$ 11,564.36		
8	Whaley Ditch	Head Gate	4.5	472	$ 11,564.36		
8	Whaley Ditch	Spill	6.0	496	$ 19,287.63	$ 94,360.51	Whaley Ditch
				Total Cost Rank 8	**$ 680,498.08**		

Table 6.3.2 Structure Replacement Schedule & Construction Costs							
Rating	**Ditch Name**	**Structure Description**	**Miles from Beginning of Ditch**	**Point No.**	**2010 Total Construction Cost**	**Individual Ditch Company 2010 Cost**	**Ditch Company**
9	Porter Canal	Head Gate	3.0	430	11564.36	$ 11,564.36	Porter Canal
				Total Cost Rank 9	**$ 11,564.36**		
10	McDonald Ditch	Check Structure	1.0	201	$ 17,251.08		
10	McDonald Ditch	Check Structure	8.0	230	$ 17,251.08		
10	McDonald Ditch	Spill	8.0	230	$ 19,287.63		
10	McDonald Ditch	Spill	8.0	230	$ 19,287.63	$ 73,077.42	McDonald Ditch
10	Porter Canal	Head Gate	5.1	439	$ 11,564.36	$ 11,564.36	Porter Canal
10	Shell Canal	Check Structure	18.2	264	$ 17,251.08	$ 17,251.08	Shell Canal
10	Whaley Ditch	Head Gate	2.4	448	$ 11,564.36	$ 11,564.36	Whaley Ditch
				Total Cost Rank 10	**$ 113,457.23**		

There are several reaches of ditches that could have concrete lining installed to eliminate seepage losses. For this study, a construction cost estimate is provided for McDonald Ditch between Location 7 and 8 to provide SVWID with an idea of construction cost. This reach of canal is approximately 5,200 feet long with a cross section width of 14' and a depth of 4'. This construction cost estimate can be easily proportioned to any length, width and depth to provide SVWID with a construction cost estimate for Level III funding.

The installation locations of concrete lining need to be determined by each individual irrigation company. Engineering Associates suggests placing concrete lining in the ditch reaches that traverse through rock/gravel soils since these are naturally high seepage areas and are carrying a large amount of irrigation water. The next reaches would be those that have an abundant growth of green grasses and cattails. After these areas have been constructed, the irrigation companies should begin at the downstream end of the systems and work upstream. The completion of these improvements depends upon the ability of the private irrigation company's ability to repay their loans.

For the ditch reaches that carry less than 20 cfs, PVC pipe could possibly be installed. Engineering Associates has found that on flatter slopes, 30" diameter PVC pipe could convey 20 cfs. As the flows decrease so will the pipe diameter. When installing PVC pipe, concrete diversion boxes with head gates are also installed for the turn outs. Engineering Associates has provided a construction cost estimate for 5,000 linear feet of 30" PVC pipe on, and for 5,000 linear feet of 18" PVC pipe. Both construction cost estimates include 3 diversion boxes and 3 head gates. It is important to note that downsizing the diameter of pipe to save construction costs is not a good idea. Usually, when the pipe is downsized, the irrigators at the end of the pipe cannot receive their full allotment of irrigation water. The only way to "fix" this problem is for a parallel pipe to be placed next to the downsized pipe. This requires retrofitting of the new diversion boxes to receive the parallel pipe. The cost of retrofitting can be as much as 80% of the original construction cost.

It is critical the irrigation companies review this list and determine which structures they want to replace.

Reinforced concrete pipe could be substituted for a concrete lined section. As a comparison, the concrete lined section between Seepage test Locations 7 and 8 would need 42" RCP if this portion were to be buried. The benefit from RCP is that it would eliminate evaporation losses and is a less expensive alternative. The RCP system would make it difficult for irrigators who use pumps in the canal. The pumps would need to be located at a concrete turnout box, or a special turnout box would need to be constructed at each pump location thus increasing the construction costs.

The following pages show the Opinion of Probable Construction Cost estimates projected in 2010 dollars.

Concrete Lining between Location 7 and 8 - McDonald Ditch ~ 5,200 lf

Width = 14 feet; Depth = 4 feet

Opinion of Probable Costs

Cost of Project Components:	Qty	Unit	Cost	
Mobilization	1	LS	$ 100,000.00	
Contract Bond	1	LS	$ 209,650.00	
Excavation of Wet Material	10000	CY	$ 150,000.00	
Concrete Lining	1450	CY	$ 1,087,500.00	
Rebar for Concrete Lining	153000	LBS	$ 459,000.00	
Crushed Fill	10000	CY	$ 300,000.00	
Total Cost of Project Components			$ 2,306,150.00	
Consultant Fees:				
Preparation of Final Design and Specifications (10%)				$ 291,727.98
Permitting and Mitigation (4%)				$ 116,691.19
Legal Fees (2%)				$ 58,345.60
Acquisition of Access and Rights of Way (3%)				$ 87,518.39
Total Cost of Project Components			$ 2,306,150.00	
Construction Costs Subtotal #1			$ 2,306,150.00	
Engineering Costs = CCS#1 x 10%			$ 230,615.00	
Subtotal #2			$ 2,536,765.00	
Contingency = Subtotal #2 x 15%			$ 380,514.75	
Construction Cost Total				$ 2,917,279.75
Project Cost Total 2008				$ 3,179,834.93
Project Cost Total 2010				$ 3,505,768.01
Shell Valley Watershed Improvement District			33%	$ 1,156,903.44
WWDC			67%	$ 2,348,864.57

48" diameter RCP between Location 7 and 8 - McDonald Ditch ~ 5,200 lf

Opinion of Probable Costs

Cost of Project Components:	Qty	Unit	Cost
Mobilization	1	LS	$ 100,000.00
Contract Bond	1	LS	$ 101,827.12
48" RCP Pipe	5200	LF	$ 624,000.00
Bedding	2400	CY	$ 74,976.00
Compacted Backfill	8500	CY	$ 55,250.00
Diversion Box w/ Head Gate	2	EA	$ 11,000.00
Appurtenances	1	LS	$ 153,045.20
Total Cost of Project Components			$ 1,120,098.32

Note: Large diameter fittings are included in pipe price. Appurtenances include removal of existing structures, removal of silty soils, placement of foundation materials, and any potential problems encountered during underground construction.

Consultant Fees:		
Preparation of Final Design and Specifications (10%)		$ 141,692.44
Permitting and Mitigation (4%)		$ 56,676.97
Legal Fees (2%)		$ 28,338.49
Acquisition of Access and Rights of Way (3%)		$ 42,507.73
Total Cost of Project Components	$ 1,120,098.32	
Construction Costs Subtotal #1	$ 1,120,098.32	
Engineering Costs = CCS#1 x 10%	$ 112,009.83	
Subtotal #2	$ 1,232,108.15	
Contingency = Subtotal #2 x 15%	$ 184,816.22	
Construction Cost Total		$ 1,416,924.37
Project Cost Total 2008		$ 1,544,447.57
Project Cost Total 2010		$ 1,702,753.44

Shell Valley Watershed Improvement District	33%	$ 561,908.64
WWDC	67%	$ 1,140,844.81

30" PVC Pipe ~5,200 lf
Opinion of Probable Costs

Cost of Project Components:	Qty	Unit	Cost
Mobilization	1	LS	$ 100,000.00
Contract Bond	1	LS	$ 91,816.00
30" PVC Pipe	5200	LF	$ 624,000.00
Bedding	5200	LF	$ 46,800.00
Diversion Box w/ Head Gate	2	EA	$ 11,000.00
Appurtenances	1	LS	$ 136,360.00
Total Cost of Project Components			$ 1,009,976.00

Note: Large diameter fittings are included in pipe price. Appurtenances include removal of e
removal of silty soils, placement of foundation materials, and any potential problems er
underground construction.

Consultant Fees:

Preparation of Final Design and Specifications (10%)
Permitting and Mitigation (4%)
Legal Fees (2%)
Acquisition of Access and Rights of Way (3%)

Total Cost of Project Components	$ 1,009,976.00
Construction Costs Subtotal #1	$ 1,009,976.00
Engineering Costs = CCS#1 x 10%	$ 100,997.60
Subtotal #2	$ 1,110,973.60
Contingency = Subtotal #2 x 15%	$ 166,646.04
Construction Cost Total	$ 1,277,619.64
Project Cost Total 2008	$ 1,392,605.41
Project Cost Total 2010	$ 1,535,347.46

Shell Valley Watershed Improvement District	33%
WWDC	67%

18" PVC Pipe ~5,200 lf
Opinion of Probable Costs

Cost of Project Components:	Qty	Unit	Cost
Mobilization	1	LS	$ 100,000.00
Contract Bond	1	LS	$ 37,528.00
18" PVC Pipe	5200	LF	$ 171,600.00
Bedding	5200	LF	$ 46,800.00
Diversion Box w/ Head Gate	2	EA	$ 11,000.00
Appurtenances	1	LS	$ 45,880.00
Total Cost of Project Components			$ 412,808.00

Note: Large diameter fittings are included in pipe price. Appurtenances include removal of e
removal of silty soils, placement of foundation materials, and any potential problems er
underground construction.

Consultant Fees:
Preparation of Final Design and Specifications (10%)
Permitting and Mitigation (4%)
Legal Fees (2%)
Acquisition of Access and Rights of Way (3%)

Total Cost of Project Components	$ 412,808.00
Construction Costs Subtotal #1	$ 412,808.00
Engineering Costs = CCS#1 x 10%	$ 41,280.80
Subtotal #2	$ 454,088.80
Contingency = Subtotal #2 x 15%	$ 68,113.32
Construction Cost Total	$ 522,202.12
Project Cost Total 2008	$ 569,200.31
Project Cost Total 2010	$ 627,543.34

Shell Valley Watershed Improvement District	33%
WWDC	67%

Head Gate Reconstruction
Opinion of Probable Costs

Cost of Project Components:	Qty	Unit	Cost	
Mobilization	1	LS	$ 1,050.00	
Contract Bond	1	LS	$ 450.00	
Remove Existing Head Gate	1	LS	$ 525.00	
Head Gate	1	EA	$ 740.00	
Concrete for Head Gate	2	CY	$ 1,480.00	
Rebar for Head Gate	140	LBS	$ 196.00	
Compacted Backfill	15	LF	$ 240.00	
Crushed Fill	1	CY	$ 25.25	
Total Cost of Project Components			$ 4,706.25	
Consultant Fees:				
Preparation of Final Design and Specifications				$ 4,000.00
Permitting and Mitigation (4%)				$ 238.14
Legal Fees (2%)				$ 119.07
Acquisition of Access and Rights of Way (3%)				$ 178.60
Total Cost of Project Components			$ 4,706.25	
Construction Costs Subtotal #1			$ 4,706.25	
Engineering Costs = CCS#1 x 10%			$ 470.63	
Subtotal #2			$ 5,176.88	
Contingency = Subtotal #2 x 15%			$ 776.53	
Construction Cost Total				$ 5,953.41
Project Cost Total 2008				$ 10,489.21
Project Cost Total 2010				$ 11,564.36
Shell Valley Watershed Improvement District			33%	$ 3,816.24
WWDC			67%	$ 7,748.12

Ramp Flume Reconstruction
Opinion of Probable Costs

Cost of Project Components:	Qty	Unit	Cost	
Mobilization	1	LS	$ 1,050.00	
Contract Bond	1	LS	$ 400.00	
Remove Existing Flume	1	LS	$ 525.00	
Concrete for Ramp Flume	2.5	CY	$ 1,850.00	
Rebar for Ramp Flume	100	LBS	$ 140.00	
Compacted Backfill	16	LF	$ 256.00	
Crushed Fill	3	CY	$ 75.75	
Total Cost of Project Components			$ 4,296.75	
Consultant Fees:				
Preparation of Final Design and Specifications				$ 5,000.00
Permitting and Mitigation (4%)				$ 217.42
Legal Fees (2%)				$ 108.71
Acquisition of Access and Rights of Way (3%)				$ 163.06
Total Cost of Project Components			$ 4,296.75	
Construction Costs Subtotal #1			$ 4,296.75	
Engineering Costs = CCS#1 x 10%			$ 429.68	
Subtotal #2			$ 4,726.43	
Contingency = Subtotal #2 x 15%			$ 708.96	
Construction Cost Total				$ 5,435.39
Project Cost Total 2008				$ 10,924.57
Project Cost Total 2010				$ 12,044.34
Shell Valley Watershed Improvement District			33%	$ 3,974.63
WWDC			67%	$ 8,069.71

Check Structure Reconstruction

Opinion of Probable Costs

Cost of Project Components:	Qty	Unit	Cost	
Mobilization	1	LS	$ 1,050.00	
Contract Bond	1	LS	$ 1,000.00	
Remove Existing Check Structure	1	LS	$ 525.00	
Concrete for Check Structure	10	CY	$ 7,400.00	
Rebar for Check Structure	150	LBS	$ 210.00	
Compacted Backfill	16	LF	$ 256.00	
Crushed Fill	3	CY	$ 75.75	
Total Cost of Project Components			$ 10,516.75	
Consultant Fees:				
Preparation of Final Design and Specifications				$ 5,000.00
Permitting and Mitigation (4%)				$ 532.15
Legal Fees (2%)				$ 266.07
Acquisition of Access and Rights of Way (3%)				$ 399.11
Total Cost of Project Components			$ 10,516.75	
Construction Costs Subtotal #1			$ 10,516.75	
Engineering Costs = CCS#1 x 10%			$ 1,051.68	
Subtotal #2			$ 11,568.43	
Contingency = Subtotal #2 x 15%			$ 1,735.26	
Construction Cost Total				$ 13,303.69
Project Cost Total 2008				$ 19,501.02
Project Cost Total 2010				$ 21,499.88
Shell Valley Watershed Improvement District			33%	$ 7,094.96
WWDC			67%	$ 14,404.92

Weir Structure Reconstruction
Opinion of Probable Costs

Cost of Project Components:	Qty	Unit	Cost	
Mobilization	1	LS	$ 1,050.00	
Contract Bond	1	LS	$ 450.00	
Remove Existing Weir Structure	1	LS	$ 525.00	
Concrete for Weir Structure	3	CY	$ 2,220.00	
Rebar for Weir Structure	100	LBS	$ 140.00	
Compacted Backfill	10	LF	$ 160.00	
Crushed Fill	2	CY	$ 50.50	
Total Cost of Project Components			$ 4,595.50	
Consultant Fees:				
Preparation of Final Design and Specifications				$ 5,000.00
Permitting and Mitigation (4%)				$ 232.53
Legal Fees (2%)				$ 116.27
Acquisition of Access and Rights of Way (3%)				$ 174.40
Total Cost of Project Components			$ 4,595.50	
Construction Costs Subtotal #1			$ 4,595.50	
Engineering Costs = CCS#1 x 10%			$ 459.55	
Subtotal #2			$ 5,055.05	
Contingency = Subtotal #2 x 15%			$ 758.26	
Construction Cost Total				$ 5,813.31
Project Cost Total 2008				$ 11,336.51
Project Cost Total 2010				$ 12,498.50
Shell Valley Watershed Improvement District			33%	$ 4,124.50
WWDC			67%	$ 8,373.99

Spill Structure Reconstruction
Opinion of Probable Cost

Cost of Project Components:	Qty	Unit	Cost	
Mobilization	1	LS	$ 1,050.00	
Contract Bond	1	LS	$ 1,000.00	
Remove Existing Spill Structure	1	LS	$ 525.00	
Concrete for Spill Structure	8	CY	$ 5,920.00	
Rebar for Spill Structure	140	LBS	$ 196.00	
Compacted Backfill	20	LF	$ 320.00	
Crushed Fill	2	CY	$ 50.50	
Total Cost of Project Components			$ 9,061.50	
Consultant Fees:				
Preparation of Final Design and Specifications				$ 5,000.00
Permitting and Mitigation (4%)				$ 458.51
Legal Fees (2%)				$ 229.26
Acquisition of Access and Rights of Way (3%)				$ 343.88
Total Cost of Project Components			$ 9,061.50	
Construction Costs Subtotal #1			$ 9,061.50	
Engineering Costs = CCS#1 x 10%			$ 906.15	
Subtotal #2			$ 9,967.65	
Contingency = Subtotal #2 x 15%			$ 1,495.15	
Construction Cost Total				$ 11,462.80
Project Cost Total 2008				$ 17,494.45
Project Cost Total 2010				$ 19,287.63

Shell Valley Watershed Improvement District	33%	$ 6,364.92
WWDC	67%	$ 12,922.71

7.0 SHELL CANAL TUNNEL

Shell Canal Tunnel was visited to assess the condition of the tunnel structurally and to determine the seepage losses caused by the tunnel.

The Shell Canal Tunnel was built in the early 1900's and is constructed of concrete but without the use of steel reinforcement. The Shell Canal Tunnel carries a maximum flow of 70 cfs during peak season and carries enough water to irrigate approximately 3,500 acres. The length of the tunnel is 561 feet from inlet to outlet with approximately 30 to 50 feet of fill over the tunnel. The cross section is in the shape of an upside down "U" which is 6 feet wide by 5.5 feet tall.

This structure has far outlived its useful design life and the concrete has been deteriorating over time. The floor of the tunnel is cracked and is eroding. Any remaining concrete in the floor has become separated from the walls. Below the water line, the existing walls are also deteriorating. These two conditions allow for seepage losses through the tunnel and also contribute to the continued degradation of the tunnel.

The ceiling at the inlet is cracked the entire thickness of the concrete and the ceiling has partially collapsed. The cover over the tunnel has pushed the cracked concrete together and put the concrete into compression which has prevented full collapse of this tunnel. The face of the inlet has failed in some areas impeding flow of water through the inlet. The outlet structure is not in as poor shape as the inlet but the wing walls are cracked and the floor and lower walls are eroded.

Photo 7.0.1: Degrading concrete at tunnel inlet.


Photo 7.0.2: Degrading Concrete at tunnel outlet

Photo 7.0.3: Missing concrete and eroded soil behind concrete.

Photo 7.0.4: Missing tunnel floor.

7.1 SHELL CANAL TUNNEL PROPOSED SOLUTIONS

Due to the current shape of the tunnel and the large fill height over the top, to excavate, and remove and replace the concrete tunnel, it would be extremely expensive and not the best option for the canal company but the costs is included anyway. Following are four (4) options to replace the tunnel. Access to the tunnel is difficult and the contractor may need to build a ramp from the road to the canal upstream of the tunnel.

7.2 63” Diameter “Snap-Tite” HDPE Pipe

This alternative uses a 63” outside diameter HDPE pipe. This pipe has a 59” interior diameter and will be slipped inside the existing tunnel. New inlet and outlet structures would be constructed beyond their existing location and connected to the HDPE pipe. These structures would allow for the smooth transition of the water and prevent water from migrating under the new pipe.

The pipe joints can be ordered in 40’ lengths so they can be trucked to the site. This type of pipe does not require fusing since each joint of pipe can be snapped together before being pushed into the tunnel. This option minimizes the amount of dirt work surrounding the tunnel. Another benefit to this pipe is it has a very smooth surface for water flow and will stop seepage losses through the tunnel. The pipe would transmit approximately 105 cfs.

A high strength grout will need to be injected in the void area between the pipe and tunnel walls. The grout will provide supporting strength to the pipe and the existing tunnel structure to avoid a future collapse of the tunnel. Grouting the voids will also eliminate the possibility of water entering the areas between the pipe and tunnel walls that could potentially damage the improvements. See Sheet D1 in Appendix N for a cross section view of this alternative. Following is a projected total cost for this option.

Shell Canal Tunnel Reconstruction
Opinion of Probable Construction Cost
63" Snap-Tite HDPE Pipe

Cost of Project Componenets:	Qty	Unit	Cost	
Mobilization	1	LS	$ 44,837.62	
Contract Bond	1	LS	$ 39,903.24	
Remove Existing Inlet	1	LS	$ 15,000.00	
Remove Existing Outlet	1	LS	$ 15,000.00	
Excavation	100	CY	$ 1,300.00	
Concrete for Inlet	25	CY	$ 19,293.75	
Rebar for Inlet	1200	LBS	$ 1,500.00	
Concrete for Outlet	25	CY	$ 19,293.75	
Rebar for Outlet	1200	LBS	$ 1,500.00	
63" Snap-tite Pipe	562	LF	$ 215,937.26	
Grout	156	CY	$ 10,920.00	
Concrete Pump Truck	15	DAY	$ 52,500.00	
Compacted Backfill	50	LF	$ 750.00	
Crushed Fill	50	CY	$ 1,200.00	
Other appurtances, as needed	1	LS	$ 66,000.00	
Total Cost of Project Componenets			$504,935.62	
Consultant Fees:				
Preparation of Final Design and Specifications				$ 63,874.36
Permitting and Mitigation (4%)				$ 25,549.74
Legal Fees (2%)				$ 12,774.87
Acquisition of Access and Rights of Way (3%)				$ 19,162.31
Construction Costs Subtotal #1			$ 504,935.62	
Const. Engineering Costs = CCS#1 x 10%			$ 50,493.56	
Subtotal #2			$ 555,429.18	
Contingency = Subtotal #2 x 15%			$ 83,314.38	
Construction Cost Total				$ 638,743.56
Project Cost Total 2008				$ 760,104.84
Project Cost Total 2010				$ 838,015.58
Shell Canal Company (if a legal irrigation district)			33%	$ 276,545.14
WWDC			67%	$ 561,470.44

7.3 54" DIAMETER "SNAP-TITE" PIPE

This alternative uses a 54" outside diameter HDPE pipe. This pipe has a 50" interior diameter and will be slipped inside the existing tunnel and installed in the same manner as the 63" diameter pipe described in Section 7.1. See Sheet D2 in Appendix N for a cross section view of this alternative.

The use of this pipe will provide the same benefits as the larger diameter pipe with respect to installation. However, the allowable flow would decrease to 71 cfs and the inlet and outlet structures would be slightly smaller. Following is a projected cost for this option.

Shell Canal Tunnel Reconstruction
Opinion of Probable Construction Cost
54" Snap-Tite HDPE Pipe

Cost of Project Componenets:	Qty	Unit	Cost
Mobilization	1	LS	$ 44,837.62
Contract Bond	1	LS	$ 34,311.05
Remove Existing Inlet	1	LS	$ 15,000.00
Remove Existing Outlet	1	LS	$ 15,000.00
Excavation	100	CY	$ 1,300.00
Concrete for Inlet	25	CY	$ 19,293.75
Rebar for Inlet	1200	LBS	$ 1,500.00
Concrete for Outlet	25	CY	$ 19,293.75
Rebar for Outlet	1200	LBS	$ 1,500.00
54" Snap-tite Pipe	562	LF	$ 151,335.36
Grout	280	CY	$ 19,600.00
Concrete Pump Truck	15	DAY	$ 52,500.00
Compacted Backfill	50	LF	$ 750.00
Crushed Fill	50	CY	$ 1,200.00
Other appurtances, as needed	1	LS	$ 57,000.00
Total Cost of Project Componenets			$ 434,421.53

Consultant Fees:		
Preparation of Final Design and Specifications		$ 54,954.32
Permitting and Mitigation (4%)		$ 21,981.73
Legal Fees (2%)		$ 10,990.86
Acquisition of Access and Rights of Way (3%)		$ 16,486.30
Construction Costs Subtotal #1	$ 434,421.53	
Engineering Costs = CCS#1 x 10%	$ 43,442.15	
Subtotal #2	$ 477,863.69	
Contingency = Subtotal #2 x 15%	$ 71,679.55	
Construction Cost Total		$ 549,543.24
Project Cost Total 2008		$ 653,956.45
Project Cost Total 2010		$ 720,986.99
Shell Canal Company (if a legal irrigation district) 33%		$ 237,925.71
WWDC 67%		$ 483,061.28

7.4 CONCRETE LINING

This alternative would leave the existing walls and ceiling in-place and using them as a form to place new concrete. The old floor would be removed and a 12" concrete floor with reinforcing steel would be placed wall-to-wall, the length of the tunnel. Steel dowels would be drilled into the existing wall and ceiling and 12" of new concrete with reinforcing steel would be placed inside the existing concrete. The steel dowels would tie the new concrete to the existing concrete. New inlet and outlet structures will be built to transition the flow through the tunnel and eliminate seepage under the tunnel. See Sheet D3 in Appendix N for a cross section view of this alternative. Following is a projected cost for this option.

Shell Canal Tunnel Reconstruction
Opinion of Probable Construction Cost
Concrete Lining

Cost of Project Componenets:	Qty	Unit	Cost
Mobilization	1	LS	$ 44,837.62
Contract Bond	1	LS	$ 57,544.31
Remove Existing Inlet	1	LS	$ 15,000.00
Remove Existing Outlet	1	LS	$ 15,000.00
Excavation	100	CY	$ 1,300.00
Concrete for Inlet	25	CY	$ 19,293.75
Rebar for Inlet	1200	LBS	$ 1,500.00
Concrete for Outlet	25	CY	$ 19,293.75
Rebar for Tunnel	2000	LBS	$ 2,500.00
Rebar for Outlet	1200	LBS	$ 1,500.00
Concrete Lining	400	CY	$ 308,700.00
Grout	280	CY	$ 19,600.00
Concrete Pump Truck	30	DAY	$ 105,000.00
Compacted Backfill	562	LF	$ 8,430.00
Crushed Fill	562	CY	$ 13,488.00
Other appurtances, as needed	1	LS	$ 89,000.00
Total Cost of Project Components			$ 721,987.44

Consultant Fees:		
Preparation of Final Design and Specifications		$ 91,331.41
Permitting and Mitigation (4%)		$ 36,532.56
Legal Fees (2%)		$ 18,266.28
Acquisition of Access and Rights of Way (3%)		$ 27,399.42
Construction Costs Subtotal #1	$ 721,987.44	
Engineering Costs = CCS#1 x 10%	$ 72,198.74	
Subtotal #2	$ 794,186.18	
Contingency = Subtotal #2 x 15%	$ 119,127.93	
Construction Cost Total		$ 913,314.11
Project Cost Total 2008		$ 1,086,843.79
Project Cost Total 2010		$ 1,198,245.27
Shell Canal Company (if a legal irrigation district)	33%	$ 395,420.94
WWDC	67%	$ 802,824.33

7.5 EXCAVATION OF EXISTING OVERBURDEN AND TUNNEL

The Shell Canal Company board requested that Engineering Associates provide a cost analysis for Excavation of overburden, at first glance, seems like the most straight forward approach. However, the need to slope the trench walls to meet the safety requirements of OSHA results in approximately 120,000 cubic yards of overburden being excavated; approximately 7,500 loads with a 16 cubic yard dump truck. This item substantially increases the costs that would be borne by the canal company.

To accomplish this construction, the 30' to 50' of overburden needs to be excavated down to the top of the tunnel. The existing tunnel would be removed and bedding gravel would be placed. Compacted bedding gravel provides a solid foundation to prevent differential settling of the sections of box culvert. A 6' x 6' RCP box culvert would be placed on the compacted bedding. Box culverts come in sections of 8' and would need to be trucked into the tunnel site. There would be approximately 70 sections delivered to the tunnel site. The culvert sections need to be set and pushed together using a crane or large excavator.

After the box culverts are set the excavated overburden would be placed around and on top of the box culverts in 12” lifts and compacted to 95% of a standard proctor. See Sheet D4 in the Shell Tunnel Drawings in Appendix N. Following is a projected cost for this option with and without backfilling.

Shell Canal Tunnel Reconstruction
Opinion of Probable Construction Cost
6' x 6' Box Culvert w/ Trench Excavation without Backfill

Cost of Project Componenets:	Qty	Unit	Cost	
Mobilization	1	LS	$ 44,837.62	
Contract Bond	1	LS	$ 156,423.96	
Remove Existing Inlet	1	LS	$ 15,000.00	
Remove Existing Outlet	1	LS	$ 15,000.00	
Excavation	91268	CY	$ 1,186,484.00	
6' X 6' Channel	562	LF	$ 281,000.00	
Compacted Backfill	562	LF	$ 8,430.00	
Crushed Fill	562	CY	$ 13,488.00	
Disposal of Excavated Materail	91268	CY	$ 232,733.40	
Other appurtances, as needed	1	LS	$ 294,000.00	
Total Cost of Project Components			$ 2,247,396.99	
Consultant Fees:				
Preparation of Final Design and Specifications				$ 284,295.72
Permitting and Mitigation (4%)				$ 113,718.29
Legal Fees (2%)				$ 56,859.14
Acquisition of Access and Rights of Way (3%)				$ 85,288.72
Construction Costs Subtotal #1			$ 2,247,396.99	
Engineering Costs = CCS#1 x 10%			$ 224,739.70	
Subtotal #2			$ 2,472,136.68	
Contingency = Subtotal #2 x 15%			$ 370,820.50	
Construction Cost Total				$ 2,842,957.19
Project Cost Total 2008				$ 3,383,119.05
Project Cost Total 2010				$ 3,729,888.76
Shell Canal Company (if a legal irrigation district)			33%	$ 1,230,863.29
WWDC			67%	$ 2,499,025.47

Shell Canal Tunnel Reconstruction
Opinion of Probable Construction Cost
6' x 6' Box Culvert w/ Trench Excavation with Backfill

Cost of Project Componenets:	Qty	Unit	Cost	
Mobilization	1	LS	$ 44,837.62	
Contract Bond	1	LS	$ 217,257.91	
Remove Existing Inlet	1	LS	$ 15,000.00	
Remove Existing Outlet	1	LS	$ 15,000.00	
Excavation	91268	CY	$ 1,186,484.00	
Concrete for Inlet	25	CY	$ 19,293.75	
Rebar for Inlet	1200	LBS	$ 1,500.00	
Concrete for Outlet	25	CY	$ 19,293.75	
Rebar for Tunnel	2000	LBS	$ 2,500.00	
Rebar for Outlet	1200	LBS	$ 1,500.00	
6' X 6' Box Culvert	562	LF	$ 207,940.00	
Concrete Pump Truck	15	DAY	$ 52,500.00	
Compacted Backfill	91268	CY	$ 593,242.00	
Crushed Fill	562	CY	$ 13,488.00	
Other appurtances, as needed	1	LS	$ 359,000.00	
Total Cost of Project Components			$ 2,748,837.04	
Consultant Fees:				
Preparation of Final Design and Specifications				$ 347,727.89
Permitting and Mitigation (4%)				$ 139,091.15
Legal Fees (2%)				$ 69,545.58
Acquisition of Access and Rights of Way (3%)				$ 104,318.37
Construction Costs Subtotal #1			$ 2,748,837.04	
Engineering Costs = CCS#1 x 10%			$ 274,883.70	
Subtotal #2			$ 3,023,720.74	
Contingency = Subtotal #2 x 15%			$ 453,558.11	
Construction Cost Total				$ 3,477,278.85
Project Cost Total 2008				$ 4,137,961.83
Project Cost Total 2010				$ 4,562,102.92
Shell Canal Company (if a legal irrigation district)			33%	$ 1,505,493.96
WWDC			67%	$ 3,056,608.96

7.6 SUMMARY

The proposed options will prevent water loss through the tunnel as well as preventing water from getting behind the tunnel. Of the options we reviewed, the 54" Snap Tite HDPE appears to be the preferred alternative WHICH WOULD CARRY THE HISTORIC FLOW. This option will minimize operation and maintenance costs over the 30-year design life.

8.0 FUNDING OPTIONS FOR PRIVATE IRRIGATION DISTRICT IMPROVEMENTS

Private irrigation districts in Wyoming do not have an available source of funding for large scale construction projects. For the larger projects such as ditch lining or enclosing a reach of canal in pipe, the irrigation companies need larger grants and loans to complete the recommended projects. To be eligible for some funding sources, the private irrigation districts would need to become part of an eligible public entity or an approved assessment district formed in accordance with Wyoming law. Currently the SVWID is considered an eligible public entity with the ability to allocate assessment.

For the smaller irrigation improvements, the landowners may be able to obtain financial assistance from the Wyoming Water Development Commission's Small Water Project Program and the Natural Resources Conservation Service (NRCS). In addition to the NRCS, individual land owners can receive funding opportunities from the Wyoming Office of State Land and Investments Small Water Development Project Loans or Regular Farm Loans. In addition, the Bureau of Reclamation has funding opportunities through the Water 2025 Challenge Grant Program to assist with water conservation efforts. Table 12.2.1 in Section 12 provides a list of programs that offer financial assistance for irrigation and watershed improvements.

8.1 WWDC: Small Water Project Program

The private irrigation districts and individual land owners can receive funding assistance through the Small Water Project Program (SWPP) Account II of the Wyoming Water Development Program. Prior to submitting an application, it is recommended applicants become familiar with the SWPP program by visiting WWDC's web page at http://wwdc.state.wy.us/small_water_projects/small_water_project.html.

The SWPP provides funding to a many types of projects, including irrigation improvements. The SWPP program funds projects that have a total project cost less than $100,000 or where the maximum financial contribution from the commission is less than or equal to $25,000. The total project cost includes estimated construction costs, permit procurement, construction engineering and project land procurement. Irrigation improvements that can improve the watershed condition and function are eligible to receive grant assistance.

Sponsors must provide all permits and clearances prior to the Wyoming Water Development Office (WWDO) issuance of the notice to proceed for construction. In the event the sponsor begins construction prior to the written notification of WWDC, the sponsor shall be responsible for all costs encountered prior to the date of the notification. With the application, the sponsor will be required to provide an operation and maintenance plan for the estimated life of the project.

The SWPP program has specific billing criteria that must be met prior to the release of funds. It is important the sponsor understand the billing procedures for WWDC at the beginning of the project. The sponsor will need to take before and after photographs of the project. In addition, it is important all parties are aware of the procedure and time required to provide WWDC with the affidavit of publication. The affidavit of publication verifies the required notes of final settlement were published.

> *Activities eligible for SWPP funding include permit procurement, project land procurement, construction engineering (design and construction inspections), project materials and invoiced contractor expenses. In-kind contributions are only eligible for installation of project materials that were purchased specifically for this project as documented by invoices.* (Operating Criteria of the Small Water Project Program of the Wyoming Water Development Program, 2008)

Applications for the SWPP program may be submitted any time of year, but must be submitted prior to January 1 of each calendar year for the year in which construction will take place. The project sponsor must be able to provide WWDC responses and documentation as required for the application process.

8.2 Wyoming Water Development Commission Grants

Currently WWDC offers 67% grants to public entities. The remaining 33% needs to be paid for by the irrigation district in its entirety or through a WWDC loan. The current interest rate for a WWDC loan is 4% and the term of the loan cannot exceed 50 years. If the life of the project is shorter than 50 years then the loan term will be adjusted to the life of the project. Typically, irrigation districts will have a loan term of 20 to 30 years.

The irrigation companies within SVWID are private entities and WWDC cannot provide grants or loans to private entities. There are two ways for the private irrigation companies to obtain WWDC funds.

The first method would require the lands encompassed by the private irrigation company to become part of the SVWID. SVWID could apply to WWDC for funding and then appropriately tax the lands benefitted from the project. A land surveyor would need to be hired by the private irrigation company to monument the newly annexed area and provide a Record of Survey showing the newly incorporated lands. The land survey could be quite costly depending on how many of the Public Land Survey monuments still exist.

The second method is to become an irrigation district under Title 41 of the Wyoming Statutes. This would require the private irrigation company hire an attorney to begin the legal paper work required. For irrigation districts to apply for these funds, they need to file paperwork with the courts to become a public irrigation district. We recommend the individual ditch companies contact their attorneys to begin this process. WWDC application deadline for new construction projects is the beginning of each September. If the court paperwork has been filed, the soonest these ditch companies could apply for construction funding is August 2010 for new projects. When an existing project is considered to be an on-going project, the applications have a later deadline of October 1. An example of an existing project is a Level I Study that progresses to a Level II Study or Level III Construction Project.

9.0 WATER RIGHTS RESEARCH & IRRIGATION EASEMENTS RESEARCH

The research on water rights for Shell Valley Watershed Improvement District was divided into three steps. First, a search on the Wyoming State Engineers website for water right permits was conducted; secondly an Auto Cad drawing was created to reflect the permit information identified in Table 9.0.1; and finally a sample of landowners was chosen for further research by a title company for irrigation easements.

A general search for water rights was conducted on the following Townships and Ranges: T.52N., R.91W.; T.52N., R.92W.; T.52N., R.93W.; T.53N., R.91W.; T.53N., R.92W.; and T.53N., R.93W. The proof number for each water right found was further refined in an advanced search on adjudicated water rights to find the permits. Once the permits were collected, they were sorted by the facility name and the amount of appropriation and acres were totaled. This information was compared against the assessor's office and used to help create an Auto Cad drawing. Table 9.0.1 lists the water right permits by Priority Date. The Water Right Permit Overview in Appendix P shows the location of permits identified by the Wyoming State Water Plan. The permits indicate some permitted areas are not irrigated and the aerial photo shows irrigated areas that do not have a permit. Further investigation was not completed since the SEO may be completing a readjudication in this area in the near future.

Auto Cad was used to show the permit location and estimated boundary for those permits identified in Table 9.0.1. The SEO breaks down water rights to a quarter of a quarter section. The maximum amount of land in this described area is 40 acres. If the permit showed less than 40 acres, we used the aerial photo to help define the smaller irrigated area.

A different boundary color was used to identify which irrigation ditch delivers to an individual permit. The water rights boundaries with a star in the center were researched further by a title company to determine if there were any descriptive irrigation easements. The majority of older irrigation ditches in the Big Horn Basin have prescriptive easements stating the easement to be a certain distance from the centerline of the ditch. Some prescriptive easement documents may be recorded in the county courthouse. Some prescriptive easement documents may be filed in the ditch company files. EA could not find any prescriptive or descriptive easement documents in the courthouse.

Following is a list of landowners the title company researched:

Landowner	Water Facility
Martin Michelena	Beaver Ditch
Gary G. Good Trust	Shell Canal
Dixie and Timothy Cummings	Shell Canal
Jackie Nelson	Shell Canal
Morgan Dean Properties, LLC	Shell Canal
Charles Smith	Shell Canal
Marvin and Beverley Hankins	Shell Canal
Larry and Jesse Bullinger	Shell Canal
Barnett Ranch	Porter Canal
Clair and Vida Cheatham	Porter Canal
Donald Reichmuth	Porter Canal
Drwenski LLC	Cottonwood Ditch

These landowners were chosen because their land covered numerous acres and were strategically placed within the Shell area. The maps shown in Appendix M are based on the water rights listed in Table 9.0.1 and the title company research.

Table 9.0.1
WYOMING STATE ENGINEER'S PERMITS USED FOR EASEMENT RESEARCH
Shell Valley Watershed Improvement District

Permit Number	Source	Facility Name	Priority Date	Adjudicated Flow	Adjudicated Acreage	Type
1716	Trapper Creek	Highline Ditch	01/12/1898	3.00 cfs	211.00	os
1415	Beaver Creek	St. Jermain Ditch	01/15/1897	1.69 cfs	118.00	os
386	Beaver Creek	Trout Ditch	01/3/1893	0.84 cfs	59.00	os
1341	Beaver Creek	Matthews Ditch	10/15/1896	1.31 cfs	92.00	os
1075	Trapper Creek	Hatten Ditch	11/13/1895	0.86 cfs	60.00	os
365	Shell Creek	Porter Ditch	11/18/1892	15.99 cfs	1120.00	os
430	Shell Creek	McDonald(Shell Canal)	3/07/1893	0.93 cfs	65.00	os
1807	Beaver Creek	Pense Ditch	3/28/1898	0.79 cfs	55.00	os
682	Beaver Creek	Kenyon Ditch	4/03/1894	0.21 cfs	15.00	os
686	South Fork Beaver Creek	London Ditch	4/07/1894	3.86 cfs	270.00	os
270	Beaver Creek	Beaver Ditch	5/05/1892	1.97 cfs	137.00	os
510	Horse Creek	Kershner-Lapman Ditch	6/01/1893	0.69 cfs	48.00	os
508	Shell Creek	Kershner Ditch	6/01/1893	1.23 cfs	86.00	os
42Enl.	Shell Creek	Enl. Whaley Ditch	6/17/1893	9.89 cfs	692.00	os
1039	Trapper Creek	Willard Ditch	8/16/1895	0.57 cfs	40.00	os
691	Beaver Creek	Crandall Ditch	9/04/1894	1.07 cfs	75.00	os
1573	Horse Creek	Lampman No. 2 Ditch	9/13/1897	1.14 cfs	80.00	os
271Enl.	Shell Creek	Enl. McDonald (Shell Canal)	9/18/1897	7.68 cfs	537.00	os
462Enl.	Shell Creek	Enl. Whaley Ditch	9/18/1899	6.20 cfs	434.00	os
2563	Trapper Creek	Jenks Ditch	4/20/1900	0.80 cfs	56.00	os
2967	South Fork Beaver Creek	Davis Ditch	12/22/1900	1.63 cfs	114.00	os
650Enl.	Shell Creek	Enl. Whaley Ditch	4/22/1901	3.85 cfs	269.00	os
3132	Trapper Creek	Sabin-Brown Ditch	4/22/1901	0.78 cfs	57.00	os
3246	Shell Creek	Fender Ditch	6/10/1901	1.05 cfs	75.00	os
3648	Horse Creek	Bench Ditch	1/9/1902	1.35 cfs	94.00	os
3722	Red Gulch	M.E. Jackson Ditch	2/13/1902	0.42 cfs	30.00	os
3721	Shell Creek	Lynn Ditch	2/13/1902	3.85 cfs	269.00	os
3720	Trapper Creek	Cull No.1 Ditch	2/13/1902	0.70 cfs	49.00	os
5274	Shell Creek	Scharen Ditch	1/12/1903	0.78 cfs	55.00	os
5363	Hudson Falls	Hunt Ditch	3/17/1903	1.97 cfs	138.17	os
1274Enl.	Shell Creek	Enl. Denny Ditch	4/18/1904	0.35 cfs	25.00	os
1244Enl.	Trapper Creek	Enl. Sabin-Brown Ditch	5/19/1904	0.12 cfs	9.00	os
1330Enl.	Shell Creek	McDonald(Shell Canal)	1/6/1905	8.79 cfs	615.00	os
1438 Enl.	Beaver Creek	Enl. Calvin Ditch	5/22/1905	0.54 cfs	38.00	os
1439Enl.	Shell Creek	Enl. McDonald (Shell Canal)	5/22/1905	2.72 cfs	190.00	os
1522Enl.	Trapper Creek	Enl. Highline Ditch	4/7/1906	0.93 cfs	65.00	os
1726Enl.	Shell Creek	Enl. Porter Ditch	4/22/1907	0.61 cfs	43.00	os
8290	Shell Creek	Shell Canal	4/22/1907	12.51 cfs	876.00	os
8538	Rath Springs	Rath-Early Ditch	7/13/1908	0.46 cfs	32.00	os
1962Enl.	Trapper Creek	Enl. Highline Ditch	10/9/1908	0.78 cfs	55.00	os
2031Enl.	Shell Creek	Enl. Odessa Ditch	3/23/1909	0.50 cfs	35.00	os
2084Enl.	Shell Creek	Enl.Shell Canal	6/1/1909	34.35 cfs	2404.55	os
2469Enl.	Trapper Creek	Enl. Highline Ditch	5/5/1911	0.20 cfs	14.10	os
11335	South Fork Beaver Creek	Kimbrow No.1 Ditch	6/21/1912	0.17 cfs	12.00	os
2747Enl.	South Fork Beaver Creek	Enl. Davis Ditch	7/27/1912	1.72 cfs	121.00	os
12217	Cedar Creek	Howe Ditch	12/18/1912	0.38 cfs	26.70	os
13194	Beaver Creek	Ewen No. 1 Ditch	6/6/1913	0.31 cfs	21.80	os
14358	Horse Creek	Emerick Ditch	6/3/1916	0.14 cfs	10.00	os
17817	Horse Creek	Frank Gould No.2 Ditch	12/12/1930	0.43 cfs	30.00	os
4715Enl.	Horse Creek	Enl.Bench Ditch	3/5/1931	0.36 cfs	25.00	os
19680	Shell Creek	Flitner Ditch	6/3/1941	0.53 cfs	37.00	os
5420Enl.	Shell Creek	Enl.Whaley Ditch	4/19/1945	0.57 cfs	40.00	os
5859Enl.	Shell Creek	Enl. Dunshee Ditch	6/19/1956	0.67 cfs	47.11	os
21842	Beaver Creek	Ewen No. 3 Ditch	6/24/1957	0.19 cfs	13.20	os
24240	Trapper Creek	Cassey Pipeline	10/15/1973	0.06 cfs	4.50	os
			Total	**145.49**	**10,190.13**	
17571	Spring Creek	Spring Creek Ditch	8/2/1922	None	115.00	ss
17878	Cottonwood Creek	Cottonwood Ditch	1/12/1931	None	513.00	ss
			Total	**None**	**628.00**	

10.0 HYDROELECTRIC POTENTIAL

The potential for hydroelectric power was considered at each potential reservoir site. Micro-hydroelectric opportunities would require a substantial water "head" or potential energy, and a firm water volume from May 1 to October 31, to provide adequate current to justify construction costs. All of the lower elevation sites that were evaluated occur in relatively flat terrain and are unlikely to generate substantial, sustained flow or current.

One high-elevation site, Willett Creek, did have substantial elevation drop and a perennial water source. Micro-hydroelectric could be generated at this site. An electrical distribution power line also occurs within approximately two miles of the site. However, this site was eliminated from further consideration for three key reasons. First, the site occurs within high-elevation terrain and would not be amenable to late-season water management, a key criterion of the SVWID. Second, the area is located on federally administered land and would result in the fill of extensive high-elevation scrub/shrub wetlands. Third, access to the site is also very limited. For these reasons, additional analysis of the site was not pursued.

11.0 WATER STORAGE SITE EVALUATION

Twelve potential reservoir or reservoir expansion sites were evaluated relative to a variety of criteria such as storage capacity, service area, water source, geotechnical hazards, elevation (as it related to the ability to manage water in winter), and environmental permitting constraints. Sites were included for evaluation based on a number of factors such as:

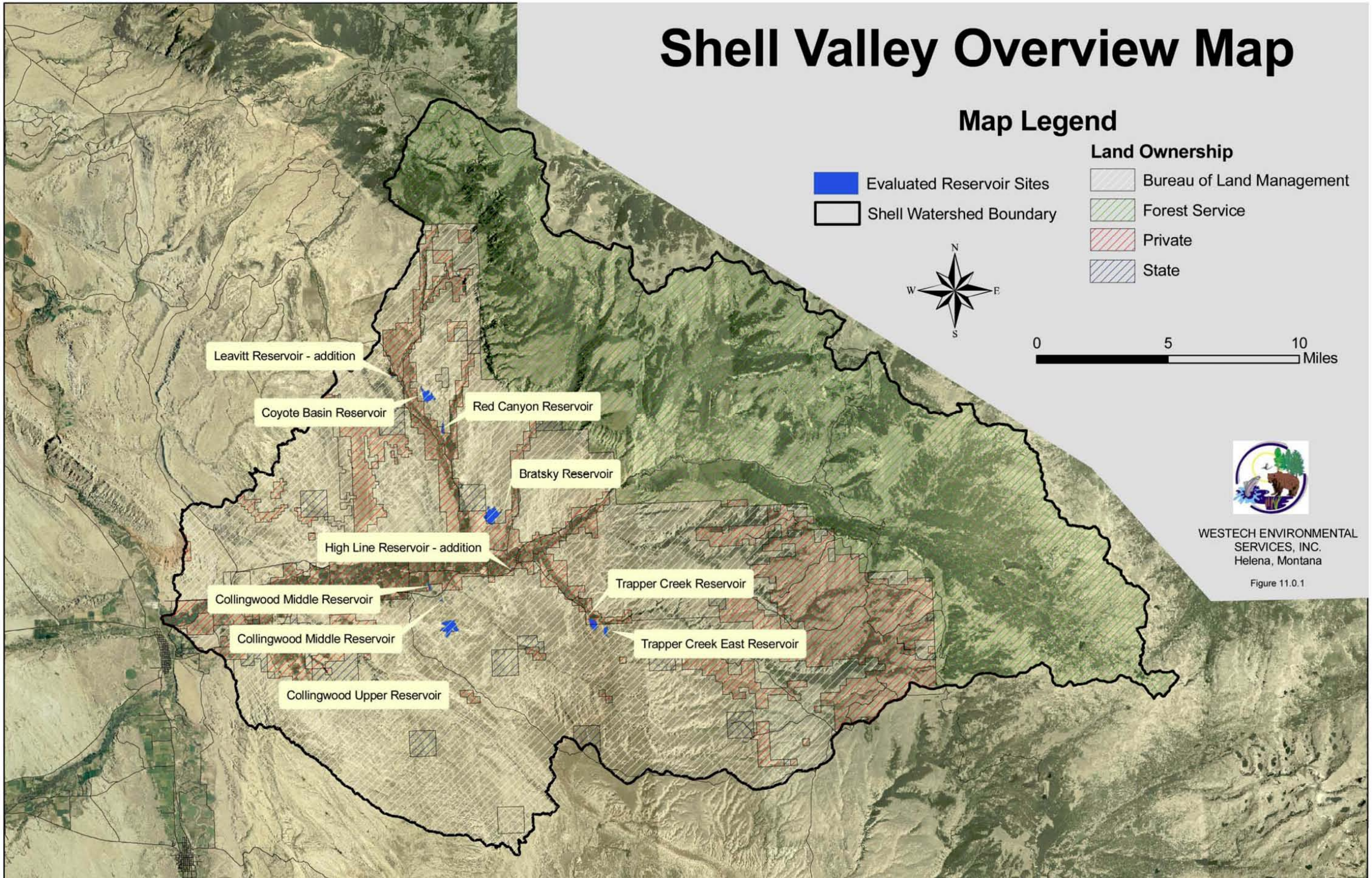
- Previous reports identifying potential storage sites;
- Local knowledge and input;
- Field reconnaissance efforts; and
- Hydrologic analysis.

Sites that were initially included for analysis are shown on Figure 11.0.1 Shell Valley Overview Map and are listed below in Table 11.0.1.

TABLE 11.0.1
Initial Reservoir Sites Included in Analysis
Shell Creek Watershed

Site Name	Contributing Watershed
Red Canyon	Beaver Creek & Red Canyon Creek above elevation 4460 feet.
Bratsky Draw	Horse Creek, Red Canyon Creek, and Beaver Creek above elevation 4220 feet. Upper Shell Creek also was considered via a new diversion canal.
Collingwood Draw	Drainage area above site, and Shell Creek above Shell Canal.
Coyote Basin	Drainage area above site. Beaver Creek and Red Canyon Creek above elevation 4575 feet.
Flitner Meadows	Moraine Creek above site.
High Line Reservoir Expansion	West of Shell
Leavitt Reservoir Extension	Drainage area above reservoir (Leavitt & Davis). Beaver Creek upstream of elevation 4800 feet.
Scharen Creek	Drainage area above site, and Shell Creek above Shell Canal.
Sheldon Gulch	Drainage area above site, and Shell Creek above Shell Canal.
Shell Reservoir	Upper Shell Creek above site.
Trapper Creek	Trapper Creek above site.
Willett Creek	Willett Creek above site.

Several sites on the initial list were eliminated prior to reconnaissance level survey work due to a variety of limiting factors such as lack of water, limited service area, or difficult permitting issues. Sites initially considered but eliminated from further analyses are listed in Table 11.0.2


Shell Valley Overview Map
Map Legend
Evaluated Reservoir Sites
Shell Watershed Boundary
Land Ownership
Bureau of Land Management
Forest Service
Private
State
N
W
E
S
0
5
10
Miles
Leavitt Reservoir - addition
Coyote Basin Reservoir
Red Canyon Reservoir
Bratsky Reservoir
High Line Reservoir - addition
Trapper Creek Reservoir
Collingwood Middle Reservoir
Collingwood Middle Reservoir
Trapper Creek East Reservoir
Collingwood Upper Reservoir
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Helena, Montana
Figure 11.0.1

TABLE 11.0.2 Sites Eliminated from Further Analysis by limiting Factors Shell Creek Watershed	
Site Name	**Contributing Watershed**
Flitner Meadows	High-elevation site with little potential for winter water management. Removal of extensive, high-elevation shrub and forested wetlands on public land.
Scharen Creek	Limited service area and available water.
Sheldon Gulch	Limited service area and available water.
Shell Reservoir	High-elevation site with little potential for winter water management. Removal of extensive, high-elevation shrub and forested wetlands on public land.
Willett Creek	High-elevation site with little potential for winter water management. Removal of extensive, high-elevation shrub and forested wetlands on public land.

Seven of the original twelve sites were evaluated with reconnaissance level field surveys. Field survey work included:

- Site characterization and description;
- Fatal flaw assessment (e.g. geotechnical hazards);
- Wetland delineation; and
- Permitting constraints.

Initial analysis and modeling were completed for these seven sites regarding criteria such as storage capacity, mean annual flow to sites based on contributing watersheds, service area, and water source. Storage capacity was estimated for elevations behind a maximum assumed dam height at each site. Dam heights were based on field-reconnaissance surveys and field mapping of potential reservoir footprints onto orthophotos overlaying digital elevation models. The maximum assumed water elevation was used as a method for comparing relative storage volume among sites. It is understood that the maximum potential dam height and water elevations are not the probable dam height that would be constructed since a thorough geotechnical review and water modeling analysis of each site was not completed in this Level 1 Study. However, assuming maximum storage potential at each site allows for ranking of sites relative to each reservoir's potential maximum storage.

Storage capacity was calculated for the approximate fill behind the dam site using Autodesk Civil 3D. Mean annual flow volume that could drain to each of the seven potential reservoir sites was calculated using regression equations developed by the U.S. Geological Survey (USGS) for streams in Wyoming (Lowham 1988). The "Immediate Direct Drainage Area (mi^2) & Assumed Mean Annual Flow Volume (af/yr)" represents an estimate of the amount of flow that would accumulate in a reservoir as a result of local runoff. Since supplemental water would likely be required to fill most potential reservoir sites, a calculation of "Supplemental Mean Annual Drainage Area (mi^2) and Mean Annual Flow (af/yr)" was also made to describe water sources that could potentially be available to fill a reservoir through a canal or pipeline. These contributing water sources are noted in the summary tables for each reservoir site.

Water sources for most reservoir sites are limited. Supplemental water from groundwater wells was also considered and researched with the Wyoming State Engineer's Office. Very few reservoir projects in Wyoming are filled from groundwater sources. The most similar example occurs at the Flathead Ranch near Tensleep, Wyoming where a center-pivot sprinkler system is used to pump water from the Madison-Bighorn geologic formations and fill a reservoir with a capacity of a few hundred acre-feet. There are no known high-capacity wells currently located in the Shell Creek watershed. Supplementing reservoir water with groundwater may be a difficult permitting endeavor since groundwater is typically of a quality suitable for municipal or personal use. Developing groundwater for open reservoirs and flood irrigation purposes may not be the most beneficial use of the groundwater resource (John Harju, Wyoming State Engineer Office, Groundwater Division, pers. comm.). Further, groundwater wells and the associated infrastructure are expensive developments that have not been typically funded or developed by the WWDC. Due to these considerations, groundwater was not considered as a supplemental source of water to the potential reservoir sites.

Although the reservoir data table indicates surplus water available in the reservoir drainage basins on an annual basis, there is insufficient data on the timing of the flows to allow an analysis of the amount of flow which could be stored. The limitation of the flow which can be stored in an off-channel reservoir is the capacity of the supply ditch and the amount of water required to satisfy prior rights. For example, on Trapper Creek the reservoir volume is 2,507 acre feet while the peak flow for a two-year storm is 620 cubic feet per second. It is simply not cost effective to construct a supply ditch with a capacity of 620 cfs to fill a reservoir with a storage volume of 2,507 acre-feet. To obtain any kind of reasonable estimate of flow available for storage is going to require more flow measurements along with a more detailed analysis of the duration and magnitude of the flows as they vary throughout the year.

TABLE 11.0.3
RESERVOIR DATA

Reservoir	Reservoir Vol AC-FT	Annual Flow AC-FT/YR	Irrigated Acreage Above Supply Ditch Point of Diversion	Irrigated Acreage Below Supply Ditch Point of Diversion	CFS Required to Supply Irrigation [1] 1CFS/35 AC	Irrigation Requirement AC-FT/Day	Days of Irrigation Storage in Reservoir	AC-FT / YR Required 200 Day Irrigation Season	Surplus Water [2] AC-FT/YR	Peak Flow [3] CFS
BRATSKY DRAW	5,839	1,900	0	8,807	251.6	486.6	12.0	97,320	-95,420	Note [4]
BRATSKY DRAW - SUPPLEMENTAL DRAINAGE	5,839	174,710	2,098	8,807	311.6	602.6	9.7	120,520	54,190	2080
COLLINGWOOD - UPPER	2,692	1,800	0	4,719	134.8	260.8	10.3	52,160	-50,360	Note [4]
COLLINGWOOD - MIDDLE	11	1,800	0	4,719	134.8	260.8	0.0	52,160	-50,360	Note [4]
COLLINGWOOD - LOWER	71	1,800	0	6,499	185.7	359.1	0.2	71,820	-70,020	Note [4]
COLLINGWOOD - LOWER BASED ON SUPPLEMENTAL DRAINAGE	71	162,200	1,578	6,499	230.8	446.3	0.2	89,260	72,940	1940
COYOTE BASIN	3,112	620	0	9,840	281.1	543.7	5.7	108,740	-108,120	Note [4]
COYOTE BASIN BASED ON SUPPLEMENTAL DRAINAGE	3,112	36,500	781	9,840	303.5	586.9	5.3	117,380	-80,880	660
HIGHLINE EXPANSION	20	35,300	1,385	5,326	191.7	370.8	0.1	74,160	-38,860	Note [4]
LEAVITT EXPANSION	45	28,000	781	9,937	306.2	592.2	0.1	118,440	-90,440	510
RED CANYON	546	1,600	0	9,765	279.0	539.6	1.0	107,920	-106,320	Note [4]
RED CANYON - SUPPLEMENTAL DRAINAGE	546	36,500	1,141	9,765	311.6	602.6	0.9	120,520	-84,020	660
TRAPPER CREEK	2,507	35,300	93	14,962	430.1	831.9	3.0	166,380	-131,080	Note [4]
TRAPPER CREEK EAST	734	35,300	0	14,962	427.5	826.8	0.9	165,360	-130,060	Note [4]

1. There must be sufficient Flow in the stream to satisfy irrigation requirements before water can be diverted into a reservoir.
2. Equal annual flow less AC-FT/YR required for irrigation. Not all of this water is available for storage because it is not practical to build a supply ditch large enough to carry peak flows. Determination of flow available for storage requires an analysis of the water rights of the drainage as well as more detailed stream flow data and is beyond the scope of this study.
3. The Peak Flow associated with a storm having a recurrence level of 2 years is used to estimate the size of the delivery canal.
4. Data indicates surplus water is not available.

Wetland delineations and procedures were completed according to the U.S. Army Corps of Engineers Wetland Delineation Manual (1987) and the Interim Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Arid West Region (2006). Upland vegetation inventories were completed within 0.01-acre plots located in representative areas of each potential reservoir site. Data were collected regarding plant canopy cover, soil texture, topography, slope, aspect, and soil cover at each plot. Scientific binomial nomenclature follows the USDA Region 1 Ecosystem Classification Handbook (1987) and Dorn (1992).

All modeling and analysis for this Level 1 Study are based on reconnaissance level field inventories and review and synthesis of existing data. Conclusions should be considered in light of this level of assessment. Modeling and analysis would need to be refined to determine specific and detailed reservoir characteristics.

The final potential reservoir sites are discussed individually below.

11.1 BRATSKY DRAW RESERVOIR

The Bratsky Draw Reservoir site occupies a wide basin of undulating topography, incised draws, and moderate slopes. One primary ephemeral draw meanders through the site, with several smaller, side draws joining the main drainage. Figure 5.1.2 Bratsky Reservoir, found in Appendix O – Water Storage Site Maps, depicts the site's location and approximate reservoir footprint. Similar to other potential reservoir sites, the dam site and lower portion of the reservoir would be located on private land, although the majority of the reservoir would fill public land administered by the BLM.

Photo 11.1: Bratsky Reservoir Site - Looking at landslide on east edge of site.

11.1.1 SITE CHARACTERISTICS

The Bratsky site is located in a broad, ephemeral valley between Beaver Creek and Horse Creek. Underlying rocks are from the Cloverly/Morrison Formations, consisting of shale and mudstone. Most soil in the area is unit 471CE (Bribute-Persayo-Pavillion complex). This soil has some limitations for embankments. The expansive soil index is low, and the erosion hazard is high. Soil texture at both the east and west potential dam abutments is comprised of silt and clay with limited coarse fragments and highly erodible slopes. The potential dam abutments are located on slopes of approximately 35 to 45 percent. Appendix J-Reservoir location photos.

Several vegetation communities occur within the Bratsky Draw site. Most slopes and ridges are dominated by Wyoming big sagebrush/bluebunch wheatgrass or Gardner's saltbush. Extensive areas of annual wheatgrass (*Agropyron triticeum*) also occupy several flats, and are interspersed with Gardner's saltbush. Several eroded badland knobs and ridges also occur within the site. Upland vegetation was sampled at five sites within the potential reservoir footprint.

Wetland vegetation was sampled at two sites. The most extensive wetland occurs within a meadow foxtail/American bulrush (*Hordeum jubatum/Scirpus americanus*) type, while the upstream portions of the wetland transition to a tamarisk/Pahute weed type (*Tamarix chinensis/Suaeda depressa*). Terraces surrounding the wetland and the upstream dry channels are dominated by greasewood.

11.1.2 WATER STORAGE CAPACITY

Water storage capacity for the site was estimated based on a dam height and maximum water depth of 98 feet. Storage capacity behind this assumed dam height is 5,839 acre-feet. A reservoir of this depth and configuration would have an average depth of approximately 36 feet, and occupy approximately 160 acres.

11.1.3 WATER SOURCE AND SERVICE AREA

Water for the Bratsky Draw Reservoir would be provided by seasonal high flows in the local upstream watershed. Upper Shell Creek water could also be diverted to this reservoir site if a new canal were constructed from a location upstream of the town of Shell.

11.1.4 GEOTECHNICAL HAZARDS

An old landslide exists near the dam site for this potential reservoir. Further geotechnical studies would be required to determine if this landslide presented a long-term hazard to the site. General clayey soil conditions may also result in limitations for embankment construction.

11.1.5 ENVIRONMENTAL PERMITTING CONSTRAINTS

A relatively small, palustrine emergent/scrub-shrub wetland occurs near the mouth of the potential reservoir site. Dominant species within the emergent, herbaceous wetland include meadow foxtail and American bulrush. Dominant species within the scrub-shrub wetland include tamarisk and pahute weed. Current dam placement would not affect the emergent, herbaceous wetland. Approximately 0.96 acre of scrub-shrub wetland would be filled by reservoir construction.

The Bratsky site occurs within mule deer crucial winter range (Wyoming Department of Game and Fish) and approximately 160 acres of this type of habitat would be displaced by the reservoir. Sage grouse leks are not known to occur near the reservoir site. There are no known special-status species or habitat at the site.

The majority of the site occurs on public land administered by the BLM although the dam site and lower portions of the reservoir would be located on private land. An Environmental Assessment or other document may be needed prior to construction as well as a 404 permit from the U.S. Army Corps of Engineers.

11.1.6 SUMMARY

The Bratsky Draw Reservoir site is the largest potential reservoir evaluated in this study. Water would be provided through seasonal run-off within the local watershed, possibly supplemented by water diverted from Horse Creek, Red Canyon Creek, Beaver Creek, and/or upper Shell Creek.

Possible limiting factors include soil characteristics with poor water holding capacity and dam building limitations. In addition, a landslide was noted in the field near the potential dam site that may prevent dam construction. Erosion potential is high in this area which could result in excessive sedimentation in the reservoir. Due to the large surface area of the reservoir, evaporation would be relatively high. Minimal environmental impact is anticipated at the site. Key characteristics are presented in Table 11.1.6.1.

TABLE 11.1.6.1
Bratsky Draw Reservoir Characteristics
Shell Creek Watershed

Characteristics	Bratsky Draw Reservoir
Maximum water depth (feet)	98
Average water depth (feet)	36
Storage Capacity (acre-feet)	5,839
Surface Area (acres)	160
Immediate Direct Drainage Area (mi^2) & Assumed Mean Annual Flow Volume (af/yr)	3.1 / 1,900
Supplemental Mean Annual Drainage Area (mi^2) and Mean Annual Flow, including Red Canyon, Beaver, Horse, and upper Shell Creeks (af/yr)	285.6 / 174,700
Water Source	Seasonal run-off, possibly diverted from Horse Creek, Red Canyon Creek, Beaver Creek, and/or upper Shell Creek
Service Area (acres)	8,807
Primary Conveyance	Horse Creek
Geotechnical Constraints	Potential soil constraints for embankments and landslide hazards
On Perennial Stream	No
Wetlands Potentially Filled (acres)	0.96
Significant Cultural Resources	None recorded
Special-Status Species	None recorded
Land Ownership	Private/Public
Mule Deer Winter Range Displacement	160 acres

11.2 COLLINGWOOD DRAW COMPLEX

The Collingwood Draw Complex includes three potential storage sites (Upper, Middle, and Lower). Initial review of available information as well as local opinion had located a site approximately one mile south of Highway 14 within Collingwood Draw, an ephemeral drainage (Figures: Collingwood Reservoir Middle and Lower Reservoir and Collingwood Reservoir Upper Reservoir located in Appendix O). Reconnaissance field surveys located two additional sites within the drainage including a defunct reservoir site immediately south of Highway 14, and a small area immediately north of Highway 14 within the same drainage. The Upper and Middle sites are located entirely on public land, while the Lower site is primarily on public land, although the potential dam site would be on private land.

11.2.1 SITE CHARACTERISTICS

The Collingwood sites are located in a broad, ephemeral valley south of Shell Creek. Underlying rocks are from the Cloverly/Morrison Formations, consisting of shale and mudstone. Most soil in the reservoir areas is unit 471CE (Bribute-Persayo-Pavillion complex). This soil has some limitations for embankments. The expansive soil index is low, and the erosion hazard is high.

Potential dam abutment locations were only assessed at the Upper site since the Middle site already included a dam with little potential for raising the dam height, and the Lower site was only assessed from a vehicle. At the Upper site, the east abutment slopes are approximately 55 percent, with few coarse fragments in a clay-loam matrix. A small rock outcrop topped the east abutment slope. Slopes at the west abutment site are approximately 13 percent, vegetated with Gardner's saltbush and contain few coarse fragments. Soil conditions are similar to the east abutment.

Several vegetation communities occur within the Collingwood Draw sites. The Upper site is the largest of the three potential reservoirs and is located with a small basin comprised of badlands, Gardner's saltbush, Wyoming big sagebrush, and annual wheatgrass communities. Upland vegetation was sampled at five locations within the potential reservoir footprint. One potential wetland was sampled at a pond located in the approximate center of the potential reservoir site. However, hydric soils were not present and only moderately hydrophytic vegetation grew within the pond. Consequently, no wetlands occur within the Upper site.

The Middle Collingwood Draw site is located behind an extensive old dam that at one time created a relatively small reservoir. A major break in the center of the dam prevents water from being impounded. This break would require repair for the site to be functional. Vegetation within the old impoundment footprint is dominated by meadow foxtail and willow dock (*Rumex salicifolius*), both hydrophytic species. However, hydric soils are not present nor is wetland hydrology present since the dam has broken and no wetlands occur within the site.

The Lower Collingwood Draw site was viewed from a nearby road but was not investigated to the extent of other sites as it was recommended for inclusion at the end of the field survey by a local resident (David Flitner). This site is located within Collingwood Draw on the north side of Highway 14 below the Shell Canal. Extensive cattail (*Typha latifolia*) wetlands appear to dominate the potential reservoir footprint; however, formal wetland delineation was not completed. Wetland extent was determined through photo-interpretation. A list of species, percent cover, and physical characteristics of all plots are included in Appendix A -Site Parameters and Canopy Cover by Species.

11.2.2 WATER STORAGE CAPACITY

Potential dam heights and maximum water depth, storage capacity, average depth, and approximate acreage are presented for each site in Table 11.2.2.1.

TABLE 11.2.2.1
Collingwood Draw Reservoirs Water Storage Capacity Characteristics
Shell Creek Watershed

Site	Maximum Potential Dam Height (Feet)	Storage Capacity (Acre-feet)	Average Depth (Feet)	Approximate Acreage
Collingwood Draw - Upper	65	2,692	17	157
Collingwood Draw – Middle	16	11	3	4
Collingwood Draw - Lower	16	71	6	13

11.2.3 WATER SOURCE AND SERVICE AREA

Water for the Upper and Middle sites would be provided by seasonal runoff in the Collingwood Draw watershed and would provide supplemental irrigation water to 4,719 acres. Water would be conveyed through McDonald Ditch and Shell Creek, but would require pumping.

Water for the Lower site would be provided from seasonal runoff collected in Collingwood Draw and could also be diverted from the Shell Canal. Service Area is approximately 6,499 acres for Collingwood Lower site. Water would be conveyed through the Whaley Ditch.

11.2.4 GEOTECHNICAL HAZARDS

No geotechnical hazards have been identified for the Collingwood sites, except that clayey soil conditions may have limitations for embankment construction.

11.2.5 ENVIRONMENTAL PERMITTING CONSTRAINTS

No permitting constraints were noted at either the Upper or Middle Collingwood Reservoir sites. Approximately 7.8 acres of palustrine emergent wetland would be inundated within the Lower Collingwood Draw's reservoir footprint.

None of the Collingwood reservoir sites are located within big game winter ranges and no sage grouse leks are known to occur near any site. There are no known cultural resources or special-status species or habitat at any site.

All of the Upper and Middle sites, as well as the majority of the Lower site, are located on public land administered by the BLM. An Environmental Assessment or other document may be needed prior to construction. The Lower site would likely require a 404 permit from the U.S. Army Corps of Engineers prior to construction.

11.2.6 SUMMARY

The Upper Collingwood Draw site is the third (3rd) largest potential reservoir site evaluated in this study. The Middle and Lower sites are both relatively small. Possible limiting factors include soil characteristics with poor water holding capacity and dam building limitations. Erosion potential is high in this area which could result in excessive sedimentation in the reservoir. Due to the relatively large surface area of the Upper Collingwood site, evaporation could be severe. Minimal environmental impacts are anticipated at the Upper and Middle sites. More wetland acreage would be disturbed by reservoir construction at the Lower Collingwood Draw site than at any other site evaluated in this study. Key characteristics of each site are presented in Table 11.2.6.1

TABLE 11.2.6.1
Collingwood Draw Reservoirs Characteristics
Shell Creek Watershed

Characteristics	Collingwood Upper	Collingwood Middle	Collingwood Lower
Maximum water depth (feet)	65	16	16
Average water depth (feet)	17	3	6
Storage Capacity (acre-feet)	2,692	11	71
Surface Area (acres)	157	4	13
Immediate Direct Drainage Area (mi^2) & Assumed Mean Annual Flow Volume (af/yr)	2.8 / 1,800		
Supplemental Mean Annual Drainage Area (mi^2) and Mean Annual Flow, including upper Shell Creek (af/yr)	None	None	257.2 / 162,200
Water Source	Seasonal runoff	Seasonal runoff	Seasonal runoff & Shell Canal
Service Area (acres)	4,719	4,719	6,499
Primary Conveyance	Shell Canal	Shell Canal	Whaley Ditch
Geotechnical Constraints	Potential soil constraints for embankments	Potential soil constraints for embankments	Potential soil constraints for embankments
On Perennial Stream	No	No	No
Wetlands Potentially Filled (acres)	0	0	7.8
Significant Cultural Resources	None recorded	None recorded	None recorded
Special-Status Species	None recorded	None recorded	None recorded
Land Ownership	Public	Public	Public/Private
Mule Deer Winter Range Displacement	0 acres	0 acres	0 acres

11.3 COYOTE BASIN

The Coyote Basin reservoir site is located east of upper Beaver Creek in a wide basin of undulating topography and incised draws. Several steep slopes occur on either side of the primary drainage within the site. One primary ephemeral drainage is located in the western portion of the site with several smaller, ephemeral drainages joining this primary drainage prior to reaching the potential dam site. Figure Coyote Basin Reservoir found in Appendix O – Water Storage Site Maps, shows the site's location, dam site, and approximate reservoir footprint. The entire site occurs on public land although access to the site is through private land.

Photo 11.3: Coyote Basin Reservoir Site

11.3.1 SITE CHARACTERISTICS

The Coyote Basin site is located in a broad ephemeral valley east of upper Beaver Creek. The site is underlain by the Cloverly/Morrison Formations, which are composed of shale and mudstone. Soils in this area are primarily of the Kinnear-Lostwells complex (map unit 368A). This soil type has moderate seepage potential, with a low expansion index and moderate erosion hazard. These soil conditions may cause some limitations to embankment construction.

The potential dam abutment on the east side of the reservoir includes slopes of approximately 55 to 65 percent comprised of eroded "badland" clays. Similarly, slopes at the west side potential dam abutment are approximately 70 to 75 percent and comprised of the same eroded badland clay. Photos are presented in Appendix J - Reservoir Location Photos.

Similar to the Bratsky Draw and Red Canyon sites that occur within the same general area, vegetation is dominated by Gardner's saltbush and Wyoming big sagebrush communities, as well as undeveloped vegetation in the badlands. Upland vegetation was sampled at four locations; data regarding species, canopy cover, and physical characteristics of each plot are included in Appendix A – Site Parameters and Canopy Cover by Species.

Wetlands were sampled at two locations, including a site within the primary drainage that would be filled by a potential reservoir, as well as a point immediately downstream of the potential dam site. Wetlands within the primary ephemeral drainage include palustrine emergent communities created by seasonal flows supplemented by potential groundwater from what appeared to be springs upstream of the reservoir site. Dominant species include Baltic rush (*Juncus balticus*) and alkali bluegrass (*Poa juncifolia*). Wetlands immediately below the dam site that would likely be affected by construction are dominated by American bulrush and Baltic rush. Low rates of flowing water were present in these wetlands and originated from a drainage immediately west of the reservoir site. Irrigation waste water and/or local springs may have been the source of this water.

11.3.2 WATER STORAGE CAPACITY

Water storage capacity for Coyote Basin was estimated based on a maximum potential dam height and water depth of 98 feet. Storage capacity behind this assumed dam height is 3,112 acre-feet. Based on these preliminary designs, the Coyote Basin reservoir would have an average depth of approximately 36 feet, and occupy approximately 86 acres.

11.3.3 WATER SOURCE AND SERVICE AREA

Water for the Coyote Basin reservoir would be provided by seasonal runoff within the local drainage watershed. Additional water might be accessible from Beaver Creek and Red Canyon Creek via construction of diversions between the drainages**.** A thorough water rights and search at the State Engineer's Office should be completed during a Level II study for cross drainage water supply. Coyote Basin reservoir water would be diverted into Beaver Creek and serve approximately 9,840 acres.

11.3.4 GEOTECHNICAL HAZARDS

No specific geotechnical hazards have been identified for the Coyote Basin site. General geotechnical problems include the clayey soil conditions that may have limitations for embankment construction.

11.3.5 ENVIRONMENTAL PERMITTING CONSTRAINTS

Approximately 1.7 acres of herbaceous, palustrine emergent wetland would be filled by reservoir construction. Additional, indirect impacts to wetlands downstream of the dam would likely occur during construction and placement of a dam spillway.

The Coyote Basin site occurs within elk and mule deer crucial winter range (Wyoming Department of Game and Fish) and approximately 86 acres of this type of habitat would be displaced by the reservoir. Sage grouse leks are not known to occur near the reservoir site. There are no known special-status species or habitat at the site. Paleontological resources may exist within the basin. Fossilized dinosaur remains have been removed in the general vicinity.

The entire site occurs on public land administered by the BLM although would through private land. Construction of a reservoir would constitute a federal action and an Environmental Assessment or other document may be needed prior to construction as well as a 404 permit from the U.S. Army Corps of Engineers.

11.3.6 SUMMARY

The Coyote Basin reservoir site is the second (2nd) largest potential reservoir site evaluated in this study but would irrigate only 320 acres. Water would be provided through seasonal run-off within the local watershed, possibly supplemented by water either in a canal or pipe from the drainage immediately west of the site. Flowing water was observed in this western drainage during field reconnaissance surveys.

Limiting factors may be soil characteristics with moderate seepage potential and minor dam building limitations. Erosion potential is moderate in this area. Due to the surface area of the reservoir, evaporation could be relatively high. Minimal environmental impact is anticipated at the site although additional surveys would be necessary to confirm the absence of paleontological resources.

Key site characteristics are presented in Table 11.3.6.1

TABLE 11.3.6.1
Coyote Basin Reservoir Characteristics
Shell Creek Watershed

Characteristics	Coyote Basin Reservoir
Maximum water depth (feet)	98
Average water depth (feet)	36
Storage Capacity (acre-feet)	3,112
Surface Area (acres)	86
Immediate Direct Drainage Area (mi^2) & Assumed Mean Annual Flow Volume (af/yr)	1.1 / 620
Supplemental Mean Annual Drainage Area (mi^2) and Mean Annual Flow, including upper Red Canyon and Beaver Creeks (af/yr)	64.9 / 36,500
Water Source	Seasonal run-off, possibly water from Beaver Creek
Service Area (acres)	9,840
Primary Conveyance	Beaver Creek and Red Canyon Creek
Geotechnical Constraints	Potential soil constraints for embankments
On Perennial Stream	No
Wetlands Potentially Filled (acres)	1.71
Significant Cultural Resources	None recorded
Special-Status Species	None recorded
Paleontological Resources	Possible
Land Ownership	Private/Public
Mule Deer Winter Range Displacement	86 acres

11.4 HIGH LINE RESERVOIR EXPANSION

The High Line Reservoir site is located at an existing reservoir along the north side of Highway 14 immediately west of the town of Shell. The existing reservoir is fed via the High Line Ditch through a siphon that passes under the highway. The existing reservoir is relatively small; enlarging the site would require raising the dam height along the old highway which currently serves as the existing dam. An extensive forested and shrub wetland has developed around the existing reservoir edge. The entire site is located on private land (Figure High Line Reservoir found in Appendix O – Water Storage Site Maps).

Photo 11.4: Existing High Line Reservoir

11.4.1 SITE CHARACTERISTICS

The High Line Reservoir site is located between two highway embankments (old and new). Underlying geologic units are the Sundance and Gypsum Springs Formations (shale, siltstone, limestone, and dolomite). The primary soil unit is 372BD (Worland-Persayo complex), characterized by low expansion index, high seepage potential, and severe erosion hazard. The potential dam abutments are located on the old highway which serves as a dam for the existing reservoir. Slopes are relatively moderate, between 5 and 10 percent, and are comprised of road mix and coarse gravels.

Forested and scrub/shrub wetlands and riparian areas dominate the majority of the area that would be inundated by raising the dam height. Common species include plains cottonwood (*Populus deltoides*), narrow-leaf cottonwood (*Populus angustifolia*), sandbar willow (*Salix exigua*), water sedge (*Carex aquatilis*), and Baltic rush. Adjacent upland communities that would be flooded include tame pasture comprised of crested wheatgrass (*Agropyron cristatum*) with minimal amounts of Wyoming big sagebrush, and areas within the existing and old highway rights-of-way that are dominated by Wyoming big sagebrush, Indian ricegrass (*Oryzopsis hymenoides*), and weedy annual forbs such as Russian thistle (*Salsola kali*). A list of species, percent cover, and physical characteristics of each plot as well as photos are included in Appendix A – Site Parameters and Canopy Cover by Species, and Appendix J – Reservoir Location Photos, respectively.

A wetlands delineation plot was completed at a representative location within the flood zone. Hydrophytic vegetation (described above) dominated a broad band around the reservoir between 15- and 75-feet wide. However, hydric soils have not developed in many places that are dominated by hydrophytic vegetation. Hydric soils were found in a relatively narrow band (approximately 6 to 20 feet) surrounding the reservoir. Wetland hydrology also occurs within the same narrow band that has developed hydric soils. The area that supports all three U.S. Corps of Engineers wetland criteria (vegetation, soils, and hydrology) appears to be the area that is within the reservoir's high-water mark when at full pool.

11.4.2 WATER STORAGE CAPACITY

Topographic data are unavailable for calculating current water storage volumes within the High Line Reservoir, although the reservoir area encompasses approximately 3.1 acres. Storage capacity is therefore presented for the entire reservoir site based on raising dam height by 16 feet. Total storage capacity within the new reservoir would be approximately 20 acre-feet. The new reservoir would increase the average depth of the existing reservoir by approximately five feet, and occupy approximately four additional acres.

11.4.3 WATER SOURCE AND SERVICE AREA

Water for the High Line Reservoir Extension would continue to be provided by the High Line Ditch, which is supplied from the Trapper Creek drainage. This reservoir would provide supplemental irrigation water for approximately 5,326 acres and could be conveyed through McDonald Ditch & Shell Canal.

11.4.4 GEOTECHNICAL HAZARDS

No geotechnical hazards have been identified for the High Line Reservoir site.

11.4.5 ENVIRONMENTAL PERMITTING CONSTRAINTS

Approximately 4 acres of forested, scrub/shrub, and herbaceous, palustrine emergent wetland would be inundated by raising the reservoir's existing dam height. However, the existing wetlands are a function of artificial water management that has created potentially isolated wetlands in an otherwise non-wetland environment. Isolated wetlands without a "significant nexus" to a traditionally navigable waterway are not considered jurisdictional wetlands and do not require a 404 permit for project construction. A jurisdictional determination regarding the existing wetlands around the High Line Ditch reservoir would have to be made by the U.S. Army Corps of Engineers to determine if a 404 permit would be necessary prior to enlarging the reservoir.

The High Line Reservoir occurs at the edge of mapped mule deer crucial winter range (Wyoming Department of Game and Fish) and approximately 4 acres of this type of habitat would be displaced by enlarging the reservoir. Sage grouse leks are not known to occur near the reservoir site. There are no known special-status species or habitat at the site.

The entire site occurs on private land. However, it may be necessary to obtain an encroachment permit from the Wyoming Department of Transportation if the reservoir backs up water to within the highways right-of-way easement.

11.4.6 SUMMARY

The High Line Reservoir site represents a relatively small reservoir addition to the watershed. However, water is currently available through an existing, managed system. In addition, the site occurs on private land and dam construction would occur within an existing disturbance (i.e. the old highway). Soil and geotechnical hazards are an unlikely concern since the site already supports a dam. One limiting factor may be loss of the forested and scrub/shrub wetlands that currently border the site, should they prove jurisdictional. Mitigation and permitting issues related to the removal or fill of these types of wetlands are often time-consuming and expensive.

Key site characteristics are presented in Table 11.4.6.1.

TABLE 11.4.6.1.
High Line Reservoir Expansion Characteristics
Shell Creek Watershed

Characteristics	High Line Reservoir Extension
Maximum additional water depth (feet)	16
Average additional water depth (feet)	5
Storage Capacity (acre-feet)	20
Surface Area (acres)	4
Immediate Direct Drainage Area (mi^2) & Assumed Mean Annual Flow Volume (af/yr)[1]	61.0 / 35,300
Supplemental Mean Annual Drainage Area (mi^2) and Mean Annual Flow from Trapper Creek (af/yr)[1]	61.0 / 35,300
Water Source	Water provided via siphon from High Line Ditch
Service Area (acres)	5,326
Primary Conveyance	Shell Canal
Geotechnical Constraints	None
On Perennial Stream	No
Wetlands Potentially Filled (acres)	4
Significant Cultural Resources	None recorded
Special-Status Species	None recorded
Land Ownership	Private
Mule Deer Winter Range Displacement	4 acres

[1] Direct and Supplemental drainage areas are the same as a reservoir expansion would rely on water sources currently supplied to the site.

11.5 LEAVITT RESERVOIR EXTENSION

Similar to the High Line Reservoir site, the Leavitt Reservoir Expansion site would entail enlarging the existing reservoir (Figure Leavitt Reservoir Expansion, found in Appendix O – Water Storage Site Maps). Unlike the High Line Reservoir site, however, this would be accomplished by damming a coulee adjacent to the existing dam and then connecting the entire site into a single reservoir. The existing dam height would not be affected as there is little opportunity for raising the dam given the surrounding topography. Construction of the additional reservoir would occur on public land administered by the BLM although access to the site would be through private land.

Photo 11.5: Leavitt Reservoir Expansion - Looking down drainage adjacent to existing reservoir

11.5.1 SITE CHARACTERISTICS

Leavitt Reservoir is located in a broad valley west of upper Beaver Creek. The site is underlain by Quaternary-age terraces and alluvium, and Cretaceous-age Cloverly/Morrison Formations (shale and mudstone). NRCS soil data were not available for this site; however, some soil information was obtained from the Wyoming Geographic Information Science Center. Primary soil type is typic torriorthents, with loamy texture and rock outcrop. Also present are typic haplargids and typic natrargids, with fine- and coarse-loamy textures. Erosion hazard is moderate. The potential dam abutments occur on slopes typically between 15 and 30 percent.

Vegetation within the coulee is primarily comprised of Wyoming big sagebrush and Gardner's saltbush communities. Dominant species include Wyoming big sagebrush, Gardner's saltbush, bluebunch wheatgrass, Sandberg's bluegrass, cheatgrass (*Bromus tectorum*), and a variety of forbs. In addition, overflow and seepage from the existing reservoir has created a scrub/shrub wetland within the drainage. Dominant species include: peachleaf willow (*Salix amygdaloides*), sandbar willow (*Salix exigua*), Russian olive (*Elaeagnus angustifolia*), cattail, and alkali bulrush (*Scirpus maritimus*). A list of species, percent cover, and physical characteristics of each plot as well as photos are included in Appendix A – Site Parameters and Canopy Cover by Species, and Appendix J – Reservoir Location Photos, respectively.

11.5.2 WATER STORAGE CAPACITY

Water storage capacity for the Leavitt Reservoir Extension was estimated based on a maximum potential dam height and water depth of approximately 33 feet. Storage capacity behind this assumed dam height is 48 acre-feet. If the reservoir were constructed with this configuration, the average depth of the Extension would be approximately 12 feet, and occupy approximately 4 acres.

11.5.3 WATER SOURCE AND SERVICE AREA

Water for the Leavitt Reservoir Extension would continue to be provided by the drainage above the reservoir and a diversion ditch from Beaver Creek, the same sources for the existing reservoir. Service Area is 9,937 acres.

11.5.4 GEOTECHNICAL HAZARDS

No geotechnical hazards have been identified for the Leavitt Reservoir site, especially since a dam already exists for the existing reservoir.

11.5.5 ENVIRONMENTAL PERMITTING CONSTRAINTS

Approximately 1.0 acre of scrub/shrub and palustrine emergent wetland would be inundated by construction of the reservoir extension dam and subsequent inundation. Similar to the High Line Ditch site, wetlands have been created at this site through artificial water management and subsequent water seepage and overflow from the existing reservoir. However, unlike the High Line Ditch site, the Leavitt Reservoir Extension site does connect through the downstream drainage to Beaver Creek, thence Shell Creek, and ultimately to the Bighorn River. Consequently, a jurisdictional determination may conclude that this wetland exhibits a significant nexus to a traditional navigable waterway and a 404 permit may be required for construction to proceed.

The Leavitt Reservoir Extension occurs at the edge of mapped mule deer crucial winter range (Wyoming Department of Game and Fish) and approximately 4 acres of this type of habitat would be displaced by enlarging the reservoir. Sage grouse leks are not known to occur near the reservoir site. There are no known special-status species or habitat at the site.
The reservoir extension would occur on public land with access to the site through private land.

11.5.6 SUMMARY

The Leavitt Reservoir Extension site represents a relatively small potential storage site, but one with access to existing managed water. Soil and geotechnical hazards are an unlikely concern since the site already supports a dam. Expansion of the reservoir, however, could undermine some sedimentary formations located along the western shoreline, which could lead to minor earth slumping or rock falls. Agreement from the BLM would be necessary to construct on the site. Consequently, a federal action would be required to allow reservoir construction and an Environmental Assessment or other document may need to be completed prior to construction. Similarly, a 404 permit from the U.S. Army Corps of Engineers may be necessary if the wetlands created by reservoir seepage are determined to be jurisdictional.

Key site characteristics are presented in 11.5.6.1 on the following page.

TABLE 11.5.6.1 Leavitt Reservoir Expansion Characteristics Shell Creek Watershed	
Characteristics	**Leavitt Reservoir Expansion**
Maximum additional water depth (feet)	33
Average additional water depth (feet)	12
Storage Capacity (acre-feet)	45
Surface Area (acres)	4
Immediate Direct Drainage Area (mi^2) & Assumed Mean Annual Flow Volume (af/yr)[1]	41.8 / 28,000
Supplemental Mean Annual Drainage Area (mi^2) and Mean Annual Flow from Beaver Creek (af/yr) [1]	41.8 / 28,000
Water Source	Beaver Creek through existing Leavitt Reservoir
Service Area (acres)	9,937
Primary Conveyance	Beaver Creek
Geotechnical Constraints	None
On Perennial Stream	No
Wetlands Potentially Filled (acres)	1.0
Significant Cultural Resources	None recorded
Special-Status Species	None recorded
Land Ownership	Public
Mule Deer Winter Range Displacement	4 acres

[1] Direct and Supplemental drainage areas are the same as a reservoir expansion would rely on water sources currently supplied to the site.

11.6 RED CANYON RESERVOIR

The Red Canyon reservoir site is located within a steeply incised, unnamed drainage between the confluence of Beaver Creek to the west, and Red Canyon Creek to the east (Figure Red Canyon Reservoir found in Appendix O – Water Storage Site Maps). Reconnaissance-level field surveys were completed at the site. An ephemeral drainage that carries seasonal high flows meanders through the bottom of the site. The dam site and lower portion of the reservoir would be located on private land. The upper portion of the reservoir would fill portions of the drainage on public land administered by the BLM. New construction was noted immediately downstream of the potential dam site. It appeared that foundation footings and septic systems had been recently installed on a small flat above the drainage. Also, an old dam, approximately six-feet-high, was noted at the mouth of the drainage. It appeared that an abandoned ditch may have provided water to a small reservoir behind the dam in the past.

Photo 11.6: Red Canyon Reservoir Site – Looking south towards drainage mouth.

11.6.1 SITE CHARACTERISTICS

The Red Canyon site occupies a relatively steep, v-shaped ephemeral drainage. The site is underlain by rocks of the Cloverly/Morrison formations, which are composed of shale and mudstone. Soil consists primarily of soil map unit 374CE (Chipeta-Persayo-Rock Outcrop complex). This soil has some limitations for embankments. The expansive soil index is low, and the erosion hazard is high. Soil texture at both the east and west potential dam abutments is comprised of clay with limited coarse fragments. Slopes are highly erodible, semi-vegetated "badlands" with numerous rills on the slope faces. The slope angle of the east dam abutment is approximately 45 percent, while the slope angle of the west dam abutment is approximately 85 percent. Photos of each potential dam abutment are presented in Appendix J – Reservoir Location Photos.

Vegetation within the Red Canyon site is dominated by Wyoming big sagebrush/bluebunch wheatgrass (*Artemisia tridentata/Agropyron spicatum*) communities on the east-facing slopes; Gardner's saltbush/rubber rabbitbrush (*Atriplex gardnerii/Chyrsothamnus nauseosus*) or Gardner's saltbush and Wyoming big sagebrush communities on the west-facing slopes; and greasewood (*Sarcobatus vermiculatus*) in the valley bottom. Limited areas of hydrophytic vegetation occur in the channel bottom. Upland vegetation was sampled at three sites within the potential reservoir footprint. Potential wetland vegetation was sampled at one site in what appeared to be the most likely wetland on the channel. A list of species, percent cover, and physical characteristics of each plot as well as photos are included in Appendix A– Site Parameters and Canopy Cover by Species, and Appendix J – Reservoir Location Photos, respectively.

11.6.2 WATER STORAGE CAPACITY

Water storage capacity for the site was estimated based on a dam height and maximum water depth of 65 feet. Storage capacity at assumed dam height is approximately 546 acre-feet. A reservoir of this depth and configuration would have an average depth of approximately 27 feet, and occupy approximately 20 acres.

11.6.3 WATER SOURCE AND SERVICE AREA

Water for the Red Canyon site would be provided by seasonal high flows in the unnamed tributary drainage between Red Canyon and Beaver creeks. Additional water for the site would have to be diverted from areas upstream (e.g., Red Canyon and Beaver Creeks). This reservoir would provide supplemental irrigation water to 9,765 acres.

11.6.4 GEOTECHNICAL HAZARDS

No specific geotechnical hazards have been identified for the Red Canyon site. Clayey soil conditions may have general limitations for embankment construction.

11.6.5 ENVIRONMENTAL PERMITTING CONSTRAINTS

Minimal wetlands occur within this drainage. Less than 0.01 acre of marginal palustrine emergent wetlands exists within the ephemeral drainage near the valley's mouth. The site is located within designated mule deer crucial winter range (Wyoming Department of Game and Fish) and would remove approximately 20 acres. Sage grouse leks are not known to occur near the site although a covey of eight juvenile birds was noted in the area.

Portions of the site occur on public land and would require agreement from the BLM to fill these areas. Further, wetland fill would require completion of a 404 permit pursuant to the Clean Water Act. Consequently, a federal action would be required to allow reservoir construction and an Environmental Assessment or other document may need to be completed prior to construction.

11.6.6 SUMMARY

Construction of the Red Canyon reservoir would create a moderate-sized storage facility within the Beaver Creek/Red Canyon Creek watershed. Water would be provided through seasonal run-off in the unnamed drainage above the reservoir, and possibly supplemented by water diverted from Red Canyon Creek.

Limiting factors may be soil characteristics with limited water holding capacity or that preclude dam building. Erosion potential also is high in this area which could result in excessive sedimentation in the reservoir. Minimal environmental impact is anticipated at the site. Key characteristics are presented in Table 11.6.6.1.

TABLE 11.6.6.1

Red Canyon Reservoir Characteristics
Shell Creek Watershed

Characteristics	Red Canyon Reservoir
Maximum water depth (feet)	65
Average water depth (feet)	27
Storage Capacity (acre-feet)	546
Surface Area (acres)	20
Immediate Direct Drainage Area (mi^2) & Assumed Mean Annual Flow Volume (af/yr)	3.0 / 1,600
Supplemental Mean Annual Drainage Area (mi^2) and Mean Annual Flow, including upper Red Canyon and Beaver Creeks (af/yr)	67.8 / 36,500
Water Source	Seasonal run-off; possibly diverted water from Red Canyon Creek
Service Area (acres)	9,765
Primary Conveyance	Beaver Creek
Geotechnical Constraints	Potential soil constraints for embankments
On Perennial Stream	No
Wetlands Potentially Filled (acres)	<0.01
Significant Cultural Resources	None recorded
Special-status species	None recorded
Land Ownership	Private/Public
Mule Deer Winter Range Displacement	20 acres

11.7 TRAPPER CREEK AND TRAPPER CREEK EAST COMPLEX

The Trapper Creek Complex includes two watershed tributaries to Trapper Creek. The primary site, Trapper Creek, is located in a u-shaped basin immediately west of the confluence of Bush Creek and Trapper Creek. The secondary site, Trapper Creek East, is located on Bush Creek (an ephemeral drainage) immediately upstream of its confluence with Trapper Creek. Both sites are shown on Figure Trapper Creek Reservoir found in Appendix O – Water Storage Site Maps. Approximately one-half of the Trapper Creek site is located on private land, including the potential dam site. The majority of the Trapper Creek East site is located on public land administered by the BLM, although the potential dam site would likely be on private land.

Reconnaissance level surveys were completed at the Trapper Creek site. The Trapper Creek East site was identified late in the project at the landowner's suggestion. Reconnaissance level field surveys were not completed at this site, although a brief scouting tour was completed.

Photo 11.7: Trapper Creek Reservoir Site - Looking north towards basin mouth

11.7.1 SITE CHARACTERISTICS

Trapper Creek is a relatively deep, u-shaped basin with steep walls and a flat bottom. Trapper Creek East is a more v-shaped drainage centered on Bush Creek, an ephemeral drainage with seasonal flows in response to snow melt and intense rain events. Both sites are underlain by the Triassic-age Chugwater Formation, a red siltstone. NRCS soil data were not available for this area; however, some soil information was obtained from the Wyoming Geographic Information Science Center. The primary soils are mesic and typic haplocambids, which has a fine-loamy texture over a sandy texture. Erosion hazard is moderate but water seepage loss may be severe in some locations.

Surface characteristics of the potential dam abutments were noted at the Trapper Creek site. Soil texture at the east abutment was a fine silt-loam with many coarse fragments and moderately erodible soil as evidenced by several rills on the slope face. Soil texture at the west abutment was a fine silt-loam with few coarse fragments and similarly erodible soil as occurs on the east side. Slopes at the east abutment were between 35 and 45 percent, while slopes at the west abutment were between 50 and 55 percent. Photos of each potential dam abutment site are presented in Appendix J- Reservoir Location Photos.

Vegetation within the Trapper Creek site includes an irrigated alfalfa meadow on the flat, bottom ground surrounded by a Wyoming big sagebrush/bluebunch wheatgrass community type on the east-facing slopes, and a shadscale/rubber rabbitbrush (*Atriplex confertifolia/Chyrsothamnus nauseosus*) community type on the west-facing slopes. The alfalfa is irrigated by gravity-feed piped from Trapper Creek through a relatively deep (i.e. 15 feet) notch in the ridge east of the site. Extensive halogeton (*Halogeton glomeratus*), a noxious weed poisonous to livestock, was noted on the west-facing slopes. Vegetation was surveyed at three points within the potential impoundment area. A list of species, percent cover, and physical characteristics of each plot are included in Appendix A - Site Parameters and Canopy Cover by Species.

As previously mentioned, a reconnaissance level survey was not completed on the Trapper Creek East site. However, a brief tour of the site with the landowner indicated that the bottom of the drainage was comprised of either grass hay meadows or Wyoming big sagebrush. Slopes surrounding the drainage appeared to be dominated by Wyoming big sagebrush.

11.7.2 WATER STORAGE CAPACITY

Water storage capacities for the Trapper Creek and Trapper Creek East sites were estimated based on maximum potential dam height and water elevations of 98 feet and 65 feet respectively. Storage capacities behind these assumed dam heights are 2,507 and 734 acre-feet for the Trapper Creek and Trapper Creek East sites, respectively. If the reservoirs were constructed with these configurations, the average depth of the Trapper Creek reservoir would be approximately 40 feet, and occupy approximately 62 acres. The average depth of the Trapper Creek East site would be about 31 feet, and the surface area would be encompass approximately 24 acres.

11.7.3 WATER SOURCE AND SERVICE AREA

Water for the Trapper Creek site would be from the current system that has gravity feed piping from Trapper Creek through a relatively deep notch cut in the ridge east of the site, and into pipe for irrigating alfalfa. It is unknown exactly how much water is currently piped into this area. Approximately 2,507acre-feet would be required to fill the Trapper Creek reservoir which could be obtained from off-season flows in Trapper Creek.

Water for the Trapper Creek East site would be provided by seasonal high flows in Bush Creek and possibly piped water from Trapper Creek.

11.7.4 GEOTECHNICAL HAZARDS

No geotechnical hazards have been identified for the Trapper Creek sites.

11.7.5 ENVIRONMENTAL PERMITTING CONSTRAINTS

Few environmental permitting constraints were noted at either site. Wetlands are not present at the Trapper Creek site. A formal wetland delineation was not completed at the Trapper Creek East site but it did not appear that wetlands would be present at this site either. Bush Creek does flow through the Trapper Creek East site and would be the primary water source for a reservoir during intermittent, seasonal flows. Bush Creek is an incised drainage approximately 2 to 6 feet deep with generally steep banks an obvious channel scouring.

Approximately 62 acres of mule deer winter range would be displaced by the Trapper Creek reservoir while approximately 24 acres of mule deer winter range would be displaced by the Trapper Creek East reservoir. No species of special concern are known to occur in either drainage according to the Wyoming Natural Diversity Database. There are no known archeologically or historically significant features at either site.

Portions of both sites occur on public land, including the majority of the Trapper Creek East site. Agreement from the BLM would be necessary to fill either site. Consequently, a federal action would be required to allow reservoir construction and an Environmental Assessment or other document may need to be completed prior to construction.

11.7.6 SUMMARY

Off-season water could be supplied to the Trapper Creek site along the existing gravity-feed pipeline from Trapper Creek, although the pipeline would require engineering and redesign. The Trapper Creek site in particular presents a relatively deep basin that would help prevent water loss due to evaporation. Limiting factors may be soil characteristics with limited water holding capacity. Minimal environmental impact is anticipated with either site. Key characteristics of both sites are presented in Table 11.7.6.1.

TABLE 11.7.6.1
Trapper Creek and Trapper Creek East Characteristics
Shell Creek Watershed

Characteristics	Trapper Creek	Trapper Creek East
Maximum water depth (feet)	98	65
Average additional water depth (feet)	40	31
Storage Capacity (acre-feet)	2,507	734
Surface Area (acres)	62	24
Immediate Direct Drainage Area (mi^2) & Assumed Mean Annual Flow Volume	60.2 / 35,300[1]	12.5 / ---[2]
Supplemental Mean Annual Drainage Area (mi^2) and Mean Annual Flow, including upper Trapper Creek (af/yr)	60.2 / 35,300[1]	60.2 / 35,300[1]
Water Source	Trapper Creek	Bush Creek seasonal flows
Service Area (acres)	14,962	14,962
Primary Conveyance	Highline Ditch	Shell Canal
Geotechnical Constraints	Potential soil constraints	Potential soil constraints for embankments
On Perennial Stream	No	No
Wetlands Potentially Filled (acres)	None	Probably none
Significant Cultural Resources	None recorded	None recorded
Special-Status Species	None recorded	None recorded
Land Ownership	Private/Public	Private/Public
Mule Deer Winter Range Displacement	62 acres	24 acres

[1]These estimates assume that water could be supplied from Trapper Creek to each reservoir site. A pipeline currently supplies water via gravity feed to the Trapper Creek site. The pipeline would likely have to be enlarged to fill a reservoir.

[2] Modeling of the 12.5 acres of immediate watershed above this site was not completed as the site was evaluated late in the project and it was determined the 12.5 acres of immediate watershed would not have the capacity to contribute a substantial amount of runoff.

11.8 RESERVOIR COSTS ANALYSIS

The cost estimates are given in February 2010, dollars, which is sufficient for comparing the relative efficiency of the various sites. If an application for funding were to be made for any site, the estimate would need to be revised to reflect estimated prices at the time the job would be bid. The unit prices for the various items of work were obtained from various jobs administered by Engineering Associates, from suppliers and from Wyoming Department of Transportation weighted average bid prices. The prices were projected to February 2010, using the Engineering News Record construction cost index. The costs of the various items were summed and mobilization of 10% more or less was added. To obtain construction cost, a contingency of 15% was added. Administrative and legal costs were estimated at 5% of construction costs. Design phase engineering and construction phase engineering were each estimated at 10% of construction costs.

11.8.1 DAM CHARACTERISTICS

Volume of foundation excavation and fill was obtained from Table 11.9.1. To calculate the volume of rip rap the following assumptions were made:

1. The upstream face of the embankment would be on a 3:1 slope
2. The width of the embankment of the bottom was equal to 1/3 of the width at the top of the embankment.
3. The rip rap would be 3 feet thick

11.8.2 OUTLET WORKS

Outlet was assumed to be reinforced concrete pipe with a butterfly valve in a pit at the downstream end. The outlet would discharge into the stilling basin, provided for the service spillway. The estimated costs for the valve and pit are shown in tables in Section 11.8.5.

Water rights with priorities prior to March 1, 1945 are allowed to divert water at the rate of 1 CFS per 35 acres irrigated, if the water is available. The assumption was made that all of the irrigated acres downstream of the reservoir had a priority earlier than March 1, 1945 and the outlet pipe was sized accordingly.

11.8.3 SERVICE SPILL WAY

The service spillway was estimated as a reinforced concrete chute with bottom and walls 12" thick down the downstream face of the dam with a stilling basin at the bottom. The slope of the downstream face of the dam was assumed to be 3:1. The stilling basins were designed using criteria found in "Hydraulic Design of Stilling Basins and Energy Dissipaters" published by the Bureau of Reclamation. The cost estimate was based on a reinforced concrete basin with walls 12" thick with the cost of concrete estimated at $650/cubic yard.

11.8.4 EMERENCY SPILL WAY

The emergency spillway was estimated as a channel excavated through one of the abutments sized to carry the 100 year storm. The channel assumed to flow at a depth of 4 feet with side slopes of 2:1 with the channel bottom slope set to maintain a velocity of 5ft/sec or less.

11.8.5 RESERVOIR CONSTRUCTION COST ESTIMATES

Individual cost estimates were created for each reservoir site. The cost estimates are summarized in Table 11.9.1.

Bratsky Draw

Opinion of Probable Construction Cost

Cost of Project Components:	Qty	Unit	Cost	
Mobilization	1	LS	$ 1,968,100.00	
Foundation Excavation	157,000	CY	$ 1,648,500.00	
Fill	1,419,000	CY	$ 17,028,000.00	
Riprap	23,050	CY	$ 461,000.00	
Outlet Works				
20" RCP Pipe	608	FT	$ 41,344.00	
Valve	1	LS	$ 10,800.00	
Service Spillway				
Chute	1	LS	$ 205,400.00	
Stilling Basin	1	LS	$ 196,300.00	
Emergency Spillway				
Excavation	12480	CY	$ 131,040.00	
Total Cost of Project Components			$ 21,690,484.00	
Consultant Fees:				
Preparation of Final Design and Specifications				$ 2,743,846.23
Permitting and Mitigation (4%)				$ 1,097,538.49
Legal Fees (2%)				$ 548,769.25
Acquisition of Access and Rights of Way (3%)				$ 823,153.87
Construction Costs Subtotal #1			$ 21,690,484.00	
Const. Engineering Costs = CCS#1 x 10%			$ 2,169,048.40	
Subtotal #2			$ 23,859,532.40	
Contingency = Subtotal #2 x 15%			$ 3,578,929.86	
Construction Cost Total				$ 27,438,462.26
Project Cost Total 2010				$ 32,651,770.09
		SVWID	33%	$ 10,775,084.13
		WWDC	67%	$ 21,876,685.96

Collingwood Upper Reservoir

Opinion of Probable Construction Cost

Cost of Project Components:	Qty	Unit	Cost	
Mobilization	1	LS	$ 325,600.00	
Foundation Excavation	133,000	CY	$ 1,396,500.00	
Fill	82,000	CY	$ 984,000.00	
Riprap	18,880	CY	$ 377,600.00	
Outlet Works				
42" RCP Pipe	410	FT	$ 50,840.00	
Valve	1	LS	$ 26,700.00	
Service Spillway				
Chute	1	LS	$ 131,300.00	
Stilling Basin	1	LS	$ 204,100.00	
Emergency Spillway				
Excavation	12960	CY	$ 136,080.00	
Total Cost of Project Components			$ 3,632,720.00	
Consultant Fees:				
Preparation of Final Design and Specifications				$ 459,539.08
Permitting and Mitigation (4%)				$ 183,815.63
Legal Fees (2%)				$ 91,907.82
Acquisition of Access and Rights of Way (3%)				$ 137,861.72
Construction Costs Subtotal #1			$ 3,632,720.00	
Const. Engineering Costs = CCS#1 x 10%			$ 363,272.00	
Subtotal #2			$ 3,995,992.00	
Contingency = Subtotal #2 x 15%			$ 599,398.80	
Construction Cost Total				$ 4,595,390.80
Project Cost Total 2010				$ 5,468,515.05
		SVWID	33%	$ 1,804,609.97
		WWDC	67%	$ 3,663,905.08

Collingwood Middle Reservoir

Opinion of Probable Construction Cost

Cost of Project Components:	Qty	Unit	Cost	
Mobilization	1	LS	$ 119,700.00	
Foundation Excavation	24,000	CY	$ 252,000.00	
Fill	45,000	CY	$ 540,000.00	
Riprap	2,620	CY	$ 52,400.00	
Outlet Works				
30" RCP Pipe	116	FT	$ 10,904.00	
Valve	1	LS	$ 19,100.00	
Service Spillway				
Chute	1	LS	$ 20,800.00	
Stilling Basin	1	LS	$ 204,100.00	
Emergency Spillway				
Excavation	10370	CY	$ 108,885.00	
Total Cost of Project Components			$ 1,327,889.00	
Consultant Fees:				
Preparation of Final Design and Specifications				$ 167,977.96
Permitting and Mitigation (4%)				$ 67,191.18
Legal Fees (2%)				$ 33,595.59
Acquisition of Access and Rights of Way (3%)				$ 50,393.39
Construction Costs Subtotal #1			$ 1,327,889.00	
Const. Engineering Costs = CCS#1 x 10%			$ 132,788.90	
Subtotal #2			$ 1,460,677.90	
Contingency = Subtotal #2 x 15%			$ 219,101.69	
Construction Cost Total				$ 1,679,779.59
Project Cost Total 2010				$ 1,998,937.71
		SVWID	33%	$ 659,649.44
		WWDC	67%	$ 1,339,288.26

Collingwood Lower Reservoir

Opinion of Probable Construction Cost

Cost of Project Components:	Qty	Unit	Cost	
Mobilization	1	LS	$ 70,400.00	
Foundation Excavation	11,000	CY	$ 115,500.00	
Fill	20,000	CY	$ 240,000.00	
Riprap	1,160	CY	$ 23,200.00	
Outlet Works				
30" RCP Pipe	116	FT	$ 10,904.00	
Valve	1	LS	$ 19,100.00	
Service Spillway				
Chute	1	LS	$ 20,800.00	
Stilling Basin	1	LS	$ 204,100.00	
Emergency Spillway				
Excavation	7780	CY	$ 81,690.00	
Total Cost of Project Components			$ 785,694.00	
Consultant Fees:				
Preparation of Final Design and Specifications				$ 99,390.29
Permitting and Mitigation (4%)				$ 39,756.12
Legal Fees (2%)				$ 19,878.06
Acquisition of Access and Rights of Way (3%)				$ 29,817.09
Construction Costs Subtotal #1			$ 785,694.00	
Const. Engineering Costs = CCS#1 x 10%			$ 78,569.40	
Subtotal #2			$ 864,263.40	
Contingency = Subtotal #2 x 15%			$ 129,639.51	
Construction Cost Total				$ 993,902.91
Project Cost Total 2010				$ 1,182,744.46
		SVWID	33%	$ 390,305.67
		WWDC	67%	$ 792,438.79

Coyote Basin Reservoir

Opinion of Probable Construction Cost

	Qty	Unit	Cost	
Cost of Project Components:				
Mobilization	1	LS	$ 1,738,300.00	
Foundation Excavation	141,000	CY	$ 1,480,500.00	
Fill	1,272,000	CY	$ 15,264,000.00	
Riprap	20,660	CY	$ 413,200.00	
Outlet Works				
18" RCP Pipe	608	FT	$ 38,304.00	
Valve	1	LS	$ 9,200.00	
Service Spillway				
Chute	1	LS	$ 126,750.00	
Stilling Basin	1	LS	$ 50,050.00	
Emergency Spillway				
Excavation	3700	CY	$ 38,850.00	
Total Cost of Project Components			$ 19,159,154.00	
Consultant Fees:				
Preparation of Final Design and Specifications				$ 2,423,632.98
Permitting and Mitigation (4%)				$ 969,453.19
Legal Fees (2%)				$ 484,726.60
Acquisition of Access and Rights of Way (3%)				$ 727,089.89
Construction Costs Subtotal #1			$ 19,159,154.00	
Const. Engineering Costs = CCS#1 x 10%			$ 1,915,915.40	
Subtotal #2			$ 21,075,069.40	
Contingency = Subtotal #2 x 15%			$ 3,161,260.41	
Construction Cost Total				$ 24,236,329.81
Project Cost Total 2010				$ 28,841,232.47
		SVWID	33%	$ 9,517,606.72
		WWDC	67%	$ 19,323,625.76

High Line Reservoir

Opinion of Probable Construction Cost

Cost of Project Components:	Qty	Unit	Cost		
Mobilization	1	LS	$ 63,400.00		
Foundation Excavation	11,000	CY	$ 115,500.00		
Fill	26,000	CY	$ 312,000.00		
Riprap	1,330	CY	$ 26,600.00		
Outlet Works					
36" RCP Pipe	146	FT	$ 15,914.00		
Valve	1	LS	$ 21,600.00		
Service Spillway					
Chute	1	LS	$ 27,300.00		
Stilling Basin	1	LS	$ 48,750.00		
Emergency Spillway					
Excavation	7850	CY	$ 82,425.00		
Total Cost of Project Components			$ 713,489.00		
Consultant Fees:					
Preparation of Final Design and Specifications					$ 90,256.36
Permitting and Mitigation (4%)					$ 36,102.54
Legal Fees (2%)					$ 18,051.27
Acquisition of Access and Rights of Way (3%)					$ 27,076.91
Construction Costs Subtotal #1			$ 713,489.00		
Const. Engineering Costs = CCS#1 x 10%			$ 71,348.90		
Subtotal #2			$ 784,837.90		
Contingency = Subtotal #2 x 15%			$ 117,725.69		
Construction Cost Total					$ 902,563.59
Project Cost Total 2010					$ 1,074,050.67
		SVWID	33%		$ 354,436.72
		WWDC	67%		$ 719,613.95

Leavitt Reservoir

Opinion of Probable Construction Cost

Cost of Project Components:	Qty	Unit	Cost	
Mobilization	1	LS	$ 56,900.00	
Foundation Excavation	15,000	CY	$ 157,500.00	
Fill	23,000	CY	$ 276,000.00	
Riprap	1,490	CY	$ 29,800.00	
Outlet Works				
14" RCP Pipe	92	FT	$ 4,876.00	
Valve	1	LS	$ 8,000.00	
Service Spillway				
Chute	1	LS	$ 14,950.00	
Stilling Basin	1	LS	$ 44,200.00	
Emergency Spillway				
Excavation	3700	CY	$ 38,850.00	
Total Cost of Project Components			$ 631,076.00	
Consultant Fees:				
Preparation of Final Design and Specifications				$ 79,831.11
Permitting and Mitigation (4%)				$ 31,932.45
Legal Fees (2%)				$ 15,966.22
Acquisition of Access and Rights of Way (3%)				$ 23,949.33
Construction Costs Subtotal #1			$ 631,076.00	
Const. Engineering Costs = CCS#1 x 10%			$ 63,107.60	
Subtotal #2			$ 694,183.60	
Contingency = Subtotal #2 x 15%			$ 104,127.54	
Construction Cost Total				$ 798,311.14
Project Cost Total 2010				$ 949,990.26
		SVWID	33%	$ 313,496.78
		WWDC	67%	$ 636,493.47

Red Canyon Reservoir

Opinion of Probable Construction Cost

Cost of Project Components:	Qty	Unit	Cost	
Mobilization	1	LS	$ 486,300.00	
Foundation Excavation	54,000	CY	$ 567,000.00	
Fill	331,000	CY	$ 3,972,000.00	
Riprap	7,610	CY	$ 152,200.00	
Outlet Works				
16" RCP Pipe	410	FT	$ 23,780.00	
Valve	1	LS	$ 8,400.00	
Service Spillway				
Chute	1	LS	$ 84,500.00	
Stilling Basin	1	LS	$ 50,050.00	
Emergency Spillway				
Excavation	2780	CY	$ 29,190.00	
Total Cost of Project Components			$ 5,373,420.00	
Consultant Fees:				
Preparation of Final Design and Specifications				$ 679,737.63
Permitting and Mitigation (4%)				$ 271,895.05
Legal Fees (2%)				$ 135,947.53
Acquisition of Access and Rights of Way (3%)				$ 203,921.29
Construction Costs Subtotal #1			$ 5,373,420.00	
Const. Engineering Costs = CCS#1 x 10%			$ 537,342.00	
Subtotal #2			$ 5,910,762.00	
Contingency = Subtotal #2 x 15%			$ 886,614.30	
Construction Cost Total				$ 6,797,376.30
Project Cost Total 2010				$ 8,088,877.80
		SVWID	33%	$ 2,669,329.67
		WWDC	67%	$ 5,419,548.12

Trapper Creek Reservoir

Opinion of Probable Construction Cost

Cost of Project Components:	Qty	Unit	Cost	
Mobilization	1	LS	$ 3,637,900.00	
Foundation Excavation	297,000	CY	$ 3,118,500.00	
Fill	2,685,000	CY	$ 32,220,000.00	
Riprap	43,610	CY	$ 872,200.00	
Outlet Works				
12" RCP Pipe	608	FT	$ 29,184.00	
Valve	1	LS	$ 7,000.00	
Service Spillway				
Chute	1	LS	$ 104,650.00	
Stilling Basin	1	LS	$ 37,050.00	
Emergency Spillway				
Excavation	1890	CY	$ 19,845.00	
Total Cost of Project Components			$ 40,046,329.00	
Consultant Fees:				
Preparation of Final Design and Specifications				$ 5,065,860.62
Permitting and Mitigation (4%)				$ 2,026,344.25
Legal Fees (2%)				$ 1,013,172.12
Acquisition of Access and Rights of Way (3%)				$ 1,519,758.19
Construction Costs Subtotal #1			$ 40,046,329.00	
Const. Engineering Costs = CCS#1 x 10%			$ 4,004,632.90	
Subtotal #2			$ 44,050,961.90	
Contingency = Subtotal #2 x 15%			$ 6,607,644.29	
Construction Cost Total				$ 50,658,606.19
Project Cost Total 2010				$ 60,283,741.36
		SVWID	33%	$ 19,893,634.65
		WWDC	67%	$ 40,390,106.71

Trapper Creek East Reservoir

Opinion of Probable Construction Cost

Cost of Project Components:	Qty	Unit	Cost	
Mobilization	1	LS	$ 960,000.00	
Foundation Excavation	107,000	CY	$ 1,123,500.00	
Fill	661,000	CY	$ 7,932,000.00	
Riprap	15,220	CY	$ 304,400.00	
Outlet Works				
12" RCP Pipe	410	FT	$ 19,680.00	
Valve	1	LS	$ 7,000.00	
Service Spillway				
Chute	1	LS	$ 69,550.00	
Stilling Basin	1	LS	$ 37,050.00	
Emergency Spillway				
Excavation	12000	CY	$ 126,000.00	
Total Cost of Project Components			$ 10,579,180.00	
Consultant Fees:				
Preparation of Final Design and Specifications				$ 1,338,266.27
Permitting and Mitigation (4%)				$ 535,306.51
Legal Fees (2%)				$ 267,653.25
Acquisition of Access and Rights of Way (3%)				$ 401,479.88
Construction Costs Subtotal #1			$ 10,579,180.00	
Const. Engineering Costs = CCS#1 x 10%			$ 1,057,918.00	
Subtotal #2			$ 11,637,098.00	
Contingency = Subtotal #2 x 15%			$ 1,745,564.70	
Construction Cost Total				$ 13,382,662.70
Project Cost Total 2010				$ 15,925,368.61
		SVWID	33%	$ 5,255,371.64
		WWDC	67%	$ 10,669,996.97

11.9 POTENTIAL RESERVOIR SITE COMPARISON

To summarize the characteristics of the potential reservoir sites, Table 11.9.1 is shown on the following page. To compare among the potential reservoir sites, a comprehensive matrix was developed relative to key criteria (e.g. storage capacity, available water, service area, construction costs and permitting complexity). The greater a variable's assigned importance, the greater the variable's numeric value. For example, with respect to the *Service Area* variable, the larger the potential area served by a site, the higher its rank and numeric value relative to other sites.

Weighting among variables was also assigned according to each variable's perceived importance. Rankings presented in Table 11.9.2 were developed according to previous professional experience with project design, construction, and permitting and are intended to represent a realistic, although not absolute, comparison of all sites. However, there is no direct correlation between measurements of widely different variables. For example, *Service Area* could be considered more or less important than *Permitting Complexity* depending upon a reviewer's background, perspective, or professional position.

Finally, the interaction of the variables *Storage Capacity, and Mean Annual Drainage Area Flow*, combine to fully describe a site's potential for water storage since large storage areas are inefficient if water is unavailable to fill them. Based on these considerations, the following assumptions were used to guide ranking assignments and comparisons.

Assumption 1: *Storage Capacity, and Mean Annual Drainage Area Flow* interact to determine how effectively the storage capacity of the reservoir can be filled by annual flows. Rankings from these variables were combined to create a single ranking variable termed *Fill Capacity*. *Fill Capacity* was considered the primary determinant in the matrix and was weighted by a factor of "3". High scores indicate a positive score for the reservoir.

Assumption 2: *Service Area* was considered a key determinant in the matrix and was weighted by a factor of "2". Sites with larger service areas were ranked higher relative to sites with smaller service areas. A higher score indicates a more favorable score.

Assumption 3: *Construction Cost per Acre-Foot of Storag*e was considered a key determinant in the matrix. To establish a positive score for a low Construction Cost per Acre-Foot of Storage, the inverse of the *Construction Cost per Acre-Foot of Storage* was multiplied by a factor of 100,000. Sites with a lower *Construction Cost per Acre-Foot of Storage* rank more favorable than a site with a high *Construction Cost per Acre-Foot of Storage*.

Assumption 4: Other factors, such as if public land, a perennial stream, wetlands or other sensitive resources would be affected, were combined into a single variable termed *Permitting Complexity* based on professional experience with similar projects. This determinant was weighted by a factor of "1.0". It is understood that permitting issues can greatly affect a project's viability, cost, and schedule. However, this variable was weighted lower than other variables since the resource must first be available and feasible to develop before permitting concerns gain relevance.

Table 11.9.1
Reservoir Site Summary

Site Number	1	2	2a	2b	3	4	5	6	7	7a
Site Name	Bratsky Draw Reservoir	Collingwood Draw Complex Upper	Collingwood Draw Complex Middle	Collingwood Draw Complex Lower	Coyote Basin	High Line Reservoir Expansion	Leavitt Reservoir Extension	Red Canyon Reservoir	Trapper Creek	Trapper Creek East Complex
Location Information										
USGS 7.5-minute Topographic Quadrangle	Shell	Shell	Shell	Shell	Leavitt Reservoir	Shell	Leavitt Reservoir & Bear Creek Ranch	Shell	White Sulfur Spring	White Sulfur Spring
Water Source	Seasonal Runoff, Beaver or Shell Creek	Seasonal Runoff	Seasonal Runoff	Seasonal Runoff	Seasonal runoff, Beaver Creek	Siphon from High Line Ditch	Beaver Creek	Red Canyon Creek / Seasonal Runoff	Trapper Creek	Bush Creek/ Seasonal Runoff
Primary Conveyance	Shell or Beaver Creek	Shell Canal	Shell Canal	Whaley Ditch	Beaver Creek	Shell Canal	Beaver Creek	Beaver Creek	High Line Ditch / Shell Canal	High Line Ditch / Shell Canal
Onstream / Offstream	Offstream	Offstream	Offstream	Offstream	Offstream	Offstream	Offstream	Offstream	Offstream	Offstream
Basin Characteristics and Hydrology										
Immediate Watershed										
Drainage Area (square miles)	3.1	2.8	2.8	2.8	1.1	61	41.8	3	60.2	12.5
Estimated Mean Annual Flow Characteristics										
Estimated Runoff Volume (thousand acre-feet)	1.9	1.8	1.8	1.8	0.62	35.3	28	1.6	35.3	No Data 1
Supplemental Watershed										
Drainage Area (square miles)	285.6	None	None	257.2	64.9	61	41.8	67.8	60.2	60.2
Estimated Mean Annual Flow Characteristics										
Estimated Peak Discharge of 2 year storm (thousand cfs)	2.08	None	None	1.94	0.66	0.63	0.51	0.66	0.32	0.32
Estimated Runoff Volume (thousand acre-feet)	174.7	None	None	162.2	36.5	35.33	28	36.5	35.3	35.3
Annual Peak Flow Characteristics										
Region	Ephemeral Valley	Ephemeral Valley	Ephemeral Valley	Ephemeral Valley	Ephemeral Valley	Existing Reservoir	Broad Valley	Ephemeral Drainage	U-Shaped Basin	Ephemeral Drainage
Average Annual Precipitation (in)	11	9.7	9.2	8.9	11.7	10	12.7	11	12.8	13.2
Reservoir Characteristics and Operation										
Normal High Water										
Capacity (acre-feet)	5,839	2,692	11	71	3,112	20	45	546	2,507	734
Surface Area (acres)	160	157	4	13	86	4	4	20	62	24
Water Surface Elevation	4295	4295	4195	4155	4605	4230	4804	4535	4575	4655
Average Water Depth (feet)	36	17	3	6	36	5	12	27	40	31
Site Geology										
Geology										
Potential Soil Constraints										
Landslide Deposits										
Soil Limitations for Embankment Material										
Borrow										
Relative apparent availability										
Relative apparent quality										
Site Environmental Conditions										
Environmental Issues										
NWI Wetlands (acres)	0.96	0	0	7.8	1.71	4	1	0.01	0	0
Sage Grouse Leks	none	none	none	none	none	none	none	none	none	none
Big Game Habitat - Crucial	Mule Deer	none	none	none	Elk / Mule Deer	Mule Deer	Mule Deer	Mule Deer	Mule Deer	Mule Deer
Big Game Parturition (Birthing Areas)										
Infrastructure and Ownership										
Infrastructure / Utilities Conflicts										
Residences / Facilities	0	0	0	0	0	X	0	X	0	0
Highways	0	0	0	0	0	1	0	0	0	0
Railroads	0	0	0	0	0	0	0	0	0	0
Pipelines	0	0	0	0	0	X	0	0	0	0
Irrigated Lands (acres)	0	0	0	0	0	0	0	0	0	0
Energy Resources										
Oil Field										
Gas Field										
Land Ownership										
Private	X			X		X		X	X	X
State										
Federal	X	X	X	X	X		X	X	X	X
Dam Characteristics and Hydraulic Structures										
Dam										
Freeboard/ Head on Spillway (ft)	5	5	5	5	5	5	5	5	5	5
Crest Elevation (feet)	4300	4300	4200	4160	4610	4235	4809	4540	4580	4660
Total Crest Length (feet)	1004	1240	700	310	900	270	530	500	1900	1000
Crest Width (ft)	20	20	20	20	20	20	20	20	20	20
Maximum Dam Height (feet)	98	65	16	16	98	21	12	65	98	65
Riprap (cy)	23050	1880	2620	1160	20660	1330	1490	7610	43610	15220
Foundation Excavation Volume (thousand cy)	157	133	24	11	141	11	15	54	297	107
Total Earthwork Fill Volume (thousand cy)	1419	820	45	20	1272	26	23	331	2685	661
Storage Efficiency (ac-ft/1000cy)	4.11	3.28	0.24	3.53	2.45	0.76	1.94	1.65	0.93	1.11
Height Efficiency (feet/ac-ft)	0.74	1.60	381.82	58.59	1.48	211.75	106.87	8.32	1.83	6.35
Outlet Works										
Proposed Type	Pipe & Valve	Pipe &Valve	Pipe &Valve	Pipe &Valve	Pipe &Valve	Pipe &Valve	Pipe &Valve	Pipe &Valve	Pipe &Valve	Pipe &Valve
Service Spillway										
Design Capacity (cfs)	5400	5000	5000	5000	1700	1600	1300	1700	800	800
Approximate Width (feet)	17.5	16.5	7	7	7	7	6	7	4	4
Emergency Spillway										
Design Capacity (cfs)	6032	5626	5626	5626	1914	1827	1479	1914	928	928
Approximate Width (feet)	317	270	270	270	90	86	70	90	41	41
Approximate Length (feet)	100	250	200	150	200	200	250	150	200	200
Cut Volume (cy/1000)	12.48	12.96	10.37	7.78	3.7	7.85	3.7	2.78	1.89	12
Supply and Delivery Facilities										
Supply Canal										
Characteristics of Supply Ditch to carry Peak Flows										
Terrain										
Other										
Access										
Cultural Resources										
Irrigated Acres Below Point of Diversion	8,807	4,719	4,719	6,499	9,840	5,326	9,937	9,765	14,962	14,962
Costing										
Total Project Cost	$ 32,651,770	$5,468,515	$1,998,937	$ 1,182,744	$ 28,841,232	$1,074,050	$ 949,990	$ 8,088,877	$ 60,283,741	$15,925,368
Total Project Cost per Irrigated Acre	$ 3,707	$ 1,159	$ 424	$ 182	$ 2,931	$ 202	$ 96	$ 828	$ 4,029	$ 1,064
Total Project Cost per AC-FT of Storage	$ 5,592	$ 2,031	$ 181,722	$ 16,658	$ 9,268	$ 53,703	$ 21,111	$ 14,815	$ 24,046	$ 21,697

Excellent or more than adequate
Favorable or adequate
Potentially marginal or unfavorable value
Probable Fatal flaw or very unfavorable value

Note 1. Site added late in the study. Previous analysis of Trapper Creek indicated surplus water was not available in the area so data not computed.

TABLE 11.9.2

Potential Reservoir Comparison Matrix Shell Creek Watershed

Potential Reservoir Site[1]	Storage Capacity (acre-feet)	Score	Assumed Mean Annual Flow Volume (af/yr) [2]	Score	Fill \ Capacity Score [3]	Service Area (irrigable acres)	Score[4]	Construction Cost Per acre-foot of Storage	Score[5]	Permitting Complexity	Score[6]	Ranking Score Sum[6]
Bratsky Draw	5,839	**5.8**	174,700	**17.5**	**69.9**	8,807	**17.6**	5,592	**17.8**	Moderate	**2**	**107.3**
Collingwood Draw - Upper	2,692	**2.7**	1,800	**0.2**	**8.7**	4,719	**9.4**	2,031	**49.2**	Moderate	**2**	**69.3**
Collingwood Draw - Middle	11	**0.0**	1,800	**0.2**	**0.6**	4,719	**9.4**	181,722	**0.5**	Moderate	**2**	**12.5**
Collingwood Draw - Lower	71	**0.0**	162,200	**16.2**	**48.6**	6,499	**12.9**	16,658	**6.0**	Complex	**1**	**68.5**
Coyote Basin	3,112	**3.1**	28,620	**2.8**	**17.7**	9,840	**19.7**	9,268	**10.8**	Moderate	**2**	**50.2**
High Line Reservoir Expansion	20	**0.0**	35,300	**3.5**	**10.5**	5,326	**10.6**	53,703	**1.9**	Complex	**1**	**24.0**
Leavitt Reservoir Expansion	45	**0.0**	28,000	**2.8**	**8.4**	9,937	**19.8**	21,111	**4.7**	Moderate	**2**	**34.9**
Red Canyon	546	**0.5**	8,500	**0.9**	**4.2**	9,765	**19.5**	14,815	**6.7**	Moderate	**2**	**32.4**
Trapper Creek	2,507	**2.5**	35,300	**3.5**	**18.0**	14,962	**29.9**	24,046	**4.2**	Simple	**3**	**55.1**
Trapper Creek East	734	**0.7**	35,300	**3.5**	**12.6**	14,962	**29.9**	21,697	**4.6**	Simple	**3**	**50.1**

NOTE:
1) See Appendix O – Water Storage Site Maps for site locations.
2) Includes drainage area currently supplying water to existing reservoirs (High Line and Leavitt), water that is piped either through a site (Trapper Creek East) or to a site (Trapper Creek), or water that could relatively easily be diverted to fill a site (Shell Canal to Collingwood Draw Lower).
3) Fill/Capacity Score equals sum of scores from Storage Capacity and Immediate Mean Annual Flow Volume, weighted by a factor of "3".
4) Service area divided by 1,000, and weighted by a factor of "2".
5) One divided by the Construction Cost per Acre-Foot of Storage per acre-feet of storage, weighted by a factor of "100,000".
6) Permitting Complexity based on professional experience with similar projects. Sites that would affect public land, substantial wetlands, streams, or other sensitive resources were considered more complex to permit. This variable was weighted by a factor of "1.0".
7) Ranking Score Sum is the sum of the Fill / Capacity Score, Service Area Score, Construction Cost per Acre Foot of Storage, and Permitting Complexity Score.

12.0 UPLAND WATERSHED MANAGEMENT AND REHABILITATION PLAN

12.1 WATERSHED REHABILITATION PROJECTS

As part of the Level I Study process, small water development projects within the watershed were identified based on interviews with participating local residents and NRCS staff. Identifying small water projects during the Level I Study process allows these projects to qualify for SWPP funding later, should the SVWID elect to continue participating in the WWDC study and funding program.

The goals of the following projects are designed to provide water to wildlife, enhance the distribution of livestock and wildlife, distribute livestock and wildlife into vegetated areas that previously did not have a reliable water source for the animals to use, provide longer rest rotations for vegetation, and minimize livestock impacts to natural seepage areas.

- Battle Creek Spring Development
- Black Mountain Pipeline Phase 1 & 2
- Collingwood Draw Pipeline Phase 1& 2
- Dutch Springs Well Phase 1 & 2
- Fox Mountain Allotment Phase 1, 2 & 3
- Home Pasture
- Little Horse Creek Pipeline
- North Slope Pipeline Phase 1 through 5
- Ralston Gulch Pipeline
- Rattlesnake Hill Pipeline Phase 1 & 2
- Red Mountain Well Phases 1 through 4
- Split Ear Spring
- Sunlight Gulch Pipeline
- White Sulphur Spring
- Whaley Spring

The goals of the following projects are designed to provide water to wildlife and livestock to enhance the distribution of the animals within the area.

- Collingwood Draw Reservoir
- Potato Ridge Allotment – Phase 1 & 2

The goals of the following projects are designed to provide year round water to wildlife and livestock to enhance the distribution of the animals. The systems will provide water to the animals in the winter, when currently water is not available in the winter.

- Mesa Well
- Mesa Pipeline Phase 1 & 2

Table 12.1.1 lists the projects identified by landowners, the BLM and the NRCS. Figures 12.1.1 through 12.1.4 on the subsequent pages identify the locations for the projects identified by the land owners and the BLM.

Table 12.1.1: Watershed Improvement Projects

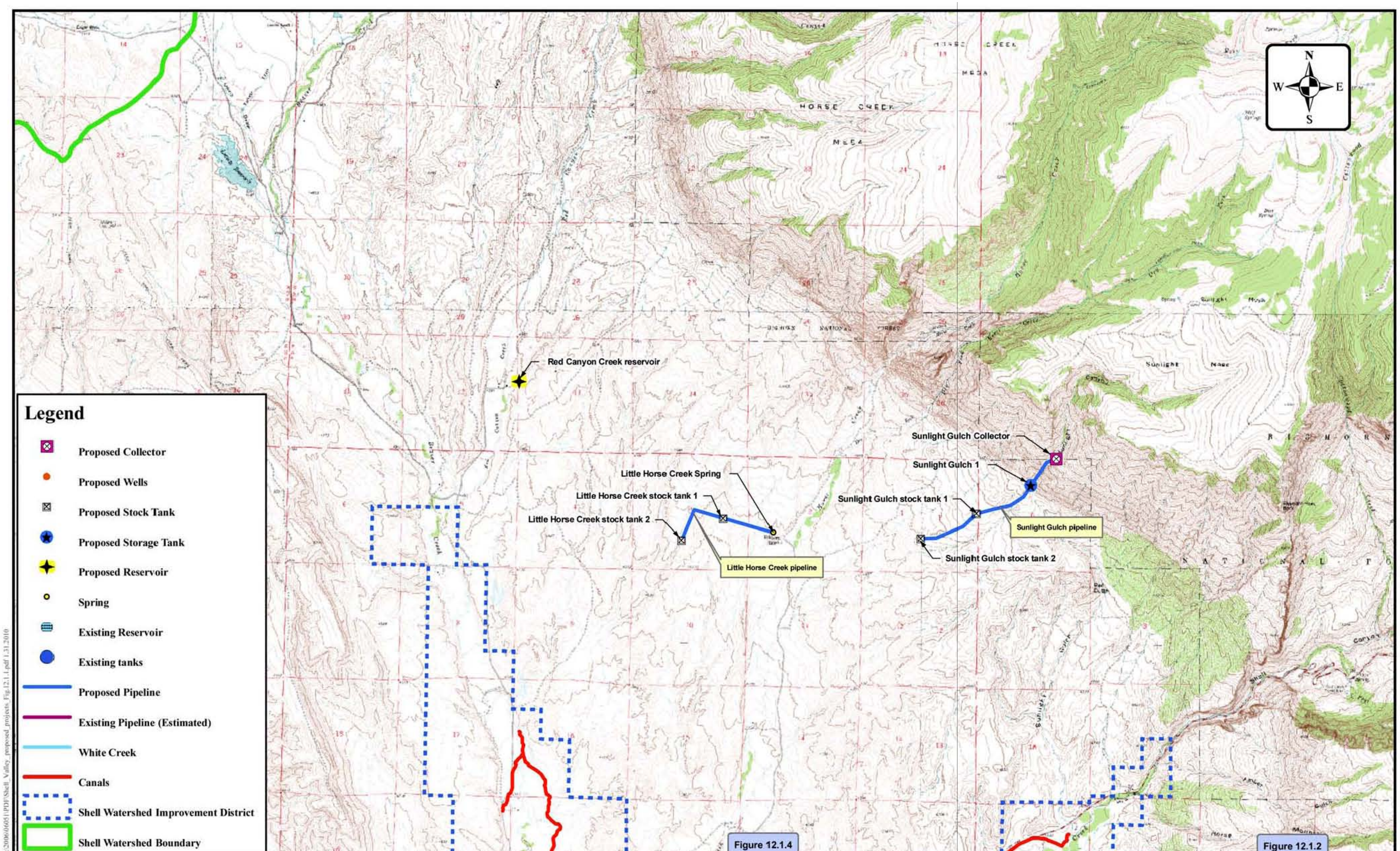
PROJECT NAME	LOCATION	WATER SOURCE		PIPELINE LENGTH (LF)	STORAGE TANKS		WATER STOCK TANKS (NUMBER)	RESERVOIR OR DIKE		2010 PROBABLE PROJECT COST*
		SPRINGS (NUMBER)	WELLS (NUMBER)		NUMBER	SIZE (GAL)		NUMBER	AVERAGE SIZE (CY)	
Battle Creek Spring Development	T 52 R88 Section 14	1		1,000			2			$ 14,200
Black Mountain Pipeline - Phase 1	Drainage - Trapper Canyon to Shell Creek Area - From top of Black Mountain to the West to Table Mountain and Trone Gulch			12,500	1	4,000	2	1-Reservoir	2,000	$ 92,090
Black Mountain Pipeline - Phase 2				20,000			3			$ 88,560
Collingwood Draw Pipeline-Phase 1	Drainage - North Sheldon to Shell Creek Area - from Hwy 14 southeast then east to South of Fox Mtn.	1 Solar Pump Shell Canal		10,000			2	1-Reservoir	3,500	$ 84,610
Collingwood Draw Pipeline-Phase 2				10,560			2	2-Reservoirs	3,500	$ 96,200
Collingwood Reservoir	Drainage - North Sheldon to Shell Creek Area - between Douglas Draw and North Sheldon along Hwy 14. Rebuild Dam and clean reservoir							1-Reservoir	9,000	$ 65,500
Dutch Springs Well - Phase 1	Drainage - North Sheldon to Shell Creek Drainage Area - North of N. Sheldon Gulch		1 Solar Well Pump	50			1			$ 99,750
Dutch Springs Well - Phase 2				10,560	1	5,000	2			$ 97,730
Fox Mountain Allotment - Phase 1	Drainage - Douglas Draw & North Sheldon to Shell Creek Area -North, South and East of Fox Mountain							7-Dikes	2,300	$ 93,550
Fox Mountain Allotment - Phase 2								2-Reservoirs	6,000	$ 72,590
Fox Mountain Allotment - Phase 3								2-Reservoirs	6,000	$ 72,590
Home Pasture	Shell Creek Drainage	4		4,800			6			$ 53,220
Little Horse Creek Pipeline	Horse Creek Drainage	1		7,500			2			$ 42,970
Mesa Well	Red Gulch Drainage		1-Solar Well Pump	25			1			$ 95,670
Mesa Pipeline - Phase 1				12,000			1	1-Reservoir	2,025	$ 68,930
Mesa Pipeline - Phase 2				9,000			1	1-Reservoir	3,500	$ 64,570
North Slope Pipeline - Phase 1	Drainage - Red Gulch to Shell Creek Area - project spans multiple State Lease areas	1		19,500			3			$ 99,650
North Slope Pipeline - Phase 2				15,000			1	1-Reservoir		$ 82,060
North Slope Pipeline - Phase 3				19,000			1			$ 87,670
North Slope Pipeline - Phase 4				7,500			1			$ 36,760
Potato Ridge Allotment - Phase 1	Drainage - Douglas Draw and North Sheldon to Shell Creek Area - North South and East of Fox Mountain							4-Reservoirs	3,500	$ 84,690
Potato Ridge Allotment - Phase 2								3-Reservoirs	3,500	$ 63,510
Ralston Gulch Pasture	Ralston Gulch Drainage	1		20,000			2			$ 98,320
Rattle Snake Hill Pipeline - Phase 1	Drainage - White creek to Shell Creek Area - South of White Creek running to the west			8,000	1	6,000	2			$ 97,830
Rattle Snake Hill Pipeline - Phase 2				10,000			3			$ 54,930
Red Canyon Creek Reservoir	Red Canyon Creek Drainage - 20 foot tall dam. 4 ac-ft storage.							1-Reservoir	32,265	$ 212,140**

* Costs include 10% Engineering Fees and 5% Permitting Fees.

** Costs for this Project included 10% Engineering and 15% Permitting

Table 12.1.1: Watershed Improvement Projects (continued)

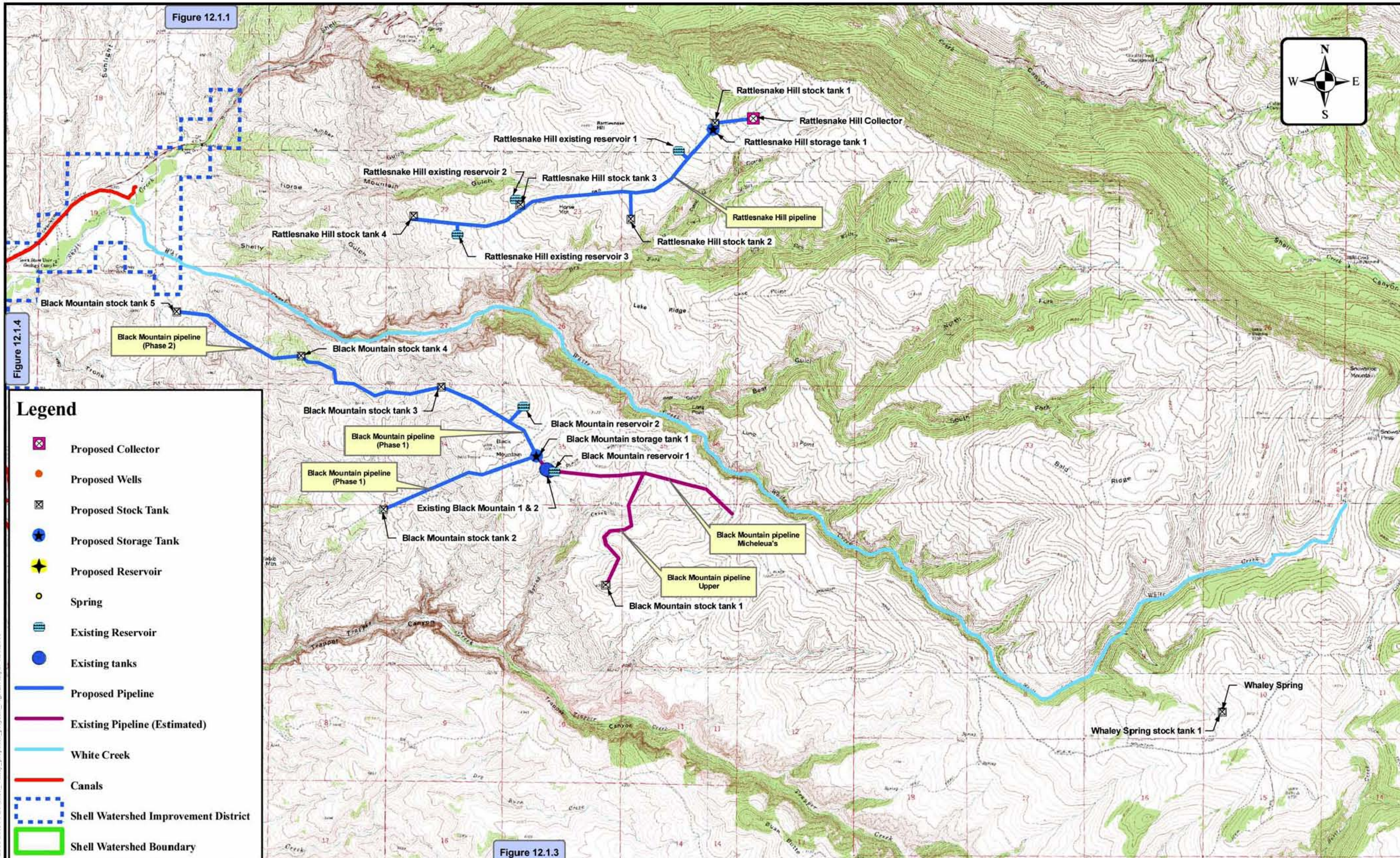
PROJECT NAME	LOCATION	WATER SOURCE		PIPELINE LENGTH (LF)	STORAGE TANKS		WATER STOCK TANKS (NUMBER)	Reservoir or Dike		2010 PROBABLE PROJECT COST*
		SPRINGS (NUMBER)	WELLS (NUMBER)		NUMBER	SIZE (GAL)		NUMBER	AVERAGE SIZE (CY)	
Red Mountain Well	Drainage - North Sheldon to Shell Creek Drainage Area between Red Gulch and North Sheldon Gulch		1 Solar Well Pump	25			1			$ 99,940
Red Mountain Pipeline - Phase 1				18,000			1			$ 83,250
Red Mountain Pipeline - Phase 2				6,000	1	7,500	1			$ 95,920
Red Mountain Pipeline - Phase 3				20,000			1			$ 92,100
Red Mountain West				6,000	1	7,500	1			$ 95,230
Red Mountain North				13,200			1			$ 69,100
Shell Creek Probst	Site Identified by NRCS Office	1		15,000			7			$ 93,940
Shell Creek Pike - Phase 1	Site Identified by NRCS Office	1	1 Solar Well Pump	100			2			$ 61,060
Shell Creek Pike - Phase 2				15,000			4			$ 80,620
Split Ear Spring	T 52 R90 Section 9		1 Solar Well Pump	100			1			$ 34,120
Sunlight Gulch Pipeline	Sunlight Gulch Drainage	1		8,000			2			$ 45,190
Trapper Creek Phase 1	Site Identified by NRCS Office	1	1 Solar Well Pump	5,000			1			$ 58,470
Trapper Creek Phase 2				15,000			5			$ 84,170
West Slope Pipeline - Phase 1	Site Identified by NRCS Office	1	1 Solar Well Pump	200	1	10,000	2			$ 98,400
West Slope Pipeline - Phase 2				20,980			2			$ 100,000
West Slope Pipeline - Phase 3				20,980			2			$ 100,000
West Slope Pipeline - Phase 4				20,980			2			$ 100,000
Whaley Spring	White Creek Drainage	1		150			1			$ 6,880
White Sulphur Spring	Sheldon Gulch Drainage	1		150			1			$ 6,880



ENGINEERING ASSOCIATES
CONSULTING ENGINEERS & SURVEYORS
CODY, WYOMING

Shell Valley Watershed - Level I

Shell Valley Watershed Improvement District
Proposed Projects
Figure 12.1.1

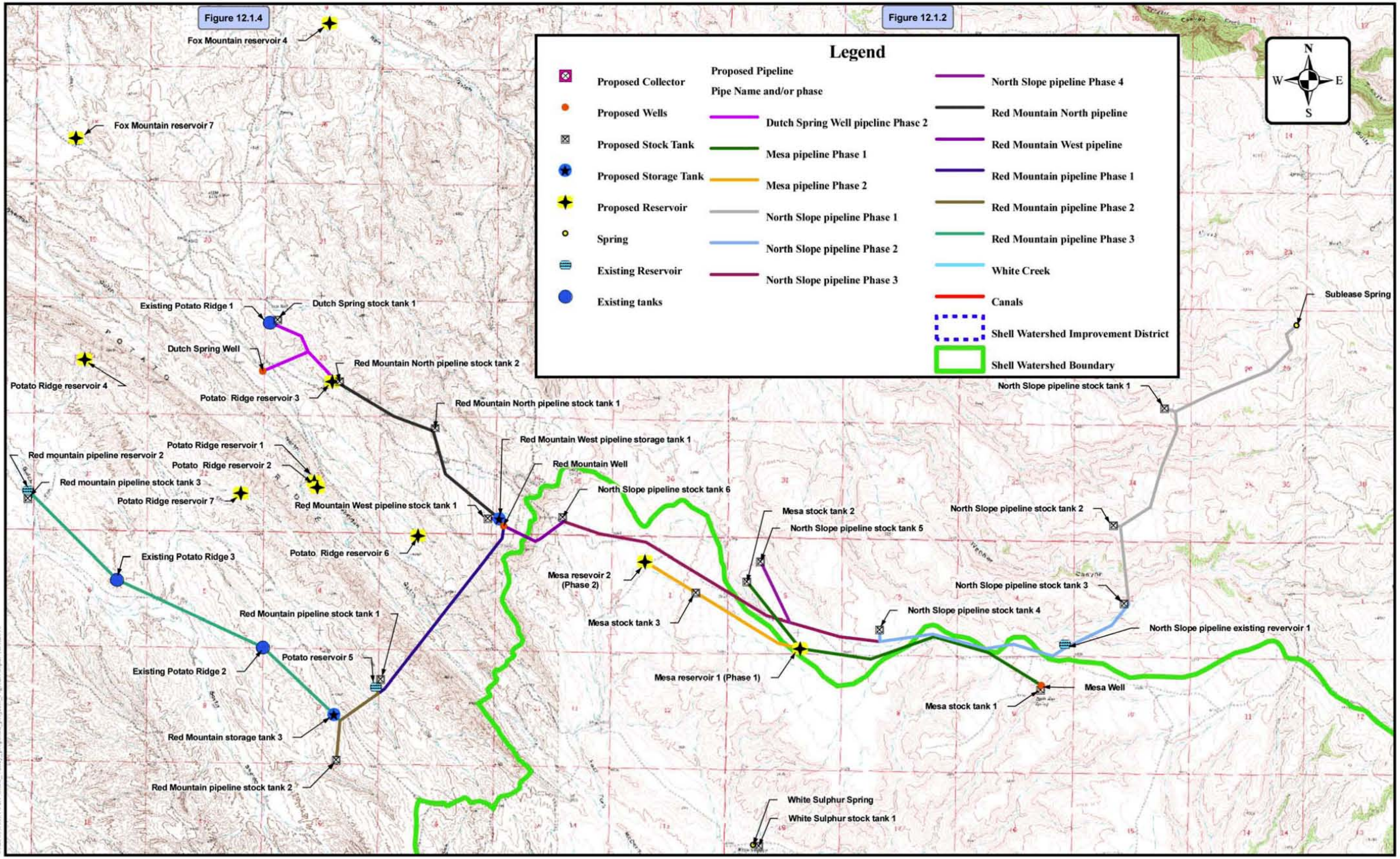


ENGINEERING ASSOCIATES
CONSULTING ENGINEERS & SURVEYORS
CODY, WYOMING

Shell Valley Watershed - Level I

Feet
0 1,000 2,000 4,000 6,000 8,000

Shell Valley Watershed Improvement District
Proposed Projects
Figure 12.1.2



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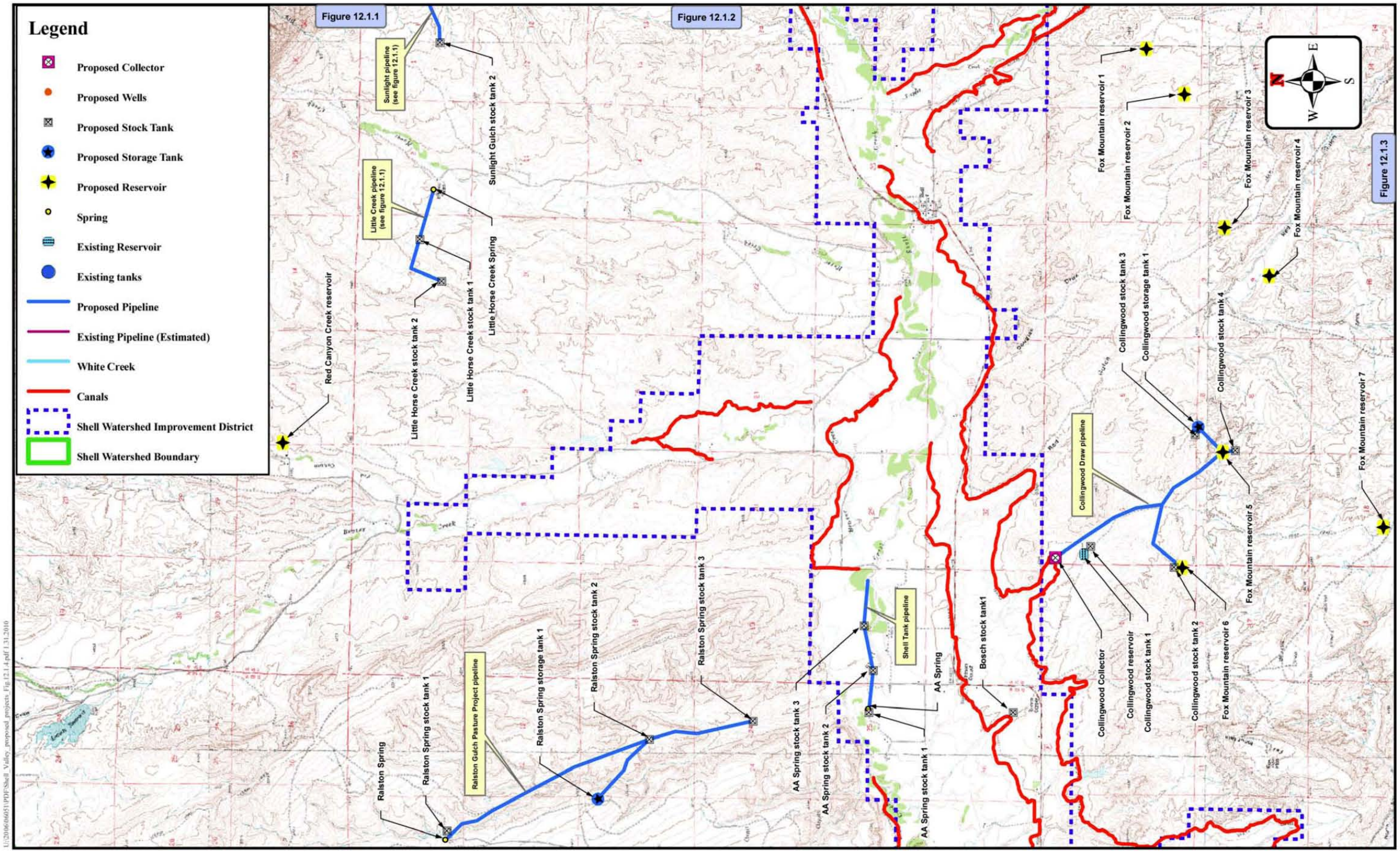
Shell Valley Watershed - Level I

Shell Valley Watershed Improvement District
Proposed Projects
Figure 12.1.3



ENGINEERING ASSOCIATES
CONSULTING ENGINEERS & SURVEYORS
CODY, WYOMING

Shell Valley Watershed - Level I

Feet
0 1,000 2,000 4,000 6,000 8,000

Shell Valley Watershed Improvement District
Proposed Projects
Figure 12.1.4

12.2 REHABILITATION FUNDING SOURCES

The watershed rehabilitation projects identified during the study could qualify for Small Water Project Program (SWPP) Account I or Account II based on the type of the project. Some projects have been identified by the producers as being improvements to existing reservoirs, but many of the projects are new projects that would qualify for Account I funding.

The landowners can receive funding assistance through the Small Water Project Program (SWPP) of the Wyoming Water Development Program, through the use of the SVWID. Prior to submitting an application, the landowner will need to work with either the SBHCD office or the SVWID to have the public entity sponsor the project. It is recommended that landowners and sponsors become familiar with the SWPP program by visiting their web page at http://wwdc.state.wy.us/small_water_projects/small_water_project.html . To be eligible for funding, the landowner will need to have a qualified public entity like the SBHCD or SVWID or another approved assessment district formed in accordance with Wyoming law be the sponsor of the project to WWDC. Approved entities include conservation district, watershed improvement districts and irrigation districts. The SWPP may provide funding to develop or rehabilitate small reservoirs, wells, solar platforms, pipelines and conveyance facilities, springs, wetland developments, irrigation projects and windmills. The SWPP program funds projects that have a total project cost less than $100,000 or where the maximum financial contribution from the commission is less than or equal to $25,000. The total project cost includes estimated construction costs, permit procurement, construction engineering and project land procurement.

Sponsors must provide all permits and clearances prior to the Wyoming Water Development Office (WWDO) issuance of the notice to proceed for construction. In the event the sponsor begins construction prior to the written notification of WWDC, the sponsor shall be responsible for all costs encountered prior to the date of the notification. With the application, the sponsor will be required to provide an operation and maintenance plan for the estimated life of the project.

> *Activities eligible for SWPP funding include permit procurement, project land procurement, construction engineering (design and construction inspections), project materials and invoiced contractor expenses. In-kind contributions are only eligible for installation of project materials that were purchased specifically for this project as documented by invoices.* (Operating Criteria of the Small Water Project Program of the Wyoming Water Development Program, 2008)

The SWPP program has specific billing criteria that must be met prior to the release of funds. It is important the sponsor understand the billing procedures for WWDC at the beginning of the project. The sponsor will need to take before and after photographs of the project. In addition, it is important all parties are aware of the procedure and time required to provide WWDC with the affidavit of publication. The affidavit of publication verifies the required notes of final settlement were published.

Applications for the SWPP program may be submitted any time of year, but must be submitted prior to January 1 of each calendar year for the year in which construction will take place. The project sponsor must be able to provide WWDC responses and documentation as required for the application process.

Landowners could also pursue the watershed improvement projects by utilizing funding opportunities provided by the local Natural Resources Conservation Service, Wyoming Game and Fish Department, Bureau of Land Management, Ducks Unlimited, and possibly even the National Fish and Wildlife Foundation. Table 12.2.1 on the following page provides a list of possible funding sources for projects within the watershed.

Table 12.2.1
Summary of Funding Source Options

Funding Source	Funding Program	Project Type	Funding Available To	Grant	Required Match for Grant	Web Site	Application Due Date
Local							
South Big Horn Conservation Distric	NA	Services range from technical guidance, administrative, and partnering with local landowners.	Land owners, organizations	See website.		http://www.conservewy.com/sbhcd/index.html	NA
County Weed and Pest	NA	Noxious weed control and identification	Land owners	See website.		http://www.bighorncountywy.gov/dep-weed-pest.htm	NA
State							
Wyoming Department of Environmental Equality	Nonpoint source Implementation Grants (319 Program)	Water Quality Best Management Practices	Conservation District, Cities, Counties	Up to $40,000	25%	http:deq.state.wy.us	Sept. 15
Wyoming Game and Fish Department	Riparian Habitat Improvement Grant	Water development for livestock; projects to stabilize stream banks, projects to improve riparian habitat	Land owners, Conservation Districts, Government agencies, Industry, non-profit organizations.	UP to $10,000	50%	http://gf.state.wy.us	Jan. 1 and Aug. 1
	Water Development/Maintenance Habitat Project	Water Developments for livestock		UP to $7500	50%		Please see website.
	Industrial Water Habitat Project Fund			NA	NA		
	Upland Development Grant	Range Management Activities		Up to $10,000	50%		
	Fish Wyoming	Activities that improve public fishing		See website.	50%		
	Wyoming Sage Grouse Conservation Fund	Projects that protect sage grouse		Please see website.		http://gf.state.wy.us/wildlife/wildlife_ management/sage grouse/index.asp	
Wyoming Office of State Lands and Investments	Regular Farm Loans	Agricultural based projects	Please see website.			http://slf-web.state.wy.us/admin/forms.aspx	Please see website.
	Small Water Development Project Loans	Improve efficiency of water delivery systems and converting native land into farm production.					
Wyoming Water Development Commission	Wyoming Water Development Program	Planning, Design & Construction of water related projects. (reservoirs, irrigation systems)	Recognized Public Entity with assessment capabilities.	NA	33%	http://wwdc.state.wy.us	New Projects: Aug. 1 On-going Projects: Oct. 1
	Small Water Project Program	Small projects that improve a watershed. (water distribution systems, water conveyance systems, etc.)	Land owners, Conservation Districts	up to $25,000	75%	http://wwdc.state.wy.us/small_water_project.html	Jan. 1
Wyoming Wildlife and Natural Resource Trust	N/A	Numerous projects that encompass range management and watershed improvement activities.	Non-profit and Governmental Organizations	See website.	8 to 1	http://wwnrt.state.wy.us	Mar. 31 and Sept. 30
Federal							
Bureau of Land Management	Riparian Habitat Management Program	Projects to create or improve wetlands and riparian areas.	Please see website.			http://www.blm.gov/wy/st/en.html	See website.
	Cooperative Agreement for Range Improvements	Livestock watering projects (wells, spring developments, pipelines, reservoirs, etc.)					
Bureau of Reclamation	Water SMART	Improvements to water systems to improve efficiency and conservation.	Please see website.			http://www.usbr.gov/WaterSMART/	See website.
Environmental Protection Agency	Targeted Watershed Grants Program	See website.				http://www.epa.gov/owow/watershed/initiative/	
Farm Service Agency	See website for current listing of programs.	Program Specific.	See website: http://www.fsa.usda.gov/FSA/stateoffapp?mystate=wy&area=home&subject=prog&topic=landing				
Fish and Wildlife Service	See website for current listing of programs.	Program Specific.	See website: http://www.fws.gov/				
Natural Resources Conservation Service	See website for current listing of programs.	Program Specific.	See website: http://www.nrcs.usda.gov/				
Non-Profit and Other Organizations							
Ducks Unlimited	NA	Projects that create, promote or enhance water fowls habitat.	See website: http://www.ducks.org/				
National Fish and Wildlife Foundation	See website: http://www.nfwf.org/AM/Template.cfm?Section=Home						
Trout Unlimited	See website: http://www.tu.org/						

13.0 WATER RIGHT MANAGEMENT PLAN

13.1 RURAL SPRAWL DEVELOPMENT

Rural sprawl is the phenomenon of widely scattered development within a rural landscape. Rural sprawl was identified as a concern by the SVWID due to water-use conflicts in open ditches and the loss of rural landscapes. Population in the Shell Valley in 1976 was approximately 618 to 680 individuals, with density concentrated on private lands – 8.6 persons per square mile on private compared to an overall density of 1.2 persons per square mile within the valley (A Plan for Shell Valley 1976). Populations for Shell Valley specifically are not available via census data. However, the population of rural Big Horn County (i.e. excluding Greybull, Manderson, Basin, etc.) increased from an average density of three people per square mile to four people per square mile between 1990 and 2006,. Although this increase still represents a sparsely populated area (the definition of "Wilderness" at the close of the frontier in 1890 was two people per square mile -http://www.pbs.org/fmc/timeline/d1890census.htm); the population increase is concentrated on relatively limited private lands located along the primary drainages (particularly Shell, Beaver, Trapper, and Horse creeks).

A recognition of the challenges posed by rural sprawl has led to a variety of studies and resolutions within the county (e.g. Subdivision Regulations for Big Horn County 1975 to 2006, A Plan for Shell Valley 1976, Big Horn County Comprehensive Plan 1977, Shell Valley Residence Water Study 1982, and Resolution of the Board of Commissioners of Big Horn County, State of Wyoming Shell Valley subarea mobile home policy amendment 1983). These plans, resolutions, and studies detail shared community values regarding land use and present a variety of regulations or suggestions for development. Typically these policies describe procedures to maintain scenic resources and wildlife habitat, prevent erosion, discourage development in floodplains or irrigated lands, and protect water quality and quantity. Population targets have been proposed for the Shell Valley as well as clustered developments, restrictions on mobile home parks, and other items.

A review of the existing development guidelines indicates that other than specific plans or permits related to structures, distances from water sources, easements, sewage and water systems, etc. there are few guidelines with regulatory authority. Most guidelines appear to be suggestions and encouraged or discouraged actions (e.g. "new development on irrigated lands shall be discouraged", A Plan for Shell Valley 1976). These target guidelines therefore appear to have few regulatory requirements to control rural sprawl. If rural sprawl is a concern within the Shell Valley community, additional zoning districts may provide greater local control within specific valleys or locales.

14.0 RECOMMENDATIONS

This Level I Study was a preliminary analyses and comparison of development alternatives and is meant to provide SVWID with reconnaissance information on their watershed and the many private irrigation companies that have facilities within the watershed boundary. This study will provide SVWID with information so they can determine if they would like to proceed to a Level II Study for hydropower and reservoir sites, or Level III Construction for rehabilitation of the irrigation systems. Following are recommendations for SVWID to proceed further to a Level II Study (with various items of this study:

- Hydropower was found to be minimally feasible. However, if SVWID is interested in pursuing hydropower, they should apply for a Level II, Phase I and II Study. The Phase I would address the project feasibility by providing amount of water that can be legally and physically developed, the water needs, technical and safety feasibility, geotechnical evaluation, preliminary operation plan, construction cost estimates, fee estimates for consultant services, operation and maintenance needs and funds required, identification of direct and indirect benefits of the project, identify economic, legal, environmental, and administrative issues, and a financing plan. A Phase II would take the feasible site identified in the Phase I and address issues such as operating plan for water management, conceptual designs, identification of state and federal permits, an environmental assessment, and preparation of itemized project budget, to be used for Level III Construction. These additional studies may provide SVWID with a level of comfort knowing they have exhausted all efforts in finding a viable hydropower site.

- SVWID should pursue a Level II, Phase I, Phase II, and Phase III Studies for their preferred reservoir sites. This study found reservoir sites that either had the storage capacity but not enough flow to fill the reservoir, or the flow to fill the reservoir but the inlet ditch would need to be extremely large to handle the maximum runoff to fill the reservoir. A Level II Study would provide SVWID with a level of comfort knowing that they have received a thorough analysis of this studies reservoir sites and any sites they prefer to have thoroughly evaluated.

  The Phase I would address the project feasibility by providing amount of water that can be legally and physically developed, the water needs, technical and safety feasibility, geotechnical evaluation, preliminary operation plan, construction cost estimates, fee estimates for consultant services, operation and maintenance needs and funds required, identification of direct and indirect benefits of the project, identify economic, legal, environmental, and administrative issues, and a financing plan.

  A Phase II would take the feasible site identified in the Phase I and address issues such as operating plan for water management, conceptual designs, identification of state and federal permits, an environmental assessment, and preparation of itemized project budget, to be used for Level III Construction.

  If the reservoir site is enlarging an existing reservoir by more than 1,000 acre-feet or a new reservoir with a capacity of 2,000 acre-feet or more, a Phase III study would provide final engineering design drawings, reviews required by National Environmental Policy Act (NEPA), consultation required by the Endangered Species Act, and acquisition of state and federal permits.

- Each private irrigation company should review Table 6.3.2 Structure Replacement Schedule and Construction Costs, to determine a plan of action for rehabilitating their systems and begin the application process to WWDC through their Small Water Projects Program. For the larger projects of lining the canals or placing the canals in pipe, the private irrigation companies should decide whether they will become a public entity and obtain WWDC Level III funding or provide descriptive easements to SVWID so SVWID can obtain WWDC Level III funding for the private irrigation company. Both the processes take a substantial amount of time to complete so additional time should be factored into the planning. WWDC SWPP applications are due by January 1 of each year. The funds become available after the March WWDC meeting, should the project receive funding. WWDC Level III (Construction) applications are due by September 1 of each year. The money will then be available by June 1 of the following year.

- Each private irrigation district should begin a maintenance program during the off-season for their systems. The maintenance program should include burning dead grass and weeds along their ditches and around their structures, repairing any broken head gates or other damaged structures, patching any concrete structures, adding fill material to badly eroded areas in the canal, mechanical cleaning of areas that would be difficult to burn, fixing ruts and potholes on the canal access roads, repairing any cattle guards that are not in good working order (or if this is the landowners responsibility notify the landowner of the needed repair).

In addition to the Natural Resources Conservation Service, individual land owners can receive funding opportunities from the Wyoming Office of State Land and Investments Small Water Development Project Loans or Regular Farm Loans for irrigation improvements. In addition, the Bureau of Reclamation has funding opportunities through the Water 2025 Challenge Grant Program to assist with water conservation efforts. The Wyoming Water Development Commission can also provide assistance through the Small Water Project Program when applicable.

- It is recommended SVWID determine the increment in which landowners would be willing to purchase water from a proposed reservoir site. EA currently recommends landowners purchase reservoir water on a 1.0 acre-foot basis. In addition, it is recommended SVWID determine the amount landowner's would be willing to pay to construct a reservoir.

- Landowners should pursue the watershed improvement projects by utilizing funding opportunities provided by the local Natural Resources Conservation Service, Wyoming Water Development Commission, Wyoming Game and Fish Department, Bureau of Land Management, Ducks Unlimited, and possibly even the National Fish and Wildlife Foundation.

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