Appendices for the Shell Valley Storage Level II Study

Prepared for Wyoming Water Development Commission

Prepared by States West Water Resources Corporation, Cheyenne WY


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Appendix A

“Geological and Geotechnical Evaluation Memorandum”

by RJH Consultants
MEMORANDUM

Project 10104

TO: Victor Anderson, P.E.
FROM: Edwin Friend, P.E., P.G.
DATE: April 20, 2012
RE: Shell Valley Storage, Level II Study
Geological and Geotechnical Evaluation Memorandum

General

The purposes of this memorandum are to present the findings, analyses, and conclusions of our reconnaissance-level geological and geotechnical evaluation of nine possible dam and reservoir sites near Shell, Wyoming that are being evaluated as part of the Shell Valley Storage Level II Study and our recommendations for future work. At some of the sites, RJH Consultants, Inc. (RJH) completed the following scope of services:

- Obtained and reviewed published geologic literature and maps near the proposed dam and reservoir sites.
- Participated in a site visit to eight proposed sites with the consultant team on October 21 and 22, 2010. The Chimney Rock site was not visited during this trip.
- Identified geologic conditions that are expected to significantly impact design and construction of a dam at each site.
- Reviewed laboratory test data from samples collected near one proposed site provided by Deere & Ault Consultants, Inc. (Deere & Ault).
- Selected five preferred sites with the consultant team.
- Prepared a conceptual-level design for dams at five preferred sites.
- Prepared conceptual-level cost estimates for dams at five preferred sites.
- Prepared this memorandum.

Eight proposed dam and reservoir sites were visited and nine were evaluated as part of this study. The sites (footprint of the dam and inundation limits of the reservoir) are identified below and the general location of the sites are shown on Figure 1.

- Upper Leavitt Reservoir
- Lower Leavitt Reservoir
- Coyote Draw
- Upper Bratsky Draw
- Lower Bratsky Draw
- Chimney Rock
Five preferred sites that were identified by the consultant team after the site visit are:

- Upper Leavitt Reservoir
- Lower Leavitt Reservoir
- Coyote Draw
- Douglas Draw
- Shell Canal Tunnel

**Fatal Flaws**

Based on data from this geologic condition; our geologic literature review; the site visit; and our experience as geological, geotechnical, and dam engineers, we identified a potential fatal flaw at the Bratsky Draw site and at the Chimney Rock site. In our opinion, the fatal flaw at Bratsky is a technical condition with the stability of the foundation and reservoir rim geology that would preclude economical development of a dam and reservoir. Additional information on the geologic conditions that provide the basis for this opinion are provided on Page 6 in the section titled “Upper and Lower Bratsky Draw.” In our opinion, the fatal flaw at the Chimney Rock site is a technical condition with the dissolution of the embankment and reservoir foundation that would preclude safe and economical development of a dam and reservoir. Additional information on the geologic conditions that provide the basis for this opinion are provided on Page 7 in the section titled “Chimney Rock.” We understand that Sheldon Gulch will also not be carried forward because of wetlands that are expected to significantly complicate or prevent permitting of the site.

Additional geologic and geotechnical evaluations, including subsurface investigations, should be completed at the sites that are carried forward into the next phase of study to evaluate key geologic and geotechnical conditions that are expected to have significant impacts on advancing the design of the dam and reservoir and to confirm that geologic fatal flaws that could not be identified at this level of study are not present. Information related to the general geologic conditions at each site are provided in the following sections.

**Seismicity**

The expected peak ground acceleration from an event with a return interval of 5,000 years is approximately 0.22g in the vicinity of the proposed dam sites. This ground motion was estimated for a single location generally near the center of the eight proposed sites using the Ground Motion Calculator developed by the U.S. Geological Survey (USGS, 2008). These ground motions may impact required freeboard and design of the embankment and facilities during future stages of Project development. The location selected for calculating the peak ground acceleration is shown on Figure 3. Seismic analysis calculations are presented in Appendix A.

No active faults were identified at the dam and reservoir sites. The closest fault classified by the USGS as active during the Quaternary period (the most recent 1.6 million years according to the USGS) is the Stagner Creek Fault, located approximately 80 miles south-southwest of the location selected for developing the peak ground acceleration (USGS,
2010a). The closest historic earthquake was a 3.0 magnitude event located approximately 20 miles southeast of the location selected for developing the peak ground acceleration (USGS, 2010b).

**Dam Site Geological and Geotechnical Conditions**

Except at the Bratsky Draw, Sheldon Gulch, and the Chimney Rock sites, the bedrock geology is similar at the sites evaluated. Generally, the Cloverly Formation is present at the sites. Descriptions and estimated thicknesses of the various geologic units provided are based on published mapping and information obtained during the site visit. Material descriptions and estimated thicknesses are likely to change from this memorandum when site-specific investigations are performed.

Geologic conditions in the Cloverly Formation that could impact design included gypsum and calcite filled fractures, and slickensided joints in mudstone. These conditions were identified during the site visit at the Douglas Draw and Shell Canal Tunnel sites. These conditions are likely present at the other sites where the Cloverly Formation is present.

Terrace gravels were identified at or near each site. Based on observations of terrace gravel deposits from road cuts, the terrace gravels generally would be classified as a clayey gravel, had low sand contents, and the durability of gravels needs to be confirmed.

**Upper and Lower Leavitt Reservoir**

An existing dam and reservoir are present at the two Leavitt Reservoir sites. Based on USGS 1960 topography, the elevation of the existing dam crest is 4,797 feet. Two dam locations are being considered at this site. One is named Lower Leavitt Reservoir. This project would replace the existing dam with a larger dam and would require a small saddle dam upstream of the left abutment. The other location would require construction of a new dam that crosses through about the middle of the existing reservoir, and is named Upper Leavitt Reservoir. The locations of both dam sites and surface geology are shown on Figure 3.

Based on published mapping, alluvium (Qal) was located in the valley floor downstream of the current dam (Noggle-Perrin, 1989). The alluvium consisted of unconsolidated deposits of gravel, sand, and loam along stream valleys at or near present stream levels. Terrace deposits (Qt) capped the left abutment and were located on high points downstream of the current dam. These deposits were unconsolidated to semi-consolidated deposits of gravel and sand representing former stream levels. Several feet of fine-grained sediment is expected in the reservoir bottom. The sediment has not been mapped, but was observed during the site visit. Reservoir sediment exposed by low water levels is shown in Photograph 1. Except for the upper few inches, the sediment was very soft and wet, and would need to be removed from within the footprint of the embankment.

On the right abutment of both dam sites, the bedrock outcropped or was covered by thin deposits of slopewash and residuum. Slopewash and residuum deposits were observed to be less than about 5 feet thick. The majority of the site was underlain by the Cretaceous aged Cloverly Formation (Kcl) (Noggle-Perrin, 1989). The portion of the Cloverly Formation observed in the field was the Sykes Mountain member, which is rusty brown siltstone and sandstone interbedded with some dark gray shale layers. This member comprises the upper about 160 feet of the Cloverly Formation (Noggle-Perrin, 1989) and was intensely weathered and friable. The depth to competent bedrock is not known. A sandstone/shale contact within the Sykes Mountain member was identified generally at about the normal high water line of the existing reservoir. At the existing dam site, the bedrock was shale with 1- to
6-inch sandstone interbeds that comprise approximately 5 to 10 percent of the rock unit. The shale was friable and very-intensely to intensely weathered. Sandstone was fine to medium grained and slightly to moderately weathered.

At the proposed upper site, the observed bedrock in the abutments was sandstone with shale in the reservoir bottom. The sandstone was mostly friable, but contained some competent blocks that appeared to have sloughed into the reservoir. The sandstone unit is shown in Photographs 2 through 4.

Noggle-Perrin (1989) also mapped the Thermopolis Shale (Kt) above the right abutments for both proposed dams. The Thermopolis Shale is a Cretaceous aged dark gray to black nonresistant shale with bentonitic layers. This formation was up to about 180 feet thick and is shown on Photograph 2.

A fault was mapped by Noggle-Perrin (1989) near the right abutment of both sites. This fault was not observed in the field, but was identified in aerial imagery from Google Earth (2010) as shown in Photograph 5. The fault is located between the centerlines of the two proposed dam locations and is about 600 feet upstream of the location shown by Noggle-Perrin (1989). An anticline was mapped by Noggle-Perin (1989) that crossed the upper portion of the current reservoir about parallel to the dam axis. Bedrock dipped 5 to 10 degrees downstream where measured on the right abutment of the upper site.

An appropriate dam type for the site geology would be a zoned earthfill dam because of the availability of both fine and coarse grained bedrock borrow and would include an internal filter/drain system.

Based on conversations with the local dam owners and operators, the existing dam and reservoir generally has minimal leakage and water loss. However, based on the presence of vegetation needing water, there appeared to be some quantity of seepage downstream of the dam and along the right abutment.

Potential borrow sources at the site include low permeability fine grained sediment from the existing reservoir bottom. The material could contain significant organic content that could prevent or significantly impact its use as borrow material and could be difficult to excavate. This material would also require drying prior to placement in the embankment. Shale underlying the reservoir may also be a source of low permeability fill but it would require significant processing. Sandstone could be used as fill for the shells of the embankment. Sand and gravel for filters, drains, and bedding could be obtained from the terrace deposits. There is also an existing gravel mine approximately 4 miles downstream of the site. The durability of this material needs to be confirmed for use as riprap bedding. Based on surface exposures, the sand content could be low, which could impact the ability to efficiently process sand for filters.

Conditions that have the potential to have the greatest impact on design include:

- The existing dam would need to be removed prior to construction at Lower Leavitt Reservoir.
- Reservoir sediment would need to be removed below the footprint of the embankment at Upper Leavitt Reservoir.
- Depth to competent bedrock is unknown and could be tens of feet.
- The need for and extent of foundation treatment is not known at this time.
- At other proposed sites with bedrock of the Cloverly Formation, gypsum crystals were identified on the ground surface, and gypsum and calcite veins were identified in the mudstones. Dissolution of these minerals could create seepage pathways or lead to foundation settlement.

- Slickensided surfaces of joints in the mudstones of the Cloverly Formation were identified at other sites and are evidence of past movement. Therefore, the foundation could be weak, which could result in the need for relatively flat slopes or stability berms on the embankment.

**Coyote Draw**

The Coyote Draw site is shown on Figure 3. A main dam would be located on Coyote Draw and a smaller saddle dam would be required in an unnamed valley to the east of the main dam. According to the Surficial Geologic Map of the Burgess Junction Quadrangle (Halberg, et al, 2001), bedrock outcrops or is covered by a thin layer of slopewash and residuum in the area of the dams and reservoir. Slopewash and residuum deposits were observed to be less than about 5 feet thick. Calcite crystals were identified on the ground surface in the valley bottom. Surficial materials in the valley bottom consisted of primarily fine grained materials and contained between 10 and 20 percent pinhole voids. Terrace deposits were mapped on the right side of the valley upstream of the main dam. Based on published mapping, terrace deposits were unconsolidated to semi-consolidated deposits of gravel and sand (Noggle-Perrin, 1989 and Manahl, 1985).

The observed bedrock at the site was the Cretaceous age Cloverly Formation according to Noggle-Perrin (1989) and Manahl (1985). Noggle-Perrin mapped the northern portion of the site and Manahl mapped the southern portion of the site including the proposed dam sites. Noggle-Perrin did not differentiate the members of the Cloverly Formation and mapped the entire formation as Kcl. Manahl maps the Sykes Mountain member (the upper member) as Ksm and the lower member as Kcl. The Sykes Mountain member was yellow or brown siltstone and sandstone, and medium gray shale and was up to about 160 feet thick. The lower member of the Cloverly Formation was variegated mudstone, shale, sandstone, and lenticular cross-bedded sandstone. This member also contained white devitrified tuffs and was up to about 170 feet thick (Noggle-Perrin, 1989 and Manahl, 1985).

The Cloverly Formation bedrock underlying the main dam was a very intensely weathered to decomposed mudstone with little to no rock structure. The bedrock units in both abutments consisted of the sandstone of the Sykes Mountain member over mudstone of the Cloverly Formation. This stratigraphy is shown in Photograph 6. Depth to competent rock is unknown but is expected to be at least 10 to 20 feet. A 5-foot-thick, competent sandstone bed was identified above the proposed maximum normal water line. A possible tuff was identified in the left abutment that had weathered from red to white. The bedrock was dipping at approximately 5 degrees downstream at the main dam and a monocline was identified upstream of the main dam and parallel to the right side of the valley. The monocline is shown in Photograph 7 where the contact between the Sykes Mountain upper member and the lower member of the Cloverly Formation steepens from nearly horizontal to approximately 5 degrees to the south.

An appropriate dam type for the site geology would be a homogenous earthfill dam based on the availability of primarily fine grained bedrock and would include an internal filter/drain system.

Potential borrow sources at this site include the terrace deposit on the right abutment, which could provide sand and gravel for filters, drains, and bedding. The durability of the terrace
deposit gravels needs to be confirmed for use as riprap bedding and based on surface exposures, the sand content could be low, which could impact the ability to efficiently process sand for filters. An existing gravel mine, located approximately 3 miles downstream, is another potential source of sand and gravel. The mudstone bedrock is a likely source of low permeability fill.

Conditions that have the potential to have the greatest impact on design include:

- Surficial materials below the footprint of the dams will likely need to be removed or treated because of the high collapse potential resulting from voids in the deposit.
- Depth to competent bedrock is unknown and could be greater than 20 feet.
- Calcite crystals were identified on the ground surface at this site and gypsum and calcite veins were identified in the mudstones of the Cloverly Formation at other sites. Dissolution of these minerals could create seepage pathways or lead to foundation settlement.
- The need for and extent of foundation treatment is not known at this time.
- Slickensided surfaces of joints in the mudstones of the Cloverly Formation were identified at other sites and are evidence of past movement. Therefore, the foundation could be weak, which could result in the need for relatively flat slopes or stability berms on the embankment.

**Upper and Lower Bratsky Draw**

Two dam locations have been proposed at Bratsky Draw. Upper Bratsky Draw was initially proposed. However, after a large landslide was identified on the left abutment at the upper site during review of published information, Lower Bratsky Draw was added. The landslide will be discussed below. The dam locations and general site geology are shown on Figure 3.

Surficial materials at the site included slopewash and colluvium overlying the bedrock in the valley bottom and along the valley sides. Slopewash and colluvium deposits were observed to be less than about 5 feet thick. The left abutment was capped by a large terrace deposit (Qt) that consisted of unconsolidated to semi-consolidated gravel and sand (Manahl, 1985). The left abutment also contained the large landslide midway up the slope.

The Jurassic age Morrison Formation (Jm) was identified in the valley bottom and the left abutment. This formation consisted of calcareous variegated siltstone and mudstone with thin sandstone and limestone beds and is up to about 320 feet thick (Manahl, 1985). The landslide mentioned above is in this formation. The right abutment contained the lower member of the Cloverly Formation (Kcl) described as variegated mudstone, shale, sandstone and lenticular cross-bedded sandstone and up to about 170 feet thick (Manahl, 1985). Large gypsum crystals were identified in the Cloverly Formation. At both dam sites, the bedrock appeared to be mostly mudstone with lesser quantities of siltstone. Both rock types were very intensely weathered to decomposed and had minimal rock structure.

The landslide at the Upper Bratsky site was approximately 1,000 feet long with a head scarp at least 50 feet high. The landslide is shown in Photograph 8. The location of the landslide shown by Manahl (1985) differs from the location based on 2009 aerial photography (Google Earth, 2010) and observations during the site visit. The updated location of the landslide is shown on Figure 5. The landslide appears in 1957 aerial photography; however, the scale on the old photos is too small to identify changes that may have occurred over the past 50 years. Examining images in Google Earth (2010) from 1994 to 2009, no apparent
changes in size or shape of the landslide could be identified. No sign of recent movement was identified at the toe of the landslide, but recent tension cracks were observed in the head scarp of the landslide as shown in Photographs 9 and 10. Wetlands were identified along the toe (Photograph 8) and it appeared that some of the water in the wetland was seeping from the landslide.

A possible landslide, which is shown in Photograph 11, was also identified in the left abutment at the Lower Bratsky site. This landslide was much smaller than the landslide at the upper Bratsky site and showed no sign of recent movement. A third landslide in the Morrison Formation was mapped by Manahl (1985) approximately 1 mile south of the Lower Bratsky Draw site as shown on Figure 3. This landslide was not examined during the field visit. Based on published mapping, the third landslide is similar in size to the landslide at the Upper Bratsky Draw site.

In our opinion, slope stability within the Morrison Formation is a fatal flaw for this site. Potential stability problems likely exist throughout the Morrison Formation. Stabilizing the left abutment during construction of a dam would require removal of the existing landslide material within the embankment footprint to a suitable foundation and flattening adjacent slopes. The volume of material requiring removal was estimated to be at least 740,000 cubic yards. Quantity calculations are provided in Appendix B.

Because there are two existing landslides in the Morrison Formation at and near the dam sites and there are slopes within the reservoir basin that have a similar slope to the landslides (Photograph 12), there is a significant possibility that water level changes in the reservoirs could cause new landslides. About 1.7 miles of the reservoir rim would have similar slopes as the existing landslides and could be prone to failure from changes in reservoir pool. If landslides were activated within the reservoirs, waves could be formed that might overtop the dams and the landslide material flowing into the reservoirs would reduce the storage capacity of the reservoirs. To stabilize the reservoir rim where landslides could occur would be prohibitively expensive. Because of the existing landslides and the potential for future landslides, the Bratsky Draw sites would be significantly more expensive to develop into reservoirs than other sites described in this memorandum and conceptual-level designs were not developed for these sites.

**Chimney Rock**

The Chimney Rock site was not visited as part of this evaluation because it was identified as a potential site after completion of the fieldwork. Identification and descriptions of geologic units at the site were based on a review of published literature. A possible dam and reservoir location have been proposed at Chimney Rock as shown on Figure 4. Alluvium was located within Trapper Creek Valley downstream of the centerline of the embankment (Finley, 1985). The alluvium consisted of unconsolidated deposits along streams at or near present stream levels. Bedrock, slopewash and residuum were present within the footprint of the embankment (Halberg et al., 2001).

Bedrock in the dam foundation and abutments included the Triassic age Chugwater Formation (\(T_c\)) and Permian to Triassic age Goose Egg Formation (\(T_{pge}\)) (Finley, 1985). The Chugwater Formation was composed of red calcareous siltstone and mudstone with a thickness of about 600 feet. According to Noggle-Perrin (1989) the Chugwater Formation typically contains layers of gypsum and the bottom 40 feet of the sequence consists of gypsiferous silty shale. The formation is capped by the Alcova Limestone Member, a laterally continuous carbonate bed, which was identified at the top of the right abutment. The Goose Egg Formation is stratigraphically below the Chugwater Formation and along the left side of the reservoir and would likely be exposed during foundation preparation of the
embankment. The upper portion of the Goose Egg Formation was composed of gypsiferous carbonate and red siltstone and the lower portion was red siltstone and shale (Finley, 1985). The total thickness of the formation was about 225 feet. In other locations in Wyoming, particularly in the Powder River Basin, the Goose Egg Formation contains a few feet to over 200 feet of salt (Parker, 1967).

According to Finley (1985), the top of the cliff that forms the right abutment is along the axis of a regional monocline that trends generally north-south near the site, but turns northwest approximately 5 miles north of the site.

Previous attempts in Wyoming to construct reservoirs in the Chugwater and Goose Egg Formations have been unsuccessful. Anchor Dam and Reservoir, approximately 30 miles west of Thermopolis, Wyoming, was built between 1957 and 1960 and has never held more than a small percentage of its intended storage capacity (Jarvis, 2003). The following are excerpts from “The Money Pit: Karst Failure of Anchor Dam, Wyoming” (Jarvis, 2003).

- During construction multiple sinkholes were identified in the reservoir within the Chugwater and Goose Egg Formations.
- Soon after closing the outlet gates a large sinkhole with a diameter of nearly 300 feet and depth of 40 to 60 feet formed upstream of the dam in the Chugwater Formation.
- By the late 1970s, 54 sinkholes had been identified within the Chugwater and Goose Egg Formations in the reservoir.

In our opinion, the presence of gypsiferous and carbonate rocks and the resulting potential for karst and other dissolution features present a fatal flaw for this site. Solution-enhanced fractures and karst are expected and will likely require extensive foundation treatment to the dam and possibly lining the reservoir. Material derived from the Chugwater and Goose Egg Formations would likely make poor quality embankment fill and liner material because of the extensive soluble materials. Constructing a clay liner to reduce reservoir seepage would require approximately 340,000 cubic yards of imported low permeability material. Some seepage would still be expected through the liner and embankment, which over time could lead to dissolution of the underlying bedrock. Because of the soluble material in the bedrock, safe development of a dam and reservoir may not be possible at the Chimney Rock site and this site would be significantly more expensive to develop into a reservoir than other sites described in this memorandum. Conceptual-level designs were not developed for this site.

**Douglas Draw**

The Douglas Draw site will require two proposed dams to create the reservoir; a main dam on Douglas Draw and a small saddle dam in an unnamed drainage to the right of the main dam as shown on Figure 4. No surficial units were mapped by Manahl (1985) at the dam sites but the abutments were capped by localized terrace deposits (Qt). According to published mapping, the terrace deposits were unconsolidated to semi-consolidated. The Cloverly Formation bedrock outcropped at the right abutment and at the right side of the valley and was interspersed with slopewash and residuum. Slopewash and residuum deposits were observed to be less than about 5 feet thick.

The bedrock was well exposed at the dam sites as shown in Photograph 13. The Sykes Mountain member (Ksm) was the bedrock under the western portion of the main dam, the left abutment, and high on the right abutment. This member consisted of interbedded yellow or brown siltstone and sandstone, and medium gray shale with a thickness of up to about 160 feet (Manahl, 1985). The lower member of the Cloverly Formation (Kcl) was located
below the eastern portion of the main dam, the majority of the right abutment, and all of the saddle dam. This rock unit consisted of interbedded buff to white channel sandstones, massive variegated red and gray mudstones, and white devitrified tuffs. The thickness of the lower member was approximately 170 feet (Manahl, 1985). The mudstones of this member were intensely weathered and friable and the depth to competent bedrock is expected to be at least 10 to 20 feet. The intensely weathered mudstone is shown in Photographs 14 and 15. Gypsum and calcite were identified filling existing fractures. Slickensided joints were also identified within the mudstone.

The Cretaceous age Thermopolis Shale (Kt) was also identified in the vicinity of the site. It was mapped high on the left abutment of the main dam and on a hill separating the main dam from the saddle dam. The Thermopolis Shale was dark gray to black nonresistant shale with bentonitic layers and was up to about 335 feet thick (Manahl, 1985).

An appropriate dam type for the site geology would be a homogenous earthfill dam based on the availability of primarily fine grained bedrock and would include an internal filter/drain system.

Shale layers in the Sykes Mountain member and mudstone in the lower member of the Cloverly Formation could likely be processed to provide low permeability fill. No source of sand and gravel was identified within the reservoir. However, large alluvial deposits were located in Shell Valley, which is about less than 0.5 mile downstream of the main dam. The durability of the terrace deposits needs to be confirmed for use as riprap bedding. Based on surface exposures, the sand content could be low, which could impact the ability to efficiently process sand for filters.

Conditions that have the potential to have the greatest impact on design are:
- Depth to competent bedrock is unknown and could be tens of feet.
- Gypsum and calcite veins were identified in the mudstones of the Cloverly Formation. Dissolution of these minerals could create seepage pathways or lead to foundation settlement.
- The need for and extent of foundation treatment is not known at this time.
- Slickensided surfaces of joints in the mudstones of the Cloverly Formation are evidence of past movement. Therefore, the foundation could be weak, which could result in the need for relatively flat slopes or stability berms on the embankment.

Shell Canal Tunnel

The proposed dam at the Shell Canal Tunnel would be located near a siphon where the Shell Canal crosses a small drainage. The site is shown on Figure 4. No surficial units were mapped at the dam site; however the bedrock is covered by slopewash and residuum over the majority of the site and only scattered bedrock outcrops are present (Halberg, et al, 2001). Slopewash and residuum deposits were observed to be less than about 5 feet thick.

According to Reppe (1986), the dam and reservoir are located entirely in the lower member of the Cloverly Formation (Kcl), which he described as variegated red and gray mudstone and shale interbedded with sandstone and siltstone. The thickness of the lower member in this area was up to 200 feet. Most, if not all, of the dam foundation bedrock observed was mudstone that was intensely weathered and had minimal rock structure. Depth to competent bedrock is expected to be at least 10 to 20 feet. Sandstone was also identified along the canal as shown on Photograph 16.
A large landslide in the lower member of the Cloverly Formation was mapped by Reppe (1986) approximately 0.5 mile southeast of the proposed dam (Figure 4). This landslide was approximately 1,100 feet wide at its widest point and approximately 900 feet long; however, this landslide was not observed during the site visit. This portion of the Cloverly Formation could be susceptible to landslides.

An appropriate dam type for the site geology would be a homogenous earthfill dam based on the availability of primarily fine grained bedrock and would include an internal filter/drain system.

The mudstone layers of the Cloverly Formation could likely be processed to provide low permeability fill. A source for sand and gravel was not identified within the reservoir; however, a large terrace deposit (Qt1) was located approximately 0.25 mile downstream toward Shell Valley. The durability of the terrace deposit needs to be confirmed for use as riprap bedding. Based on surface exposures, the sand content could be low, which could impact the ability to efficiently process sand for filters.

We understand that material to construct the embankment could be derived from the excavation to uncover the exiting Shell Canal Tunnel south of the site. Based on communications with the engineer investigating the tunnel, the material available for embankment construction would be mudstone of the Cloverly Formation. Based on laboratory tests performed by Deere & Ault, the material is a high plasticity clay with moderate to high swell potential.

Conditions that have the potential to have the greatest impact on design are:

- Depth to competent bedrock is unknown and could be tens of feet.
- At other sites, the mudstones of the Cloverly Formation contained gypsum and calcite veins. Dissolution of these minerals could create seepage pathways or lead to foundation settlement.
- The need for and extent of foundation treatment is not known at this time.
- Slickensided surfaces of joints in the mudstones of the Cloverly Formation were identified at other sites and are evidence of past movement. Therefore, the foundation could be weak, which could result in the need for relatively flat slopes or stability berms on the embankment.
- Stability of the reservoir rim because a landslide was identified about 0.5 mile from the dam site in the same formation as the dam site foundation.

**Sheldon Gulch**

The Sheldon Gulch site is shown on Figure 4. Unconsolidated alluvium (Qal) was identified along the stream and consisted of predominantly fine grained material with localized areas of sand and gravel. The alluvium appeared to be 10 to 20 feet thick. Localized small terrace deposits (Qt), which consisted of unconsolidated to semi-consolidated deposits, capped both abutments. Based on published mapping, larger terrace deposits were identified east and west of Sheldon Gulch approximately 0.5 mile downstream from the proposed dam (Reppe, 1986).

Three Cretaceous age bedrock formations composed the foundation of the proposed dam and will be discussed from west to east. The lower part of the Mowry Shale (Kmr) was located in the upper portion of the left abutment. It was a gray-black, fissile shale with thin
bentonite layers and is up to about 295 feet thick (Reppe, 1986). The Thermopolis Shale (Kt) was identified in the lower left abutment. This formation contained a basal gray black shale, as shown in Photograph 17, that was approximately 220 feet thick, and the upper Muddy Sandstone member (Kmd), which was light gray, bentonitic sandstone and was approximately 50 feet thick (Reppe, 1986). Bentonite beds and gypsum infilling of fractures were identified in the Thermopolis Shale including the Muddy Sandstone member as shown in Photograph 18. Bedrock in the left abutment dipped 20 to 30 degrees to the west and is shown in Photograph 19. The third rock unit was the Sykes Mountain member (Ksm) of the Cloverly Formation and was identified in the right abutment. This unit was thin-bedded, light brown, siltstone, ferruginous siltstone, sandstone, and dark gray shale and was approximately 100 feet thick (Reppe, 1986).

Bedrock under the eastern portion of the reservoir consisted of the lower member of the Cloverly Formation (Kcl) and the Morrison Formation (Jm). The lower member of the Cloverly Formation was variegated red and gray mudstone and shale interbedded with sandstone and siltstone, and was up to about 200 feet thick (Reppe, 1986). The Morrison Formation was variegated red and light green calcareous mudstone and siltstone, and up to 300 feet thick (Reppe, 1986).

Extensive wetlands were identified along the stream at the Sheldon Gulch site. RJH understands that this site will not move forward to the next phase because of permitting concerns and remediation costs associated with the wetlands. A conceptual-level design was not developed for this site.

**Conceptual Level Designs**

Based on the data collected from our geologic literature search, data from our site visit, and our experience as geotechnical and dam engineers, we developed conceptual design concepts for a dam at:

- Lower Leavitt Reservoir
- Upper Leavitt Reservoir
- Coyote Draw
- Douglas Draw
- Shell Canal Tunnel

These concepts were developed without the benefit of site-specific geotechnical data and engineering analyses, and are based primarily on our experience and judgment. Changes to these concepts should be anticipated after site-specific geotechnical and geological data are collected and completion of preliminary engineering analyses.

Based on the geology at each site, the appropriate dam type for each site would be an earthfill embankment. Lower Leavitt Reservoir and Upper Leavitt Reservoir should be zoned embankments because of the significant quantity of sandy material available for shell material. Coyote Draw, Douglas Draw, and Shell Canal Tunnel would be homogeneous embankments with an internal filter and drain system because the majority of onsite borrow materials are primarily fine grained. A typical section of a zoned embankment is shown on Figure 6 and a typical section for a homogeneous embankment is shown on Figure 7.

Based on our experience with similar foundation conditions and available construction materials, we developed the conceptual designs for the five sites using the general design
concepts listed below. Minor exceptions to these general design concepts specific to a particular site are listed after the general design concepts.

**General Design Concepts**

- Foundation preparation would consist of excavating a 20-foot-wide cutoff trench below the centerline of the dam that would extend several feet into competent bedrock. For this level of study we assumed that an average depth of 15 feet would be reasonable.

- We included a grout curtain for the entire length of each embankment. We assumed the following for the grout curtain:
  - A double row of grout holes spaced every 10 feet.
  - One-half of the grout curtain would require a third center row of confirmation holes spaced every 5 feet.
  - The grout curtain would extend about two-thirds of the embankment height into bedrock or a minimum of 20 feet, whichever is greater.

- A chimney drain that is connected to a blanket drain would be included downstream of the centerline and the cutoff trench (and adjacent to the core materials if applicable) to manage seepage through the embankment and provide protection against internal erosion. For the zoned embankment, the chimney drain would be 6 feet wide and slope along the downstream edge of the core. For the homogeneous embankment, the chimney drain would be vertical and 3 feet wide. For both embankment types, the blanket drain would be 3 feet thick. The chimney drain would consist primarily of sand and it is likely that the blanket drain would consist of a layer of fine gravel with a layer of sand above and below the gravel. Seepage collected in the chimney and blanket drain would be discharged to the downstream toe of the embankment using PVC pipes.

- A slope angle of 3.5 horizontal to 1 vertical (3.5H:1V) was assumed for both the upstream and downstream slopes. Slope stability analyses were not performed as part of this conceptual-level design. Based on limited laboratory data, stability berms or flatter slopes may be needed.

- Upstream slope protection would consist of 2 feet of riprap over 1 foot of bedding, placed from the toe to the crest of the embankment. If during future phases of design there is a requirement to maintain a permanent dead pool, the limits of the slope protection could likely be raised to extend to only several feet below the permanent dead pool.

- Dam heights included 5 feet of freeboard above maximum normal pool; however, wave run-up calculations have not been performed as part of this conceptual-level design. Crest widths were calculated for each embankment, according to the Wyoming State Engineers Office Rules and Regulations. A summary of the embankment heights and crest widths is provided in Table 1 and crest width calculations are provided in Appendix B.
TABLE 1
SUMMARY OF EMBANKMENT HEIGHTS AND CREST WIDTHS

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<th>Dam</th>
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<th>Crest Width (ft)</th>
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<tr>
<td></td>
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<td></td>
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<td>Shell Canal Tunnel</td>
<td></td>
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</tbody>
</table>

Notes:
1. Main dam heights were provided by States West. Saddle dam heights were calculated by RJH using USGS topography.
2. Crest widths calculated by RJH according to Wyoming SEO Rules and Regulations.
3. Crest width widened to accommodate an existing road.

Site-Specific Design Criteria

The site-specific modifications to the general design criteria are provided below:

- Lower Leavitt Reservoir – Removal of an existing dam because the foundation preparation and strength of the existing dam is likely not adequate for a new embankment. The saddle dam would be 30 feet wide to accommodate the existing road and would not contain a grout curtain.

- Upper Leavitt Reservoir – Removal of sediment below the entire footprint of the embankment because sediment is likely low strength and would not be able to support an embankment.

- Coyote Draw – Removal of surficial materials below the entire footprint of the embankment because of potential for collapse of the alluvial materials.

Future Study

The following tasks should be completed during the next phase of study:

1. Site-specific detailed topography should be obtained for the reservoir, dam site, and surrounding area. This is required to provide an adequate base map for preliminary design-level geologic mapping and engineering evaluations.

2. Site-specific geologic mapping of the dam and reservoir sites should be performed to identify and characterize the geologic units and any geologic hazards that may be present and to identify possible borrow sources.

3. Subsurface investigations should be performed. Subsurface investigations should include the following items:

   a. Test pits should be excavated within the dam footprint and borrow areas to investigate shallow subsurface structure and collect bulk samples for laboratory testing, to evaluate if clayey materials are suitable embankment fill, and if terrace deposits are suitable for drainage and riprap bedding materials.

   b. Borings should be advanced within the dam footprint to: 1) investigate depths deeper than can be obtained from test pits, 2) collect undisturbed samples of surficial materials and bedrock, and 3) collect geotechnical data that is only
obtainable from drilling methods (i.e., standard penetration tests (SPT) and
bedrock rock quality designation (RQD)).

c. Packer permeability tests should be performed within the borings, especially the
sandstone beds, to estimate the hydraulic conductivity of the bedrock, which can
be used to approximate reservoir seepage losses and identify general foundation
treatment requirements.

4. Laboratory tests should be performed on soil and bedrock samples collected during
the subsurface investigation to identify index, strength, durability, and dispersion
properties of the foundation and available borrow materials and in particular, the
residual strength of the bedrock.

5. Borrow sources should be confirmed and potential borrow quantities estimated,
based on the findings of the geologic mapping, subsurface investigation, and
laboratory testing.

6. The internal embankment geometry presented in this report should be refined, as
necessary, based on the available borrow material identified during the subsurface
investigation and laboratory testing.

7. Material properties should be developed for the foundation and embankment fill
materials based on the results of laboratory testing and published correlations for
similar materials.

8. Static slope stability analyses should be performed for the maximum embankment
sections using material properties developed from laboratory testing to update the
preliminary embankment configuration provided in this memorandum.

9. Evaluation of expansive materials should be performed to evaluate impact on and
properly design foundations of appurtenant structures.

10. Seismic deformation analyses should be performed to estimate the permanent
embankment crest deformation that would result from the design peak ground
acceleration. The embankment freeboard presented in this report should be refined,
as necessary, to provide adequate residual freeboard.

11. The collapse potential of surficial materials with pinhole voids should be evaluated.

12. Seepage analyses should be performed to evaluate foundation conditions and revise
the concept and depth of the grout curtains.

13. Preliminary geotechnical evaluations should be performed for spillway excavations
and other ancillary facilities.

14. The construction material quantities presented in this report should be refined, based
on foundation conditions identified during the subsurface investigation and any
revisions to embankment geometry.

References

Survey of Wyoming Map MS 16.

Google Earth (2010) Aerial images of Shell Valley, Wyoming; image date: July 2009,
Accessed Nov 16, 2010

Halberg, L.L.; Case, J.C.; and Noecker, B.L. (2001) Preliminary Digital Surficial Geologic
Map of the Burges Junction 30’ x 60’ Quadrangle, Sheridan, Big Horn, and Johnson
Counties, Wyoming; Wyoming State Geological Survey Map HSDM 01-2


Photographs

Photograph 1: Upper Leavitt Reservoir site, looking at exposed reservoir sediment.

Photograph 2: Upper Leavitt Reservoir site, looking from the left abutment south at the right abutment generally along the dam alignment.
Photograph 3: Upper Leavitt Reservoir site, looking south at the sandstone outcrop in the right abutment.

Photograph 4: Upper Leavitt Reservoir site. The sandstone outcrop in the right abutment is generally intensely weathered and friable but contains competent blocks.
Photograph 5: Leavitt Reservoir site showing fault location in relation to proposed dam locations.
Photograph 6: Coyote Draw site from upstream of the right abutment of the main dam looking east toward the left abutment at the Sykes Mountain member of the Cloverly Formation (Ksm) over the main body of the Cloverly Formation (Kcl).

Photograph 7: Coyote Draw site looking west toward the valley wall, upstream of the right abutment. Calcite crystals are visible in the foreground and a monocline is visible at the contact between the upper and lower members of the Cloverly Formation.
Photograph 8: Bratsky Draw site from right abutment of lower site, looking northeast toward large landslide in the left abutment of the upper site.

Photograph 9: Bratsky Draw site from the left abutment, looking south along the head scarp of the landslide. The tension cracks could indicate recent movement.
Photograph 10: Bratsky Draw site from the left abutment, looking south along the tension crack, which was approximately 5 feet deep.

Photograph 11: Lower Bratsky Draw site from the valley bottom, looking east at the left abutment where a possible second smaller landslide was identified.
Photograph 12: Bratsky Draw site from the right abutment, looking north toward the steep slopes that would form the reservoir rim.

Photograph 13: Douglas Draw Main Dam site from upstream of the left abutment, looking northeast toward the right abutment of the main dam.
Photograph 14: Douglas Draw Main Dam site looking at the right abutment and the Sykes Mountain Member (Ksm) of the Cloverly Formation over the main body of the Cloverly Formation (Kcl).
Photograph 15: Douglas Draw Main Dam site looking at the intensely weathered mudstone of the Cloverly Formation in the right abutment.

Photograph 16: Shell Canal Tunnel site from the right abutment, looking southeast at the sandstone of abutment above the Shell Canal and the siphon structure.
Photograph 17: Sheldon Gulch site from the valley bottom, looking west at the left abutment, which contained Thermopolis Shale.

Photograph 18: Sheldon Gulch site looking at a gypsum-filled fractures within the Thermopolis Shale.
Photograph 19: Sheldon Gulch site from the valley bottom, looking southeast along the left abutment toward an outcrop of Thermopolis Shale dipping 20 to 30 degrees to the west.
PROJECT LOCATION MAP
NOT TO SCALE

SITE LOCATION MAP
NOT TO SCALE

SHELL VALLEY STORAGE
VICINITY MAP
PROJECT NO. 10104
April 2012
Figure 1
**EXPLANATION**

- **Qt** - TERRACE DEPOSITS, Qt, IS LOWEST SURFACE
- **Qp** - PEDIMENT, Qp, IS CLOSEST TO MOUNTAIN FRONT
- **Qes** - EROSION SURFACE
- **Qtc** - TALUS CONE
- **Qts** - LANDSLIDE MATERIAL
- **Qal** - ALLUVIUM
- **Qaf** - ALLUVIAL FAN
- **Kf** - FRONTIER FORMATION
- **Kmr** - MOWRY SHALE
- **Kt** - THERMOPOLIS SHALE
  - **Kmd** - MUDDY SANDSTONE MEMBER OF THE THERMOPOLIS SHALE
  - **Kt** - LOWER MEMBER OF THE THERMOPOLIS SHALE
- **Kol** - CLOVERLY FORMATION, MEMBERS NOT DIFFERENTIATED IN NORTHERN PORTION OF FIGURE 3
  - **Ksm** - SYKES MOUNTAIN MEMBER OF THE CLOVERLY FORMATION
  - **Kol** - LOWER MEMBER OF THE CLOVERLY FORMATION
- **Jm** - MORRISON FORMATION
- **Js** - SUNDACE FORMATION
- **Jgs** - GYPSUM SPRING FORMATION
- **Trc** - CHUGWATER FORMATION
- **TRPge** - GOOSE EGG FORMATION
- **Pt** - TENSLEEP SANDSTONE
- **Pma** - AMSDEN FORMATION
- **Mm** - MADISON LIMESTONE
- **Dd** - DARBY FORMATION
- **Ohb** - BIGHORN DOLOMITE
- **Cg** - GALLATIN LIMESTONE

---

- **FORMATION CONTACT** - DASHED WHERE APPROXIMATELY LOCATED; DOTTED WHERE CONCEALED.
- **FAULT** - DOTTED WHERE INFERRED, [D DENOTES DOWNTHROWN SIDE, U DENOTES UPTHRONG SIDE]
- **ANTICLINE** - TRACE OF AXIAL PLANE AND DIRECTION OF PLUNGE, DASHED WHERE APPROXIMATELY LOCATED.
- **SYNCLINE** - TRACE OF AXIAL PLANE AND DIRECTION OF PLUNGE, DASHED WHERE APPROXIMATELY LOCATED.
- **STRIKE AND DIP OF BEDS**
- **NORMAL HIGH WATERLINE**
- **EMBANKMENT CENTERLINE**

---

**SECTION LOCATION. THE NUMBER "1" REFERS TO THE SECTION DESIGNATION. THE NUMBER "2.0" REFERS TO THE FIGURE NUMBER WHERE THE SECTION IS SHOWN.**
1. EXPLANATION ON FIGURE 2.
2. GEOLOGIC MAPPING COMPLETED BY INTERPRETATION OF AERIAL PHOTOGRAPHY.

SHELL VALLEY STORAGE PROPOSED SITE LOCATIONS

PROJECT NO. 10104 April 2012 Figure 3
NOTE
1. EXPLANATION ON FIGURE 2.
2. GEOLOGIC MAPPING COMPLETED BY INTERPRETATION OF AERIAL PHOTOGRAPHY.
NOTE

1. SECTION TYPICAL FOR LOWER LEAVITZ RESERVOIR AND UPPER LEAVITZ RESERVOIR. EXCEPT AT
   UPPER LEAVITZ RESERVOIR THERE IS NOT AN EXISTING EMBANKMENT AND SURFICIAL MATERIALS
   WOULD BE REMOVED BELOW THE FOOTPRINT OF THE EMBANKMENT. CREST MORTN WOULD CHANGE
   AS LISTED IN TABLE 1.
NOTE
1. SECTION TYPICAL FOR COYOTE DRAIN, DOUGLAS DRAIN, AND SHELL CANAL TUNNEL SITES EXCEPT SURFICIAL MATERIALS BELOW THE EMBANKMENT TO BE REMOVED AT COYOTE DRAIN CREST WIDTH WOULD CHANGE AS LISTED IN TABLE 1.
APPENDIX A

SEISMIC ANALYSIS
Purpose: Estimate ground acceleration value, locate nearest Quaternary fault, and locate closest historical earthquake.

Ground Acceleration:
Method: USGS Ground Motion Calculator.

A location was selected approximately in the middle of the six proposed sites. The coordinates of this location are:

Latitude: 44.577°
Longitude: -107.861°

The expected ground acceleration at this site for an event with a 5,000 year return interval is 0.22g. (p. 2)

Quaternary Faults:
Method: USGS Quaternary Fault and Fold Database

The closest fault categorized as active during the Quaternary is the Shoshone Creek Fault approximately 80 miles south-southwest of the location in the center of the proposed sites. (p. 3)

Historic Earthquake:
Method: USGS/NEIC 1973-2010 Database

The closest historic earthquake was approximately 20 miles southeast and was magnitude 3.0. (p. 4)

EASTERN, CENTRAL, & MOUNTAIN STATES OF US DATABASE:

latest EQ w/ unknown magnitude was about 12.5 miles (2004) East.
### Probabilistic hazard curves

#### Geographic Region:
- Continuous 48 States

#### Data Edition:
- 2002 Data (most current)

#### Latitude (Degrees) & Longitude (Degrees):
- Latitude: 44.577
- Longitude: -107.861

#### Hazard Curve for PGA

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Data are based on a 0.05 deg grid spacing. Frequency of Exceedance values less than 1E-4 should be used with caution.

**Additional Notes:**
- Calculate: Press to perform the calculation.
- View: Press to view maps.
- Clear Data: Press to clear all data.

*Source: USGS*
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Heading: 14.84 degrees
NEIC: Earthquake Search Results

U. S. Geological Survey
Earthquake Data Base

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Data Selection: Historical & Preliminary Data

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U.S. Geological Survey
Earthquake Data Base

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**Purpose:** To estimate embankment crest widths for six proposed dam sites.

**Assume:** Dam heights provided by States West or calculated by RJH.

**Method:** Crest width = \( H \div 5 + 4 \) (p. 3)

Where \( H = \) dam height

---

**Leavitt**
- Rise: \( H = 100 \text{ ft} \)
  - Crest width: \( \frac{100}{5} + 4 = 24 \text{ ft} \)

**Repsite**
- Base: \( H = 85 \text{ ft} \)
  - Crest width: \( \frac{85}{5} + 4 = 21 \text{ ft} \)

**Coyote**
- Main: \( H = 110 \text{ ft} \)
  - Crest width: \( \frac{110}{5} + 4 = 26 \text{ ft} \)

**Salde**
- H: \( 45 \text{ ft} \)
  - Crest width: \( \frac{45}{5} + 4 = 13 \text{ ft} \)

**District**
- H: \( 110 \text{ ft} \)
  - Crest width: \( \frac{110}{5} + 4 = 26 \text{ ft} \)

**Dayles**
- Main: \( H = 100 \text{ ft} \)
  - Crest width: \( \frac{100}{5} + 4 = 24 \text{ ft} \)

- Saddle: \( H = 35 \text{ ft} \)
  - Crest width: \( \frac{35}{5} + 4 = 11 \text{ ft} \)

**Canal**
- H: \( 50 \text{ ft} \)
  - Crest width: \( \frac{50}{5} + 4 = 14 \text{ ft} \)

**Shelden**
- H: \( 80 \text{ ft} \)
  - Crest width: \( \frac{80}{5} + 4 = 20 \text{ ft} \)
Kevin Mininger

From: Edwin Friend [efriend@rjh-consultants.com]
Sent: Wednesday, November 10, 2010 10:05 AM
To: Kevin Mininger
Subject: FW: Shell Res Sites
Attachments: Shell Sites2_DamJlUimit.shp; Shell Sites2_DamJlUimit.shp.xml; Shell Sites2_DamJlUimit.shx; Shell Sites2_HWL.dbf; Shell Sites2_HWL.prj; Shell Sites2_HWL.shp; Shell Sites2_HWL.shp.xml; Shell Sites2_HWL.shx; Shell Sites2_DamPR_CL.dbf; Shell Sites2_DamPR_CL.pj; Shell Sites2_DamPR_CL.shp; Shell Sites2_DamPR_CL.shp.xml; Shell Sites2_DamPR_CL.shx; Shell Sites2_Dam_PR_limit.dbf; Shell Sites2_Dam_PR_limit.pj; Shell Sites2_Dam_PR_limit.shp; Shell Sites2_Dam_PR_limit.shp.xml; Shell Sites2_Dam_PR_limit.shx; Shell Sites2_DamJlUimit.dbf; Shell Sites2_DamJlUimit.prj; Shell Sites2_DamJlUimit.shp; Shell Sites.dwg

See if this is what you need for dam layouts for shell valley. The dam heights are in the below text. Work with Eric and Ron as necessary. Please also save this into the CAD folder of this project. It could go under a new folder, data received. Please do this review this week so that if we need more info, we can ask for it early next week. Thanks.

Edwin Friend, P.E., P.G.
RJH Consultants, Inc.
9800 Mt. Pyramid Court, Suite 330
Englewood, CO 80112
303-225-4611 Phone
303-225-4615 Fax
303-598-5403 Cell
efriend@rjh-consultants.com

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-----Original Message-----
From: Jennifer Russell [mailto:JRussell@stateswest.com]
Sent: Wednesday, November 10, 2010 9:57 AM
To: Ed Friend
Subject: FW: Shell Res Sites

Ed:
Attached are the GIS files we sent to others plus the AutoCAD drawing (in metric units) that was used to create the GIS files. (When it comes to GIS, I am about as dumb as a doorknob and I don't have the software on my computer; someone else in our office 'translated' the files.) At the present moment, I only have the largest size considered shown. Top of Dam Elevations (in feet) and dam heights (to nearest 5ft): Leavitt=4845 & 100ft (85ft if go through middle of existing reservoir); Coyote=4645 & 110ft; Bratsky=4345 & 110ft; Douglas=4285 & 100ft; Sheldon=4005 & 80ft; Canal=4165 & 50ft. All have a freeboard of 5ft.
Hope this takes care of what you need.

Jennifer Russell, PE
Project Engineer
States West Water Resources
Cheyenne WY
307-634-7848 phone
307-634-7851 fax
Section 1. Reservoirs or Dams.

a. A permit from the State Engineer is required before commencing construction of any dam or reservoir involving the storage or impoundment of water in Wyoming. Maps or plans must be submitted with the application for a permit to construct such a dam. See Section 1(c) of Chapter VIII, page 55, for special conditions applicable to maps for applications for certain stock reservoirs, fishing preserve reservoirs, and floodwater detention reservoirs; additional details are provided in Chapter VI of this Manual.

b. Special requirements for plans of dams include:
   
   (1) A profile of the damsite along center line, and a maximum cross-section of the proposed dam.

   (2) The outlet works and spillway in detail. The spillway cross-section must be shown. A computation of capacity and all necessary data used must be included.

   (3) The scale used on any part of the map or plans should be sufficiently large to reflect all important details. Reservoir contour maps shall normally be drawn to a scale of 1" = 400' or larger. When the maximum length or width of the reservoir basin is more than 2 miles, the scale of the reservoir contour map may be reduced to not less than 1" = 1000' providing that all necessary detail is clearly shown. Profiles shall be drawn to a longitudinal scale of 1" = 200' or larger. Cross-section plans shall be on a scale of not less than 1" = 20'. Detailed plans including plans of outlet works and other structures, shall be on a scale of not less than 1" = 4'. Important dimensions must be shown on all plans of structures.

   (4) For earth dams, the slope must not be less than 3 to 1 for the front or water side and 2 to 1 for the back side unless conditions justify steeper slopes. In this case, engineering data must be submitted in support of steeper slopes than these maximums. Special conditions may require flatter slopes. The width on top shall be at least 1/5 of the height plus 4 feet, and in no case less than 8 feet for dams 10 feet or more in height. A minimum freeboard (from the top of the dam to the bottom of the spillway) of 5 feet is ordinarily required on all earth dams. This minimum may be reduced, but only when specifically requested and prior approval is granted by the State Engineer. Justification for reducing the freeboard requirement below 5 feet must be submitted along with the application and should include information on the conditions, size and characteristics of the drainage area above the reservoir, the location of buildings, roads and other structures downstream from the dam, the effect of wave action on the face of the dam at maximum water level, and any other information concerning the
Purpose: To estimate embankment heights for saddle dam at Coyote Draw and Douglas Draw.

**Coyote Draw**

- Crest Elevation = 4645 ft
- Ground Elevation = 4600 ft
- 45 ft

**Douglas Draw**

- Crest Elevation = 4255 ft
- Ground Elevation = 4250 ft
- 35 ft
Purpose: Estimate quantities needed to mitigate slope stability issues at Blatsky Draw site.

**Rim Stability**

The length of reservoir rim with slopes of similar angle to the area with the mapped landslide and located in the Morrison Formation was measured in CAD.

- Upstream of left abutment = 5725 ft \(\approx 1.1\) miles
- Upstream of right abutment = 3365 ft \(\approx 0.6\) miles

**Removal of Landslide in Left Abutment of Upper Blatsky Draw**

Estimate volume of material to be excavated prior to construction.

Assumptions:
- Plan dimensions measured on p. 3
- Excavation slopes would be 2:1
- Cross-section dimensions from type on p. 3 and from field observations on p. 4

**Dimensions**

- Length = \(\frac{650 + 410}{2} = 550\) ft
- Width = \(\frac{340 + 225}{2} = 262.5\) ft

**Transfer Section**

(central portion of excavation)

\[
\begin{align*}
\text{Volume} &= 10 \times 160 \times 550 \div 27 \text{ cy} \\
&= 32,600 \text{ cy} \\
\text{Volume} &= 100 \times 250 \times 550 \div 27 \text{ cy} \\
&= 128,300 \text{ cy} \\
\text{Volume} &= 100 \times 250 \times 250 \div 27 \text{ cy} \\
&= 91,750 \text{ cy} \\
\text{Volume} &= 70 \times 110 \times 550 \div 27 \text{ cy} \\
&= 73,300 \text{ cy} \\
\text{Volume} &= 70 \times 110 \times 550 \div 27 \text{ cy} \\
&= 92,750 \text{ cy} \\
\text{Total} &= 418,650 \text{ cy}
\end{align*}
\]
Longitudinal Section (Upstream and downstream ends of excavation)

The side slopes of the excavation must be keyed back to a 2:1 slope forming two triangular prisms.

For a triangular prism \( V = \frac{\text{Area of base} \times \text{Height}\ (H)}{2} \)

Area of base is the sum of areas 1 through 6 on page 1.

\[ A = (10' \times 160') + \left( \frac{140' \times 30'}{2} \right) + \left( \frac{160' + 90' \times 60'}{2} \right) + \left( \frac{20' + 50' \times 60'}{2} \right) + \left( \frac{70' \times 120'}{2} \right) \]

\[ A = 20,550 \, \text{ft}^2 \]

\[ H = 260' \]

\[ V = \left( \frac{20,550 \times 260'}{2} \right) = 98,900 \, \text{cubic yards} \]

Total Volume:

\[ 418,600 \, \text{cy} + 98,900 \, \text{cy} + 98,900 \, \text{cy} = 616,400 \, \text{cy} \]

Add 20% for over excavation

\[ \frac{616,400 \, \text{cy} \times 1.2}{739,700 \, \text{cy}} \]
Purpose: Estimate quantity of liner needed to line both the upper and lower Chimney Rock reservoirs.

Area - measured in CAD (\( \text{ft}^2 \))

**Lower Reservoir**
\[
A = 28476.2 \text{ m}^2 \times 10.76 \text{ ft}^2 / \text{m}^2 = 306,863 \text{ yd}^2
\]
Slope correction: Abutments: Slopes = 20 - 25%  
Reservoir: Bottom = 9%  
Assume Average Slope = 15% OK
\[
15' = \frac{9 \text{ ft}}{100'} \Rightarrow \text{correct factor} = \frac{101}{100} = 1.01\]
\[
A' = 306,863 \text{ yd}^2 \times 1.01 = 310,232 \text{ yd}^2
\]

**Upper Reservoir**
\[
A = 28900.8 \text{ m}^2 \times 10.76 \text{ ft}^2 / \text{m}^2 = 338,352 \text{ yd}^2
\]
\[
A' = 338,352 \text{ yd}^2 \times 1.01 = 342,635 \text{ yd}^2
\]

Volume - assume 3 ft depth of clay liner, 3 ft = 1 yd
\[
V = \text{depth} \times A'
\]

**Lower reservoir**
\[
V = 1 \text{ yd} \times 310,232 \text{ yd}^2 = 340,232 \text{ yd}^3 \approx 340,000 \text{ yd}^3
\]

**Upper Reservoir**
\[
V = 1 \text{ yd} \times 342,635 \text{ yd}^2 = 342,635 \text{ yd}^3 \approx 342,600 \text{ yd}^3
\]
Appendix B

“Wetlands, Sensitive Species, Riparian Areas, and Big Game Habitat Associated with Potential Reservoir Sites – Shell Basin”

Western EcoSystems Technology, Inc.
WETLANDS, SENSITIVE SPECIES, RIPARIAN AREAS, AND BIG GAME HABITAT ASSOCIATED WITH POTENTIAL RESERVOIR SITES – SHELL BASIN

Prepared for:
States West Water Resources Corporation
Cheyenne, Wyoming

Prepared by:
Luke Martinson and Greg Johnson
Western EcoSystems Technology, Inc.
2003 Central Avenue
Cheyenne, WY 82001

March 30, 2012
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Appendix A. Photographs of potential reservoir sites in Shell Basin
INTRODUCTION

The Wyoming Water Development Commission is considering construction of a reservoir to supply additional storage for the Shell Basin area in Big Horn County, Wyoming. Based on initial screening, the number of potential reservoir locations was reduced to 16 (Figure 1). The purpose of this report is to characterize and summarize environmental issues associated with each site, including presence of wetlands; threatened, endangered and sensitive wildlife and plants; woody riparian areas; migratory birds; and big game habitats.

METHODS

U.S. Fish and Wildlife Service National Wetland Inventory (NWI) maps are available for all proposed sites. The area of wetlands within the dam footprint and inundation areas within each site were calculated using electronic files of the NWI maps (Figures 2-10; Table 1). NWI maps were only created in this report for sites with wetlands present. To further assess the potential wetland impacts at the proposed sites, six of the reservoir sites were visited on October 21 and 22, 2010. During the field investigation the extent of wetlands potentially present on each site was examined. The site visits included those potential reservoir sites with the greatest potential based on an initial screening process. Those sites that were visited included Leavitt Reservoir, Coyote Draw, Bratsky Draw, Sheldon/Potato Reservoir, Canal Tunnel Reservoir, and Douglas Draw.

Previously documented occurrences of federally listed species and other species of concern within the Shell basin were determined through searching the Wyoming Natural Diversity Database (WNDD) maintained by the University of Wyoming. To obtain information on big game habitats associated with each site, digital big game herd unit maps were obtained from the Wyoming Game and Fish Department (WGFD) and overlaid on maps of the reservoirs. Maps of greater sage-grouse core population areas were also obtained from the WGFD and overlaid on maps of the reservoirs. In addition, potential habitat for sensitive species and raptor nesting habitat was assessed during the site visit.

RESULTS

Wetlands

Leavitt Reservoir

The existing Leavitt reservoir at this site is approximately 35.51 acres in size. The NWI mapping for this site indicates only 1.36 acres of palustrine emergent wetland and 0.39 acres of palustrine forested/shrub wetland within the inundation area of an expanded Leavitt Reservoir (Figure 2, Table 1). However, based on the field visit to this site, this appears to be a substantial underestimate of the actual wetland acreage. There is a fairly large (2 to 3–acre) wetland dominated by cattail below the existing Leavitt Dam that would be impacted by a larger dam. In addition, there were fairly extensive fringe wetlands dominated by cattail and sandbar willow along the west side of the existing reservoir. Photographs of wetlands are provided in Appendix A. The actual area of wetland impact would likely be 5–10 acres, and perhaps more.
Coyote Draw
According to NWI maps there are no wetlands present within the reservoir limits. However, based on the site visit, there are fringe wetlands averaging five to six feet in width within the bottom of the existing drainage through the proposed reservoir site. Total wetland impacts associated with construction of a reservoir at this site would likely be approximately 0.5 to 0.75 acres.

Confluence Reservoir
The NWI mapping shows an area of palustrine emergent wetlands (1.93 acres) within the proposed reservoir limits (Figure 3, Table 1). This site was not evaluated during the site visit.

North Beaver Creek
Based on NWI maps no wetlands are present within the reservoir limits. This site was not evaluated during the site visit.

Highline Reservoir
Based on NWI maps no wetlands are present within the reservoir limits. This site was not evaluated during the site visit.

Chimney Rock Reservoir
Based on NWI maps no wetlands are present within the reservoir limits. This site was not evaluated during the site visit.

Trapper Creek On Channel
The NWI mapping shows an area of palustrine emergent wetlands totaling 0.80 acres within the proposed reservoir limits (Figure 4, Table 1). This site was not evaluated during the site visit.

Douglas Draw
The NWI mapping indicates the presence of 0.16 acres of wetland at the eastern extent of the proposed reservoir limits (Figure 5, Table 1). This site was examined during the site visit and was found to be a small stock pond with a breached dam. No other wetlands were present on site and wetland impacts would be very minor for this site.

Trapper Creek Off Channel
Based on NWI maps no wetlands are present within the reservoir limits. This site was not evaluated during the site visit.

Canal Tunnel Reservoir
Based on NWI maps no wetlands are present within the reservoir limits. During the site visit, however, one very small wetland (<0.1 acres) dominated by cattail was observed in the vicinity of the proposed dam. Wetland impacts would be very minor for this site.

Bratsky Draw
The NWI mapping indicates that 2.96 acres of palustrine emergent wetlands are present within the proposed reservoir site near the dam. The wetland is located at the bottom of the draw and is associated with an intermittent drainage (Figure 6, Table 1). Presence of this wetland was confirmed during the site visit.
Lower Willet Reservoir
NWI mapping indicates the presence of 9.66 acres of wetland. A total of three separate palustrine emergent wetlands are depicted on the NWI map. Each of the wetland sections are associated with the drainage running through the proposed reservoir limits (Figure 7, Table 1). This site was not evaluated during the site visit.

Upper Willet Reservoir
NWI mapping indicates the presence of 4.95 acres of wetland. A total of five separate palustrine emergent wetlands are depicted on the NWI map. Each of the wetland sections are associated with the drainage running through the proposed reservoir limits (Figure 7, Table 1). This site was not evaluated during the site visit.

Willet Lake Reservoir
NWI mapping indicates the presence of 17.41 acres of palustrine emergent wetland. Additionally, 4.14 acres of freshwater pond also exist within the reservoir limits. The USGS mapping identifies the pond as Willet Lake, while the emergent wetland surrounds this water feature. Two smaller areas of wetland are also depicted within the proposed reservoir limits. Fairly substantial wetland impacts are likely at this site (Figure 8, Table 1). This site was not evaluated during the site visit.

Shell Reservoir
NWI mapping indicates the presence of 4.78 acres of palustrine emergent wetland within the expanded reservoir. Multiple pockets of emergent wetlands are present within the proposed reservoir inundation area (Figure 9, Table 1). This site was not evaluated during the site visit.

Sheldon/Potato Reservoir
The NWI mapping indicates that 3.82 acres of palustrine emergent wetlands are present within the potential reservoir site near the proposed dam. The wetland is associated with the Sheldon Gulch feature (Figure 10, Table 1). During the site visit, however, this wetland was found to continue into the proposed reservoir limits to a substantially greater extent than indicated on the NWI map. Wetland impacts at this site would likely be substantial (several acres).

Woody Riparian Areas
No extensive woody riparian areas were found to be associated with those reservoirs examined during the field evaluation. Enlarging the dam at Leavitt Reservoir site would entail removal of a small number of cottonwood and Russian olive trees, although Russian olives are classified as a noxious weed. Construction of a dam at the Canal Tunnel Reservoir site would also require removing a relatively small number (~20) of cottonwood trees. Based on NWI mapping and the site visit, only Leavitt Reservoir has scrub/shrub wetlands, which were found to be dominated by sandbar willow. Although the NWI map indicated only a total of 0.39 acres of scrub-shrub wetland within the reservoir polygon, the actual acreage of scrub-shrub wetland at this site is much more extensive based on the field evaluation.
Listed or Other Sensitive Species

The only federally listed species that may occur in the project area are the black-footed ferret and grizzly bear. According to the WNDD, one record of black-footed ferret occurs north of the Sheldon/Potato Reservoir site (Figure 11b), but this record is historical. The entire Shell basin has been identified as potential grizzly bear habitat (Figure 11c). Grizzly bear records in the area are considered historical and do not reflect the current situation.

The greater sage-grouse was recently found to be warranted, but precluded for listing as threatened under the Endangered Species Act. Therefore it is currently classified as a federal candidate species. The Wyoming Game and Fish Department (WGFD) recently updated the map designating greater sage-grouse “Core Population Areas” within the state of Wyoming, and the Governor previously issued an Executive Order mandating that new development within Core Population Areas should be authorized or conducted only when it can be demonstrated that the activity will not cause declines in greater sage-grouse populations. Reservoir sites Coyote Draw, Confluence Reservoir, Highline Reservoir, Douglas Draw, and Trapper Creek Off Channel are within core sage grouse areas (Figure 12). Given the Governor’s executive order, it may be difficult to obtain state approval for the reservoir sites within the core area if significant areas of sage-grouse habitat are inundated.

Several species tracked by the WNDD as species of concern may occur in or near the proposed reservoir sites (Figure 11a-d). Observations of Bighorn Mountain pika, Townsend’s big-eared bat, water vole (Bighorn Mountain population), northern leopard frog, and wood frog (Bighorn Mountain wood frog) have all been identified within the Shell basin (Figure 11a and 11d). Four species of sensitive bird species have been documented within the Shell basin (Figure 13), including American three-toed wood pecker, Brewer’s sparrow, sage sparrow, and sage thrasher. Eleven species of sensitive plants have been documented in the Shell basin (Figure 14a-b). Prior to constructing reservoirs in this area, surveys for sensitive wildlife and plant species would likely be required, especially for any sites located on land managed by the Bureau of Land Management (BLM). If any sensitive species are found, mitigation measures would likely be required.

Migratory Birds

No raptor nests were observed during the site visit, but some raptor nesting habitat in the form of either trees, steep bluffs or rock outcrops is present near each site and nest surveys would likely be required prior to initiating construction activities.

Big Game

No crucial habitat has been identified in the Shell Basin for either moose or pronghorn (Figure 15 and 16). Crucial elk winter habitat is designated within the Shell basin; however, only the Coyote Draw site is within this crucial habitat (Figure 17). Multiple elk parturition areas and migration routes are mapped within the Shell Basin. None of the proposed reservoir sites directly impact these areas (Figure 17). Large amounts of crucial winter range for mule deer occurs in Shell Basin and the Leavitt Reservoir, Coyote Draw, Confluence Reservoir, Chimney Rock Reservoir, Trapper Creek On Channel, Trapper Creek Off Channel, and Bratsky Draw sites all occur within crucial mule deer habitat (Figure 18).
CONCLUSIONS

There does not appear to be any significant environmental concerns for the majority of the proposed reservoir sites. Construction of a new reservoir at the Willet Lake Reservoir site would potentially have greater than 17 acres of wetland impact, while the Lower Willet site could have nearly 10 acres. Fairly substantial wetland impacts would also likely be associated with enlarging Leavitt Reservoir and construction of a new reservoir at the Sheldon/Potato, Shell and Upper Willet reservoir sites. Wetland impacts associated with the other sites would likely be relatively minor and could easily be mitigated. No significant woody riparian area impacts would be associated with construction of a reservoir at any of the sites evaluated during the site visit.

The presence of federally listed species does not appear to be a major issue for any of the sites. Five of the 16 reservoir sites (Coyote Draw, Confluence Reservoir, Highline Reservoir, Douglas Draw, and Trapper Creek Off Channel) are located within greater sage-grouse core population areas. The WGFD will likely require assurance that construction of reservoirs within these areas will not impact greater sage-grouse populations. Only the Coyote Draw site is within crucial winter range for elk, while Leavitt Reservoir, Coyote Draw, Confluence Reservoir, Chimney Rock Reservoir, Trapper Creek On Channel, Trapper Creek Off Channel, and Bratsky Draw are in crucial winter range for mule deer. The WGFD would likely require that impacts to crucial winter range be mitigated. Several sensitive wildlife and plant species occur in the region, and some of these species may be present on the reservoir sites. Surveys for sensitive species may be required prior to construction. Impacts to sensitive species, if present, can likely be mitigated.
Table 1. NWI Wetland Acres for Proposed Reservoir Sites

<table>
<thead>
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<th>Proposed Reservoir Site</th>
<th>NWI Acres</th>
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<td>1.75&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Coyote Draw&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0&lt;sup&gt;b&lt;/sup&gt;</td>
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<sup>a</sup> Indicates potential reservoir site was evaluated during field site visit; <sup>b</sup> based on field visit wetland acreage is greater than NWI mapping indicates; see text for details.
Figure 1. Location of the 16 reservoir sites being considered for the Shell Basin Project
Figure 2. Location of wetlands within the inundation area of Leavitt Reservoir
Figure 3. Location of wetlands within the inundation area of Confluence Reservoir
Figure 4. Location of wetlands within the inundation area of Trapper Creek On Channel
Figure 5. Location of wetlands within the inundation areas of Douglas Draw
Figure 6. Location of wetlands within the inundation area of Bratsky Draw
Figure 7. Location of wetlands within the inundation area of Upper and Lower Willet Reservoirs
Figure 8. Location of wetlands within the inundation areas of Willet Lake Reservoir
Figure 9. Location of wetlands within the inundation area of Shell Reservoir
Figure 10. Location of wetlands within the inundation area of Sheldon/Potato Reservoir
Figure 11a. Observations of sensitive mammal species in relation to the Shell basin reservoir sites
Figure 11b. Observations of sensitive mammal species in relation to the Shell basin reservoir sites
Figure 11c. Observations of sensitive mammal species in relation to the Shell basin reservoir sites
Figure 11d. Observations of sensitive mammal species in relation to the Shell basin reservoir sites
Figure 12. Greater sage-grouse Core Population Areas in relation to the Shell basin reservoir sites
Figure 13. Observations of sensitive bird species in relation to the Shell basin reservoir sites
Figure 14a. Observations of sensitive plant species in relation to the Shell basin reservoir sites
Figure 14b. Observations of sensitive plant species in relation to the Shell basin reservoir sites
Figure 15. Big game (moose) habitat classifications in relation to the Shell basin reservoir sites
Figure 16. Big game (pronghorn) habitat classifications in relation to the Shell basin reservoir sites
Figure 17. Big game (elk) habitat classifications in relation to the Shell basin reservoir sites
Figure 18. Big game (mule deer) habitat classifications in relation to the Shell basin reservoir sites
Appendix A. Photographs of potential reservoir sites in Shell Basin
Wetlands below and adjacent to the dam at the existing Leavitt Reservoir Site
Wetland fringes along Leavitt Reservoir
Wetland fringes along Leavitt Reservoir
Typical wetland fringes in channel of Coyote Draw Reservoir Site
Overview and close up of wetland near proposed dam location at the Bratsky Draw site
Wetland in channel at the Sheldon/Potato Reservoir site
Riparian trees and small wetland at the Canal Tunnel site
Appendix C

“Greater Sage-Grouse Density and Disturbance Calculation Tool Analysis for the Proposed Douglas Draw Reservoir”

by Western EcoSystems Technology
Greater Sage-Grouse Density and Disturbance Calculation Tool Analysis for the Proposed Douglas Draw Reservoir
Bighorn County, Wyoming

Draft Report

Prepared for:
States West Water Resources
1904 E. 15th Street
Cheyenne, Wyoming 82001

Prepared by:
Greg Johnson and Jon Cicarelli
Western EcoSystems Technology, Inc.
2003 Central Avenue
Cheyenne, Wyoming

October 17, 2011
INTRODUCTION

The Wyoming Water Development Office is considering construction of a new dam and reservoir south of Shell, Wyoming, referred to as the Douglas Draw Reservoir. The proposed reservoir would be 172.25 acres in size. A portion of the inundation pool of this reservoir (73.07 acres) is located within a greater sage-grouse (*Centrocercus urophasianus*) Core Population Area (Figure 1).

In an effort to prevent listing of greater sage-grouse, the Wyoming Governor’s office developed a map of greater sage-grouse Core Population Areas (Version 3). The Core Population Areas include areas with the highest densities of breeding greater sage-grouse in the state, as well as identified areas important for connectivity between populations. The Core Population Areas include roughly 25% of the state but contain 83.1% of the greater sage-grouse population. On June 2, 2011, Governor Mead issued Greater Sage-Grouse Executive Order (EO) 2011-5, which states that new development or land uses within Core Population Areas should be authorized or conducted only when it can be demonstrated that the activity will not cause declines in greater sage-grouse populations.

The EO included a method for use in determining compliance with the EO for new projects, referred to as the Density and Disturbance Calculation Tool (DDCT). The DDCT is used to determine if the proposed new disturbance, combined with existing and permitted disturbances in the area, are below 5% of the DDCT area and result in an average of <1 disruptive activity per 640 acres within the area affected by the project. Based on scientific literature, it is assumed that as long as the maximum disturbance is <5% of the DDCT area and the density of disruptive activities is <1 per 640 acres, the proposed activity should not result in declines in greater sage-grouse populations provided that other general and specific stipulations are followed.

METHODS

To determine the DDCT analysis area, a 4-mile buffer was placed around the proposed reservoir within the Core Population Area to determine which occupied leks may be affected by the project. Two occupied leks are located within the 4 mile boundary as identified from the piaa_occlekper110210 shapefile. It was assumed that both leks within 4 miles of the reservoir may be affected. Next, a four-mile buffer was placed around the perimeter of each affected occupied lek. The 4-mile buffer of the proposed reservoir within the Core Population Area and the 4-mile boundary of affected occupied leks were merged to create the DDCT analysis area for the Douglas Draw Reservoir project. Any portion of the DDCT area occurring outside of the Core Population Area was removed from the analysis. For the Douglas Draw analysis we assumed that the entire area within the Core Population Area boundary was suitable sage-grouse habitat. Following the above steps resulted in a DDCT analysis area of 20,019.79 acres (Figure 2). Disturbance was analyzed for the DDCT area as a whole and for each individual affected occupied lek within the DDCT area.
Figure 1. Location of the proposed Douglas Draw Reservoir in relation to greater sage-grouse Core Population Areas
Figure 2. Location of affected occupied leks and the Density and Disturbance Calculation Tool (DDCT) analysis area for the proposed Douglas Draw Reservoir.
A shape file of the new reservoir dam and inundation pool was used to determine total size of the new disturbance. We classified all land area within the maximum high water line of the proposed reservoir as being disturbed. Once the DDCT area was defined, the acreage of existing surface disturbance was digitized using ArcGIS Version 10 on 2009 True Color National Agricultural Imagery Program (NAIP) aerial imagery at a 1:5,000 scale. Surface disturbances digitized were limited to those anthropogenic in nature, and included the following:

Roads: All roads greater than or equal to 10 feet wide that did not have a noticeable strip of vegetation down the middle were digitized as disturbance. Roads less than 10 feet wide that were clearly discernable as improved roads also were included. The actual footprints of the road were digitized from the 2009 NAIP imagery.

Oil and Gas Wells: Locations of active as well as plugged and abandoned oil and gas wells were obtained from the Wyoming Oil and Gas Commission website. Each well pad in the DDCT area was digitized as disturbance.

Mining: Mine plan permit boundaries were obtained from the Wyoming Department of Environmental Quality (DEQ) website and actual mining disturbance was digitized.

Cropland: All cropland in the DDCT area was digitized and counted as disturbance.

Buildings: All buildings, including ranches and developed subdivisions, as well as any ground disturbance associated with buildings, were digitized.

Transmission Lines: The entire Right-Of-Way (ROW) for overhead transmission lines was digitized and counted as surface disturbance.

Pipelines: All disturbance associated with pipeline scars was digitized. Pipelines contribute towards the disturbance calculation until the area has been successfully reclaimed.

In addition to surface disturbance, all disturbances associated with oil and gas as well as mining activities were considered anthropogenic disruptions for determining if the disruption threshold of an average of one disruption per 640 acres was exceeded. Once all input variables were determined, the model described in the Wyoming Game and Fish Department Density and Disturbance Calculation Tool (DDCT) Manual (WGFD 2011) was run to calculate percent surface disturbance and disruption density associated with oil and gas well and mines.

RESULTS

That portion of the proposed Douglas Draw Reservoir in the DDCT analysis area was 73.07 acres (Table 1). Existing surface disturbances in the DDCT area included buildings, roads, cropland, oil wells, pipeline scars, existing small reservoirs and other miscellaneous forms of disturbance (Figure 3). The total existing disturbance was 178.09 acres. The combined existing and proposed disturbance was 251.16 acres, which represents 1.25% of the 20,019.79
acres included in the DDCT analysis area (Figure 3). The mean density of disruptions in the DDCT area was calculated to be 0.12 disruptions/640 acres (Table 1).

Table 1. Types and acres of disturbance within the Douglas Draw Density and Disturbance Calculation Tool analysis area

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<tr>
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<td><strong>Mean # disruptions/640 acres</strong></td>
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</table>

For the two affected leks in the DDCT, surface disturbance totaled 218.27 acres, or 1.39% of the analysis area for the Douglas Draw Lek, and 116.36 acres, or 0.70% of the analysis area for the Six Mile Lek.

DISCUSSION

Based on results of this DDCT analysis, the proposed Douglas Draw reservoir project would be in compliance with the Governor’s EO because total surface disturbance (1.25%) is <5%, and the mean density of disruptions (0.12/640 acres) is less than 1/640 acres. Results of this DDCT analysis were provided to the WGFD for concurrence. The WGFD determined that the DDCT was conducted properly, although results of their analysis indicated that the total surface disturbance was 1.75% of the DDCT, rather than 1.25% (Appendix A). Regardless, both analyses indicated the project was in compliance with the Governor’s EO based on disturbance and disruption criteria; however, other aspects of the project also must be considered to be in full compliance with the EO. These include the following stipulations applicable to development of a new reservoir:
Figure 3. Proposed and existing disturbance within the DDCT analysis area for the Douglas Draw Reservoir Project
1. **Surface Occupancy:** No surface occupancy will occur within 0.6 miles of the perimeter of occupied sage-grouse leks;

2. **Seasonal Use:** No construction activity will be allowed from March 15 to June 30 outside of the 0.6-mile perimeter of a lek in core areas where breeding, nesting and early brood-rearing habitat is present. In areas used solely as winter concentration areas, construction activity will not be allowed from December 1 through March 14.

3. **Transportation:** All roads used to provide facility site access and maintenance should be located >0.6 miles from the perimeter of occupied sage-grouse leks.

4. **Noise:** New noise levels, at the perimeter of a lek, should not exceed 10 dBA above ambient noise (existing activity included) from 6:00 p.m. to 8:00 a.m. during the initiation of breeding (March 1 – May 15). Ambient noise levels should be determined by measurements taken at the perimeter of a lek at sunrise.

5. **Vegetation Removal:** Vegetation removal should be limited to the minimum disturbance required by the project. All topsoil stripping and vegetation removal in suitable habitat will occur between July 1 and March 14 in areas that are within 4 miles of an occupied lek.

6. **Monitoring/Adaptive Management:** Proponents of new projects are expected to coordinate with the permitting agency and local WGFD biologist to determine which leks need to be monitored and what data should be reported by the proponent. Certain permits may be exempted from monitoring activities pending permitting agency coordination. If declines in affected leks (using a 3-year running average during any five year period relative to trends on reference leks) are determined to be caused by the project, the operator will propose adaptive management responses to increase the number of birds. If the operator cannot demonstrate a restoration of bird numbers to baseline levels (established by pre-disturbance surveys, reference surveys and taking into account regional and statewide trends) within three years, operations will cease until such numbers are achieved.
Appendix A. Comment letter from Wyoming Game and Fish Department for the Douglas Draw DDCT analysis
October 17, 2011

WER 12437
Western EcoSystems Technology, Inc
Density/Disturbance Calculation Tool (DDCT) Analysis
Douglas Draw Reservoir

Greg Johnson
Western EcoSystems Technology, Inc
2003 Central Ave
Cheyenne, Wyoming 82001

Dear Mr. Johnson:

The staff of the Wyoming Game and Fish Department has reviewed the Density/Disturbance Calculation Tool (DDCT) Analysis for the Douglas Draw Reservoir. We offer the following comments for your consideration.

The Douglas DDCT was done to the letter of the Sage Grouse Executive Order. All of the disturbance was captured and captured accurately.

The DDCT showed 1.75% disturbed with the proposed project. The disruption count was at .12 per 640 acres. Please note though that should the final permitting actually take place far into the future, another DDCT should be run to make sure that no DDCT exceedences have occurred during that time frame. We recommend additional consultation with WGFD prior to construction to make sure that construction activities are consistent with the Sage Grouse Executive Order.

Thank you for the opportunity to comment. If you have any questions or concerns, please contact Mary Flanderka, 307-777-4587.

Sincerely,

John Emmerich
Deputy Director

cc: USFWS
Mark Zornes, Green River Region

"Conserving Wildlife - Serving People"
Appendix D

Irrigated Lands and Hydrologic Analysis Feature Locations

by Leonard Rice Engineers, Inc.
Substantial efforts have been made to accurately compile GIS data and documentation. Accuracy is not guaranteed. This product is for reference purposes only and is not to be construed as a legal document or survey instrument.
Substantial efforts have been made to accurately compile GIS data and documentation. Accuracy is not guaranteed. This product is for reference purposes only and is not to be construed as a legal document or survey instrument.
Substantial efforts have been made to accurately compile GIS data and documentation. Accuracy is not guaranteed. This product is for reference purposes only and shall be used and referred to as legal documents.
Irrigated Lands and Hydrologic Analysis

Beaver and Horse Creeks
Substantial efforts have been made to accurately compile GIS data and documentation. Accuracy is not guaranteed. This product is for reference purposes only and is not to be construed as a legal document or survey instrument.
Appendix E

Fish Sampling Data on Beaver Creek and Shell Creek

from the Wyoming Game and Fish Department
Event Information
Water: CY8H2O50BN Beaver Creek
Data Collected By: Welker
Sampling Gear: Backpack Electrofishing Unit
Station Length: 370 feet; 0.07 miles
Station Width: 15 feet
Acres: 0.13
Elevation at Sample Site: 5118 feet
Location: CON FLU W CEDAR CR.

Remarks:

Species Summaries

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Nonmeasured Fish
Species Mark Capture History Number

Relative Abundance
Species Abundance

LND = Longnose Dace
MTS = Mountain Sucker
WHS = White Sucker
YSC = Yellowstone Cutthroat

http://gfi.state.wy.us/StreamLake/RiverStation/RiverStation/StationSummaryReport.mvc.a... 8/16/2011
Detailed Station Summary Report

Event Information
Water: CY8/200505N Beaver Creek
Data Sampled: 9/17/2007
Data Collected By: O. Miller
Sampling Gear: Backpack Electrofishing Unit
Station Length: 650 feet; 0.12 miles
Station Width: 8 feet
Acres: 0.12
Elevation at Sample Site: 4294 feet
Location: State Land
Zone: 73
Easting: 275976
Northing: 4639179
Remarks: Warmwater Stream Survey

Species Summaries

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Relative Abundance

- **BNT** = Brown trout
- **FHM** = Fathead minnow
- **TRT** = Unidentified trout species

http://gfi.state.wy.us/StreamLake/RiverStation/RiverStation/StationSummaryReport.mvc.a... 8/16/2011
Detailed Station Summary Report

Event Information
Water: CYSH20428N Shell Creek, below Beaver Creek
Date Sampled: 9/13/2010
Data Collected By: MJ, MS
Sampling Gear: Backpack, Electrofishing Unit
Station Length: 1200 feet; 0.23 miles
Station Width: 0 feet
Acres: 0
Elevation at Sample Site: 4025 feet
Location: Stan Fittner Property
  Zone: 13
  Easting: 271529
  Northing: 4906961

Remarks: J4-100v, 200v, 2 backpacks used with 4 total netters. Water temperature was 60 degrees at 1300 and water was cloudy.

Species Summaries

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Nonmeasured Fish

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Relative Abundance

Species Abundance

MWF = Mountain Whitefish
LNS = Longnose Sucker
Detailed Station Summary Report

Event Information
- **Water**: CY8H2040BN Shell Creek, below Beaver Creek
- **Date Sampled**: 8/14/2007
- **Data Collected By**: B Bear
- **Sampling Gear**: Backpack Electrofishing Unit
- **Station Length**: 1000 feet; 0.19 miles
- **Station Width**: 43 feet
- **Acres**: 0.99
- **Elevation at Sample Site**: 3953 feet
- **Location**: Section 2, Rech Property
  - **Zone**: 13
  - **Easting**: 267958
  - **Northing**: 493366

**Remarks**: Warmwater Stream Survey 2007, Habitat data also collected.

## Species Summaries

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**Relative Abundance**

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http://gfi.state.wy.us/StreamLake/RiverStation/RiverStation/StationSummaryReport.mvc.a... 8/16/2011
Detailed Station Summary Report

Event Information
Water: CY8H2040BN Shell Creek, below Beaver Creek
Date Sampled: 8/14/2007
Data Collected By: B Bear
Sampling Gear: Backpack Electrofishing Unit
Station Length: 1000 feet; 0.19 miles
Station Width: 60 feet
Area: 1.38
Elevation at Sample Site: 3228 feet.
Location: near BH River confluence (Fiddleback Farm)


Species Summaries

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Relative Abundance

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http://gfi.state.wy.us/StreamLake/RiverStation/RiverStation/StationSummaryReport.mvc.a... 8/16/2011