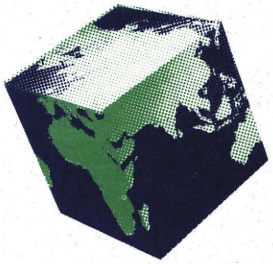

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Geotechnical Investigation and Report for Green River Pump Station Green River, Utah

IGES Job No. 454-001

March 06, 2008

Prepared for:

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Geotechnical Investigation and Report for
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March 06, 2008

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APPENDIX

1.0 EXECUTIVE SUMMARY

The purposes of this investigation were to assess the nature and engineering properties of the subsurface soils and bedrock at the proposed site, to provide recommendations for general site grading and the design and construction of foundations, and to assess potential geologic hazards at the site and the affect that any potential geologic hazard may have on the proposed development of the site.

We understand the project as planned will consist of the construction of a pump station on the Green River. Two proposed designs for the pump station were provided, the first would be a structure built on the river bank that bears the weight of the pumps and the structure on a footing design; the second hangs a platform over the river and is supported by piles or columns where the weight of the pumps and platform rests. The pump house site is located on the eastern bank of the Green River. The site is to be located partially up the slope at an approximate elevation of 4,050 feet above mean sea level.

Based on the subsurface conditions encountered at the site, it is our opinion that the subject site is suitable for the proposed construction provided that the recommendations contained in this report are properly implemented in the design and during construction. Conventional spread and strip footings or a mat foundation system may be used to support the proposed pump station on the banks of the river. Based on the potential settlement associated with the near surface soils, we recommend that a minimum of 2 feet of structural fill be placed beneath all proposed foundations. The structural fill should be compacted to the requirements presented in the structural fill section of this report.

NOTICE: The scope of services provided within this report is limited to the assessment of the subsurface conditions for the proposed pump house development. This executive summary is not intended to replace the report of which it is part and should not be used separately from the report. The executive summary is provided solely for purposes of overview. The executive summary omits a number of details, any one of which could be crucial to the proper application of this report.

2.0 INTRODUCTION

2.1 PURPOSE AND SCOPE OF WORK

This report presents the results of a geologic/geotechnical investigation conducted at the proposed pump station site located on the eastern bank of the Green River, within the Green River Valley, approximately 3.5 miles northeast of Green River, Utah. The purposes of this investigation were to assess the nature and engineering properties of the subsurface soils and bedrock at the proposed site, to provide recommendations for general site grading and the design and construction of foundations, and to assess potential geologic hazards at the site and the affect that potential geologic hazards may have on the proposed development of the site. Specifically, our scope of services included the following:

- Review of available references and maps of the area;
- Review and evaluation of aerial photographs covering the site area;
- Geologic reconnaissance of the site by an engineering geologist to observe and document pertinent surface features indicative of possible geologic hazards;
- Subsurface geotechnical investigation consisting of a single boring; and
- Engineering analysis of our observations combined with existing information and preparation of this written report with conclusions and recommendations regarding possible geologic hazards affecting the site.

Our services were performed in accordance with our proposal and signed authorization, dated January 28, 2008. The recommendations contained in this report are subject to the limitations presented in the "Limitations" section of this report and are good for a five-year period from the date of the report issuance.

2.2 PROJECT DESCRIPTION

We understand the project as planned will consist of the construction of a pump station. The exact location for the planned facility has not currently been selected. We understand that the pump station will be built either on the bank of the river or extend into the river and be founded on the exposed bedrock shelf. Details about the structure are preliminary at this time, but we have assumed loads from the structure will be on the order of 3,500-4,500 psf.

The project site is shown on the Site Vicinity Map included in Appendix A at the end of this report (Plate A-1). A more local and detailed Site Map, showing the location of the boring is located in Appendix A as well (Plate A-2). For additional reference an aerial photo of the site and a geologic map with unit descriptions are included in appendix A (Plates A-3, A-4a and A-4b).

3.0 METHOD OF STUDY

3.1 OFFICE RESEARCH

An engineering geologist investigated the geologic conditions at the proposed pump station location. A literature review was conducted which consisted of reviewing previous geologic reports of the area and other available geologic literature and geologic maps pertinent to the site, as indicated in the references cited.

3.2 FIELD INVESTIGATION

A field geologic reconnaissance was conducted at the subject site, to observe existing geologic conditions and to evaluate existing and potential geologic hazards. The findings of the geologic investigation are presented in Sections 4.0 and 5.0 of this report.

As part of this investigation, subsurface soil conditions were explored by completing one soil boring to a depth of 17 feet below the existing ground surface. Refusal was encountered at 17 feet in weak to moderately strong SHALE bedrock. The boring was located in an area identified during our geologic reconnaissance. Plate A-2 in Appendix A shows the approximate location of the boring in relation to the location of the proposed pump station and the existing contours of the site. A log of the subsurface conditions, as encountered in the boring was recorded at the time of our investigation by a qualified engineering geologist and is presented on the enclosed boring logs, Plate B-1 Appendix B. A key to soil symbols and terms is found on Plate B-2.

The boring was completed using a truck mounted drill rig. Due to the shallow depth to bedrock at the site, a limited amount of soil samples could be obtained. However, samples of the soils and bedrock were collected from the boring and the river bank slope below the boring location and these samples were classified by the engineering geologist. Our field geologist classified the observed soils according to the Unified Soil Classification System (USCS). Classifications for the individual soil units are shown on the attached exploration logs.

The samples were transported to our laboratory for testing to evaluate the pertinent engineering properties of the soils. Soil samples are normally discarded 30 days after submittal of the final report unless IGES receives a specific request to retain the samples for a longer period.

3.3 LABORATORY INVESTIGATION

Representative samples of the soils and bedrock were sampled and tested in the laboratory to assess pertinent engineering properties. A consolidation test was performed on the Clayey SAND material at a depth of 5 to 6 feet. A gradation test was performed on the Silty Clayey SAND at a depth of 11 to 12 feet. In addition, Atterberg limit tests were completed on the weathered SHALE encountered at the bottom of the boring and the Clayey SAND at the 5 foot depth. This test was completed to aid in classification and further evaluates the expansive properties of the material.

Results of the laboratory tests indicate the SHALE has a liquid limit of 21 and a plasticity index of 9, classifying the material as a Lean CLAY (CL). The consolidation test indicates that the Clayey SAND material may be subject to excessive settlement under an increased load and moisture conditions. The test presents data that indicates unusually high settlement. It is possible that this sample was excessively disturbed prior to testing and the test results over estimate the amount of anticipated settlement. Finally the gradation test on the material at a depth of 10 feet classified the soil as a Lean CLAY.

3.4 ENGINEERING ANALYSIS

Based on the proposed construction at the site, the following engineering analyses were performed:

- Bearing capacity of foundation soils
- Foundation settlement
- Lateral earth pressures against foundations and retaining walls
- Lateral resistance against sliding
- Excavatability
- Excavation slopes

Engineering analyses were performed using soil data obtained from the laboratory test results and empirical correlations from material density, depositional characteristics and classification. Appropriate factors of safety were applied to the results consistent with industry standards and the accepted standard of care.

Bearing capacity values were calculated using Vesic's, Meyerhof's and Hansen's modifications to Terzaghi's original bearing capacity formula. Strength parameters for the bearing soils were assigned based on the laboratory test data and field observations. A factor of safety of 3 was used in developing allowable bearing values. Bearing capacities were also limited to minimize settlement of foundation elements.

Lateral earth pressures were calculated using Rankine's correlation of lateral pressures to the internal friction angle of the material a conservative friction angle of 30 degrees was estimated based on the laboratory test data and the field observations. Lateral resistance against sliding was evaluated using published information pertaining to the relationship between the internal friction angle values and soil type against concrete.

Excavation stability was evaluated based on the field conditions encountered, laboratory test results and soil type. OSHA minimum requirements are typically prescribed unless conditions warrant further flattening of slopes.

4.0 GENERALIZED SITE CONDITIONS

4.1 SURFACE CONDITIONS

The site is located immediately to the west of Hastings Road approximately 3.5 miles outside of Green River, Utah. The site is located on a west-facing slope, on the eastern cut bank of the Green River (Plate A-1). The general area east of the subject site is a large plateau, which slopes generally west and contains elevations up to 6,300 feet. North of the site the Green River exits Grays Canyon into the Green River Valley.

The site for the proposed pump house is covered by silty, sandy slope wash overlying stream alluvium and Mancos Shale bedrock (Plate A-4). Vegetation near and at the site is sparse and consists of grasses, sagebrush and river willow trees. The Green River has eroded a steep bank approximately 20 feet high, as it has downcut through the silty sand of the slope wash to the shale bedrock, on the western boundary of the subject site (Plate A-2). On the northern boundary of the property a small drainage has downcut into the slope wash. The drainage has been piped under Hastings Road in the northeastern corner of the site to allow runoff to continue through the site to the river. On the southern boundary of the property are the concrete remains of an old pump house. Photographs of the site are included in appendix C of this report.

4.2 SUBSURFACE CONDITIONS

As previously mentioned, the subsurface soil conditions were explored at the subject property for the proposed pump station, by completing 1 boring at the subject site. The depth of the boring was 17 feet below the existing natural site grade. Subsurface soil conditions were logged at the time the boring was drilled, and are included in the boring log in Appendix B at the end of this report (Plate B-1).

The cut bank of the green river has been locally eroded to expose the shale bedrock that underlies the surface sediments. Between the seasonally low and high water levels approximately 5 to 10 feet of bedrock was exposed on the river bank. Where the river bank meets the seasonally high water level the river has eroded into the slope wash deposits leaving a shelf of bedrock. The silty, sandy material of the slope wash at the high water lever appears to be easily eroded.

The stratification lines shown on the enclosed boring log represent the approximate boundary between soil types. The actual in-situ transition may be gradual. Due to the nature and

depositional characteristics of the native soils, care should be taken in interpolating subsurface conditions between and beyond the exploration locations. The soil, bedrock and moisture conditions encountered, during our investigation, are discussed below.

4.2.1 Soils

Based on the exploration completed for this investigation, along with observations made around the site (Appendix B), the soils exposed at the site appeared to be locally sandy and contain frequent gravel and cobbles. The soil-profile was observed to transition into bedrock at depth. Sediment at the subject site ranges in depth between approximately 0 to 20 feet. At the location of the boring the slope wash was approximately 16 feet thick and consists of brown silty and clayey sand. At a depth of approximately 16 feet stream alluvium was encountered consisting of silty gravel with sand. Well rounded pebbles of shale, pink and gray sandstone and gray quartzite are included within the alluvium. Below the alluvium, at 17 feet, the drill rig reached refusal within the Mancos Shale.

4.2.2 Bedrock

Bedrock at the subject site consists of the Blue Gate member of the Mancos Shale. This unit where exposed along the river bank consisted of

4.2.3 Groundwater/Moisture Content Conditions

No indication of groundwater was observed at the proposed pump house site. However, seasonal fluctuations in precipitation and runoff may increase moisture conditions at the site. Due to the season of our investigation, we anticipate moisture contents to be near their seasonal low. If construction occurs during wetter seasons, some groundwater may be encountered and soft, very moist soil conditions should be expected.

5.0 GEOLOGIC CONDITIONS

5.1 GEOLOGIC SETTING

The site is located, at an elevation of approximately 4035 to 4060 feet, within the southern portion of the Green River Valley in the SW ¼ of the NE ¼ of Section 3, Township 21 South, Range 16 East, Uinta Special Meridian, on the Blue Castle Butte 7.5 minuet Quadrangle (Plate A-1). The Colorado Plateau is a broad, uplifted, crustal block. The uplift of the Colorado Plateau occurred in the Late Cretaceous-early Tertiary (Stokes, 1986). The Green River has down-cut into the uplifted Colorado Plateau forming the broad Green River Valley. The Green River Valley is located along the central portion of the Green River as it flows across the Colorado Plateau to the Colorado River. The Green River Valley is a shallow, sediment-filled valley occurring where the green river is unconfined by steep canyon walls as it exits Gray canyon to the north.

The near-surface geology of the Green River Valley is dominated by sediments, which were deposited in the shallow seas of the Cretaceous, forming limestone, shale, siltstone and sandstone. The Mancos Shale is the main unit mapped in the site vicinity. The Mancos Shale units are all marine deposits. The Mancos Shale, deposited in the Upper Cretaceous, consists of six members (in descending order): upper part of the Blue Gate, Emery Sandstone, Garley Canyon Sandstone, Ferron Sandstone, and Tununk. Total thicknesses of the units range from 2,300 feet to 6,100 feet. The Mancos Shale is overlain by Holocene alluvium, and slope wash, and Holocene to Pleistocene Piedmont Mantle.

Surface sediments at the subject site consist of a thin layer of Pleistocene to Holocene age slope wash mapped as light to dark gray thin to thick bedded clay, silt, sand, granules and some pebbles derived from formations exposed in adjacent uplands (Witkind, 1988). Quaternary deposits are associated with the down cutting of the Green River and erosional processes (Hintze 1993, Witkind 1988).

Bedrock underlying the subject site is mapped as the Blue Gate member of the Mancos Shale. The Blue Gate member of the Upper Cretaceous age Mancos Shale is reported to consist of light gray, bluish gray, and dark gray, thin to medium bedded shale and shaley siltstone with few inter-layered brown sandstone beds. The unit is covered in places by Quaternary pediment, slope wash and alluvial deposits. The Blue Gate member of the Mancos Shale is up to 3,500 feet thick.

5.2 SEISMICITY AND FAULTING

No active faults are reported to run through or immediately adjacent to the site (Witkind, 1988; Black and others, 2003). The Nephi segment of the Wasatch fault zone is approximately 100 miles east of the site. The Nephi segment is reported to be active and thought to generate earthquakes of approximate magnitude 7.0 to 7.5 every 1350 ± 200 years (Black and others, 2003).The Ten Mile Graben faults are approximately 9.5 miles north of the site. The Quaternary Ten Mile Graben faults are related to salt dissolution, but may have a tectonic component. The Salt and Cache Valleys warp faults and folds, a poorly understood zone of Quaternary deformation related to the collapse of the Salt Valley anticline north of Moab are located 9.8 miles west of the site. The Price River area faults are located 14.5 miles south of the. The Price River faults are east-west striking Quaternary faults along the Price River west of the book cliffs. The West fault in the Joes Valley Fault Zone is located approximately 60 miles east of the site. The most recent event on this series of faults was <15,000 years ago. The faults have the potential of producing a 7.5 magnitude earthquake.

Using the criteria outlined in the 2003 IBC, the maximum considered earthquake (MCE) ground motion is taken as that motion represented by an acceleration response spectrum having a 2% chance of exceedance within a 50-year period (Section 1615.2.1). This hazard was identified for the site using the NEHRP-based software program, "Seismic Parameters" (Leyendecker et al., 2000), which correlates with the International Building Code (IBC) seismic hazard maps. This program, as with the IBC maps, is used to develop the probabilistic spectral accelerations corresponding to MCE seismic hazard level for rock-like conditions. To account for site soil effects, site coefficients (F_a and F_v) were used to attenuate the rock-based spectral acceleration values. IGES proposed two locations for the foundation of the pump house, one being on bedrock and one being on the soils overlying the bedrock. Based on our field exploration, we believe that the soils at this site if the foundation for the pump house is built on the soils overlying the bedrock are representative of a "stiff soil" profile; best described by IBC Site Class D with Fa and Fv values of 1.587 and 2.4, respectively. However, IBC requires that the site class be defined based on the average over a 100 foot depth. Given that bedrock was encountered at 17 feet, the appropriate site class for the structure would be Site Class B. The soils at this site if the foundation for the pump house are representative of a "rock" profile; best described by IBC Site Class B with Fa and Fv values of 1.0 and 1.0, respectively. The following table presents response accelerations for 0.2 and 1.0 second periods.

MCE Seismic Response Spectrum Spectral Acceleration Values for IBC Site Class B [a]	
Site Location: **Latitude = 39.022 N** **Longitude = -110.139 W**	**Site Class D Site Coefficients:** **Fa = 1.0** **Fv = 1.0**
Spectral Period (sec)	**Response Spectrum Spectral Acceleration (g)**
0.2	0.266xFa = 0.266
1.0	0.083xFv = 0.083
[a] IBC 1615.1.3 recommends scaling the MCE values by 2/3 to obtain the design spectral response acceleration values.	

5.3 OTHER GEOLOGIC HAZARDS

Geologic hazards can be defined as naturally occurring geologic conditions or processes that could present a danger to human life and property. These hazards must be considered before development of the site. There are several hazards in addition to seismicity and faulting that may be present at the site, and which should be considered in the design of roads and critical facilities such as pump stations and structures designed for human habitation. The hazards considered for this site include liquefaction, stream flooding and erosion.

5.3.1 Liquefaction

Certain areas within the Intermountain region possess a potential for liquefaction during seismic events. Liquefaction is a phenomenon whereby loose, saturated, granular soil deposits lose a significant portion of their shear strength due to excess pore water pressure buildup resulting from dynamic loading, such as that caused by an earthquake. Among other effects, liquefaction can result in densification of such deposits causing settlements of overlying layers after an earthquake as excess pore water pressures are dissipated. The primary factors affecting liquefaction potential of a soil deposit are: (1) level and duration of seismic ground motions; (2) soil type and consistency; and (3) depth to groundwater.

Based on the field data collected for this site and the depth to underlying bedrock it is our opinion that the liquefaction potential at the site is very low.

5.3.2 Stream Flooding and Erosion

Stream flooding is a hazard related to spring snowmelt, run-off and flash–flooding from summer rainstorms. Flood hazards should be considered when planning for development for habitable structures and other critical facilities located in areas having a potential flood risk.

Due to the proximity of the pump house location to the Green River, stream flooding hazards are present at the subject site. At the time of our field reconnaissance the Green River was seasonally low. Based on observations of the banks at the site the River may rise as much as 2 to 4 feet during the normal seasonal high. Summer storms may increase the level of the river during flash flooding events. The river has been as high as 22 feet higher than current conditions during years with extremely high precipitation. There is a drainage located at the north end subject site. The drainage has cut a considerable channel into the slope wash sediment. Run-off during rainstorms and snowmelt has caused erosion of the weathered slope wash at the site and may potentially

affect the proposed pump station. Stream flooding is a hazard at the site. Recommendations for site grading to limit damage to structures resulting from potential stream flooding and erosion to the proposed pump house will be made in the CONCLUSIONS AND RECOMMENDATIONS Section of this report.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 GENERAL CONCLUSIONS

Supporting data upon which the following recommendations are based have been presented in the previous sections of this report. The recommendations presented herein are governed by the physical properties of the soils encountered in the exploratory borings, the anticipated design data discussed in the PROJECT DESCRIPTION section of this report and the Engineering Analyses outlined previously. If subsurface conditions other than those described herein are encountered in conjunction with construction, and/or if design and layout changes are initiated, IGES must be informed so that our recommendations can be reviewed and revised as changes or conditions may require.

Based on the subsurface conditions encountered at the site, it is our opinion that the subject site is suitable for the proposed construction provided that the recommendations contained in this report are properly implemented in the design and during construction. Additional sub-sections present our recommendations for general site grading, excavation, foundations, lateral earth pressures, erosion protection, moisture protection and surface drainage.

6.2 EARTHWORK

We anticipate site grading will be performed for construction of the pump station. Final site grading is also recommended to provide proper drainage and moisture control on the subject property and to aid in preventing differential movement in foundation materials and erosion of the slopes.

6.2.1 General Site Preparation and Grading

Within the areas where the pump station is to be placed, any topsoil, vegetation and debris should be removed prior to the placement of structural fill and concrete foundations. All loose or disturbed material remaining after excavation should be compacted to a minimum of 95 percent of the maximum dry density as determined by ASTM D-1557 if possible or to the maximum density verified by testing or observation. Alternatively, the material may be removed and replaced with structural fill as outlined in Section 6.2.4. Based on the consolidation test results, it is possible that excessive settlements may occur with an increase in moisture and loading. We recommend that a 2 foot thick structural fill zone be created beneath all footings.

6.2.2 Excavatability

Following the removal of vegetation, debris, loose and disturbed material, as described above, the exposed soil should be excavated to the design elevation of the foundations.

As previously mentioned, the majority of the near surface soils consisted of Clayey and Silty SAND, transitioning into weathered bedrock at a depth of 17 feet below existing site grade. We anticipate excavations can be completed in these soils with conventional construction equipment. Excavations into the underlying bedrock may require the use of heavy duty equipment. Based on our observations, we anticipate the weathered bedrock may be rippable and not require blasting. The contractors should satisfy themselves as to the ease of excavation into this bedrock material. Excavations for structural fill beneath all foundations should extend 1 foot laterally for every foot of depth. For example, if 2 feet of structural fill is to be provided, then the footing excavation should extend a minimum of 2 feet beyond the external limits of all footings. We recommend that an IGES representative be present at completion of the excavation to assess the soils conditions encountered prior to placement of structural fill.

6.2.3 Excavation Slopes

Based on our field observations the site soils are classified as Type C soils in accordance with OSHA designations. Shallower temporary excavation including trenches can be constructed near vertical to a total depth of 4 feet and should then be constructed at 1.5:1 (horizontal: vertical side slopes to a maximum depth of 12 feet. We recommend the excavation slopes be rounded and flattened near the surface to minimize the sloughing potential if saturated conditions are encountered, the excavation slopes will likely require flattening to maintain stability.

The contractor is ultimately responsible for trench and site safety and pertinent OSHA requirements should be met to provide a safe work environment. If site specific conditions arise that require engineering analysis in accordance with OSHA regulations, IGES can respond and provide recommendations as needed. Qualified personnel should inspect all excavations frequently to evaluate stability. We recommend that an IGES representative be on-site after completion of all excavations to assess the suitability of the exposed foundation soils.

6.2.4 Structural Fill and Compaction

All fill placed for the support of structures or concrete flatwork, should consist of structural fill. We anticipate that the majority of the on-site overburden soils will be suitable for use as structural

fill. Structural fill from on-site sources should be free of vegetation and debris, and contain no inert materials larger than 6-inches in nominal size.

If imported material is required, the material should be approved prior to importing. All imported fill should be well graded granular soils with a maximum of 50 percent passing the No. 4 mesh sieve, a maximum fines content (minus No.200 mesh sieve) of 20 percent. The fines should have a liquid limit less than 25 and plasticity index less than 10.

Structural fill should be placed in maximum 12-inch loose lifts and compacted on a horizontal plane, unless otherwise approved by the Geotechnical Engineer. Structural fill should be compacted to at least 95 percent of the maximum dry density, as determined by ASTM D-1557. The moisture content should be within 2 percent of optimum at the time of compaction. Prior to placing fill, the excavations should be observed by the Geotechnical Engineer to confirm that unsuitable materials have been removed. In addition, proper grading should precede placement of structural fill, as described in the General Site Preparation and Grading subsection of this report.

Utility trenches backfilled below concrete slabs, should be backfilled with structural fill compacted to at least 95 percent of ASTM D-1557. We recommend trenches in landscape areas be backfilled and compacted to approximately 90 percent of the maximum density. Structural fill comprised on the on-site native soils will have an approximately Unit weight of 130 to 140 pounds per cubic foot, depending on the moisture content. Loose, uncompacted fill will have an approximate unit weight of 120 to 130 pounds per cubic foot.

6.3 FOUNDATIONS

We understand that the Owner is considering putting the pump station either on the bedrock in the stream channel or on the bank and associated soils. The following paragraphs define the foundation elements based on the location of the pump station.

Conventional spread and strip footings or a mat foundation system may be used to support the proposed pump station on the banks of the river. Based on the potential settlement associated with the near surface soils, we recommend that a minimum of 2 feet of structural fill be placed beneath all proposed foundations. The structural fill should be compacted to the requirements presented in the structural fill section of this report. Conventional spread and strip footings may be proportioned for a maximum net allowable bearing capacity of **1,800 pounds per square foot (psf).**

Strip footings should be a minimum of 24-inches wide and exterior shallow footings should be embedded at least 30-inches below final grade for frost protection and confinement. Interior footings should be embedded a minimum of 18-inches below final grade for confinement purposes.

Settlements of properly designed and constructed conventional footings, founded as described above, are anticipated to be less than 1.0 inch. Differential settlements should be on the order of ½ the total settlement. Excessive settlement may occur if the foundation soils become saturated. All efforts should be made to keep the all surface drainage away from the foundation systems. Surface drainage control recommendations are presented later in this report.

If the foundations are to be constructed within the channel on the bedrock shelf, the foundations should extend a minimum depth of 10 inches into competent bedrock. If pier type footings are to be used in construction, the embedment depth into the foundation should extend a minimum of 2D of the pier diameter. Footings on bedrock should not be founded within the weathered bedrock zone; an IGES representative should determine the thickness of the weathered zone. The footings may consist of conventional strip and spread footings or pier type footings. The footings may be proportioned for a maximum net allowable bearing capacity of **4,000 pounds per square foot (psf)**. Consideration should be given to lateral pressures, scour associated with flooding events that may reach the foundations within the stream channel. If excessive lateral pressures develop, consideration should be given to embedding the footings deeper into the bedrock layer.

6.4 LATERAL PRESSURES

Lateral forces imposed upon conventional foundations due to wind or seismic forces may be resisted by the development of passive earth pressures and friction between the base of the footing and the supporting structural fill. In determining the frictional resistance, a coefficient of friction of 0.58 for the weathered mudstone bedrock or structural fill against concrete should be used.

Ultimate active pressures provided by natural soils acting against retaining structures allowed to rotate slightly may be considered equivalent to a fluid having a density of 37 pounds per cubic foot.

Ultimate passive resistance generated by structural fill may be considered equivalent to a fluid having a density of 360 pounds per cubic foot. If passive resistance is calculated in conjunction

with frictional resistance, the combined resistance should be reduced by 1/2. For transient wind or seismic loads, these values may be increased by 1/3. Ultimate at-rest pressures for soil against basement walls or other retaining walls not allowed to rotate may be considered equivalent to a fluid having a density of 60 pounds per cubic foot.

The above values assume a horizontal ground surface behind the walls. If the soils are to be compacted adjacent to the walls then the design fluid density should be increased by 30%. The values presented are ultimate values and an appropriate factor of safety should be applied to these values in design. Typically factor of safety of 1.5 against overturning or sliding is used

These coefficients and densities assume no buildup of hydrostatic pressures. The force of the water should be added to the presented values if hydrostatic pressures are anticipated. Walls and structures allowed to rotate slightly should use the active condition. If the element is constrained against rotation, the at-rest condition should be used. These values should be used with an appropriate factor of safety against overturning and sliding.

6.5 MOISTURE PROTECTION AND DRAINAGE

Every effort should be taken to ensure positive drainage away from the tank. The recommended minimum slope is two percent (2%). Moisture should not be allowed to infiltrate the soils in the vicinity of, or upslope from, the tank. Erosion from surface runoff may also cause damage to slopes and create maintenance issues. Site design should include Diversion berms and/or ditches to direct runoff to suitable drainage areas.

The pump station will be located near the river bank, field observations indicate that the soils are highly erodible from surface drainage and rain events. Consideration should be given to stabilizing all channel banks located near foundation systems. A retaining wall or other type of retaining system may be required to stabilize and minimize the erosion occurring on the slope wash bank, particularly if the pump station is located close to the slope.

6.6 SOIL CORROSION

Resistivity, sulfate and other corrosion tests were not completed as a part of this investigation. Given our experience in the area, we recommend that concrete used for construction of the facilities be created with Type V cement. To minimize the potential for early corrosion of valves

and other metal works all metal should be galvanized. If additional corrosion concerns exist, we recommend that a corrosion engineer be contacted to design mitigation measures as required.

7.0 CLOSURE

7.1 LIMITATIONS

The recommendations contained in this report are based on limited field exploration and our understanding of the proposed construction. The subsurface data used in the preparation of this report were obtained from the seismic investigations made for this investigation. It is possible that variations in the soil and groundwater conditions might exist. The nature and extent of variations may not be evident until construction occurs. If any conditions are encountered at this site that are different from those described in this report, our firm should be immediately notified so that we may make any necessary revisions to recommendations contained in this report. In addition, if the scope of the proposed construction changes from that described in this report, our firm should also be notified.

This report was prepared in accordance with the generally accepted standard of practice at the time the report was written. No warranty, expressed or implied, is made.

It is the Client's responsibility to see that all parties to the project including the Designer, Contractor, Subcontractors, etc. are made aware of this report in its entirety. The use of information contained in this report for bidding purposes should be done at the Contractor's option and risk.

7.2 ADDITIONAL SERVICES

The recommendations made in this report are based on the assumption that an adequate program of tests and observations will be made during the construction. IGES staff should be on site to verify compliance with these recommendations. These tests and observations should include, but not necessarily be limited to, the following:

- Observations and testing during site preparation, earthwork and structural fill placement.
- Consultation as may be required during construction.
- Quality control on concrete placement to verify slump, air content, and strength.

We also recommend that project plans and specifications be reviewed by us to verify compatibility with our conclusions and recommendations. Additional information concerning the scope and cost of these services can be obtained from our office.

We appreciate the opportunity to be of service on this project. Should you have any questions regarding the report or wish to discuss additional services, please do not hesitate to contact us at your convenience (801) 501-0583.

8.0 REFERENCES CITED

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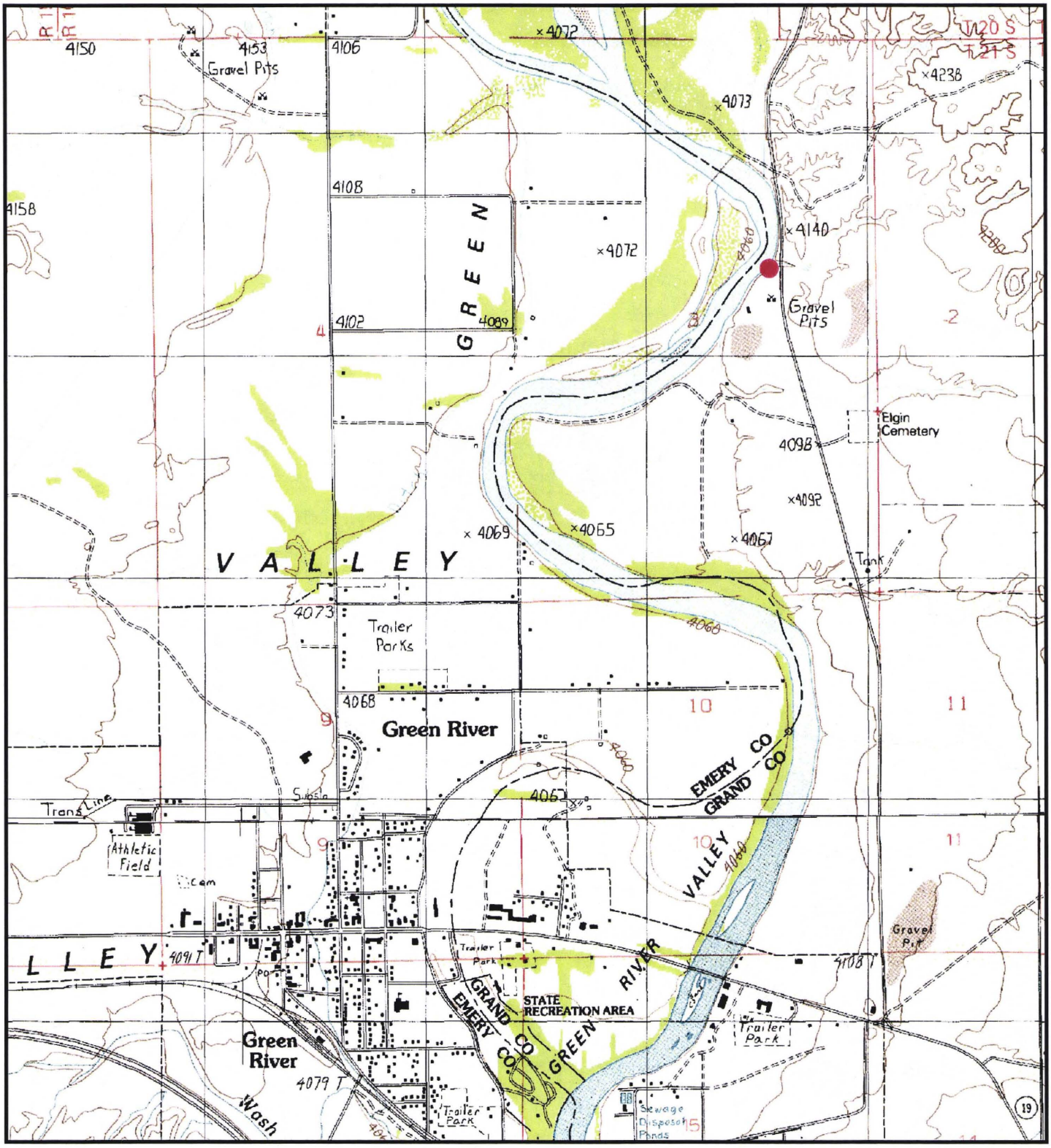
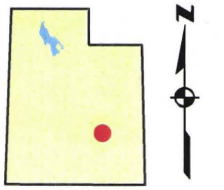
Appendix A



BASE MAP:
Blue Castle Butte, Tusher Canyon, Green River, Green River NE U.S.G.S. 7.5 MINUTE QUADRANGLES

0 950 1,900 3,800 5,700 7,600 Feet

Scale 1:24,000



N

Legend

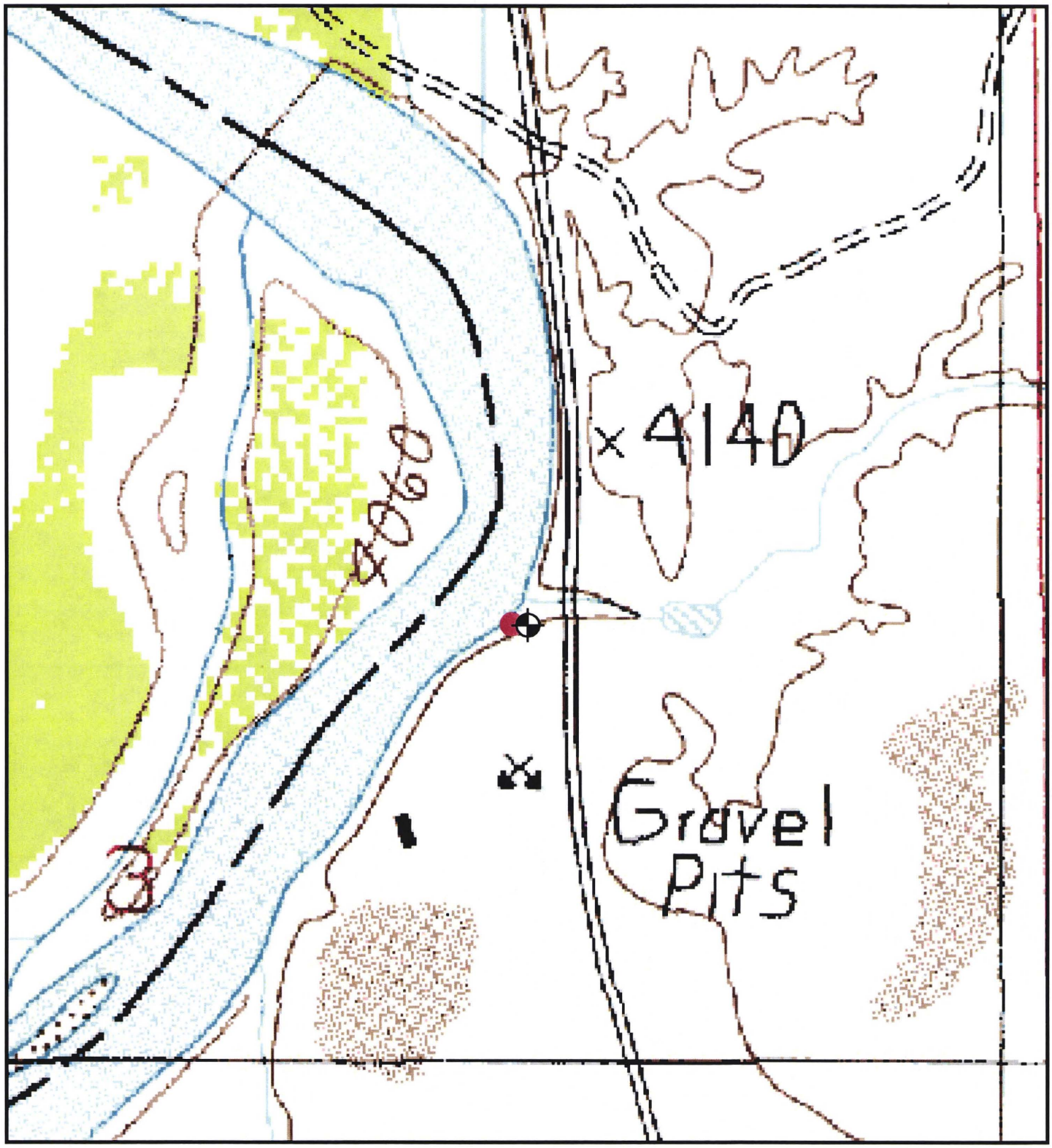
● Proposed Pump House Location

IGES

GEOTECHNICAL INVESTIGATION
GREEN RIVER PUMP HOUSE
GREEN RIVER, UTAH
Project Number - 454-001

SITE VICINITY MAP

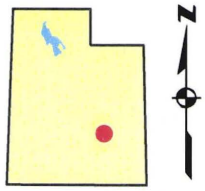
Plate A-1



BASE MAP:
Blue Castle Butte, Tusher Canyon,
Green River, Green River NE
U.S.G.S. 7.5 MINUTE QUADRANGLES

0 195 390 780 1,170 1,560 Feet

Scale 1:4,800



Legend

Boring Location

Proposed Pump House Location

IGES

GEOTECHNICAL INVESTIGATION
GREEN RIVER PUMP HOUSE
GREEN RIVER, UTAH
Project Number - 454-001

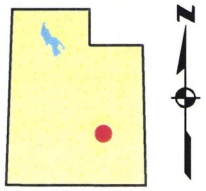
SITE VICINITY MAP

Plate A-2

BASE MAP:
Blue Castle Butte SE 2006 Color NAIP

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

Scale 1:24,000



Legend

- Proposed Pump House Location
- Boring Location

IGES

GEOTECHNICAL INVESTIGATION
GREEN RIVER PUMP HOUSE
GREEN RIVER, UTAH
Project Number - 454-001

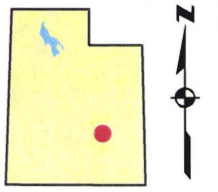
AERIAL PHOTO

Plate A-3

BASE MAP:
Blue Castle Butte, Tusher Canyon, Green River, Green River NE U.S.G.S. 7.5 MINUTE QUADRANGLES

0 950 1,900 3,800 5,700 7,600 Feet

Scale 1:24,000



Legend

- Proposed Pump House Location
- Boring Location

geologic units

UNITSYMBOL

Qal	QTpm
Qsw	Kmbg

IGES

GEOTECHNICAL INVESTIGATION
GREEN RIVER PUMP HOUSE
GREEN RIVER, UTAH
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GEOLOGIC MAP

Plate A-4a

DESCRIPTION OF MAP UNITS

QUATERNARY DEPOSITS

Qal — **Alluvium (Holocene)**—Dark-brown to gray, thin- to thick-bedded deposit of clay, silt, sand, granules, pebbles, and sparse cobbles. Unconsolidated. Forms broad, even surfaces of low relief. Thickness ranges widely; commonly less than 15 m (50 ft) thick

Qsw — **Slope wash (Holocene)**—Light- to dark-gray, thin- to thick-bedded deposit of clay, silt, sand, granules, and some pebbles. Faintly crossbedded. Unconsolidated to weakly cemented. Clasts, chiefly siltstone and sandstone, reflect formations exposed in adjacent upland. Forms broad, gently sloping sheets. Thickness ranges from a thin film to as much as 8 m (25 ft)

QTpm — **Pediment mantle (Holocene to Pliocene)**—Light-brown to brown, gray, and locally reddish-brown deposit of silt, sand, granules, pebbles, cobbles, and boulders derived from adjacent uplands. Massive to crudely bedded. Unconsolidated to well cemented. Chiefly siltstone and sandstone clasts. Surfaces are even and slope gently away from uplands. Ranges in thickness from about 3 m (10 ft) to more than 45 m (150 ft)

Mancos Shale (Upper Cretaceous)—Consists of six members (in descending order): upper part of the Blue Gate, Emery Sandstone, Blue Gate, Garley Canyon Sandstone, Ferron Sandstone, and Tununk. Marine deposit. Total thickness ranges from 700 m (2,300 ft) to 1,860 m (6,100 ft)

Kmbg — **Blue Gate Member**—Light-gray, bluish-gray, and gray, thin- to medium-bedded shale and shaly siltstone. Sparse interlayered thin sandstone beds. Forms low rounded hills. Resembles upper part of Blue Gate and Tununk Members. As much as 610 m (2,000 ft) thick

Geotechnical Investigation
Green River Pump House
Green River, Utah
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GEOLOGIC UNIT DESCRIPTIONS

PLATE
A-4b

Appendix B

DATE
STARTED: 1/31/08
COMPLETED: 1/31/08
BACKFILLED: 1/31/08

Geotechnical

Green Valley, Utah

Project Number 454-001

IGES Rep: JC
Rig Type: Truck Mounted
Boring Type:

BORING NO: 1
Sheet 1 of 1

LOCATION
NORTHING 4,319,596.00 EASTING 574,511.00 ELEVATION 4,051.00

DEPTH METERS	DEPTH FEET	SAMPLES	WATER LEVEL	GRAPHICAL LOG	UNIFIED SOIL CLASSIFICATION	MATERIAL DESCRIPTION	N	N*	SPT BLOW COUNT 10 20 30 40 50 60 70 80 90	Dry Density(pcf)	Moisture Content %	Percent minus 200	Liquid Limit	Plasticity Index	Moisture Content and Atterberg Limits: Plastic Limit / Moisture Content / Liquid Limit 10 20 30 40 50 60 70 80 90
0	0				SC-SM	Silty clayey SAND, Brown, moist, Loose, 5% to 10% angular clasts 1/8 inch average size.					6.5				
1								8			8.8				
	5				SC	Clayey SAND, Brown, dry, medium dense.				90.0	5.9		20	4	
2								16							
3	10				SC-SM	Silty clayey SAND with gravel, Brown, dry, Medium dense, 20% to 30% angular clasts ranging in size from 1/4" to 1".					9.7				
4								19							
	15				GM	Silty GRAVEL with sand, Brown, dry, Very dense, clast supported, rounded pebbles consiting of dark gray shale, pink and tan sandstone and gray quartzite, ranging in size from 1/8" to 2".		50			5.4				
5						Refusal at Mancos Shale									
6						Bottom of Boring @ 17 Feet									

N - OBSERVED UNCORRECTED BLOW COUNT

* N - UNCORRECTED, EQUIVALENT SPT BLOW COUNT

NEW_LOG OF BORING (A) - INPROGRESS BORING LOGS.GPJ IGES.GDT 2/12/08

IGES

SAMPLE TYPE
- 2" O.D./1.38" I.D. SPLIT SPOON SAMPLER
- 3.25" O.D./2.42" I.D. U SAMPLER
- 3" O.D. THIN-WALLED SHELBY SAMPLER
- GRAB SAMPLE
- Modified California Sampler

NOTES:

WATER LEVEL
▼ - MEASURED ▽ - ESTIMATED

Plate

B - 1

UNIFIED SOIL CLASSIFICATION SYSTEM

MAJOR DIVISIONS			USCS SYMBOL	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS (More than half of material is larger than the #200 sieve)	GRAVELS (More than half of coarse fraction is larger than the #4 sieve)	CLEAN GRAVELS WITH LITTLE OR NO FINES	GW	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES WITH LITTLE OR NO FINES
			GP	POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES WITH LITTLE OR NO FINES
		GRAVELS WITH OVER 12% FINES	GM	SILTY GRAVELS, GRAVEL-SILT-SAND MIXTURES
			GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES
	SANDS (More than half of coarse fraction is smaller than the #4 sieve)	CLEAN SANDS WITH LITTLE OR NO FINES	SW	WELL-GRADED SANDS, SAND-GRAVEL MIXTURES WITH LITTLE OR NO FINES
			SP	POORLY-GRADED SANDS, SAND-GRAVEL MIXTURES WITH LITTLE OR NO FINES
		SANDS WITH OVER 12% FINES	SM	SILTY SANDS, SAND-GRAVEL-SILT MIXTURES
			SC	CLAYEY SANDS SAND-GRAVEL-CLAY MIXTURES
FINE GRAINED SOILS (More than half of material is smaller than the #200 sieve)	SILTS AND CLAYS (Liquid limit less than 50)		ML	INORGANIC SILTS & VERY FINE SANDS, SILTY OR CLAYEY FINE SANDS, CLAYEY SILTS WITH SLIGHT PLASTICITY
			CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
			OL	ORGANIC SILTS & ORGANIC SILTY CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS (Liquid limit greater than 50)		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILT
			CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
			OH	ORGANIC CLAYS & ORGANIC SILTS OF MEDIUM-TO-HIGH PLASTICITY
HIGHLY ORGANIC SOILS			PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

LOG KEY SYMBOLS

BORING SAMPLE LOCATION

TEST-PIT SAMPLE LOCATION

WATER LEVEL (level after completion)

WATER LEVEL (level where first encountered)

CEMENTATION

DESCRIPTION	DESCRIPTION
WEAKELY	CRUMBLES OR BREAKS WITH HANDLING OR SLIGHT FINGER PRESSURE
MODERATELY	CRUMBLES OR BREAKS WITH CONSIDERABLE FINGER PRESSURE
STRONGLY	WILL NOT CRUMBLE OR BREAK WITH FINGER PRESSURE

OTHER TESTS KEY

C	CONSOLIDATION	SA	SIEVE ANALYSIS
AL	ATTERBERG LIMITS	DS	DIRECT SHEAR
UC	UNCONFINED COMPRESSION	T	TRIAXIAL
S	SOLUBILITY	R	RESISTIVITY
O	ORGANIC CONTENT	RV	R-VALUE
CBR	CALIFORNIA BEARING RATIO	SU	SOLUBLE SULFATES
COMP	MOISTURE/DENSITY RELATIONSHIP	PM	PERMEABILITY
CI	CALIFORNIA IMPACT	-200	% FINER THAN #200
COL	COLLAPSE POTENTIAL	Gs	SPECIFIC GRAVITY
SS	SHRINK SWELL	SL	SWELL LOAD

MODIFIERS

DESCRIPTION	%
TRACE	<5
SOME	5 - 12
WITH	>12

MOISTURE CONTENT

DESCRIPTION	FIELD TEST
DRY	ABSENCE OF MOISTURE, DUSTY, DRY TO THE TOUCH
MOIST	DAMP BUT NO VISIBLE WATER
WET	VISIBLE FREE WATER, USUALLY SOIL BELOW WATER TABLE

STRATIFICATION

DESCRIPTION	THICKNESS
SEAM	1/16 - 1/2"
LAYER	1/2 - 12"

DESCRIPTION	THICKNESS
OCCASIONAL	ONE OR LESS PER FOOT OF THICKNESS
FREQUENT	MORE THAN ONE PER FOOT OF THICKNESS

GENERAL NOTES

1. Lines separating strata on the logs represent approximate boundaries only. Actual transitions may be gradual.
2. No warranty is provided as to the continuity of soil conditions between individual sample locations.
3. Logs represent general soil conditions observed at the point of exploration on the date indicated.
4. In general, Unified Soil Classification designations presented on the logs were evaluated by visual methods only. Therefore, actual designations (based on laboratory tests) may vary.

APPARENT / RELATIVE DENSITY - COARSE-GRAINED SOIL

APPARENT DENSITY	SPT (blows/ft)	MODIFIED CA. SAMPLER (blows/ft)	CALIFORNIA SAMPLER (blows/ft)	RELATIVE DENSITY (%)	FIELD TEST
VERY LOOSE	<4	<4	<5	0 - 15	EASILY PENETRATED WITH 1/2-INCH REINFORCING ROD PUSHED BY HAND
LOOSE	4 - 10	5 - 12	5 - 15	15 - 35	DIFFICULT TO PENETRATE WITH 1/2-INCH REINFORCING ROD PUSHED BY HAND
MEDIUM DENSE	10 - 30	12 - 35	15 - 40	35 - 65	EASILY PENETRATED A FOOT WITH 1/2-INCH REINFORCING ROD DRIVEN WITH 5-LB HAMMER
DENSE	30 - 50	35 - 60	40 - 70	65 - 85	DIFFICULT TO PENETRATED A FOOT WITH 1/2-INCH REINFORCING ROD DRIVEN WITH 5-LB HAMMER
VERY DENSE	>50	>60	>70	85 - 100	PENETRATED ONLY A FEW INCHES WITH 1/2-INCH REINFORCING ROD DRIVEN WITH 5-LB HAMMER

CONSISTENCY - FINE-GRAINED SOIL

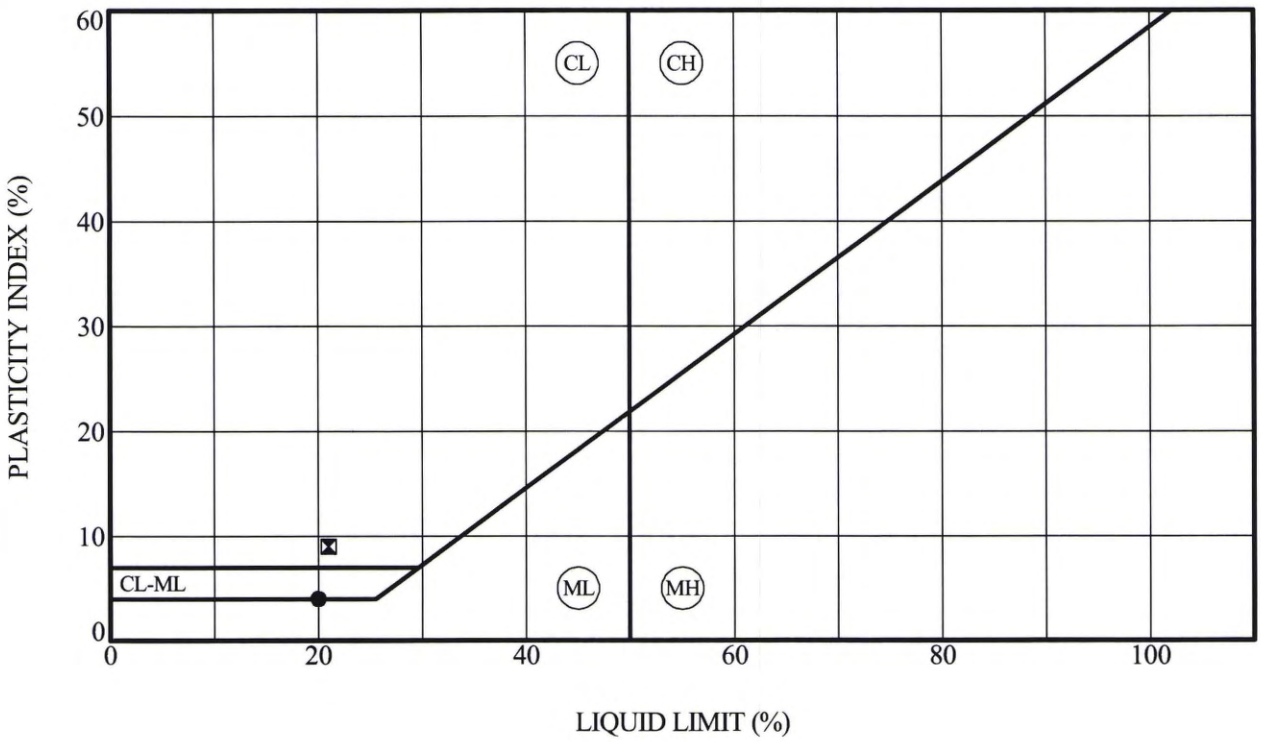
CONSISTENCY	SPT (blows/ft)	TORVANE UNTRAINED SHEAR STRENGTH (tsf)	POCKET PENETROMETER UNCONFINED COMPRESSIVE STRENGTH (tsf)	FIELD TEST
VERY SOFT	<2	<0.125	<0.25	EASILY PENETRATED SEVERAL INCHES BY THUMB. EXUDES BETWEEN THUMB AND FINGERS WHEN SQUEEZED BY HAND.
SOFT	2 - 4	0.125 - 0.25	0.25 - 0.5	EASILY PENETRATED ONE INCH BY THUMB. MOLDED BY LIGHT FINGER PRESSURE.
MEDIUM STIFF	4 - 8	0.25 - 0.5	0.5 - 1.0	PENETRATED OVER 1/2 INCH BY THUMB WITH MODERATE EFFORT. MOLDED BY STRONG FINGER PRESSURE.
STIFF	8 - 15	0.5 - 1.0	1.0 - 2.0	INDENTED ABOUT 1/2 INCH BY THUMB BUT PENETRATED ONLY WITH GREAT EFFORT.
VERY STIFF	15 - 30	1.0 - 2.0	2.0 - 4.0	READILY INDENTED BY THUMBNAIL.
HARD	>30	>2.0	>4.0	INDENTED WITH DIFFICULTY BY THUMBNAIL.

IGES

Geotechnical Investigation
Green River Pump House
Green River Utah

Key to Soil Symbols and Terminology

Plate
B-2



	Sample Location	Depth (ft)	LL (%)	PL (%)	PI (%)	Classification
●	1	**5.0**	**20**	**16**	**4**	
⊠	1	**17.0**	**21**	**12**	**9**	

B_ATTERBERG - (USCS) BORING LOGS.GPJ IGES.GDT 3/3/08

IGES

ATTERBERG LIMITS' RESULTS

Geotechnical
Green River Pump House

Green River, Utah
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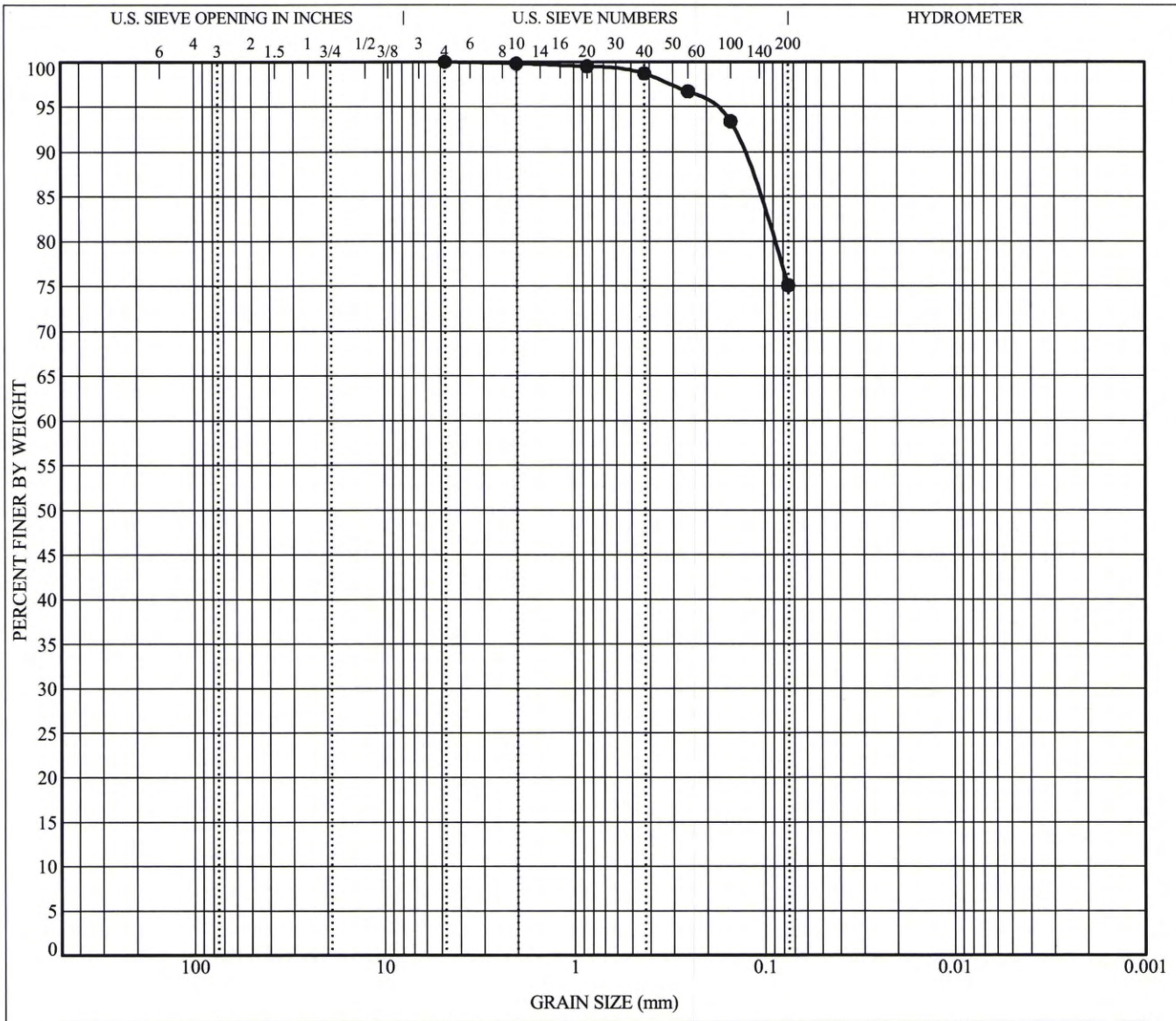
Plate

B - 3



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Sample Location	Depth	Classification	LL	PL	PI	Cc	Cu
●	1	12.0						

	Sample Loctaion	Depth	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	1	12.0	4.75				0.0	24.9	75.1	

B_GSD BORING LOGS.GPJ IGES.GDT 2/25/08

IGES

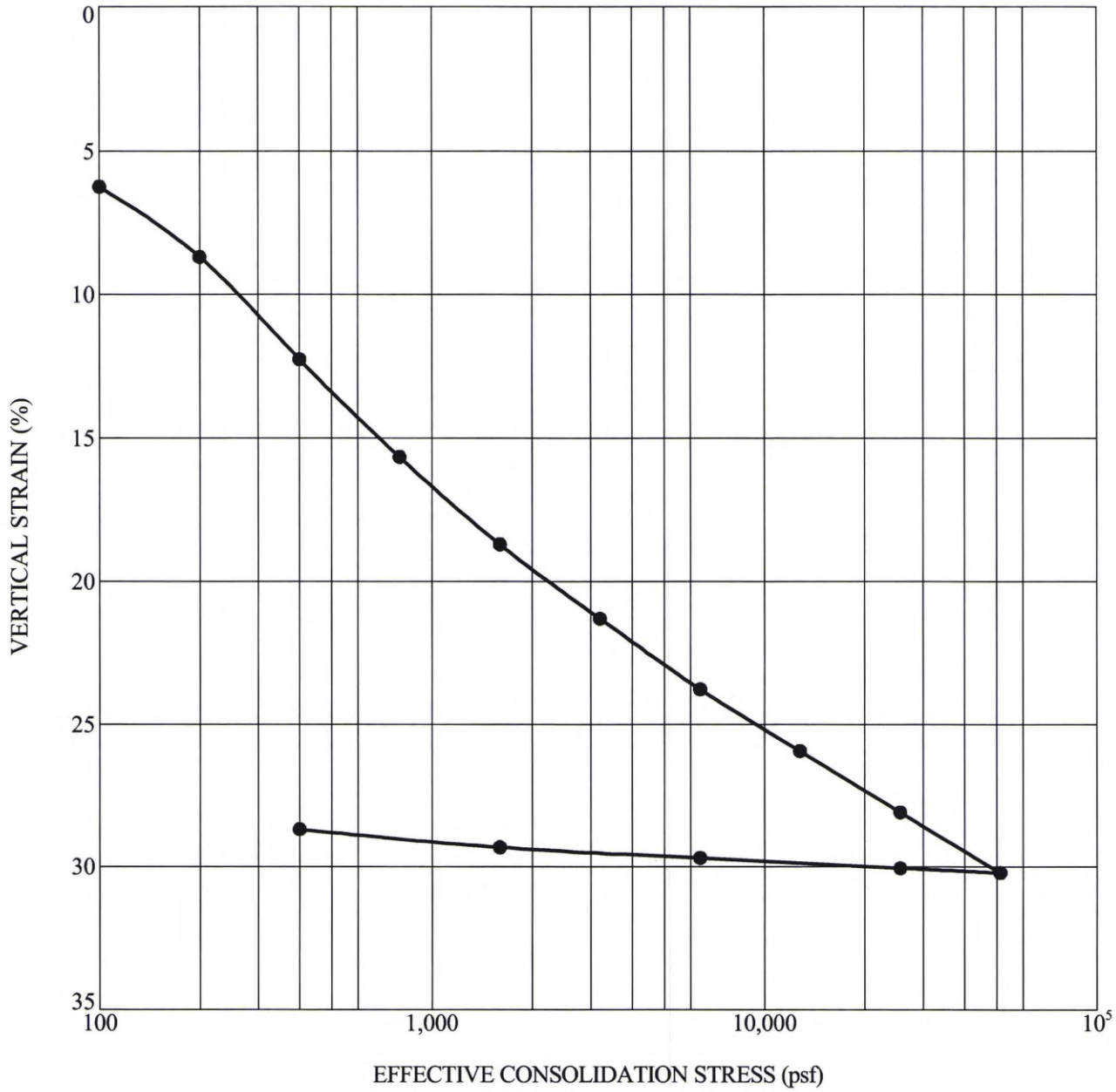
GRAIN SIZE DISTRIBUTION

Geotechnical
Green River Pump House

Green River, Utah
Project Number: 454-001

Plate

B - 4



	Sample Location	Depth (ft)	Classification	γ_d (pcf)	MC (%)	C'_c	C'_r	OCR
●	1	6.0						

B_CONSOL BORING LOGS.GPJ IGES.GDT 3/3/08

IGES

1-D CONSOLIDATION TEST

Geotechnical
Green River Pump House

Green River, Utah
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Plate

B - 5

Geotechnical Investigation
Green River Pump House
Green River, Utah
Project Number – : LLC 454-001

Eastern Bank of Green River
Proposed Pump House Location

PLATE
C-1

Geotechnical Investigation
Green River Pump House
Green River, Utah
Project Number – : LLC 454-001

Eastern Bank of Green River
Proposed Pump House Location

PLATE
C-2

IGES

Geotechnical Investigation
Green River Pump House
Green River, Utah
Project Number – : LLC 454-001

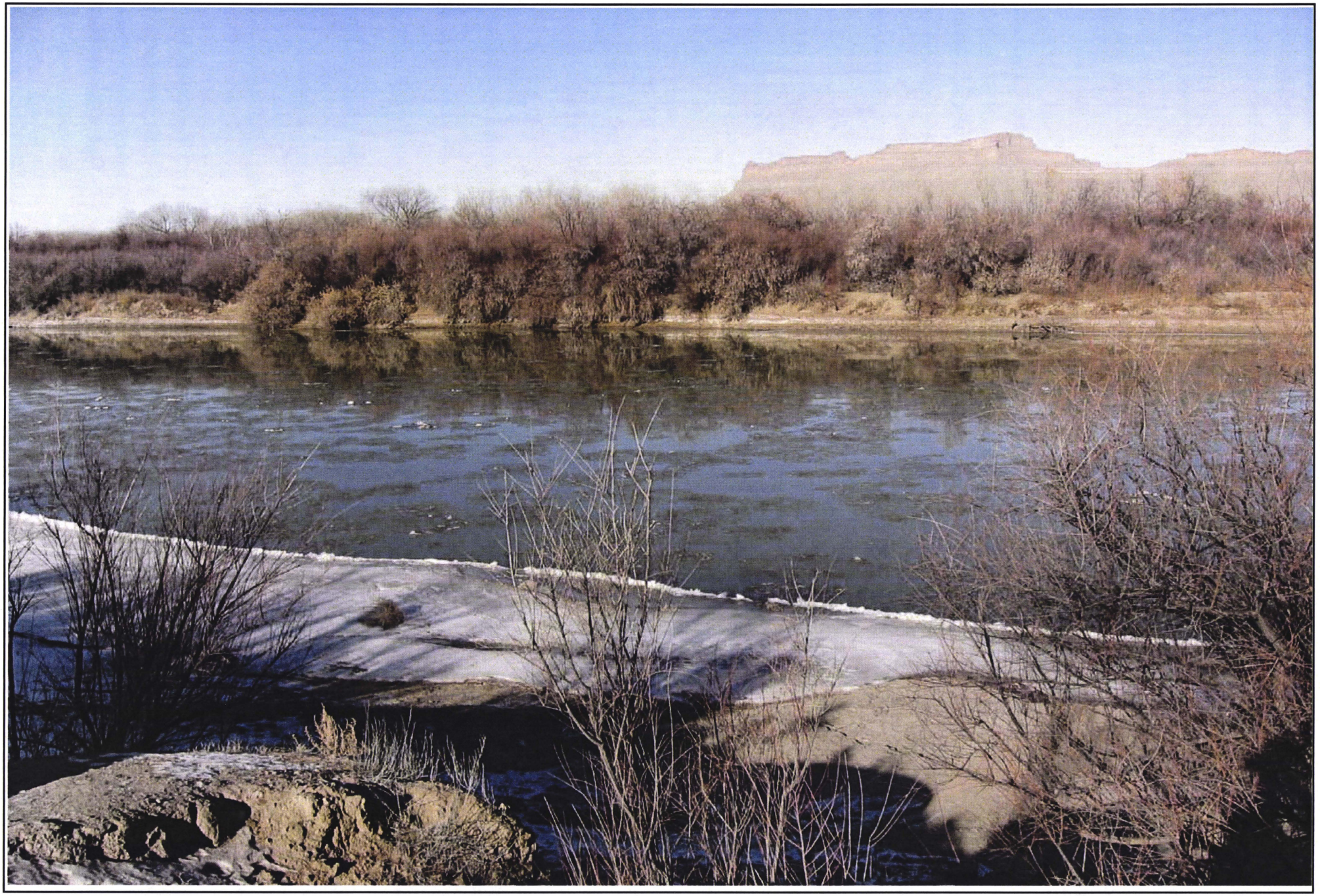
Eastern Bank of Green River Facing North

PLATE
C-3

Geotechnical Investigation
Green River Pump House
Green River, Utah
Project Number – : LLC 454-001

From Boring Location Looking East to Road

PLATE
C-4



IGES

Geotechnical Investigation
Green River Pump House
Green River, Utah
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From Boring Location Looking West Across River

PLATE
C-5

Geotechnical Investigation
Green River Pump House
Green River, Utah
Project Number – : LLC 454-001

Old Pumping Station

PLATE
C-6