Smithfield Hog Production

Groundwater Discharge Report and Application
Modification of Existing Permit
For
Dalton Finisher Farm Sites Addition
Garfield County, Utah

Prepared by

Joel A. Myers, P.E.

GEM Engineering, Inc.

January 7, 2021

Report Number: RE0958

Gem ENGINEERING, INC.
485 North Aviation Way ♦ Cedar City, UT 84721
Phone (435) 867-6478 ♦ Fax (435) 867-4372
www.gemengineeringinc.com

January 7, 2021

Division of Water Quality
Utah Department of Environmental Quality
Salt Lake City, Utah 84114-4870

Subject: Groundwater Discharge Permit Application and Report
Modification of Existing Permit
For Smithfield Hog Production
Dalton Finisher Farm Addition
Garfield County, Utah

Enclosed are the application, required backup information and reports for the submission of the Utah Groundwater Discharge Permit Application for the project listed above. The project is to be located approximately 2.6 miles south of Circleville, in Garfield County, Utah.

We appreciate this opportunity to be of service on this phase of the project and look forward to being of service as the project progresses. If you have any questions, please contact this office at your convenience.

Sincerely,
GEM Engineering, Inc.

LICENSED PROFESSIONAL ENGINEER
1/7/21
No. 179058
JOEL A. MYERS
STATE OF UTAH

Joel A. Myers, P.E.
President

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SECTION 1: INTRODUCTION

1.1 Nature of Application

Dalton Finisher Site Addition will be four additional 1100 hog finisher barns at the existing 8800 hog spaces for a site total of 13,200 hog spaces with a primary existing basin and an additional basin to contain the additional wastewater. The wastewater from the both the original lagoon and a newly constructed lagoon will be applied to the nearby fields annually.

1.2 Manure Handling System

The swine will be confined inside environmentally controlled buildings. The floors supporting the swine will consist of concrete slats (reinforced concrete slats spaced approximately 1.25" apart). Manure will be worked through the slats and temporarily stored in shallow concrete pits below. The pit floors and exterior walls will be constructed according to specifications and drawings, submitted in Attachment D, to assure wastewater is retained. The manure will be emptied approximately once a day into a temporary storage basin. No recycle water will be utilized. The barns will utilize a scraper plate manure collection system. The manure collected in the basin will be land applied at the appropriate time of the year for growing crops.

1.3 Topography and Soils

The topography surrounding the facility slopes roughly 2.5% down towards the Northwest (see **Attachment A**). The soil types in the area surrounding the facility site are typical alluvial materials consisting primarily of silt, sand, and gravel. The surface soil types at the proposed facility location are typically organic silt and silty sands**.**

The groundwater table is located roughly 43 to 72 feet below existing grade based on information from the closest well logs. The groundwater will be protected by certified Flexible Membrane Liners (FML), inspection procedures and monitoring wells.

1.4 Climate

Table 1-1 shows weather data collected near Circleville, Utah area roughly 2.6 miles north of the facility lacation.

The climate in the area is typically warm and dry in the summer and cold and dry in the winter.

Table 1-1 Weather Data For Circleville, Utah

	Jan	Feb	Mar	Apr	May	Jun
Average high in °F:	42	47	53	61	70	81
Average low in °F:	13	18	23	28	37	44
Av. precipitation in inch:	0.59	0.55	0.75	0.63	0.91	0.55
Average snowfall in inch:	5	2.9	3.6	1.0	0.2	0.0

	Jul	Aug	Sep	Oct	Nov	Dec
Average high in °F:	87	85	77	66	52	44
Average low in °F:	51	50	41	30	20	13
Av. precipitation in inch:	0.87	1.42	0.94	0.91	0.51	0.43
Average snowfall in inch:	0.0	0.0	0.1	0.6	1.9	3.8

Climate data for Circleville, UT Longitude: -112.27, Latitude: 38.17
Average weather Circleville, UT - 84723 - 1961-1990 normals

Circleville, Utah weather averages

Annual average high temperature:	63.8°F
Annual average low temperature:	30.7°F
Average temperature:	47.25°F
Average annual precipitation - rainfall:	9.06 inches
Av. annual snowfall:	19.2 inches

1.5 Groundwater

The Utah Groundwater Discharge Permit Application was obtained from the Utah Department of Environmental Quality – Division of Water Quality web site and is incorporated into this report on the following 9 pages.

MAIL TO:
Division of Water Quality
Utah Department of Environmental Quality
Salt Lake City, Utah 84114-4870

Application No.:____________________
Date Received:_____________________
(leave both lines blank)

UTAH GROUNDWATER DISCHARGE PERMIT APPLICATION

Part A - General Facility Information

Please read and follow carefully the instructions on this application form. Please type or print, except for signatures. This application is to be submitted by the owner or operator of a facility having one or more discharges to groundwater. The application must be signed by an official facility representative who is: the owner, sole proprietor for a sole proprietorship, a general partner, an executive officer of at least the level of vice president for a corporation, or an authorized representative of such executive officer having overall responsibility for the operation of the facility.

1. **Administrative Information.** Enter the information requested in the space provided below, including the name, title and telephone number of an agent at the facility who can answer questions regarding this application.

   Facility Name: Dalton Finisher Sites

   Mail Address: Dalton Hay Company, LLC, P.O. Box 189, Circleville, UT 84723
   (Number & Street, Box and/or Route, City, State, Zip Code)

   Facility Legal Location* County: Garfield
   T. 31S, R. 4W, Sec. 11, 12, North 1/2,
   Site # 1 Lat. 38 ° 8 ' 2.86"N. Long. 112 ° 15 ' 58.84 "W
   *Note: A topographic map or detailed aerial photograph should be used in conjunction with a written description to depict the location of the facility, points of groundwater discharge, and other relevant features/objects. **(See Attachment** B**)**

   Contact's Name: Jade Dalton Phone No.: (435) 616-3081
   Title: Owner

2. **Owner/Operator Information.** Enter the information requested below, including the name, title, and phone number of the official representative signing the application.

   Owner
   Name: Jade Dalton Phone No.: (435) 616-3081

   Mail Address: Dalton Hay Company, LLC, P.O. Box 189, Circleville, UT 84723
   (Number & Street, Box and/or Route, City, State, Zip Code)

   Operator
   Name: Same Phone No.:(____)________________
   (If different than Owner's above)

   Mail Address:______________________________
   (Number & Street, Box and/or Route, City, State, Zip Code)

   Official Representative
   Name: Same Phone No(435) 577-2861

   Title: Owner

3. **Facility Classification** (check one)

   [X] New Facility
   [ ] Existing Facility
   [ ] Modification of Existing Facility

4. **Type of Facility** (check one)

   [ ] Industrial
   [ ] Mining
   [ ] Municipal
   [X] Agricultural Operation
   [ ] Other, please describe:____

5. **SIC/NAICS Codes:** NAICS-112210 – Hog Farms and Hog Production
   Enter Principal 3 Digit Code Numbers Used in Census & Other Government Reports

6. **Projected Facility Life**: 20+ years

7. **Identify principal processes used, or services preformed by the facility. Include the principal products produced, and raw materials used by the facility:**

   This facility will be utilized for hog production. Hogs will be raised to maturity and then transported to other off-site facilities by truck for processing

8. **List all existing or pending Federal, State, and Local government environmental permits:**

		Permit Number
[X]	NPDES or UPDES (discharges to surface water)	UGW170004______]
	CAFO (concentrated animal feeding operation)	
[ ]	UIC (underground injection of fluids)	
[ ]	RCRA (hazardous waste)	
[ ]	PDS (air emissions from proposed sources)	
[ ]	Construction Permit (wastewater treatment)	
[ ]	Solid Waste Permit (sanitary landfills, incinerators)	
[x]	Septic Tank/Drainfield	TBD by Health Dept
[ ]	Other, specify__________________________	

9. Name, location (Lat.______°______'______"N,Long.______°______'______"W) and description of: each well/spring (existing, abandoned, or proposed), water usage(past, present, or future); water bodies; drainages; well-head protection areas; drinking water source protection zones according to UAC 309-600; topography; and man-made structures within one mile radius of the point(s) of discharge site. Provide existing well logs (include total depth and variations in water depths).

Name	Location	Description	Status	Usage

See report and location maps included with this application

The above information must be included on a plat map and attached to the application.

Part B - General Discharge Information

Complete the following information for each point of discharge to groundwater. If more than one discharge point exists, photocopy and complete this Part B form for each discharge point.

1. **Location** (if different than Facility Location in Part A): County: **Same as in Part A all sites**
   T._________, R._________, Sec._________, _________1/4 of _________1/4,
   Lat._______°_______'_______"N.Long. _______°_______'_______"W

2. **Type of fluid to be Discharged or Potentially Discharged**
   (check as applicable)

   Discharges (fluids discharged to the ground)

   - [ ] Sanitary Wastewater: wastewater from restrooms, toilets, showers and the like
   - [ ] Cooling Water: non-contact cooling water, non contact of raw materials, intermediate, final, or waste products
   - [ ] Process Wastewater: wastewater used in or generated by an industrial process
   - [ ] Mine Water: water from dewatering operations at mines
   - [x] Other, specify: Hog Production Waste Water

   Potential Discharges (leachates or other fluids that may discharge to the ground)

   - [ ] Solid Waste Leachates: leachates from solid waste impoundments or landfills
   - [ ] Milling/Mining Leachates: tailings impoundments, mine leaching operations, etc.
   - [ ] Storage Pile Leachates: leachates from storage piles of raw materials, product, or wastes
   - [ ] Potential Underground Tank Leakage: tanks not regulated by UST or RCRA only
   - [x] Other, specify: None

3. **Discharge Volumes**
   For each type of discharge checked in #2 above, list the volumes of wastewater discharged to the ground or groundwater. Volumes of wastewater should be measured or calculated from water usage. If it is necessary to estimate volumes, enclose the number in parentheses. Average daily volume means the average per operating day: ex. For a discharge of 1,000,000 gallons per year from a facility operating 200 days, the average daily volume is 5,000 gallons.

Discharge Type:	Daily Discharge Volume (Average)	(Maximum)	all in units of
None	0	0	

4. **Potential Discharge Volumes**
   For each type of potential discharge checked in #2 above, list the maximum volume of fluid that could be discharged to the ground considering such factors as: liner hydraulic conductivity and operating head conditions, leak detection system sensitivity, leachate collection system efficiency, etc. Attach calculation and raw data used to determine said potential discharge.

Discharge Type:	Daily Discharge Volume (Average)	(Maximum)	all in units of
Leakage	0	0	

5. **Means of discharge or Potential Discharge** (check one or more as applicable)

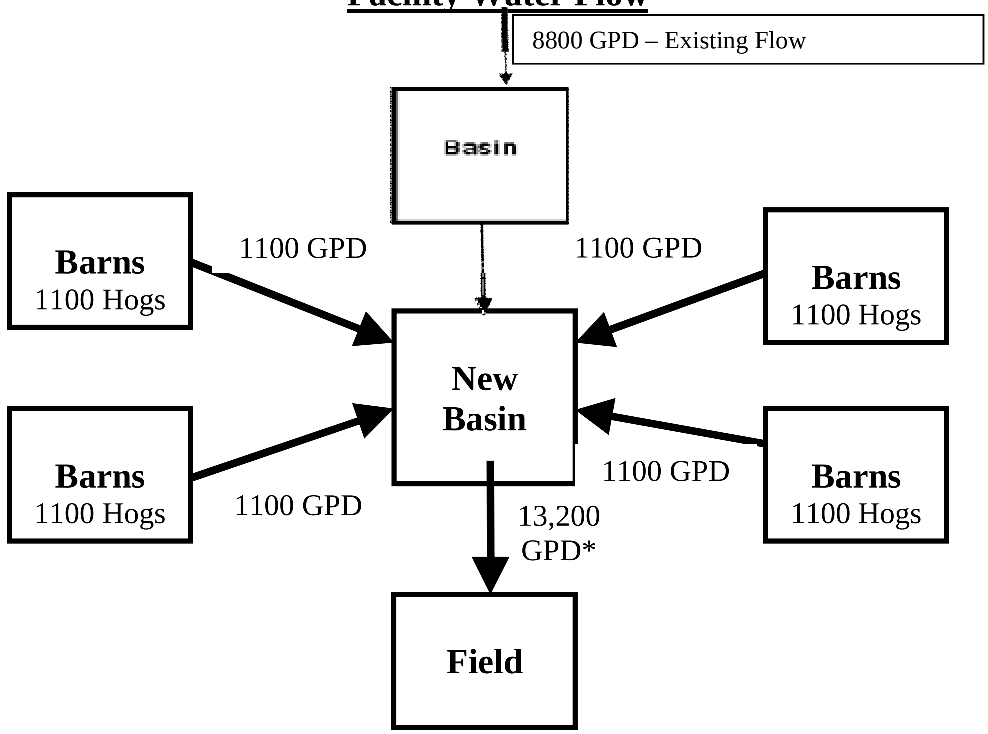
[x]	lagoon, pit, or surface impoundment (fluids)	[ ]	industrial drainfield
[x]	land application or land treatment	[ ]	underground storage tank
[ ]	discharge to an ephemeral drainage (dry wash, etc.)	[ ]	percolation/infiltration basin
[ ]	storage pile	[ ]	mine heap or dump leach
[ ]	landfill (industrial or solid wastes)	[ ]	mine tailings pond
[ ]	other, specify______________________		

6. **Flows, Sources of Pollution, and Treatment Technologies**

Flows. Attach a line drawing showing: 1) water flow through the facility to the groundwater discharge point, and 2) sources of fluids, wastes, or solids which accumulate at the potential groundwater discharge point. Indicate sources of intake materials or water, operations contributing wastes or wastewater to the effluent, and wastewater treatment units. Construct a water balance on the line drawing by showing average flows between intakes, operations, treatment units, and wastewater outfalls. If a water balance cannot be determined, provide a pictorial description of the nature and amount of any sources of water and any collection or treatment measures. See the following example.

This chart needs to be updated to reflect the existing facilities and the new ones. Total spaces is 13,200

Facility Water Flow



* Flow from Basins to Field will be on an as needed basis with an average Total flow of 13,200 GPD* - 4400 GPD Average New Flow

7. **Discharge Effluent Characteristics**

Established and Proposed Groundwater Quality Standards - Identify wastewater or leachate characteristics by providing the type, source, chemical, physical, radiological, and toxic characteristics of wastewater or leachate to be discharged or potentially discharged to groundwater (with lab analytical data if possible). This should include the discharge rate or combination of discharges, and the expected concentrations of any pollutant (mg/l). If more than one discharge point is used, information for each point must be provided.

Hazardous Substances - Review the present hazardous substances found in the Clean Water Act, if applicable. List those substances found or believed present in the discharge or potential discharge.

Part C - Accompanying Reports and Plans

The following reports and plans should be prepared by or under the direction of a professional engineer or other groundwater professional. Since groundwater permits cover a large variety of discharge activities, the appropriate details and requirements of the following reports and plans will be covered in the pre-design meeting(s). For further instruction refer to the Groundwater Permit Application Guidance Document.

8. **Hydrogeologic Report**

Provide a Geologic Description, with references used, that includes as appropriate:

Structural Geology – regional and local, particularly faults, fractures, joints and bedding plane joints; **Stratigraphy** – geologic formations and thickness, soil types and thickness, depth to bedrock; **Topography** – provide a USGS MAP (7 ½ minute series) which clearly identifies legal site location boundaries, indicated 100 year flood plain area and applicable flood control or drainage barriers and surrounding land uses.

Provide a Hydrologic Description, with references used, that includes:
Groundwater – depths, flow directions and gradients. Well logs should be included if available. Include name of aquifer, saturated thickness, flow directions, porosity, hydraulic conductivity, and other flow characteristics, hydraulic connection with other aquifers or surface sources, recharge information, water in storage, usage, and the projected aerial extent of the aquifer. Should include projected groundwater area of influence affected by the discharge. Provide hydraulic gradient map indicating equal potential head contours and groundwater flow lines. Obtain water elevations of nearby wells at the time of the hydrologic investigation. Collect and analyze groundwater samples from the uppermost aquifer which underlies the discharge point(s). Historic data can be used if the applicant can demonstrate it meets the requirements contained within this section. Collection points should be hydraulically up and downgradient and within a one-mile radius of the discharge point(s). Groundwater analysis should include each element listed in Groundwater Discharge Permit Application, Part B7.

NOTE Failure to analyze for background concentrations of any contaminant of concern in the discharge or potential discharge may result in the Executive Secretary's presumptive determination that zero concentration exist in the background groundwater quality.

Sample Collection and Analysis Quality assurance – sample collection and Preservation must meet the requirements of the EPA RCRA Technical Enforcement Guidance Document, OSWER-9959.1, 1986 [UAC R317-6-6.3(I,6)]. Sample analysis must be performed by State of Utah certified laboratories and be certified for each of the parameters of concern. Analytical methods should be selected from the following sources [UAC R317-6-6.3L]: Standard Methods for the Examination of Water and Wastewater, 20th Ed.,1998; EPA, Methods for Chemical Analysis of Water and

Wastes, 1983; Techniques of Water Resources Investigation of the U.S. Geological Survey, 1998, Book 9; EPA Methods published pursuant to 40 CFR Parts 141, 142, 264 (including Appendix IX), and 270. Analytical methods selected should also include minimum detection limits below both the Groundwater Quality Standards and the anticipated groundwater protection levels. Data shall be presented in accordance of accepted hydrogeologic standards and practice.

Provide Agricultural Description, with references used, that includes:
If agricultural crops are grown within legal boundaries of the site the discussion must include: types of crops produced; soil types present; irrigation system; location of livestock confinement areas (existing or abandoned).

Note on Protection Levels:

After the applicant has defined the quality of the fluid to be discharged (Groundwater Discharge Permit Application, Part B), characterized by the local hydrogeologic conditions and determined background groundwater quality (Hydrogeologic Report), the Executive Secretary will determine the applicable groundwater class, based on: 1) the location of the discharge point within an area of formally classified groundwater, or the background value of total dissolved solids. Accordingly, the Executive Secretary will determine applicable protection levels for each pollutant of concern, based on background concentrations and in accordance with UAC R317-6-4.

9. **Groundwater Discharge Control Plan:**
Select a compliance monitoring method and demonstrate an adequate discharge control system. Listed are some of the Discharge Control Options available.

No Discharge – prevent any discharge of fluids to the groundwater by lining the discharge point with multiple synthetic and clay liners. Such a system would be designed, constructed, and operated to prevent any release of fluids during both the active life and any post-closure period required.

Earthen Liner – control the volume and rate of effluent seepage by lining the discharge point with a low permeability earthen liner (e.g. clay). Then demonstrate that the receiving groundwater, at a point as close as practical to the discharge point, does not or will not exceed the applicable class TDS limits and protection levels* set by the Executive Secretary. This demonstration should also be based on numerical or analytical saturated or unsaturated groundwater flow and contaminant transport simulations.

Effluent Pretreatment – demonstrate that the quality of the raw or treated effluent at the point of discharge or potential discharge does not or will not exceed the applicable groundwater class TDS limits and protection levels* set by the Executive Secretary.

Contaminant Transport/Attenuation – demonstrate that due to subsurface contaminant transport mechanisms at the site, raw or treated effluent does not or will not cause the receiving groundwater, at a point as close as possible to the discharge point, to exceed the applicable class TDS limits and protection levels* set by the Executive Secretary.

Other Methods – demonstrate by some other method, acceptable to the Executive Secretary, that the groundwater class TDS limits and protection levels* will be met by the receiving groundwater at a point as close as practical to the discharge point.

*If the applicant has or will apply for an alternate concentration limit (ACL), the ACL may apply instead of the class

TDS limits and protection levels.

Submit a complete set of engineering plans and specifications relating to the construction, modification, and operation of the discharge point or system. Construction Permits for the following types of facilities will satisfy these requirements. They include: municipal waste Containment Basins; municipal sludge storage and on-site sludge disposal; land application of wastewater effluent; heap leach facilities; other process wastewater treatment equipment or systems.

Facilities such as storage piles, surface impoundments and landfills must submit engineering plans and specifications for the initial construction or any modification of the facility. This will include the design data and description of the leachate detection, collection and removal system design and construction. Provide provisions for run on and run-off control.

10. Compliance Monitoring Plan:

The applicant should demonstrate that the method of compliance monitoring selected meets the following requirements:

Groundwater Monitoring – that the monitoring wells, springs, drains, etc., meet all of the following criteria: is completed exclusively in the same uppermost aquifer that underlies the discharge point(s) and is intercepted by the upgradient background monitoring well; is located hydrologically downgradient of the discharge point(s); designed, constructed, and operated for optimal detection (this will require a hydrogeologic characterization of the area circumscribed by the background sampling point, discharge point and compliance monitoring points); is not located within the radius of influence of any beneficial use public or private water supply; sampling parameters, collection, preservation, and analysis should be the same as background sampling point; groundwater flow direction and gradient, background quality at the site, and the quality of the groundwater at the compliance monitoring point.

Source Monitoring – must provide early warning of a potential violation of groundwater protection levels, and/or class TDS limits and be as or more reliable, effective, and determinate than a viable groundwater monitoring network.

Vadose Zone Monitoring Requirements – Should be: used in conjunction with source monitoring; include sampling for all the parameters required for background groundwater quality monitoring; the application, design, construction, operation, and maintenance of the monitoring system should conform with the guidelines found in: Vadose Zone Monitoring for Hazardous Waste Sites; June 1983, KT-82-018(R).

Leak Detection Monitoring Requirements – Should not allow any leakage to escape undetected that may cause the receiving groundwater to exceed applicable groundwater protection levels during the active life and any required post-closure care period of the discharge point. This demonstration may be accomplished through the use of numeric or analytic, saturated or unsaturated, groundwater flow or contaminant transport simulations, using actual filed data or conservative assumptions. Provide plans for daily observation or continuous monitoring of the observation sump or other monitoring point and for the reporting of any fluid detected and chemical analysis thereof.

Specific Requirements for Other Methods – Demonstrate that: the method is as or more reliable, effective, and determinate than a viable groundwater monitoring well network at detecting any violation of groundwater protection levels or class TDS limits, that may be caused by the discharge or potential discharge; the method will provide early warning of a potential violation of groundwater protection levels or class TDS limits and meets or exceeds the requirements for Vadose zone or leak detection monitoring.

Monitoring well construction and groundwater sampling should conform to A Guide to the Selection of Materials for Monitoring Well Construction. Sample collection and preservation, should conform to the EPA RCRA Technical Enforcement Guidance Document, OSWER-9950.1, September, 1986. Sample analysis must be performed by State-certified laboratories by methods outlined in UAC R317-6-6.3L. Analytical methods used should have minimum detection levels which meet or are less than both the groundwater quality standards and the anticipated protection levels.

11. **Closure and Post Closure Plan:** The purpose of this plan is to prevent groundwater contamination after cessation of the discharge or potential discharge and to monitor the discharge or potential discharge point after closure, as necessary. This plan has to include discussion on: liquids or products, soils and sludges; remediation process; the monitoring of the discharge or potential discharge point(s) after closure of the activity.

12. **Contingency and Corrective Action Plans:** The purpose of this Contingency plan is to outline definitive actions to bring a discharge or potential discharge facility into compliance with the regulations or the permit, should a violation occur. This applies to both new and existing facilities. For existing facilities that may have caused any violations of the Groundwater Quality Standards or class TDS limits as a result of discharges prior to the issuance of the permit, a plan to correct or remedy any contaminated groundwater must be included.

    Contingency Plan – This plan should address: cessation of discharge until the cause of the violation can be repaired or corrected; facility remediation to correct the discharge or violation.

    Corrective Action Plan – for existing facilities that have already violated Groundwater Quality Standards, this plan should include: a characterization of contaminated groundwater; facility remediation proposed or ongoing including timetable for work completion; groundwater remediation.

Certification

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Jade Dalton - Owner | 435-616-3081
NAME & OFFICIAL TITLE (type or print) | PHONE NO. (area code & no.)

SIGNATURE | DATE SIGNED

SECTION 2: DESCRIPTION OF PRODUCTION FACILITIES

The facility is to be located in the north ½ of sections 11 and 12, T31S, R4W SLB & M. The site will be an 13,200 hog finisher site with a double basin to contain the waste. The waste will be contained only temporarily and will be utilized as fertilizer on the adjacent fields to grow crops. There will be no treatment of the waste except that which occurs naturally as the waste sets in the containment basin before it is applied to the fields as fertilizer.

Potential discharges would include the possible leaking of the basins or the pipes into or out of the facility. Both the influent into and the efluent out of the facility will be closely monitored. Therefore, any leakege will be identified by a corespoinding drop in the amount of either influent or effluent. Furthermore, in compliance with groundwater discharge permit requirements, monitoring wells will be installed to verify that the groundwater is not contanimated due to sewage leakage.

2.1 Farm Site Population

There is one farm site proposed for this permit. The sites will consist of 8 (1100) head wean to finisher barns containing pigs sized from 60 to 270+ pounds. Table 1-2 summarizes the swine population anticipated for the farm sites:

Table 1-2

Animal Type	Average Animal Weight (lbs)	Population	Total Live Animal Weight (LAW) for Animal Type (lbs)
Finisher Pig	150	13,200/site	1,980,000

2.2 Farm Site Locations

The locations of the finishing farms are identified on Attachment A. Table 1-3 indicates the latitude and longitude of the site.

Table 1-3

Farm Number	Latitude	Longitude
1	N 38° 8’ 2.86”	W 112° 15’ 58.84”

SECTION 3: GEOLOGIC AND HYDRAULIC EVALUATION

3.1 Geologic Conditions

The rocks in and around the Upper Sevier River Valley range in age from Triassic, Jurassic, Cretaceous, Tertiary and Quaternary. The mountains surrounding the, basin contain rocks of Precambrian through Tertiary age; these rocks are of sedimentary, metamorphic, and igneous types. Volcanic rocks of Tertiary and Quaternary age and consolidated-to-unconsolidated sedimentary deposits compose the basin fill. The valley fill material of the Circle Valley consists of alluvial deposits of silt, clay and sand up to gravel size materials. The thickness of valley fill deposits may be up to 680 feet in thickness in the vicinity near the proposed sites.

3.1.1 Faulting & Seismicity

The Upper Sevier River Valley lies within a zone of pronounced seismic activity. There are many faults in the Tushar Mountains approximately 3.5 miles to the west of the proposed farm sites with the closest mapped faults to the site being the Sevier Valley-Maysvale-Circleville area faults approximately 3.3 miles northwest of the proposed farm sites.

It does not appear that any known active faults transect the proposed farm sites.
From southwestern Utah to northwestern Montana (Christenson and Dean, 1983).

3.2 Stratigraphy

The stratigraphy at the site generally consists of alluvium and colluvium (Quatenary) The following description was taken from “Geologic Map of Utah and Ground-Water Conditions . and Geologic Reconnaissance of the Upper Sevier River Basin, Utah".

Faulting, erosion, and deposition by streams have shaped the several ground-water basins in the upper Sevier River basin. The valley fill in these basins has been derived from the consolidated and unconsolidated formations in the uplands that surround the valleys. In Circle and Grass Valley basins all the sediments are derived from volcanic rocks; in Panguitch and East Fork

Valley basins, the sediments are derived from both volcanic and sedimentary rocks. The sediments includes old alluvium, young alluvium, and flood-plain deposits.

Circle Valley is about 8 miles long and is more than 6 miles wide at Circleville. The altitude of the valley floor ranges from about 6,000 feet at the north end to about 6,200 feet at the south end. The valley is bordered on the west by the Tushar Mountains, which reach an altitude of more than 11,000 feet, and on the east by the Sevier Plateau.

3.3 Topography and Drainage

The proposed farm sites located in the Central Sevier Valley as described previously. The topographical slope at the proposed site and the surrounding area is approximately 2.5%. The approximate elevation at the proposed farm sites is approximately 6220 feet above sea level (see **Attachment A**).

3.4 Hydrologic Description

USGS topographic maps show that the Sevier River is approximately 7500 feet to the northwest from the proposed site. The Sevier River runs primarily in a north north-east direction in the Circle valley. Based on the location of the proposed sites the Sevier River is not likely to have an impact or be impacted by the proposed site location.

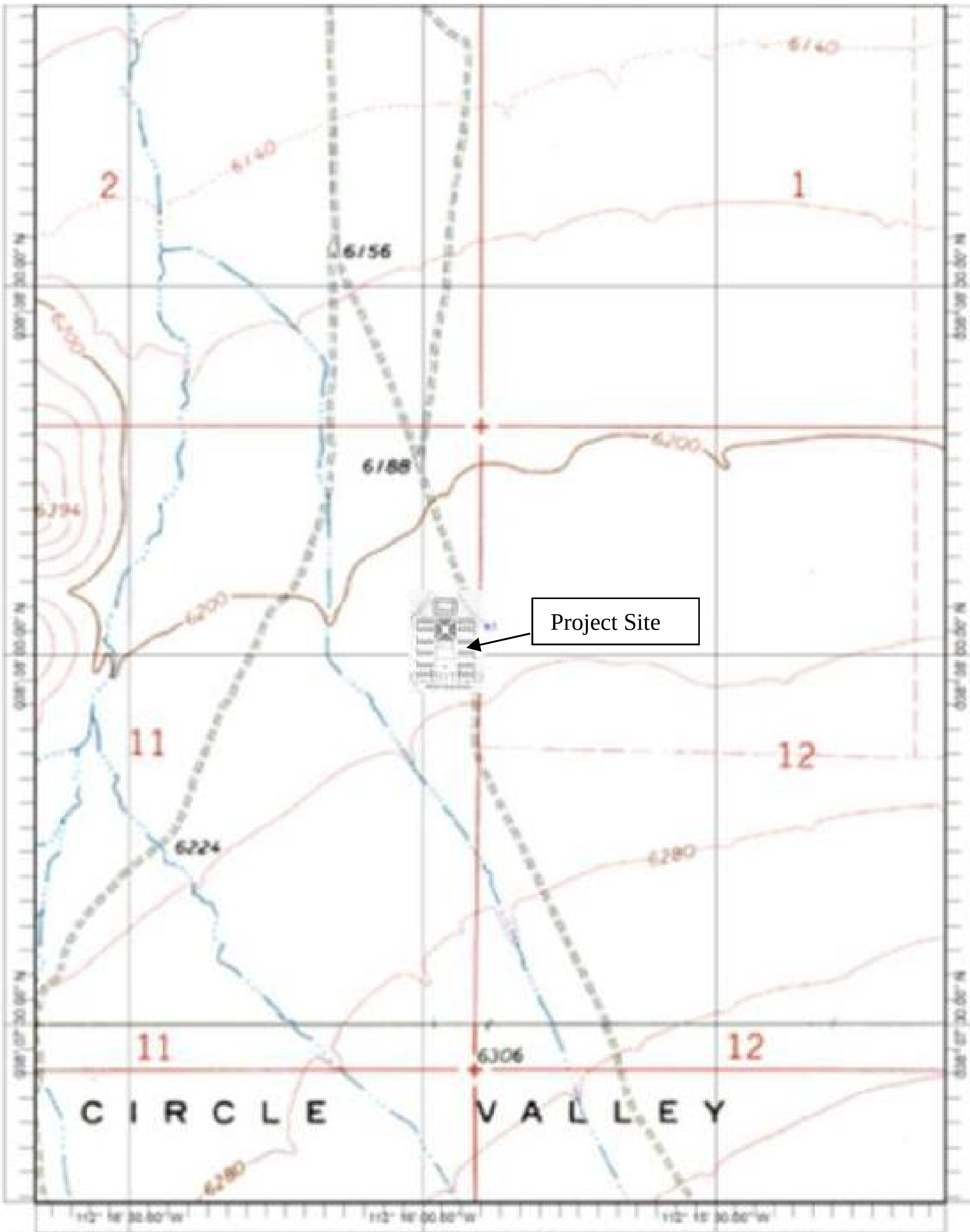


Figure 3-1 Topographic Map (USGS Map)

3.4.1 Groundwater Reservoir

In the State of Utah Geological Survey Paper #1836 entitled "Ground-Water Conditions and Geologic Reconnaissance of the Upper Sevier River Basin, Utah" (Carpenter, Robinson & Bjorklund), the hydraulic properties of the groundwater reservoir in the area of the proposed farm sites are documented. The information from this publication is drawn upon freely in the following discussion.

The groundwater reservoir underlying the proposed sites is in the Circle Valley portion of the Sevier River Basin. The ground water deposit in the vicinity of the farm sites is mostly unconsolidated and semi-consolidated alluvial deposits that form interbedded lenticular soil layers. Pump tests conducted by the Department of Natural Resources suggest that the reservoir acts as a single aquifer over time, but due to the lenticular nature of the deposits, extensive hydraulic continuity most likely does not exist everywhere. The unconsolidated deposits that make up the reservoir are composed of gravel, sand, silt and clay. The thickness of the reservoir exceeds 500 feet through the central valley and is approximately 100 to 300 feet thick under the proposed facility location.

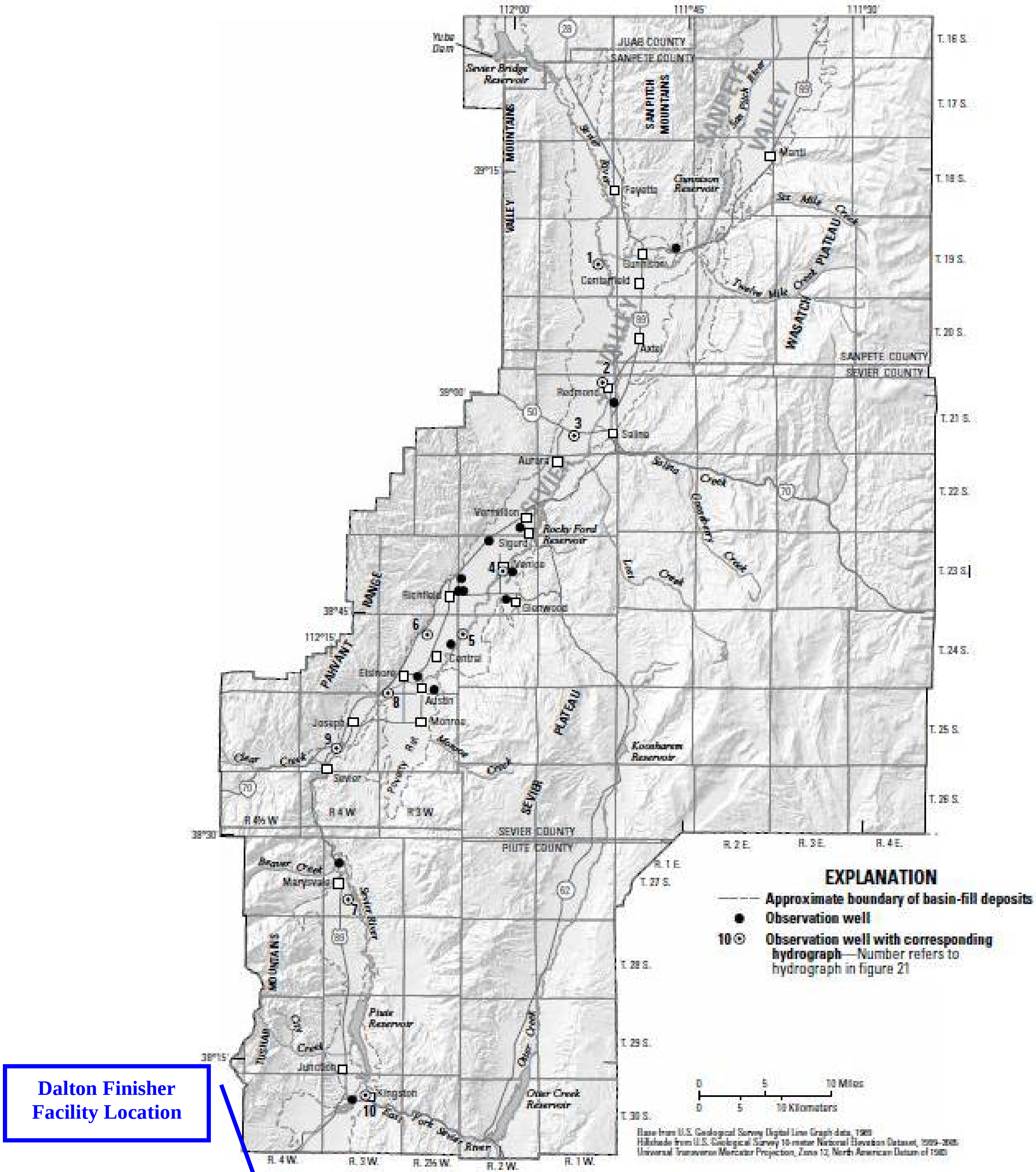


Figure 3-2 Well Locations Near Dalton Finisher Farm Sites

3.4.2 Groundwater Movement

The groundwater in the southern portion of the Circle Valley of the Sevier River Basin is recharged by ephemeral streams (Mostly the Sevier River), subsurface inflow from bedrock in the mountains, precipitation on the valley floor. The groundwater in the area flows to the northwest generally down in the direction of the flow of the Sevier River. - (Appendix F - Sevier "Ground-Water Conditions and Geologic Reconnaissance of the Upper Sevier River Basin, Utah" (Carpenter, Robinson & Bjorklund)) the ground water slope in the basin is estimated 0.22 to 0.3 % to the north - northwest under the proposed site. The groundwater's approximate depth under the proposed facility site is 45 to 65 feet below existing ground level in the vicinity of the proposed sites.

The rate of lateral movement in the aquifer is extremely slow compared to that of a surface stream. The well logs for the wells in the area indicate silty sand and sandy clay at water table depth. Therefore, the percentage of sand in the aquifer beneath the site can be assumed to be between 10% and 15%. The Transmissivity for the full underling aquifer thickness is approximately 3,000 to 5000 ft^2 /day as interpreted from the 1993 study as shown in **Figure 3-5 below.**

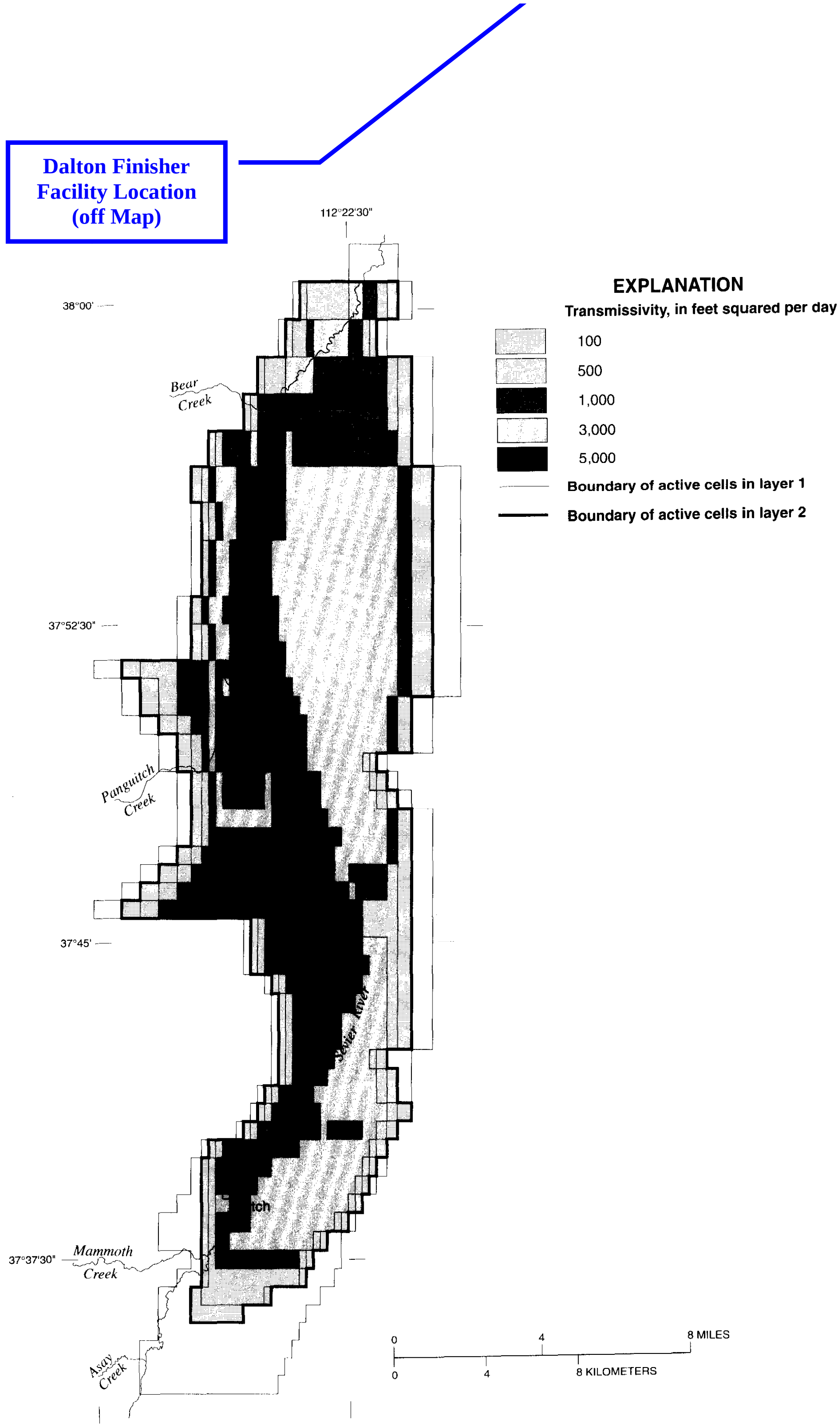


Figure 19. Distribution of transmissivity used in layer 2 of the digital-computer model.

Figure 3-5 Transmissibility of Lower and Upper Artesian Aquifers

3.4.3 Groundwater Quality

Existing wells referred to as piezometric wells in this report have been used to analyze the groundwater quality surrounding the proposed sites. Some of these wells are described in **Table 3-1** and the water quality test results are shown in table 1-4 below. The well logs and portion of water quality report from the USGS and Utah Department of Natural Resources are included in Appendix B.

Table 1-4 - Water Quality Test Results 2016 – Upper Sevier River Valley Area – Groundwater Conditions in Utah, Spring of 2016

Potassium dissolved, in mg/L	Sodium, dissolved, in mg/L	ANC, fixed end point, lab, in mg/L as $CaCO_3$	Bromide, dissolved, in mg/L	Chloride, dissolved, in mg/L	Fluoride, dissolved, in mg/L	Silica,dissolved, in mg/L	Sulfate, dissolved, in mg/L	Solids, dissolved, residue at 180°C, in mg/L	Nitrate plus nitrite, dissolved, in mg/L as N	Orthophosphate, dissolved, in mg/L as P
Upper Sevier River Area										
5.89	14.5	181	0.16	26.4	0.2	50.5	16.7	281	1.02	0.081
3.27	17	126	0.04	9.5	0.27	38.3	8.5	187	2.62	0.176

3.4.4 Chemical Quality of Water

Chemical analyses taken from the groundwater surrounding the proposed sites are included Table 1-4 represents data taken in 2016.

SECTION 4: GROUNDWATER DISCHARGE CONTROL PLAN

The finisher farm is designed as a closed system and therefore with the exception of the Septic system which will be designed and approved through the local health department no wastewater will be discharged to the surrounding soil.

4.1 Finisher Waste Management Description

A diagram of the overall operation of the finisher facility is found in **Figure 4-1**

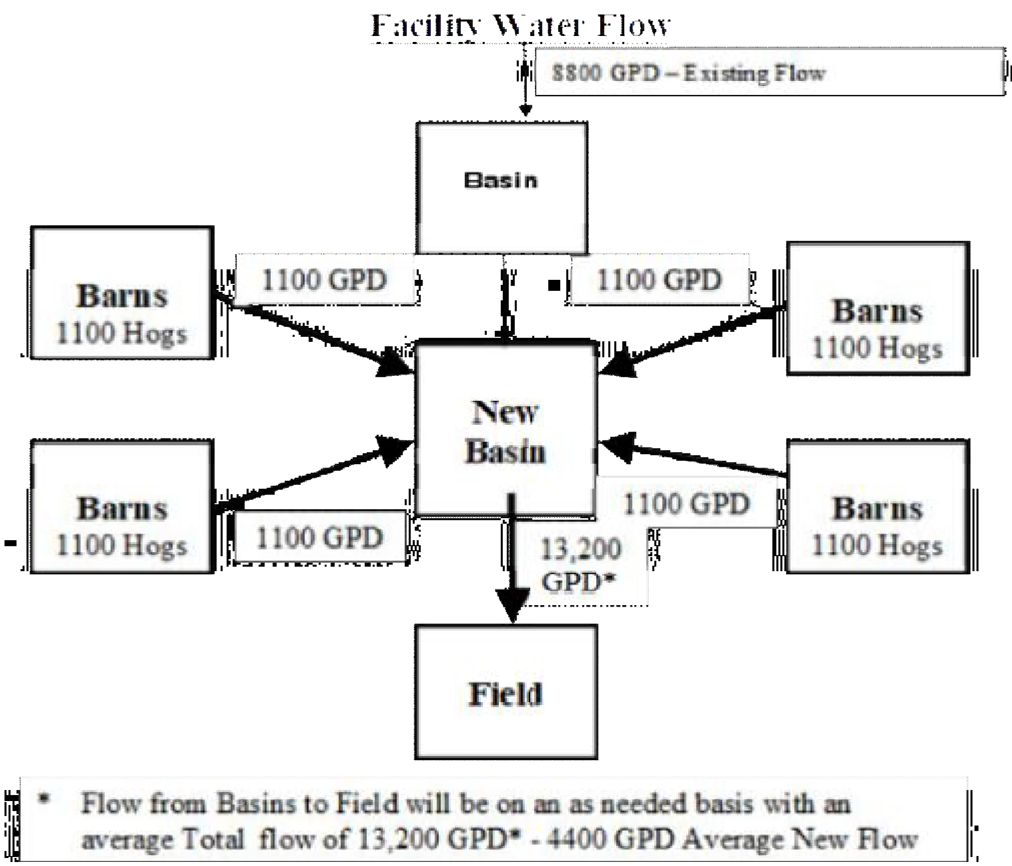


Figure 4-1 Finisher Flow Diagram

4.1.1 Waste Flow Description

The sewage collected from the individual finisher buildings will drain into the waste containment basin. The waste will not be treated but will be pumped to agricultural fields at an agronomic rate to be utilized as fertilizer. The level of fluid in the containment will be strictly monitored and controlled. The basins are designed to hold approximately 425 days of waste produced by the hogs in the barn at full capacity.

4.1.2 Soil Information

The soil and water table around the site were investigated by reviewing the well logs for the wells which are near the facilities:

Well # 1 – WIN#: 22343:	S 15 ft, W 660 ft from NE corner of Section 2, T 31S, R 4W, SL B&M
Well # 2 – WIN#: 429786:	N 28 ft, W 78 ft from SE corner of Section 35, T 30S, R 4W, SL B&M

Soil logs for the locations listed above are located in **Attachment B**. Information was obtained from Utah Division of Water Rights.

The shallowest groundwater in the surrounding borings was located roughly 43 feet below existing grade at Well # 1 which is closest to the facility site. An excavation was made at the site and the groundwater is estimated to be about 60 feet below the ground surface.

In order to meet DEQ criteria for Containment Basin construction, the seasonal high water table elevation must be at least 2 feet below the floor of the containment basin in hydrogeologically stable soil strata. At the facility location, the seasonal high water table will be more than 2 feet below the bottom of the proposed containment basin. Also, the soil strata underlying the facility site appear to be hydrogeologically stable. It appears that the proposed site will meet this criteria.

4.1.3 Containment Basin Overview

The owner of this facility will follow the previously accepted design criteria in developing containment basins for this facility. No digestion of the waste is necessary, because the hog manure will be utilized as fertilizer on an agricultural field.

A plan view of the containment basin is shown in **Figure 4-3**

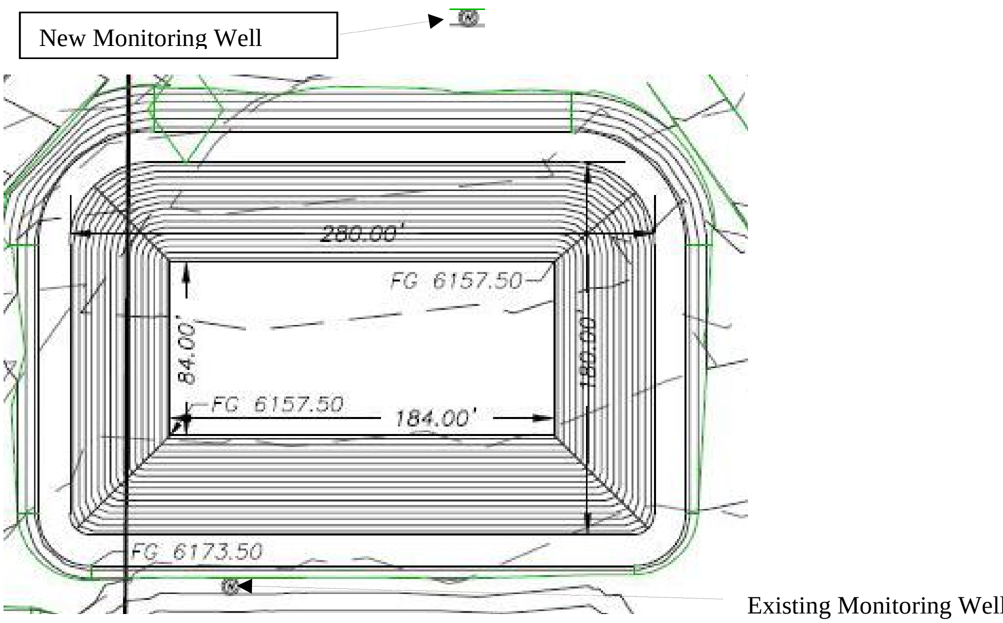


Figure 4-3 New Containment Basin Detail and Monitoring Well Location (There is an existing containment basin than proceeds this basin)

4.1.4 Waste Conveyance System

Waste shall be conveyed from the farm sites to the containment basin through either HDPE SDR 35 or PVC Schedule 40 sewer pipe, as shown in the Composite Location & Plot Map included in **Attachment A**. The waste will gravity flow from the barns to the waste containment basins. The containment basin will be lined with a Flexible Membrane Liner (FML).

4.1.5 Containment Basin Management Plan

As previously described, the waste flows from the barn to containment basins and then is pumped to the fields at an agronomic rate. Should problems be encountered either in the liner or piping, the flow of sewage from the individual farm sites can be shut off and the contents of the basin(s) can be pumped to the existing field or containment basin so that repairs can be made and the containment basin be put back into use.

SECTION 5: COMPLIANCE MONITORING PLAN

5.1 Groundwater Monitoring

One additional down gradient monitoring well be drilled for compliance monitoring of the new containment basin site at the facility site. There is an existing upgradient well at the site which is currently the down gradient well for the existing basin. A Water Quality Sampling, Handling and Analysis Plan is included as **Attachment F**. All water samples taken from the monitoring wells will be processed according to the guidelines set forth in this plan. The installation guidelines and an outline of the proposed groundwater monitoring plan are as follows:

1.) A Downgradient monitor well will be constructed. The proposed locations of these wells are shown in **Figure 4-3**. The monitor wells will have a total depth of 10' below the first encountered water table and will be constructed and developed as per requirements of the State of Utah, Department of Environmental Quality. The monitor wells will typically be constructed as shown in **Figure 5-1**. The upgradient wells will provide background data for the downgradient monitoring wells. The wells will be constructed at the location shown in **Figure 4-3** and in **Attachment D** at the proposed site.

2.) The static water level in each well and the elevation of the water level will be determined at least 8 days after the well has been completed. The water levels at each well will be compared with existing data to confirm the direction of groundwater movement.

3.) Monitoring wells will be sampled and tested according to the procedures outlined in the Water Quality Handling and Analysis Plan (**Attachment F**). It is anticipated that the monitoring wells will be 70 to 80 feet in depth below the ground surface at the proposed farm site location.

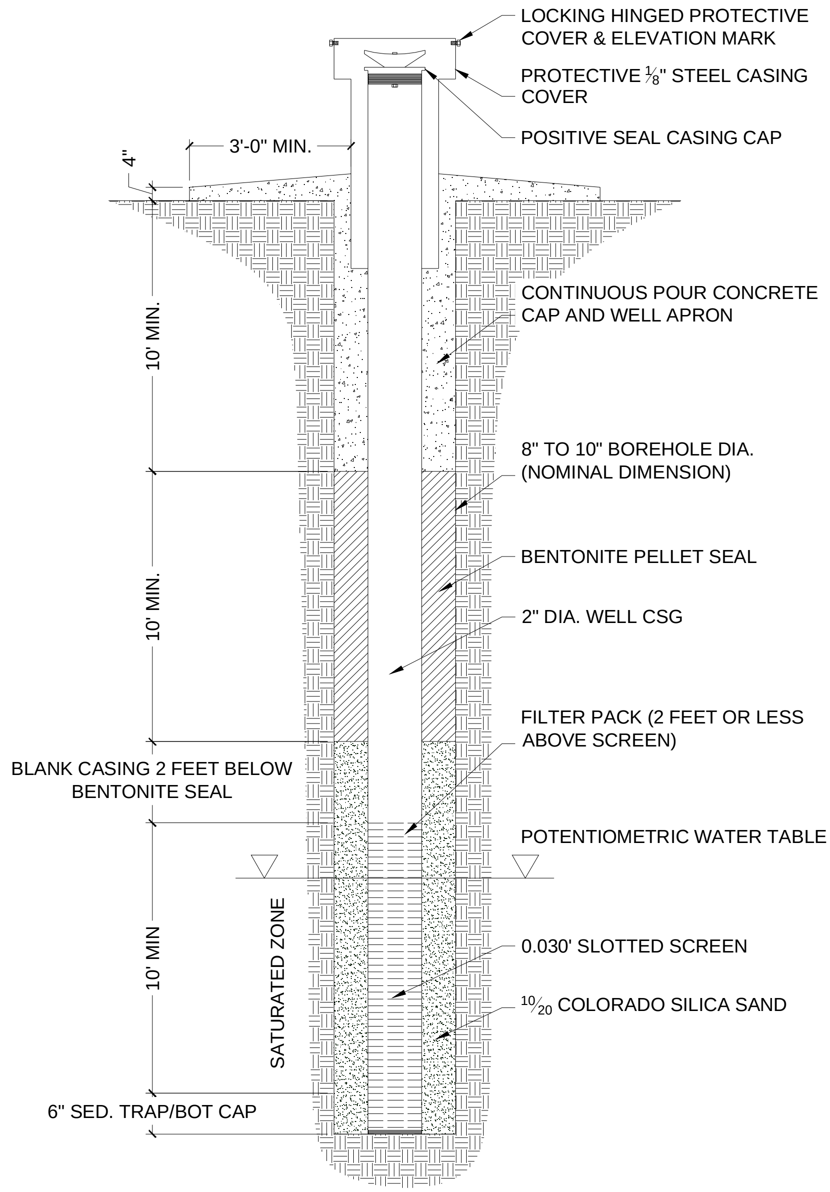


Figure 5-1 Typical Monitor Well Detail

5.1.1 Upgradient Groundwater Monitoring

The upgradient monitor well will be constructed and sampled prior to waste introduction to the Containment Basin at the site. The water in the upgradient well will be sampled and analyzed at least 8 days after the well is completed in order to determine the groundwater class protection levels and begin to establish background mean concentration levels. The groundwater protection levels of the upgradient well will be determined according to UAC R317-6-4 from the analysis of eight independent samples taken at equal intervals during a period of one year. The accelerated background constituents that will be analyzed in a laboratory include: total dissolved solids, sulfate, calcium, magnesium, potassium, sodium, carbonate, bicarbonate, total phosphorous, chloride, nitrate-N/nitrite-N, and ammonia-N. The parameters that will be determined at the monitor well include: static water level, pH, temperature, and specific conductance.

The background mean concentration levels will be determined by averaging the upgradient monitor wells accelerated background data, then adding 2 standard deviations. The following parameters will constitute the quarterly monitoring from the upgradient well after all eight background analysis: static water level, pH, temperature and specific conductance. Also, the following constituents will be monitored quarterly: nitrate-N/nitrite-N, ammonia-N, total dissolved solids, bicarbonate, and chloride. After the groundwater properties have been well established the analysis frequency may be decreased to semi-annually.

5.1.2 Downgradient Groundwater Monitoring

If data from upgradient monitor wells indicate differing movement of groundwater than what is shown in this application, the locations for the downgradient monitor wells will be changed, sent to the DEQ for approval, and drilled at a different location than proposed in this application.

A first sample will be taken from the downgradient well at least eight days after it's construction and prior to waste flow to the digester system. Only the first sample from the downgradient well will be analyzed for the background parameters described in Section 5.1.1. After the first analysis, the well will be analyzed on a quarterly basis for the following constituents: nitrate-N/nitrite-N, ammonia-N, total dissolved solids, bicarbonate and chloride. The following field parameters will also be analyzed: static water level, pH, temperature, and specific conductance. After the groundwater properties have been well established the analysis frequency may be decreased to semi-annually.

5.1.3 Alternative & Additional Monitoring

In the event that the chemical quality proves that a common source comparison does not exist between the upgradient and downgradient well, a different background monitoring schedule may be proposed to the Department of Environmental Quality's Executive Secretary.

Additional Monitoring: Identification of the contaminants in the wastewater will be analyzed once a year. The analysis will identify the parameters required under the accelerated background monitoring at upgradient wells and also, the metals listed in Table 1 of the Groundwater Regulations, R317-6-6.3, (arsenic, barium, cadmium, chromium, copper, lead, mercury, selenium, silver and zinc).

SECTION 6: CONTAINMENT BASIN SYSTEM LOCATION AND DESIGN

6.1 Containment Basin Description

Containment basins will be used at this finisher site to store the swine manure produced at the finisher sites. Effluent will be collected from the production building in two Containment Basins where the effluent will be stored allowed to evaporate. The Containment Basins will be lined. The liners will consist of a Flexible Membrane Liner (FML). The waste contained in the containment basins will be pumped and utilized as fertilizer in the near by fields.

6.2 Containment Basins Site Soils Investigation

A soil and water table investigation will be performed near the proposed Containment Basin locations before construction. The soil investigations consisted of 2 backhoe trenches approximately 12 feet in depth near the proposed farm sites. The groundwater underlying the Containment Basin must be at least 8 feet below the existing ground level. In order to meet DEQ criteria for Containment Basin construction, the seasonal high water table elevation must be at least 2 feet below the floor of the Containment Basin in hydrogeologically stable soil strata. At the proposed farm site the seasonal high water table was more than 2 feet below the bottom of the proposed Containment Basin based on the hrydorgeolocical information available. Also, the soil strata underlying the Containment Basins appear to be hydrogeologically stable. It is proposed that bottom of containment basin be placed approximately 15 feet below the ground surface at these farm site locations. It is estimated that the groundwater is approximately 60 feet below the ground surface at the proposed site loation.

6.3 Containment Basins Design

The containment basins will be constructed with 60 mil HDPE liners as described in section 7 of this report and in accordance with the State of Utah Department of Environmental Quality regulations. A plan view and cross section of the containment basin can be found in Attachment D.

6.4 Waste Transfer System

Waste from the barns is transferred to the containment basin through either 12” SDR 32.5 HDPE or 12” SDR 35 PVC sewer pipe, installed at a 0.5% minimum slope. The effluent pipe and Containment Basins elevations allow the waste to gravity flow from the pits to the Containment Basins. The waste will then be pumped to the agricultural field for use as fertilizer at an agronomic rate.

6.5 Containment Basins Safety System Considerations

Access to the Containment Basins by humans and animals will be controlled by fencing. The fences will help to prevent damage to the Flexible Membrane Liners (FMLs) in the instances where they are used. Only authorized personnel will have access to the Containment Basin areas to prevent damage to the FMLs. Additionally, safety-warning signs will be posted near the Containment Basins.

6.6 Containment Basins Management Plan

The Containment Basins will be managed as a fertilizer producing system. The Containment Basins are designed to contain all of the waste produced by the hogs for 425 days. The waste will be pumped to the fields at an agronomic rate. Since the prevailing climatological conditions result in more evaporation than precipitation no excess volume will be provided other than the free board of 1.5 feet as show on the lagoon cross section in Attachment D. However, should unforeseen precipitation events occur, excess effluent could be land applied at agronomic rates at any time. The effluent will be applied according to soil and plant nutrient uptake rates. In this case, the effluent will be applied in a manner such as to avoid any contamination of surface waters, drinking wells, springs or pipelines.

SECTION 7: LAGOON AND CONTAINMENT BASIN CONSTRUCTION

7.1 Containment Basins Construction

Construction of the Barns and Containment Basins shall be done in accordance with design drawings and specifications. Earthwork and liner construction shall be tested and inspected by qualified independent geotechnical and/or engineering firms. At the completion of construction, and prior to operation of the facility, an independent performance certification document will be completed by a qualified professional engineer licensed in the State of Utah containing test information and certification that basin and liner construction meets requirements of the project design documents and the requirements contained within this report.

7.1.1 General Earthwork Construction

Earthwork and dike construction for excavation of digesters and equalization basins shall be done as follows:

A. The area scheduled for construction of basins and building pads shall be cleared and grubbed to remove topsoil and surface vegetation from the digester/basin areas.

B. Soil shall be excavated from the basin area and be used to construct building pads or dikes.

C. Basin dikes shall be constructed in 6-inch compacted lifts to obtain proper compaction. For building pad and digester dike construction, the soil shall be moistened and compacted to 90% of maximum dry density, as defined by AASHTO T-99**.** Moisture will be added to the soil during compaction to target 2% above the optimum moisture.

D. The dikes will be constructed of relatively impermeable compacted native material.

E. A qualified inspector will perform the moisture content and dry density testing per every two feet of lift at random locations once every 400 feet along the Containment Basin dikes.

7.2 Flexible Membrane Liner

Specifications for manufacture, delivery, subgrade preparation, installation, and testing for FML liner installation are included in **Attachment E**. The QA/QC plan is also included in this attachment. The specifications were adapted from requirements set forth in previous projects and permit applications. Moreover, an industry standard known as the GRI standard GM13 which covers smooth and textured geosynthetics has been developed with the intent of forming an industry standard for manufacture and testing of geosynthetic liner material. This standard was developed by the Geosynthetic Research Institute at Drexel University, Philadelphia, PA. As stated in the specifications, the requirements of latest revision of the GRI standard will be applicable.

If the basins are to remain empty for an extended period of time they shall be properly ballasted using ultraviolet ray resistant sand bags with nylon ties. The minimum specification for ballasting liner is 30-lb. sand bags spaced 5-feet apart along the entire toe of dike in containment basins. Sand-filled HDPE tube or pipe may also be used as long as an equivalent amount of ballasting per lineal foot (6 lbs./ln.-ft.) is maintained.

On occasion, repairs may have to be made to liners if damage occurs out of the norm, or modifications need to be made. All repairs made to liner seams, or incident holes found in the liner shall be vacuum/bubble tested, documented and sent to the State DEQ for informational purposes and approval of the repairs. Unless significant modifications to the liner are made, such repairs shall be made without any requirements for approval from the State DEQ.

7.2.1 Flexible Membrane Liner Installation

The Containment Basins at the finishing farms will be lined with a Flexible Membrane Liner (FML) constructed of a High Density Polyethylene (HPDE). The subgrade will conform to the FML specifications of the Manufacture and the previously stated most resent GRI standards. The installation of the FML will also comply with the Quality Assurance/Quality Control (QA/QC) found in Attachment E. In Addition to the FML specifications and QA/QC, detailed drawings of typical liner anchoring methods, pipe penetrations, air vents and water level markings of liners are found in attachment E. The following procedures will be used for installation of liners for the Containment Basins at the farm sites.

The Subgrade will be constructed according to the specifications as detailed below:

1. The subgrade material will come from either on-site material or approved stockpiles.
2. The earthwork for the anaerobic Containment Basins will be free of any foreign material such as stones greater than 3/8 inch in diameter, vegetation, brush, roots or similar material which could damage the FML.
3. The subgrade material shall be classified as either CH, CL, CL-ML, ML, SM, SC, SW or SP by the USCS Classification System.
4. A Moisture density curve will be developed for the subgrade material.
5. The minimum compacted thickness of the subgrade layer shall be 8 inches.
6. The subgrade will be compacted and graded to meet the FML contractor's specifications so as to avoid any ruts, irregularities or soft areas. The subgrade will be thoroughly compacted to provide support for the FML.
7. The subgrade will be compacted to a minimum of 90% maximum dry density as defined by AASHTO T-99. For proper compaction, moisture will be added to the soil during compaction to target 2% above the optimum moisture.
8. Installed density shall be confirmed by field test methods at a frequency of one test per 100'x100' grid square at the surface of the subgrade.

A 60-mil HDPE will be installed over the compacted subgrade. The HDPE material will meet the specifications indicated in the most resent GRI standard and in the QA/QC references in Attachment E. The drawings in Attachment E show typical liner anchoring methods and pipe penetrations of the liner material.

The HDPE liner will be installed according to the following procedure:

1. The earthwork for the anaerobic Containment Basins will be constructed so the subgrade will be free of any foreign material such as stones greater than 3/8 inch in diameter, vegetation, brush, roots or other similar materials which could damage the FML.
2. The earthwork will be compacted and graded to meet the FML contractor's specifications so as to avoid any ruts, irregularities or soft areas. The subgrade will be thoroughly compacted to provide support for the FML.
3. An anchor trench will be constructed along the crest of the berms for the purpose of securing the FML.
4. The FML will be assembled, seamed, tested and installed by the methods specified by a liner material recognized by the NSF (National Sanitation Foundation, Standard 54).
5. The FML will be certified as "holiday free" by electrical potentiometric means (spark tested) during manufacture.
6. Adequate slack will be maintained in the liner material during assembly and installation to minimize stresses due to variations in ambient temperature and incident radiation.
7. Heavily creased or otherwise defective liner material must be rejected.
8. Testing of coupons (strips of material) before seaming, stress cracks and all seams must be done in accordance with the manufacture's requirements.
9. Installation of the FML will ideally take place in temperatures ranging from 40 degrees Fahrenheit to 110 degrees Fahrenheit. In the event that the FML is installed during colder conditions (between 20 degrees Fahrenheit and 40 degrees Fahrenheit) the cold weather seaming procedures detailed in FML QA/QC, Attachment E, shall be followed.
10. Air Vents will be installed on all four sides of the Containment Basin as detailed in Attachment E and Compaction of the anchor trench backfill will provide a firm unyielding surface to secure the FML along the berms.

SECTION 8: FACILITY CLOSURE AND POST CLOSURE

Should facility operation terminate the liquid and sludge will be removed and land applied at agronomic rates unless alternative technologies are developed. The sludge and Containment Basins liquid will be land applied in such a way as to avoid ground water pollution as well as contamination of surface waters, drinking wells, springs or pipelines. Additionally, the parameters and constituents of the water in the monitoring wells detailed in Sections 5.1.1 and 5.1.2 will be observed for 5 years thereafter. The actual duration of post operation monitoring may be less, if justified by long term operation and a history of compliance.

SECTION 9: CONTINGENCY AND CORRECTIVE ACTION

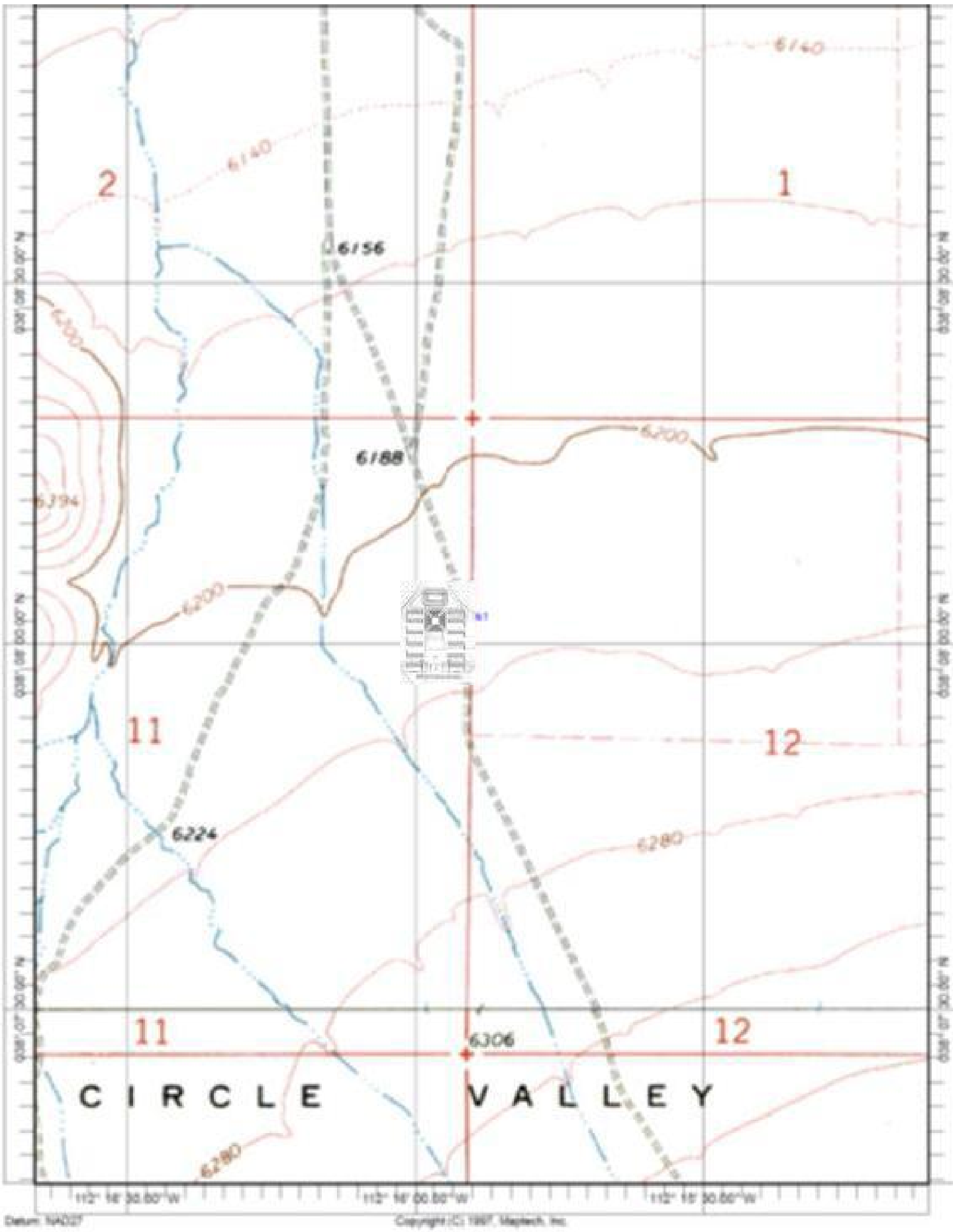
In addition to monitoring wells described in the previous section additional precautions will be implemented. The influent and effluent will be monitored on a regular basis to check for variations in the composition and quantity. The facility condition will also be checked on a daily basis to check for, among other things, damage to piping or liners and waste elevation in the containment basin. Should it become necessary to empty the containment basins for repairs, the liquid from the target basin will be transferred to one or more of the other existing Containment Basins or applied to the land at agronomic rates. Once any necessary repair work has been completed, the liner will be evaluated and re-certified prior to the reintroduction of liquid.

SECTION 10: ADJACENT PROPERTY OWNERS

The Dalton Hay Company, LLC own all of the land surrounding the proposed site.

ATTACHMENTS

Attachment A – Composite Location and Topographic Map



6140
6140
2
1
6156
6300
6188
6200
6194
6200
11
12
6224
6280
11
6306
12
CIRCLE VALLEY
6280
112° 16' 30.00" W
112° 16' 00.00" W
112° 15' 30.00" W
038° 08' 30.00" N
038° 08' 00.00" N
038° 07' 30.00" N
Datum: NAD27
Copyright (C) 1997, Maptech, Inc.

Attachment B –Well Logs and Water Quality Report

Utah Division of Water Rights

WELLPRT Well Log Information Listing

Version: 2003.09.18.00 Rundate: 10/12/2003 12:39 PM

Utah Division of Water Rights

Water Well Log

LOCATION:
S 10 ft W 660 ft from NE CORNER of SECTION 2 T 31S R 4W BASE SL Elevation: feet

DRILLER ACTIVITIES:
ACTIVITY # 1 NEW WELL
DRILLER: GRIMSHAW DRILLING LICENSE #: 240
START DATE: 06/27/2000 COMPLETION DATE: 07/03/2000

BOREHOLE INFORMATION:

Depth(ft) From	To	Diameter(in)	Drilling Method	Drilling Fluid
0	185	12.2	MUD ROTARY	BENTONITE

LITHOLOGY:

Depth(ft) From	To	Lithologic Description	Color	Rock Type
0	43	SILT,SAND		
43	73	WATER-BEARING,HIGH-PERMEABILITY,SAND,GRAVEL,COBBLES,BOULDERS		
73	125	WATER-BEARING,HIGH-PERMEABILITY,SAND,GRAVEL		
125	155	WATER-BEARING,HIGH-PERMEABILITY,GRAVEL,COBBLES PEA GRAVEL		
155	185	GRAVEL,COBBLES,BOULDERS		

WATER LEVEL DATA:

Date	Time	Water Level (feet) (-)above ground	Status
07/03/2000		43.00	STATIC

CONSTRUCTION - CASING:

Depth(ft) From	To	Material	Gage(in)	Diameter(in)
+2	185	A53 GRADE B	.188	8.62

CONSTRUCTION - SCREENS/PERFORATIONS:

Depth(ft) From	To	Screen(S) or Perforation(P)	Slot/Perf. siz	Screen Diam/Length Perf(in)	Screen Type/# Perf.
105	185	PERFORATION	.125	3	8 ROUND

CONSTRUCTION - FILTER PACK/ANNULAR SEALS

Depth(ft) From	To	Material	Amount	Density(pcf)
0	20	BENTONITE HOLE PLUG	10 BAGS	
20	195	3/8 PEA GRAVEL	6 YDS	

WELL TESTS:

Date	Test Method	Yield (CFS)	Drawdown (ft)	Time Pumped (hrs)
07/03/2000	AIR LIFT	1.114	2	2

GENERAL COMMENTS:

CONSTRUCTION INFORMATION
Well Head Configuration: Steel plate
Casing joint type: Butt weld
Perforataor used: milled slot
Surface seal installed: yes
Depth of seal: 20 ft.
Drive shoe: no
Surface seal placement method: Tremie 20 ft back to surface
FILTER PACK
Grout density: 100%
Additional data not available.

WELL DRILLER'S REPORT
State of Utah
Division of Water Rights

For additional space, use "Additional Well Data Form" and attach

Well Identification

Change Application: a29728 (61-968)

WIN: 429786

RECEIVED
08 JUN 2 2 2007
~~WATER RIGHTS~~
SALT LAKE

Owner *Note any changes*

Dalton Brothers Farm
PO Box 326
Kingston, UT 84743

Contact Person/Engineer: ______

Well Location *Note any changes*

N 50 W 66 from the SE corner of section 35, Township 30S, Range 4W, SL B&M

Location Description: (address, proximity to buildings, landmarks, ground elevation,local well #)

Drillers Activity Start Date: 4-25-07 Completion Date: 4-30-07

Check all that apply: ☒ New ☐ Repair ☐ Deepen ☐ Clean ☐ Replace ☐ Public Nature of Use: ______

If a replacement well, provide location of new well. ______ feet north/south and ______ feet east/west of the existing well.

DEPTH (feet) FROM	TO	BOREHOLE DIAMETER (in)	DRILLING METHOD	DRILLING FLUID
0	202	17 1/2"	ROTARY	BENTONITE / POLYMER

Well Log

DEPTH (feet) FROM	TO	WATER	PERMEABLE High	PERMEABLE Low	UNCONSOLIDATED CLAY	SILT	SAND	GRAVEL	COBBLES	BOULDER	OTHER	CONSOLIDATED ROCK TYPE	COLOR	DESCRIPTION AND REMARKS (e.g., relative %, grain size, sorting, angularity, bedding, grain composition density, plasticity, shape, cementation, consistancy, water bearing, odor, fracturing, minerology, texture, degree of weathering, hardness, water quality, etc.)
0	27				X		X						BROWN	
27	37			X			X	X						
37	62			X			X	X	X					
62	103	X		X			X	X						
103	107	X		X			X							
107	117	X		X			X		X					
117	123	X	X				X	X						
123	155	X	X				X		X					
155	164	X	X				X	X	X	X				
164	177	X	X				X			X				
177	202	X	X				X		X					

Static Water Level

Date 4-30-07 Water Level 72 feet Flowing? ☐ Yes ☒ No

Method of Water Level Measurement FLOAT If Flowing, Capped Pressure — PSI

Point to Which Water Level Measurement was Referenced TOP OF CASING Elevation —

Height of Water Level reference point above ground surface 2 feet Temperature — degrees ☐C ☐F

Construction Information

DEPTH (feet)		CASING			DEPTH (feet)		☐SCREEN ☒PERFORATIONS ☒OPEN BOTTOM		
FROM	TO	CASING TYPE AND MATERIAL/GRADE	WALL THICK (in)	NOMINAL DIAM. (in)	FROM	TO	SCREEN SLOT SIZE OR PERF SIZE (in)	SCREEN DIAM. OR PERF LENGTH (in)	SCREEN TYPE OR NUMBER PERF (per round/interval)
+2	202	A 53 GRADE B	.280	10 3/4	112	202	.125	2.50	10 PER ROW 20 PER FOOT

Well Head Configuration: STEEL PLATE Access Port Provided? ☐Yes ☒No

Casing Joint Type: BUTT WELD Perforator Used: MILLED SLOT

Was a Surface Seal Installed? ☒Yes ☐No Depth of Surface Seal: 30 feet Drive Shoe? ☐Yes ☐No

Surface Seal Material Placement Method: TREMIED 30 FT TO TOP OF WELL

Was a temporary surface casing used? ☐Yes ☒No If yes, depth of casing: ____ feet diameter: ____ inches

DEPTH (feet)		SURFACE SEAL / INTERVAL SEAL / FILTER PACK / PACKER INFORMATION		
FROM	TO	SEAL MATERIAL, FILTER PACK and PACKER TYPE and DESCRIPTION	Quantity of Material Used (if applicable)	GROUT DENSITY (lbs./gal., # bag mix, gal./sack etc.)
0	30	3/8 BENTONITE HOLE PLUG	45 - 50 lb SACKS	100% WET
30	202	1/4" PEA GRAVEL	8.5 YARDS	100% WET.

Well Development and Well Yield Test Information

DATE	METHOD	YIELD	Units Check One: GPM	CFS	DRAWDOWN (ft)	TIME PUMPED (hrs & min)
4-30-07	AIR LIFT	1200	X		18	4 hrs

Pump (Permanent)

Pump Description: ____ Horsepower: ____ Pump Intake Depth: ____ feet

Approximate Maximum Pumping Rate: ____ Well Disinfected upon Completion? ☐Yes ☐No

Comments

Description of construction activity, additional materials used, problems encountered, extraordinary Circumstances, abandonment procedures. *Use additional well data form for more space.*

Well Driller Statement

This well was drilled and constructed under my supervision, according to applicable rules and regulations, and this report is complete and correct to the best of my knowledge and belief.

Name GRIMSHAW DRILLING (Person, Firm, or Corporation - Print or Type) License No. 240

Signature [signature] (Licensed Well Driller) Date 5-22-07

Central Sevier Valley

By Bradley A. Slaugh

Central Sevier Valley, located in northern Piute, Sevier, and southern Sanpete Counties, in south-central Utah, is surrounded by the Sevier and Wasatch Plateaus to the east and the Tushar Mountains, Valley Mountains, and Pahvant Range to the west (fig. 20). Altitude ranges from 5,100 feet on the valley floor at the north end of the valley near Gunnison to more than 12,000 feet in the Tushar Mountains. Groundwater occurs in unconsolidated basin-fill deposits under both water-table and artesian conditions.

Total estimated withdrawal of water from wells in central Sevier Valley in 2015 was about 30,000 acre-feet, which is 1,000 acre-feet less than reported for 2014 and 5,000 acre-feet more than the average annual withdrawal for 2005–2014 (tables 2 and 3).

The location of 24 wells in central Sevier Valley in which the water level was measured during March 2016 is shown in figure 20. The relation of the water level in selected observation wells to annual discharge of the Sevier River at Hatch, Utah, to cumulative departure from average annual precipitation at Richfield Radio KVSC, to annual withdrawal from wells, and to concentration of dissolved solids in water from well (C-23-2)15dcb-4 is shown in figure 21.

Discharge of the Sevier River at Hatch, Utah, in 2015 was about 47,300 acre-feet, which is about 32,400 acre-feet less than the 1940–2015 average annual discharge. Precipitation at Richfield Radio KVSC was about 11.0 inches in 2015, which is about 2.9 inches more than the 1950–2015 average annual precipitation and 1.0 inch more than in 2014.

Water levels in central Sevier Valley generally declined in most areas from March 2015 to March 2016. Hydrographs for selected wells show that March water levels generally rose from about 1978 to 1985 and declined from 1985 to about 1993. Since 1993, water levels have fluctuated depending upon the amount and timing of precipitation and recharge to the basin-fill aquifer from snowmelt runoff.

The concentration of dissolved solids in water samples collected from well (C-23-2)15dcb-4, located 0.1 mile south of Sevier River in Venice, from 1955 to 2015, is shown in figure 21. The concentration has ranged from 307 to 630 mg/L. There were substantial increases and decreases in dissolved-solids concentrations during the mid- to late 1960s and 1980s. Dissolved-solids concentrations in samples collected from 1990 through 2015 show little variability and are generally near the median value (410 mg/L) for all sample concentrations.

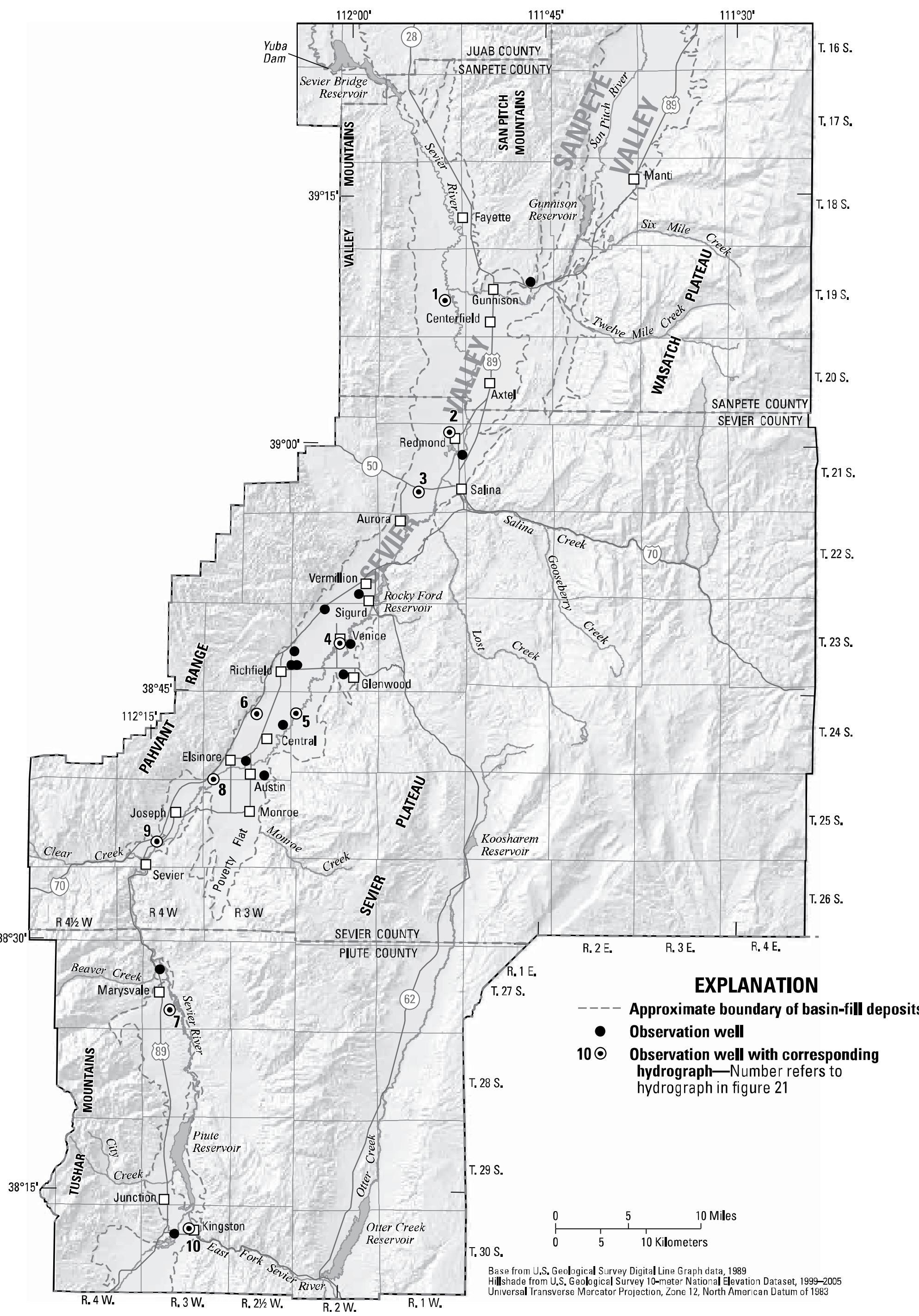


Figure 20. Location of wells in central Sevier Valley in which the water level was measured during March 2016.

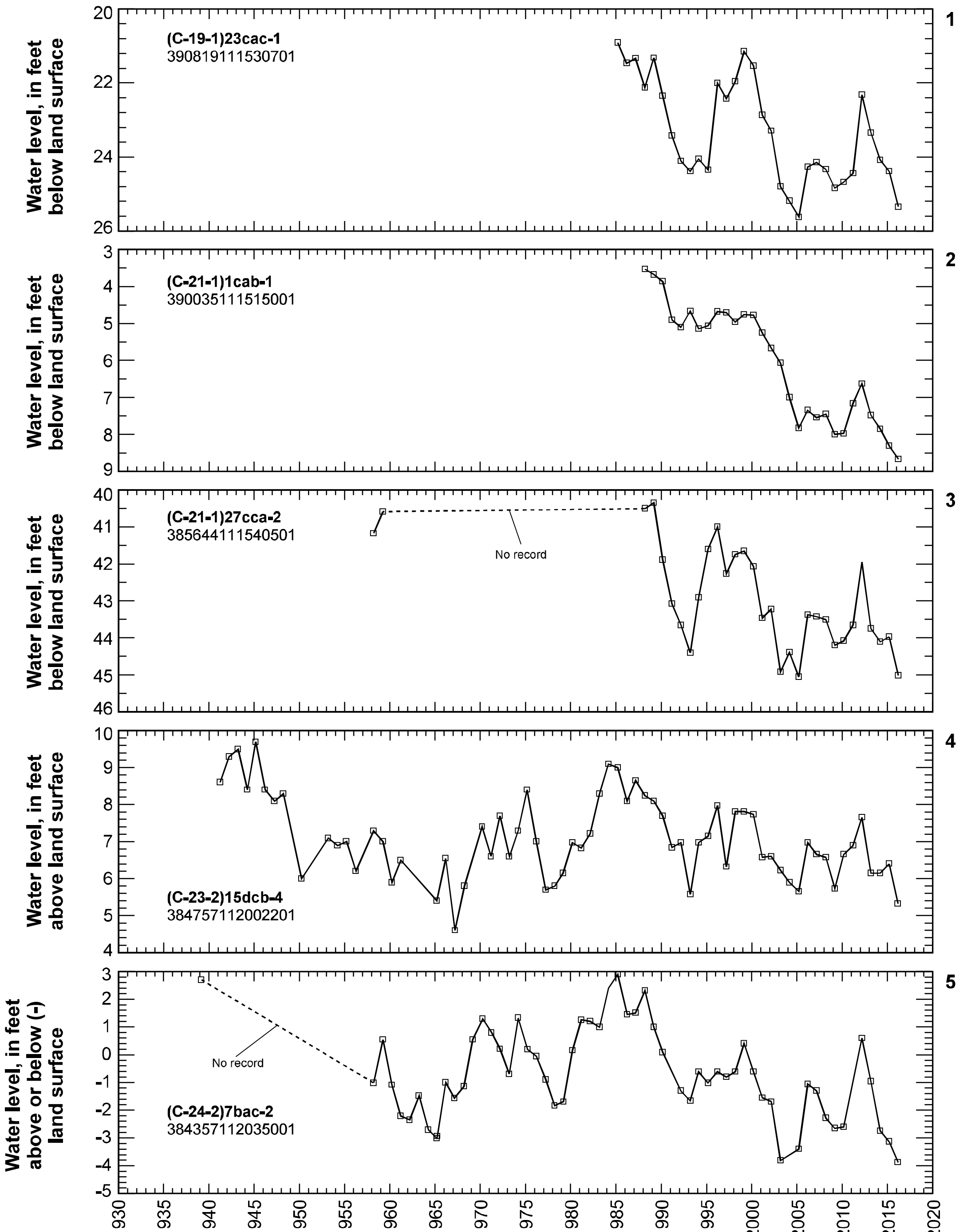


Figure 21. Relation of water level in selected wells in central Sevier Valley to annual discharge of the Sevier River at Hatch, Utah, to cumulative departure from average annual precipitation at Richfield Radio KVSC, to annual withdrawal from wells, and to concentration of dissolved solids in water from well (C-23-2)15dcb-4.

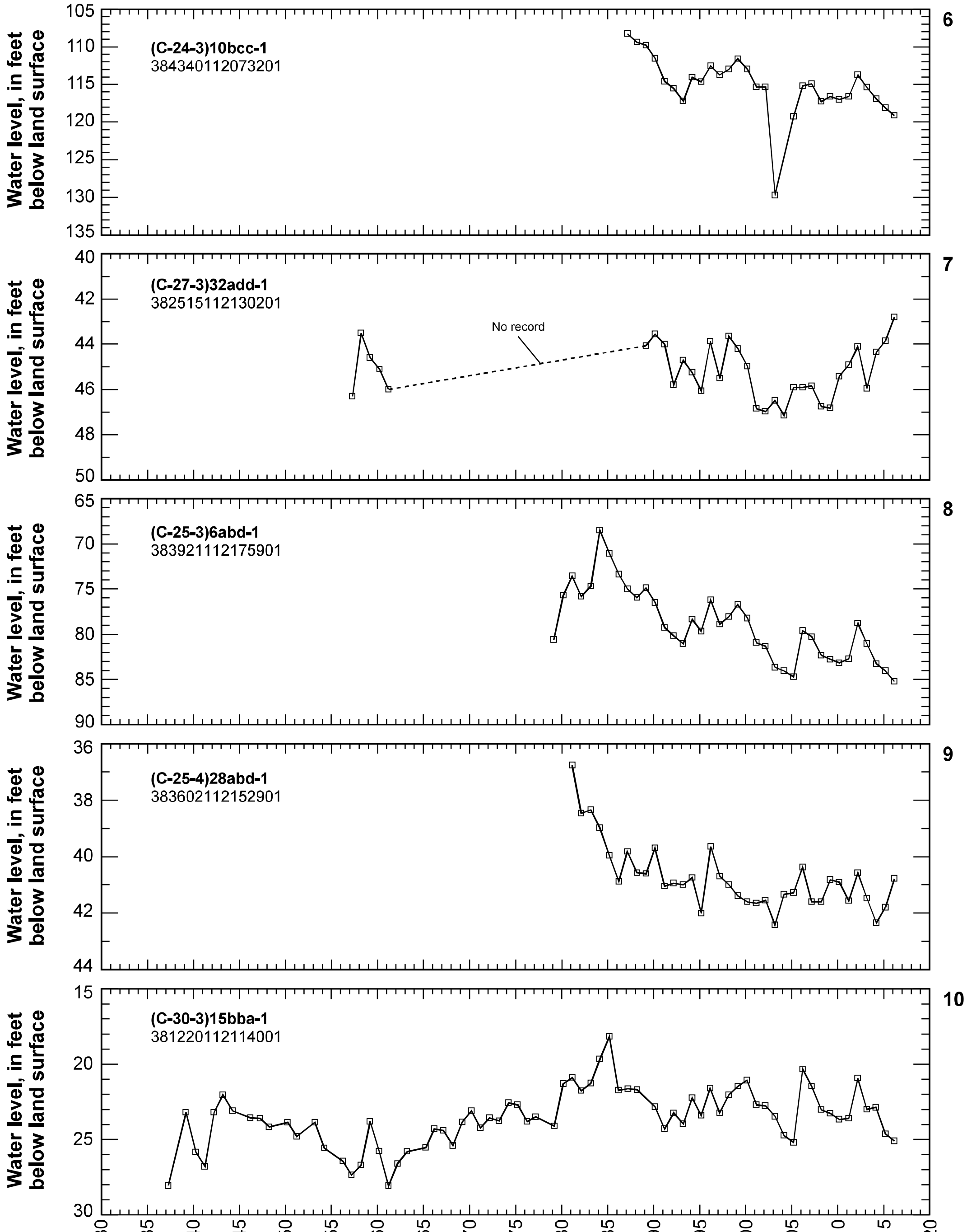


Figure 21. Relation of water level in selected wells in central Sevier Valley to annual discharge of the Sevier River at Hatch, Utah, to cumulative departure from average annual precipitation at Richfield Radio KVSC, to annual withdrawal from wells, and to concentration of dissolved solids in water from well (C-23-2)15dcb-4.—Continued

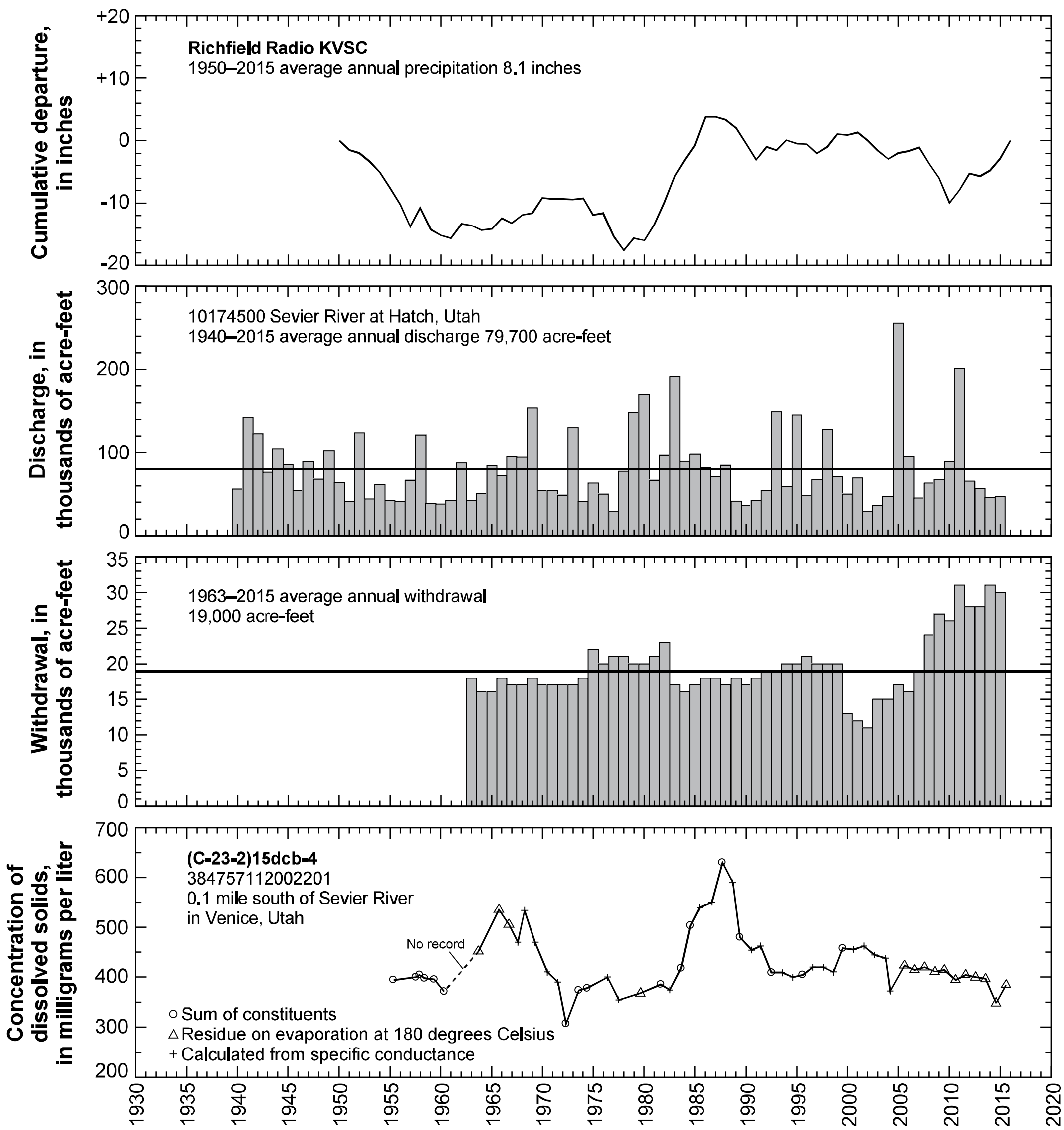
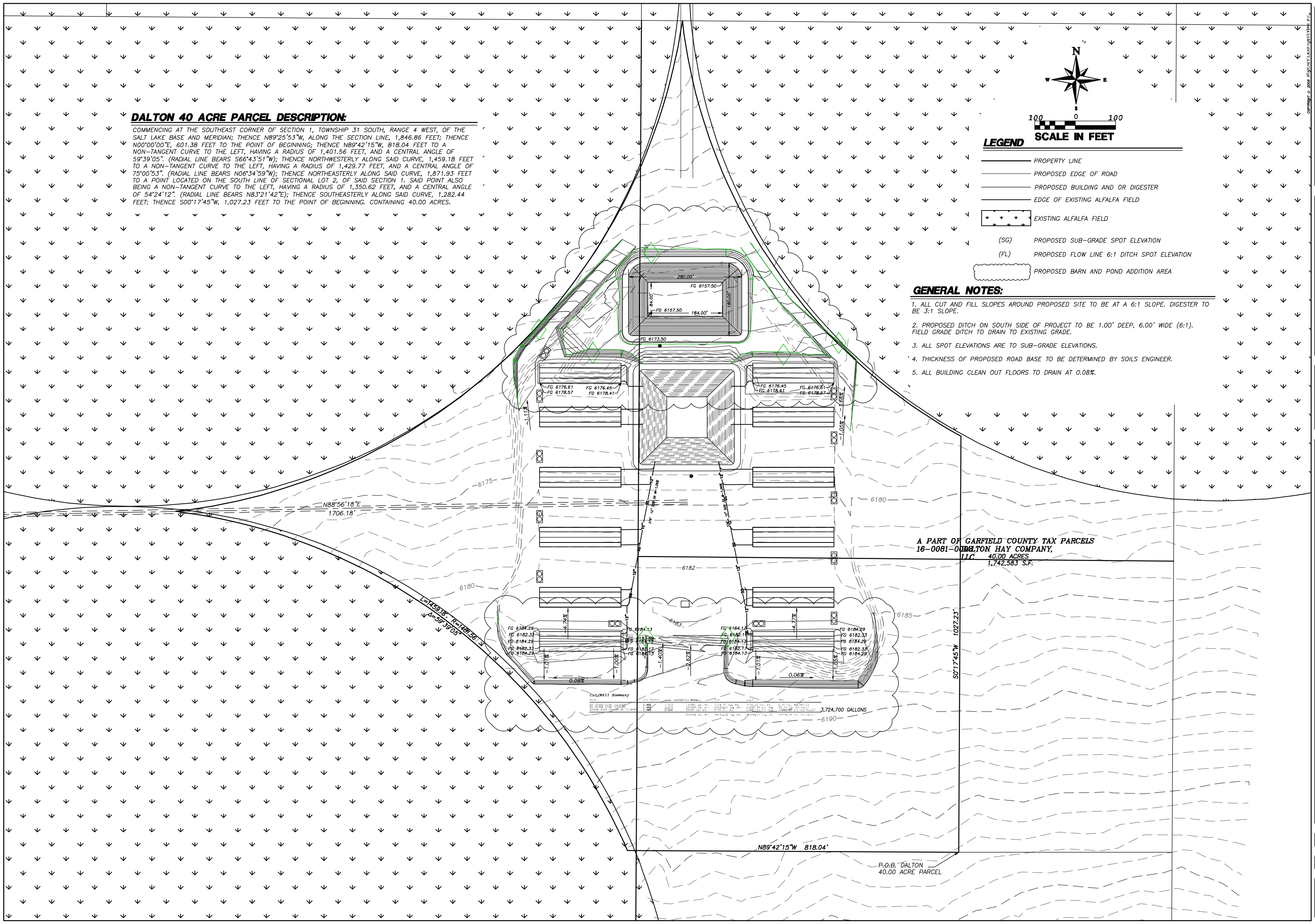


Figure 21. Relation of water level in selected wells in central Sevier Valley to annual discharge of the Sevier River at Hatch, Utah, to cumulative departure from average annual precipitation at Richfield Radio KVSC, to annual withdrawal from wells, and to concentration of dissolved solids in water from well (C-23-2)15dcb-4.—Continued

Attachment C – Project Documents

SITE PLAN OF:
DALTON-8800 HEAD WEAN TO FINISH SITE

CIRCLEVILLE, PIUTE COUNTY, UTAH
SITE LOCATION: GARFIELD COUTNY, UTAH
LOCATED IN THE S 1/2 OF SECTION 1, T31S, R3W, S.L.B.&M.



DALTON 40 ACRE PARCEL DESCRIPTION:

COMMENCING AT THE SOUTHEAST CORNER OF SECTION 1, TOWNSHIP 31 SOUTH, RANGE 4 WEST, OF THE SALT LAKE BASE AND MERIDIAN; THENCE N89°25'53"W, ALONG THE SECTION LINE, 1,846.86 FEET; THENCE N00°00'00"E, 601.38 FEET TO THE POINT OF BEGINNING; THENCE N89°42'15"W, 818.04 FEET TO A NON-TANGENT CURVE TO THE LEFT, HAVING A RADIUS OF 1,401.56 FEET, AND A CENTRAL ANGLE OF 59°39'05". (RADIAL LINE BEARS S66°43'51"W); THENCE NORTHWESTERLY ALONG SAID CURVE, 1,459.18 FEET TO A NON-TANGENT CURVE TO THE LEFT, HAVING A RADIUS OF 1,429.77 FEET, AND A CENTRAL ANGLE OF 75°00'53". (RADIAL LINE BEARS N06°34'59"W); THENCE NORTHEASTERLY ALONG SAID CURVE, 1,871.93 FEET TO A POINT LOCATED ON THE SOUTH LINE OF SECTIONAL LOT 2, OF SAID SECTION 1. SAID POINT ALSO BEING A NON-TANGENT CURVE TO THE LEFT, HAVING A RADIUS OF 1,350.62 FEET, AND A CENTRAL ANGLE OF 54°24'12". (RADIAL LINE BEARS N83°21'42"E); THENCE SOUTHEASTERLY ALONG SAID CURVE, 1,282.44 FEET; THENCE S00°17'45"W, 1,027.23 FEET TO THE POINT OF BEGINNING. CONTAINING 40.00 ACRES.

LEGEND

- PROPERTY LINE
- PROPOSED EDGE OF ROAD
- PROPOSED BUILDING AND OR DIGESTER
- EDGE OF EXISTING ALFALFA FIELD
- EXISTING ALFALFA FIELD
- (SG) PROPOSED SUB-GRADE SPOT ELEVATION
- (FL) PROPOSED FLOW LINE 6:1 DITCH SPOT ELEVATION
- PROPOSED BARN AND POND ADDITION AREA

GENERAL NOTES:

1. ALL CUT AND FILL SLOPES AROUND PROPOSED SITE TO BE AT A 6:1 SLOPE. DIGESTER TO BE 3:1 SLOPE.
2. PROPOSED DITCH ON SOUTH SIDE OF PROJECT TO BE 1.00' DEEP, 6.00' WIDE (6:1). FIELD GRADE DITCH TO DRAIN TO EXISTING GRADE.
3. ALL SPOT ELEVATIONS ARE TO SUB-GRADE ELEVATIONS.
4. THICKNESS OF PROPOSED ROAD BASE TO BE DETERMINED BY SOILS ENGINEER.
5. ALL BUILDING CLEAN OUT FLOORS TO DRAIN AT 0.08%.

NO	DESCRIPTION	DATE	BY

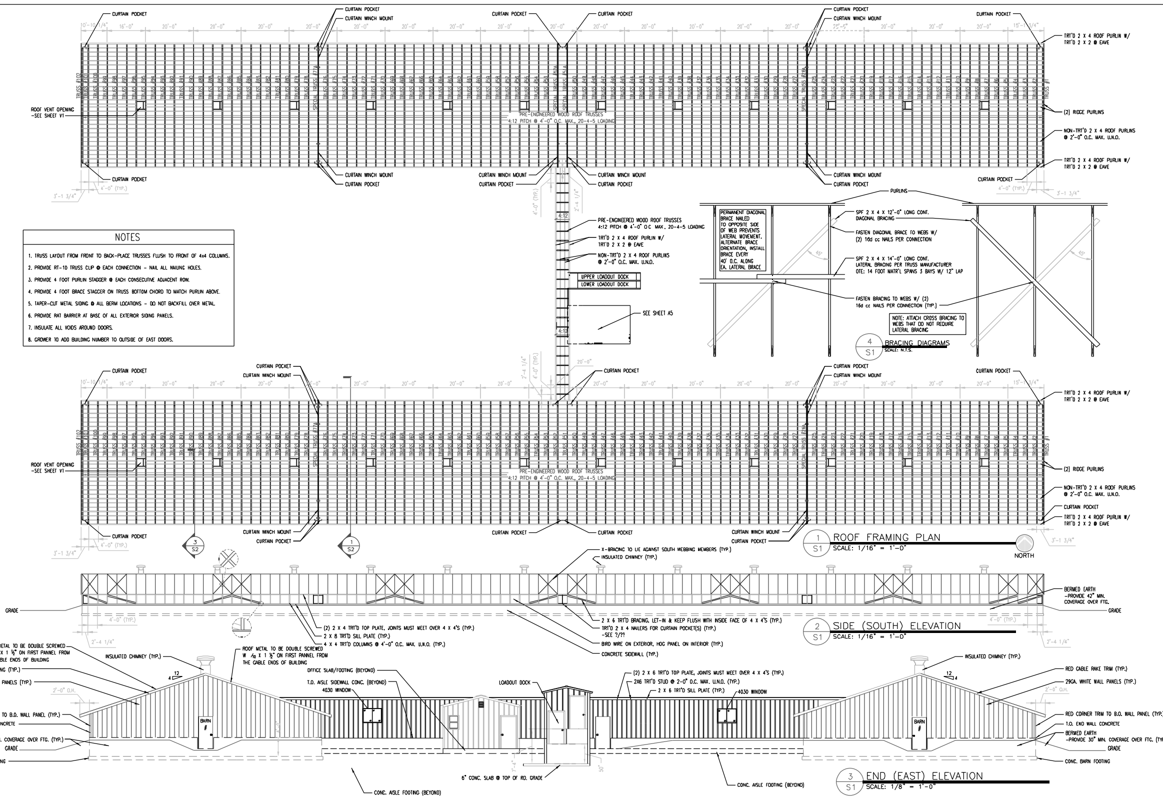
REVISIONS

WOOLSEY LAND SURVEYING, P.C.
Land Surveyors - Land Planners
50 WEST 3600 NORTH
ENOCH CITY, UTAH 84721
435-559-2315 CELL
steve@tfrowest.com

DATE: 8-29-2020
SCALE: 1"=80'

JOB NO.
1319

SHEET NO:
1 OF 1



NOTES

1. TRUSS LAYOUT FROM FRONT TO BACK-PLACE TRUSSES FLUSH TO FRONT OF 4x4 COLUMNS.
2. PROVIDE RT-10 TRUSS CLIP @ EACH CONNECTION - NAIL ALL NAILING HOLES.
3. PROVIDE 4 FOOT PURLIN STAGGER @ EACH CONSECUTIVE ADJACENT ROW.
4. PROVIDE 4 FOOT BRACE STAGGER ON TRUSS BOTTOM CHORD TO MATCH PURLIN ABOVE.
5. TAPER-CUT METAL SIDING @ ALL BERM LOCATIONS - DO NOT BACKFILL OVER METAL.
6. PROVIDE RAT BARRIER AT BASE OF ALL EXTERIOR SIDING PANELS.
7. INSULATE ALL VOIDS AROUND DOORS.
8. GROWER TO ADD BUILDING NUMBER TO OUTSIDE OF EAST DOORS.

No.	Revisions	Date	By	No.	Revisions	Date	By	Reference Dwg.

Smithfield Hog Prod.
341 South Main
Milford , UT 84752
Phone :(435) 387-2107

Project Title : 4400 HEAD H BARN

Sheet Title : ROOF FRAMING PLAN & ELEVATIONS

Project Location :

Sheet Group : S1

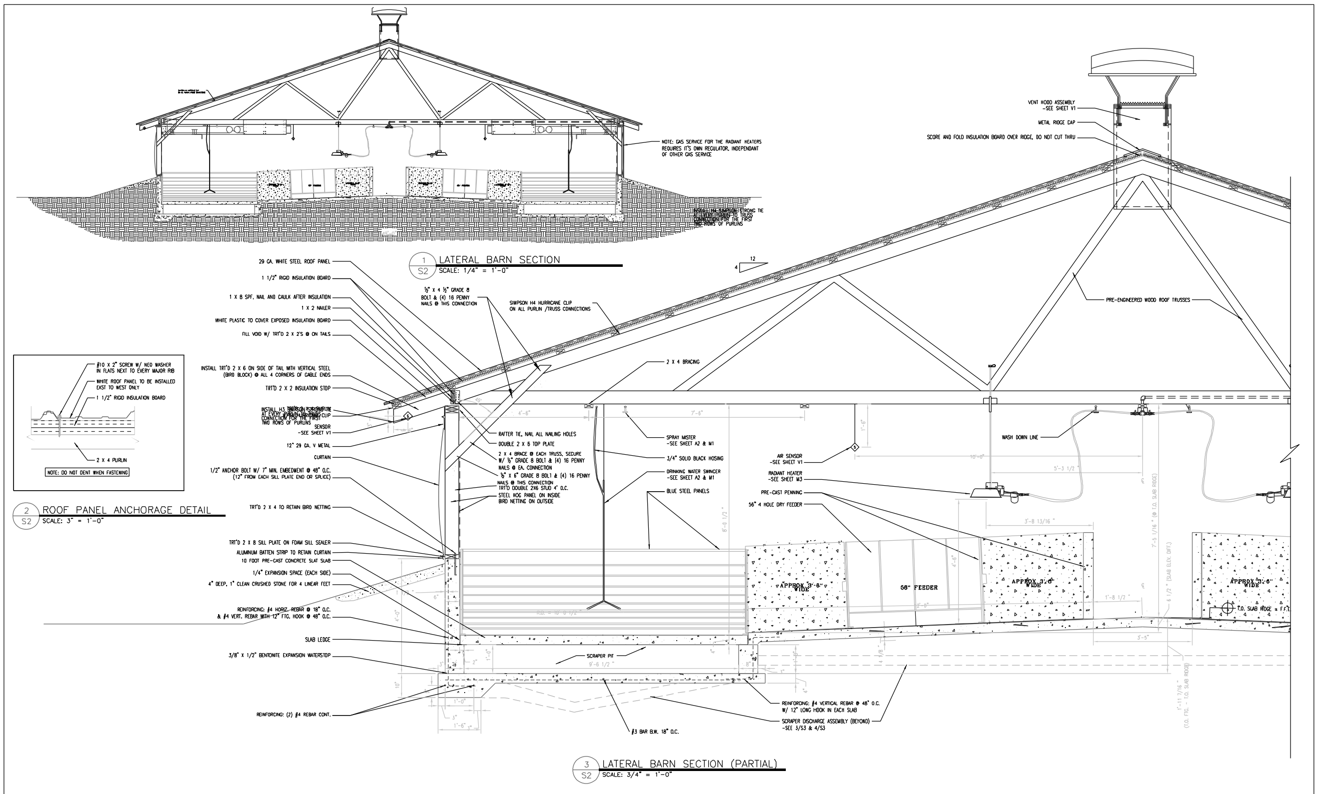
Drawn By: T BLACKNER

Checked By:

Date Drawn:

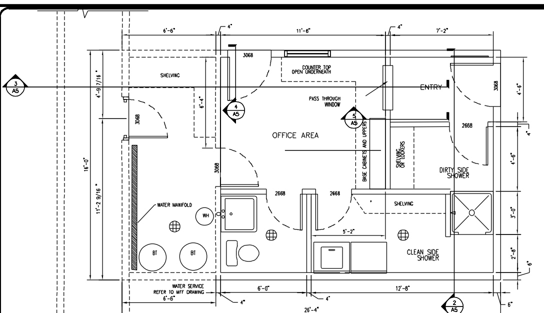
Scale:

Sheet #: of

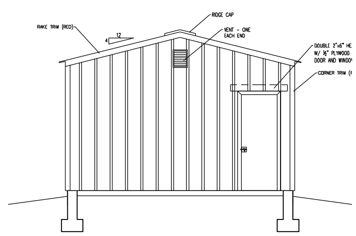


No.	Revisions	Date	By	No.	Revisions	Date	By	Reference Dwg.

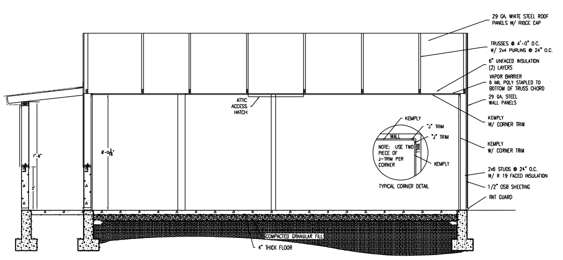
Smithfield Hog Prod. 341 South Main Milford , UT 84752 Phone :(435) 387-2107 THIS DRAWING IS THE PROPERTYOF CIRCLE FOUR FARMS. ANY REPRODUCTION OR OTHER USE OF THIS DOCUMENT WITHOUT EXPRESS WRITTEN CONSENT OF CIRCLE FOUR FARMS IS PROHIBITED.	THIS DOCUMENT IS FOR INFORMATION PURPOSES ONLY. THE PREPARER OF THE DOCUMENT DISCLAIMS ANY RESPONSABILITY WHATSOEVER CONCERNING THE ACCURACY OF THE DOCUMENT. ANY USE OF THIS DOCUMENT WITHOUT CONSULTING A QUALIFIED ENGINEER OR SUCH OTHER CONSTRUCTION PROFESSIONAL DOES SO AT THEIR OWN RISK AND ASSUMES SUCH RISK. NO REPRESENTATIONS OF WARRANTY, EXPRESS OR IMPLIED, ARE CONFERRED BY OR TO ANY USER OF THIS DOCUMENT.	Project Title : 4400 HEAD H BARN Sheet Title : LATERAL SECTIONS & DETAILS	Project Location : Sheet Group : S2	Drawn By: T BLACKNER Checked By: Date Drawn:	Scale: Sheet #: of



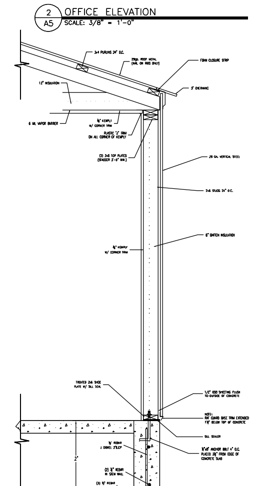
1 OFFICE PLAN
A5 SCALE: 3/8" = 1'-0"



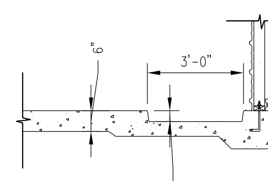
2 OFFICE ELEVATION
A5 SCALE: 3/8" = 1'-0"



3 OFFICE SECTION
A5 SCALE: 3/8" = 1'-0"



4 OFFICE WALL SECTION
A5 SCALE: 1" = 1'-0"



5 OFFICE SECTION
A5 SCALE. 3/8" = 1'-0"

SPECIFICATIONS: CONCRETE CONTRACTOR

1. CONTRACTOR RESPONSIBLE TO SCHEDULE DELIVERY OF CONCRETE AT 4000 PSI.
2. PROVIDE AND PLACE ALL REQUIRED REINFORCING AND ANCHOR BOLTS WITH WASHERS AND NUTS.
3. PROVIDE AND ROUGH-IN ALL REQUIRED DRAIN LINES AND SERVICE UTILITY ENTRANCES AS SHOWN ON DRAWINGS. DOUBLE CHECK DRAIN ELEVATIONS FOR PROPER SLOPE OF CONCRETE FLOOR TO DRAINS. EXTEND ALL ROUGH IN PLUMBING LINES TO MIN. 3' OUTSIDE OF THE BUILDING LINES.
4. PLACE FILL SAND AS REQUIRED MACHINE COMPACTION REQUIRED.
5. FORM AND POUR OFFICE FLOOR TRUE TO FORM WITH SMOOTH TROWELED FINISH. PROVIDE RECESSED AREA AS SHOWN ON DRAWINGS.
6. STRIP FORMS AND COMPLETELY CLEAN UP SITE OF ITEMS AND REFUSE RELATED TO YOUR WORK.
7. CONTRACTOR TO FURNISH TO CUSTOMER PROOF OF GENERAL LIABILITY AND WORKMANS COMPENSATION INSURANCE PRIOR TO COMMENCING WORK. A COPY OF CERTIFICATE OF INSURANCE TO BE FILED WITH MFF. ACCOUNTING DEPT.
8. COMPLETELY CLEANUP SITE OF ITEMS AND REFUSE RELATED TO YOUR WORK. ALL WORK TO BE DONE IN A WORKMAN LIKE MANNER AND SITE KEPT FREE OF TRASH, DEBRIS, AND HAZARDOUS FLUIDS SUCH AS DIESEL, HYDRAULIC, MOTOR OIL, ETC.
9. CONTRACTOR RESPONSIBLE FOR WEATHER RELATED PROTECTION.

SPECIFICATIONS: PLUMBING CONTRACTOR

1. PROVIDE LABOR AS REQUIRED.
2. INSTALL ALL PLUMBING INSIDE THE OFFICE INCLUDING SHUT-OFF VALVES, WATER METERS, MEDICATORS, SEDIMENT TRAPS, BALL VALVES, PRESSURE TANK CONNECTION, HOSE BIBS FOR WASHING MACHINE, DEEP BASIN SINK CONNECTIONS, SHOWER CONNECTIONS, HOT WATER HEATER CONNECTIONS, BOOT WASH HOSE BIB, TRAPS FOR DRAINS, AND OTHER ITEMS REQUIRED FOR A COMPLETE INSTALLATION.
3. INCLUDE INSTALLATION OF SEPTIC SYSTEM PER COUNTY REGULATIONS
4. FLUSH AND CHECK SYSTEM FOR LEAKS.
5. CONTRACTOR TO FURNISH TO CUSTOMER PROOF OF GENERAL LIABILITY AND WORKMANS COMPENSATION INSURANCE PRIOR TO COMMENCING WORK. A COPY OF CERTIFICATE OF INSURANCE TO BE FILED WITH MFF. ACCOUNTING DEPT.
6. COMPLETELY CLEANUP SITE OF ITEMS AND REFUSE RELATED TO YOUR WORK. ALL WORK TO BE DONE IN A WORKMAN LIKE MANNER AND SITE KEPT FREE OF TRASH, DEBRIS, AND HAZARDOUS FLUIDS SUCH AS DIESEL, HYDRAULIC, MOTOR OIL, ETC.
7. CONTRACTOR RESPONSIBLE FOR WEATHER RELATED PROTECTION.

SPECIFICATIONS: ELECTRICAL CONTRACTOR

1. PROVIDE ALL MATERIALS AND LABOR AS REQUIRED FOR A COMPLETE INSTALLATION.
2. PROVIDE TEMP SERVICE BOARD FOR CONSTRUCTION PHASE.
3. PROVIDE AND INSTALL ALL CONDUIT, LIGHTS, OUTLETS, DEVICES, CONNECTIONS TO APPLIANCES AS REQUIRED, CLOTHES DRYER OUTLET, LOW VOLTAGE CONNECTIONS, AND ALL OTHER ITEMS SHOWN ON DRAWINGS FOR A COMPLETE INSTALLATION.
4. CONTRACTOR RESONSIBLE TO HOOK UP MODEM, TELEPHONE LINE IN OFFICE.
5. CONTRACTOR TO FURNISH TO CUSTOMER PROOF OF GENERAL LIABILITY AND WORKMANS COMPENSATION INSURANCE PRIOR TO COMMENCING WORK.
6. COMPLETELY CLEANUP SITE OF ITEMS AND REFUSE RELATED TO YOUR WORK. ALL WORK TO BE DONE IN A WORKMAN LIKE MANNER AND SITE KEPT FREE OF TRASH, DEBRIS, AND HAZARDOUS FLUIDS SUCH AS DIESEL, HYDRAULIC, MOTOR OIL, ETC.
7. CONTRACTOR RESPONSIBLE FOR WEATHER RELATED PROTECTION.

SPECIFICATIONS: FRAMING CONTRACTOR

1 PROVIDE LABOR AND NAILS ONLY UNLESS OTHERWISE SPECIFIED
2. INSTALL SILL SEALER, TREATED BOTTOM PLATES, SUDS, TOP PLATES, DOOR AND WINDOW OPENINGS WITH HEADERS AS SHOWN, TRUSSES, PURLINS, GIRTS AND BRACING.
3. FRAME INTERIOR WALLS AS SHOWN ON DRAWINGS.
4. INSTALL INSULATION AS SHOWN ON DRAWINGS.
5. INSTALL ALL ROOF PANELS, WALL PANELS, TRIM AND FLASHINGS AS REQUIRED.
6. INSTALL DOORS AND WINDOWS PLUMB, TRUE, AND LEVEL. CHECK FOR SMOOTH OPERATION AND CAULK AS NEEDED TO PREVENT DRAFTS.
7. INSTALL INTERIOR WALL AND CEILING COVER AS SHOWN ON DRAWINGS AS WELL AS ALL TRIM WORK REQUIRED.
8. CAULK INSIDE AND OUTSIDE AS REQUIRED.
9. CONTRACTOR TO FURNISH TO CUSTOMER PROOF OF GENERAL LIABILITY AND WORKMANS COMPENSATION INSURANCE PRIOR TO COMMENCING WORK.
10. COMPLETELY CLEANUP SITE OF ITEMS AND REFUSE RELATED TO YOUR WORK. ALL WORK TO BE DONE IN A WORKMAN LIKE MANNER AND SITE KEPT FREE OF TRASH, DEBRIS, AND HAZARDOUS FLUIDS SUCH AS DIESEL, HYDRAULIC, MOTOR OIL, ETC.
11. CONTRACTOR RESPONSIBLE FOR WEATHER RELATED WORK.

No.	Revisions	Date	By	No.	Revisions	Date	By	Reference Dwg.

Smithfield Hog Prod.
341 South Main
Milford , UT 84752
Phone : (435) 387-2107

Project Title : 4400 HEAD H BARN

Sheet Title : OFFICE PLAN, ELEVATIONS, AND DETAILS

Project Location :

Sheet Group : A4

Drawn By: T BLACKNER

Checked By:

Date Drawn:

Scale:

Sheet #: of

MATERIAL LIST

THE SYMBOLS AND THE MATERIAL LIST ARE FOR THE CONVENIENCE OF THE CONTRATOR. EACH CONTRACTOR SHALL BE RESPONSIBLE FOR VERIFICATION OF QUANTITIES AND SHALL FURNISH ALL MATERIAL REQUIRED, WHETHER SPECIFIED OR NOT, TO PRODUCE A SATISFACTORY WORKING SYSTEM.

CATALOG NUMBERS SHALL NOT BE CONSIDERED COMPLETE BUT ARE GIVEN ONLY TO AID THE CONTRACTOR IN THE SEARCH FOR MATERIAL. NO MATERIAL SHALL BE ORDERED BY MANUFACTURER AND CATALOG NUMBER ONLY. EACH CONTRACTOR SHALL FIRST READ THE COMPLETE DESCRIPTION OF THE MATERIAL ON THE DRAWINGS AND SPECIFICATIONS. THE FIRST MANUFACTURER LISTED IS THE BASIS OF DESIGN. "STANDARD COLOR" INDICATES FACTORY FINISH COLORS AVAILABLE AT NO ADDITIONAL CHARGE.

WHERE SEVERAL DEVICES ARE GANGED TOGETHER, THE PLATE SHALL BE OF THE GANGED STYLE FOR THE NUMBER OF DEVICES USED.

ITEM	SYMBOL	DESCRIPTION	APPROVED MFG
1	CONDUIT	ALL CONDUIT SHALL BE RIGID PVC SCHEDULE 40 UNLESS OTHERWISE NOTED. ELECTRICAL CONTRACTOR SHALL ALLOW FOR EXPANSION AND CONTRACTION.	
2	0	PANEL BOARD SURFACE MOUNT, 120/240 VOLT , 1 PHASE, 3 WIRE, S/N, GROUND BUS PLUG-ON BREAKERS. COPPER BUS NEMA 3R ENCLOSURE SEE ONE-LINE DIAGRAM AND PANEL SCHEDULE.	SQUARE D QO
3	PANEL B1, B2, B3, B4	PANEL BOARD SURFACE MOUNT 120/240 VOLT, 1 PHASE, 3 WIRE, S/N, GROUND BUS PLUG-ON BREAKERS, COPPER BUS NEMA 3R ENCLOSURE. SEE ONE-LINE DIAGRAM AND PANEL SCHEDULE. A 42 SPACE PANEL	SQUARE D QO
4	SO	SWITCH TOGGLE HANDLE, MAINTAINED CONTACT, SINGLE POLE, SINGLE THROW, SPECIFICATION GRADE SIDE AND BACK WIRED, 20 AMP, 120/277 VOLT. UL USTED	EAGLE LEVITON #CSB1-20 PASS & SEYMOUR
5	SS	SWITCH DOUBLE TOGGLE HANDLE, MAINTAINED CONTACT, SINGLE POLE, SINGLE THROW SPECIFICATION GRADE SIDE AND BACK WIRED, 20 AMP, 120/277 VOLT. UL USTED, COMPLETE WITH A WEATHERPROOF DEVICE COVER.	EAGLE LEVITON #CSB1-20 PASS & SEYMOUR COVER SHALL BE FARMTEK #LJ2305 OR EQUAL
6		RECEPTACLE, DUPLEX, 125 VOLT, 20 AMP, 3 WIRE GROUNDING TYPE, NYLON OR POLYCARBONATE FACE, STRAIGHT BLADE, N.E.M.A. 5-20R, U.L. LISTED. COMPLETE WITH WEATHERPROOF DEVICE COVER AND MOUNTED IN A FS PVC BOX. COMPLETE WITH PVC SINGLE GANG N.E.M.A. 3R IN USE COVER.	EAGLE #CR20 PASS & SEYMOUR BRYANT COVER SHALL BE FARMTEK #LJ5000 OR EQUAL
7		RECEPTACLE, SIMPLEX, 125 VOLT, 15 AMP, 3 WIRE GROUNDING TYPE, NYLON OR POLYCARBONATE FACE, STRAIGHT BLADE, N.E.M.A. 5-15R, U.L. LISTED COMPLETE WITH WEATHERPROOF DEVICE COVER AND MOUNTED IN A FS PVC BOX. COMPLETE WITH PVC SINGLE GANG N.E.M.A. 3R IN USE COVER.	EAGLE LEVITON #5258 PASS & SEYMOUR COVER SHALL BE FARMTEK #LJ5005 OR EQUAL
8		RECEPTACLE, SIMPLEX, 250 VOLT, 50 AMP, SPECIFICATION GRADE, 2 POLE, 3 WIRE GROUNDING TYPE, BROWN NYLON OR POLYCARBONATE FACE, STRAIGHT BLADE, N.E.M.A. 6-50R, U.L. USTED. COMPLETE WITH WEATHERPROOF DEVICE COVER AND MOUNTED IN A FS PVC BOX. COMPLETE WITH PVC N.E.M.A. 3R IN USE COVER.	HUBBLE #5661 BRYANT EAGLE LEVITON PASS & SEYMOUR COVER SHALL BE TAYMAC #9551D OR EQUAL
9	FDS/1	FUSED ELECTRICAL DISCONNECT SWITCH, ON/OFF OPERATOR, CORROSION-RESISTANT PVC ENCLOSURE, WEATHERPROOF AND WATERTIGHT, RATED FOR 1 HP AT 240 VOLTS SCREW IN TYPE PLUG FUSE. SIZE FUSES PER MOTOR FULL LOAD AMPS.	FARMTEK #CR2400 OR EQUAL
10	MDP	PANELBOARD SURFACE MOUNT. 120/240 VOLT, 1 PHASE, 3 WIRE, S/N GROUND BUS 400 AMP BOLT-ON BREAKERS N.E.M.A. 3R ENCLOSURE, SURFACE MOUNT, SEE ONE LINE DIAGRAM.	SQUARE D QO CUTLER HAMMER
11		RECEPTACLE, DUPLEX, 125 VOLT, 20 AMP, 3 WIRE GROUNDING TYPE, NYLON OR POLYCARBONATE FACE, STRAIGHT BLADE, N.E.M.A. 5-20R, U.L. LISTED, INSTALL IN SINGLE GANG BOX AND COVER.	LEVITON #3420 PASS & SEYMOUR BRYANT EAGLE
12		RECEPTACLE, DOULE DUPLEX, 125 VOLT, 20 AMP, 3 WIRE GROUNDING TYPE, NYLON OR POLYCARBONATE FACE, STRAIGHT BLADE, N.E.M.A. 5-20R, U.L. LISTED, INSTALL IN COMMON SURFACE MOUNTED BOX COVER.	LEVITON #CR20 PASS & SEYMOUR BRYANT EAGLE
13		RECEPTACLE, DUPLEX, 250 VOLT, 50 AMP, 2 POLE, 3 WIRE GROUNDING TYPE, BROWN NYLON OR POLYCARBONATE FACE, STRAIGHT BLADE, N.E.M.A. 6-50R, U.L. LISTED, COMPLETE WITH BOX AND COVER.	HUBBELL #5661 BRYANT LEVITON PASS & SEYMOUR
14	TS/1	THERMOSTATIC SWITCH FOR SPLIT CURTAIN CONTROL	*
15	J/1	JUNCTION BOX 12" X 12" X 6"	* (OPTIONAL MATERIAL)
16	MTS/1	GRADE LEVEL MANUAL TRANSFER SWITCH, 400 AMP MAIN CONTACTS AND 400 AMP AUXILIARY CONTACTS 600 VOLT, 3 POLE FOR SWITCHING OF NEUTRAL, THREE PHASE DOUBLE THROW, RATED FOR USE OUTDOORS (ONLY REQUIRED FOR SITES WITH EMERGENCY POWER)	RONK #7808 OR EQUAL EMERGENCY POWER
17	FRS/1	FORWARD/REVERSE SWITCH FOR SCRAPER MOTOR.	*
18	TC/2	TIME CLOCK (5 MINUTE) FOR SCRAPER	*
19	S	TWO SOLENOID VALVES	*
20	DS/1	DISCONNECT SWITCH, FUSED, 240 VOLT, 2 POLE, 400 AMP, SOLID NEUTRAL, GROUND LUG, N.E.M.A. 3R, INSTALL 2-350 AMP RK-1 FUSE, N.E.M.A. 3R, INSTALL 2-350 AMP RK-1 FUSE.	SQUARE D #H225NR SIEMENS CUTLER HAMMER
21		LIQUID LEVEL SENSOR	

ELECTRICAL INSTALLATION KEY

1. "1/E300" INDICATES DETAIL NUMBER/SHEET NUMBER.
2. "(DS/1)" INDICATES MATERIAL LIST ITEM IN HEX SYMBOL.
3. " (E#) " INDICATES KEY NOTE USED TO DESCRIBE ADDITIONAL INFORMATION OF WORK REQUIRED. SPECIFIC TO THE SHEET IT IS SHOWN ON.
4. SHADED FIXTURE INDICATES NIGHT LIGHT WITH CONNECTION TO EMERGENCY CIRCUIT.
5. ALL ELECTRICAL CONDUCTORS SHALL BE COPPER, UNLESS OTHERWISE NOTED.
6. INDICATES NUMBER OF WIRES IN CONDUIT. (Ground, Neutral, Phase)
7. SUBSCRIPT KEY:
   a. RECEPTACLES:
      R MOUNTED FACE DOWN ON BOTTOM CORD OF ROOF TRUSS
      O RECEPTACLES INSTALLED INSIDE OFFICE ONLY
   b. REFER TO MATERIAL LIST AND FOR FULL DESCRIPTIONS AND MANUFACTURERS OF ALL DEVICES.
8. ABBREVIATION KEY:

EC	ELECTRICAL CONTRATOR
GC	GENERAL CONTRACTOR
MC	MECHANICAL CONTRACTOR
AFF	ABOVE FINISH FLOOR
C	CONDUIT
NIC	NOT IN CONTRACT
TYP	TYPICAL
UG	UNDERGROUND
+#"	MOUNTING HEIGHT FROM FINISHED FLOOR TO CENTERLINE
E.C.	ELECTRICAL CONTRACTOR
MTG.	MOUNTING
MTR.	MOTOR

NEW WORK BY THIS CONTRACTOR (DARK SOLID LINE)

NEW WORK UNDERFLOOR OR UNDERGROUND BY THIS CONTRACTOR (DARK LONG DASHED LINE)

NEW WORK BY OTHERS (LIGHT SOLID LINE)

INDICATES DEVICE ENCLOSURE

ELECTRICAL INSTALLATION NOTES

1. CONTRACTOR SHALL COORDINATE INSTALLATION LOCATION OF CONDUIT, WIRING, AND ELECTRICAL EQUIPMENT LOCATION WITH OTHER TRADES.
2. ALL WIRING INSIDE BUILDING SHALL BE THHN COPPER. ALL FEEDER WIRING AND INCOMING SERVICE SHALL BE ALUMINUM UNDERGROUND SERVICE ENTRANCE (U.S.E) WITH XLPE INSULATION.
3. THE ELECTRICAL CONTRACTOR SHALL FURNISH AND INSTALL ALL TEMPERATURE CONTROL WIRING AND TERMINATIONS.
4. ALL RACEWAY INSIDE THE FINISH BUILDINGS SHALL BE IN PVC SCHEDULE 40 CONDUIT UNLESS NOTED OTHERWISE.
5. ALL WIRING SHALL BE LABELED WITH WIRE MARKERS AT ALL SERVICE LOCATIONS (I.E. JUNCTION BOXES, PANELS, DISCONNECT SWITCHES, UNIQUE SWITCHES). UNIQUE NUMBERS SHALL BE ASSIGNED FOR EACH DEVICE AND UTILIZED FOR ALL BUILDINGS.
6. ALL WORK SHALL CONFORM TO THE LATEST EDITION OF THE NATIONAL ELECTRICAL CODE. ALL INSTRUCTIONS ARE MEANT AS A GUIDE AND IS NOT MEANT TO REPLACE THE NATIONAL ELECTRICAL CODE.
7. ELECTRICAL EQUIPMENT AND INSTALLATION OF ALL ELECTRICAL MATERIAL, INSIDE THE FINISH BUILDINGS, SHALL BE WATERPROOF. CONDUIT, FITTINGS, BOXES, COVERS, SEAL JOINTS, ETC. SHALL BE INSTALLED SO THAT WATER CAN NOT PENETRATE INTERIOR'S DURING WASH DOWN AND WATER SPRAY APPLICATIONS. WEATHER TIGHT CONNECTORS ON COMMUNICATIONS BOXES SHALL BE TIGHTENED TO PREVENT MOISTURE PENETRATION
8. THE ENTIRE INSTALLATION SHALL BE GUARANTEED BY THIS CONTRATOR
9. ALL ELECTRICAL EQUIPMENT SHALL BE SURFACE MOUNTED.
10. A GREEN INSULATED GROUND CONDUCTOR SHALL BE INSTALLED IN ALL CIRCUITS TO ALL DEVICES INSIDE BUILDINGS.
11. ALL WALL MOUNTED SWITCHES AND RECEPTACLES SHALL BE INSTALLED AS NOTED.
12. ELECTRICAL CONTRACTOR SHALL BE RESPONSIBLE FOR ALL OPENINGS REQUIRED IN WALLS, OPENINGS SHALL BE SEALED.
13. ELECTRICAL CONTRACTOR SHALL PROVIDE A PERMANENT CIRCUIT DIRECTORY FOR EACH PANEL.
14. THE CONTRACTOR SHALL SELECT AND PURCHASE THE SAME NAME BRAND MATERIAL FOR ALL BUILDINGS AT ALL SITES.
15. CIRCUIT NUMBERS ARE SHOWN FOR CIRCUIT IDENTIFICATION. CIRCUITING SHALL AGREE WITH NUMBERING ON THE PANEL PROVIDED.

SPECIFICATIONS – ELECTRICAL

1. PROVIDE ALL MATERIALS AND LABOR AS REQUIRED FOR A COMPLETE INSTALLATION.
2. PROVIDE UNDERGROUND SERVICE FROM METER TO OFFICE.
3. PROVIDE UNDERGROUND SERVICE FROM OFFICE TO BARNS W/ 200 AMP PANEL.
4. PROVIDE ALL LIGHTS INCLUDING EXTERIOR LIGHTING, MOTOR WIRING, CHIMNEY ACTUATOR WIRING, CURTAIN OPERATOR WIRING, HEATER CONNECTIONS, OUTLETS, CONTROLLER POWER, INSTALLATION OF LOW VOLTAGE WIRING (SEPARATE MIN. 12" IF PLACED IN SAME TRENCH AS POWER CABLE) MODEM & ALARM, PLACEMENT OF CONTROLLER SENSORS, AUTOMATIC CURTAIN DROP OUTLET AND ALL OTHER ITEMS SHOWN ON DRAWINGS FOR A COMPLETE INSTALLATION.
5. BACKFILL ALL TRENCHES AND COMPACT PRIOR TO LEAVING SITE.
6. 1-800-CALL CONTRACTOR IS RESPONSIBLE TO CONTACT THE PUBLIC UTILITIES TO ASCERTAIN THE LOCATION OF ANY PUBLIC UTILITY LINES INCLUDING PIPELINES, ELECTRICAL LINES, WATER LINES, TILE LINES, TELEPHONE LINES, AND SEWER LINES PRIOR TO TRENCHING.
7. CONTRACTOR IS RESPONSIBLE FOR THE COST OF REPAIR TO ANY UTILITY LINES INCLUDING PIPELINES, ELECTRICAL LINES, WATER LINES, TILE LINES, TELEPHONE LINES, AND SEWER LINES IF DAMAGED WHEN TRENCHING.
8. CONTRACTOR TO FURNISH TO CUSTOMER PROOF OF GENERAL LIABILITY AND WORKMAN'S COMPENSATION INSURANCE PRIOR TO COMMENCING WORK.
9. COMPLETELY CLEAN UP SITE OF ITEMS AND REFUSE RELATED TO YOUR WORK. ALL WORK TO BE DONE IN A WORKMAN LIKE MANNER AND SITE KEPT FREE OF TRASH, DEBRIS AND HAZARDOUS FLUIDS SUCH AS DIESEL, HYDRAULIC, MOTOR OIL, ETC
10. CONTRACTOR RESPONSIBLE FOR WEATHER RELATED PROTECTION.

LIGHTING FIXTURE SCHEDULE

MOUNTING (MTG) KEY:
RE – RECESSED
SP – SUSPENDED
CL – CEILING SURFACE
WL – WALL
UC – UNDERCABINET
CV – COVE
PL – POLE
O – OTHER (SEE REMARKS)

LAMP TYPE KEY:
CF – COMPACT FLUORESCENT
IN – INCANDESCENT
HS – HIGH PRESSURE SODIUM
MH – METAL HALIDE
MV – MERCURY VAPOR
LV – LOW VOLTAGE
O – OTHER (SEE REMARKS)

MOUNTING (MTG) KEY:
RE – RECESSED
B – BLACK MILLIGROOVE
C – CLEAR ALZAK?
D – PARABOLIC
E – GOLD ALZAK
F – FRESNEL

LENS/LOUVER (L/L) KEY:
A – .125" ACRYLIC
G – TEMPERED GLASS
H – WALL WASHER
N – NONE
O – OTHER SEE REMARKS

CATALOG NUMBERS SHALL NOT BE CONSIDERED COMPLETE AND MATERIAL SHALL NOT BE ORDERED BY MANUFACTURER AND CATALOG NUMBER ONLY. FIRST READ THE COMPLETE DESCRIPTION, NOTES AND REMARKS AND THE SPECIFICATION IN COORDINATION WITH CATALOG NUMBER TO DETERMINE THE EXACT MATERIAL AND ACCESSORIES TO BE ORDERED.

ALL LAMPS FOR THIS PROJECT SHALL BE FURNISHED AND INSTALLED BY THE ELECTRICAL CONTRACTOR UNLESS OTHERWISE NOTED.

REFER TO SPECIFICATION SECTION 16510 FOR LAMP AND BALLAST REQUIREMENTS, SHOP DRAWING SUBMITTAL REQUIREMENTS, AND ADDITIONAL INFORMATION.

FIXT NO.	DESCRIPTION	FIXT SIZE	MTG	TYPE	QUANTITY AND SIZE	VOLT	L/L	MANUFACTURER	REMARKS
F2	GLASS GLOBE FRUIT JAR TYPE	5" ROUND	CL/WL BASE UP	IN	1-15W A-LAMP	120		CARLON #E960BBD E960GLB OR EQUAL	COMPLETE WITH GLASS GLOBE MOUNTING BOX
F3	OUTDOOR	-	CL/WL BASE UP	IN 150W FLOOD	2-PAR 38	120		CARLON #P8010 OR EQUAL	COMPLETE WITH LAMPS

No.	Revisions	Date	By	No.	Revisions	Date	By	Reference Dwg.

Smithfield Hog Prod.
341 South Main
Milford , UT 84752
Phone : (435) 387-2107

Project Title : 4400 HEAD H BARN

Sheet Title : SCHEDULES & NOTES

Project Location :

Sheet Group : 2651 E1

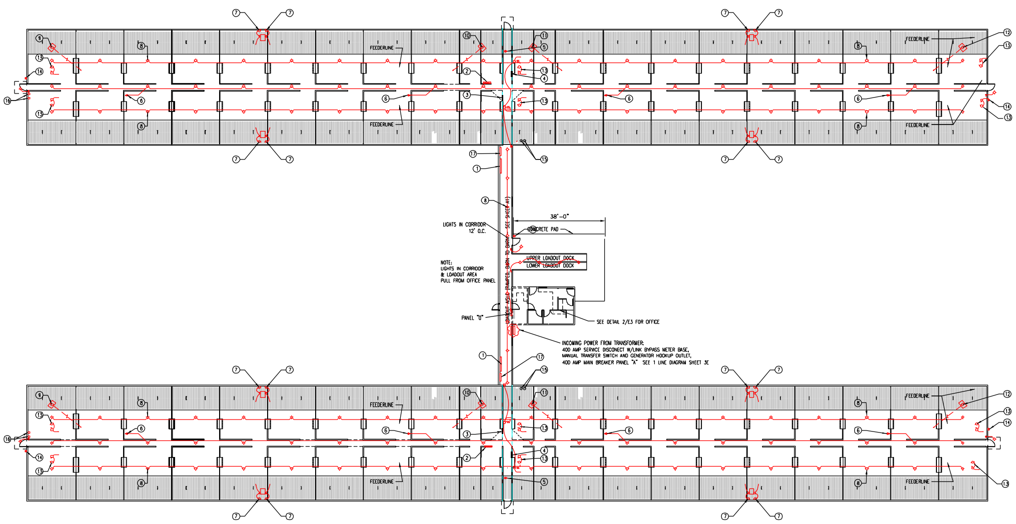
Drawn By: T BLACKNER

Checked By:

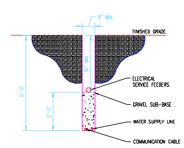
Date Drawn:

Scale:

Sheet #: of



1/E2 ELECTRICAL FLOOR PLAN
SCALE: 1/16" = 1'-0"



2/E2 UTILITY TRENCH DRAIN (TYPICAL)
SCALE: 1/2" = 1'-0"

PLAN DETAIL NOTES

(1)	EDGE VENTITLATION CONTROL PANEL @ 60" A.F.F. SEE SHEET V1
(2)	GAS CONTROL PANEL
(3)	WEST LINEAR ACTUATOR FOR CHIMNEY DAMPER, 120V 15A "6" LOCATED ON EAST SIDE OF RAFTER #?? - NOTE FULL OPEN OR FULL CLOSE LINEAR ACTUATOR, TRAVEL TIMES MUST BE 45 SECONDS
(4)	EAST LINEAR ACTUATOR FOR CHIMNEY DAMPER, 120V 15A "6" LOCATED ON EAST SIDE OF RAFTER #?? - NOTE FULL OPEN OR FULL CLOSE LINEAR ACTUATOR, TRAVEL TIMES MUST BE 45 SECONDS
(5)	CURT-O-MATIC OUTLET 115V
(6)	120V, 15A SIMPLEX OUTLET
(7)	CURTAIN MOTOR AND DISCONNECT, REFER TO CURTAIN MACHINE DETAIL 1/S3
(8)	WEATHERPROOF LIGHT FIXTURE, 100W INCANDESCENT (TYP.)
(9)-(12)	120V, 15A UNIT HEATER, LOCATE ON EACH RAFTER RESPECTIVELY - SEE NOTE 2
(13)	240V, 20A FEEDLINE MOTOR - SEE NOTE 4
(14)	250V, 50A SIMPLEX OUTLET FOR POWER WASHER
(15)	WATER SOLENOIDS: 1 - SPRAY COOL, 2 - WASH DOWN
(16)	SCRAPER - SEE NOTE 5 AND DETAIL 4/E3
(17)	PANEL B1 - SEE DETAIL 2/E4

ELECTRICAL SHEET

1. AIR SENSORS ARE TO BE LOCATED ALONG THE CENTER LINE OF THE 14th & 38th TRUSS IN FROM EACH END OF WALL, ON BOTH SIDES OF CENTER ISLE. THE SENSORS SHOULD BE INSTALLED APPROXIMATELY 8'-0" IN FROM ISLE PEN WALL AND SHOULD EXTEND 18" DOWN FROM THE BOTTOM OF THE LOWER ROOF TRUSS CHORD.
   AIR SENSORS SHALL BE INSTALLED A MINIMUM OF 24" FROM LIGHTING FIXTURES.
2. HEATERS ARE TO BE PLACED IN FROM THE END WALL BETWEEN THIRD AND FOURTH AND FOURTY-EIGHTH AND FOURTY-NINTH RAFTERS. INSTALL RECECPTACLE FOR UNIT HEATER ON RAFTER CHORD. (HEATER INTERNAL THERMOSTAT WIRES MAY BE TIED TOGETHER TO OPERATE.)
3. FASTEN THE OUTSIDE SENSOR TO SOFFIT SCREEN, AND PROTECT FROM BIRDS.
4. ABSOLUTE DISCONNECT FOR THE FEED MOTORS TO BE MOUNTED ON THE RAFTER CHORD.
5. MASTER PIT ELECTRICAL BOARD IN EACH BUIDING LOCATED AT THE NEAREST END TO THE SLURRYSTORE SCRAPER CONTROL CIRCUIT TO INCLUDE RECEPTION PIT TIME CLOCK,
   FORWARD/REVERSING CONTRACTOR AND PUMP SWITCHES
   RECEPTION PIT SWITCHES MOUNTED ON 1 BOARD ONLY CLOSEST TO THE RECEPTION PIT AREA
6. ABSOLUTE DISCONNECT SWITCH FOR ACTUATORS TO BE MOUNTED ON RAFTER CHORD.
7. ALL ARROW LEADERS POINTING TO NOTHING INDICATE THE DIRECTION OF THE WIRE HOMRUN.
8. THE POWER WASHER AND THE SCRAPER SHALL BE HOOKED UP DIRECT TO PANEL "B1" AND NOT THRU THE CONTROL PANEL.
9. RECEPTACLES NOTED WITH R MOUNTED FACE DOWN ON BOTTOM CHORD OF ROOF TRUSS. RECEPTACLES NOTED WITH O INSTALLED INSIDE OFFICE ONLY. REFER TO DWG. #3266-F-96 FOR DESCRIPTIONS AND MANUFACTURERS OF ALL DEVICES.
10. COMMUNICATIONS CABLE MUST BE RUN SEPARATED FROM LINE VOLTAGE CABLES BY 24" MINIMUM. CROSS ALL LINE VOLTAGE CABLES AT 90°.
11. CURTAIN DROP AND HEATERS MAY NOT SHARE THE SAME OUTLET.
12. ALL MOTOR DISCONNECTS MUST BE THE CORRECT POLE TO ENSURE COMPLETE SHUT OFF OF ALL POWER TO MOTORS.

SITE ELECTRICAL NOTES

1. NORTH ORIENTATION OF SITE AND BUILDING NUMBERING MAY VARY.
2. SEE SHEET E2 FOR WIRE SIZE REQUIREMENTS.
3. SEE SHEET E2 FOR GROUNDING PROCEDURES.
4. ALL FINISHING BUILDINGS ARE 48'-6" x 401'-0". THE CONTROL PANELS ARE LOCATED IN THE APROXIMATE CENTER OF EACH BUILDING.
5. THE MINIMUM DISTANCE BETWEEN BURIED COMMUNICATION CABLE AND ELECTRICAL LINES IS 24". THE PREFERRED METHOD OF PLACING THE COMMUNICATION CABLE IS IN UNDISTURBED SOIL, BACK FILLING SHOULD BE WITHOUT ROCK AND EARTH CLODS.
6. PROVISIONS MUST BE MADE TO ALLOW FOR ENOUGH CABLE TO EXTEND UNSPLICED TO THE CENTER OF THE BUILDING PLUS A 4'-0" MINIMUM SURPLUS LOOP. ALLOWABLE FOOTAGE MUST INCLUDE EXTENDING UP THE WALL AND ACROSS BUILDING AND DOWN TO THE JUNCTION BOX, PLUS SURPLUS.
7. ALL ELECTRIC IS MOUNTED MIN. 5'-0" ABOVE FLOOR.

No.	Revisions	Date	By	No.	Revisions	Date	By	Reference Dwg.

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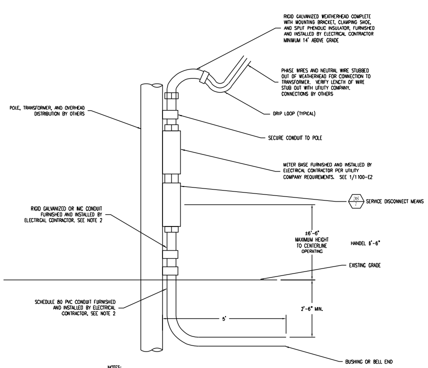
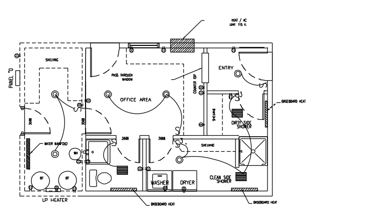
341 South Main
Milford, UT 84752
Phone: (435) 387-2107

Project Title: 4400 HEAD H BARN
Sheet Title: ELECTRICAL FLOOR PLAN
Project Location:
Sheet Group: E2
Drawn By: T BLACKNER
Checked By:
Date Drawn:
Scale:
Sheet #: of



NOTES:
1. PRIMARY GROUNDING AT POLE SERVICE ENTRANCE SHALL BE UTILITY COMPANY REQUIREMENTS
2. SIZE CONDUITS PER WIRING REQUIREMENTS

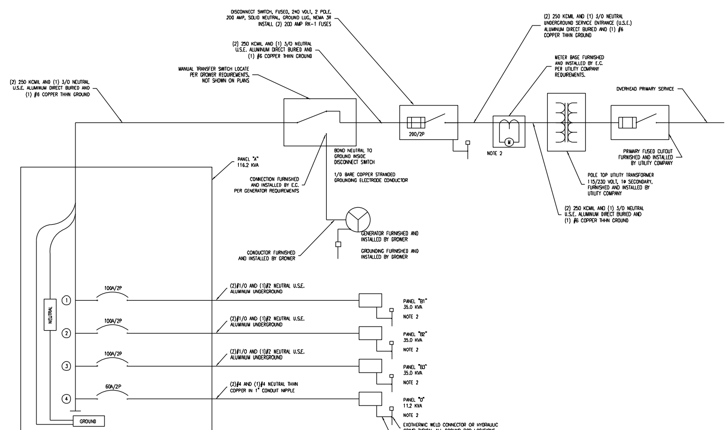
1 / E3 TYPICAL POLE TOP WEATHER HEAD
SCALE: N.T.S.



NOTES:
1. ALL CONDUIT IN OFFICE TO SWITCHES AND RECEPTICALS SHALL BE SURFACE MOUNTED EMT. (OPTIONAL DONDUIT TYPE MAY BE SCHEDULE 40 PVC PER MURPHY FARMS PERMISSION)

2. E.C. SHALL VERIFY WITH GROWER REQUIREMENTS FOR PUMP CONTROLS, PUMP FEEDER, WATER HEATER, CLOTHES DRYER AND POWER WASHER REQUIREMENTS. E.C. SHALL ADJUST RECEPTICAL LOCATION PER EQUIPMENT LOCATIONS.

2 / E3 OFFICE ELECTRICAL FLOOR PLAN
SCALE: 1/4" = 1'-0"
NORTH

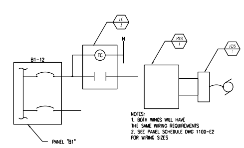


NOTES:
1. TOTAL KVA INDICATED MAY BE HIGHER THAN ACTUAL LOAD BECAUSE POWER WASHERS ARE USED ONLY WHEN THE BUILDING IS EMPTY AND PRESUMABLY ONLY ONE POWER WASHER IS USED AT A TIME.

2. GROUND ROD SHALL BE ¾"x10'-0" COPPER CLAD TOP OF GROUND ROD SHALL BE DRIVEN TO 12" BELOW GRADE.

3. SIZE OF BREAKER AND WIRING MAY VARY PER OFFICE LOAD. E.C. SHALL VERIFY REQUIREMENTS WITH OWNER.

3 / E3 ONE LINE DIAGRAM
SCALE: N.T.S.



NOTES:
1. BOTH WINGS WILL HAVE THE SAME WIRING REQUIREMENTS
2. SEE PANEL SCHEDULE DWG 1100-E2 FOR WIRING SIZES

4 / E3 SCRAPER MOTOR WIRING DIAGRAM
SCALE: N.T.S.

No.	Revisions	Date	By	No.	Revisions	Date	By	Reference Dwg.

Smithfield Hog Prod.
341 South Main
Milford , UT 84752
Phone : (435) 387-2107

Project Title : 4400 HEAD H BARN
Sheet Title : ELECTRICAL POWER SCHEMATICS
Project Location :
Sheet Group : 2651 E3
Drawn By: T BLACKNER
Checked By:
Date Drawn:
Scale:
Sheet #: of

Site Name: Pinicale 9200 Head Site 9-6 ...

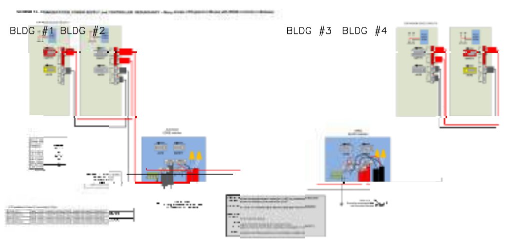
Expansion box #: Barn 1

Note: Cards in box will likely need to be moved to match this layout

Type of expansion box: 6 slots

	Slot #1		Slot #2		Slot #3		Slot #4	Slot #5	Slot #6
Notes:	West Zone (New Card)	Notes:	Middle Zone (New Card)	Notes:	East Zone (New Card)	Notes:		Notes:	Notes:
	4 inputs, 8 relays FAILSAFE (type H)		4 inputs, 8 relays FAILSAFE (type H)		4 inputs, 8 relays FAILSAFE (type H)		4 inputs, 8 relays (Type A)	Empty	Empty
IN 1	Room Probe 1 (NW)	IN 1	Room Probe 2 (NM)	IN 1	Room Probe 3 (NE)	IN 1	Brooder 1 Probe 1		
IN 2	Room Probe 4 (SW)	IN 2	Room Probe 5 (SM)	IN 2	Room Probe 6 (SE)	IN 2	Brooder 2 Probe 1		
IN 3	Water Meter	IN 3		IN 3		IN 3			
IN 4	Outside Probe	IN 4		IN 4		IN 4			
R 1 NC		R 1 NC		R 1 NC	Curtain 3 (NE) -- Open	R 1	Brooder 1 -- Low Fire		
R 1 NO	Curtain 1 (NW) -- Open	R 1 NO	Curtain 2 (NC) -- Open	R 1 NO		R 2	Brooder 1 -- High Fire		
R 2 NO	Curtain 1 (NW) -- Close	R 2 NO	Curtain 2 (NC) -- Close	R 2 NO	Curtain 3 (SE) -- Close	R 3	Brooder 2 -- Low Fire		
R 2 NC		R 2 NC		R 2 NC		R 4	Brooder 2 -- High Fire		
R 3 NC		R 3 NC	Chimney 2 (C) -- Open	R 3 NC		R 5	Soaker		
R 3 NO	Chimney 1 (W) -- Open	R 3 NO		R 3 NO	Chimney 1 (E) -- Open	R 6	Mist		
R 4 NO	Chimney 1 (W) -- Close	R 4 NO	Chimney 2 (C) -- Close	R 4 NO	Chimney 1 (E) -- Close	R 7	Night Lights		
R 4 NC		R 4 NC		R 4 NC		R 8	Heater 4		
R 5 NC	Curtain 4 (SW) -- Open	R 5 NC		R 5 NC					
R 5 NO		R 5 NO	Curtain 5 (SC) -- Open	R 5 NO	Curtain 6 (SE) -- Open				
R 6 NO	Curtain 4 (SW) -- Close	R 6 NO	Curtain 5 (SC) -- Close	R 6 NO	Curtain 6 (SE) -- Close				
R 6 NC		R 6 NC		R 6 NC					
R 7 NC		R 7 NC		R 7 NC					
R 7 NO		R 7 NO		R 7 NO					
R 8 NO	Heater 1	R 8 NO	Heater 2	R 8 NO	Heater 3				
R 8 NC		R 8 NC		R 8 NC					

1/E4 EXPANSION BOX SCH. (TYP. EACH BARN)
SCALE: N.T.S.



3/E4 RS 42 CABLE WIRE DIAGRAM
SCALE: N.T.S.

PANEL "B1" TYP. SURFACE MOUNT — 120/208 VAC 3PH 4W. 225A. ML.

CKT NO.	LOAD V.A.	LOAD TYPE	LOAD DESCRIPTION	WIRE SIZE	P	AMP SIZE	PH	AMP SIZE	P	SIZE	LOAD DESCRIPTION	LOAD TYPE	LOAD V.A.	CKT NO.
1	450	LTS	FEED MOTORS	12	1	20	A	20	1	12	LIGHTS ROOM #2	LTS	450	2
3	450	LTS	NORTH LINE	12	1	20	B	20	1	12	LIGHTS ROOM #2	LTS	450	4
5	500		FEED MOTORS	12	1	15	C	–	–	–	SPARE	–	–	6
7	850	MTR	SOUTH LINE	12	2	15	A	15	2	12	2-24" FANS	MTR	850	8
9	850		FEED MOTORS	–	–	–	B	–	–	–	ROOM #2		850	10
11	850	MTR	INCOMING	12	2	15	C	15	2	12	2-18" FANS	MTR	700	12
13	850		SW & SM CURTAIN MACHINE	–	–	–	A	–	–	–	ROOM #2		700	14
15	700	MTR	2-18" FANS	12	2	15	B	15	2	12	2-18" FANS	MTR	700	16
17	700		ROOM #1	–	–	–	C	–	–	–	ROOM #1 & #2		700	18
19	1000	MTR	HEATER ROOM #1	12	1	20	A	20	1	12	HEATER ROOM #2	MTR	1000	20
21	1000	MTR	PRE-HEAT HEATERS #1&#3	12	1	15	B	20	1	12	HALLWAY CONV. RECEP.	RECP	1000	22
23	1000	MTR	PRE-HEAT HEATER #2	12	1	15	C	20	1	12	PRE-HEAT LIGHTS	LTS	1000	24
25			SPARE		1	20	A	20	1	12	SPARE			26
27	1100	LTS	HEAT LAMPS RM1-R1	12	1	20	B	20	1	12	HEAT LAMPS RM2-R1	LTS	1100	28
29	1100	LTS	HEAT LAMPS RM1-R2	12	1	20	C	20	1	12	HEAT LAMPS RM2-R2	LTS	1100	30
31	1100	LTS	HEAT LAMPS RM1-R3	12	1	20	A	20	1	12	HEAT LAMPS RM2-R3	LTS	1100	32
33	1100	LTS	HEAT LAMPS RM1-R4	12	1	20	B	20	1	12	HEAT LAMPS RM2-R4	LTS	1100	34
35	1100	LTS	HEAT LAMPS RM1-R5	12	1	20	C	20	1	12	HEAT LAMPS RM2-R5	LTS	1100	36
37	1100	LTS	HEAT LAMPS RM1-R6	12	1	20	A	20	1	12	HEAT LAMPS RM2-R6	LTS	1100	38
39			SPARE		1	20	B	20	1		SPARE			40
41			SPARE		1	20	C	20	1		SPARE			42

2/E4 ELEC. BREAKER PANEL (TYP.)
SCALE: N.T.S.

No.	Revisions	Date	By	No.	Revisions	Date	By	Reference Dwg.

Smithfield Hog Prod.
341 South Main
Milford, UT 84752
Phone: (435) 387-2107

Project Title: 4400 HEAD H BARN

Sheet Title: PANEL SCH & RELAY ASSIGN.

Project Location:

Sheet Group: 2651 E4

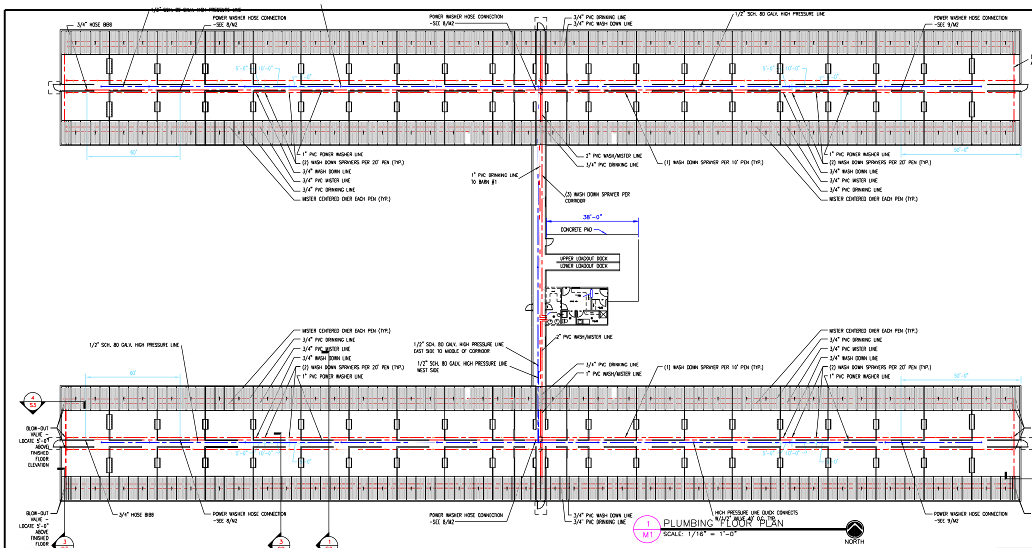
Drawn By: T BLACKNER

Checked By:

Date Drawn:

Scale:

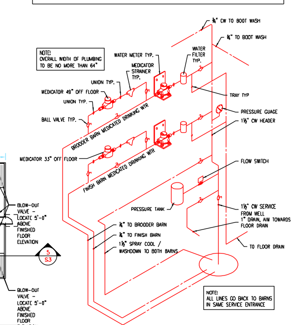
Sheet #: of



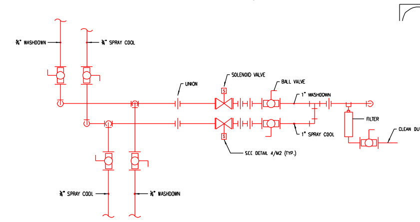
1 M1 PLUMBING FLOOR PLAN
SCALE: 1/16" = 1'-0"

PLUMBING SPECIFICATIONS

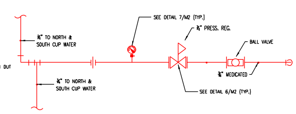
1. CRITICAL - INSTALL BALL VALVES & COMPLETELY FLUSH ALL LINES.
2. PROVIDE LABOR AS REQUIRED.
3. INSTALL ALL PLUMBING INSIDE THE BARNS INCLUDING BOTH WASH DOWN LINES AND FITTINGS, BOTH DRINKER LINES INCLUDING FITTINGS, HOSE AND CUP WATERERS BOTH SPRAY COOL LINES AND FITTINGS, PRESSURE REGULATORS, PRESSURE GAUGES ELECTRIC SOLENOID VALVES, PRESSURE WASHER CONNECTIONS AND OTHER ITEMS AS REQUIRED FOR A COMPLETE INSTALLATION.
4. MAKE CERTAIN THAT ALL SADDLE SHUT-OFF VALVES ARE ORIENTED WITH OFF POSITION TOWARDS THE LOAD-OUT DOOR OF BARN. INSTALL SADDLE SHUT-OFF VALVES ON ALL WASH DOWN AND SPRAY COOL LINES.
5. BE CERTAIN TO FLUSH ALL WATER LINES PRIOR TO USE AS FOLLOWS: SHUT OFF ALL SADDLE VALVES, CHARGE LINES AND FLUSH COMPLETLEY SHUT OFF WATER AND GLUE CAPS ON END OF WATER LINE, CHARGE SYSTEM AGAIN AND CHECK FOR LEAKS AT ANY AND ALL FITTINGS.
6. INSTALL WATER SPIGOT IN THE BARN AT END NEAREAST SLURRY STORE TANK.
7. CONTRACTOR TO FURNISH TO GENERAL CONTRACTOR PROOF OF GENERAL LIABILITY AND WORKMANS COMPENSATION INSURANCE PRIOR TO COMMENCING WORK.
8. COMPLETLY CLEANUP SITE OF ITEMS AND REFUSE RELATED TO YOUR WORK, ALL WORK TO BE DONE IN A WORKMAN LIKE MAMER AND SITE KEPT FREE OF TRASH, DEVRIS AND HAZARDOUS FLUIDS SUCH AS DIESEL, HYDRAULIC, MOTOR OIL, ETC.
9. CONTRACTOR RESPONSIBLE FOR WEATHER RELATED PROTECTION.
10. PERMANENTLY LABEL INDIVIDUAL WATER LINES AT MEDICATERS TO CORRESPONDING BARN.
11. MAXIMUM SLOPE FOR 8" WASTE LINE IS 1%.



5 M1 OFFICE WATER DISTRIBUTION DIAGRAM
SCALE: N.T.S.



4 M1 MISTER / WASHDOWN DIAGRAM
SCALE: N.T.S.



6 M1 MEDICATED WATER DIAGRAM
SCALE: N.T.S.

No.	Revisions	Date	By	No.	Revisions	Date	By	Reference Dwg.

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Project Title :	4400 HEAD H BARN
Sheet Title :	PLUMBING PLANS & DIAGRAMS
Project Location :	
Sheet Group :	2651 M1
Drawn By:	T BLACKNER
Checked By:	
Date Drawn:	
Scale:	
Sheet #:	of

PLAN DETAIL NOTES

② GAS HEATER REGULATOR PANEL. GAS PANEL SHALL ALWAYS BE PLACED NEXT TO THE VENTILATION CONTROL PANEL.
- SEE SHEET V1

③ RADIANT HEATER (17,200 BTU)/ HOSE ASSEMBLY. (TYP. PER 20' PEN)
- SEE DETAIL 2/M3

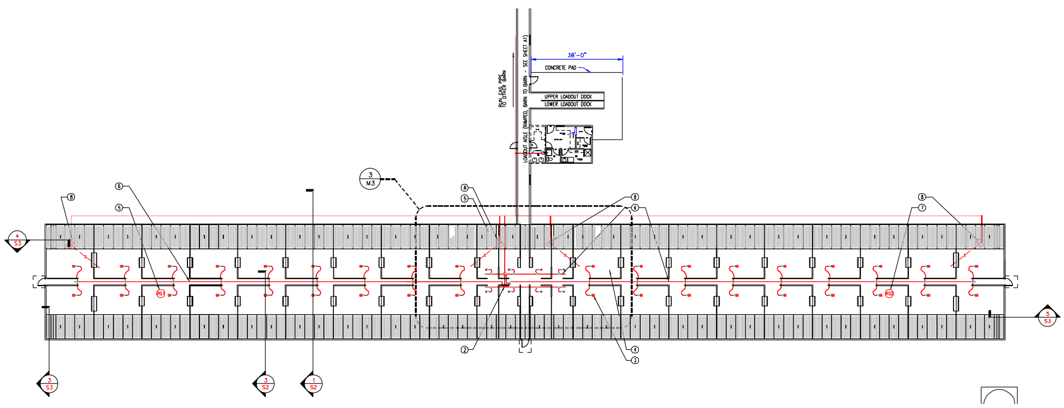
④ RADIANT HEATER (5,500 BTU), SUPPLIED BY SINGLE AUTO/MANUAL REGULATOR ON GAS PANEL. (TYP. PER 10' PEN)

⑤ RADIANT HEATER GAS SERVICE ENTRANCE, 3/4" BLACK IRON PIPE. THIS GAS SERVICE REQUIRES A REGULATOR WHICH IS INDEPENDANT FROM THE REGULATOR FOR ALL OTHER GAS APPLIANCES WITHIN THE BUILDING.
- SEE DETAIL 1/S2

⑥ GAS LINE HOME RUN, 3/4" BLACK IRON PIPE.

⑦ HEATER BRACKET RADIANT SENSOR MOUNTED IN THIRD PEN FROM BUILDING END AS INDICATED.
- SEE DETAIL 3/M3

⑧ FORCED AIR HEATER



1 / M3 HEATING FLOOR PLAN
SCALE: 1/16" = 1'-0"
NORTH

– ATTENTION –

THIS DRAWING IS PROVIDED AS AN EXAMPLE ON HOW TO CONFIGURE THE GAS HEATER SYSTEM. IT IS THE RESPONSIBILITY OF THE GAS INSTALLER TO MAKE NECESSARY CHANGES TO COMPLY WITH ALL CURRENT LOCAL AND NATIONAL GAS CODES.

RAYDOT IS NOT RESPONSIBLE FOR ANY LIABILITY RESULTING FROM THE USE/MISUSE OF THIS DOCUMENT.

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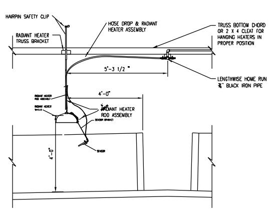
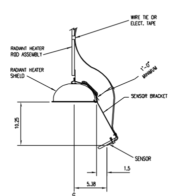
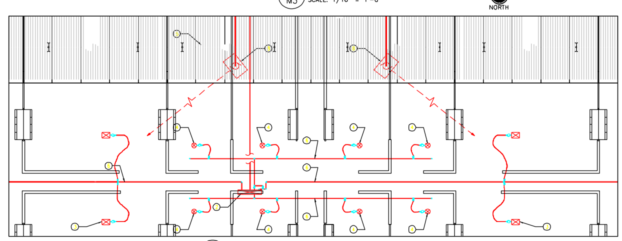


2 / M3 RADIANT HEATER ASSEMBLY
SCALE: N.T.S.



3 / M3 RADIANT HEATER SENSOR ASSEMBLY
SCALE: N.T.S.



4 / M3 BROODER BARN HEATING PLAN
SCALE: 3/16" = 1'-0"
NORTH

No.	Revisions	Date	By	No.	Revisions	Date	By	Reference Dwg.

Smithfield Hog Prod.
341 South Main
Milford , UT 84752
Phone : (435) 387-2107

Project Title : 4400 HEAD H BARN

Sheet Title : HEATING FLOOR PLANS & DIAGRAMS

Project Location :

Sheet Group : M3

Drawn By: T BLACKNER

Checked By:

Date Drawn:

Scale:

Sheet #: of

Attachment D – Specifications and QA / QC for HDPE Liners

Specifications and QA / QC for HDPE Liners

1.0 SCOPE

1.1 These specifications describe High Density Polyethylene (HDPE) Lining Membranes. The supply and installation of these materials shall be in strict accordance with the Engineer's specifications and engineering drawings and be subject to the terms and conditions of the contract. The subgrade and the HDPE material will meet the specifications contained herein and in the GRI Test Method GM13.

2.0 MATERIAL

2.1 Physical Properties:

A. The HDPE liner material used in this project shall be a minimum of 60 mil in thickness and have the properties as called out in Table 1(a) of GRI Test Method GM13 (Attachment G).

B. Raw material shall be first quality polyethylene resin containing no more than 2% clean recycled polymer by weight.

C. Melt Index (ASTM D1238 Condition 190/2.16): <= 1.0 g / 10 min.

D. Dimensional stability in each direction at +/- 2% max (ASTM D 1204 – 100^{o}C 1 hr).

E. Environmental stress crack resistance of 1500 hrs min (ASTM D 1693 Condition B).

F. The new membrane liner shall comprise HDPE material manufactured of new, first-quality products designed and manufactured specifically for the purpose of liquid containment in hydraulic structures.

G. The lining material shall be manufactured a minimum of 22.5 feet seamless widths. Labels on the roll shall identify the thickness, length and manufacturer's roll number. There shall be no factory seams.

H. The liner material shall be so produced as to be free of holes, blisters, undispersed raw materials, or any sign of contamination by foreign matter. Any such defect shall be repaired using the extrusion fusion welding technique in accordance with the manufacturer's recommendations.

I. The contractor shall, at the time of bidding, submit a certification from the manufacturer of the sheeting, stating that the sheeting meets physical property requirements for the intended application. FML rolls will not be installed, if any tested property is below the National Sanitation Foundation (NSF 54) minimum standard.

2.2 Handling:

A. Delivery: Transportation of the geomembrane shall be performed by the geomembrane manufacturer through an independent trucking firm or other party as agreed by the owner.

B. Offloading: Geomembrane, when off-loaded, shall be placed on a smooth well drained surface, free of rocks or any other protrusions which may damage the material. No special covering is necessary for geomembrane The following should be verified prior to off-loading the geomembrane:

1. Handling equipment used on the site is adequate and does not pose any risk of damage to the geomembrane.

2. Personnel informed of proper handling techniques and will do so with care.

C. Any welding rod delivered to the site prior to the geomembrane installation contractor's arrival should be kept covered and dry or placed in a storage facility.

D. Upon arrival at the site the geomembrane installation contractor shall conduct a surface observation of all rolls for defects and for damage. This inspection shall be conducted without unrolling rolls unless defects are found or suspected. The geomembrane installation contractor shall indicate any damage to the Project Manager / Owner.

E. Storage: The Project Manager / Owner shall provide storage space in a location(s) such that on-site transportation and handling are minimized. Storage space should be protected from theft, vandalism, passage of vehicles, and be adjacent to the area to be lined.

3.0 MANUFACTURER

3.1 Experience: The manufacturer of the lining material specified in the previous section shall have previously demonstrated the ability to produce this membrane by having successfully manufactured a minimum of ten million square feet of similar liner material for hydraulic lining installations. The liner material provided by the manufacturer must be listed by the NSF (National Sanitation Foundation) Standard 54.

3.2 Factory Quality Assurance and Control

A. Quality Assurance testing shall be carried out by the geomembrane manufacturer to demonstrate that the product meets this specification.

B. Raw Material: All compound ingredients of the HDPE materials shall be randomly sampled on delivery to the HDPE manufacturing plant to ensure compliance with specifications. Tests to be carried out shall include Density ASTM D1505 and Melt Index ASTM D1238, Condition E.

C. Manufactured Roll Goods: Samples of the production run shall be taken and tested according to ASTM D638 to ensure that tensile strength at yield and break, elongation at yield and break meet the minimum specifications. A quality control certificate shall be issued with the material.

D. All welding material shall be of a type supplied by the manufacturer.

E. All FML material shall be certified as "holiday free" by electrical potentiometric means (spark tested) or other equivalent approved means, during manufacture.

3.3 Submittals: The geomembrane manufacturer shall submit the following information to the Project Manager / Owner:

A. The origin (resin supplier's name, resin production plant), identification (brand name, number) and production date of resin.

B. A copy of the quality control certificates issued by the resin supplier noting results of density and melt index.

C. Reports on the tests conducted by the geomembrane manufacturer to verify the quality of the resin used to manufacture the geomembrane rolls assigned to the considered facility (these tests should include specific gravity [ASTM D792 Method A or ASTM 1505 and melt index ASTM D1238 Condition 1902.16]).

D. Reports on these tests conducted by the geomembrane manufacturer to verify the quality of the sheet.

E. A properties sheet including, at a minimum, all specified properties, measured using test methods indicated in the specifications or equivalent.

F. After receipt of material, the geomembrane manufacturer shall provide the Project Manager / Owner with one quality control certificate for every roll of FML provided. The quality control certificate shall be signed by a responsible party. The quality control certificate shall include: roll numbers, identification and results of quality control tests. As a minimum, the quality control certificates shall include the results of the geomembrane properties tested by the method and at the frequency shown in the table below.

Property	**Test Method**	**Frequency**
Thickness	ASTM D 751	Every Roll
Density	ASTM D 792/1505	Every 5th Roll
Tensile Yield Strength	ASTM D 638	Every Roll
Yield Elongation	ASTM D 638	Every Roll
Tensile Break Strength	ASTM D 638	Every Roll
Break Elongation	ASTM D 638	Every Roll
Dimensional Stability	ASTM 1204	Every Roll
Tear Resistance	ASTM D 1004	Every Roll
Puncture Resistance	FRMS 101C-2065	Every Roll
Environmental Stress Crack Resistance	ASTM D 1693B	Every Roll
Carbon Black Content	ASTM D-1603	Every 5th Roll
Carbon Black Dispersion	ASTM D-3015	Every Resin Lot

4.0 INSTALLATION

4.1 Area Subgrade Preparation: The earthwork contractor shall be responsible for preparing the subgrade according to the basin's design and in accordance with the following specifications. If there is a discrepancy between the project design drawings and the following specifications the more stringent requirements shall apply.

A. The earthwork shall be smooth and free of all rocks, stones, sticks roots, sharp objects, or debris of any kind. No stones or other hard objects that will not pass through a 3/8" screen shall be present in the top 1" of the surfaces to be covered. No vegetation, brush roots or other foreign material shall be present on the surfaces to be lined.

B. The surface should be compacted so as to provide a firm, unyielding foundation for the membrane with no sudden, sharp or abrupt changes or break in grade. No ruts, irregularities or soft areas will be present on the surfaces to be lined. The subgrade shall be thoroughly compacted.

C. No standing water or excessive moisture shall be allowed.

D. An anchor trench shall be constructed in a square in accordance with detail DF3 / C.DF3 to secure the FML along the berm of the containment structure to be covered. See attached drawings at end of this specification for anchor and cover details.

E. The installation contractor shall certify in writing that the surface on which the membrane is to be installed is acceptable before commencing work. The FML will be assembled, seamed, tested and installed by the methods specified by a manufacturer recognized by the National Sanitation Foundation, Standard 54.

F. The subgrade shall be constructed so as to meet the following:

1. The subgrade material will come from either on-site or from approved stockpiles.

2. The earthwork for the anaerobic digesters and the equalization basins will be constructed so the subgrade will be free of any foreign material such as stones greater than 3/8 inch in diameter, vegetation, brush, roots or similar material which could damage the FML.

3. The subgrade material will be classified as CH, CL, CL-ML, ML, SM, SC, SW or SP by the USCS Classification System.

4. A moisture/density curve will be developed for the subgrade material.

5. The minimum compacted thickness of the subgrade layer shall be 8".

6. The subgrade will be compacted and graded to meet the installation contractor's specifications so as to avoid any ruts, irregularities and soft areas. The subgrade will be thoroughly compacted to provide support for the FML.

7. The subgrade will be compacted to a minimum of 90% dry density. For proper compaction, moisture will be added to the soil in quantities comparable to the OMC.

8. Installed density shall be confirmed by field test methods at a frequency of one test per 200’ x 200’ grid square.

9. A written statement by an independent professional engineer regarding the subgrade’s structural integrity, along with supporting data will be submitted with the liner certification packet.

4.2 Dike Construction: The earthwork contractor shall be responsible for constructing dikes according to the following specifications:

A. The dike will be constructed of relatively impermeable material.

B. Each lift shall not exceed 6 inches in depth.

C. A geotechnical inspector will conduct compaction testing for each two vertical foot intervals at a frequency of 1 per every 400 linear feet.

D. A written statement by an independent professional engineer regarding the dike’s structural integrity, along with supporting data will be submitted with the liner certification packet.

4.3 Anchor Trench:

A. The attached schematic detail DF3 / C.DF3 at the end of this specification indicates the anchor trench installation. Deviations from this design must be approved by the design engineer prior to use.

B. Compaction of the anchor trench backfilling will be done promptly after installation of the FML.

C. Compaction of the trench backfill shall include moisture added to the top 6 inches, with compaction done by a vibratory roller or tamper to firm unyielding surface.

D. Final grading will be implemented to produce a smooth uniform finish that slopes away from the digester and basins.

E. A client approved quality control technician shall inspect the anchor trench upon completion. Any portion of the anchor trench inadequately constructed will be re-dug and repaired in accordance with the specifications above.

4.4 Geomembrane Placement:

A. The installation of the HDPE must be done by the manufacturer, or a manufacturer’s authorized distributor, using the manufacturer’s extrusion or hot wedge welding equipment and installation methods. All supervisors overseeing the liner installation must have five million square feet of supervisory liner experience. All field technicians must have one million square feet of seaming experience.

B. Field Panel identification: A field panel is the unit area of polyethylene which is to be seamed in the field, i.e., a field panel may be a complete roll or partial roll cut in the field. Smaller units used in the lining systems such as repairs, tabs, extensions, etc. need not be documented in the same manner as a field panel.

1. The installer will be responsible for marking each panel with the identification number and the appropriate manufacturer's roll number. It is suggested that the panel number be marked on each end of the panel, after each panel is placed, for ease of reference.

C. Field Panel Placement:

1. Placement Plan: Panel placement should take into account: site drainage (including sump or low point considerations), prevailing wind direction, subgrade construction, access to the site and the production schedule of the project. Adequate slack will be maintained in the liner material during assembly and after installation to minimize stress due to variations in ambient temperature and incident radiation.

2. Installation Sequence: Field deployed panels should be seamed as soon as possible after deployment to minimize the risk of wind or water damage.

3. Weather Conditions: Geomembrane panel deployment shall not proceed when ambient air temperature or adverse weather conditions exist which will jeopardize the integrity of the liner installation. Typically, installation shall not proceed when the ambient temperature is below 20^{o}F or above 110^{o}F. Special low temperature welding techniques may be required in conditions of ambient temperatures between 20^{o}F and 40^{o}F.

4. Geomembrane panel deployment shall not proceed if subgrade conditions have deteriorated due to moisture, or in the presence of high winds which might cause damage to the liner material. Deployed panels should be adequately ballasted at all times to limit the risk of wind damage.

5. Method of Deployment: The FML installation contractor shall proceed with deployment provided the following conditions are met. If the conditions below are not met the FML installation contractor shall cease deployment and resolve the problems with the Project Manager / Owner.

    - Any equipment used does not damage the subgrade.
    - The subgrade conditions have not deteriorated.
    - The subgrade is free of loose rocks, debris, ruts, etc.
    - The personnel who are in contact with the liner do not smoke wear damaging shoes or engage in other activities which risk damage to the liner.

- Adequate sandbags are present to weight the edges of the liner to avoid wind uplifting.
- Excessive traffic across the liner is avoided.

6. Damage: The FML installation manager and quality assurance technical shall visually inspect each panel, as soon as possible after deployment, for damage or areas needing repair. Appropriate marks indicating a need for repairs shall be done during the inspection. Heavily creased or otherwise defective material shall be rejected.

4.5 Field Seaming & Layout:

A. Individual panels of liner material shall be laid out and overlapped by a maximum of four inches (101 millimeters) for extrusion weld prior to welding or five inches (127 millimeters) for hot wedge weld prior to welding. Extreme care shall be taken by the installer in the preparation of the areas to be welded.

All sheeting shall be welded together by means of integration of the extrudate bead with the lining material. The composition of the extrudate shall be identical to the lining material, or all sheeting shall be welded together using the hot wedge welding system.

B. Seam Layout: In general, seams shall be oriented parallel to the plane of maximum slope, i.e., oriented along, not across the slope. In corners and odd shaped geometric locations the number of seams should be minimized. No horizontal seams should occur on a panel less than 5 lineal feet from the top of the slope. On slopes of less than 10% (6:1) this rule shall not apply. Seams will be installed at least four feet into the anchor trench.

1. A seam is considered a separate entity if it joins two panels. Repairs are not considered seams in this context.

2. A seam numbering system can be used to identify the seams. It is suggested that a simple numerical system be used or adjacent panel numbers can be utilized to identify the seam.

3. Seams will be welded to at least four feet into the anchor trench.

C. Seaming Equipment and Products: Approved processes for field seaming and repairing are extrusion welding and fusion welding. All welding equipment should have accurate temperature monitoring devices installed and working to ensure proper measurement of the fusion welding wedge temperature or the extrusion barrel temperature.

D. Extrusion Welding Process: This process shall be used primarily for repairs, patching and special detail fabrication and can also be used for seaming.

1. The extrusion welding apparatus (Handwelder) shall be equipped with gauges or other temperature monitoring devices to indicate temperature of the extrudate (resin) as well as the applicable pre-heat settings.

2. The FML installation contractor shall verify the following:

a. Equipment in use is functioning properly.

b. Welding personnel are purging the machine of heat-degraded extrudate prior to actual use.

c. All work by the personnel is performed on clean surfaces and done in a professional manner.

d. No seaming is done in adverse weather conditions.

E. Fusion Welding Process: This process shall be used for seaming panels together and is not generally used for patching or detail work.

1. The apparatus may be of a hot wedge type and shall be equipped with a "split wedge", used for pressure type seam testing.

2. Fusion welding equipment shall be self-propelled devices and shall be equipped with functioning speed controllers and monitors to assure proper control by the welding technician. The welding equipment used shall be capable of continuously monitoring and controlling the temperatures in the zone of contact where the machine is actually fusing the lining material so as to ensure that changes in environmental conditions will not affect the integrity of the weld.

3. The FML installation contractor shall verify the following:

   a. Equipment in use is functioning properly.

   b. Welding personnel are performing seaming in a professional manner and are attentive to their duties.

4. **Figure F-1** below is a schematic detail which indicates acceptable fusion weld. Deviations from these must be approved by the design engineer prior to use.

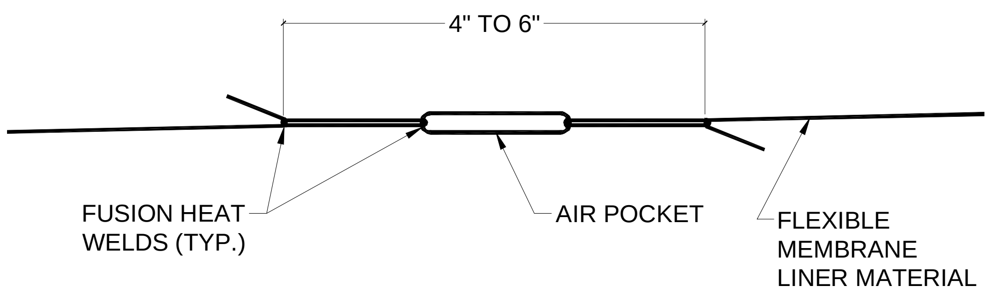


Figure F-1 – Typical Fusion Weld

F. Seam Preparation: The area to be welded shall be cleaned and prepared in accordance with this specification and the recommendations of the material manufacturer. The welding technician shall verify the following:

1. Prior to seaming the seam area shall be free of moisture, dust, dirt, sand or debris of any nature.

2. Seam is overlapped for fusion welding.

3. Seem is overlapped or extended beyond damaged areas at least 4" when extrusion welding.

4. Seam is properly heat tacked and abraded when the extrusion welding is done.

5. Seams are performed with the fewest number of unmatched wrinkles or "fish mouths".

G. Fish Mouths: No "fish mouths" shall be allowed within the seam area. Where "fish mouths" occur the material shall be cut, overlapped and an overlap extrusion weld shall be applied.

H. Slack: Adequate slack will be maintained in the liner during assembly and after installation to minimize stresses due to variations in ambient temperature and incident radiation.

I. Defective Material: Heavily creased or otherwise defective liner material will be rejected.

J. Weather Conditions for Seaming: No seaming shall be performed in ambient air temperatures or adverse weather conditions which will jeopardize the integrity of the liner installation. Ambient air temperatures shall not exceed 110^{o}F nor be below 20^{o}F during seaming. Additionally, seaming shall not proceed in conditions in which the liner is subject to dew or other condensation, rain, snow, frost or frozen subgrade.

K. Low Temperature Welding Procedures: The most important criteria for performing welding when the ambient temperature is between 20^{o}F to 40^{o}F is the condition of the trial weld. All trial welds should be made in conditions duplicating the actual welding environment. The following procedures should be used to maintain the quality of the weld in low temperature ambient conditions (20^{o}F to 40^{o}F).

1. Conduct additional trial welds when a welding machine has been shut off, or after a major change in ambient conditions. A major change in ambient conditions would include but is not limited to the following:

   a. Change in temperature of more than 20^{o}F

   b. Change in wind speed of more than 10 mph.

   c. Change in the amount of sunshine on the liner.

2. The geomembrane and extrudate material must be dry and free from frost, dew, condensation or other moisture.

3. Hot wedge set temperatures may be increased up to 700^{o}F in 10^{o}F increments as necessary.

4. The hot wedge rate of travel should be slowed as necessary.

5. Length of trial weld seams should be increased to 5 ft for extrusion welds and 24 ft for fusion welds.

6. Clean the seam area immediately in front of the welding apparatus with a clean dry cloth.

7. Destructively test one specimen, no greater than 6” from the end of each seam to confirm the quality of the seam.

8. Increase handwelder (extrusion welder) pre-heat temperature up to 600^{o}F in 20^{o}F increments as necessary.

9. Increase handwelder extrudate temperature up to 530^{o}F in 10^{o}F increments as necessary.

10. If additional measures are needed to produce acceptable welds the following additional measures may be implemented:

    a. Install an insulating material such as a geotextile cushion beneath the seam being welded.

    b. Use hot air pre-heat (additional pre-heat for extrusion welding) 6” to 12” in front of the welding apparatus (both fusion and extrusion welders). Verify weld quality be means of a trial weld.

11. If trial welds still indicate that a quality weld cannot be produced be the above steps, a wind shield or an enclosure may be placed over the area to be welded. In the case of an enclosure, the enclosed area shall be heated by forced air or radiant means to an air temperature at or above 40^{o}F.

12. All trial welds will be documented with samples (failures and approved) recorded, retained with samples attached to completion submittal records.

L. <u>Temporary Bonding</u>: The FML installation contractor shall verify that no solvents or adhesives are used in the seaming area. Tape or heat tacking is permissible for temporarily holding patches but is not a substitute for welding.

M. <u>Trial seams / Welds</u>: Trial seams / welds shall be made on appropriate sized pieces of geomembrane material to verify that seaming conditions are adequate.

1. Trial seams / welds shall be performed for each welder to be used and by each operator of extrusion welders, and by the primary operator of the fusion welder.

2. A passing trial seam / weld shall be made prior to seaming each day. If the apparatus is cooled down after use and additional trial seam may be required.

3. Fusion welded trial seams shall be approximately 5 foot long by 1 foot wide with the seam centered lengthwise. For extrusion welding the trial seam sample size shall be approximately 3 feet long by 1 foot wide with the seam centered lengthwise.

4. Test welds shall be marked with date, ambient temperature and welding machine number. All test weld samples will be retained and submitted with approved inspection reports.

5. Samples of weld ¼” to ½” wide shall be cut from the test weld and pulled by hand in peel. The weld should not peel.

6. Refer to Quality Assurance and Quality Control Section 5.2.B for testing requirements.

7. The geomembrane installation contractor shall assign each trial seam / weld sample a number and record the test results in the appropriate log.

8. Upon passing, unless otherwise specified, all trial seam / weld specimens must be retained and submitted with approval inspection reports.

4.6 Defects and Repairs

A. Once defective or areas requiring repair are identified as called out in Section 5.3. Each area shall be repaired in accordance with this section and non-destructively tested.

B. Repair Procedures: Any portion of the polyethylene lining system exhibiting a defect which has been marked for repair shall be repaired with one or more of the following appropriate procedures:

1. Repair Methods:

    - Patching: Used to repair holes, tears, un-dispersed raw materials in the sheet.
    - Grind and Re-Weld: Used to repair small section of extruded seams.
    - Spot Welding: Used to repair small, minor, localized flaws.
    - Flap Welding: Used to extrusion weld the flap of fusion weld in lieu of a full cap.
    - Capping: Used to repair failed seams.
    - Topping: Application of extrudate bead directly to existing seams.

2. The following conditions shall apply to all of the above methods:

    a. Surfaces of the polyethylene which are to be repaired shall be abraded.

b. All surfaces must be clean and dry at the time of the repair.

c. All seaming equipment and personnel used in repairing procedures shall be qualified and documented by the client's third party inspector.

d. All patches and caps shall extend at least 4" beyond the edge of the defect and all patches shall have rounded corners.

C. Large Wrinkles: Large wrinkles that remain in the sheet as a result of temperature expansion or uneven surface preparation may need removal in consideration of applied dead loads on the wrinkle, etc. Should the wrinkle need removing, the lower down slope edge of the wrinkle shall be cut, overlapped and repaired as described above. Both ends of the wrinkle repair shall be patched. Caution must be taken in removing any wrinkles. Wrinkles are needed to allow for future contraction of the geomembrane, especially in cold weather.

4.7 Liner Vents

A. The attached schematic detail DF4A / C.DF4 depicts a typical vent. Vents shall be installed in accordance with manufacturer's recommendations as well as requirements and recommendations indicated on project design drawings.

4.8 Pipe Penetrations

A. The attached schematic detail DF4B / C.DF4 depicts a pipe penetration. Pipe penetrations shall be installed in accordance with manufacturer's recommendations as well as requirements and recommendations indicated on project design drawings.

4.9 Final Earthwork, Backfilling and Equipment

A. Backfilling of Anchor Trench: Promptly after installation of the FML, the anchor trench shall be backfilled by the earthwork contractor or the installer, as specified in the contract. Backfilling should occur when the geomembrane is in its most contracted (taut) state. Care must be taken when backfilling to avoid damage to the FML.

B. Construction Equipment: Construction equipment or vehicles with steel tracks shall not be permitted directly on the geomembrane liner. Vehicles with rubber tires, without a tugged tread and with a loading of less than 6.0 lbs / in^2 weight are allowed, provided proper care is taken when operating the vehicle to avoid stressing the geomembrane. Other equipment such as portable generators shall be permitted if the support apparatus for the equipment protects the liner from being damaged.

5.0 QUALITY ASSURANCE AND QUALITY CONTROL

5.1 Materials:

A. The FML installation contractor or quality control technician shall verify that the property values certified by the geomembrane manufacturer meet all of the specifications; that the measurements of properties by the geomembrane manufacturer are properly documented; and that the test methods used are acceptable.

5.2 Field Seam Testing / Quality Control

A. The end user company, or their designated representative, reserves the right of access for inspection of any or all phases of this installation at their expense.

B. Qualifications of personnel: All personnel performing seaming operations shall be qualified by experience. At least one welder (Master Welder) shall be on site at all times during the seal welding process and have experience seaming a minimum of 5,000,000 ft^2 of geomembrane. The "Master Welder" shall provide supervision of the less experienced welding technicians during seaming, patching and testing operations.

C. Testing of coupons (strips of material) before seaming, stress cracks and all seams must be done in accordance with the FML manufacture's requirements.

D. Trial Welds / Seams:

1. Four specimens, each 1" wide and 6" apart from each other shall be cut from the trial seam. Two of the specimens shall be tested in shear and two specimens tested in peel. Both shear and peel tests shall be conducted to the yield point of the geomembrane. When testing a fusion welded seam the outside (top) weld of a split-wedge weld should be considered the primary weld and shall be the weld tested in peel. The specimen must exhibit the following properties to pass:

   a. Shear Test: Both specimens must meet or exceed the bonded seam strength values in shear of both specimens shall exhibit a bonded seam strength in shear that is greater than 90% of the minimum yield tensile strength of the parent material.

   b. Peel Test: Both specimens must exhibit failure of the parent material or meet or exceed the bonded seam strength values in peel, or strength values shall be greater than 70% of the minimum yield tensile strength of the parent material.

2. General seaming operations may proceed prior to the test being complete. Should a trial seam fail, a sample shall be removed 3 lineal feet from the start of the seaming operations and tested per the above. This procedure will be repeated and followed until a passing sample is located. All work preceding the passing sample shall be repaired.

E. Non-Destructive Seam Continuity Testing

1. Concept: The FML installation contractor shall non-destructively test and document all field seams over their full length using an air pressure test or vacuum test. The purpose of non-destructive tests is to check the continuity of the seams.

2. The FML installation contractor shall:

    a. Schedule all non-destructive testing operations.

    b. Instruct the testing personnel regarding marking of repairs needed, leaks and sign-off marks on seams and repairs.

    c. Monitor the operations of testing personnel to ensure that procedures for testing are followed.

3. On seams that cannot be non-destructively tested by vacuum or air-pressure methods due to physical constraints, (i.e. a boot detail) the seam shall be tested using other approved methods.

4. Vacuum Testing:

    a. Equipment:

        - Vacuum box assembly consisting of a rigid housing, a transparent viewing window, a soft gasketing material attached to the bottom, a valve assembly and a certified vacuum gauge.
        - Vacuum pumping device. Including back-up device
        - Foaming agent in solution.
        - Equipment suitable for applying the foaming agent.

    b. Procedure:

        - Wet the section of the seam with foaming agent.
        - Place the vacuum box over the wetted area.
        - Energize the pumping apparatus.
        - Obtain a minimum pressure of -5.0 psi.
        - For a period of approximately 10 seconds, observe, through the viewing window, for the presence of soap bubbles.
        - If no bubbles are observed, reposition the box on the next area for testing.
        - If bubbles are detected, mark and document location of the leak so repairs can be made.

5. Air Pressure Testing: The following procedures are applicable for seams produced by a double-fusion welding apparatus.

a. Equipment:

- Air pump or air tank equipped with pressure gage and capable of producing pressures between 25 to 30 psi.
- Sharp hollow needle to insert the air into the air chamber of the seam.

b. Testing Procedure:

- Installer will provide for approval a detailed seam testing map prior to the starting of seal tests.
- Seal both ends of the air channel in the seam to be tested.
- Insert the hollow needle into the air chamber at either end of the seam to be tested.
- Energize the air pump to a pressure between 25 and 30 psi and read pressure inserted into the chamber. Allow the pressure to stabilize and if necessary, re-pressurize to between 25 and 30 psi. Then record the pressure.
- Wait for a minimum of 5 minutes and then record the air pressure again.
- If the difference between the initial and the final pressure is greater than 4 psi the seam failed. Documentation required on all failed tests.
- Upon completion of all readings, open the opposite end of the seam with a needle. The escaping air will confirm that the entire length of the seam was pressurized and therefore tested.
- Upon passing the air pressure test, the seam shall be marked and documented.
- All Seam tests shall be witnessed by client or clients inspector.

c. Procedure for Air Pressure Test Failure:

- While the seam air-channel is under pressure, traverse the length of the seam and listen for the leak. Once the area of the leak has been narrowed down, apply a soapy solution to the seam edge (do not trim excess material from edge of seam) and observe for bubbles formed by escaping air.
- As an alternative to the step above the seam may be re-tested in progressively smaller increments, until the area of leakage is identified.
- Repair the identified leaking area by extrusion welding the excess material at the edge of the seam and then vacuum test.
- In areas where the air channel is closed and the integrity of the weld is not suspect, vacuum testing is acceptable.

F. Destructive Seam Testing

1. Concept: Destructive seam tests shall be performed at locations selected by client's inspectors. The purpose of these tests is to evaluate bonded seam strength. Seam strength testing shall be performed and documented as work progresses.

2. Location and Frequency: The minimum frequency of sample removal shall be one sample per 750 ft of seam. The location of the test sample will be taken no greater than 6" from the end of the seam. Additional test samples removal as requested by the client or client's inspector.

3. <u>Size of Samples</u>: The size of the sample for independent testing shall be 12" by minimal length with the seam centered lengthwise. The sample shall be cut into the following segments and distributed as follows:

   a. The first segment cut shall be 12" x 12" marked with the appropriate D/S number and given to the AQ technician for testing.

   b. The second segment, 12" x requested length (18" max) shall be marked with the appropriate D/S number and transmitted at the contractors cost to the independent testing laboratory or the quality assurance technician personnel for their dispersal.

4. <u>Field Testing</u>: The segments given to the quality assurance technician shall be tested in peel and in sheer using the following criteria:

   a. Ten specimens of 1" width shall be cut from the segment.

   b. Five of the specimens shall be tested in a peel configuration. The outside (top) weld of a split wedge weld shall be considered the primary weld and shall be the weld tested in peel.

   c. Five of the specimens shall be tested in a shear configuration.

   d. The geomembrane manufacturer shall supply a field tensiometer equipped with a drive / pull apparatus adjusted to a pull rate of 2"/min to 20"/ min and a means of measuring the strength of the sample.

   e. <u>Pass Fail Criteria</u>: The installers sample will pass when:

      - The peel specimens exhibit failure of the parent material.
      - The bonded strength peel values shall be greater than or equal to 70% of the minimum yield tensile strength of the parent material.
      - The shear specimens display parent material failure.
      - If the bonded seam strength in shear values is not listed, the shear values shall be greater than or equal to 90% of the minimum yield tensile strength of the parent material.

        Note: Locus of break determinations is to be in accordance with ANSI/NSF 54
      - Four out of five specimens meeting the above criteria constitute a passing test.

   f. <u>Procedure for Failing Tests</u>:

      - Two samples of the same size shall be removed from the failed seam. The first sample shall be removed 10 lineal feet in front of the failed sample and the second shall be removed from behind the failed sample.
      - Label the samples A and B and test in accordance with procedures listed above.

- If both samples A and B pass, seam between the location of samples A and B shall have the flap extrusion welded or be capped and non-destructively tested accordingly.
- If either sample A or B fails, additional samples shall be taken a minimum distance of 10 feet away from the failed test location. Testing shall continue as outlined above until the area of incorrect seam is isolated.
- In lieu of taking an excessive number of samples, the installer may opt at their cost to extrusion weld the flap or cap for the entire length of the seam then non-destructively test the seam.
- All failing tests shall be documented and forwarded to the client or client's representative within 24 hours, along with recommendation of correction

5.3 Defects and Repairs

A. Identification: All seams and non-seam areas of the polyethylene lining system shall be examined for defects in the seam or sheet.

B. Identification of the defect may be made by marking on the sheet/seam with paint or other marks. The following procedure shall be followed:

1. For any defect in the seam or sheet that is an actual breach (hole) larger than ¼" in the liner system, the installer personnel shall circle the defect and mark the letter "P" inside the circle. The letter "P" indicates that a patch is required.

2. For any defect in the seam or sheet that is less than a ¼" hole, the installer personnel shall only circle the defect indicating that the repair method may be only an extruded bead and a patch may not necessarily be required. Repair methods will be at the sole discretion of the client and the client's qualified inspection representative.

C. Unless otherwise specified, only the geomembrane installation contractor or quality assurance technician shall be permitted to mark on the liner system. The quality assurance technician shall use markings that are distinguishable from the geomembrane installation contractor markings.

D. Verification of Repairs: Each repair shall be non-destructively tested in accordance with requirements of these specifications and manufacturer's recommendations. Once passing tests are achieved a marking shall be placed on the repair, indicting the test is complete and the area has passed the test. If defects remain, appropriate markings shall be made to clearly indicate that additional repairs are required.

5.4 Final Approval

A. A final inspection of the completed liner will be conducted by the FML installation contractor, quality assurance technician and project manager / owner. This careful evaluation will occur before the Division of Water Quality is asked to approve the use of the lined lagoon. The purpose of the inspections is to verify the following:

1. All repairs have been appropriately performed.

2. All test results are positive.

3. Area is free of scrap, trash and debris.

4. Anchor trench has been properly backfilled.

5. Liner has been installed according to the requirements of these specifications, the project documents and the manufacturer's recommendations.

6. Four (4) copies in three ring binders of all installation record documents will be required prior to final acceptance.

B. Each liner material test, construction inspection checklist, data sheet, or narrative report will be preserved for inspection by the Division of Water Quality. Waste shall not be discharged into the digesters or equalization basins prior to the approval of the Division of Water Quality.

6.0 Warranty and Guarantee

6.1 The manufacture / Installer shall provide a written warranty in accordance with the requirements specified by the owner and / or design engineer.

Attachment E

State of Utah Geological Survey Paper #1836 entitled "Ground-Water Conditions and Geologic Reconnaissance of the Upper Sevier River Basin, Utah"

Ground-Water Conditions and Geologic Reconnaissance of the Upper Sevier River Basin, Utah

By C. H. CARPENTER, G. B. ROBINSON, JR., and L. J. BJORKLUND

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1836

Prepared in cooperation with the Utah State Engineer

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UNITED STATES DEPARTMENT OF THE INTERIOR

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GROUND-WATER CONDITIONS AND GEOLOGIC RECONNAISSANCE IN THE UPPER SEVIER RIVER BASIN, UTAH

By C. H. Carpenter, G. B. Robinson, Jr., and L. J. Bjorklund

Abstract

The upper Sevier River basin is in south-central Utah and includes an area of about 2400 square miles of high plateaus and valleys. It comprises the entire Sevier River drainage basin above Kingston, including the East Fork Sevier River and its tributaries. The basin was investigated to determine general ground-water conditions, the interrelation of ground water and surface water, the effects of increasing the pumping of ground water, and the amount of ground water in storage.

The basin includes four main valleys—Panguitch Valley, Circle Valley, East Fork Valley, and Grass Valley—which are drained by the Sevier River, the East Fork Sevier River, and Otter Creek. The plateaus surrounding the valleys consist of sedimentary and igneous rocks that range in age from Triassic to Quaternary. The valley fill, which is predominantly alluvial gravel, sand, silt, and clay, has a maximum thickness of more than 800 feet.

The four main valleys constitute separate ground-water basins. East Fork Valley basin is divided into Emery Valley, Johns Valley, and Antimony subbasins, and Grass Valley basin is divided into Koosharem and Angle subbasins. Ground water occurs under both artesian and water-table conditions in all the basins and subbasins except Johns Valley, Emery Valley, and Angle subbasins, where water is only under water-table conditions. The water is under artesian pressure in beds of gravel and sand confined by overlying beds of silt and clay in the downstream parts of Panguitch Valley basin, Circle Valley basin, and Antimony subbasin, and in most of Koosharem subbasin. Along the sides and upstream ends of these basins, water is usually under water-table conditions.

About 1 million acre-feet of ground water that is readily available to wells is stored in the gravel and sand of the upper 250 feet of saturated valley fill. About 370,000 acre-feet is stored in Panguitch Valley basin, about 210,000 in Circle Valley basin, about 8,500 in Emery Valley subbasin, about 98,000 in Johns Valley subbasin, about 48,000 in Antimony subbasin, about 90,000 in Koosharem subbasin, and about 50,000 in Angle subbasin. Additional water, although it is not readily available to wells, is stored in beds of silt and clay. Some ground water also is available in the bedrock underlying and surrounding the basins, although the bedrock formations generally are poor aquifers.

The principal source of recharge to the valley fill in the upper Sevier River basin is infiltration from streams, canals, and irrigated fields. Some ground water also moves into the valley fill from the bedrock surrounding the basins.

The basin contains about 500 wells, most of which are less than 4 inches in diameter, are less than 250 feet deep, and are used for domestic purposes and stock watering. More than half the wells are flowing wells in Panguitch Valley.

Approximately 158,000 acre-feet of ground water was discharged in 1963 from the valley fill. Springs discharged about 88,000 acre-feet, wells about 8,700, and drains about 3,000; and evapotranspiration from phreatophyte areas about 42,000 acre-feet. Springs in bedrock discharged an additional 77,000 acre-feet. Most of the water discharged by springs, wells, and drains was used for irrigation.

The ground water in the basin generally is of good chemical quality. The water is excellent for irrigation and stock, but is not as desirable for some domestic and industrial uses because of its hardness. The dissolved-solids content of the ground water generally increases slightly from the upstream end of the individual ground-water basins to the downstream end owing mostly to repeated reuse of the water for irrigation.

Surface water and ground water in the upper Sevier River basin are interconnected, and the base flows of streams are affected by changes in ground-water levels. Increased pumping of ground water would result in (1) an increase in the recharge to the aquifers from surface-water sources or (2) a decrease in the discharge from streams, springs, flowing wells, and areas of phreatophytes or (3) a combination of these.

About 42,000 acre-feet of ground water is now discharged annually by evapotranspiration from phreatophyte areas, and perhaps one-third of this loss, or about 14,000 acre-feet, could be salvaged by eliminating wet areas and phreatophytes. The areas where water could be salvaged are at the downstream ends of Panguitch Valley basin, Circle Valley basin, and Antimony subbasin. Most of the 14,000 acre-feet of water could be pumped from irrigation-type wells or developed by properly designed drains without greatly affecting streamflow and with only moderate effect on spring discharge. If the wells were properly located, the pumping would lower water levels and dry up wet areas where phreatophytes grow. Conjunctive use of ground water and surface water would facilitate the most efficient use of all water resources in the basin.

INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

The U.S. Geological Survey, in cooperation with the Utah State Engineer, investigated ground-water and geologic conditions in the upper Sevier River basin to determine the following: the availability of water in the unconsolidated valley fill and the consolidated rocks in the basin, the amount of water in storage in the valley fill, the relation of ground water and surface water, and the effect of pumping additional quantities of ground water. The investigation was part of a cooperative program of ground-water investigation in the entire Sevier River basin, which began with a study of ground-water conditions in the central Sevier Valley in 1960 (Young and Carpenter, 1965).

The investigation in the upper Sevier River basin included determination of the relation of geology to ground water; source, occurrence, recharge, and discharge of ground water; present ground-water development; fluctuations of water levels; chemical quality of ground and surface waters; relation between ground water and surface water; inflow-outflow analyses of several subbasins; the amount of ground water stored in the valley fill; and conclusions about potential development and its effect on hydrologic conditions in the area.

LOCATION AND EXTENT OF THE AREA

The upper Sevier River basin occupies about 2,400 square miles in south-central Utah, and it includes parts of Garfield, Iron, Kane, Piute, and Sevier Counties (fig. 1). It comprises the Sevier River drainage area above Kingston, including the Sevier River, the East Fork Sevier River, and their tributaries. The geologic reconnaissance covered the entire drainage basin, but the detailed hydrologic study was concentrated in the valleys in an area of about 300 square miles.

PREVIOUS WORK

Previous hydrologic studies in the upper Sevier River basin by the U.S. Geological Survey resulted in reports on the surface-water resources of the Sevier Lake basin (Woolley, 1947), the ground-water resources of the Bryce Canyon National Park area ([illegible]), and the hydrology and hydrogeology of Navajo Lake (Wilson and Thomas, 1964). The Geological Survey has collected streamflow records in the basin since 1911 and has measured ground-water levels in the basin since 1935. These data have been published annually or at intervals of 5 years in U.S. Geological Survey Water-Supply Papers. The Sevier River water commissioners have measured and compiled records of diversions for irrigation for most years since 1917.

Investigations of the geology and geography of parts of the upper Sevier River basin and adjacent areas have been made by Averitt (1962), Callaghan (1938, 1939), Callaghan and Parker (1961, 1962a, b), Gregory (1944, 1945, 1949, 1950a, b, 1951), Gregory and Moore (1931), and Willard and Callaghan (1962).

Honorable LeRoy H. Cox (1936), judge of the Fifth Judicial District of the State of Utah, compiled water rights in the upper Sevier River basin in a court decree adjudicating the Sevier River system.

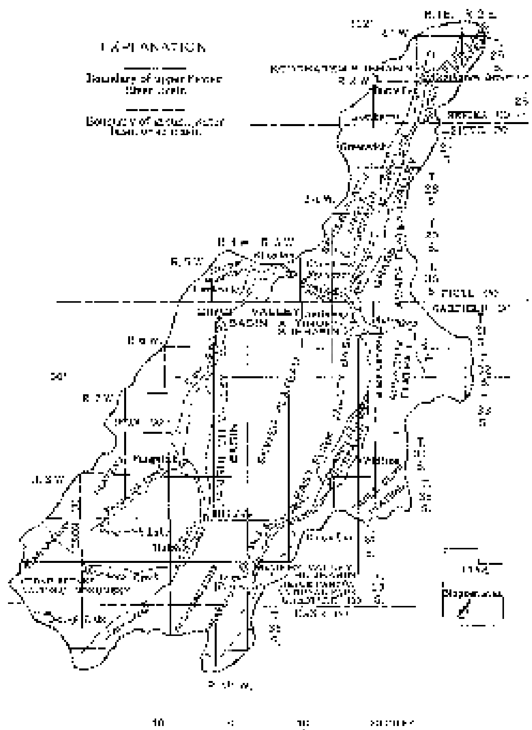

FIGURE 1. Map of the upper Sevier River basin showing physiography and ground-water basins and subbasins.

PERSONNEL AND METHODS OF INVESTIGATION

R. A. Young, project chief, and C. H. Carpenter began the investigation in July 1961. Mr. Young was transferred in December 1961, and L. J. Bjorklund was assigned as project chief. Mr. Bjorklund was assigned to another investigation in the Sevier River basin in September 1962, and Mr. Carpenter was designated project chief. G. B. Robinson, Jr., was assigned to the project in February 1963. R. D. Feltis supervised the test-drilling program during the summer of 1962, assisted by G. B. Robinson, Jr., and they prepared a report on the test drilling (Feltis and Robinson, 1963.)

Many types of basic data were collected and analyzed during the investigation. Much of the data, including well and spring records, water-level measurements, well logs, and chemical analyses, are included in a separate report (Carpenter, Robinson, and Bjorklund, 1964).

More than 400 wells and 50 springs were recorded; periodic water-level measurements were made in 58 observation wells and water-level recording gages were maintained on 4 wells. Estimates of ground-water discharge from wells, springs, and drains were made using periodic discharge measurements at selected locations and single measurements at other locations. Aquifer tests were made using selected wells to determine well performance and the hydraulic properties of the aquifers. Chemical analyses were made for 10 samples collected from surface-water sources and 56 samples collected from ground-water sources.

Many drillers' logs were studied to provide information about the thickness and composition of the valley fill, and in addition 21 test holes were drilled during 1962. The test-drilling program was financed by the U.S. Geological Survey in cooperation with Garfield, Piute, Sevier, Sanpete, and Millard Counties, many of the irrigation companies in those counties, and the Utah State Engineer. The test holes were drilled by the rotary method, and composite samples were obtained for 10-foot intervals. The samples were examined microscopically to determine their mineral and fossil content, and electric and gamma-ray logs of several of the holes were made to help indicate the character and thickness of the material penetrated. Seven of the test holes were cased and used as observation wells.

A geologic map was compiled mainly from field reconnaissance and photogeologic data and partly from data from available reports.

Stream-gaging stations were installed at Panguitch Creek near Panguitch, East Fork Sevier River near Antimony, and Otter Creek near Antimony. Streamflow data from these and other stations and records of diversions for irrigation were studied and compared with ground-water levels and precipitation data to determine the relation between ground water and streamflow.

The amount of ground water consumed by evapotranspiration was estimated from data on consumptive use by phreatophytes in other areas in Utah and in other Western States. These data were applied to areas of phreatophyte growth in the upper Sevier River basin. Evaporation was estimated from areas of surface reservoirs and rates of evaporation measured at Piute Reservoir in the central Sevier Valley (Young and Carpenter, 1965).

Inflow-outflow studies were made for all basins and subbasins, using all available data for ground water, surface water, evapotranspiration, geology, and climatology. These studies accounted for all water entering and leaving each area.

ACKNOWLEDGMENTS

Officials of Garfield, Piute, Sevier, Sanpete, and Millard Counties and of some irrigation companies assisted in financing and organizing the test-drilling program.

Information on streamflow was furnished by the Sevier River water commissioner, R. B. Christensen. Personnel of the Soil Conservation Service, U.S. Department of Agriculture, helped map and classify phreatophytes and provided information on irrigation. Personnel of the National Park Service helped with the collection of water-level data in the Bryce Canyon National Park area. Many individuals contributed information about their wells and permitted the measurement of water levels in the wells.

WELL AND SPRING NUMBERING SYSTEM

The well and spring numbers used in this report indicate the location by land subdivision according to a numbering system that was devised cooperatively by the Utah State Engineer and the Geological Survey about 1935. The system is illustrated in figure 2. The complete number comprises letters and numbers that designate consecutively the quadrant and township (shown together in parentheses by a capital letter designating the quadrant in relation to the base point of the Salt Lake Base and Meridian, and numbers designating the township and range); the number of the section; the quarter section (designated by a letter); the quarter of the quarter section; the quarter of the quarter-quarter section; and, finally, the particular well within the 10-acre tract (designated by a number). If a spring is indicated, the final number is omitted. By this system the letters A, B, C, and D designate respectively the northeast, northwest, southwest, and southeast quadrants of the standard base and meridian system of the Bureau of Land Management, and the letters a, b, c, and d designate respectively the

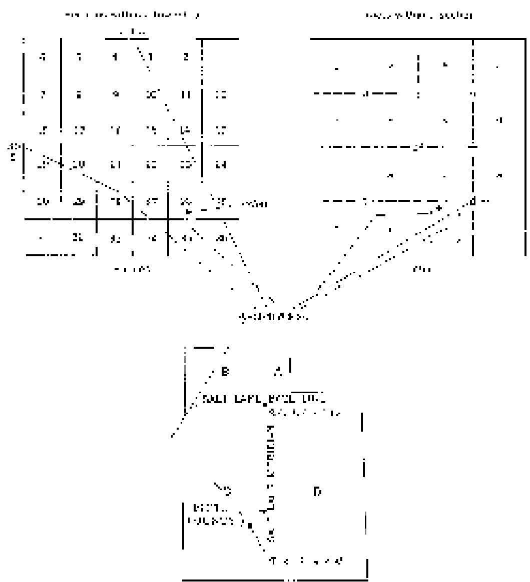

FIGURE 2.—Well- and spring-numbering system used in Utah.

northeast, northwest, southwest, and southeast quarters of the section, of the quarter section, and of the quarter-quarter section. Thus, the number (C-30-4)29dcb-1 designates well 1 in the NW¼SW¼SE¼ sec. 29, T. 30 S., R. 4 W., the letter C showing that the township is south of the Salt Lake Base Line and the range is west of the Salt Lake Meridian.

GEOGRAPHY

PHYSIOGRAPHY

The upper Sevier River basin is in the High Plateaus of Utah section of the Colorado Plateaus physiographic province (Fenneman, 1931, p. 283). The basin comprises four main valleys—Panguitch Valley, Circle Valley, East Fork Valley, and Grass Valley—which are surrounded by high plateaus and mountains (fig. 1). Panguitch Valley and Circle Valley combined locally are called South Fork Valley.

Panguitch Valley is approximately 40 miles long and is as much as 8 miles wide in the area north of Panguitch. The altitude of the valley ranges from about 6,300 feet at the north end to about 7,500 feet at the south end. The valley is bordered on the west by the Markagunt Plateau, which reaches an altitude of more than 11,000 feet above mean sea level, and on the east by the Paunsaugunt and Sevier Plateaus, which reach altitudes of more than 9,000 and 11,000 feet, respectively.

Circle Valley is about 8 miles long and is more than 6 miles wide at Circleville. The altitude of the valley floor ranges from about 6,000 feet at the north end to about 6,200 feet at the south end. The valley is bordered on the west by the Tushar Mountains, which reach an altitude of more than 11,000 feet, and on the east by the Sevier Plateau.

East Fork Valley is approximately 75 miles long and is more than 5 miles wide near Widtsoe. The altitude of the valley floor ranges from more than 6,200 feet at the head of Kingston Canyon to more than 8,000 feet south of Tropic Reservoir. The valley is bordered on the west by the Paunsaugunt and Sevier Plateaus, and on the east by the Table Cliff and Aquarius Plateaus, which reach altitudes exceeding 10,000 and 11,000 feet, respectively.

Grass Valley is approximately 30 miles long and ranges in width from half a mile in the area south of Greenwich to about 4 miles at Greenwich. The altitude of the valley floor ranges from about 6,400 feet at Otter Creek Reservoir to about 7,200 feet north of Koosharem Reservoir. The valley is bordered on the west by the Sevier Plateau and on the east by the Awapa and Fish Lake Plateaus, which reach altitudes exceeding 9,000 and 11,000 feet, respectively.

Each of the valleys consists of three parts: (1) a valley floor, the flood plain of the main stream in the valley, (2) a valley basin, those areas that are underlain by unconsolidated deposits, and (3) the valley sides—areas that are underlain by bedrock. These features are shown on the geologic cross sections (pl. 1), and a more detailed description of the structure of the basins is given in the section on geology (p. 11).

The discussion of ground-water conditions in this report is by valley basins. These basins are Panguitch Valley basin, Circle Valley basin, East Fork Valley basin, and Grass Valley basin. East Fork Valley and Grass Valley basins are further divided into subbasins. East Fork Valley basin includes Emery Valley subbasin, Johns Valley subbasin, and Antimony subbasin; and Grass Valley basin includes Koosharem subbasin and Angle subbasin (fig. 1).

CLIMATE

The climate in the upper Sevier River basin ranges from semiarid in the valleys to humid on the plateaus. The climatological data recorded at Panguitch are regarded as typical of the valleys in the region.

Large daily ranges in temperature are usual in the valleys. The temperature rarely exceeds 90°F in the summer and is usually between 40° and 50°F during summer evenings. Winters are usually cold in the valleys, and temperatures below 0°F are common. The average annual temperature at Panguitch is 45°F. The frost-free, or growing, season ranges from 2 to 3½ months in the valleys, and below-freezing temperatures have been recorded in every month of the year. The lowest temperature recorded at Panguitch was −32°F in January 1937, and the highest was 96°F in June 1951. The average frost-free period at Panguitch is from June 16 to September 9.

The principal precipitation in the valleys is during July, August, and September when warm moist air moves into the area from the Gulf of Mexico. The annual precipitation in the valleys ranges from about 7 to 10 inches; November and June usually are the driest months and July and August the wettest. The area is influenced also by storms, however, from both the northern and southern Pacific coasts between September and May. Most of the precipitation from these storms falls on the surrounding high plateaus in the form of snow. This precipitation has an annual range from about 20 to 40 inches, and the snow accumulates in places to depths of more than 10 feet and often has a water content of as much as 40 inches.

Annual precipitation at Panguitch ranged from a minimum of 5.41 inches in 1942 to a maximum of 18.02 inches in 1910 and averaged 9.12 inches for 30 years of record (1931–60). The trend in precipitation between 1930 and 1965 is illustrated by a graph of the cumulative departure from the mean annual precipitation at Panguitch (fig. 3). The wettest years are shown by the most steeply rising parts of the graph and the driest years by the steepest descents. The late 1930's and late 1940's were wetter than average, and the climate has been relatively dry since 1950 except during 1953, 1957, and 1961.

Winds in the area usually are light to moderate in all seasons. The only strong winds usually are associated with thunderstorms and squalls.

Evaporation in the valleys greatly exceeds annual precipitation. Mean annual evaporation at Piute Reservoir, 8 miles north of Kingston, is [illegible] inches (U.S. Weather Bureau, written commun., 1958) and is considered to be representative of potential evaporation in the valleys of the upper Sevier River basin.

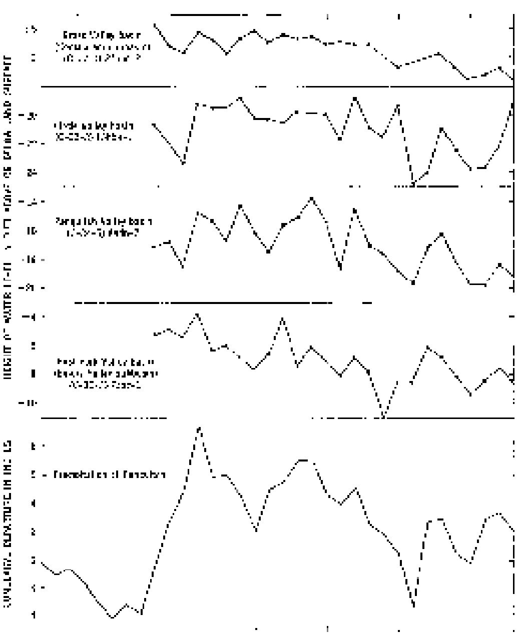

FIGURE 3.—Hydrographs of selected wells for the period 1939–61 and cumulative departure from the 1931–60 average annual precipitation at Panguitch.

VEGETATION

Native vegetation in the upper Sevier River basin ranges in type from desert to alpine. Saltgrass (*Distichlis stricta*), rabbitbrush (*Chrysothamnus nauseosus*), greasewood (*Sarcobatus vermiculatus*), willows (*Salix* sp.), and sagebrush (*Artemisia tridentata*) grow in the uncultivated lands of the valleys. The vegetation on the alluvial fans and lower hills up to an altitude of about 7,000 feet is mainly sagebrush, juniper (*Juniperus* sp.), scrub oak (*Quercus* sp.), mountain-mahogany (*Cercocarpus* sp.), and pinyon pine (*Pinus edulis*).

Above an altitude of about 7,000 feet, aspen (*Populus tremuloides aurea*), ponderosa or yellow pine (*Pinus ponderosa*), spruce (*Picea* sp.), and Douglas fir (*Pseudotsuga taxifolia*) predominate. These genera are most dense on the plateaus and mountain slopes having a northern exposure. Along all stream channels in the valleys, willows and cottonwoods (*Populus* sp.) are the principal vegetation.

POPULATION, AGRICULTURE, AND INDUSTRY

The total population in the upper Sevier River basin is about 3,000. Panguitch, the largest community, has a population of about 1,430. Most of the local residents are engaged in agriculture and related activities and live in towns near their farm. The principal crops are alfalfa, native hay, small grains, and potatoes. Sheep and cattle raising is an important part of the agricultural economy. Next to agriculture, lumbering and sawmills are the most important sources of income.

A large part of the area is administered by the U.S. Forest Service (Dixie and Fish Lake National Forests), the Bureau of Land Management, and the National Park Service (Bryce Canyon National Park and Cedar Breaks National Monument).

GEOLOGY

The geologic map of the upper Sevier River basin was compiled partly from maps in previous geologic reports and partly from photogeologic and geologic field studies conducted during this investigation. The previous maps are primarily the work of Gregory (1949, 1950, 1951) and Marine (1962). (See pl. 1.)

During this investigation the geology of approximately 1,800 square miles of the basin was mapped. This mapping was done in a single field season and, hence, is considered a reconnaissance. The valley and mountain areas containing sedimentary bedrock were studied in greatest detail; these areas were mapped on aerial photographs, primarily in the field, but some were not checked in the field. Areas containing only volcanic rocks were mapped by photogeologic methods, with but slight field checking.

The geology obtained from maps in previous reports was adopted with only a few changes: the valley fill was subdivided into several formations, some contacts were modified to conform with those shown on aerial photographs, contacts were modified along map boundaries to conform with mapping done during this study, and faults and small outcrops were added in places to show slightly greater detail. These changes are primarily in the valley areas, in the area around and north of Panguitch Lake, and in the northern Paunsaugunt Plateau.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING CHARACTERISTICS

The geologic formations exposed in the upper Sevier River basin include rocks of Triassic, Jurassic, Cretaceous, Tertiary, and Quaternary age. Rocks older than Late Cretaceous age, however, although widely exposed in surrounding areas, are limited to an exposure of less than 11 square miles near the head of Antimony Creek; elsewhere in the basin they are deeply buried. Rocks of Late Cretaceous age are exposed principally on the Paunsaugunt Plateau, and rocks of Tertiary age are exposed almost everywhere in the area except where covered with valley fill. Unconsolidated deposits of Quaternary age fill the valley basins, and form the reservoir for most of the ground water in the project area.

The areal distribution and structure of the various formations are shown on the geologic map (pl. 1). The structure and some of the prominent physiographic elements of the area are shown on the geologic sections (pl. 1). The age, thickness, lithology, surface expression, and water-bearing characteristics of the formations are summarized in table 1 and described in detail in the pages that follow.

MESOZOIC FORMATIONS

The oldest rocks exposed in the upper Sevier River basin are in the upthrown block of the Paunsaugunt fault on the northwest edge of the Aquarius Plateau in Antimony Creek canyon and Dry Wash (pl. 1). The outcrops include six formations and one additional formation member of Late Triassic and Jurassic age and two formations of Late Cretaceous age (Gregory, 1951, p. 582–589). These formations, individually listed in table 1, have only small areal exposure and elsewhere in the basin lie at great depth; hence, they are not important as sources of ground water. They are shown on the geologic map (pl. 1) as nonsedimentary rocks.

CRETACEOUS SYSTEM

UPPER CRETACEOUS SERIES

UNDIVIDED FORMATIONS

General description

Upper Cretaceous formations include the Straight Cliffs and Wahweap Sandstones and the Kaiparowits Formation. The Straight Cliffs and Wahweap Sandstones are lithologically and hydrologically similar; are exposed along the sides of the Paunsaugunt Plateau, along the east side of Emery Valley subbasin and bordering the southeast part of Johns Valley subbasin (pl. 1); and are probably continuous

TABLE 1.—Generalized geologic section in the upper Sevier River basin

System	Series	Stratigraphic unit		Thickness (feet)	Description of rocks	Surface expression and areal extent	Water-bearing properties
Quaternary	Pleistocene and Recent	Alluvium	Flood-plain deposits	0-50±	Interbedded lenses of silt and well-sorted sand and gravel in channel deposits; [illegible] sand, silt, and clay in overbank deposits.	Narrow ribbonlike flood plains of Sevier River, East Fork Sevier River, and Otter Creek.	Principal aquifer in upper Sevier River basin; yields large quantities of water to wells and springs, ranging from clean sand and [illegible]
			Younger alluvium and older alluvium	0-300±	Interbedded, lensed, and tongue-fingered deposits of cobbles, pebbles, sand, silt, and clay, poorly to moderately well sorted and stratified. Old alluvium is [illegible] distinguishable [illegible] in the subsurface and may be [illegible] Sevier River Formation.	Coalescing and single alluvial fans fill in major valleys and [illegible] exposed only in [illegible] Valley, [illegible] and [illegible]	
		Lacustrine deposits		0-300±	[illegible]	[illegible] valley [illegible] limited to Grass Valley.	Low permeability; not known to yield water to wells or springs in the basin.
		[illegible]		0-700±	Poorly sorted and partly stratified deposits of [illegible] cobbles, pebbles, sand, and [illegible]	[illegible]	Low permeability; not known to yield water to wells or large springs in the basin.
		Unconformity					
		Basalt		0-1,500	Olivine and basalt [illegible]	Flows, dikes, plateaus, cones, and [illegible] from eastern Markagunt Plateau.	Not known to yield water to wells or large springs in the area. [illegible]
		Unconformity					

TABLE 1.—*Generalized geologic section in the upper Sevier River basin*—Continued

System	Series	Stratigraphic unit		Thickness (feet)	Description of rocks	[illegible]	Water-bearing characteristics
[illegible]	Upper Pliocene and Pleistocene	Sevier River formation		[illegible]	[illegible]	[illegible] Valley.	Generally low [illegible]
		Unconformity					
		Intrusive rocks		[illegible]	[illegible]	[illegible] Valley.	[illegible]
	Miocene(?) and Pliocene(?)	Extrusive rocks		[illegible]	[illegible]	[illegible] Mountains.	Generally low permeability, [illegible]
		Unconformity					
Tertiary		Brian Head formation	[illegible]	[illegible]	[illegible]	[illegible]	Low to high permeability [illegible]
	[illegible](?)				[illegible]	[illegible]	Low to [illegible]

		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		Wasatch Formation	[illegible]	[illegible]	[illegible]	[illegible]
		Unconformity				
		[illegible] Formation	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	Unconformity				
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Upper [illegible]	Sedimentary rocks	?	[illegible]	[illegible]	[illegible]

in the subsurface throughout most of the area. The Kaiparowits Formation is exposed around the east, south, and west sides of the Paunsaugunt Plateau, but thins rapidly in a northerly direction, extending only about to the middle of the upper Sevier River basin. The combined thickness of these formations ranges from about 500 to 2,300 feet (Gregory, 1951, p. 27; Marine, 1963, p. 456–457).

The following lithologic description was derived largely from Gregory and Moore (1931), Gregory (1951), and Marine (1963). The combined Straight Cliffs and Wahweap Sandstones consist mostly of massive to thin-bedded sandstone which intergrades and intertongues unsystematically with material that ranges from shale to shaly sandstone. The predominant sandstone of the unit is tan to yellow tan and buff brown, fine to coarse grained, cemented mainly by calcite and some iron oxide, and is mostly massive bedded, beds thicker than 10 feet predominating. The shale and shaly sandstone is tan to gray, mostly argillaceous, carbonaceous, or calcareous, and thin bedded. In addition, irregular beds and lenses of conglomerate occur in the two formations. Coal is also present in the Straight Cliffs Sandstone, as described in Feltis and Robinson (1963, p. 24–26), Carpenter, Robinson, and Bjorklund (1967, p. 23–24), and Marine (1963, p. 457, pl. 26).

The Straight Cliffs Sandstone forms prominent steep-sided ledges and cliffs; the Wahweap Sandstone forms a group of steplike cliffs which are distinguishable from the cliffs of the Straight Cliffs Sandstone in some places but in other places combine with them to form a single slope interrupted by ledges.

The Kaiparowits Formation consists of dark-gray, gray-green, yellow, and tan arkosic sandstone which is medium to coarse grained and weakly cemented by calcium carbonate. The sandstone is highly variable, both horizontally and vertically, in bedding, texture, and composition. Beds range in thickness from several inches to less than 5 feet. The unit forms predominantly dark-gray receding slopes interrupted by shelflike benches.

Water-bearing characteristics

The best water-bearing zones in the Upper Cretaceous formations are in the Straight Cliffs and Wahweap Sandstones. These zones contain the more permeable sandstone beds and also fractures in the sandstone beds. The Upper Cretaceous formations on the north end of the Paunsaugunt Plateau yield small quantities of water, generally less than 10 gpm (gallons per minute), to wells that range from about 180 to 310 feet in depth. Well (C-37-4)10dd-1 in Bryce Canyon National Park, however, is 2,000 feet deep and yields about 220 gpm from the Straight Cliffs and Wahweap Sandstones (Marine, 1963, p.

450). The depth to the Cretaceous formations in most of the upper Sevier River basin is too great for economical well construction.

Many small springs and seeps around the Paunsaugunt Plateau yield water from the Upper Cretaceous formations. Only a few of these springs, however, discharge into the upper Sevier River basin. Marine (1963, table 6, p. 461-466) listed 18 springs in the Bryce Canyon area which discharge from the Upper Cretaceous formations southeastward into the Paria River drainage. Recharge to the formations, however, is from the upper Sevier River basin. Of these 18 springs, 15 discharge from about 2 to 165 gpm from the Straight Cliffs and Wahweap Sandstones and 3 springs discharge unmeasured amounts from the Kaiparowits Formation. Several springs on the plateau, usually yielding 10 gpm or less, issue from the Kaiparowits Formation south of Tropic Reservoir, but the source of the water is probably from the basal conglomerate of the overlying Wasatch Formation (Marine, 1963, p. 462).

TERTIARY SYSTEM

EOCENE AND MIOCENE(?) SERIES

WASATCH AND BRIAN HEAD FORMATIONS

General description

The Wasatch and Brian Head Formations are well exposed throughout much of southern Utah. Although both formations are distinct in appearance, a gradational zone between them makes separation difficult; hence, they have been mapped as an undifferentiated unit in previous reports (Gregory, 1949, 1950a).

The Wasatch Formation is one of the most widely exposed formations in the upper Sevier River basin. It forms prominent pink cliffs on the Markagunt, Paunsaugunt, and Table Cliff Plateaus and on the south ends of the Sevier and Aquarius Plateaus; in Bryce Canyon National Park it forms cliffs, spires, and columns. The formation thins rapidly to the north, ranging in thickness from 400 to 1,100 feet on the Paunsaugunt and Table Cliff Plateaus to practically zero north of Johns Valley subbasin (Gregory, 1944, p. 600-601; 1951, p. 44; Marine, 1963, p. 456). It consists of thick-bedded pink to red fresh-water limestone which contains irregularly interbedded pink to yellow shaly limestone, shale, siltstone, sandstone, and conglomerate. At many localities the lowest part of the formation is a red massive calcareous basal conglomerate which is lenticular and discontinuous.

Gregory (1945, p. 105) described the Brian Head Formation as containing a lower unit of evenly stratified fine-grained material and an upper unit of coarse agglomerate. The lower unit generally is exposed in the same areas as is the Wasatch Formation, except that the lower unit generally has been "stripped" from the Paunsaugunt Plateau. In addition, the lower unit is well exposed on the northern end of the Markagunt Plateau, northwest of Panguitch, where erosion has not yet exposed much of the underlying Wasatch Formation. The thickness of the lower unit in the area reportedly ranges from 0 to nearly 1,000 feet (Gregory, 1944, p. 601; 1945, p. 111; 1949, p. 967, 980; 1951, p. 50). It is composed of well-stratified siliceous limestone, lignitic marl, calcareous silt, shale, calcareous and clayey sandstone, tuffaceous sandstone and conglomerate, and water-lain pyroclastic material of various types. The material is shades of white, gray, green, tan, and brown. There is some evidence that the deposits included in the unit in the northern Markagunt Plateau are not part of the Brian Head Formation. Determining the exact age of these deposits was beyond the scope of this investigation, however, and they were mapped as part of the Wasatch and Brian Head Formations.

A notable feature of the lower unit is an increase, from south to north, of the amount of volcanic debris and of grain size. In general, the unit forms cliffs, ledges, and steep slopes, or a cap on parts of the major plateaus. It also forms rounded hills along valley edges and often weathers into badlands.

The upper unit of the Brian Head Formation is exposed on the west side and the lower end of Panguitch Valley and near Antimony on both sides of East Fork Sevier River between the head of Black Canyon and the head of Kingston Canyon (pl. 1) (Gregory, 1944, p. 593). Much of the unit as described in these areas, however, may later prove to be part of the Bullion Canyon volcanic sequence. Part of the rocks mapped as Sevier River Formation on the eastern margin of the Markagunt Plateau between Panguitch and Hatch (pl. 1) may be part of the upper unit of the Brian Head Formation. The upper unit of the Brian Head thickens to the north, reaching an estimated maximum of about 800 feet.

The upper unit has indefinite upper and lower boundaries and is sometimes difficult to distinguish from the volcanic rocks with which it intergrades. It was described by Gregory (1945, p. 108; 1949, p. 983) as "dark gray, remarkably coarse agglomerate." The conglomerate in Black Canyon was further described by Gregory (1944, p. 595) as being "roughly bedded, but very poorly sorted * * * and including * * * rare lenses of thin-bedded, medium-grained sandstone * * *." Except for the outcrops in Black Canyon, much of the dark-gray agglomerate assigned by Gregory to the upper unit at several places (Gregory, 1944, p. 594; 1945, p. 108; 1949, p. 983) probably is part of the Tertiary volcanic rock series. Most of these outcrops lack notable stratification and are probably pyroclastic debris belonging to the

Roger Park Basaltic Breccia. In this report the upper unit of the Brian Head Formation is considered to include primarily only a stratified and apparently water-laid tuffaceous conglomerate and sandstone deposit of volcanic origin. The upper unit is believed to crop out north of Kingston Canyon but it is interbedded with volcanic rocks of Tertiary age; therefore, it is not differentiated on the geologic map (pl. 1). The upper unit is expressed topographically as terraces and formed of a succession of conglomerate ledges and receding sandstone slopes.

Water-bearing characteristics

The Wasatch and Brian Head Formations both contain water-bearing zones that consist mainly of fractures and joints in otherwise impervious strata or thin porous strata within the sandstone and conglomerate beds. In addition, the Wasatch Formation transmits large quantities of water in solution channels in limestone beds, and the upper unit of the Brian Head Formation in Black Canyon transmits large quantities of water from fractures and joints and at the contact between the conglomerate and intraformational volcanic flows.

The Wasatch and Brian Head Formations yield small quantities of water to wells, chiefly in East Fork Valley area. These wells usually produce less than 30 gpm, mainly from the Wasatch Formation, and are generally less than 150 feet deep. Wells penetrating the upper unit of the Brian Head Formation near Antimony produce from about 5 to 25 gpm.

These formations also are the sources of many springs. Springs in the Wasatch Formation in the eastern Markagunt Plateau normally discharge from 25 to 1,500 gpm from solution channels in limestone; Mammoth Springs, (C-38-7)31dac, has discharged as much as 121,000 gpm (Wilson and Thomas, 1964, fig. 13). The Wasatch Formation elsewhere in the area generally yields less than 100 gpm to springs.

The lower unit of the Brian Head Formation yields small quantities of water (generally less than 50 gpm) to a few springs and seeps. The upper unit yields water to a few springs in Black Canyon and near Antimony. Five of the springs in Black Canyon issue at the contact of fractured intraformational volcanic rocks and underlying relatively impermeable conglomerate and sandstone. These springs discharge from 50 to more than 1,500 gpm. Large quantities of water also issue from contact zones between volcanic rocks and relatively impermeable conglomerate in the upper unit at the head of Antimony Creek. These springs are largely responsible for the consistent base flow of the creek, about 11 cfs (cubic feet per second).

MIOCENE(?) AND PLIOCENE(?) SERIES

VOLCANIC ROCKS

General description

Volcanic rocks of Miocene(?) and Pliocene(?) age compose the bulk of the Fish Lake, Awapa, Aquarius, and Sevier Plateaus, the southern Tushar Mountains, and the highlands of the northern Markagunt Plateau between Panguitch and Circleville Canyon (pl. 1). These rocks include two separate formations: the Bullion Canyon Volcanics of Miocene(?) age, exposed mainly north of Circleville and Kingston Canyons, and the Roger Park Basaltic Breccia of Pliocene(?) age, exposed in the remainder of the area. The Bullion Canyon Volcanics overlies and interfingers with the upper unit of the Brian Head Formation north of Kingston Canyon and is possibly conformable to it. In fact, much of the upper Brian Head unit described in Black Canyon and near Antimony may later prove to be part of the Bullion Canyon volcanic sequence. Elsewhere the Bullion Canyon Volcanics and the Roger Park Basaltic Breccia are probably unconformable on the underlying rocks. The combined volcanic rocks in the northern part of the upper Sevier River basin are more than 4,000 feet thick (Willard and Callaghan, 1962) and are estimated to range in thickness from 0 to a few hundred feet in the southern part of the basin.

According to Willard and Callaghan (1962), the Bullion Canyon Volcanics "consists of a thick series of latitic breccias, tuffs, and thin flows at the base, a succession of latite and quartz latite flows with thin intervening beds of volcanic breccia, and more mafic flows and breccias at the top." The Roger Park Basaltic Breccia is described (Callaghan and Parker, 1962b) as "a breccia composed of fragments and matrix of basaltic andesite."

Topographically, the volcanic rocks form caps, jagged cliffs, ledges, and rubbly slopes on most of the major plateaus and mountains and underlie foothills on the valley sides.

Water-bearing characteristics

Water-bearing zones consist of fractures and joints which occur irregularly; therefore, ground-water conditions in the volcanic rocks in any single locality are unpredictable. In most places these rocks impede the movement of ground water. Only one well, (C-27-1)20dcc-1, is known to produce water from the volcanic rocks; this well reportedly yields 90 gpm.

The volcanic rocks yield water to many springs, the largest being Hoe Springs, (C-25-1)26bc (pl. 2), which produced about 1,440 gpm in July 1962. Other springs issuing from volcanic rocks of Tertiary age yield from less than 1 to more than 900 gpm.

INTRUSIVE ROCKS

General description

Intrusive rocks of Tertiary age are exposed at the north end of Panguitch Valley basin near the head of Circleville Canyon (pl. 1). Because they appear to have intruded the upper unit of the Brian Head(?) Formation of Miocene(?) age and are overlain by the Roger Park Basaltic Breccia of Pliocene(?) age, the intrusive rocks probably are of Miocene(?) age.

The intrusive rocks consist of quartz monzonite and quartz monzonite porphyry, are light to medium gray, and are finely to coarsely crystalline. They form steep-sided, rubbly to smooth slopes, cliffs, and highly jointed ridges.

Water-bearing characteristics

The intrusive rocks are compact and homogeneous and are not lineated; therefore, they are poor aquifers. In fact, they form a barrier to ground-water movement at the lower end of Panguitch Valley basin and are largely responsible for the marshy conditions there.

TERTIARY OR QUATERNARY SYSTEMS

UPPER PLIOCENE OR LOWER PLEISTOCENE DEPOSITS

SEVIER RIVER FORMATION

General description

The Sevier River Formation of late Pliocene or early Pleistocene age is exposed in the upper Sevier River basin only as relatively small, isolated to semiconnected deposits in the south end and on both sides of Panguitch Valley basin (pl. 1). It is a valley-fill deposit, consisting primarily of old alluvial fans, and, therefore, it is similar in most respects to, and is usually difficult to distinguish from, deposits of Recent alluvium. (The phrase "valley fill," as used in this report, includes all alluvium, lake(?) or marsh(?) deposits, landslide deposits, and the Sevier River Formation.) The Sevier River Formation can be differentiated in outcrops, however, by (1) topographic form, (2) excessive, deficient, or reversed dip of bedding planes (Willard and Callaghan, 1962), (3) a generally poorer degree of sorting and stratification, (4) a generally greater degree of consolidation, (5) faulting within the formation (Callaghan and Parker, 1962b), and (6) the presence of lacustrine deposits similar to those in the type area of the formation near Sevier, Utah (Callaghan, 1938, p. 101, and Callaghan and Parker, 1962a).

The Sevier River Formation is believed to underlie much of the surficial Quaternary and Recent alluvium in the southern part of Panguitch Valley basin (pl. 1, section *D–D'*). Gregory (1949, p. 987 and pl. 1) mapped exposures of the formation on the west side of Panguitch Valley between Panguitch and Hatch, but much of this may be the upper unit of the Brian Head Formation. No attempt was made in this study to alter Gregory's (1949) mapping of the Sevier River Formation.

The Sevier River Formation is greatly eroded and mostly buried by younger sediments; therefore, the thickness of the formation cannot be determined from outcrops. Study of outcrops, drillers' logs, and logs of test holes in Panguitch Valley basin, however, indicates a thickness ranging from 0 to more than 450 feet. The formation generally is poorly sorted and poorly stratified valley fill which consists of unconsolidated to partly consolidated cobbles, pebbles, sand, silt, and clay deposited as alluvial fans. It also contains lacustrine deposits of sand, silt, clay, and argillaceous limestone beds which contain fossil gastropods, pelecypods, and microfossils(?).

Topographically, the Sevier River Formation forms high rounded hills, isolated by stream-incised bluffs, fans, and terracelike forms, and long "trainlike" deposits which were dissected from old alluvial fans by recent streams.

Water-bearing characteristics

The lack of sorting and consolidation and the abundance of silt in the Sevier River Formation generally results in low permeability. The best water-bearing zones are lenses of well-sorted sand and gravel that contain little silt. These permeable zones yield small to moderate amounts of water to domestic and stock wells. Reported yields from wells generally range between 10 and 50 gpm.

The formation yields water to springs and seeps in an area about 2½ miles west of Red Canyon; the largest of which, Myers Springs, (C-35-5)25cb, flows about 450 gpm. Yields of other springs range from less than 1 to about 10 gpm.

QUATERNARY SYSTEM

PLEISTOCENE AND RECENT SERIES

BASALT

General description

Basalt flows of Quaternary age cover large areas of the Markagunt Plateau and occur as small isolated flows along the east side of Panguitch Valley and on the northern Paunsaugunt Plateau near the entrance to Red Canyon (pl. 1). The estimated thickness of the basalt on the Markagunt Plateau ranges from 0 to 1,200 feet (Gregory, 1950a, p. 26). The flows on the Paunsaugunt Plateau are estimated to be less than 100 feet thick.

The basalt flows of the Markagunt Plateau include dense gray to black, finely crystalline and porphyritic olivine or hornblende basalt (Gregory, 1949, p. 985). The basalt is black, dense, often vesicular and scoriaceous; in many places it displays well-marked flow structures. The basalt forms sheets, streams, cones, and ash fields.

Water-bearing characteristics

The basalt flows of the Markagunt Plateau were described as being "* * * permeable enough that they can absorb the water of maximum cloudburst storms or maximum snowmelt without runoff * * *," but "* * * sufficiently impermeable to form effective barriers to water movement along the pre-basalt valleys * * * where the drainage is now achieved by channels in the limestone [Wasatch] beneath the basalt" (Wilson and Thomas, 1964, p. 19). The basalt is not known to yield water to wells or large springs on the Markagunt Plateau, but it does yield water to many seeps and small springs.

The basalt flows of the Markagunt Plateau have "dammed" the flow of many surface streams, and thereby forced them to seek new drainages. Many of these streams have bypassed the damming effect by the existing solution channels in the underlying Wasatch Formation. These solution channels yield large quantities of water to springs that exist in and along the base flow of the Sevier River above Hatch (Wilson and Thomas, 1964, p. 24–25).

IGNEOUS RUBBLE

General description

Gregory (1949, p. 981, 991) briefly noted patches of mixed layers of igneous gravel on the northeast edge of the Markagunt Plateau. He mapped this material in two areas (1949, pl. 1) as "Quaternary igneous gravel." Similar deposits on the north end of the Markagunt Plateau and on the south end of the Sevier Plateau (pl. 1) were mapped during this study. These deposits and one of the deposits mapped by Gregory are shown on the geologic map as "Quaternary igneous rubble" because most of the material is angular. The second deposit mapped by Gregory as igneous gravel near the north boundary of his map is believed to be part of the Tertiary volcanic rocks. The deposits mapped during this study cover the slopes, cap most of the ridges, and form long extended deposits in the vicinity of Castle Bluff. This material is not considered to be part of the valley fill.

The age of the igneous rubble is unknown, but the rubble probably was deposited during an earlier cycle of erosion and deposition similar to that described by Williams and Callaghan (1962). Thus, it may be as old as or older than the Sevier River Formation, which is of late Pliocene or early Pleistocene age. However, inasmuch as there is little evidence that the rubble is of Pliocene age, the formation is here assumed to be of Quaternary age, although parts or all of it may be older.

The thickness of the igneous rubble ranges from 0 to more than 100 feet and averages about 25–50 feet. The outcrops of the formation are quite uniform and consist of poorly sorted and poorly stratified boulders, cobbles, pebbles, sand, and silt. The larger fragments are generally angular to subangular. The rubble is composed almost entirely of volcanic rock fragments similar to the Roger Park Basaltic Breccia. In many areas the rubble is about 5 percent box-shaped to oblate boulders and cobbles of white and maroon banded quartzite. This quartzite is foreign to the upper Sevier River basin, and its source is unknown.

The Quaternary igneous rubble forms hummocky and rubbly masses which cap interstream divides and slopes of the drainages of the Sevier and Paunsaugunt Plateaus.

Water-bearing characteristics

The Quaternary igneous rubble probably is not a good water-bearing formation because it contains abundant silt and loose sorting. It is not known to yield water to wells or large springs in the area.

LANDSLIDE DEPOSITS

Two small landslides are shown on the geologic map (pl. 1). One slide is several miles east of Otter Creek Reservoir and the other is about 8 miles southeast of Greenwich. The slides have a combined area of less than 3 square miles and are composed of a heterogeneous unsorted mass of material that has moved downslope from the face of the Awapa Plateau. The maximum thickness of these deposits probably is more than 300 feet. The landslides are not important water-bearing units because of their small areal extent and poor sorting.

ALLUVIUM

The alluvium in the upper Sevier River basin was subdivided into three mappable units—old alluvium, young alluvium, and flood-plain deposits. The old alluvium, which is exposed only in Panguitch Valley basin, generally is distinguishable from the young alluvium only on the basis of topographic expression. It consists of old dissected alluvial fan remnants which are topographically higher than present young alluvial fans. All alluvium elsewhere in the basin other than flood-plain deposits is shown on the geologic map as young alluvium, even though much of this alluvium may be equivalent to the old alluvium. "Flood-plain deposits," as used in this report, refers to sediments deposited in the present flood plains of the Sevier River, the East Fork Sevier River, and Otter Creek. The old alluvium is similar to the young alluvium in water-bearing properties. The flood-plain deposits constitute the best aquifers in the alluvium, but they are lenticular and discontinuous and interfinger with the other alluvial deposits in the subsurface. Therefore, although the three units are shown separately on the geologic map, they are discussed as a single hydrologic unit in this report.

Old and young alluvium

The old alluvium (pl. 1) is exposed only in Panguitch Valley basin as isolated bluffs and terrace-like forms or outliers 75–100 feet high on the valley sides as large semidissected fans whose aprons are being stripped away by the Sevier River, and within side canyons as small remnant hanging terraces. Its topographic form is similar to that of the Sevier River Formation, which is also exposed in the valley, and the old alluvium may be equivalent in age to the Sevier River Formation. Much of the material underlying the outcrops of young alluvium in all the major valley basins probably is equivalent in age to the old alluvium.

The young alluvium includes alluvial-fan sediments in the valley basins and alluvium in mountainous tributary valleys. Lake(?) or marsh(?) deposits, not exposed in the upper Sevier River basins, but penetrated by test holes and wells in Koosharem subbasin, are assigned to the young alluvium in this report, even though they are technically not of alluvial origin.

Both the old and young alluvium generally consist of interbedded, lenticular, and interfingering deposits of cobbles, pebbles, sand, silt, and clay. The pebbles and sand range in size from very fine to very coarse and contain small to large amounts of silt and clay. Sorting and stratification range from poor to moderately good. The most permeable water-bearing zones in the old and young alluvium are the gravel and sand beds which have been deposited in stream channels in alluvial fans.

The lake(?) or marsh(?) deposits identified only in the subsurface of Koosharem subbasin interfinger with and underlie the alluvial-fan sediments of the subbasin. They consist of regularly interbedded light- or blue-gray carbonaceous silt and clay and sand and pebbles. Some of the silt and clay beds contain fossil gastropod and pelecypod shells. The lake(?) or marsh(?) deposits were penetrated in test holes (C–27–1)3aaa–2, (C–27–1)6cba–1, and (C–27–1)27bac–1 (Feltis and Robinson, 1963, p. 27–31).

The thickness of the combined old and young alluvium ranges from 0 to more than 900 feet in the upper Sevier River basin.

Flood-plain deposits

Flood-plain deposits, as shown on plate 1, consist of channel and overbank deposits within the present flood plains of the Sevier River, the East Fork Sevier River, and Otter Creek. Outcrops of the unit are differentiated from the old and young alluvium only by location, and all deposits exposed within the present flood plains of these three streams are classified as flood-plain deposits. Channel deposits generally are well-sorted and well-stratified sand and gravel which contain little silt, whereas overbank deposits generally are sand, silt, and clay. Although ancient flood-plain deposits extend in the subsurface beyond the present flood plains of the three streams, their full extent is not known anywhere in the upper Sevier River basin.

The maximum known thickness of the ancient and present flood-plain deposits is about [illegible] feet in Panguitch Valley basin, about 340 feet in Circle Valley basin, about 150 feet in East Fork Valley basin, and about 270 feet in Grass Valley basin (Feltis and Robinson, 1963).

Water-bearing characteristics

The alluvium is the principal aquifer in the upper Sevier River basin, and it yields small to large quantities of water to wells and springs. The main water-bearing beds are sand and gravel. The extent and thickness of the alluvium is described in the section "Valley fill" (p. [illegible]), and water-bearing characteristics of the alluvium in each valley basin are discussed in detail in the section "Ground-water conditions in the basins" (p. [illegible]).

STRUCTURE

The major structural features of the upper Sevier River basin include (1) a prevailing northeasterly dip of both surface and deeper seated strata in the major plateaus (Gregory, 1951, p. 78), (2) two great faults of large displacement, the Sevier and Paunsaugunt faults (pl. 1), which are the chief causes of continuous and nearly straight depressions in the area, and (3) three prominent north-south strips formed of several plateaus and separated by depressions or basins which parallel the strips (Fenneman, 1931, p. 295).

REGIONAL DIP AND FOLDS

Most formations in the plateaus in the upper Sevier River basin have a regional dip of 2°–5° N., NE., and E. (Gregory, 1949, p. 98; 1950, p. 105; 1951, p. 73–74). This regional dip is remarkably uniform, and dips that exceed 5° or dips in southerly or westerly directions generally are due to local faults (see pl. 1). According to Gregory (1951, p. 78), the regional dip played a minor role in the physiographic development of the upper Sevier River basin, not only as a control to surface drainage, but to areal exposure of formations as well. The regional dip also commonly controls the movement of ground water in bedrock aquifers. For example, water moves down the dip through a permeable basalt that overlies an impermeable conglomerate in the upper unit of the Brian Head Formation and discharges through springs at the base of the basalt along the west wall of Black Canyon.

Prominent or large-scale folding is nonexistent in the upper Sevier River basin. Small local folds are merely small flexures in the regional dip and usually occupy less than 1 square mile. They are of little significance in the structure of the area. A typical small fold is the Johns Valley anticline, 5 miles south of Widtsoe (pl. 1).

FAULTS

The Sevier and Paunsaugunt faults delineate the major valleys and plateaus in southern and central Utah. These two north- to northeast-trending master faults are parallel and about 16–26 miles apart.

The Sevier fault is a normal fault, the downdropped block being on the west, and it forms the boundary between the Sevier and Paunsaugunt Plateaus and the Panguitch and Circle Valley basins (pl. 1). The fault can be traced from northern Arizona to the upper end of Sanpete Valley in central Utah (Dutton, 1880, p. 200; Gregory, 1951, p. 74–76). The throw along the Sevier fault within the upper Sevier River basin ranges from 300 to about 2,000 feet and varies greatly within short distances (Gregory, 1951, p. 76). The fault generally is marked by a prominent scarp or fault-line scarp, the upthrown side forming the scarp.

The Paunsaugunt fault is also a normal fault, the downdropped block being on the west. It can be traced from near the southern boundary of Utah, through the upper Sevier River basin to near the Fish Lake Plateau. It forms the boundary along the eastern edge of the Paunsaugunt Plateau and, farther north, the boundary between the Table Cliff, Aquarius, Awapa, and Fish Lake Plateaus and the East Fork Valley and Grass Valley basins (pl. 1). The throw of the fault is mostly between 600 and 2,000 feet (Gregory, 1951, p. 77), but it exceeds 3,200 feet along the Aquarius Plateau (Gregory, 1944, p. 601). Like the Sevier fault, its displacement varies greatly within short distances. The Paunsaugunt fault generally is not as well expressed in the topography as the Sevier fault. The Paunsaugunt fault generally lies in the foothills at a distance from the plateaus; it is often covered by alluvium and in places displays topographic inversion, the downthrown block forming the plateau.

Many other faults, shorter and having smaller displacements than the Sevier and Paunsaugunt faults, occur in the highlands and foothills of the upper Sevier River basin. Many of these faults parallel the two major fractures and lie in close proximity to them (pl. 1). Apparently the two master faults controlled the formation and orientation of the smaller faults.

VALLEY BASINS

Faulting, erosion, and deposition by streams have shaped the several ground-water basins in the upper Sevier River basin. The valley fill in these basins has been derived from the consolidated and unconsolidated formations in the uplands that surround the valleys. In Circle and Grass Valley basins all the sediments are derived from volcanic rocks; in Panguitch and East Fork Valley basins, the sediments are derived from both volcanic and sedimentary rocks. The word "alluvium," as used in the following discussion, includes old alluvium, young alluvium, and flood-plain deposits. A description of the physiographic elements of the valley basins is given in the section "Physiography" (p. 7).

PANGUITCH VALLEY BASIN

Panguitch Valley basin is the segment of the upper Sevier River basin between the mouth of Mammoth Creek and the head of Circleville Canyon (pl. 1). It includes an area of about 70,000 acres. The basin is bounded on the south by sedimentary rocks which constrict the valley, on the west by sedimentary and volcanic strata which descend from the eastern and northeastern Markagunt Plateau and continue beneath the valley fill (pl. 1, sections *A–A'* and *B–B'*), on the east by the Paunsaugunt and Sevier Plateaus and the Sevier fault, and on the north by sedimentary and igneous rocks. The Sevier fault is more responsible for the presence of Panguitch Valley basin than any other structural element. A maximum known thickness of 835 feet of valley fill, all of which is alluvium, was penetrated by test hole (C-33-5)13dd-1 (Feltis and Robinson, 1963, p. 10) in the northeastern part of the valley.

Panguitch Valley basin is separated from Circle Valley basin downstream by a constriction of volcanic rock between the Sevier Plateau and the southern Tushar Mountains. The Sevier River flows through this constriction in a steep-sided gorge about 5½ miles long and about 100–800 feet wide called Circleville Canyon (pl. 1, geologic map and section *D–D'*).

CIRCLE VALLEY BASIN

Circle Valley basin includes about 14,000 acres, and it occupies the area between the mouth of Circleville Canyon and the bedrock constriction west of Kingston (pl. 1). The basin was formed by en echelon faulting in the surrounding volcanic rocks. It is bounded on the west by the southern Tushar Mountains and on the east by the

Sevier Plateau. A constriction formed by volcanic rock at the northeast corner of the basin separates Circle Valley basin from the central Sevier Valley downstream (Young and Carpenter, 1965). A maximum known thickness of 680 feet of valley fill, all of which is alluvium, was penetrated by test hole (C-31-3)32bab-1 near the center of the basin.

EAST FORK VALLEY BASIN

East Fork Valley basin is the basin between Tropic Reservoir and the upper end of Kingston Canyon (pl. 1). The basin is subdivided into three subbasins by two bedrock constrictions, one formed by Flake Mountain and the other by the rock at the lower end of Johns Valley subbasin (see pl. 1, section *E–E'*).

EMERY VALLEY SUBBASIN

Emery Valley subbasin, between Tropic Reservoir and Flake Mountain, includes an area of about 12,760 acres. Part of the subbasin is bounded on both sides by faults (pl. 1), along which the subbasin was uplifted; a horst was thus formed, which has since been eroded to form the present valley. The subbasin is bounded at its southern end and on its eastern and western sides by sedimentary bedrock and at its northern end by volcanic and sedimentary rocks. A maximum known thickness of 60 feet of valley fill, all of which is alluvium, was penetrated by well (C-30-1)26cca-1 in the south-central part of the subbasin.

JOHNS VALLEY SUBBASIN

Johns Valley subbasin, between Flake Mountain and the head of Black Canyon, includes an area of about 63,000 acres (pl. 1). It is bounded at its southern end by the volcanic-rock constriction formed by Flake Mountain, on its western side by sedimentary and volcanic rocks of the Sevier Plateau, on its eastern side by sedimentary and volcanic rocks of the Table Cliff and Aquarius Plateaus, and at its northern end by bedrock at the head of Black Canyon. The Paunsaugunt fault separates the valley from the Table Cliff and Aquarius Plateaus along much of the eastern valley margin and is the main structural element forming the subbasin. Several other faults are in the subbasin, one along the western side and one assumed at depth beneath the valley floor. A maximum known thickness of 300 feet of valley fill, all of which is alluvium, was penetrated by test hole (C-33-2)32dcd-1 in the central part of the subbasin.

Johns Valley subbasin is separated from Antimony subbasin downstream by a bedrock constriction between the Aquarius and Sevier Plateaus. The East Fork Sevier River flows through the constriction in Black Canyon, a steep-sided gorge about 8 miles long, 100–400 feet wide, incised in sedimentary and volcanic bedrock (pl. 1, geologic map and section *E–E'*).

ANTIMONY SUBBASIN

Antimony subbasin includes an area of about 6,000 acres between the mouth of Black Canyon and the head of Kingston Canyon (pl. 1, geologic map and section *E–E'*). It is a small valley bounded at its southern end by the bedrock at Black Canyon, on its western side by volcanic and sedimentary rocks of the Sevier Plateau, on its eastern side by eastward-dipping sedimentary and volcanic rocks of the Aquarius Plateau, and at its northern end by junction with the Grass Valley basin and the bedrock at the head of Kingston Canyon (pl. 1). This subbasin, like Johns Valley subbasin, is due largely to the Paunsaugunt fault, which occurs several miles east of the valley and separates it from the Aquarius Plateau (pl. 1). A maximum known thickness of 201 feet of valley fill, all of which is alluvium, was penetrated by test hole (C–31–3)3bbc–1 in the central part of the subbasin.

Downstream from Antimony subbasin, the East Fork Sevier River flows through the Sevier Plateau in Kingston Canyon, a narrow, steep-sided gorge, approximately 9 miles long, 100 feet to half a mile wide, incised in sedimentary (?) and volcanic rock.

GRASS VALLEY BASIN

Grass Valley basin is between the low topographic divide 2 miles north of Koosharem Reservoir and the Otter Creek Reservoir dam near the head of Kingston Canyon (pl. 1). The low topographic divide at the north end of the basin separates the Otter Creek drainage from the central Sevier Valley to the west and north. Grass Valley basin is divided into two subbasins by a bedrock constriction about 5½ miles south of Greenwich (pl. 1, section *F–F'*).

KOOSHAREM SUBBASIN

Koosharem subbasin includes an area of about 50,000 acres between the low topographic divide north of Koosharem Reservoir and the bedrock constriction south of Greenwich (pl. 1). It is bounded by the volcanic rocks of the Sevier Plateau on the west and the volcanic rocks of the Awapa and Fish Lake Plateaus on the east (pl. 1). The subbasin is a graben valley between the Paunsaugunt fault on the east and an unnamed fault on the west. A maximum known thickness of 770 feet of valley fill, most of which is alluvium, was penetrated by test hole (C–27–1)27aac–1 near the central part of the subbasin.

ANGLE SUBBASIN

Angle subbasin includes an area of about 20,000 acres between the bedrock constriction south of Greenwich and Otter Creek Reservoir dam, which is near the junction with Antimony subbasin and the head of Kingston Canyon (pl. 1). It also is a graben valley, bounded on the east by the Awapa Plateau and the Paunsaugunt fault, and on the west by the Sevier Plateau and an unnamed fault. Several large outcrops of volcanic rock within the subbasin define smaller basins which contain valley fill (pl. 1, section A–A′). A maximum known thickness of 400 feet of valley fill, all of which is alluvium, was penetrated by test hole (C-29-3)5dbc-1 near Angle.

WATER RESOURCES

HISTORY OF WATER-RESOURCES DEVELOPMENT

Irrigation began in the upper Sevier River basin in the early 1860's when the first white settlers constructed diversion dams on some of the larger streams. Surface-water development reached its maximum in about 1920 (Woolley, 1947, p. 155).

Development of ground water in the basin began at about the same time as surface-water development but was limited mainly to the use of springs for public supply and irrigation. The first wells were constructed in about 1890, and the number has steadily increased to about 800. Most of the wells are used for domestic and stock supply, and periods of drought have increased interest in the possibilities of using additional water from wells for irrigation.

Controversies over water rights on the Sevier River system have occurred continually since the 1880's, mostly during drought periods. These controversies have resulted in many court decrees, including the Cox Decree of 1936 (Cox, 1936), which is used by the Utah State Engineer to distribute the water of the Sevier River system to the water users.

In the Cox decree, water rights pertaining to ground water are mostly for springs, but rights for a few drains and wells are also listed. The decree made little mention of wells in the upper Sevier River basin because it was assumed that unappropriated ground water was not available for additional appropriation. This assumption has persisted and has been an important factor in deterring large-scale development of ground water. The rights in the decree concerning wells specify only use for irrigation. Water rights for many domestic, stock, public-supply, and industrial wells and some irrigation wells that are not listed in the decree are in the files of the State Engineer.

SURFACE WATER

The source of all streams in the upper Sevier River basin is precipitation within the basin. Most of the surface flow that leaves the basin is in the Sevier River and its largest tributary, the East Fork Sevier River. These streams merge about 1½ miles north of the basin near Kingston. Some water also leaves the basin in irrigation canals near Kingston and by a transmountain diversion from a point on the East Fork Sevier River below Tropic Reservoir eastward to Paria Valley in the Colorado River basin.

Surface water is stored in several reservoirs in the basin and is diverted from the river and its main tributaries by many canals. The Sevier River, its tributaries, reservoirs, and canals are discussed in the following pages.

THE SEVIER RIVER AND ITS TRIBUTARIES

The Sevier River above Kingston (locally called the South Fork Sevier River) drains about 1,110 square miles. The chief water-yielding areas are high in the Markagunt Plateau near Cedar Breaks National Monument and Navajo Lake (pl. 2), and the main stem of the river is formed by the merging of Asay and Mammoth Creeks south of Hatch. As the river flows northward through Panguitch Valley and Circle Valley basins it receives water from many tributaries and from ground-water discharge, part of which was originally water diverted for irrigation upstream.

The monthly flow of the Sevier River at three stream-gaging stations for the period 1943–62 is shown in figure 4, and the locations of the gaging stations are shown on plate 2. The Sevier River at Hatch had an average annual flow of 96,800 acre-feet for 40 years of record (1911–28, 1939–62); the Sevier River near Circleville, 171,600 acre-feet for 22 years of record (1914–15, 1923–24, 1940–62); and the Sevier River near Kingston, 94,191 acre-feet for 44 years of record (1917–62).

Both gains and losses have been recorded in the flow of the Sevier River between Hatch and Circleville and between Circleville and Kingston (fig. 4). The gains occur mainly during the nonirrigation season when little water is diverted from the main stream or its tributaries. The losses occur mainly during the growing season when much water is diverted for irrigation. The gains and losses in streamflow are discussed in greater detail on pages 40–49.

Near Kingston, the Sevier River merges with the East Fork Sevier River, its largest tributary, which drains both East Fork and Grass Valleys. The East Fork Sevier River originates high on the south end of the Paunsaugunt Plateau. Otter Creek, whose source is high on the Fish Lake Plateau, is the chief tributary of the East Fork Sevier River, and it drains Grass Valley. Data for the principal perennial tributaries of the Sevier River, the East Fork Sevier River, and Otter Creek are listed in table 2. Some of these tributaries are perennial only in their upper reaches, and flow reaches the main stream only during periods of high runoff.

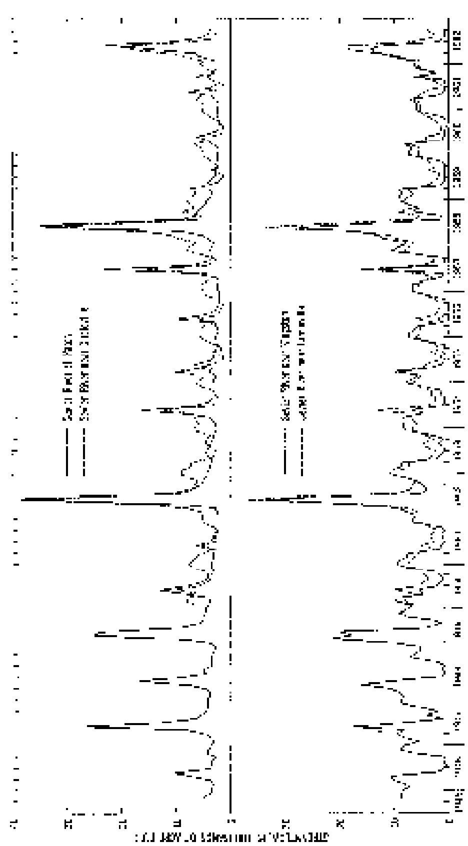

FIGURE 4.—Hydrographs of Sevier River flows at Hatch, near Circleville, and near Kingston.

TABLE 2.—*Data for the principal perennial tributaries of the Sevier River, East Fork Sevier River, and Otter Creek*

Stream (in downstream order)	Stream length (miles)	Approximate drainage area (square miles)	Average annual flow (acre-feet per water year)	Period of record	Estimated base flow (cfs)	Area irrigated by stream (acres)	Stream diversions and remarks
Panguitch Valley basin							
Sevier River (main stem) (South Fork):							
Asay Creek	18	131	27,900	1951–58	28		Several small diversions. Storage in Navajo Lake.
Mammoth Creek	22	134	58,300	1910–13	14		One canal and one diversion to Panguitch Creek.
Panguitch Creek	25	[illegible]	20,000	1917–18, 1961–63	4	4,000	Two diversions. Storage in Panguitch Lake.
Threemile Creek	9	35	2,300	Estimated	2	100	One diversion.
Sandy Creek	6	25	1,500	do	5	120	One diversion. One small reservoir.
Sanford Creek	12	45	5,000	do	2	220	Several diversions.
Bear Creek	15	45	3,000	do	2	370	Several diversions and small reservoirs.
Circle Valley basin							
Deer Creek	11	45	4,500	Estimated	1	52	One diversion. One small reservoir.
East Fork Sevier River	75	1,200	38,800	1912–63	10		Many diversions and several reservoirs.

[illegible]

East Fork Sevier River:							
Hunt Creek	16	56	7,700	Estimated	1	200	One diversion.
Pine (Clay)[1] Creek	14	55	4,100	do	2	3,075	One diversion. Storage in Pine Lake Reservoir.
South Creek	7	14	1,000	do	.5	400	One diversion.
Sweetwater Creek	8	15	1,700	do	1	280	Do.
Horse Creek	9	19	1,200	do	2	200	One diversion. One small reservoir.
Birch Creek	6	7	1,100	do	.6	200	Do.
Box Creek	4	7	800	do	.5	200	Several diversions. One small reservoir.
Cottonwood (Needle Rock)[1] Creek	12	50	8,700	do	<2.5	638	Several diversions.
Deer (Mitchell)[1] Creek	14	25	4,200	do	4		No diversions or regulation.
North Creek	10	19	3,000	do	2		Do.
Cedar (Crystal)[1] Creek	6	20	2,300	do	1		Several diversions. One small reservoir.
Forest (Willow Spring)[1] Creek	12	18	2,800	do	1	12	One diversion.
Poison Creek	6	10	800	do	1	92	Several diversions.
Antimony Creek	15	112	18,000	1910–18, 1957–63	15	[illegible]	Do.
Pole Canyon (Hoodle)[1] Creek	10	24	3,100	Estimated	2	54	One diversion.
Otter Creek	48	330	12,600	1915–20, 1961–63	15		Many diversions and several reservoirs.

TABLE 2.—*Data for the principal perennial tributaries of the Sevier River, East Fork Sevier River, and Otter Creek*—Cont.

Tributary (in downstream order)	Stream length (miles)	Approximate drainage area (square miles)	Average annual flow (acre-feet per water year)	Period of record	Method of average (see p. [illegible])	Area irrigated by stream (acres)	Source of diversions and regulation
				Grass Valley basin			
Otter Creek:							
Dooby Hole Creek	9	11	1,100	Estimated	1	760	One diversion. One reservoir. Small diversion from adjacent drainage into creek.
Daniels Canyon Creek	9	23	6,100	do	2	1,380	Several diversions.
Proctor Creek	6	9	2,300	do	1	170	One diversion.
Bear Creek	8	21	3,300	do	4	655	Several diversions.
Koosharem Creek	11	22	2,800	do	.6	75	One diversion.
Greenwich Creek	10	29	3,100	do	1		Several diversions.
Box (Beaver)[1] Creek	12	41	3,100	do	4	560	Several diversions. Two reservoirs.
Pole Canyon Creek	8	13	100	do	.5	110	One diversion.

[1] Local name.

Intermittent and ephemeral tributaries of the Sevier River, the East Fork Sevier River, and Otter Creek drain areas that range from a few to more than 50 square miles. The quantity of water yielded by these tributaries is dependent largely upon precipitation, drainage area, topography, vegetative cover, and geology. The annual yield of an intermittent or ephemeral tributary is in general small compared to a perennial tributary, and it may range from a few to as much as several thousand acre-feet following a cloudburst.

RESERVOIRS

The total storage capacity of reservoirs in the upper Sevier River basin is about 90,000 acre-feet. The principal reservoirs are listed in table 3 and are shown in figure 8.

Besides the reservoirs listed in table 3, many small reservoirs and natural lakes (less than 20 acres in area) are scattered throughout the plateaus surrounding the valleys. They are particularly numerous on the Aquarius Plateau and on the southwestern part of the Markagunt Plateau.

CANALS AND DITCHES

The principal canals and ditches that divert water for irrigation in the upper Sevier River basin from the Sevier River and its tributaries are shown in figure 8 and are listed in table 4. More than 30 irrigation companies maintain about 140 miles of canals and ditches. Individual canals vary in length from approximately 1 to 5 miles and discharge from about 250 to 25,000 acre-feet per year. Most of the canals and ditches are constructed of natural earth materials, but some of the canals are lined with concrete in places to prevent water losses.

TABLE 3.—*Data for the principal surface-water reservoirs in the upper Sevier River basin*

[Data [illegible]]

Reservoir	Location	Major drainage basin	Source of supply	Storage capacity (acre-feet)
Navajo Lake	T. 38 S., Rs. 8 and 9 W.	Sevier River (south fork)	Springs and Long Valley Creek and Deer Hollow.	[illegible]
Panguitch Lake	Tps. 35 and 36 S., R. 7 W.	do	[illegible], Blue Spring, [illegible], Clear, and [illegible] Creeks.	18,[illegible]
Tropic	Secs. 7 and 8, T. 37 S., R. 3 W.	East Fork Sevier River	East Fork Sevier River.	[illegible]
Pine Lake	Secs. 24 and 25, T. 35 S., R. 2 W.	do	Pine Creek	1,5[illegible]
[illegible] Hole	Sec. 32, T. 31 S., R. 1 E.	Otter Creek	[illegible] Hole Creek	4[illegible]
Koosharem	T. 27 S., R. 1 E.	do	[illegible] Canyon Creek.	[illegible]
Upper Box Creek	Sec. 10, T. 28 S., R. 2 W.	do	Box Creek	[illegible]
Lower Box Creek	Sec. 11, T. 27 S., R. 2 W.	do	do	[illegible]
Otter Creek	Tps. 29 and 30 S., R. 2 W.	do	Otter Creek and East Fork Sevier River	[illegible]
Total				[illegible]

TABLE 5.—*Principal canals and ditches that divert water for irrigation from the Sevier River and its tributaries*

Canal or ditch (in the downstream order)	Source of water	Location of diversion point	Approximate canal length (miles)	Estimated average annual diversion (acre-feet)	Remarks
		Panguitch Valley			
[illegible] Yardley Ditches	[illegible] Creek	SE¼ sec. 12, T. 37 S., R. 5 W.	[illegible]	[illegible]	Flow regulated by Sevier River [illegible]
West Ditch [illegible] Canal	Mammoth Creek	[illegible]	[illegible]	[illegible]	Do.
[illegible] Ditch	Sevier River	[illegible]	[illegible]	[illegible]	Do.
Upper [illegible] Ditch	do	[illegible]	[illegible]	[illegible]	Do.
[illegible] Ditch	do	[illegible]	[illegible]	[illegible]	Do.
[illegible] Ditch	do	[illegible]	[illegible]	[illegible]	Do.
Long and [illegible] Canal	do	[illegible]	[illegible]	[illegible]	Do.
[illegible] Ditch	do	[illegible]	[illegible]	[illegible]	Do.
[illegible] Ditch	do	[illegible]	[illegible]	[illegible]	Do.
East Panguitch Canal	do	[illegible]	[illegible]	[illegible]	Do.
West Panguitch Main Canal	Panguitch Creek	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] Canal	Sevier River	[illegible]	[illegible]	[illegible]	Flow regulated by Sevier River [illegible]
[illegible] Canal	do	[illegible]	[illegible]	[illegible]	Do.
Bear Creek Canal	do	[illegible]	[illegible]	[illegible]	Do.
Marshall Ditch	do	[illegible]	[illegible]	[illegible]	Do.
Marshall Slough Ditch	Marshall Slough	[illegible]	[illegible]	[illegible]	Do.
[illegible] Ditches	[illegible]	[illegible]	[illegible]	[illegible]	Do.

Circle Valley basin					
[illegible]	[illegible]	[illegible]	2	600	Flow measured by Sevier River water commissioner.
Parker [illegible]	do	[illegible]	1	[illegible]	Do.
[illegible] Canal	do	[illegible]	1	[illegible]	Do.
[illegible]	do	[illegible]	[illegible]	[illegible]	Do.
[illegible]	do	[illegible]	[illegible]	[illegible]	Do.
[illegible] Canal	do	[illegible]	1	[illegible]	Do.
[illegible] Canal	[illegible] Slough	[illegible]	5	[illegible]	Do.
[illegible] Ditch	[illegible]	[illegible]	2	[illegible]	Do.
[illegible]	[illegible]	[illegible]	2	[illegible]	Estimated.[a]
[illegible]	[illegible]	[illegible]	2	[illegible]	Flow measured by Sevier River water commissioner.
Kingston [illegible] Canal	do	[illegible]	2	[illegible]	Do.
East Fork Valley basin					
[illegible] and [illegible] Canal	East Fork Sevier River	[illegible]	1	[illegible]	Flow measured by Sevier River water commissioner. [illegible]
[illegible]	do	[illegible]	6	[illegible]	Estimated.
[illegible]	do	[illegible]	2	[illegible]	Do.
[illegible]	do	[illegible]	3	[illegible]	Do.
[illegible] Canal	[illegible]	[illegible]	1	[illegible]	Do.
[illegible]	East Fork Sevier River	[illegible]	[illegible]	[illegible]	Do.
Grass Valley basin					
[illegible] Canal	Otter Creek	[illegible]	1	[illegible]	Estimated.
[illegible] Ditch	do	[illegible]	1	[illegible]	Do.
[illegible] Ditch	do	[illegible]	1	[illegible]	Do.

[a] Local name.

GAINS AND LOSSES IN STREAMFLOW

The Sevier River and its principal tributaries gain or lose water in many places in the upper Sevier River basin. Gains are largely from tributaries, drains, springs, and seeps; and losses are by diversion into canals and ditches, by evapotranspiration, and by seepage into stream beds and banks.

The gains and losses to the Sevier River between Hatch and Kingston for the water years 1956-62, as indicated by measurements of streamflow and diversions, are summarized in table 5.

Panguitch Creek is the only measured tributary between the gaging stations at Hatch and Kingston, and except for a period between 1916 and 1920 it has been measured only since 1951. The net unmeasured inflow from tributaries, however, is included in the measured flow of the river near Circleville and near Kingston. The quantities of water diverted by the 30 canals and ditches between Hatch and Kingston are shown in table 5. Although this water is lost from the stream at the point of diversion, part of it seeps to the ground-water reservoirs from the canals and ditches and from irrigated fields, and eventually some water leaves the ground-water reservoirs to return to the river downstream. Much of the water diverted in canals and ditches is consumed by evapotranspiration. Use of water by this means is discussed in the section "Evapotranspiration" (p. 59), so the amounts lost in this way are not listed in table 5.

Table 5 indicates that the Sevier River consistently gains water in both Panguitch and Circle Valley basins. In Panguitch Valley basin this gain is principally from the various tributaries to the river, return flow of irrigation water, and ground water from springs and seeps. The amount supplied by tributaries varies considerably from year to year, depending on the amount of precipitation. The amount of return flow of irrigation water also varies from year to year, depending on the amount of water diverted for irrigation, but the discharge from springs and seeps is more consistent from year to year. The average annual gain in the river for the 1956-62 period in Panguitch Valley basin is about 47,000 acre-feet. The authors' study of the Sevier River water commissioners reports indicate that about 15 percent of the gain is ground-water discharge and that most of the water diverted by the Bear Creek Canal, Marshall Ditch, and Whittaker Ditches is ground-water discharge.

The gain in flow of the river in Circle Valley basin also comes principally from tributaries, return flow of irrigation water, and springs and seeps, but inflow from tributaries is smaller than it is in Panguitch Valley basin. The 1956-62 average gain in Circle Valley basin is about 21,000 acre-feet, of which about 80 percent is from ground-water

TABLE 5.—*Inflow, outflow, and gains of the Sevier River between Hatch and Kingston, in acre-feet, for the water years [illegible]*

[Canal diversion-point locations shown in table [illegible] and pl. [illegible]. Data from U.S. Geological Survey water-supply papers or Sevier River [illegible] reports]

	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Panguitch Valley basin							
Inflow:							
Sevier River at Hatch	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Panguitch Creek							[illegible]
Total inflow	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Diversions:							
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] Ditch	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] and [illegible] Ditches	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Long and East Bench Canals	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] Ditch	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
East Panguitch Canal	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] Ditch	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] Canal	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Bear Creek Canal	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Marshall Ditch and [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Whittaker Ditches	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sevier River near Circleville	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total outflow	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Gain	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Circle Valley basin							
Inflow: Sevier River near Circleville	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Diversions:							
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] Ditch	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] Canal	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Circleville West Canal	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] Canal	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] Canal	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Junction Canal	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Junction Middle Ditch	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sevier River near Kingston	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total outflow	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Gain	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

discharge. Nearly all the water diverted by the Junction Canal and Junction Middle Ditch is from return flow or ground-water discharge.

The East Fork Sevier River usually is dry between the Tropic and East Fork Canal diversion and a point south of Black Canyon in sec. 15, T. 33 S., R. 3 W., but there is enough inflow from tributaries in this reach to supply the Steed Canal and several smaller ditches.

The East Fork Sevier River gains about 20 cfs, or 15,000 acre-feet, in 10 miles, from the area south of Black Canyon to Antimony Creek. About 30 percent of this gain is from tributaries and about 70 percent is from springs. The entire flow of the East Fork Sevier River downstream from Antimony Creek generally is diverted into the Otter Creek Reservoir Feeder Canal. Between this diversion and Otter Creek, at the head of Kingston Canyon, the East Fork Sevier River gains about

5–10 cfs, or 3,600–7,200 acre-feet. About half of this gain is the combined flow of Pole Canyon plus seepage from Otter Creek Reservoir, and half is discharge from drains and seeps.

Otter Creek consistently gains about 15 cfs, or 10,000 acre-feet, between Koosharem Reservoir and a point about 16 miles downstream, in sec. 19, T. 28 S., R. 1 W., although the Koosharem Canal, Meridian Ditch, and several other ditches divert water from the Creek. Almost the entire gain is from seeps and springs. Enough water enters Otter Creek during the irrigation season, when diversions are at a maximum, to supply the Jolley Ditches near Angle.

GROUND WATER

SOURCE, OCCURRENCE, AND MOVEMENT

The source of all water in the upper Sevier River basin is precipitation within the basin. Water that reaches the land surface as precipitation either (1) evaporates, (2) transpired by plants, (3) becomes streamflow, or (4) seeps into the ground and either (1) is retained by soil moisture or (2) percolates downward to the zone of saturation and becomes part of the ground-water body. The source of ground water is discussed in greater detail in the next section on "Recharge."

The principles of the occurrence of ground water have been discussed in detail by Meinzer (1923a, p. 2–102; 1923b). Only a few essential statements will be made here.

Water in an aquifer may be under either confined (artesian) or unconfined (water-table) conditions. Water is confined where a saturated permeable bed, such as gravel, is overlain by less permeable confining beds, such as clay or silt. Because it is confined, the water in the permeable bed is under hydrostatic pressure. A well that penetrates such a bed and flows at the ground surface is a flowing artesian well; a well that penetrates such a bed and does not flow is a nonflowing artesian well. The imaginary surface that everywhere coincides with the static level of the water in an artesian aquifer is called the piezometric surface.

If water is unconfined, that "surface" within the zone of saturation at which the pressure is everywhere atmospheric, is called the water table. If the water level in an artesian aquifer declines below the overlying confining bed, the aquifer will then be under water-table conditions. Where water-table conditions grade into artesian conditions within an aquifer, a common occurrence in the upper Sevier River basin, the water table and the piezometric surface are continuous or, in other words, are parts of the same surface.

Most of the available ground water in the upper Sevier River basin is contained in the sand and gravel deposits in the several ground-water basins, and it occurs under both artesian and water-table conditions.

Ground water is not stationary; it moves through an aquifer in the direction of greatest hydraulic slope. The rate of movement is slow, usually ranging from less than an inch to a few feet per day, but the quantity of water moving may be relatively large if the cross section of the aquifer is large.

RECHARGE

The principal source of recharge to the valley fill in the upper Sevier River basin is infiltration from the Sevier River and its tributaries, irrigation canals and ditches, and irrigated fields. Such recharge occurs only where the ground water is unconfined.

The Sevier River and its tributaries recharge the valley fill where the streams flow across deposits of gravel and sand that are above the water table. Such areas of recharge are generally where streams enter the several ground-water basins. Thus for the major streams, the area of recharge is the upper end of the basin; but for small streams it is where they emerge from canyons onto alluvial fans bordering the valleys.

Canals and ditches recharge the ground-water reservoir where they cross permeable material, such as gravel, sand, and friable soil, along the margins of the various valleys. Water infiltrates from irrigated fields mainly in the upper ends and along the sides of the ground-water basins where the soils generally are coarse grained.

Another source of recharge to the valley fill is from consolidated aquifers in the mountains around the valleys. The aquifers in the mountains in turn are recharged from precipitation and runoff.

Water-level contours may indicate areas of recharge, as ground water moves at right angles to the contours from areas of recharge toward points of discharge. Plate 8 indicates that the main recharge areas in Panguitch Valley basin are along the sides and at the upper end of the basin; recharge areas are in similar places in the other basins (pl. 8).

AQUIFER CHARACTERISTICS

The amount of ground water that can be withdrawn from an aquifer and the effects of withdrawal depend upon the hydraulic characteristics of the aquifer as well as its extent and saturated thickness. The principal hydraulic properties of an aquifer are its ability to store water, expressed by a "coefficient of storage," and its ability to transmit water, expressed by a "coefficient of transmissibility."

The coefficients of storage and transmissibility help determine, among other things, the magnitude, rate, and extent of the lowering of the water level in an aquifer caused by a discharging well. The coefficient of storage of an aquifer is defined as the volume of water it releases from or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface. The coefficient of transmissibility is the rate of flow of water, at the prevailing water temperature, in gallons per day, through a vertical strip of the aquifer 1 foot wide extending the full saturated height of the aquifer under a hydraulic gradient of 100 percent. Methods used to determine the hydraulic characteristics of aquifers are described by Wenzel (1942), Ferris and others (1962), Jacob and Lohman (1952) and Theis, Brown and Meyer (1963).

The known range in coefficients of storage and transmissibility for each of the main ground-water basins in the upper Sevier River basin is shown in table 6. The coefficient of storage of artesian aquifers in the basin ranges from about 0.0001 to 0.001 and that of water-table aquifers from about 0.05 to 0.15. Circle Valley basin contains the aquifers having the highest known coefficient of transmissibility, 50,000 gpd per ft (gallons per day per foot), whereas the aquifers in Johns and Emery Valley subbasins have a maximum known coefficient of transmissibility of only 800 gpd per ft.

TABLE 6.—*Range in measured and estimated coefficients of storage and transmissibility in the upper Sevier River basin*

Basin or subbasin	Coefficient of storage	Coefficient of transmissibility (gpd per ft)
Panguitch Valley	[1] 0.10 – 0.15	500–15,000
Circle Valley	.001– .15	100–50,000
East Fork Valley:		
Johns and Emery Valleys	.05 – .10	100–800
Antimony	.001 – .15	1,000–20,000
Grass Valley (Koosharem and Angle subbasins)	.0001– .10	100–5,000

[1] No determinations or estimates were made of the coefficient of storage for the artesian aquifer in Panguitch Valley basin.

A wide range of values for the coefficients of storage and transmissibility, such as that shown in table 6, is common in alluvial aquifers where various degrees of sorting have taken place. If more complete data were available, however, they would probably show a range in coefficient of storage from 0.0001 to 0.15 in all the basins.

ESTIMATE OF RECOVERABLE GROUND WATER IN STORAGE

The recoverable ground water in storage in the principal ground-water reservoirs in the upper Sevier River basin was estimated from the areal extent, the saturated thickness, and the average coefficient of storage of the water-bearing sediments. The areal extent and thickness of the aquifers were determined by test drilling and a study of drillers' logs. The average values of coefficient of storage assigned to the sand and gravel comprising the principal aquifers of the area were estimated to range from 0.05 to 0.15. The storage estimate was made only for the upper 200 feet of saturated valley fill because sediments at greater depths probably cannot be economically dewatered under present conditions. The estimated amount of recoverable ground water in the sand and gravel of the upper 200 feet of saturated valley fill in the various ground-water basins is about 1 million acre-feet (table 7).

The 1 million acre-feet does not represent all the recoverable ground water stored in the upper 200 feet of saturated valley fill; the rest is in silt and clay which do not yield water readily to wells. The silt and clay, however, could ultimately yield some water to the sand and gravel aquifers if and when the latter are depleted by pumping.

TABLE 7.—*Estimated amount of recoverable ground water in storage in the sand and gravel of the upper 200 feet of saturated valley fill in the upper Sevier River basin*

Basin or subbasin	Average thickness of saturated sand and gravel (feet)	Estimated average coefficient of storage	Approximate area of aquifer (acres)	Estimated storage (acre-feet)
Panguitch Valley	50	0.15	76,000	570,000
Circle Valley	100	.15	14,000	210,000
East Fork Valley:				
Emery Valley [1]	10	.05	12,000	6,000
Johns Valley	30	.10	30,000	90,000
Antimony [1]	40	.15	5,000	30,000
Grass Valley:				
Koosharem	30	.10	30,000	90,000
Angle	30	.10	20,000	60,000
Total				1,062,000

[1] Upper 100 feet of valley fill.

FLUCTUATIONS OF WATER LEVEL

Ground-water levels fluctuate primarily in response to the net withdrawals of water from or additions to the ground-water reservoir. The fluctuations may range in duration from minutes to years, and they are here classified as short term, annual, and long term.

SHORT-TERM FLUCTUATIONS

Short-term fluctuations of water levels can be caused by changes in streamflow, evapotranspiration, discharge from wells, and other factors. Some of the short-term changes observed in wells in the upper Sevier River basin are discussed below.

Changes in flow in nearby waterways cause changes in water levels in wells (C-35-5)30cca-1 and (C-35-5)20dbd-1 near Panguitch. Both wells tap unconfined water and were equipped with automatic water-level recording gages. Well (C–33–6)29acs–1 is about 70 feet from an irrigation canal, and well (C–34–5)26dbd–1 is about 100 feet from a small irrigation ditch and about 0.2 mile from Panguitch Creek. Records show that changes in flow in the waterways are followed in 1–3 days by changes in water level in the wells.

Daily fluctuations of water level are caused by evapotranspiration in areas where the water table is near the land surface. In such areas the water levels decline during the day and rise during the night. These fluctuations are relatively small and probably occur to some degree in all the area in the basin that is covered by phreatophytes (p. 5).

Short-term fluctuations of water levels also are caused by discharge from wells. When a well discharges, the water table or piezometric surface of the aquifer penetrated by the well is depressed and assumes the approximate form of an inverted cone with the well at the apex. The extent and depth of this cone, called the cone of depression, depends on the hydraulic properties of the aquifer and the rate and duration of discharge. The cone of depression develops much faster under artesian conditions, where it is caused largely by the release of hydrostatic pressure, than it does under water-table conditions, where it is caused by gravity drainage of water from storage. When the spreading cone of depression reaches a nearby well, it causes a decline of water level in that well.

Records of a continuous water-level recording gage on well (C–36–4)34bdc–2 show a decline in water level caused by pumping wells (C–36–4)34bda–1 and (C–36–4)34bca–2. Well (C–36–4)34bda–1 is 360 feet east and well (C–36–4)34bca–2 is 250 feet northwest of the well having the recording gage. The three wells tap the valley fill under water-table conditions at about the same depth. When well (C–36–4)34bca–1 was pumped for 48 hours on May 17–18, 1957, at a rate of about 25 gpm, the water level declined 0.21 foot in the gaged well; when the pump was turned off, the water level in the gaged well recovered 0.13 foot in 20 hours.

ANNUAL FLUCTUATIONS

Water levels fluctuate annually in most wells in the upper Sevier River basin. An annual rise of the water table is caused mostly by seepage of water from streams and by diversions of water from streams for irrigation. Annual fluctuations in artesian head generally are small, but they show some similarity to water-table fluctuations. The fluctuations in selected wells in each ground-water area are shown on plate 3.

The pattern of annual fluctuation of water levels in wells that tap water-table aquifers is similar in all the ground-water basins in the upper Sevier River basin. Water levels usually begin to rise in March or April in response to recharge resulting from spring runoff and early irrigation. The levels continue to rise throughout the irrigation season, and they usually are highest in July, August, or September, near the end of the irrigation season. Water levels usually decline between the end of the irrigation season and the following spring; but in some areas irrigation in the fall causes a slight rise in water levels.

Annual fluctuations in artesian head are caused by discharge of flowing wells which are opened at the beginning of the irrigation season and closed at the end. This fluctuation is observed mainly in Panguitch subbasin. The condition exists especially where there is a high concentration of wells, such as in secs. 26 and 24, T. 26 S., R. 1 W., and secs. 1 and 2, T. 37 S., R. 1 W. (see pl. 2).

LONG-TERM FLUCTUATIONS

Long-term fluctuations of water levels in the several upper Sevier River ground-water basins were generally similar during the period 1935–63 (fig. 5). Water levels in all basins were highest during the late 1930's and through the 1940's and declined during the 1950's, although water levels generally rose in 1952, 1958, and 1962, which were years of above-normal recharge. The correlation between water-level changes and precipitation and streamflow is shown in figures 3 and 4. Ground-water levels usually rise during periods of high precipitation and streamflow, whereas they decline during dry periods. Precipitation and streamflow were below normal from 1950 through 1956 (except for 1952), and ground-water levels generally declined during the same period.

DEVELOPMENT AND DISCHARGE

Although more than 500 wells have been constructed in the upper Sevier River basin, springs supply most of the ground water used in the basin. The wells supply water mostly for domestic use and stock, but the springs furnish the public supply for most of the communities and also much of the irrigation supply. Drains also supply some water for irrigation.

In 1963 the discharge of ground water, in acre-feet, in the upper Sevier River basin by wells, springs, and drains is summarized as follows:

Source	Use, in acre-feet				
	Public supply	Irrigation	Industry	Domestic and stock	Total (rounded)
Wells	510	5,600	3	1,100	[illegible]
Springs	1,530	96,400	5		[illegible]
Drains	0	3,100	0	0	3,000
Total	1,950	105,300	8	1,100	108,000

In addition to discharge from wells, springs, and drains, ground water is discharged by evapotranspiration and, in some basins, by subsurface outflow. Most of the discharge is directly from the valley fill, but several springs along the valley margins discharge from the bedrock of the surrounding highlands.

WELLS

More than 300 wells have been constructed in the upper Sevier River basin by digging, jetting, and cable-tool and rotary drilling. A description of these well-construction methods is given by Todd (1959, p. 116–148). The locations of selected wells are shown on plate 2 and details of construction and other features are given by Carpenter, Robinson, and Bjorklund (1964). Many domestic and stock wells were dug by hand before the other methods were introduced into the area. These dug wells, many of which are still in use, range from 14 to 120 inches in diameter and are from 6 to 100 feet deep. They generally are lined with rock or concrete. Most of the wells less than 4 inches in diameter were jetted, whereas most wells 4 to 16 inches in diameter were drilled by the cable-tool method. A few wells have been drilled by the rotary method.

Most of the drilled and jetted wells in the valley fill are less than 250 feet deep and are drilled just deep enough to produce a moderate amount of water. Generally only a small part of the aquifer is penetrated, especially in areas of artesian flow. Most of the well casings are unperforated and admit water through the open bottom, but a few casings have been perforated at water-bearing zones. Wells designed to discharge large amounts of water usually are equipped with perforated casing and are developed by surging and pumping in order to remove silt and fine sand around the well.

The small-diameter domestic and stock wells are pumped mostly by gasoline or electrically driven centrifugal or piston pumps. Jet and small submersible turbine pumps supply water to many rural homes. Most of the irrigation and public-supply wells are equipped with turbine pumps driven by electric motors. Water flows freely from many domestic, irrigation, and stock wells in areas where the ground water is under artesian pressure.

"Specific capacity" is a term used to indicate the efficiency of a well. It is calculated by dividing the discharge of a well by the water-level drawdown, after the well has been discharging at a constant rate for at least several hours; it is expressed in gallons per minute per foot (gpm per ft) of drawdown. The specific capacity of a given well varies slightly depending on the rate of discharge and the length of time pumped. Table 6 shows that observed specific capacities of wells in the upper Sevier River basin range from 0.01 to 53 gpm per ft.

TABLE 5.—*Range and average of specific capacities of wells in the upper Sevier River basin*

Basin and subbasin	Wells for which data are available	Range in specific capacity (gpm per ft)	Average specific capacity (gpm per ft)
Panguitch Valley	16	0.0–10	2.5
Circle Valley	9	.4–53	9.0
East Fork Valley:			
Johns Valley-Emery Valley	11	.01–7.6	2.4
Antimony	5	.8–16	4.2
Grass Valley	118	.02–35	2.0

The wide range in specific capacities of wells in the basin is mainly due to differences in methods of well construction, differences in the permeability of the water-bearing zones, or a combination of both. For example, well (C-30-4)25bcc-1, which has a specific capacity of 32 gpm per ft, is an irrigation well constructed to produce a large yield. The well is 159 feet deep, penetrates 65 feet of saturated sand and gravel, and has a 16-inch casing, of which 59 feet is perforated. In contrast, well (C-30-5)20bcc-1, which has a specific capacity of about 4 gpm per ft, was constructed to produce only a small amount of water for stock. The well is 183 feet deep, penetrates 26 feet of saturated gravel, and has a 6-inch unperforated casing which receives water only through its open end.

The average annual discharge from wells in the upper Sevier River basin is about 3,000 acre-feet. Approximately 1,800 acre-feet is used for irrigation, 1,100 acre-feet for domestic use and stock, 100 acre-feet for public supply, and 3 acre-feet for industry. Of the 1,800 acre-feet used for irrigation, about 1,200 acre-feet is from flowing wells and about 600 is from pumped wells. The amounts discharged by wells in the four main basins, classified by use and type of well, are listed in table 6. The discharge by wells in Grass Valley basin is about 60 percent of the total discharge by wells in all four basins. The quantities in table 6 were estimated for 1962 from information on the type and period of use of wells, periodic measurements of discharge of selected wells, discharge measurements made during the well inventory, and yields reported by owners and drillers.

The discharge of flowing wells is greatest when artesian head is high, usually during years of high precipitation and high streamflow, when recharge also is high. Discharge of pumped wells is usually greatest when precipitation and streamflow are low, and wells are used to supplement streamflow and spring discharge.

TABLE 9.—Use of water, number of wells, and estimated discharge from wells in 1964 in four basins of the upper Sevier River system

Basin	Domestic and stock: Wells	Domestic and stock: Discharge (acre-feet)	Industry: Wells	Industry: Discharge (acre-feet)	Irrigation: Wells	Irrigation: Discharge (acre-feet)	Public supply: Wells	Public supply: Discharge (acre-feet)	Wells not used	Total: Wells	Total: Discharge (acre-feet)
All wells											
Panguitch Valley	39	5	0	0	0	0	1	44	33	73	49
Circle Valley	15	18	1	3	2	500	1	37	9	27	519
East Fork Valley	21	5	0	0	0	0	0	37	25	51	12
Grass Valley	188	1,145	0	0	35	1,820	0	0	7	173	2,167
Total	263	1,255	1	3	36	1,320	2	118	73	420	3,395
Flowing wells											
Panguitch Valley	0	0	0	0	0	0	0	0	1	1	0
Circle Valley	3	9	0	0	0	0	0	0	0	3	9
East Fork Valley	0	0	0	0	0	0	0	0	0	0	0
Grass Valley	138	1,132	0	0	35	1,320	0	0	0	143	2,452
Total	141	1,141	0	0	35	1,320	0	0	1	147	2,461
Pumped wells											
Panguitch Valley	39	5	0	0	0	0	1	44	32	72	49
Circle Valley	12	1	1	3	1	500	1	37	0	24	501
East Fork Valley	21	5	0	0	0	0	0	37	25	51	12
Grass Valley	22	5	0	0	0	0	0	0	7	30	5
Total	94	14	1	3	1	500	2	109	72	179	825

SPRINGS

Most of the ground water used beneficially in the upper Sevier River basin comes from springs. Springs furnish the public supplies for Panguitch, Circleville, Kingston, Antimony, Junction, and Koosharem; most of these springs discharge from bedrock in the mountains and plateaus adjacent to the valleys. Development for public supply ordinarily consists of one or more collecting chambers at the spring site, a gravity conveyance system from the spring to the town, and a distribution system.

Many springs in the valleys and in the surrounding mountains and plateaus are important sources of water for irrigation. For example, springs discharging from bedrock in the Mammoth and Asay Creek drainages ordinarily contribute more than half the annual flow of the Sevier River at Hatch (Wilson and Thomas, 1964, p. 31). The location of some of the principal springs in the upper Sevier River basin is shown on plate 2, and the discharge from these springs is given in table 10.

TABLE 10.—[illegible]

[illegible]	[illegible]	Use: [illegible]		Use: [illegible]
[illegible] Valley	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] Valley	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] Valley	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] Valley	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]		[illegible]

[1] [illegible]

About 95 percent of the spring discharge listed in table 10 is used for irrigation and stock and the remainder is used for public supply. Approximately 30 percent of the water discharged by these springs is from the valley fill and 70 percent is from bedrock. Many other bedrock springs are in remote parts of the mountains and plateaus surrounding the valleys, and the water discharged from them is accounted for in the flow of the perennial streams.

DRAINS

Control of water levels by artificial drainage in areas underlain by artesian aquifers has been attempted in Circle Valley basin and Antimony subbasin. The two drainage systems yield about 5,000 acre-feet of water annually, and they have become more important as a source of supply for irrigation downstream than as a means of controlling water levels. The drains are open channels, deep enough to penetrate to the water table in the saturated clay and silt near the surface but not deep enough to tap directly the underlying artesian aquifers. Water is forced through the confining silt and clay overlying the aquifer and it eventually moves into the drains. The drains also collect some water that has been applied for irrigation of areas adjacent to the wet bottom lands. Several canals have been constructed in Panguitch and Circle Valley basins and in Koosharem subbasin to collect water from slough and spring areas and deliver it to irrigated land. Although these canals in a sense are drains, they have not lowered water levels significantly, and their intended result was not drainage but recovery of water for irrigation.

Drains and canals in artesian areas such as the downstream parts of Panguitch Valley and Circle Valley basins and most of Antimony and Koosharem subbasins have not lowered water levels greatly because they are not deep enough to tap the more permeable water-bearing beds in the valley fill. The sand and gravel deposits in artesian areas generally are overlain by at least 5–20 feet of relatively impermeable silt and clay which will yield water to drains slowly but not in sufficient quantity to lower water levels significantly. Water levels could be lowered significantly by penetrating the underlying permeable deposits of gravel and sand with wells, deeper drains, a more efficient type of drain, or flowing wells in the bottom of drains.

Discharge of ground water by drains in the upper Sevier River basin is estimated to be about 8,000 acre-feet per year (table 11), and almost all the water is used for irrigation. The discharge from drains usually fluctuates in direct proportion to the amount of water distributed for irrigation.

EVAPOTRANSPIRATION

Evapotranspiration includes water discharged to the atmosphere by transpiration of vegetation or by direct evaporation. Water can evaporate directly from open-water surfaces, from the water table when it is at or near the land surface, from the soil, and from any exposed surface on which precipitation falls. About 12,000 acre-feet of surface water is evaporated annually from eight reservoirs in the upper Sevier River basin. In addition, about 46,000 acre-feet of water is discharged annually by evapotranspiration from about 28,000 acres of wet land in the basin. Most of this 46,000 acre-feet of water is derived from the ground-water reservoir, but some seeps in from adjacent irrigated areas.

TABLE 11.—*Estimated average annual discharge of drains in the upper Sevier River basin*

Drain	Length of drains (miles)	Average annual discharge (acre-feet)
Panguitch Valley	0	0
Circle Valley	5	2,000
East Fork Valley, Antimony subbasin	4	1,000
Grass Valley	0	0
Total	9	3,000

EVAPORATION FROM SURFACE-WATER RESERVOIRS

The average annual evaporation from surface-water reservoirs in the upper Sevier River basin is more than five times the long-term average annual precipitation. Evaporation data have been collected for 45 years (1964) at Piute Dam, which is 8 miles north of Kingston and about 6,000 feet above sea level; a standard U.S. Weather Bureau land pan was used. Since 1918 the average annual evaporation from May through November has been about 55 inches (U.S. Weather Bureau, written commun., 1963).

The annual evaporation from the eight largest surface-water reservoirs in the upper Sevier River basin is estimated to be about 12,000 acre-feet; it is summarized below:

Reservoir	Annual evaporation[1] (acre-feet)	Reservoir	Annual evaporation (acre-feet)
Navajo Lake	1,300	Rocky Ford	70
Panguitch Lake	2,700	Koosharem	500
Tropic	500	Lower Box Creek	30
Pine Lake	200	Otter Creek	6,600
		Total (rounded)	12,000

[1] Based on an evaporation rate of 3 feet per year at Piute Dam. Adjustments made for differences in altitude [illegible] [illegible].

DIRECT EVAPORATION OF GROUND WATER

The amount of ground water discharged directly by evaporation depends upon many factors, including depth to the water table, soil type, and various climatological factors. Where the water table intersects the land surface, evaporation takes place directly from the ground-water body. Where the water table is only a few feet below the land surface and the soils are fine grained, the capillary fringe above the water table may reach the land surface; water then evaporates from the damp soil and is replaced from the ground-water reservoir by capillary action. (According to Meinzer (1923b, p. 26), "The capillary fringe * * * contains capillary interstices some or all of which are filled with water that is continuous with the water in the zone of saturation * * *.")

The amount of ground water that is discharged directly by evaporation in the upper Sevier River basin is not known.

TRANSPIRATION

Transpiration is the discharge of water to the atmosphere by plants. If the water table or capillary fringe is within reach of the roots of plants, ground water will be discharged by transpiration. The rate of transpiration depends upon many conditions, including climate, plant type, size and density, depth to water, and the quality of the water. Transpiration of water by plants that have some recognized benefit to mankind is a consumptive use; transpiration of water by plants that do not benefit man is a consumptive waste (Thomas, 1951, p. 217).

Phreatophytes are plants that depend for their water supply on ground water that lies within reach of their roots (Robinson, 1958, p. 1.) The principal phreatophytes in the upper Sevier River basin are saltgrass, willow, cottonwood, greasewood, and rabbitbrush.

Areas that contain small bodies of surface water fed by springs and areas where the water table is close to the land surface generally support extensive growths of phreatophytes. Studies and experiments in the western conterminous United States, made under wide varieties of climate, plant growth density, depth to water, quality of ground water, and soil type, indicate that fully developed cottonwoods use from 5 to more than 7 acre-feet of water per acre per year and that saltgrass, willow, greasewood, and rabbitbrush use approximately 2 to 3 acre-feet per year (Robinson, 1958, p. 45–75).

Phreatophytes in the upper Sevier River basin probably consume water at 50–75 percent of the rates given by Robinson, because much of the data on which Robinson's figures are based were collected in areas having higher average temperatures and longer growing seasons. The gross rate of evapotranspiration for the valleys in the upper Sevier River basin is estimated to be 20–30 inches per acre per year. Values in this range were used in table 13 in estimating the average annual evapotranspiration from the principal areas of phreatophyte growth in wet areas in the basin. (See pl. 2.)

SUBSURFACE OUTFLOW

Some ground water leaves the upper Sevier River basin or moves between the individual ground-water basins in the area by subsurface outflow through both the valley fill and bedrock. The amount

TABLE 13.—*Average annual consumptive use of water from phreatophytes in wet areas in the ground-water basins of the upper Sevier River basin*

Basin or subbasin	Area (acres)	Estimated evapotranspiration (inches per year)	Estimated average annual discharge by evapotranspiration (acre-feet)
Panguitch Valley	8,300	20	14,000
Circle Valley	3,200	30	8,000
East Fork Valley:			
Emery Valley	3,000	20	5,000
Johns Valley	700	20	1,200
Antimony	2,100	30	5,200
Grass Valley:			
Kingston	7,300	20	9,300
Angle	800	30	900
Total	25,400		43,600

leaving each ground-water basin through valley fill generally is small because subsurface bedrock barriers at the downstream end of each of the basins make the cross-sectional area of valley fill small. Circle Valley basin and Angle subbasin are the only areas from which there is any significant amount of subsurface outflow. Gravel and sand beds at the downstream end of Circle Valley basin transmit about 1,000-2,000 acre-feet of water per year to the central Sevier Valley downstream. About 1,000 acre-feet per year moves from Angle subbasin to Antimony subbasin at the Otter Creek Reservoir damsite.

Ground water leaves the upper Sevier River basin by subsurface outflow through solution channels in limestone of the Wasatch Formation near Navajo Lake. This water discharges southward from Cascade Spring in the NE¼SE¼SE¼ sec. 17, T. 38 S., R. 9 W., in the Virgin River basin at a rate of about 1,000-2,000 acre-feet annually (Wilson and Thomas, 1964). Some ground water also seeps through bedrock eastward into the Paria River drainage from the Paunsaugunt Plateau (Marine, 1963, p. 161-165). A determination of the total amount seeping out of the upper Sevier River basin through bedrock is beyond the scope of this investigation, but recent studies by Gordo (1964) and the U.S. Soil Conservation Service (written commun., 1965) indicate that the amount from the Markagunt Plateau alone may be several thousand acre-feet annually.

RELATION BETWEEN GROUND WATER AND STREAMFLOW

The base flow of the Sevier River, the East Fork Sevier River, and Otter Creek in most parts of their channels is affected by discharge to or recharge from the ground-water reservoir. The streams lose water where the water table or piezometric surface is lower than the stream surface, especially where the stream beds overlie permeable materials such as gravel or coarse sand. Conversely, the streams gain water where ground-water levels are above the stream levels. The water that enters the ground from the streams moves through the aquifers at velocities of only a few feet per day or less. The quantity of water moving through the aquifers, however, probably is relatively large because the aquifers generally have a high average permeability, a large cross-section area, and a hydraulic gradient of several feet per mile.

At several places in the upper Sevier River basin, subsurface barriers of bedrock impede the downstream movement of ground water, force the water toward the surface, and thus cause the ground-water reservoirs to overflow. These barriers are at the downstream ends of Panguitch Valley and Circle Valley basins, Johns Valley and Antimony subbasins of East Fork Valley basin, and Koosharem and Angle subbasins of Grass Valley basin. Upstream from these barriers, ground water is discharged mainly by evapotranspiration, by springs, and by seeps that return much of the water to the stream. For example, the base flow of the Sevier River in Circleville Canyon can be correlated directly with water levels in the valley fill at the downstream end of Panguitch Valley basin. This direct relation is illustrated in figure 5, which shows that high water levels in the valley fill correspond to a high base flow in the Sevier River and low water levels correspond to a low base flow.

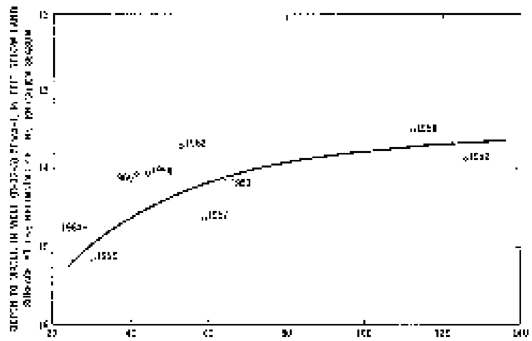

FIGURE 5.—Graph showing the relation between the water level in well (C-33-5)9bca-1 and the base flow of the Sevier River near Circleville (in Circleville Canyon).

Withdrawals of ground water by wells and drains may lower water levels and consequently reduce the base flow of streams. If enough water is withdrawn, the natural discharge of ground water to a stream may decrease significantly or stop. The surface-water and ground-water systems in the upper Sevier River basin are in approximate equilibrium, and the removal of large amounts of ground water would eventually (1) increase recharge to the aquifers from surface streams and thereby decrease streamflow, (2) decrease ground-water discharge to streams and from springs, flowing wells, and evapotranspiration, or (3) have combined effects of (1) and (2).

INFLOW-OUTFLOW ANALYSES OF THE GROUND-WATER BASINS

In any basin, the quantity of water entering by surface-water inflow, ground-water inflow, and precipitation is equal to the quantity of water leaving the basin by surface-water outflow, ground-water outflow, and evapotranspiration, plus or minus the quantity gained or lost in surface- and ground-water storage and changes in soil moisture. All these quantities can be related by means of an inflow-outflow analysis, a type of hydrologic budget.

Inflow-outflow analyses were made for each of the ground-water basins in the upper Sevier River basin for the 1961 and 1962 water years. The major difficulties in making the analyses were the complexity of the distribution system for irrigation water, insufficient precipitation data, and lack of data (1) for several important surface-water sites, (2) for inflow from perennial, intermittent, and ephemeral streams, and (3) for ground water entering each basin by inflow from bedrock. Because of these difficulties, some estimates and assumptions were necessary, and the data listed in tables 18–19 should not be considered as absolute.

Surface-water inflow and outflow were based upon measurements, where available, and upon estimates. Estimates of surface-water inflow were based largely upon size, altitude, and geology of the drainage area and upon precipitation on the drainage area. Some of the ungaged inflow from intermittent and ephemeral streams is included in the item "Inflow from other sources."

Ground-water inflow and outflow at the upper and lower ends of the basins were estimated on the basis of the thickness of, permeability of, and hydraulic gradient in the valley fill. Sufficient information was not available to make a separate estimate of the amount of ground water moving into the basins directly from bedrock. An indirect estimate of this amount, however, is included in the item "Inflow from other sources."

Precipitation was estimated from records of the U.S. Weather Bureau. Precipitation data at a station within a basin were used when available, but an average of data from surrounding stations was used when local data were not available.

The evapotranspiration from cultivated areas was estimated using a method described by Criddle, Harris, and Willardson (1962). The croplands were classified according to crop type (including alfalfa, small grains, corn, potatoes, pasture, wild hay) or as idle land. The acreage of each crop type varied from year to year depending upon the water supply and other factors. Gross water-use requirements for each type were multiplied by the acreage of each type to determine the annual amount of water consumed.

The method of estimating evapotranspiration from noncultivated wet areas is described in the section on "Evapotranspiration." No data are available for evaporation from waterlogged land; therefore, the estimates are based on transpiration from phreatophytes in all wet areas, including marshes and sloughs.

Evapotranspiration from noncultivated brushland was assumed to equal all the precipitation on those lands. Much of the area that comprises the ground-water basins in the upper Sevier River basin is not cultivated. It is covered with native brush and other vegetation that depend for their water supply entirely on soil moisture derived directly from precipitation. Little, if any, of the precipitation recharges the ground-water reservoir.

The method of estimating evaporation from Otter Creek and Koosharem Reservoirs is described in the section on "Evaporation from surface-water reservoirs." The other reservoirs in the upper Sevier River basin are outside the ground-water basins. The rates of evaporation from Otter Creek and Koosharem Reservoirs are assumed to be similar for both the 1961 and 1962 water years. However, the large difference in storage in Otter Creek Reservoir during the period of high evaporation (May–September) caused a significant change in the total evaporation from 1961 to 1962.

The changes in storage in Otter Creek Reservoir were measured. Records of changes in storage in Koosharem Reservoir are not available, but about the same amount of water is in the reservoir at the beginning and end of every water year; therefore, there is little significant change in storage.

The changes in ground-water storage were determined as the product of three factors: (1) the area where ground water is under water-table conditions, (2) the annual change in the level of the water table, and (3) the average storage coefficient of the water-table aquifer. Changes in storage in artesian aquifers were not included in the analyses because they were considered to be negligible owing to the extremely small storage coefficient of artesian aquifers and small changes in head. Changes in soil moisture were not considered in the analyses because it was assumed that there was little net change on an annual basis.

The inflow from other sources is inflow not otherwise accounted for in the analyses. It includes surface flow from some perennial, intermittent, and ephemeral streams and inflow of ground water from the following sources: seepage from streams into the valley fill near the plateau and mountain fronts and seepage from bedrock in the mountains and plateaus directly to the valley fill of the ground-water basins.

The inflow from the other sources is the unknown quantity in the analyses, and it was approximated by taking the difference between all other items of estimated inflow and outflow, plus or minus changes in storage. This difference, of course, also includes all errors involved in making the estimates or assumptions.

PANGUITCH VALLEY BASIN

The inflow-outflow analyses of Panguitch Valley basin for the 1961 and 1962 water years are given in table 13 (next page). Precipitation generally was above normal during the 1961 water year throughout the upper Sevier River basin. Subsequently, streamflow generally was high during the 1962 water year. The inflow during these years was 187,000 and 175,000 acre-feet, respectively. Of this amount, about one-third to one-half left the basin in the Sevier River, whereas the remainder was consumed in the basin or else went into temporary ground-water storage.

During the 1961 and 1962 water years, an average of about 25 percent of the water consumed in the basin was used in cultivated areas, about 16 percent was used in noncultivated wet areas, and about 59 percent in noncultivated brushland. The measured streams supplied an average of about 40 percent of the total inflow, precipitation on the basin supplied about 43 percent, and inflow from other sources provided about 17 percent.

CIRCLE VALLEY BASIN

The inflow-outflow analyses of Circle Valley basin for the 1961 and 1962 water years are given in table 14. The inflow during these years was 75,000 and 108,000 acre-feet. Of this amount, about 60 percent left the basin in the Sevier River and in two canals, about 2 percent left the basin as underflow, about 36 percent was consumed in the basin, and about 2 percent went into temporary ground-water storage.

During the 1961 and 1962 water years, an average of about 54 percent of the water consumed in the basin was used in cultivated areas, about 31 percent was used in wet noncultivated areas, and about 15 percent in noncultivated brushland. The Sevier River supplied about 77 percent of the total inflow to the basin, precipitation on the basin contributed about 13 percent, and inflow from other sources supplied about 16 percent.

TABLE 13.—*Inflow and outflow of water and change in storage, Panguitch Valley basin, in thousands of acre-feet*

	Water year 1961	Water year 1962
Surface-water inflow at upper end (Sevier River plus West Hatch Canal and East Hatch Ditch)	46	60
Ground-water inflow at upper end	Negligible	
Precipitation on ground-water basin (76,000 acres)	87	61
Inflow from other sources (includes Panguitch Creek)	26	34
Total water entering the basin	167	175
Surface-water outflow (Sevier River)	53	91
Ground-water outflow	Negligible	
Evapotranspiration from—		
Cultivated areas (10,300 acres)	22	23
Noncultivated wet areas (3,500 acres)	14	14
Noncultivated brushland (57,000 acres)	71	58
Total water leaving the basin	160	185
Change in ground-water storage	+7	−10
Total water entering the basin	167	175

TABLE 14.—*Inflow and outflow of water and change in storage, Circle Valley basin, in thousands of acre-feet*

	Water year 1961	Water year 1962
Surface-water inflow at upper end (Sevier River)	58	101
Ground-water inflow at upper end	Negligible	
Precipitation on ground-water basin (14,000 acres)	15	9
Inflow from other sources	9	9
Total water entering the basin	75	109
Surface-water outflow (Sevier River plus Junction and Junction Middle Canals)	46	78
Ground-water outflow	1	2
Evapotranspiration from—		
Cultivated areas (1,900 acres)	11	11
Noncultivated wet areas (3,500 acres)	8	9
Noncultivated brushland (6,000 acres)	5	5
Total water leaving the basin	74	105
Change in ground-water storage	+1	+3
Total water entering the basin	75	109

EAST FORK VALLEY BASIN

EMERY VALLEY SUBBASIN

The inflow-outflow analyses of Emery Valley subbasin for the 1961 and 1962 water years are given in table 15. The inflow during each of these years was about 26,000 acre-feet. Of this amount, about 27 percent left the subbasin in the East Fork Sevier River, about 12 percent left the subbasin and the Sevier River drainage basin by transmountain diversion in the Tropic and East Fork Canal, and about 61 percent was consumed in the subbasin or went into temporary ground-water storage.

During the 1961 and 1962 water years, an average of about 33 percent of the water consumed in the subbasin was used in noncultivated wet areas and about 67 percent was used in noncultivated brushland. The East Fork Sevier River supplied about 19 percent of the total inflow to the subbasin, precipitation on the subbasin contributed about 54 percent, and inflow from other sources supplied about 27 percent.

TABLE 15.—*Inflow and outflow of water and change in storage, Emery Valley subbasin, in thousands of acre-feet*

	Water years 1961	1962
Surface-water inflow at upper end (East Fork Sevier River)	4	6
Ground-water inflow at upper end	Negligible	
Precipitation on ground-water subbasin (12,000 acres)	17	11
Inflow from other sources	5	9
Total water entering the subbasin	26	26
Surface-water outflow:		
East Fork Sevier River	5	9
Tropic and East Fork Canal	2	4
Ground-water outflow	Negligible	
Evapotranspiration from—		
Noncultivated wet areas (2,000 acres)	6	7
Noncultivated brushlands (9,000 acres)	12	6
Total water leaving the subbasin	25	26
Change in ground-water storage	+1	0
Total water entering the subbasin	26	26

JOHNS VALLEY SUBBASIN

The inflow-outflow analyses of Johns Valley subbasin for the 1961 and 1962 water years are given in table 16. The inflow during these years was 67,000 and 47,000 acre-feet. Of this amount, about 35 percent left the subbasin in the East Fork Sevier River, about 61 percent was consumed in the subbasin, and about 4 percent went into temporary ground-water storage.

During the 1961 and 1962 water years, an average of about 13 percent of the water consumed in the subbasin was used in cultivated areas, about 3 percent was consumed in noncultivated wet areas, and about 84 percent was consumed in noncultivated brushland. The East Fork Sevier River supplied about 13 percent of the total inflow, precipitation on the subbasin contributed about 55 percent, and inflow from other sources supplied about 32 percent.

TABLE 16.—*Inflow and outflow of water and change in storage, Johns Valley subbasin, in thousands of acre-feet*

	Water year 1961	Water year 1962
Surface-water inflow at upper end (East Fork Sevier River)	5	9
Ground-water inflow at upper end	Negligible	
Precipitation on ground-water subbasin (30,000 acres)	11	23
Inflow from other sources	21	15
Total water entering the subbasin	67	47
Surface-water outflow (East Fork Sevier River)	21	10
Ground-water outflow	Negligible	
Evapotranspiration from:		
Cultivated areas (2,300 acres)	5	4
Noncultivated wet areas (700 acres)	1	1
Noncultivated brushland (26,900 acres)	39	21
Total water leaving the subbasin	66	36
Change in ground-water storage	+1	+11
Total water entering the subbasin	67	47

ANTIMONY SUBBASIN

The inflow-outflow analyses of Antimony subbasin for the 1961 and 1962 water years are given in table 17. The inflow during each of these years was about 80,000 acre-feet. Of this amount, about 83 percent left the subbasin in the East Fork Sevier River and the Otter Creek Reservoir Feeder Canal for use downstream, and about 17 percent was consumed in the subbasin or went into temporary ground-water storage.

During the 1961 and 1962 water years, an average of about 38 percent of the water consumed in the subbasin was used in cultivated areas, about 48 percent was used in noncultivated wet areas, and about 14 percent in noncultivated brushland. The East Fork Sevier River supplied about 55 percent of the total inflow and Antimony Creek about 30 percent; precipitation on the subbasin contributed about 6 percent, inflow from other sources supplied about 5 percent, and underflow from Angle subbasin contributed about 2 percent.

GRASS VALLEY BASIN

KOOSHAREM SUBBASIN

The inflow-outflow analyses of Koosharem subbasin for the 1961 and 1962 water years are given in table 18. The analyses indicate that 81,000 acre-feet of water entered the subbasin during each of these years. Of this amount, about 30 percent left the subbasin as surface flow in Otter Creek for use downstream, about 65 percent was consumed in the subbasin, and about 5 percent went into temporary ground-water storage.

TABLE 17.—*Inflow and outflow of water and change in storage, Antimony subbasin, in thousands of acre-feet*

	Water years 1961	1962
Surface-water inflow at upper end (East Fork Sevier River)	30	35
Inflow from Antimony Creek	16	17
Ground-water inflow:		
At upper end	Negligible	
From Angle subbasin	1	1
Precipitation on ground-water subbasin (6,000 acres)	6	4
Inflow from other sources	4	3
Total water entering the subbasin	59	62
Surface-water outflow (East Fork Sevier River and Otter Creek Reservoir Feeder Canal)	47	52
Ground-water outflow	Negligible	
Evapotranspiration from—		
Cultivated areas (2,000 acres)	4	4
Noncultivated wet areas (2,300 acres)	5	5
Noncultivated brushland (1,100 acres)	2	1
Total water leaving the subbasin	58	62
Change in ground-water storage	+1	0
Total water entering the subbasin	60	62

TABLE 18.—*Inflow and outflow of water and change in storage, Koosharem subbasin, in thousands of acre-feet*

	Water years 1961	1962
Surface-water inflow (from tributaries)	30	24
Precipitation on ground-water subbasin (30,000 acres)	33	15
Inflow from other sources	11	22
Total water entering the subbasin	64	61
Surface-water outflow (Otter Creek)	15	22
Ground-water outflow	Negligible	
Evapotranspiration from—		
Cultivated areas (6,400 acres)	11	24
Noncultivated wet areas (4,000 acres)	10	11
Noncultivated brushland (25,400 acres)	20	17
Evaporation from Koosharem Reservoir	1	1
Total water leaving the subbasin	59	57
Change in ground-water storage	+2	+4
Total water entering the subbasin	61	61

During the 1961 and 1962 water years, an average of about 30 percent of the water consumed in the subbasin was used in cultivated areas, about 24 percent was used in noncultivated wet areas, about 43 percent in noncultivated brushland, and about 2 percent was evaporated from Koosharem Reservoir. The surface flow of tributaries supplied about 41 percent of the total inflow, precipitation on the subbasin contributed about 42 percent, and inflow from other sources supplied about 17 percent.

ANGLE SUBBASIN

The inflow-outflow analyses of Angle subbasin for the 1961 and 1962 water years are given in table 19. The inflow during these years was 61,000 and 69,000 acre-feet of water. Of this amount, about 63 percent left the subbasin as surface flow through Otter Creek Reservoir for use downstream, about 2 percent left the subbasin as underflow, about 26 percent was consumed in the subbasin, about 7 percent went into temporary surface-water storage, and about 2 percent went into temporary ground-water storage.

During the 1961 and 1962 water years, about 4 percent of the water consumed in the subbasin was used in cultivated areas, about 4 percent in noncultivated wet areas, about 65 percent in noncultivated brushland, and about 27 percent evaporated from Otter Creek Reservoir. Otter Creek and Otter Creek Reservoir Feeder Canal supplied about 68 percent of the total inflow, precipitation on the subbasin contributed about 23 percent and inflow from other sources contributed about 9 percent.

TABLE 19.—*Inflow and outflow of water and change in storage, Angle subbasin, in thousands of acre-feet*

	Water years 1961	1962
Surface-water inflow in upper end (Otter Creek and Otter Creek Reservoir Feeder Canal)	40	49
Precipitation on ground-water subbasin (20,000 acres)	18	12
Inflow from other sources	3	8
Total water entering the subbasin	61	69
Surface-water outflow (Otter Creek Reservoir outlet)	40	42
Ground-water outflow	1	1
Evapotranspiration from—		
Cultivated areas (640 acres)	1	1
Noncultivated wet areas (200 acres)	1	1
Noncultivated brushland (19,160 acres)	9	12
Evaporation from Otter Creek Reservoir	4	5
Total water leaving the subbasin	56	62
Change in surface-water storage	+4	+5
Change in ground-water storage	+1	+2
Total water entering the subbasin	61	69

GROUND-WATER CONDITIONS IN THE BASINS

PANGUITCH VALLEY BASIN

Availability and storage of ground water

Ground water is readily available to wells in Panguitch Valley basin, mainly in the valley fill from Hatch to the head of Circleville Canyon. The valley fill in the northern part of Panguitch Valley basin ranges in thickness from 0 to more than 800 feet (Feltis and Robinson, 1963, p. 7-17). Test hole (C-33-5) 2bdd-1, in the northeastern part of the valley, penetrated 838 feet of valley fill, all of which is alluvium, without reaching bedrock. The thickest zone of valley fill, 200–600 feet thick, extends north-south through the central and eastern parts of the valley. From this zone the valley fill probably thins to the north, west, and south toward the basin boundaries (pl. 1, sections *B–B'* and *D–D'*). Generally it is coarsest on the eastern side of the valley in proximity to the Sevier fault and the plateau, but the most permeable deposits are along the Sevier River channel. About 25–50 percent of the valley fill in the northern part of the basin is permeable sand and gravel.

The valley fill in the southern part of Panguitch Valley basin between Panguitch and Hatch is much thinner and less permeable than that in the northern part of the basin. On the basis of data from the few wells that have been drilled in this area, the valley fill was estimated to range in thickness from 0 to 200 feet.

Ground water is under artesian conditions in the valley fill in a small area at the lower end of the basin (see pl. 2). It is impounded there by a constriction in the bedrock which forms a barrier to further subsurface movement toward the north. The ground water is confined in permeable gravel by 6–20 feet of overlying silty clay of low permeability, and the piezometric surface in wells in the gravel ranges from 0 to 5 feet above the land surface and averages about 2 feet above the land surface. At the lower end of the basin the artesian area is marked by marshes and meadowlands.

Ground water generally is under water-table conditions in the southern four-fifths of Panguitch Valley basin. The observed water table ranges from less than 1 foot below the land surface in well (C-33-5)9adb-1 to more than 89 feet in well (C-34-5)2dac-2.

An estimated 570,000 acre-feet of ground water is stored in the sand and gravel in the upper 500 feet of saturated valley fill in the basin (table 7), mostly under water-table conditions. The sand and gravel deposits are separated by saturated silt and clay which are not permeable enough to yield water readily to wells.

The Sevier River Formation on both the east and west sides of the southwestern part of the basin contains ground water, some of which is perched above the water levels shown in plate 2.

No production wells have been constructed in the bedrock that surrounds and underlies the valley. Therefore, although the rocks are known to contain ground water, it is not known if they will yield water readily to wells.

Existing use

Most of the ground water used in Panguitch Valley basin is discharged by springs which issue from either the valley fill or from bedrock. The largest springs that discharge from valley fill are in the Marshall and Yeater Sloughs (sec. 35, T. 33 S., R. 5 W.). These springs have a combined discharge of about 1,800 gpm. Many smaller springs discharge from less than 1 to about 450 gpm from permeable zones in the alluvial fans and in the Sevier River Formation along the sides of the basin. Many of these springs are along the edge of the bluffs on the east side of the Sevier River between Hatch and Casto Canyon and along the edge of the alluvial fans on the west side of the river between Threemile Creek and Bear Creek.

The bedrock springs are mostly in mountainous areas, generally remote from the valley floor. Information on the major bedrock springs is summarized below:

Name	Location	Discharge (cfs)	Date of measurement	Use of water
Blue Spring	(C-36-7)18acb	10	Aug. 1962	Irrigation and stock.
Mammoth Spring	32dac	3–270	Apr.–June 1957.	Do.
Upper Asay Spring.	(C-37-6)33dcc	8	Oct. 1962	Do.
Lower Asay Spring.	8bac	22–35	1954	Do.
Duck Creek Spring.	(C-38-8)12cd	9.4–25	1954	Do.
Indian Hollow (or Panguitch) Springs.	(C-34-6)18c	1	Dec. 1961	Public supply, Panguitch.

These springs usually have a combined flow of about 90 cfs and supply about 65,000 acre-feet of water annually to the Sevier River system. All except Indian Hollow Springs discharge from solution channels in the limestone of the Wasatch Formation, although the water from many of them emerges from broken basalt overlying the limestone. Indian Hollow Springs issue from volcanic rocks of Tertiary age.

Most of the wells in Panguitch Valley basin were constructed for domestic and stock use, but one well is used for public supply at Hatch. All the wells obtain water from the alluvial deposits or the Sevier River Formation, and yields from individual wells range from about 1 to 75 gpm. Wells produce less than 55 acre-feet of water annually in Panguitch Valley basin, and all the water is pumped.

There are approximately 70 wells in the basin. About 30 are dug wells, and they range from 24 to 54 inches in diameter and from 3 to 70 feet in depth. About 40 are drilled wells, and they range from 3 to 10 inches in diameter and from 45 to 458 feet in depth; most of them, however, are less than 200 feet deep. Most of the ground water pumped in Panguitch Valley basin is from well (C-36-5)29dcd-1, which yields about 40 acre-feet annually for public supply at Hatch.

Potential development

About 7,000 acre-feet of additional ground water could be withdrawn annually in Panguitch Valley basin without greatly affecting the flow in the Sevier River if the water can be salvaged from existing uses. About 14,000 acre-feet of water (table 12) is discharged annually by evapotranspiration from 9,000 acres of marshes and wet meadowland which support growths of saltgrass and other phreatophytes. Probably about half of the 14,000 acre-feet could be salvaged by means of new drains or wells which would lower water levels in the gravel and sand deposits in the lower end of the basin and thereby decrease losses by evapotranspiration. The lowering of water levels, however, would undoubtedly decrease the flow of water from the Marshall Slough. The wells and drains used to lower water levels must be constructed within the wet areas if they are to lower water levels within these areas.

In addition to salvaging water, reduction of evapotranspiration would improve the productivity of some of the land by decreasing the precipitation of salts at the land surface. Furthermore, if the land were drained, crops requiring much less water than do phreatophytes could then be grown. Lining of canals and mechanical eradication of phreatophytes are other methods of salvaging water.

CIRCLE VALLEY BASIN

Availability and storage of ground water

The valley fill is the main source of ground water in Circle Valley basin. The fill ranges in thickness from a thin edge near the valley margins to more than 600 feet near the center of the valley, where test holes have been drilled without penetrating bedrock (Feltis and Robinson, 1963, p. 18–21; Young, 1960, p. 2, 6–7). The valley fill consists of the flood-plain and alluvial-fan deposits, about 50–60 percent of which are well sorted and highly permeable. The fill in Circle Valley basin has the highest proportion of permeable material of any of the valley fill in the upper Sevier River basin. The most permeable deposits are along the Sevier River channel. Ground water in the valley fill is under artesian conditions at the lower end of the basin and under water-table conditions at the upper end of the basin (pl. 3).

In the artesian area, the subsurface movement of water is impeded by a ground-water barrier of volcanic bedrock, and the water is confined in permeable sand and gravel under a layer of silty clay of low permeability which is 5–25 feet thick. The piezometric surface in the artesian area ranges from about 5 feet above the land surface in well (C-30-3)19daa-1 to about 11 feet below the land surface in well (C-30-3)19dcc-1. At the lower end of the basin the artesian area contains springs and wet meadowlands. The artesian aquifers are recharged at the upper end and along the margins of the valley where the ground water is unconfined (pl. 9). The observed depth to the water table ranges from about 2 feet below the land surface in well (C-30-4)1dabd-1 to about 95 feet in well (C-30-4)31ddc-2.

An estimated 230,000 acre-feet of ground water is stored in the sand and gravel of the upper 250 feet of saturated valley fill in Circle Valley basin (table 7). The beds of sand and gravel are separated by saturated silt and clay of low permeability.

The bedrock formations that surround and underlie Circle Valley basin contain some ground water, but these formations generally are poor aquifers. Only one well, (C-30-5)16bbb-1, is known to penetrate bedrock in Circle Valley basin, and it yields about 50 gpm of water from sedimentary or volcanic rocks of Tertiary age.

Existing use

Most of the ground water used in Circle Valley basin is obtained from springs which discharge from the valley fill. The largest of the springs are in the Mitchell Slough in secs. 17 and 18, T. 30 S., R. 3 W., and in sec. 13, T. 30 S., R. 4 W.; they have a combined discharge of about 3,670 gpm, and the water is used for irrigation and stock.

Several bedrock springs, which are in the mountains and plateaus surrounding Circle Valley basin, discharge less than 200 gpm each. Part of the public supply of Circleville is obtained from Circleville Spring, (C-31-4)16ab, which yielded 90 gpm in December 1968 from volcanic rocks of Tertiary age.

Other than from springs, ground water used in Circle Valley basin is obtained from only a few wells and drains which produce minor quantities of water. Pumped wells produce only about 600 acre-feet of water annually, and all except three wells are used for domestic or stock purposes. Well (C-30-4)26dab-1 is pumped to supplement the Circleville public supply (Circleville Spring) during the summer, and it produces 20-50 acre-feet of water annually; well (C-30-4)25aad-1 produces about 3 acre-feet of water annually for a potato processing plant; and well (C-30-4)25acc-1, which is pumped for irrigation, yields most of the ground water pumped in the basin. The pumpage supplements a supply from the Sevier River, and it varies from year to year depending on the surface-water supply. The pumpage has varied from 0 in 1956 to 825 acre-feet in 1960, and it averaged about 500 acre-feet annually during the period 1957-62.

All the wells in the basin except one (C-30-5)16bbb-1, tap valley fill, and individual well yields range from about 1 to 1,475 gpm. Dug wells range from 12 to 38 inches in diameter and from 12 to 90 feet in depth, and 13 drilled wells range from 1¼ to 12 inches in diameter and from 10 to 407 feet in depth. Most of the drilled wells are less than 200 feet deep. Three of the drilled artesian wells (C-30-3)19daa-1, (C-30-3)29bad-1, and (C-30-4)14dac-1, flow, yield about 1-2 gpm of water each, and supply water for stock.

A few open drains have been excavated in the artesian area at the north end of Circle Valley basin. These drains, which are 3-8 feet deep and total about 5 miles in length, do not lower the water level appreciably because they are constructed in silty clay of low permeability, are not properly designed, and are inadequately maintained. They yield about 2,000 acre-feet of water to the Sevier River during most years.

Potential development

Wells that would yield several hundred gallons per minute could be constructed in the valley fill throughout Circle Valley basin, but wells drilled near the center of the valley would have the best yields. About 4,000 acre-feet of additional ground water could be withdrawn annually in Circle Valley basin without greatly affecting the flow in the Sevier River if the water can be salvaged from existing uses. Most of the water could be developed by lowering the water level in about 3,000 acres of wet phreatophyte-infested bottom land that comprises most of the artesian area. About 8,000 acre-feet of water is discharged by evapotranspiration annually in this wet area. Much of the area is wet because artesian ground water leaks to the land surface through the silty clay surface layer. Probably about half of the 8,000 acre-feet of loss could be salvaged by means of carefully spaced and designed wells and drains which would lower artesian heads in the sand and gravel deposits underlying the silty-clay layer. Furthermore, if the artesian head causing the upward leakage could be reduced, it would help alleviate waterlogging, but probably would result in a reduction of flow from the Mitchell Slough. This loss, however, would be compensated by water pumped from wells or obtained from more efficient drains. Lining of canals and mechanical eradication of phreatophytes would salvage additional water.

EAST FORK VALLEY BASIN

EMERY VALLEY SUBBASIN

Availability and storage of ground water

Ground water is under water-table conditions in the valley fill throughout Emery Valley subbasin. Bedrock is near the land surface in most of the subbasin, and playalike deposits at the downstream end indicate that ground water is impounded there. The valley fill is all alluvium and ranges from 0 to less than 100 feet in thickness (pl. 1, section E–E'), and about 10 percent is permeable sand and gravel.

The most permeable deposits are along the East Fork Sevier River channel. The observed depth to water ranges from about 4 feet below the land surface in well (C-36-4)34bda-2 to about 46 feet in well (C-36-3)6dba-1. About 6,000 acre-feet of ground water is stored in the upper 100 feet of saturated valley fill in the subbasin, and the principal water-bearing zones are beds of sand and gravel.

The bedrock underlying and surrounding the subbasin contains ground water, but the water-yielding characteristics of the bedrock and the quantity of water in storage are not well known. The available data, however, suggests that the bedrock formations are poor aquifers. Depth to water in the bedrock adjacent to the subbasin ranges from about 1 foot below the land surface in well (C-36-3)18acc-1 to about 892 feet in well (C-37-4)11ddd-1.

Existing use

Most of the ground water used in Emery Valley subbasin is obtained from the more than 50 wells that have been constructed in or adjacent to the subbasin. Nine of the wells in the subbasin obtain water from the valley fill, and the remainder obtain water from sedimentary formations of Tertiary or Cretaceous age. Wells in the valley fill generally yield less than 10 gpm, but one well, (C-36-4)34bca-1, is reported to yield 150 gpm. Discharge of wells penetrating bedrock ranges from less than 10 to 200 gpm. Most of the wells in or adjacent to the subbasin are drilled, range from 50 to 2,000 feet in depth, and range from 6 to 16 inches in diameter. Only two wells have been dug in Emery Valley subbasin; although several others adjacent to the subbasin were originally dug, they were later deepened by drilling.

Six wells are pumped for public supply and have a combined annual yield of more than 50 acre-feet; the other wells are pumped for domestic and stock use or are unused. Wells (C-36-3)7bbc-1 and (C-36-3)7bbd-1 penetrate the sedimentary formations of Cretaceous age underlying Emery Valley subbasin and supply water to the Federal Aviation Agency housing area near Bryce Canyon. Four wells supply water to Bryce Canyon National Park. Wells (C-36-4)32ada-1 and (C-36-4)34bda-2 obtain water from the valley fill; well (C-36-4)36acc-1, adjacent to the subbasin, penetrates limestone of the Wasatch Formation; and well (C-37-4)12ddd-2, also adjacent to the subbasin, penetrates sedimentary formations of Tertiary and Cretaceous ages.

Some ground water is obtained from springs in and adjacent to the subbasin. Bryce Canyon National Park obtains water from a seep area in the valley fill of East Creek, NW¼ sec. 34, T. 36 S., R. 4 W. The discharge of the seep ranges from 1 to 40 gpm, and the water is used for public supply. Other small springs and seeps in the valley fill are used for stock watering and usually discharge less than 20 gpm.

Many small springs mark the contact between the Wasatch and Kaiparowits Formations near Tropic Reservoir. The individual springs generally yield less than 10 gpm, and the water is used for stock.

Potential development

It is doubtful that wells capable of yielding more than 200 gpm could be pumped in Emery Valley subbasin for irrigation without affecting streamflow. The most permeable aquifers are the flood-plain deposits of the East Fork Sevier River, but pumping wells close to the stream would cause losses in streamflow.

JOHNS VALLEY SUBBASIN

Availability and storage of ground water

Ground water is under water-table conditions in the valley fill throughout Johns Valley subbasin. The fill is composed entirely of alluvium and ranges in thickness from a thin edge on the valley sides to more than 850 feet in the center and east-central side of the valley (pl. 1, section C-C'). About 15 percent of the valley fill in the subbasin is composed of permeable sand and gravel. The most permeable deposits are near the East Fork Sevier River channel. The wet meadows at the lower end of the subbasin are evidence that ground water is impounded there by a bedrock barrier (pl. 1, section D-D'). The observed depth to water in the valley fill ranges from about 10 feet below the land surface in test hole (C-35-2)23aaa-1 to about 150 feet in test hole (C-34-2)20ccd-1.

About 80,000 acre-feet of ground water is stored in sand and gravel beds in the upper 200 feet of saturated valley fill. The sand and gravel beds are the most permeable water-bearing deposits.

The sedimentary rocks of Tertiary and Cretaceous age underlying and surrounding the subbasin contain small quantities of water. The water-yielding characteristics of the bedrock and the quantity of water in storage are not known, but the available data suggest that, in general, the bedrock formations are poor aquifers. The observed depth to water in the bedrock ranges from about 30 feet in well (C-35-2)22dbb-1, which is adjacent to the subbasin, to about 300 feet in well (C-34-3)22dab-1.

Existing use

Most of the ground water used in Johns Valley subbasin is obtained from springs which discharge from either the valley fill or bedrock. A considerable amount of ground water seeps from the valley fill into the East Fork Sevier River south of Black Canyon in secs. 11, 14, 15, and 22, T. 42 S., R. 5 W. In this area, the stream gains about 6,000 acre-feet annually or 8 cfs in a channel length of about 9½ miles.

Large amounts of water are discharged from bedrock by springs in the plateaus adjacent to the subbasin. The largest springs discharge from the Wasatch and Brian Head Formations of Tertiary age. The largest of these, Deer Creek Spring, (C-32-3)[illegible], discharges about 1,040 gpm from fractures and joints in volcanic rock within the formations. Tom Best Spring, (C-34-3)27ddc, discharges about 500 gpm from fractures and solution channels in the limestone of the same formations. Many other springs in Black Canyon discharge from the same formations along contacts between volcanic flows and an underlying conglomerate. Individual yields of these springs range from 60 to 450 gpm.

Little ground water is withdrawn from wells in the subbasin. The seven wells in the subbasin range in depth from 24 to 230 feet; one taps bedrock and six tap the valley fill. None of the wells were used in 1963.

Potential development

Information for yields of wells in Johns Valley subbasin is not available, but wells that probably would each yield several hundred gallons per minute could be drilled into the flood-plain deposits of the valley fill along the East Fork Sevier River. Wells penetrating alluvial fans and bedrock probably would yield lesser amounts. It is doubtful that wells yielding more than about 700 gpm each could be developed in the subbasin to furnish irrigation supplies without affecting streamflow. Inasmuch as the most permeable aquifer in the subbasin is the flood-plain deposits of the East Fork Sevier River, pumping from wells in the lower part of the subbasin in secs. 13 and 24, T. 33 S., R. 2 W., probably would lower the water table and diminish the flow of the river.

ANTIMONY SUBBASIN

Availability and storage of ground water

Ground water is under both artesian and water-table conditions in the valley fill in Antimony subbasin. The valley fill, which is composed entirely of alluvium, generally is 60–75 feet thick in most parts of the subbasin, although in the valley bottom it is more than 200 feet thick (pl. 1, section E–E'). About 40 percent of the valley fill in Antimony subbasin is permeable gravel and sand. The fill in this subbasin has the highest proportion of permeable material of any in the East Fork Valley basin. The most permeable deposits are along the channel of the East Fork Sevier River.

The water is under artesian conditions in the lower part of the subbasin (pl. 2) where subsurface movement is impeded by a barrier formed by bedrock near the head of Kingston Canyon in sec. 30, T. 30 S., R. 2 W. The water is in beds of permeable sand and gravel, and it is confined by 5–10 feet of overlying silty clay of low permeability. The piezometric surface is near the land surface throughout the artesian area, which is marked by marshes, wet meadowland, and seepage areas. The artesian aquifers are recharged in the upper part and along the margins of the valley where ground water is unconfined (pl. 2).

Bedrock is near the surface in most parts of the valley, and the observed depth to water in the valley fill in the water-table area ranges from about 11 feet below the land surface in well (C-31-2)25ccu-1 to about 14 feet in well (C-32-2)2ddu-1.

Ground water also occurs in the bedrock of Tertiary age underlying the valley fill and adjacent to the subbasin, and the observed depth to water in the bedrock underlying the subbasin ranges from about 26 feet in well (C-31-2)25cd-1 to about 165 feet in well (C-31-2)24da-1.

About 28,000 acre-feet of ground water is stored in the sand and gravel of the upper 100 feet of saturated valley fill in Antimony subbasin. Additional ground water is stored in the bedrock underlying and adjacent to the subbasin, but the water-yielding characteristics of the bedrock and the quantity in storage are not known.

Existing use

Most of the ground water used in Antimony subbasin issues from springs in the valley fill in the subbasin or from bedrock in the surrounding plateaus and adjacent to the valley floor. As much as 5 cfs, or 3,600 acre-feet, of ground water seeps from the valley fill in the artesian area in the north end of the subbasin into the East Fork Sevier River.

Bedrock springs on the Sevier Plateau outside the subbasin yield water for public supply to Antimony and Kingston. Antimony Spring, (C-31-2)19ba, discharges about 220 gpm from volcanic rocks of Tertiary age. Kingston is supplied by a spring in Kingston Canyon, (C-30-3)22cab, which yields about 15 gpm from volcanic rocks of Tertiary age.

Ground water has been little developed by wells in Antimony subbasin. Of 16 wells in the subbasin, 14 are pumped for domestic and stock use and 1 is unused. The wells obtain water from the valley fill and from permeable zones in volcanic rocks or conglomerate of the Wasatch and Brian Head Formations. Yields of individual wells penetrating the valley fill average about 20 gpm and yields of wells penetrating bedrock range from about 4 to 26 gpm. Drilled wells generally range from 4 to 6 inches in diameter and from 40 to 160 feet in depth.

A few open drains, which discharge about 1,000 acre-feet of water annually, have been excavated in the silt and clay overlying the artesian aquifer. The drains, which are 1–3 feet deep and total about 4 miles in length, are ineffective in lowering the water level because they are not deep enough to penetrate the underlying permeable beds of sand and gravel, are improperly designed, and are inadequately maintained.

Potential development

Possibly 3,000 acre-feet of additional ground water could be withdrawn from wells and drains annually in Antimony subbasin without greatly affecting streamflow if water can be salvaged from existing uses. Construction of pumped wells and drains designed to penetrate confined aquifers would reduce artesian head and help drain the wet bottom land. The wells and drains could result in salvage of about 3,000 acre-feet of water annually, which is approximately half of the annual loss of 5,200 acre-feet by evapotranspiration from about 2,100 acres of wet bottom land. Furthermore, crops requiring less water than phreatophytes could be grown on the drained land.

GRASS VALLEY BASIN

KOOSHAREM SUBBASIN

Availability and storage of ground water

Ground water is under both artesian and water-table conditions in the valley fill in Koosharem subbasin. The valley fill, most of which is alluvium, is more than 500 feet thick in the center of the valley south of Koosharem and more than 779 feet thick in midvalley about 1 mile northeast of Greenwich (pl. 4, section F–F′; see also Feltis and Robinson, 1963, p. 27–31). About 15 percent of the alluvium in the subbasin is permeable sand and gravel. The most permeable deposits are confined layers of sand and gravel in the lake(?) or marsh(?) deposits near the channel of Otter Creek between the vicinity of Burrville and Greenwich.

Ground water is under artesian conditions throughout most of the valley fill (pl. 9), and the observed piezometric surface ranges from about 15 feet below the land surface in well (D-25-1)8cad-1 to more than 31 feet above the land surface in well (C-29-1)22dab-1. The water is confined under layers of silt and clay in the more permeable beds of sand and gravel that slope from the sides of the valley toward the center. The marsh and meadowland and the discharge of ground water to Otter Creek at the lower end of the valley indicate that ground water is impounded there by a bedrock constriction.

The artesian aquifers are recharged through permeable alluvial-fan deposits along the valley sides where the ground water is unconfined (pl. 2). The observed depth to water in the water-table areas ranges from about 6 feet below the land surface in well (C-27-1)21bca-1 to about 120 feet in well (C-27-1)29dbc-1.

About [illegible] acre-feet of ground water is stored in the sand and gravel of the upper 200 feet of saturated valley fill in Koosharem subbasin. Small amounts of ground water are also in the volcanic rocks of Tertiary age underlying and adjacent to Koosharem subbasin, but the quantity in storage and the water-yielding potentialities of the rocks are not known.

Existing use

Springs issuing from bedrock or the valley fill yield most of the ground water used in Koosharem subbasin. The bedrock springs on the surrounding plateaus and adjacent to the valley floor discharge from volcanic rocks of Tertiary age. Two of the largest are Burr Springs, (C-25-1)36bc, which yield about 1,420 gpm, and Red Cedar Grove Springs, secs. 13, 14, and 23, T. 26 S., R. 1 W., which yield about 340 gpm. Many small springs and seeps issue from the valley fill, and they have a combined yield of several hundred gallons per minute. Many of the springs and seeps are at the toes of alluvial fans on the valley sides, and others are adjacent to Otter Creek.

Most of the water from springs in Koosharem subbasin is used for irrigation and stock; however, part of the discharge of Burr Springs is used for public supply in Burrville, and the discharge from Brown Spring, (D-26-1)30ab, is used for public supply at Koosharem. Both springs discharge from volcanic rocks of Tertiary age.

More ground water is withdrawn from wells in Koosharem subbasin than in any of the other ground-water basins or subbasins in the upper Sevier River basin. Wells produce more than 2,400 acre-feet of water annually in this subbasin, mostly from flowing artesian wells. Of the approximately 164 wells that have been constructed in the subbasin, all but 1 obtain water from the valley fill and 143 are flowing artesian wells, 9 of the wells are dug, 12 are drilled, and 143 are jetted. The dug wells range from 10 to 150 feet in depth and from 30 to 120 inches in diameter, the drilled wells from 79 to 510 feet in depth and from 4 to 10 inches in diameter, and the jetted wells from 11 to 279 feet in depth and from 1 to 8 inches in diameter. Yields of individual wells penetrating the valley fill range from about 0.1 to more than 140 gpm; the well that penetrates bedrock, (C-27-1)20cc-1, yields about 20 gpm. Most of the wells are used for domestic and stock purposes, but about 85 are used solely for irrigating pastures. Individually owned wells are used for domestic water supply in Greenwich, which has no public-supply system.

The 35 irrigation wells are flowing wells which discharge about 1,800 acre-feet of water annually. These wells are mostly 200–250 feet deep, are 2 inches in diameter, and obtain water through the open end of unperforated casing. Generally only 20–30 feet of casing was installed in these flowing wells, and the rest of the hole commonly has collapsed and restricted the flow. Many of these wells were constructed before 1920, and the casings have almost rusted away. Many local wet spots, 10–30 feet in diameter, mark places where flowing wells once existed but have been virtually obliterated.

Drains have not been dug in Koosharem subbasin to develop ground water. However, some ditches in the Red Cedar Grove Springs area, sec. 23, T. 26 S., R. 1 W., convey water from the springs for irrigation downstream.

Potential development

More than 8,000 acre-feet of water per year is discharged by evapotranspiration from about 6,800 acres of wet bottom land in Koosharem subbasin. It is doubtful, however, that much of this water could be salvaged by additional withdrawal of ground water from the artesian areas without greatly affecting present water use. Lowering artesian heads would affect most of the flowing wells and the flow of artesian springs into Otter Creek. Otter Creek gains water in Koosharem subbasin largely by upward leakage from artesian aquifers, and wells of large discharge would reduce artesian head and in turn reduce the discharge of ground water to the stream. However, constructing drains, lining canals, and eradicating phreatophytes could salvage some water in the subbasin.

ANGLE SUBBASIN

Availability and storage of ground water

The valley fill is the main source of ground water in the Angle subbasin. The thickness of the valley fill, which is mostly alluvium, ranges from a thin edge near the valley margins and near bedrock outcrops within the valley to 400 feet near Angle, as indicated by the log of test hole (C-29-2)20dac-1 (Feltis and Robinson, 1963, p. 31). About 15 percent of the valley fill is permeable sand and gravel. The most permeable deposits are near the channel of Otter Creek.

Ground water is mostly under water-table conditions in the valley fill throughout the subbasin, but it may be under artesian conditions near the north end of Otter Creek Reservoir. The measured depth to water in the valley fill in Angle subbasin averages about 30 feet.

below the land surface. Wells do not penetrate the bedrock underlying or adjacent to Angle subbasin, but knowledge of springs in the bedrock suggests that small quantities of water are available in bedrock.

About 60,000 acre-feet of ground water is stored in the sand and gravel of the upper 200 feet of saturated valley fill in Angle subbasin. The principal water-bearing zones in the valley fill are deposits of sand and gravel.

Existing use

Springs in bedrock or the valley fill provide most of the ground water used in Angle subbasin. The bedrock springs discharge from volcanic rocks of Tertiary age in the surrounding plateaus or adjacent to the valley floor. The water from the largest springs, Pole Canyon Spring, (C-29-2)15abb, which discharges about 270 gpm, and Pete's Spring No. 1, (C-30-1)5bb, which discharges about 225 gpm, is used for irrigation and stock. A small amount of ground water seeps from the valley fill bordering Otter Creek just above Otter Creek Reservoir and is used for irrigation and stock.

Of the total of seven wells in Angle subbasin, two are dug and five are drilled, all are used for domestic and stock purposes, and all penetrate the valley fill. Individual wells yield from about 5 to 10 gpm, although wells constructed by modern methods could yield as much as 100 gpm. The drilled wells range from 65 to 197 feet in depth and from 2 to 6 inches in diameter.

Potential development

Lowering water levels in Angle subbasin by means of additional wells and drains could salvage some water lost by evapotranspiration near the upstream end of Otter Creek Reservoir. However, inasmuch as the most permeable deposits are near Otter Creek, it is doubtful that wells yielding more than about 500 gpm could be pumped without greatly affecting the flow of the creek.

EFFECTS OF PUMPING ADDITIONAL GROUND WATER IN THE UPPER SEVIER RIVER BASIN

Pumping additional water from wells in any of the ground-water basins in the upper Sevier River basin would eventually lower the water level and reduce artesian heads in that basin. The amount of water-level decline would be approximately proportional to the net amount of water pumped. If water is pumped from wells penetrating artesian aquifers, the water-level decline would spread rapidly over a relatively large area and would eventually affect adjoining water-table areas. If the water is pumped from wells penetrating water-table aquifers, the water-level decline would spread slowly and be limited largely to an area in the vicinity of the pumped wells. If pumping from the water-table aquifers is continued long enough, the water-level declines would eventually extend to the artesian areas and reduce artesian head.

Important benefits would result from reducing artesian pressures. Pressure reduction would reduce or stop the seepage of ground water to the land surface, mainly at the lower ends of the basins. Eventually many sloughs and waterlogged areas would dry up except some wet areas that may be sustained by shallow movement of water from adjacent irrigated lands. Much of the water now being discharged by evapotranspiration in these areas might be salvaged and used beneficially. In addition, the waterlogged land, now impregnated with salts that are deposited when the ground water evaporates, could eventually be reclaimed if irrigation water were applied at intervals to leach the salts from these soils. If the overall use of water were more efficient, more water would be available to satisfy local and downstream demands.

Streamflow would decrease if water levels were lowered appreciably in the valley fill. In water-table areas adjacent to streams, lowering water levels would increase the hydraulic gradient from the stream bed to the reservoir, and seepage from the stream bed would thus be increased. In artesian areas the hydraulic gradient is from the ground-water reservoir to the streams. Although the streams are separated from the aquifers by layers of relatively impermeable silty clay, small amounts of water seep through the clay and discharge into the streams.

The construction of additional wells in the upper Sevier River basin should be carefully planned. The first production wells should be spaced several miles apart, and water levels should be measured periodically in a network of observation wells to determine the amount and extent of the change resulting from pumping. In artesian areas, the discharge of springs and flowing wells in the vicinity of production wells should be measured periodically to observe changes. In the water-table areas, where water levels are near the altitude of the streams, production wells should be at least half a mile from streams so that the cone of depression does not reach the streams. To be most effective, ground-water development should be coordinated with improvement of surface-water diversion, more effective drainage, improved distribution systems, and phreatophyte control. The most efficient use of water in the basin would require that the ground-water reservoir be managed in a way similar to the management of surface-water reservoirs.

About 12,000 acre-feet of water per year, in addition to the amount now pumped, eventually could be developed from the ground-water reservoirs in the upper Sevier River basin. The 14,000 acre-feet would be salvaged from water now discharged by evapotranspiration from wet areas that support phreatophytes.

QUALITY OF WATER

The chemical quality of the ground water in the upper Sevier River basin is good for most uses. The following sections describe the mineral constituents found in the water and the quality of the water in relation to use.

DISSOLVED MINERALS

The major chemical constituents in the water of the upper Sevier River basin are silica, calcium, magnesium, sodium, potassium, chloride, sulfate, and nitrate. The chemical constituents commonly present in smaller amounts are iron, fluoride, manganese, and boron. Other properties and characteristics that help determine water quality are temperature, specific conductance, pH, and hardness. Chemical analyses of water from selected wells and springs in the basin and from a few sites along the Sevier River and its tributaries are included in a compilation of basic data by Carpenter, Robinson, and Bjorklund (1964).

QUALITY IN RELATION TO USE

IRRIGATION

The characteristics of water that appear to be most important in determining the suitability of water for irrigation are "(1) total concentration of soluble salts; (2) relative proportion of sodium to other cations; (3) concentrations of boron or other elements that may be toxic; and (4) under some conditions, the bicarbonate concentration as related to the concentration of calcium plus magnesium" (U.S. Salinity Lab. Staff, 1954, p. 69).

1. The total concentration of soluble salts, or salinity, may be expressed in units of dissolved solids concentration or of specific conductance. Chemical analyses were made of samples of ground water from 22 wells and 23 springs in the upper Sevier River basin. The dissolved solids range from 80 to 773 ppm (parts per million) and average 265 ppm for 40 samples, and the specific conductance ranges from 81 to 690 micromhos per centimeter and averages 338 micromhos per centimeter for 40 samples. Thus, the ground water has a salinity hazard that ranges from low to medium for irrigation, according to the classification of the U.S. Salinity Laboratory Staff (1954, p. 79-81).

   The relation of dissolved solids and specific conductance for surface water in the upper Sevier River basin at certain times of the year is quite similar to that of ground water. (See fig. 6.)

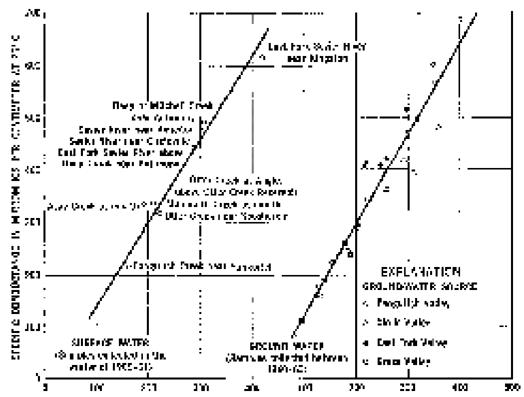

FIGURE 6.—Graphs showing the relation between the dissolved solids and specific conductance of selected surface- and ground-water samples.

Chemical analyses of 10 samples of surface water collected during the winter of 1960–61 indicate that the dissolved solids ranged from 160 to 460 ppm and averaged 262 ppm and the specific conductance ranged from 216 to 618 micromhos per centimeter and averaged 404 micromhos per centimeter. The surface-water samples were collected during a period of low flow when most of the streamflow was derived from ground water. During periods when much of the streamflow is derived from snowmelt or rainfall, however, the dissolved-solids content generally is less.

2. The proportion of sodium to other cations, and the probable extent to which a soil may adsorb sodium from water (and thereby become less permeable) is expressed in terms of the sodium-adsorption ratio (SAR). The SAR of the ground water in the upper Sevier River basin ranges from 0.1 to 1.9 and averages about 0.6. Thus the ground water in the basin has a low sodium hazard for irrigation, according to the classification of the U.S. Salinity Laboratory Staff (1954, p. 79–81).
3. A small quantity of boron is essential to the normal growth of all plants, but excessive concentrations are toxic. Toxicity varies

according to the tolerance of individual species (U.S. Salinity Lab. Staff, 1954, tables 9, 10). In general, water containing less than 0.33 ppm of boron is not harmful to any plant, whereas water containing more than 3.75 ppm may be toxic to all crops. The amount of boron in 29 ground-water samples collected in the upper Sevier River basin ranged from 0.02 to 0.16 ppm and averaged 0.05. These small concentrations are not harmful to plants.

4. The relation between the bicarbonate concentration and the concentration of calcium plus magnesium is expressed as residual sodium carbonate (RSC). The U.S. Salinity Laboratory (1954, p. 81) states that "* * * waters with more than 2.5 meq per l (milliequivalents per liter) 'residual sodium carbonate' are not suitable for irrigation purposes." None of the ground-water samples collected in the upper Sevier River basin had a RSC that exceeded 2.5 meq per l.

Ground water in the valley fill in Panguitch, Circle, and Grass Valleys deteriorates in quality slightly from the upper to the lower end of each valley (pl. 3). Although few data are available for the quality of water in the valley fill of East Fork Valley, the fact that the quality of the surface water deteriorates downstream indicates that this deterioration also probably occurs in the ground water. The deterioration in quality in all the valleys in a downstream direction is due largely to use and reuse of water for irrigation.

DOMESTIC AND PUBLIC SUPPLY

The U.S. Public Health Service (1962) has recommended the following maximum concentrations for some of the more common constituents in water used for domestic and public supply:

Constituent	Parts per million
Chloride	250
Fluoride	(1)
Iron	.3
Manganese	.05
Nitrate	45
Sulfate	250
Dissolved solids	500

[1] The recommended maximum fluoride concentration is variable, depending on air temperature. For temperatures similar to that at Panguitch, the maximum recommended fluoride concentration is 1.3 ppm. (See U.S. Public Health Service, 1962, p. 8.)

The concentrations of chemical constituents observed in samples of ground water from the upper Sevier River basin commonly are less than the maximums recommended by the Public Health Service. The recommended concentrations were exceeded in a few of the ground water samples as follows: the concentration of fluoride in three samples, iron in eight samples, manganese in one sample, and dissolved solids in two samples. The recommended fluoride concentration was exceeded in samples collected from spring (C-30-3)24cab (3.2 ppm), well (C-30-3)16bbb-1 (5.1 ppm), and well (C-30-4)26dcb-1 (2.9 ppm). Igneous rocks often yield water with a high fluoride concentration, and spring (C-30-3)24cab and well (C-30-3)16bbb-1 tap volcanic rocks of Tertiary age and sedimentary or volcanic rocks of Tertiary age, respectively. Well (C-30-4)26dcb-1 obtains water from valley fill which is derived from volcanic rocks.

The recommended iron concentration was exceeded in samples collected from wells (C-35-5)31ccb-1 (3.0 ppm) and (C-30-3)16bbb-1 (0.33 ppm) and from springs (C-30-3½)17d (0.52 ppm) and (C-31-3)10bb (0.8 ppm); it was also exceeded in two samples from well (C-30-4)26dcb-1 (2.8 and 1.6 ppm) and well (C-36-2)6dba-1 (1.0 and 0.99 ppm). The source of the iron is believed to be igneous- or carbonate-type rocks that supply water directly to six of the eight springs and wells. Wells (C-30-4)26dcb-1 and (C-36-2)6dba-1 tap valley fill that is derived largely from igneous- and carbonate-type rocks, respectively. Some of the iron, however, may possibly be derived from the well casing or pipe-conduit systems.

The recommended manganese content was exceeded in a sample from well (C-30-3)16bbb-1 (0.15 ppm). The well obtains water from volcanic or sedimentary rocks of Tertiary age which are probably rich in manganese.

The recommended dissolved solids content was exceeded in samples from two wells. The high concentration in the water from well (C-30-3)7ccc-1 (778 ppm) may be caused by return flow from irrigation. The high concentration in the water from well (C-35-5)24ccb-1 (812 ppm) may be due to the fact that the sample was collected during deepening of the well and could have been contaminated with drilling fluid.

The hardness of water is important in domestic and public supply because soap consumption for washing and laundering increases as the hardness increases and hardness causes part of the incrustation (boiler scale) found in pipes, coils, and boilers. The U.S. Geological Survey uses the following classification for hardness of water: less than 60 ppm, soft; 61–120 ppm, moderately hard; 121–180 ppm, hard; and more than 180 ppm, very hard. Water having a hardness of more than 200 ppm needs to be softened for most purposes.

Of the ground-water samples from 24 wells and 23 springs for which hardness was determined, 3 contained less than 60 ppm of hardness, 16 contained 61–120, 9 contained 121–180, and 19 contained more than

180. The hardness of the water in the 47 samples ranged from 35 to 508 ppm and averaged 170 ppm. The hardness is generally highest in water obtained from the valley fill and lowest in water obtained from volcanic rocks of Tertiary age. The three samples which contained less than 70 ppm of hardness are all from springs in volcanic rocks of Tertiary age: springs (C-30-6)6cb (67 ppm), (C-30-4)16ab (25 ppm), and (D-28-1)29ab (17 ppm). Most of the samples containing more than 80 ppm of hardness are from the valley fill, but some are from consolidated sedimentary rocks. Plate 8 shows graphically the values of hardness for a few selected samples collected from the valley fill or bedrock.

LIVESTOCK

Although animals are more able to tolerate water having a high dissolved-solids content than man, prolonged periods of drinking highly mineralized water may cause physiological disturbances such as wasting, gastrointestinal disorders, disease, and even death. Other effects include reduced lactation and rate of reproduction. The State of Montana (W. F. Storey, oral commun., 1961) rates water containing less than 2,500 ppm of dissolved solids as good for livestock use, from 2,500 to 3,500 ppm as fair, from 3,500 to 4,500 ppm as poor, and more than 4,500 ppm as unfit. On the basis of this classification, the water sampled in the upper Sevier River basin is good for livestock.

INDUSTRY

The chemical characteristics of water that are most important in determining the suitability of the water for industrial use vary according to the particular use involved and the product manufactured. Two characteristics that are significant to practically all industries, however, are hardness (discussed in the section on "Domestic and public supply") and silica content. Silica forms a hard, adherent scale in boilers; Moore (1940, p. 263) has suggested the following allowable concentration of silica in water for boilers operating at various pressures: for a pressure less than 150 psi (pounds per square inch), 40 ppm; 150–250 psi, 20 ppm; 250–400 psi, 5 ppm; and more than 400 psi, 1 ppm.

Of the ground-water samples collected from 28 wells and 23 springs in the upper Sevier River basin that were analyzed for silica, 17 contained more than 40 ppm of silica, 34 contained more than 20 ppm, and all but 1 contained more than 5 ppm. The average silica content of the ground-water samples was 32 ppm. The sample with less than 5 ppm silica was from well (C-37-4)14dd-1 (1.7 ppm) which derives water from limestone of the Wasatch Formation. In the upper Sevier River basin, igneous rocks generally yield water having the greatest content of dissolved silica and limestone yields water that contains the least silica.

Temperature is an important characteristic of water used for cooling. Low temperatures, of course, are preferred, and water having a relatively constant temperature is considered desirable. The temperature of water from wells in the upper Sevier River basin commonly ranges from 50° to 58°F. The average temperature of water from 281 wells is 53°F, the range being from 41° to 61°F; the average temperature of water from 47 springs is 51°F, the range being from 40° to 68°F. By comparison, the temperature of surface water in the basin varies with the season and the stream and ranges from freezing to tepid. The temperature of the water from a spring in sec. 17, T. 33 S., R. 5 W., is 80°F; however, this water issues from considerable depth along a fault, and its temperature is not representative of ground-water temperatures in the basin.

SUMMARY

The upper Sevier River basin contains four ground-water basins which were formed by geologic processes including faulting and stream action. They are Panguitch Valley basin, Circle Valley basin, East Fork Valley basin, and Grass Valley basin. East Fork Valley basin is divided into Emery Valley, Johns Valley, and Antimony subbasins. Grass Valley basin is divided into Koosharem and Angle subbasins.

Ground water occurs under both artesian and water-table conditions in the valley fill in Panguitch and Circle Valley basins and in Antimony and Koosharem subbasins. It is under water-table conditions in the valley fill in Johns Valley, Emery Valley, and Angle subbasins. In Panguitch and Circle Valley basins and Antimony subbasin, the artesian conditions are at the downstream ends, and the water-table conditions are at the upstream ends. Ground water is under artesian conditions throughout most of Koosharem subbasin but is under water-table conditions in places along the sides. Depths to water in wells in the valley fill range from practically 0 to about 150 feet below the land surface. Many wells flow in the artesian areas, and artesian heads reach a maximum of about 30 feet above the land surface.

The valley fill in the basins and subbasins consists of gravel, sand, silt, and clay. An average of about 25 percent of the valley fill is permeable sand and gravel which yields water readily to wells and springs. The approximate percentages of sand and gravel in the valley fill are: 25-30 percent in Panguitch Valley basin, 30-40 percent in Circle Valley basin, 10 percent in Emery Valley subbasin, 15 percent in Johns Valley subbasin, 40 percent in Antimony subbasin, 15 percent in Koosharem subbasin, and 15 percent in Angle subbasin.

About 1 million acre-feet of ground water that is recoverable by wells is stored in the upper 200 feet of saturated valley fill in the various basins and subbasins. The amounts of water in the sand and gravel deposits are (in acre-feet): Panguitch Valley basin, 370,000; Circle Valley basin, 210,000; Emery Valley subbasin, 6,000; Johns Valley subbasin, 90,000; Antimony subbasin, 80,000; Koosharem subbasin, 90,000; and Angle subbasin, 60,000. The silt and clay deposits in each basin and subbasin contain large quantities of water, but little of this water is readily available to wells. Some of the water in the silt and clay, however, is indirectly available to wells because it would move into the permeable gravel and sand deposits if water were removed from those deposits.

The bedrock surrounding and underlying the various basins and subbasins also contains ground water, but the quantity is not known. In places the bedrock will yield significant amounts of water to wells, but in most of the basin the bedrock has low permeability.

The ground-water reservoirs are recharged mostly by the Sevier River and its tributaries at the upper ends and sides of the ground-water basins and by seepage from irrigation systems and irrigated lands in water-table areas. Inflow from bedrock aquifers surrounding the valleys also recharges the reservoir. The ultimate source of all recharge is precipitation within the upper Sevier River basin.

Water is discharged from the ground-water reservoir by flowing and pumped wells, springs, drains, evapotranspiration, and subsurface outflow. The discharge in 1962 from the valley fill by wells was about 3,000 acre-feet, by drains about 2,600 acre-feet, by springs about 33,000 acre-feet (springs in bedrock discharged an additional 75,000 acre-feet), and by evapotranspiration from areas of phreatophytes about 45,000 acre-feet. A slight decline in ground-water levels in the valley fill during the 1938–63 period indicates that the total discharge of ground water slightly exceeded the recharge.

The surface- and ground-water systems in the upper Sevier River basin are interrelated, and increasing the ground-water discharge will, in general, decrease the surface-water discharge. The most efficient use of water in the basin, however, requires that the ground-water reservoir be managed in a way similar to the management of surface-water reservoirs.

About 45,000 acre-feet of the ground water discharged in the upper Sevier River basin is consumed by phreatophytes in wet areas in the valleys; part of this water might be salvaged without significantly decreasing surface-water discharge and ground-water discharge from existing wells, springs, and drains. If new large wells and drains were carefully designed and spaced, they could lower water levels enough to dry up wet areas; thus about 14,000 acre-feet of water could be salvaged, and little decrease would result in the flow of existing wells, springs, and streams in most basins.

Of the 14,000 acre-feet of water to be salvaged from existing uses, about 7,000 acre-feet could be supplied by wells and drains in Panguitch Valley basin, about 4,000 acre-feet could be supplied by wells and drains in Circle Valley basin, and about 3,000 acre-feet could be supplied by wells and drains in Antimony subbasin. Additional withdrawal of ground water, however, in (1) Johns Valley or Emery Valley subbasins, would ultimately decrease the flow of East Fork Sevier River and in (2) Koosharem or Angle subbasins would decrease the yield of flowing wells and the flow of Otter Creek.

The ground water in the upper Sevier River basin generally is suitable in chemical quality for irrigation, domestic and public supply, livestock, and industry. The dissolved-mineral content of the ground water within individual basins generally increases downstream, owing mainly to repeated use of the water for irrigation.

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[Italic page numbers indicate major references]

Attachment F – Water Quality Handling & Analysis Plan

WATER QUALITY SAMPLING, HANDLING, AND ANALYSIS PLAN

A Compliance Document for

Groundwater Discharge Permit Application

FOR:

DALTON FINISHER SITES

GARFILE COUNTY, UTAH

November 29, 2017

Prepared For:

Dalton Hay Company, LLC

P.O. Box 189

Circleville, Utah 84723

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ATTACHMENTS

Water Quality Handling and Analysis Plan

1.0 INTRODUCTION

The following **Water Quality Sampling, Handling and Analysis Plan** (The Plan) presents the organization and procedures for water quality investigations near Delta, Utah. This plan is required by the Utah State Department of Environmental Quality (DEQ), Division of Water Quality as a condition of the Final Ground Water Discharge Permit for the Dalton Finisher Hog Production Sites.

1.1 Implementation

The Plan is submitted as a Compliance Document for the Utah Ground Water Discharge Permit ("the Permit"). The Plan has been approved by Jade Dalton and Circle Four Farms.

2.0 PROJECT DESCRIPTION

2.1 Purpose

<u>Specific objectives of the Groundwater Monitoring Plan:</u>

A. To evaluate background water quality at the Dalton Finisher Site approximately 2.6 miles south of Circleville, Utah.

B. To provide information for the DEQ to establish ground water protection levels for the facility.

C. To establish procedures for groundwater monitoring and sample collection at the facility.

2.2 Methodology

<u>Engineering Activities for Achieving the Specific Objectives</u>: Water quality data reports will be submitted to the DEQ on a regular schedule, in accordance with the requirements of the Groundwater Quality Discharge Permit for the facility.

A. Installation of monitoring wells in the most shallow aquifer, upgradient and downgradient from the facility.

B. Measurement of groundwater elevations at the monitor wells.

C. Evaluation of hydrologic gradients in all aquifers penetrated by monitor wells.

D. Collection and analysis of ground water quality samples from the monitor wells according to a schedule recommended by the Utah State Division of Water Quality in the Permit.

E. Preparation and submission of quarterly "Groundwater Sampling Reports" during the one year accelerated background monitoring period.

3.0 PROJECT ORGANIZATION AND RESPONSIBILITY

3.1 Organization

Organization for studies and field investigations required by this Plan

A. **Construction Management Company:**
Dalton Finisher Sites
Contact: Jade Dalton **-** Owner
Construction Manager (CM) will be appointed by Jade Dalton.

B. **Quality Assurance Company:**
GEM Engineering, Inc.
Contact: Joel A. Myers, P.E. – President
Quality Assurance Officer (QAO) will be appointed by GEM Engineering.

C. **Department of Environmental Quality Official:**
Ed Hickey. P.G. **–** Environmental Scientist
State of Utah – Department of Environmental Quality
Division of Water Quality

3.2 Responsibilities

A. The CM and the QAO review and conduct or oversee the field activities described in the Plan. They will review all data generated during the investigation and will be responsible for validating and submitting data to the DEQ.

B. Analytical results of each completed sampling round will be submitted to the Division of Water Quality.

C. The CM and the QAO will review and approve the Plan, review all quality control data and identify problems, if any. The QAO will report directly to the CM and recommend corrective measures.

D. The state official will advise the owner of any comments, or objections to the Plan, its implementation, or any proposed changes to the Plan.

4.0 MONITOR WELL INSTALLATION

4.1 Site

Monitor wells are installed in the shallowest aquifer where unconsolidated quaternary sand and gravel contain unconfined water.

4.2 Construction

Requirements for monitor wells constructed for the Dalton Finisher facilities are included in the section of the Groundwater Discharge Permit Report. Unless required by the Division of Environmental Quality additional specifications will not be included as part of this Plan.

4.3 Published Standards

Well construction conforms to the EPA RCRA Groundwater Monitoring Technical Enforcement Guidance Document and the National Water Well Association's Handbook of Suggested Practices for the Design and Installation of Groundwater Monitoring Wells.

5.0 ANALYTICAL PARAMETERS AND QA OBJECTIVES

Required analytical parameters and holding times are given in Tables A-1 and A-2. Specific conductance, temperature and pH will be measured in the field. Table A-1 provides parameters which will be analyzed on a quarterly basis, until the State official determines an adequate base line has been established. After this the samples will be analyzed on a semi-annual or annual basis, as determined by the state, for the parameters listed in Table A-2.

Water Quality Handling and Analysis Plan

5.1 Procedures

A. Check analyses for the field parameters pH and specific conductance will be run in the laboratory. Chemical analysis for all certified constituents will be performed by a commercial laboratory certified under either, The Clean Water Act, The Safe Drinking Water Act or The Resource Conservation and Recovery Act.

5.2 Quality Assurance

A. Internal quality assurance for this project will be in accordance with the Utah DEQ protocol. Laboratory certification will be monitored by the QAO.

B. Routine analysis of samples will be performed in accordance with standard EPA procedures. Special analyses will be performed according to EPA methods for chemical analyses of water and wastes.

C. Specific analytical methodologies and references are listed in Table A-1. These methodologies specify the documentation needed to complete and evaluate the data. They also define acceptable accuracy and precision criteria that must be met for the data to be considered valid.

1. Accuracy: defined by the EPA as the percent recovery of a spiked sample. Laboratory matrix spikes are actual field samples spiked in the laboratory with a representative group from the list of required parameters as per Table A-1. One sample per alternate set of field samples will be split for matrix spike analysis.

2. Precision: defined by the EPA as the relative percent difference of duplicate sample analyses f similar matrix.

D. Re-sampling will be required if contaminant concentration in a trip blank (to be submitted on alternate sampling rounds) are within one order of magnitude of actual field sample concentrations.

5.3 Data Quality Objectives

A. The data collected as part of this investigation is intended for use by the State of Utah DEQ and by Blue Mountain Dalton Finisher and its consultants.

B. Laboratory and field procedures have been designed to provide a high confidence level in the analytical results based on precision, accuracy, completeness and comparability.

5.4 Data Quality Control Management

A. Field data quality control will be managed by the QAO in consultation with the State DEQ official for each type of data defined in this Plan.

B. Field data will be compared to previously collected data at the site to test for probable consistency. Historic data will also be assessed for accuracy to assure consistency and comparability of all data taken at the site.

C. Data will be compared in the same area and / or at similar depths during this study to determine whether or not the results are reasonable and consistent.

D. Unreasonable data points will be evaluated by technical personnel who will decide whether re-sampling or retesting are required.

6.0 FIELD PROCEDURES

This section presents the water quality research methods for water level measurements, sample collection and handling.

6.1 Water Level Measurements

A. Static water level measurements are to be made in all monitor wells during this investigation. Water levels will be measured before sampling with a steel tape or electric sounding device to the nearest 0.01 foot. The measuring device and reel will be cleaned with distilled water before and after each measurement.

B. Measurements will be made from a standard reference point at the top of the well casing.

C. Interpolation will be used to estimate the depth to the nearest 0.01 foot. Sufficient “runs” to the top of the ground water will be attempted to assure accuracy of the measurements. The total depth of each well will be measured after the water level is determined to verify the integrity of the well.

D. Water levels will be reported as depths below the standard reference point and as elevations relative to mean seal level.

1. Measurements obtained while drilling and immediately after completion of each monitor well will be reported on the boring logs.

2. Measurements obtained during the water quality sampling program will be recorded on a field log (Figure A-1) and will be transferred to permanent records.

E. All field and office records will be retained for reference.

6.2 Groundwater Sampling for Laboratory Analysis

A. Collection Methods

1. Groundwater samples will be collected following monitor well development.

2. Development will continue until water removed from the well is reasonably free of sand, silt and clay so that the well can be sampled without damage to the pump or bailer.

3. If possible, turbidity will be less than 5 NTU.

4. Analytes will be sampled in order of decreasing volatility.

5. Teflon, PVC or stainless steel bailers will be used to sample wells that do not yield adequate quantities of water to be purged by pumping. Each well will be ailed until the field parameters (temperature, pH and conductance) have stabilized, thus assuring that the sample will be representative of groundwater conditions.

6. Any abnormal sampling conditions that may have an effect on sampling will be recorded in the field sampling notes. Examples of such conditions would include, but would not be limited to; equipment malfunctions, unusual recharge rates of the well, unusual pumping rates, or conditions which could lead to contamination of the sample. Field notes will also record:

   a. Whether high (pump) or low (bailer) yield procedures for well evacuation were followed.

b. The types of samples taken during a particular sampling event.

c. The sample numbers.

B. <u>Measurements</u>

1. Field measurements and observations will be recorded on field logs which will be copied and stored for reference. A field log from for groundwater sampling is included with this Plan as Figure A-2.

2. Water Levels will be measured before sampling. The height of the water column above the screened completed interval will be used to determine three casing volumes for evacuation prior to sampling.

3. Estimated discharge rates and pumping durations necessary for ensuring evacuation of three casing volumes will be prepared to guide sampling personnel after completion of the monitor well drilling program.

C. <u>Equipment</u>

1. A Groundfos MP1 submersible pump will be used to pump wells. Alternatively a stainless steel PVC or Teflon bailer may be used.

2. Pumping and bailing shall be conducted to ensure that three casing volumes are evacuated before sample retention. A work sheet showing water column calculations for each of the monitor wells is enclosed as Figure A-2. Pump or bailer discharge shall be measured to verify the evacuation volume.

D. <u>Calibration</u>

1. Field instruments for pH and specific conductivity will be calibrated according to manufacturer's recommendations before sampling begins. Cole-Parmer pH and conductivity meter or their functional equivalents will be used.

2. Calibration standards for pH and conductivity will be chosen to be representative of values expected in the naturally occurring waters.

3. Calibrations will be rechecked after sample collection, and all calibration procedures will be documented on the sampling field log. Measurements of pH,

conductivity and temperature will be made at the beginning and just before the end of voiding three casing volumes.

E. Storage and Handling

1. Groundwater samples will be bottled directly from the discharge of the pump or bailer. Bottles will be labeled prior to filling and stored on ice immediately after collection.

2. Sample bottles of appropriate size and with the required preservative will be obtained from the selected certified laboratory.

6.3 Procedures to Avoid Contaminating Groundwater Samples

A. Restrict pump and bailing discharge rates so that drawdown does not cause sample aeration.

B. Decontaminate sampling equipment prior to utilization at another site. Decontamination methods will include:

1. Cleaning with a non phosphate detergent.
2. Rinsing pump and hose with culinary water
3. Rinsing bailers with deionized or distilled water.

6.4 Sample Handling

A. Sample containers will be (1) stored out of direct sunlight and (2) preserved, shipped and analyzed within the maximum allowable holding times as specified in Tables A-1 & A-2.

B. Samples will be shipped to the appropriate laboratory as soon as possible on the same day as collection, but in all cases within the time required by the accepting laboratory.

C. Other specific laboratory requirements and EPA guidelines will be observed for each parameter, including container type, preservation dosages and refrigeration.

7.0 SAMPLE CUSTODY

7.1 Field Operations

A. Documentation of field collection procedures and sample integrity from collection to reporting are essential parts of the Plan.

B. Documentation of sample possession assures that samples may be traced from the time of collection through analysis and final statistical evaluation.

1. Documentation of the history of the sample is referred to as chain-of-custody.

7.2 Necessary Records and Actions

A. Sample Labels: prevent misidentification of samples. The sample label shown as Figure A-3 or its equivalent will be filled out and attached to each sample bottle before collection.

B. Field Sampling and Analysis Records will be maintained. Pertinent field measurements and observation will be recorded.

C. Equipment used to measure the field parameters shall be calibrated before the collection of each sample.

D. Appropriate forms such as Figure A-2 will be filled out for each sample site. Documentation of the sources of buffers, standards, reagents, sample containers and so forth will be recorded on these forms.

E. A chain-of-custody record (equivalent to Figure A-4) will be filled out for each set of samples. A copy will accompany every sample shipment from the time of collection through receipt by the analytical results for inclusion in the yearly reports.

F. A copy of the form sent to the laboratory with each sample shipment will be retained with the analytical results for inclusion in the yearly reports.

G. Jade Dalton, at his option may elect to protect sample integrity by use of seals applied in the field immediately after sampling. Such seals may be required by the State of Utah in the event that sampling is related to enforcement issues.

7.3 Laboratory Operations

A. The analytical laboratory will acknowledge receipt of the samples by signing and dating in the appropriate box in the form shown as Figure A-4. This form will be returned to Jade Dalton with the analytical results.

B. The laboratory will maintain internal chain-of-custody control in accordance with protocol as per the Utah DEQ.

8.0 CALIBRATION PROCEDURES AND FREQUENCY

8.1 General

A. Meters used to measure pH and specific conductance will be calibrated as outlined below prior to and during use. Source and identification of standards used to calibrate will be recorded on the form as presented in Figure A-2.

8.2 Field pH

A. Field pH will be determined via a Cole Parmer pH Tester Meter (or equivalent). The meter has automatic temperature correction capabilities.

B. Field personnel will follow the manufacturer’s instructions for operation and standardization of instruments.

8.3 Standardization

A. Standardization will utilize a buffer of 7 pH units.

B. The meter will be sterilized prior to each sample collection and checked against the standard after each sample collection. Where sample pH values vary widely, the meter will be standardized with buffers having pH of 7 and 10.

8.4 Equipment Storage and Cleaning

A. The pH meter electrode will be stored in accordance with the manufacturer’s recommendation.

B. Any oil on the electrodes shall be cleaned with methanol f HCL as needed.

8.5 Field Specific Conductance

A. Field specific conductance will be measured with a Col-Parmer Model 0481-40, or equivalent. This meter automatically indicates specific conductance normalized to 25^{o}C.

B. Calibration will be accomplished according to manufacturer's instruction before each measurement.

8.6 Temperature and Water Levels

A. Temperature will be measured using a good grade mercury thermometer. Temperatures will be reported to the nearest o degree Fahrenheit.

B. Water level measurements will be made with a steel tape or electronic sounding device capable of accuracy to within 0.01 feet.

C. Water levels will be recorded in the field on the form shown as Figure A-1 along with pertinent observations.

9.0 INTERNAL QUALITY CONTROL

9.1 Field Operations

A. At least one blind field groundwater duplicate sample will be prepared and submitted to the laboratory during alternate sampling events.

B. Obtaining Water Samples for Duplicates:

1. Water samples will be obtained directly from the pump discharge line.

2. One field equipment blank will also be collected during alternate sampling events.

C. Preparing Field Equipment Blank Sample (one of the following methods):

1. Pump distilled water through the submersible pump.

2. Fill sample containers from the bailer in the same manner as is done for a typical sample.

9.2 Preservation

A. Preservatives are planned for use in sample bottles.

B. A trip blank for each one of the preserved sample bottle types will be included for alternate sampling events.

C. Each of these trip blank bottles will be prepared by the laboratory (filled with distilled water and appropriate preservatives) and be subjected to the same field conditions and laboratory analytical tests as required for ground water samples.

9.3 Laboratory Operations

A. The laboratory will conduct quality control checks in accordance with the State of Utah certification requirements.

B. This quality control check will include running at least 5 percent duplicated and spike samples.

C. The laboratory will summarize the results of these quality control checks and submit them with the analytical results.

D. At least one groundwater sample from alternate sampling events will be utilized for laboratory matrix spike duplicate analyses. Field personnel will ensure that sufficient sample material is provided to the appropriate laboratory for the matrix spike.

9.4 Summary of Quality Control Samples

A. The following “extra samples” will be analyzed during alternate sampling events.

1. Groundwater duplicate samples from each upgradient well.

2. One field equipment blank.

3. One trip blank for each of the preserved bottle types (prepared by the laboratory).

4. One laboratory matrix spike duplicate sample.

10.0 DATA REDUCTION MANAGEMENT, VALIDATION, AND REPORTING

All field data and chain-of-custody forms generated from sampling will be appropriately identified and included in each water quality data report.

10.1 Standardization

A. Use of standardization forms will enable consistent presentation of the data throughout the project life. Therefore, standardization data forms will be used by all field personnel as well as by the laboratory during the project.

10.2 Validation

A. Validation of all analytical data will be performed. Laboratory will be required to submit results which are supported by sufficient back up data and QA/QC reports to enable the Quality Assurance Officer to determine the quality of the data.

B. Validity of all data will be determined from the precision and accuracy assessments outlined in Section 5.0 of this Plan. All data will be stored and maintained according to the procedures outlined.

10.3 Data Processing

A. Data will be processed through an orderly, easily traceable and logical sequence. Field data will be assessed for accuracy.

B. Subsequent analysis, interpretation and reporting of results will be conducted by trained professionals, using documents which are initialed and dated whenever appropriate.

C. Backup copies of electronic media will be prepared daily. Any calculations will be checked and all assumptions necessary for calculations will be approved by the QAO.

D. Results will be reported with all necessary supporting documentation after proper review.

11.0 AUDIT PROCEDURES

The CM and the QAO will monitor and audit performance of the quality assurance procedures outlined in this report. The QAO will conduct random field and office audits which will assure that the information being gathered is reliable and of good quality. This information will be provided to the DEQ Official.

11.1 Field Audits

A. The CM or his representative will conduct unscheduled field activity audits during each sampling event. Audits will evaluate the execution of (1) sample identification, (2) sample control, (3) chain-of-custody procedures, (4) field documentation, (5) equipment calibration and (6) sampling operations.

B. Evaluation: The following list of items will be used to evaluate the water sampling and handling:

1. Field documents pertaining to sample identification and control will be examined for completeness and accuracy.

2. Field documents will be reviewed to see that (1) all entries are dated and signed with waterproof ink or pencil and that (2) the contents are legible, accurate and inclusive.

3. The field documents form the basis for reports and will contain all measurements and observations.

4. Field instruments will be checked for proper calibration and completely prepared calibration documentation.

C. Conformance and Security

1. Sampling operations will be evaluated for conformance to Section 6.0 of this Plan. The proper number of samples will be collected at the assigned locations in proper containers with correct labels and appropriate preservatives.

2. Required field measurements and quality assurance checks will be performed and documented as directed by the CM and the QAO.

3. The CM or his representative will check chain-of-custody procedures and confirm that samples are kept in secure custody at all times.

11.2 Office Audits

A. Upon completion of each sampling event, the individual files will be assembled, organized and securely stored.

B. Documents will be examined to determine that all necessary signatures, dates and project numbers are included. The CM or his representative will examine all documents and determine if they have been handled and stored in the proper manner. Such files will be maintained by Jade Dalton or a member of his company.

C. The CM or his representative will review product quality to assure that the project is being performed in accordance with approved quality assurance procedures.

D. Prior to the production of the draft Background Groundwater Quality Report, all work products will undergo review by the QAO.

E. QAO assessment will include review of calculation, test analysis, graphs, tables, computer input/outputs and any other document which involves interpretation of the field data.

12.0 CORRECTIVE ACTION

12.1 Criteria

A. Corrective action will be undertaken if sample collection deficiencies or unreliable analytical results prevent QA objectives for the project from being met.

B. Specific criteria for acceptable data collection are given in section 5.0. The QA program(s) of the selected laboratory will provide the criteria for acceptable analytical results.

C. Analytical results supplied by the laboratory will have been subjected to the internal QA plan and will be considered to be acceptable unless the results significantly contradict previously acquired data.

D. If significant contradiction occurs, the QAO will request that the laboratory review the quality control documentation for the sample or analysis in question.

E. Further corrective action will be based on the results of the documentation review.

12.2 Correction

A. The principal corrective action that may be required as a result of deficiencies in sample collection is re-sampling. Re-sampling will be required if one or more of the following problems occur:

1. Contaminating samples due to collection procedure errors which result in a sample not representative of site conditions.
2. Loosing sample in transit to the laboratory.
3. Surpassing holding times for required parameters.
4. Trip blank showing contaminant concentrations within one order of magnitude of the original field sample.
5. Ion balance in error (either plus or minus) by more than 5%.

B. Variations between duplicate analyses, which are outside control limits, will be evaluated by the CM QAO and DEQ Official to determine whether re-sampling is required.

C. Re-analysis may be substituted for re-sampling if the holding time has not expired and sample condition is satisfactory.

D. A request for corrective action (RCA) may be initiated by the CM, the QAO or the DEQ Official.

13.0 QUALITY ASSURANCE REPORTS

Water quality data reports will be submitted every three months during the initial background groundwater quality report study period and annually thereafter. Quarterly sampling reports will document any deviations from field, handling or laboratory procedures contained in the approved plan.

QA reports will be prepared annually and submitted in conjunction with water quality data reports to the DEQ, Division of Water Quality.

13.1 Contents

A. Quality Assurance reports will contain:

1. Results of system and / or performance audits of sample collection activities.
2. A summary of the laboratory QA report(s), including notation of QA modifiers.
3. Listing and basis for any unacceptable data.
4. Discussion of significant QA problems and recommended solutions.

13.2 Format

A. The QA report will be prepared by the QAO and the CM or his representative and distributed to the DEQ Official.

B. The final background groundwater quality report will contain a separate QA section which will summarize the data quality information.

14.0 MONITORING STATIONS

A map of the monitor wells to be sampled is included as Figure A-5. The map shows the physical location of the wells with respect to the proposed facility location.

ATTACHMENTS

Table A-1 -- Base Line Water Sample Analysis Parameters

Parameters	Units	Analytical Methods		Preservation	Max Holding Time
		EPA	Std Methods		
Alkalinity, Carbonate as CaCO3	mg/l		2320 B	Cool, ≤ 6°C	14 days
Ammonia-nitrogen as N	mg/l	350.1	4500-NH3	Cool, ≤ 6°C, H_2SO_4 to pH<2	28 days
Bicarbonate	mg/l	310.2	2320 B	Cool, ≤ 6°C	14 days
Bromide	mg/l	300.0		None Req'd	28 days
Calcium	mg/l	215.1	3111 B	HNO_3 to pH<2	6 months
Carbon dioxide	mg/l				--
Carbonate	mg/l	310.2	2320 B	Cool, ≤ 6°C	14 days
Chloride	mg/l		4500-Cl-B	None Req'd	28 days
Hardness, Ca + Mg	mg/l		2340 B or C	HNO_3, H_2SO_4 to pH<2	14 days
Hydroxide	mg/l				--
Inorganic nitrogen (nitrate and nitrite) as N	mg/l	353.2	4500--NO3-F	Cool, ≤ 6°C, H_2SO_4 to pH<2	28 days
Magnesium	mg/l	242.1	3111 B	HNO_3 to pH<2	6 months
pH					on site
Phosphate-phosphorus as P	mg/l	365.3	4500-P-E	Cool, ≤ 6°C, H_2SO_4 to pH<2	28 days
Potassium	mg/l	258.1	3111 B	HNO_3 to pH<2	6 months
Sodium	mg/l	273.1	3111 B	HNO_3 to pH<2	6 months
Solids, Total Dissolved	mg/l	160.1	2540-C	Cool, ≤ 6°C	7 days
Solids, Total Suspended (TSS)	mg/l	160.1	2540-C	Cool, ≤ 6°C	7 days
Specific conductance	uS/cm	120.1	2510 B	Cool, ≤ 6°C	7 days
Sulfur, sulfate (SO4) as SO4	mg/l	375.2		Cool, ≤ 6°C	28 days
Turbidity	NTU	180.1	2130 B	Cool, ≤ 6°C	48 hours

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Table A-2 -- Steady State Water Sample Analysis Parameters

Parameters	Units	Analytical Methods		Preservation	Max Holding Time
		EPA	Std Methods		
Alkalinity, Carbonate as CaCO3	mg/l		2320 B	Cool, ≤ 6°C	14 days
Ammonia-nitrogen as N	mg/l	350.1	4500-NH3	Cool, ≤ 6°C, H_2SO_4 to pH<2	28 days
Bicarbonate	mg/l	310.2	2320 B	Cool, ≤ 6°C	14 days
Bromide	mg/l	300.0		None Req'd	28 days
Carbon dioxide	mg/l				--
Carbonate	mg/l	310.2	2320 B	Cool, ≤ 6°C	14 days
Chloride	mg/l		4500-Cl-B	None Req'd	28 days
Hydroxide	mg/l				--
Inorganic nitrogen (nitrate and nitrite) as N	mg/l	353.2	4500--NO3-F	Cool, ≤ 6°C, H_2SO_4 to pH<2	28 days
Kjeldahl Nitrogen, Total (TKN)	mg/l		4500-Norg B or C and 4500-NH3B	Cool, ≤ 6°C	28 days
pH					on site
Phosphate-phosphorus as P	mg/l	365.3	4500-P-E	Cool, ≤ 6°C, H_2SO_4 to pH<2	28 days
Solids, Total Dissolved	mg/l	160.1	2540-C	Cool, ≤ 6°C	7 days
Solids, Total Suspended (TSS)	mg/l	160.1	2540-C	Cool, ≤ 6°C	7 days
Specific conductance	uS/cm	120.1	2510 B	Cool, ≤ 6°C	7 days
Sulfur, sulfate (SO4) as SO4	mg/l	375.2		Cool, ≤ 6°C	28 days
Turbidity	NTU	180.1	2130 B	Cool, ≤ 6°C	48 hours

Table A-2

Dalton Finisher Sites
Monitor Well Water Level Measurements Log

Well	Date	Time	Reference Point	Ref. Pt. Elevation	Depth (ft)	Depth to Water (ft)	Water Elevation	By:

Figure A-1

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Dalton Finisher Sites
Water Quality Sampling Field Record

Well Name: ______________________ **Date:** __________

Sampling Personnel: ______________________

Instrument Calibrations

pH meter Calibrated? ☐ **Yes**

Conductivity Meter Calibrated? ☐ **Yes**

Field Measurements

Time	Volume Evacuated	Temp. (F)	pH	Conductivity	Comments

Base intake slots (feet below ground) ______________________

Top water surface (feet below ground) ______________________

Water Column (feet): ______________ Casing - Inside Diameter: __________

Gallons of Water in Casing: ______________ Gallons X 3: __________

Note: One gallon - 231 cubic inches. Height of water column in inches is obtained by multiplying the water column in feet by 12; this column height is then multiplied by the area of the casing to obtain the volume of water in cubic inches. This volume is then divided by 231 to obtain the volume of water in gallons.

Pump Started - Time: __________ Pump Stoped - Time: __________

Pump Started - Time: __________ Pump Stoped - Time: __________

Pump Started - Time: __________ Pump Stoped - Time: __________

Pump Started - Time: __________ Pump Stoped - Time: __________

Pump Rate (gpm): __________ Total Time Pumped (min): __________

Volume evacuated before sampling (gal): __________

Notes:

____

____

____

Figure A-2

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Dalton Finisher Sites
Field Water Sample Label

Well Name: ____________________

Sample Number: ____________________

Analytical parameter(s): dfsd

Date Sampled: ____________________

Time Sampled: ____________________

Sampler: ____________________

Preservative: ☐ Acid ☐ Base ☐ Filtered

Destination Laboratory: ____________________

Figure A-3

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Dalton Finsier Sites
Field Water Sample - Chain-of-Custody Record

Sampler Signature: ______________________________

Sample ID	Sample Source	Sampled Date & Time:	# of Containers	Parameters to Analyze: Group 1 Characteristics	Group 2 Characteristics	Other

Group 1 Characteristics:

Alkalinity, Carbonate as $CaCO_3$
Carbonate
pH
Specific Conductance
Ammonia-nitrogen as N
Chloride
Phosphate-phosphorus as P
Sulfur, sulfate (SO_4) as SO_4
Bicarbonate
Hydroxide
Solids, Dissolved
Turbidity
Carbon Dioxide
Inorganic nitrogen (nitrate & nitrite) as N
Solids, Total Suspended (TSS)

Group 2 Characteristics:

Calcium
Hydroxide
Magnesium
Potassium
Sodium

Relinquished By:	Date & Time	Sent Via	Received By:	Date & Time

Notes:

____

____

____

Figure A-4

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