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WHISKEY CREEK STREAM CHANNEL RESTORATION

The Whiskey Creek channel restoration plans when implemented will reclaim the water way in a stable and habitat-enhancing manner. The attached design presents the plan and profile drawings proposed for this channel. Plate 1 presents the plan view of the site and channel alignment and Plates 2 and 3 present the profiles of the three channel reaches to be reconstructed.

The following criteria and/or conditions were considered to design the channels for the Whiskey Creek area:

- The existing sedimentation pond will be closed (drained, breached, and capped)
- Channel alignments will make use of natural bedrock where possible
- The existing channel immediately downstream from the outlet of the site bypass culvert is cut into bedrock, with cobble and boulder lining
- The boulder field at the toe of the sedimentation pond embankment is stable and shows no sign of erosion
- On-site rock will be used for riprap
- It is imperative that a stable channel be installed
- Any habitat or other enhancements along the reclamation channel should be limited to areas of shallow slopes
- The overall magnitude of excavation and grading efforts associated with channel construction should be minimized to the extent practical to permit as much on-site reclamation as the available funding will allow

Based on these criteria and conditions, the channel was designed to allow the required peak flow to be safely conveyed through the reclaimed area. The permit document indicates that the peak flows for the area are: 3.1 cubic feet per second ("cfs") from the unnamed drainage from the west (RC-3), 13.4 cfs from the drainage from the southwest (RC-2) and 32.2 cfs at the toe of the pond embankment (RC-1). These flows were used to design the associated channel reaches.

A review of the rock available on site indicated that materials available for riprap production are similar to that found in the natural materials both up- and downstream from the area to be reclaimed. Therefore, the available on-site rock is suitable as a source of riprap. Based on observation of the rock on the disturbed area, riprap with an approximate D_{50} of up to 12 inches can be achieved for channel reclamation. Smaller rock sizes are available for use in smaller channels and as subgrade materials.

Design flow calculations for the reclamation channels are presented in Attachment A. Plate 2 shows the profile for the reach RC-1. Plate 3 shows the profiles for reaches RC-2 and RC-3.

The channel configuration will consist of a trapezoidal channel shape with 2:1 side slopes and a minimum bottom width of 5 feet. This configuration allows the maximum exposure of flow to the riprap roughness resulting in a reduction in flow velocity. Also, under low flow conditions, a smaller channel will develop naturally within the larger channel.

Based on this channel configuration and the riprap that is available from the site, the maximum allowable velocity for the main, riprapped channel (RC-1) was determined to be approximately 9 feet per second. This can be achieved with the above-mentioned cross section at a maximum channel slope of about 25%. Based on this limitation, the vertical profile of the channel was established. The overall profile consists of a series of steep slopes and shallow riffle areas. At the downstream end of RC-1, where the channel will flow from the main pad elevation to the boulder field at the toe of the sedimentation pond embankment, it was not possible to develop any ladder or drop structures. This was due to the horizontal distance that would be required to handle the hydraulics of such structures. Therefore, a cascading chute was designed to allow the flow to be conveyed down the slope adjacent to the face of the embankment in a stable and controlled manner.

The channels were divided into different portions that, while having the same basic cross sections, will have different channel linings based on the allowable velocities. During construction, the contractor will not be screening riprap materials, but will segregate the rock based on size to approximate the required gradations. Plate 1 shows the proposed cross-sections for the various portions of the channels.

Due to the fact that the channels are being reclaimed on a fill rather than a bedrock base, efforts will be made to minimize the potential for seepage from the channel from saturating the fill. This will be accomplished by lining the channel bottoms with at least 6 inches of silty and/or clayey materials found naturally in the mined material. Inspection of the site shows that some quantity of such materials is available on-site. These materials will be used to the extent that they are available, concentrating on areas of new fill that have not settled over time.

In the riffle areas between the drops, the channel gradient is reduced to less than 1 percent. This will allow the development of sediment collection and wetland/wildlife habitat enhancement areas. Specific details of these enhancements have not been developed; however, they could include channel depressions, channel widening, meanders, etc. The only limitation is that the minimum channel width cannot be reduced. These structures will be field fit based on the funds available. Also, it must be recognized that these improvements will result in the expansion of the channel development area. Therefore, with that expansion, the required clayey material lining will also increase and with a limited amount of material, it may well limit the improvements that can take place.

Beginning at a point 15 to 20 feet upstream from points where channels transition from shallow slopes of less than 1% to steeper slopes, the channel will be lined with the riprap to be used for the drop. At the beginning of this section, the riprap will be keyed into the subgrade to a depth of at least 3 feet below the bottom of the designed riprap depth across the width of the channel. Also, where a steep section enters a section with a decrease in lining requirements (i.e., smaller or no riprap), the riprap from the upper drop section will be extended a minimum of 50 feet into the next channel reach before transitioning to the new lining. Additionally, at the downstream end of each transition section, the riprap from the upper section will be keyed into the channel bottom similar to the crest key. These transitions and keys will help minimize the potential for erosional failure of the reclamation channels.

To aid in the re-establishment of vegetation and to increase the stability of the riprap, soil will be worked into the riprap. This is similar to the concept of a buried riprap channel. However, due to the steep slopes to be encountered at this site, flow velocities for even small storms could erode the soil cover of a buried riprap channel before vegetation could become established. By mixing the soil with the riprap either before or during emplacement, the soil will be better retained and the vegetation will have better protection to allow establishment. Such a channel would from its initial construction have an appearance similar to the natural channels upstream and downstream from the site and would function similar to these channels. Similar efforts have been implemented during reclamation of the Star Point mine and have successfully handled significant runoff events.

ATTACHMENT A

CALCULATIONS

Whiskey Creek
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	RC-1- Reach 1 - 40% Slope
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.060	
Slope	0.400000	ft/ft
Left Side Slope	2.00	H : V
Right Side Slope	2.00	H : V
Bottom Width	5.00	ft
Discharge	32.20	cfs

Results		
Depth	0.56	ft
Flow Area	3.5	ft²
Wetted Perimeter	7.52	ft
Top Width	7.25	ft
Critical Depth	0.95	ft
Critical Slope	0.061806	ft/ft
Velocity	9.32	ft/s
Velocity Head	1.35	ft
Specific Energy	1.91	ft
Froude Number	2.38	
Flow Type	Supercritical	

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Whiskey Creek
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	RC-1 - Reach 2 - 25% Slope
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.050	
Slope	0.250000	ft/ft
Left Side Slope	2.00	H : V
Right Side Slope	2.00	H : V
Bottom Width	5.00	ft
Discharge	32.20	cfs

Results		
Depth	0.58	ft
Flow Area	3.6	ft^2
Wetted Perimeter	7.60	ft
Top Width	7.32	ft
Critical Depth	0.95	ft
Critical Slope	0.042921	ft/ft
Velocity	9.00	ft/s
Velocity Head	1.26	ft
Specific Energy	1.84	ft
Froude Number	2.27	
Flow Type	Supercritical	

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Whiskey Creek
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	RC-1 - Reach 3 - 8% Slope
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.045	
Slope	0.080000	ft/ft
Left Side Slope	2.00	H : V
Right Side Slope	2.00	H : V
Bottom Width	5.00	ft
Discharge	32.20	cfs

Results		
Depth	0.76	ft
Flow Area	4.9	ft^2
Wetted Perimeter	8.38	ft
Top Width	8.02	ft
Critical Depth	0.95	ft
Critical Slope	0.034766	ft/ft
Velocity	6.55	ft/s
Velocity Head	0.67	ft
Specific Energy	1.42	ft
Froude Number	1.47	
Flow Type	Supercritical	

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Whiskey Creek
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	RC-1 - Reach 4 - 0.9% Slope
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.030	
Slope	0.009000	ft/ft
Left Side Slope	2.00	H : V
Right Side Slope	2.00	H : V
Bottom Width	5.00	ft
Discharge	32.20	cfs

Results		
Depth	1.10	ft
Flow Area	7.9	ft²
Wetted Perimeter	9.93	ft
Top Width	9.41	ft
Critical Depth	0.95	ft
Critical Slope	0.015451	ft/ft
Velocity	4.05	ft/s
Velocity Head	0.25	ft
Specific Energy	1.36	ft
Froude Number	0.78	
Flow Type	Subcritical	

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Whiskey Creek
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	RC-1 - Reach 5 - 20% Slope
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.050	
Slope	0.200000	ft/ft
Left Side Slope	2.00	H : V
Right Side Slope	2.00	H : V
Bottom Width	5.00	ft
Discharge	32.20	cfs

Results		
Depth	0.62	ft
Flow Area	3.9	ft^2
Wetted Perimeter	7.77	ft
Top Width	7.48	ft
Critical Depth	0.95	ft
Critical Slope	0.042920	ft/ft
Velocity	8.34	ft/s
Velocity Head	1.08	ft
Specific Energy	1.70	ft
Froude Number	2.05	
Flow Type	Supercritical	

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Whiskey Creek
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	RC-1 - Reach 6 - 0.9% Slope
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.030	
Slope	0.009000	ft/ft
Left Side Slope	2.00	H : V
Right Side Slope	2.00	H : V
Bottom Width	5.00	ft
Discharge	32.20	cfs

Results		
Depth	1.10	ft
Flow Area	7.9	ft²
Wetted Perimeter	9.93	ft
Top Width	9.41	ft
Critical Depth	0.95	ft
Critical Slope	0.015451	ft/ft
Velocity	4.05	ft/s
Velocity Head	0.25	ft
Specific Energy	1.36	ft
Froude Number	0.78	
Flow Type	Subcritical	

Whiskey Creek
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	RC-1 - Reach 7 - 20% Slope
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.050	
Slope	0.200000	ft/ft
Left Side Slope	2.00	H : V
Right Side Slope	2.00	H : V
Bottom Width	5.00	ft
Discharge	32.20	cfs

Results		
Depth	0.62	ft
Flow Area	3.9	ft²
Wetted Perimeter	7.77	ft
Top Width	7.48	ft
Critical Depth	0.95	ft
Critical Slope	0.042920	ft/ft
Velocity	8.34	ft/s
Velocity Head	1.08	ft
Specific Energy	1.70	ft
Froude Number	2.05	
Flow Type	Supercritical	

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Whiskey Creek
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	RC-2 - Reach 1 - 13% Slope
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.045	
Slope	0.130000	ft/ft
Left Side Slope	2.00	H : V
Right Side Slope	2.00	H : V
Bottom Width	5.00	ft
Discharge	13.40	cfs

Results		
Depth	0.40	ft
Flow Area	2.3	ft²
Wetted Perimeter	6.78	ft
Top Width	6.59	ft
Critical Depth	0.56	ft
Critical Slope	0.039705	ft/ft
Velocity	5.80	ft/s
Velocity Head	0.52	ft
Specific Energy	0.92	ft
Froude Number	1.73	
Flow Type	Supercritical	

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Whiskey Creek
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	RC-2 - Reach 2 - 20% Slope
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.045	
Slope	0.200000	ft/ft
Left Side Slope	2.00	H : V
Right Side Slope	2.00	H : V
Bottom Width	5.00	ft
Discharge	13.40	cfs

Results		
Depth	0.35	ft
Flow Area	2.0	ft^2
Wetted Perimeter	6.57	ft
Top Width	6.41	ft
Critical Depth	0.56	ft
Critical Slope	0.039705	ft/ft
Velocity	6.69	ft/s
Velocity Head	0.70	ft
Specific Energy	1.05	ft
Froude Number	2.11	
Flow Type	Supercritical	

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Whiskey Creek
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	RC-2 - Reach 3 - 12% Slope
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.045	
Slope	0.120000	ft/ft
Left Side Slope	2.00	H : V
Right Side Slope	2.00	H : V
Bottom Width	5.00	ft
Discharge	13.40	cfs

Results		
Depth	0.41	ft
Flow Area	2.4	ft²
Wetted Perimeter	6.82	ft
Top Width	6.63	ft
Critical Depth	0.56	ft
Critical Slope	0.039705	ft/ft
Velocity	5.65	ft/s
Velocity Head	0.50	ft
Specific Energy	0.90	ft
Froude Number	1.67	
Flow Type	Supercritical	

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Whiskey Creek
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	RC-3 - Reach 1 - 4% Slope
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.035	
Slope	0.040000	ft/ft
Left Side Slope	2.00	H : V
Right Side Slope	2.00	H : V
Bottom Width	5.00	ft
Discharge	3.10	cfs

Results		
Depth	0.21	ft
Flow Area	1.1	ft^2
Wetted Perimeter	5.92	ft
Top Width	5.82	ft
Critical Depth	0.22	ft
Critical Slope	0.030992	ft/ft
Velocity	2.79	ft/s
Velocity Head	0.12	ft
Specific Energy	0.33	ft
Froude Number	1.12	
Flow Type	Supercritical	

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Whiskey Creek
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	RC-3 - Reach 2 - 25% Slope
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.035	
Slope	0.250000	ft/ft
Left Side Slope	2.00	H : V
Right Side Slope	2.00	H : V
Bottom Width	5.00	ft
Discharge	3.10	cfs

Results		
Depth	0.12	ft
Flow Area	0.6	ft^2
Wetted Perimeter	5.53	ft
Top Width	5.48	ft
Critical Depth	0.22	ft
Critical Slope	0.030992	ft/ft
Velocity	4.96	ft/s
Velocity Head	0.38	ft
Specific Energy	0.50	ft
Froude Number	2.59	
Flow Type	Supercritical	

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Whiskey Creek
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	RC-3 - Reach 3 - 12% Slope
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.035	
Slope	0.120000	ft/ft
Left Side Slope	2.00	H : V
Right Side Slope	2.00	H : V
Bottom Width	5.00	ft
Discharge	3.10	cfs

Results		
Depth	0.15	ft
Flow Area	0.8	ft²
Wetted Perimeter	5.66	ft
Top Width	5.59	ft
Critical Depth	0.22	ft
Critical Slope	0.030992	ft/ft
Velocity	3.94	ft/s
Velocity Head	0.24	ft
Specific Energy	0.39	ft
Froude Number	1.85	
Flow Type	Supercritical	

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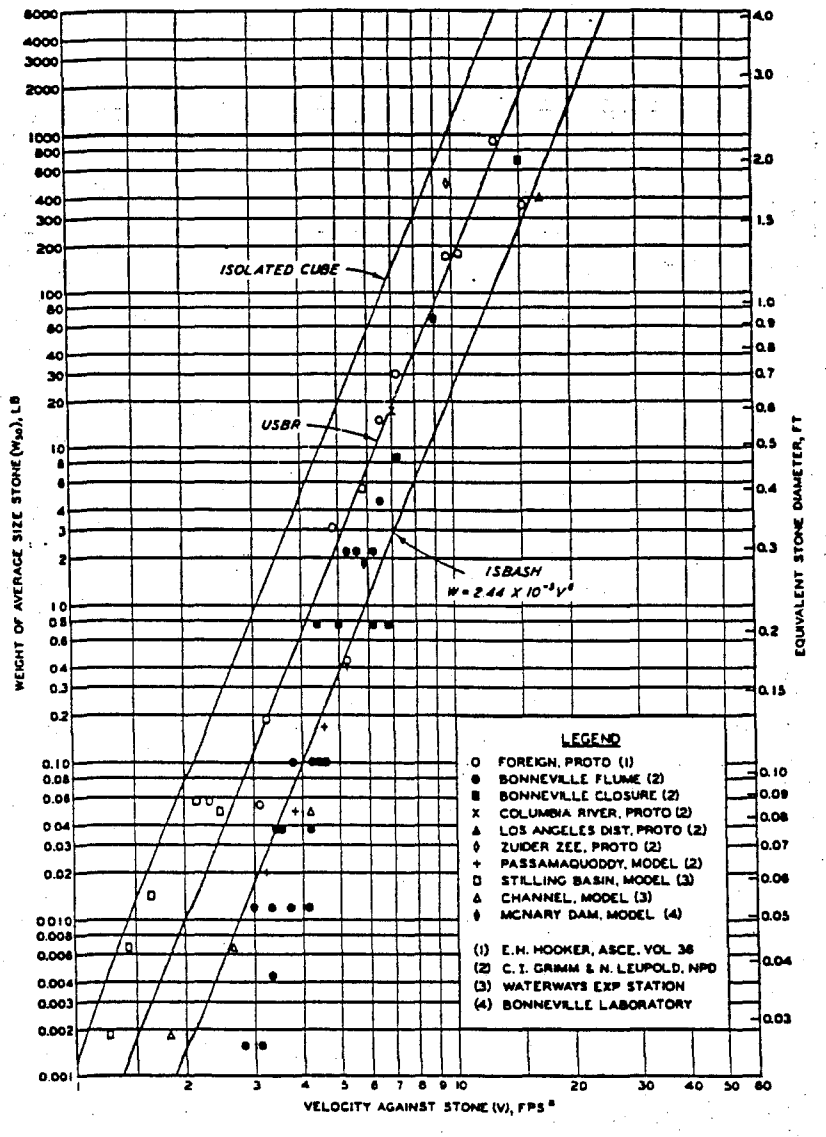
Table 1

Manning's N for Cascading Flows

Channel Section	Reach	Channel Slope (ft/ft)	D50 Rock Size (in)	Maning's n Estimate* Value	Maning's n Design Value	Evaluation Criteria
RC-1	2	0.250	12	0.054	0.05	OK
RC-1	3	0.080	12	0.045	0.045	OK
RC-1	4	0.009	0.5	0.030	0.03	OK
RC-1	5	0.200	12	0.052	0.05	OK
RC-1	6	0.009	0.5	0.030	0.03	OK
RC-1	7	0.200	12	0.052	0.05	OK
RC-2	1	0.130	8	0.046	0.045	OK
RC-2	2	0.200	8	0.049	0.045	OK
RC-2	3	0.120	8	0.045	0.045	OK
RC-3	1	0.040	6	0.036	0.035	OK
RC-3	2	0.250	6	0.049	0.04	OK
RC-3	3	0.120	6	0.043	0.04	OK

* If channel slope is less than or equal to 2%, then Estimate is set to 0.03 for earthen channel or no riprap. Under this slope no cascading flows exist.



NOTE: SPECIFIC WEIGHT OF ROCK = 165 LB/CU FT.
*FOR STONE PROTECTION BELOW ENERGY DISSIPATORS USE AS AVERAGE VELOCITY ACROSS END SILL

VELOCITY VS STONE WEIGHT

SEE TEXT PAGE 36

Plate 29

FROM: U.S. ARMY CORPS OF ENGINEERS, 1970. HYDRAULIC DESIGN OF FLOOD CONTROL STRUCTURES. EM-1110-2-1601.