BASELINE HYDROLOGY MODELING REPORT

Rev.0 **Date: 03/27/09**

OF THE

ENVIRONMENTAL REPORT

IN SUPPORT OF THE APPLICATION FOR LICENSE FOR SOURCE MATERIAL MILLING

PIÑON RIDGE URANIUM MILL

Montrose County, Colorado

Submitted to:

Radiation Management Unit
Colorado Department of Public Health and Environment

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Project No. 83088
DCN 83088/DEN8R006

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1.0 INTRODUCTION

The following report discusses the baseline (pre-project) hydrology model for the Energy Fuels Resources Corp. Piñon Ridge Uranium Mill site. The main objectives in developing this baseline model were to compute hydrographs and peak flow estimates for the existing subbasins exiting at the property boundaries for the 10-, 100-, and 1,000-year storm events. A HEC-1 (COE, 1998) rainfall-runoff model was developed so that runoff volumes could be computed and modifications can be made to the baseline model at a later date to reflect site improvements and mill layout including required detention facilities, drainage improvements and roadway culverts.

The existing (pre-project) peak flow estimates for the Piñon Ridge site are summarized in Section 5.0 for the 10-, 100-, and 1,000-year events. The results from the SCS curve number method, unit hydrograph plots, peak discharge summaries and comparisons, and selected HEC-1 model runs are included in the appendices.

2.0 HYDROLOGY MODELING METHODOLOGY

The hydrologic characteristics of the Piñon Ridge Uranium Mill site for 10-year and 100-year storm events were analyzed using the SCS curve number method and a synthetic unit hydrograph calibrated for the Rocky Mountain Region. The Piñon Ridge site was divided into five subbasins. The subbasins were delineated on a USGS quadrangle map with a scale of approximately 1:24,000, and the subbasin areas were drawn and measured electronically. The site boundary and the subbasins are shown on Figure 1.

A local soils report, included in Appendix A, was downloaded from the Natural Resources Conservation Service (NRCS, 2007) website for use in delineating soil types for the area. Areas of each soil type within the individual subbasins were measured with a planimeter and tabulated. Curve numbers (CNs) were established for all areas of the subbasins based on the NRCS soil data, photos and video of the site. Table 2-2d from TR-55, published by the NRCS, 1986, was used as a reference for selecting the CNs and is included in Appendix A of this report. The effective CNs are provided below in Table 2.1. A CN calculation table (Table A.1) is included in Appendix A with a reference to the sub-basins delineated in Figure 1.

TABLE 2.1
PIÑON RIDGE SITE SUBBASIN CURVE NUMBERS

Subbasin	Curve Number (CN)
1	67
2	53
3	51
4	62
5	65
Effective	64

Synthetic unit hydrographs were developed using hydrologic lag data for the Colorado region from the Flood Hydrology Manual (FHM) published by the Bureau of Reclamation, (Cudworth, 1989). The lag time was determined from equation (1) below, provided in the FHM.

$$L_g = 26K_n\left(\frac{LL_{ca}}{S^{0.5}}\right)^{0.33} \quad (1)$$

Where:

- L_g = Lag time (hours)
- L = Distance of the longest watercourse (miles)
- L_{ca} = Distance from the gauging station to a point opposite the centroid of the subbasin (miles)
- S = Effective slope of the subbasin (ft/ft)
- K_n = Average Manning's value for the principal watercourse of the subbasin

The length of watercourse, distance to centroid of basin, and basin slope were measured from Figure 1. Watercourse paths within individual basins were divided into reaches with uniform slopes so an effective slope for each subbasin could be calculated. The effective slopes were calculated using equation (2) taken from the Urban Storm Drainage Criteria Manual (USDCM) published by the Urban Drainage and Flood Control District, 2001.

$$S = \left[\frac{L_1S_1^{0.24} + L_2S_2^{0.24} + ... + L_nS_n^{0.24}}{L_1 + L_2 + ... + L_n}\right]^{4.17} \quad (2)$$

Where:

- S_n = Slope (ft/ft)
- L_n = Reach distance (ft)

The synthetic hydrographs were created assuming a "Thunderstorm" event and plots are included in Appendix B. The hydrographs in Appendix B use Kn values of 0.07, 0.10 and 0.13 and a 5-minute time step. The Kn value represents the average Manning's roughness in the principal watercourse of the respective subbasin and the values were chosen from Figure 4.7 in the FHM (Cudworth, 1989) representing the upper bound of a "Thunderstorm" event in the Rocky Mountain Region. A "Thunderstorm" rather than "General" storm was chosen because the intensity, not volume, of runoff will govern the design of future hydraulic structures at the Piñon Ridge site. Figure 4.7 from the FHM is included in this report in Appendix B.

Rainfall depths for the 24-hour, 10- and 100-year storm events were 2.0 and 3.0 inches, respectively, according to Figures 28 and 31 in the NOAA Atlas 2 (Vol. III – Colorado) maps. The NOAA Atlas 2 figures are included in this report in Appendix C.

3.0 10-YEAR AND 100-YEAR HYDROLOGY

The data generated from the synthetic unit hydrographs were used in a HEC-1 rainfall-runoff model to create a 24-hour hydrograph for each subbasin. The HEC-1 model was run for 10-year and 100-year storm events using a SCS Type II rainfall distribution. The precipitation data were entered with a 60-minute time step, and the hydrographs were created using 300, 5-minute time steps (for a total simulation of 25 hours). A sensitivity analysis was performed on the HEC-1 model by changing the hydrograph increments to 500, 3-minute steps (for a total of 25 hours), and there was no distinguishable difference evident in the peak discharges. The model included hydrograph data using Kn values of 0.07, 0.10, and 0.13. These values were chosen based on regression equations developed for the Rocky Mountain Region by the Bureau of Reclamation and were adapted from Table 4-2 in the FHM. The 10- and 100-year HEC-1 peak discharge results for each subbasin and the SCS Type II rainfall depths are tabulated in Appendix D.

The summary in Appendix D also includes peak discharges calculated from two USGS regional regression equations. Equations (3) and (4) below were taken from the Nationwide Summary of USGS Regional Regression Equations for Estimating Magnitude and Frequency of Floods for Ungaged Sites (1993). Equations (5) and (6) below are from Analysis of the Magnitude and Frequency of Floods in Colorado (2000). These have been included only as a check for reasonableness.

$$Q_{10} = 69.4A^{0.685} \tag{3}$$

$$Q_{100} = 128A^{0.68} \tag{4}$$

$$Q_{10} = 66A^{0.697} \tag{5}$$

$$Q_{100} = 118.4A^{0.715} \tag{6}$$

Where:

Q_i = Peak discharge (cfs)

A = Area (square miles)

The results from equations (3) through (6) are compared to the HEC-1 results, using a Kn = 0.07, in Table 3.1 below.

TABLE 3.1
SUMMARY OF 10- AND 100-YEAR PEAK DISCHARGES FOR PIÑON RIDGE SITE SUBBASINS USING HEC-1 AND USGS REGRESSION EQUATIONS

	10-Year Peak Discharges (cfs)			100-Year Peak Discharges (cfs)		
Subbasin	**HEC-1[1]**	**USGS (1993)**	**USGS (2000)**	**HEC-1[1]**	**USGS (1993)**	**USGS (2000)**
1	46	81	78	155	150	140
2	6	26	24	9	49	43
3	3	17	16	5	32	28
4	14	50	47	51	92	84
5	7	22	21	25	41	36

[1]HEC-1 values calculated using $K_n = 0.07$

The regression equations are rather simple, single-variable relationships that account only for basin area, but not other factors such as basin slope or soil infiltration capacity. It is important to note that the average standard error range for equations (3) and (4) is 31% to 71% and equations (5) and (6) is 40% to 80%. Those are judged to be large standard errors for single-variable regression equations and would indicate a large confidence interval in the computed value, and would partially explain the significant differences between the HEC-1 results and the regression results.

The HEC-1 results should be used for comparing pre- and post-project hydrology and for sizing any drainage facilities. HEC-1 is a lumped-parameter model capable of accounting for basin-specific information like basin area, slope, watercourse length, soil types, and vegetation conditions and, therefore, is more appropriate than the single-variable regression equations. The HEC-1 results are also more useful because they include runoff hydrographs and corresponding volumes. The HEC-1 output summaries for the 10-year and 100-year events are presented in Appendix D.

4.0 1000-YEAR HYDROLOGY

The 1,000-year storm event was also analyzed for the Piñon Ridge site and an additional rainfall-runoff model was constructed for the event. The same methodology used for the 10- and 100-year rainfall-runoff analyses was used for the 1,000-year analysis.

The rainfall depth for the 1,000-year storm is not available in the NOAA Atlas 2 document, so NOAA Atlas 14 data were used (Appendix C). NOAA Atlas 14, available online only, was published in 2003 to replace the NOAA Atlas 2 volumes for Southern California, Nevada, Arizona, New Mexico, and Utah. While Colorado is not included, a rainfall depth of 4.43 inches was computed for the 24-hour, 1,000-year storm event from a location on the Utah-Colorado border, approximately 15 miles due west of the site. The Utah-Colorado border site has an elevation and geography such that its rainfall depth will be comparable to the uranium mill site's depth. The Utah-Colorado NOAA Atlas 14 rainfall depths for the 10- and 100-year storm events were within ± 0.1 inches of the NOAA Atlas 2 depths determined at the site, giving confidence to the estimated 1,000-year depth. In addition, several sites in western Colorado were included in the data sets used to generate the NOAA Atlas 14 storm depths for the various frequencies. As a final check for reasonableness, the 2- through 100-year 24-hour rainfall depths obtained from NOAA Atlas 2, Vol. III were plotted on log-probability paper and extrapolated out to a 1,000 year frequency depth of 4.1 inches. The plot is included in Appendix C with the NOAA Atlas 14 rainfall depths. Extrapolating beyond the 100-year to as far out as the 1,000 year frequency would normally be considered an unacceptable practice. In this case, however, that exercise provided a check of the 1,000-year value obtained from NOAA Atlas 14, and confirmed that our computed depth of 4.43 inches used in the HEC-1 analysis is conservative.

The Nationwide Summary of USGS Regional Regression Equations for Estimating Magnitude and Frequency of Floods for Ungaged Sites (1993) and the Analysis of the Magnitude and Frequency of Floods in Colorado (2000) documents did not contain regression equations for the 1,000-year storm event and are not included in that summary. The HEC-1 results should be used for pre- and post-project hydrology comparisons and facility design.

The peak discharge results from the HEC-1 model and output are summarized in Appendix E.

5.0 HYDROLOGY SUMMARY

The existing (pre-project) peak flow estimates for the Piñon Ridge site, based on HEC-1 modeling using Kn = 0.07, are summarized below for the 10-, 100-, and 1,000-year events.

TABLE 5.1
SUMMARY OF PIÑON RIDGE SUBBASIN PEAK DISCHARGES FOR 10-, 100-, AND 1,000-YEAR EVENTS

Subbasin	Area (mi^2)	Peak Discharge (cfs)[1]		
		10-yr	100-yr	1,000-yr
1	1.26	46	155	405
2	0.24	6	9	36
3	0.13	3	5	20
4	0.62	14	51	155
5	0.19	7	25	70

(1) based on HEC-1 values calculated using $K_n = 0.07$

6.0 STANDARDS AND REFERENCES

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