TECHNICAL MEMORANDUM

To: Emmett Turner – Balanced Rock Power, LLC.

From: Ashley Teani, PE – Kimley-Horn and Associates, Inc.

Date: February 8, 2024

Subject: Ebba Solar
Limited Detail 2D Hydrology Study
Lincoln County, Colorado

Kimley-Horn and Associates, Inc. (Kimley-Horn) has prepared a two-dimensional flow study for the potential Ebba Solar development in Lincoln County, Colorado. The intent of this study is to evaluate the approximate 100-year ponding depths within the subject tract due to flows associated with local rainfall in the vicinity of the subject tract. This study should be used for internal planning purposes only and should not be used for submittal to regulatory agencies.

The subject tract is approximately 2,313 acres and is located in Lincoln County, approximately 4 miles south of Limon, Colorado. The subject tract location shown on the attached *Vicinity Map*.

The following memorandum describes the methodology used to perform this analysis and results of the study.

METHODOLOGY

Hydrology

The hydrologic analysis was performed in general accordance with the currently published Colorado Department of Transportation (CDOT) Drainage Design Manual ("Manual").

Kimley-Horn created a hydrologic model for this study using U.S Army Corps HEC-HMS (Hydrologic Engineering Center Modeling System) v. 4.8 hydrologic modeling program. The hydrologic model consists of two subbasins that encompass the contributing watershed to the subject tract. The 2D subbasin covers approximately 44.4 square miles and the offsite subbasin O-1 covers 13.5 square miles. The NOAA Precipitation Frequency Data Server was used to determine the NOAA Atlas 14 rainfall depths for the subject tract. The model was used to generate the incremental precipitation hyetograph and incoming peak flow hydrograph used as boundary conditions for the HEC-RAS 2D model. The model uses SCS Curve Number for method for losses and SCS Unit Hydrograph method for peak flow calculations. An areal reduction factor was applied to the offsite subbasin O-1 since it was greater than 10 square miles. The drainage boundaries for this study are shown in the attached *Drainage Area Map*.

Hydraulics

Hydraulic modeling of the site was performed using the U.S. Army Corps of Engineers' HEC-RAS 2D v. 6.2 hydraulic modeling software. HEC-RAS 2D is a two-dimensional hydrodynamic routing model that performs hydraulic routing using Implicit Finite Volume solution to the 2D unsteady flow equations. This type of model is generally used to estimate flooding limits and velocity distributions for both confined and unconfined flow.

Topographic information for the two-dimensional area is based on publicly available 1-m digital terrain model (DEM) downloaded from USGS. The vertical datum is NAVD88.

A 2D computational mesh based on the topographic information was generated in HEC-RAS to perform hydraulic modeling. A grid size of 80' X 80' was used for the model area. Breaklines were added in areas of topographic relief to align the cells with the direction of flow and capture the detail of underlying topographic high points and low points. Breaklines were added along flow centerlines, embankments, road centerlines, and ridge lines within the model area to further refine the grid. A breakline grid spacing of 40' was used for these areas.

Ten (10) structures were considered significant and included in this study based on available topographic information and engineering judgment. A site visit was not performed as part of this study. Culverts were modeled using the 2D connection function. The terrain of the driveway, road, or major highway that the culvert crossed was based on available topography. The overflow computation method for all culvert structures was set to the weir equation.

One inflow hydrograph was applied to the 2D mesh via an inflow hydrograph boundary condition where Long Branch enters the mesh west of the subject tract.

One rainfall hyetograph for the 2D mesh subbasin was developed from the hydrologic model. Within the mesh, the incremental precipitation from the respective existing HEC-HMS model 2D Subbasin was applied uniformly to each cell of the mesh. The runoff was routed through each cell using the Diffusion Wave 2D equation. The flow direction and depth are based on several factors, including topography and surface roughness. The Manning's "n" value for friction losses are based on existing land cover as defined in the 2021 National Land Cover Database and engineering judgement.

An infiltration layer using the SCS Curve Number Method was created to accurately model infiltration loss within the 2D mesh. The infiltration layer takes the intersection from the NRCS Web Soil Survey and the Curve Number Data input to calculate infiltration losses within the model.

RESULTS

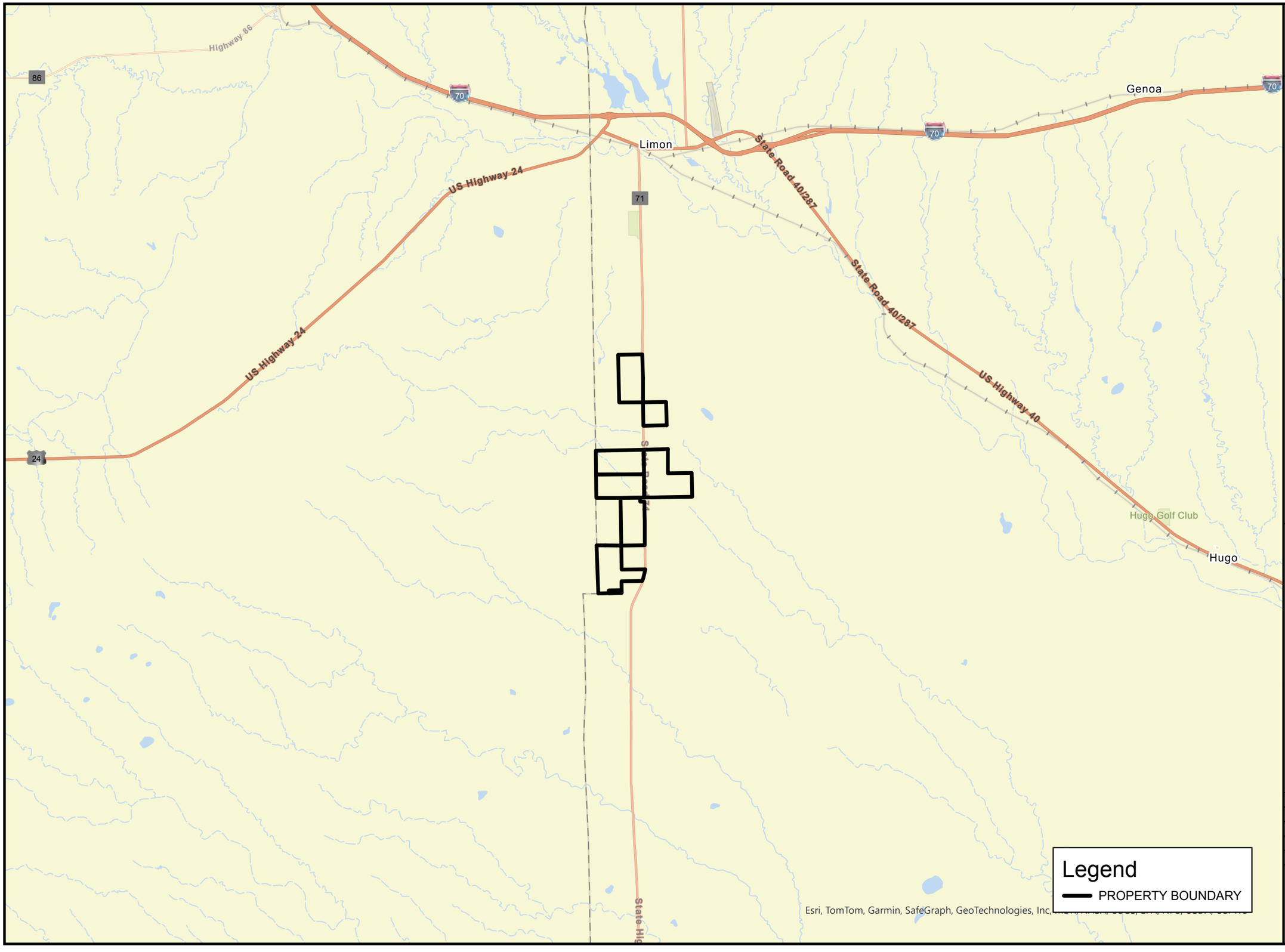
Results of the hydraulic model are shown on the attached *100-Year Inundation Depth Map*. The following table summarizes the results as a breakdown of the percentage of the subject tract by inundation.

Table 1: Percentage of Project Area by Depth

Depth (ft)	Percentage (%)	Cumulative Percentage (%)
0.00 – 0.50	82.76	82.76
0.51 - 1.00	7.83	90.59
1.01 - 1.50	2.77	93.36
1.51 - 2.00	1.90	95.26
2.01 - 3.00	2.44	97.70
3.01 - 5.00	1.64	99.34
> 5.00	0.66	100.00

ATTACHMENTS

Vicinity Map
Drainage Area Map
Hydrologic Calculations
NOAA Atlas 14 Precipitation Data
100-Year Inundation Depth Map
100-Year Velocity Map
100-Year Scour Map



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EBBA SOLAR
LINCOLN COUNTY, CO

VICINITY MAP

PROJ NO.:	068927116
DATE:	FEBRUARY 2024
DESIGN:	AAT
DRAWN:	AAT
CHECKED:	BWP

N

1 inch = 10,000 feet

SHEET
1

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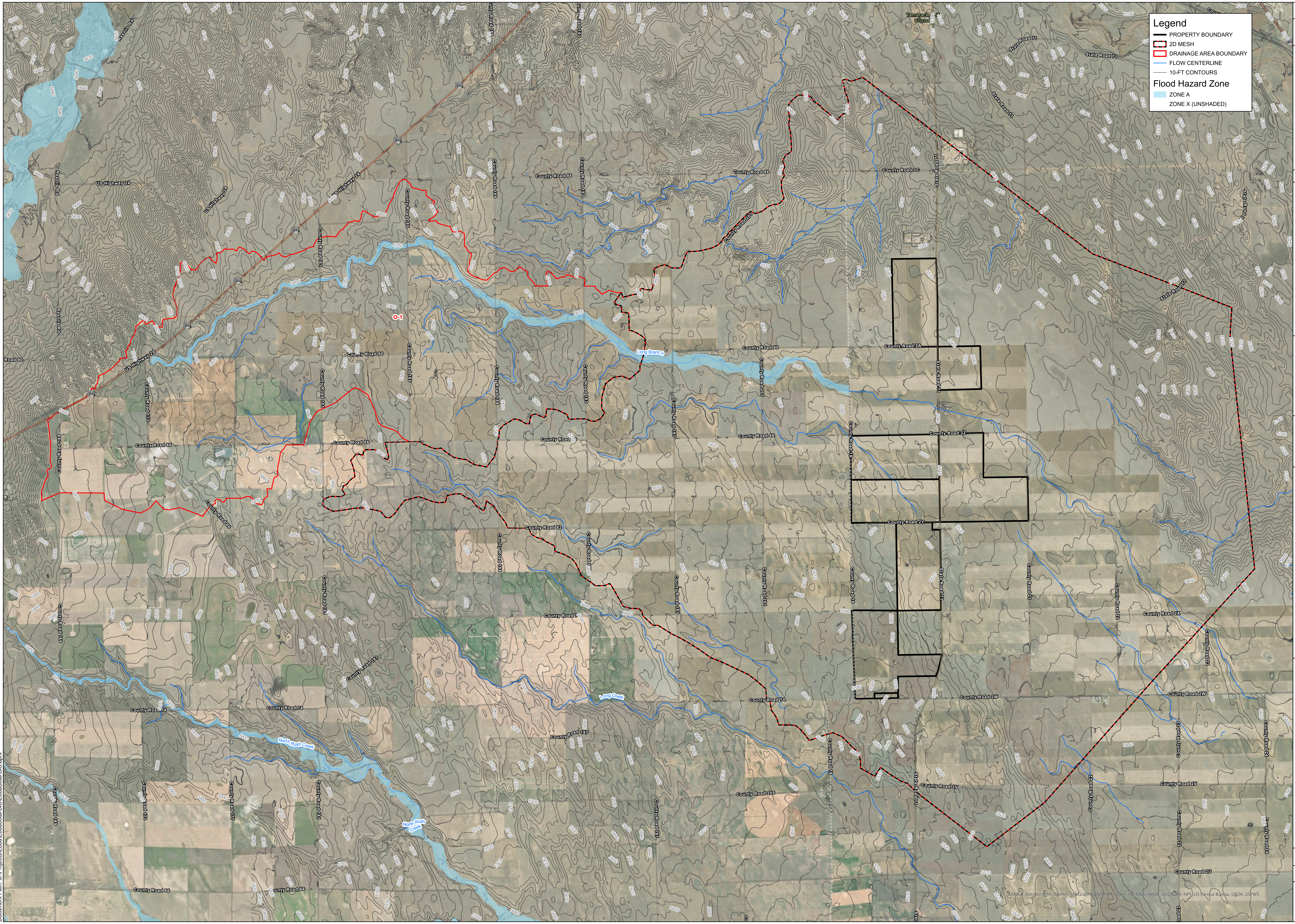

N

1 inch = 2,400 feet

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REVIEW:	BWP

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EBBA SOLAR
LINCOLN COUNTY, COLORADO

DRAINAGE AREA MAP

DATE
FEBRUARY 2024

PROJECT NO.
068927116

SHEET NUMBER
2

TIME OF CONCENTRATION & LAG TIME
EXISTING WATERSHED CONDITIONS
Methodology from CODOT Manual

	SHEET FLOW Tc = (1.8*(1.1-C)*(D^0.5)))/(S^0.33) C = 0.45 (i) + 0.508 i = 0.02						**OPEN CHANNEL FLOW** Tc = L / 60*V V assumed based on model						**TOTAL**	
Basin	Length (ft)	$Elev_1$	$Elev_2$	Slope (ft/ft)	RAT "C"	T_{c1} (min)	Length (ft)	$Elev_2$	$Elev_3$	Slope (ft/ft)	V_{avg} (ft/s)	T_{c3} (min)	T_{cTOTAL} * (min)	T_{lag} $0.6*T_c$ (min)
O-1	500	5990.3	5978.6	0.0234	0.517	81.0	51033	5978.6	5639.5	0.0066	3.00	283.52	364.5	218.7

Table 7.5 Percent imperviousness for computing Runoff Coefficients in Rational Method

Land Use or Surface Characteristics	Percentage Imperviousness (%)
Business:	
Downtown Areas	95
Suburban Areas	75
Residential:	
Single-family	
2.5 acres or larger	12
0.75 – 2.5 acres	20
0.25 – 0.75 acres	30
0.25 acres or less	45
Apartments	75
Industrial:	
Light areas	80
Heavy areas	90
Parks, cemeteries	10
Playgrounds	25
Schools	55
Railroad yard areas	50
Undeveloped Areas:	
Historic flow analysis	2
Greenbelts, agricultural	2
Off-site flow analysis (when land use not defined)	45
Streets:	
Paved	100
Gravel (packed)	40
Drive and walks	90
Roofs	90
Lawns, sandy soil	2
Lawns, clayey soil	2

Table 7.6 Runoff Coefficient equations based on NRCS soil groups and storm return period (UDFCD, 2016)

NRCS Soil Group	Storm Return Period					
	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
A	$C_A = 0.89i$	$C_A = 0.93i$	$C_A = 0.94i$	$C_A = 0.944i$	$C_A = 0.95i$	$C_A = 0.81i + 0.154$
B	$C_B = 0.89i$	$C_B = 0.93i$	$C_B = 0.81i + 0.125$	$C_B = 0.70i + 0.23$	$C_B = 0.59i + 0.364$	$C_B = 0.49i + 0.454$
C/D	$C_{C/D} = 0.89i$	$C_{C/D} = 0.87i + 0.052$	$C_{C/D} = 0.74i + 0.2$	$C_{C/D} = 0.64i + 0.31$	$C_{C/D} = 0.54i + 0.418$	$C_{C/D} = 0.45i + 0.508$

Upper watershed is Soil Type C

7.6 CALIBRATION

7.6.1 Definition

Calibration is a process of varying the parameters, coefficients, or recurrence-interval curve of a hydrologic method so that it estimates peak discharges and hydrographs consistent with local rainfall, basin characteristics, streamflow data and flood history.

Figure 7.3 is an illustration of a hydrograph resulting from flow data compared to hydrographs resulting from using a non-calibrated and a calibrated hydrologic procedure. It can be seen that the calibrated hydrograph, although not exactly duplicating the hydrograph from streamflow data, is a much better representation of the streamflow hydrograph than the non-calibrated hydrograph.

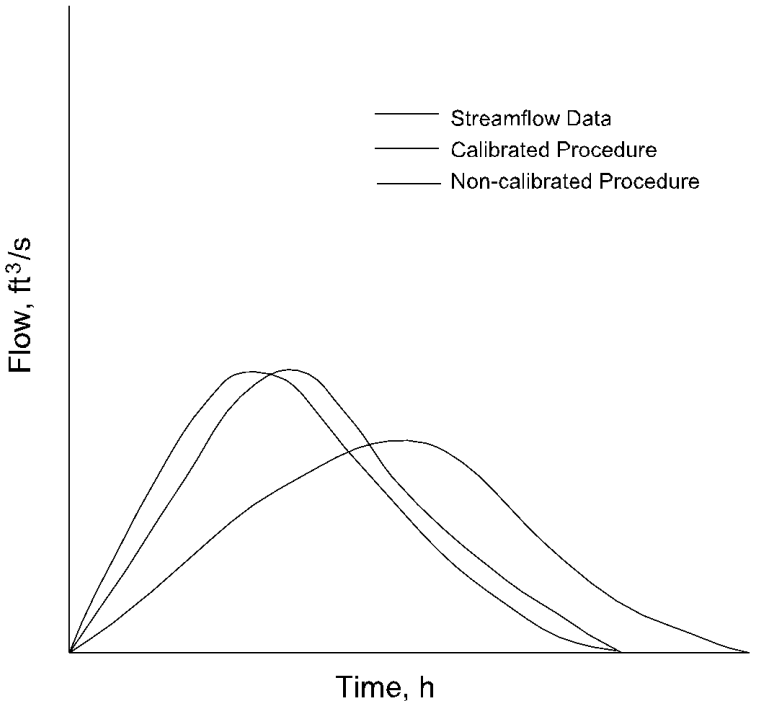

Figure 7.3 Calibrated Hydrograph

Composite CN Calculation

DA Name	Descript	HSG	CN	Area_inc	CN*A
	O-1		**68.8**	**8649.50**	**595484**
O-1	Barren Land	B	79	11.697	924.063
O-1	Barren Land	C	86	2.312	198.832
O-1	Cultivated Crops	A	70	45.7504	3202.528
O-1	Cultivated Crops	B	79	2582.36	204006.4
O-1	Cultivated Crops	C	84	1111.46	93362.64
O-1	Developed_High Intensity	B	92	7.78277	716.0148
O-1	Developed_Low Intensity	A	61	0.549558	33.52304
O-1	Developed_Low Intensity	B	75	14.4092	1080.69
O-1	Developed_Low Intensity	C	83	0.858067	71.21956
O-1	Developed_Medium Intensity	B	85	4.68988	398.6398
O-1	Developed_Open Space	A	39	2.61575	102.0143
O-1	Developed_Open Space	B	61	188.798	11516.68
O-1	Developed_Open Space	C	74	35.1468	2600.863
O-1	Emergent Herbaceous Wetlands	B	58	1.94815	112.9927
O-1	Emergent Herbaceous Wetlands	C	71	4.94516	351.1064
O-1	Hay_Pasture	B	70	111.972	7838.04
O-1	Hay_Pasture	C	77	35.0108	2695.832
O-1	Herbaceous	A	30	82.9407	2488.221
O-1	Herbaceous	B	58	3483.97	202070.3
O-1	Herbaceous	C	71	512.113	36360.02
O-1	Open Water	C	100	0.44473	44.473
O-1	Shrub_Scrub	A	39	3.13006	122.0723
O-1	Shrub_Scrub	B	61	365.627	22303.25
O-1	Shrub_Scrub	C	74	38.9672	2883.573

NOAA Atlas 14, Volume 8, Version 2
Location name: Limon, Colorado, USA*
Latitude: 39.16°, Longitude: -103.75°
Elevation: m/ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Deborah Martin, Sandra Pavlovic, Ishani Roy, Michael St. Laurent, Carl Trypaluk, Dale Unruh, Michael Yekta, Geoffery Bonnin

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.289 (0.223-0.376)	0.352 (0.271-0.458)	0.462 (0.354-0.602)	0.559 (0.426-0.731)	0.702 (0.522-0.963)	0.819 (0.595-1.14)	0.944 (0.663-1.34)	1.08 (0.727-1.58)	1.26 (0.821-1.90)	1.41 (0.893-2.15)
10-min	0.424 (0.327-0.550)	0.516 (0.397-0.670)	0.676 (0.519-0.881)	0.818 (0.624-1.07)	1.03 (0.765-1.41)	1.20 (0.871-1.67)	1.38 (0.971-1.97)	1.58 (1.06-2.31)	1.85 (1.20-2.78)	2.06 (1.31-3.14)
15-min	0.517 (0.398-0.671)	0.629 (0.484-0.817)	0.824 (0.632-1.07)	0.998 (0.761-1.31)	1.25 (0.933-1.72)	1.46 (1.06-2.03)	1.68 (1.18-2.40)	1.92 (1.30-2.82)	2.25 (1.47-3.40)	2.52 (1.59-3.83)
30-min	0.712 (0.549-0.924)	0.864 (0.665-1.12)	1.13 (0.866-1.47)	1.37 (1.04-1.79)	1.72 (1.28-2.36)	2.01 (1.46-2.79)	2.31 (1.62-3.29)	2.64 (1.78-3.87)	3.10 (2.02-4.67)	3.47 (2.19-5.28)
60-min	0.882 (0.680-1.14)	1.07 (0.821-1.39)	1.40 (1.07-1.82)	1.69 (1.29-2.22)	2.14 (1.60-2.94)	2.51 (1.83-3.50)	2.91 (2.05-4.15)	3.34 (2.26-4.90)	3.95 (2.57-5.96)	4.44 (2.81-6.76)
2-hr	1.05 (0.819-1.35)	1.27 (0.987-1.63)	1.66 (1.29-2.14)	2.02 (1.56-2.62)	2.56 (1.93-3.50)	3.02 (2.22-4.16)	3.50 (2.50-4.96)	4.04 (2.76-5.87)	4.79 (3.16-7.17)	5.41 (3.46-8.15)
3-hr	1.13 (0.886-1.45)	1.36 (1.06-1.74)	1.78 (1.39-2.28)	2.16 (1.68-2.79)	2.75 (2.10-3.75)	3.26 (2.41-4.48)	3.80 (2.72-5.35)	4.39 (3.02-6.36)	5.24 (3.47-7.79)	5.93 (3.81-8.87)
6-hr	1.27 (1.00-1.60)	1.51 (1.20-1.92)	1.97 (1.55-2.50)	2.39 (1.87-3.05)	3.04 (2.34-4.11)	3.60 (2.70-4.91)	4.21 (3.05-5.88)	4.88 (3.40-7.00)	5.84 (3.92-8.60)	6.62 (4.31-9.81)
12-hr	1.41 (1.12-1.76)	1.68 (1.34-2.10)	2.17 (1.72-2.73)	2.62 (2.07-3.31)	3.30 (2.56-4.40)	3.88 (2.94-5.22)	4.51 (3.30-6.21)	5.19 (3.65-7.34)	6.16 (4.17-8.96)	6.95 (4.56-10.2)
24-hr	1.61 (1.30-2.00)	1.88 (1.52-2.34)	2.38 (1.91-2.96)	2.84 (2.27-3.55)	3.54 (2.78-4.66)	4.13 (3.16-5.50)	4.78 (3.53-6.51)	5.48 (3.90-7.68)	6.49 (4.44-9.34)	7.31 (4.86-10.6)
2-day	1.85 (1.51-2.27)	2.15 (1.75-2.64)	2.68 (2.18-3.31)	3.17 (2.56-3.93)	3.91 (3.09-5.07)	4.52 (3.49-5.94)	5.19 (3.87-6.98)	5.91 (4.24-8.16)	6.92 (4.78-9.83)	7.75 (5.20-11.1)
3-day	2.00 (1.64-2.44)	2.34 (1.92-2.86)	2.94 (2.40-3.60)	3.47 (2.82-4.27)	4.26 (3.38-5.48)	4.91 (3.80-6.39)	5.60 (4.20-7.46)	6.33 (4.57-8.68)	7.37 (5.12-10.4)	8.19 (5.53-11.7)
4-day	2.12 (1.75-2.58)	2.50 (2.06-3.04)	3.14 (2.58-3.83)	3.71 (3.03-4.55)	4.54 (3.61-5.80)	5.22 (4.06-6.75)	5.93 (4.46-7.86)	6.68 (4.84-9.10)	7.74 (5.39-10.8)	8.57 (5.81-12.1)
7-day	2.46 (2.05-2.97)	2.87 (2.39-3.47)	3.58 (2.96-4.33)	4.20 (3.46-5.10)	5.10 (4.09-6.45)	5.83 (4.57-7.47)	6.60 (5.01-8.66)	7.41 (5.41-10.0)	8.54 (6.00-11.8)	9.43 (6.46-13.2)
10-day	2.77 (2.32-3.32)	3.21 (2.68-3.85)	3.96 (3.30-4.76)	4.62 (3.82-5.58)	5.57 (4.50-7.00)	6.35 (5.00-8.08)	7.16 (5.46-9.34)	8.02 (5.89-10.8)	9.21 (6.52-12.7)	10.2 (6.99-14.2)
20-day	3.65 (3.09-4.33)	4.20 (3.55-4.98)	5.12 (4.31-6.09)	5.90 (4.95-7.06)	7.03 (5.72-8.70)	7.92 (6.30-9.94)	8.84 (6.81-11.4)	9.80 (7.26-13.0)	11.1 (7.93-15.1)	12.1 (8.44-16.7)
30-day	4.40 (3.74-5.18)	5.05 (4.29-5.96)	6.12 (5.19-7.24)	7.02 (5.92-8.34)	8.26 (6.75-10.1)	9.23 (7.38-11.5)	10.2 (7.90-13.0)	11.2 (8.34-14.7)	12.5 (8.99-16.9)	13.5 (9.48-18.5)
45-day	5.35 (4.59-6.27)	6.15 (5.26-7.21)	7.42 (6.33-8.72)	8.44 (7.16-9.97)	9.82 (8.05-11.9)	10.9 (8.71-13.3)	11.9 (9.22-14.9)	12.9 (9.61-16.7)	14.1 (10.2-18.8)	15.1 (10.6-20.5)
60-day	6.18 (5.32-7.21)	7.10 (6.10-8.28)	8.53 (7.31-9.98)	9.66 (8.24-11.4)	11.1 (9.14-13.4)	12.2 (9.82-14.9)	13.2 (10.3-16.5)	14.2 (10.6-18.2)	15.4 (11.1-20.3)	16.2 (11.5-21.9)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

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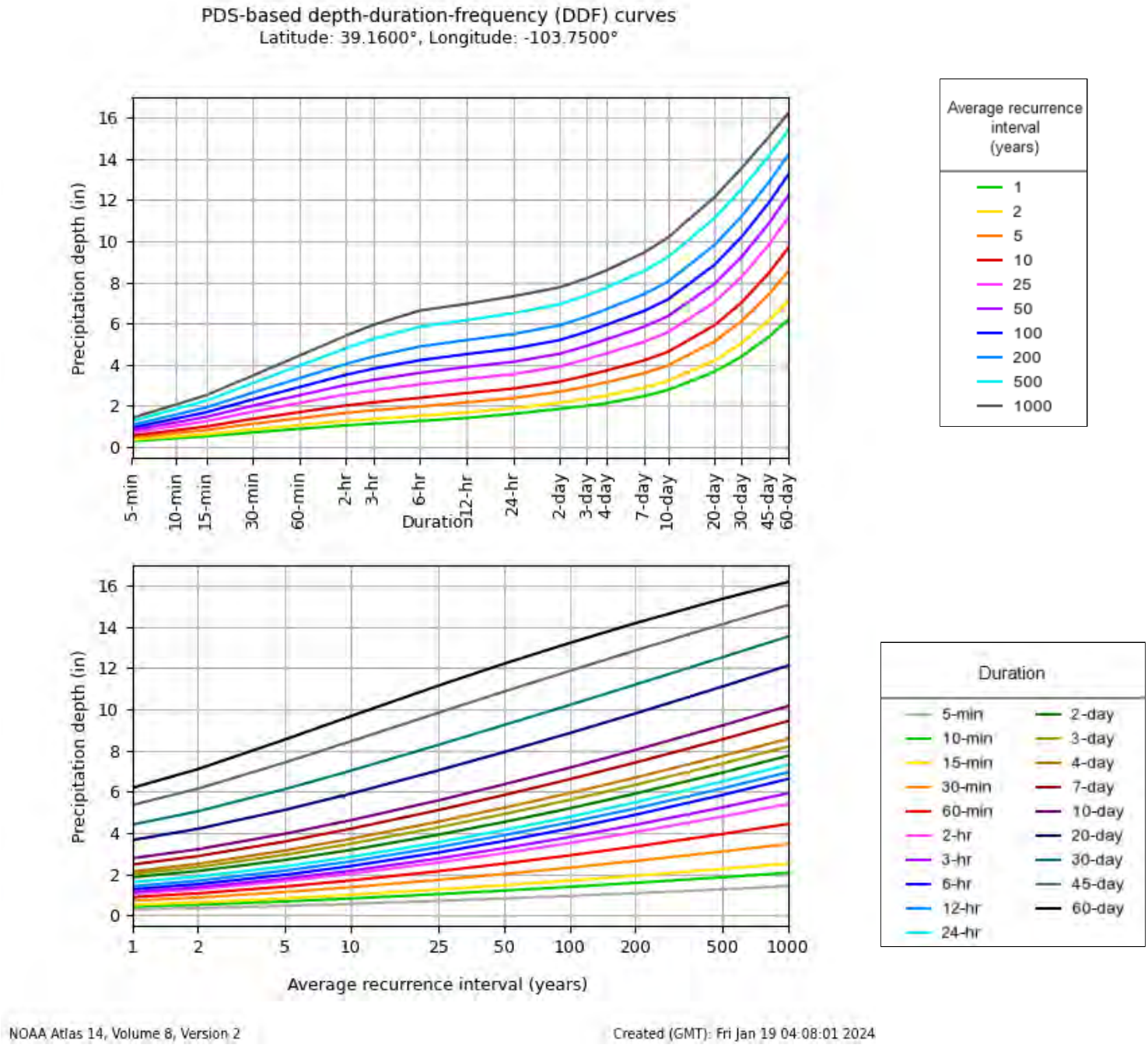
PF graphical



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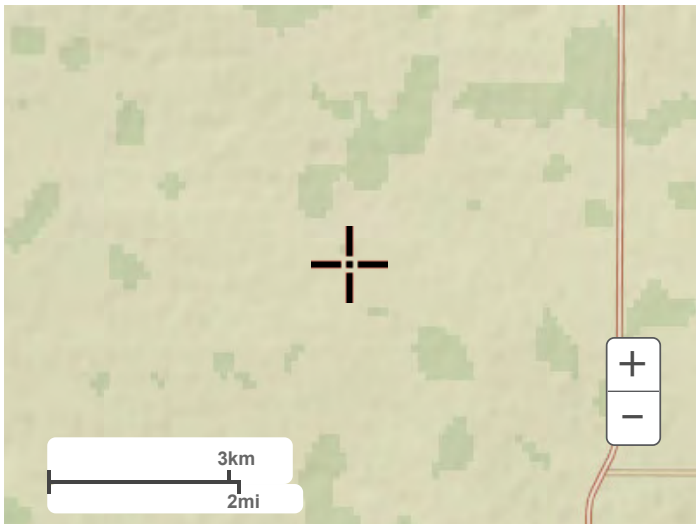
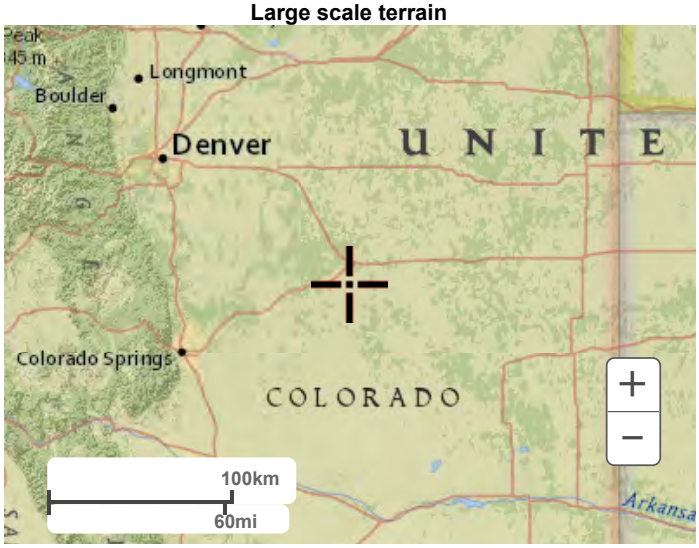
Maps & aerials

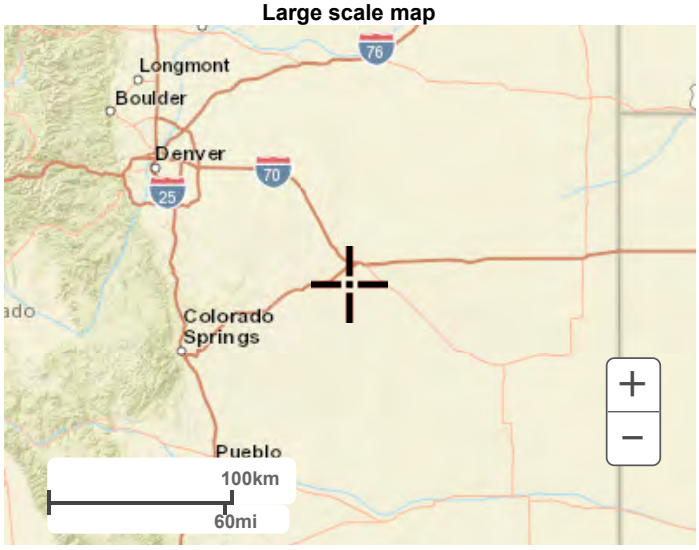
Small scale terrain



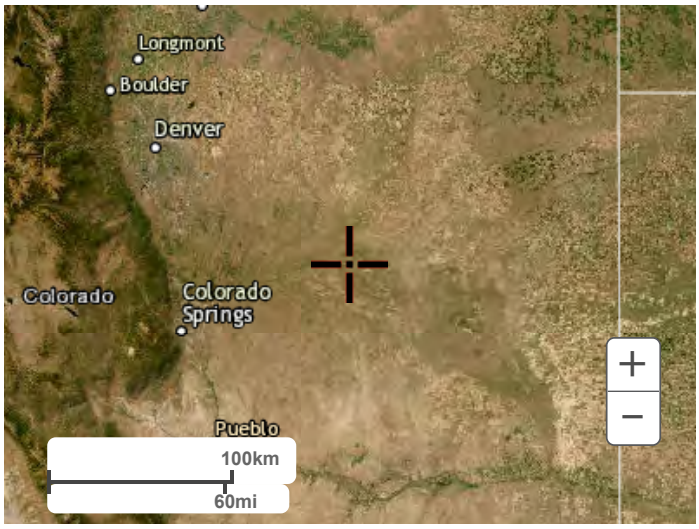
Large scale terrain



Large scale map



Large scale aerial



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National Oceanic and Atmospheric Administration
National Weather Service
National Water Center
1325 East West Highway
Silver Spring, MD 20910
Questions?: HDSC.Questions@noaa.gov

Disclaimer

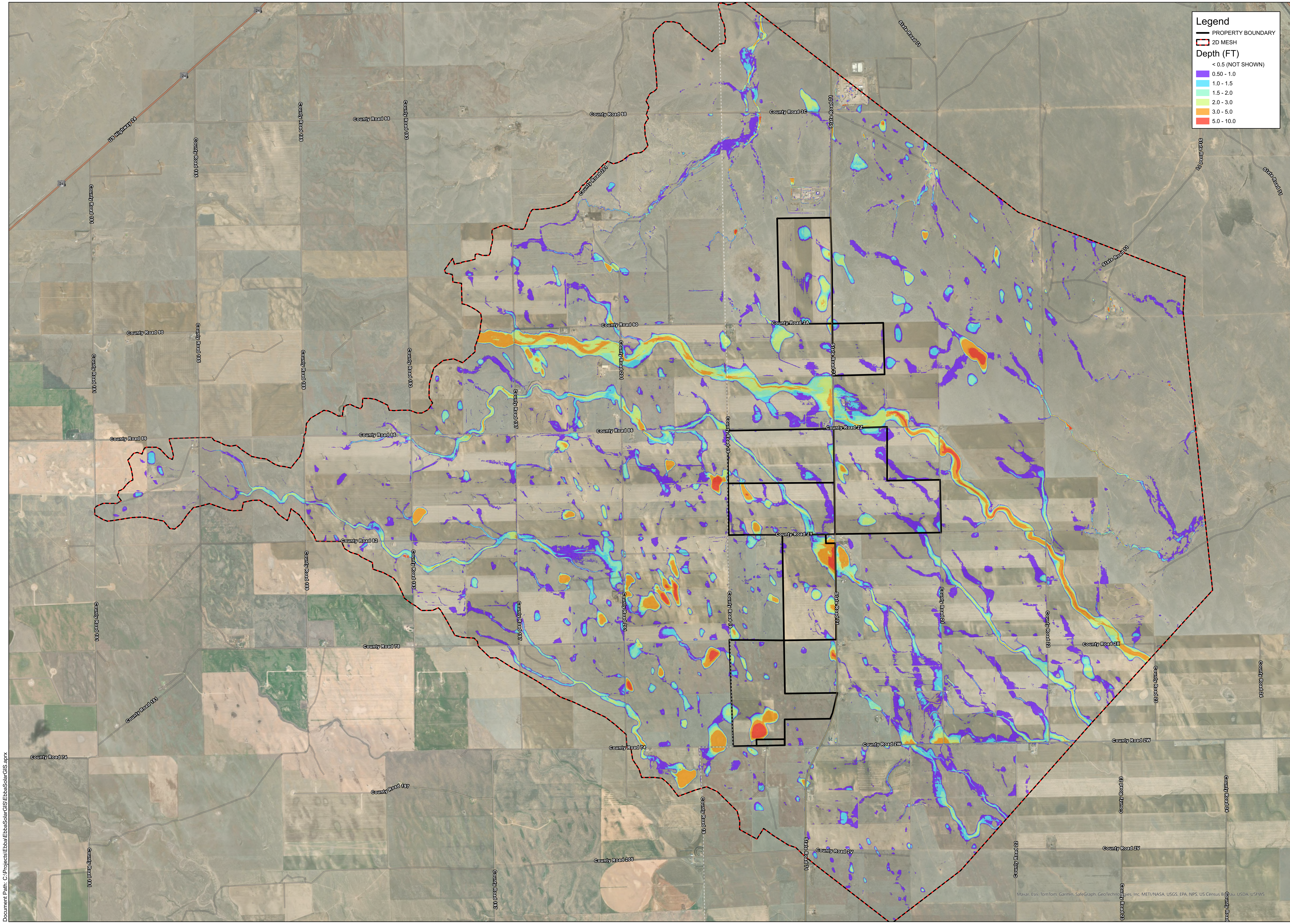
HEC-HMS RESULTS

Project: Ebba Solar Simulation Run: Offsite AR

Start of Run: 01Jan2024, 00:00
End of Run: 04Jan2024, 00:00

Basin Model: Offsite
Meterologic Model: 100-yr AR
Control Specifications: Control 1

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
O-1	13.5148	2543.78	01Jan2024, 16:06	1.7302



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N
1 inch = 2,000 feet

EBBA SOLAR
LINCOLN COUNTY, COLORADO

100-YEAR INUNDATION DEPTH MAP

DATE
FEBRUARY 2024

PROJECT NO.
068927116

SHEET NUMBER
3

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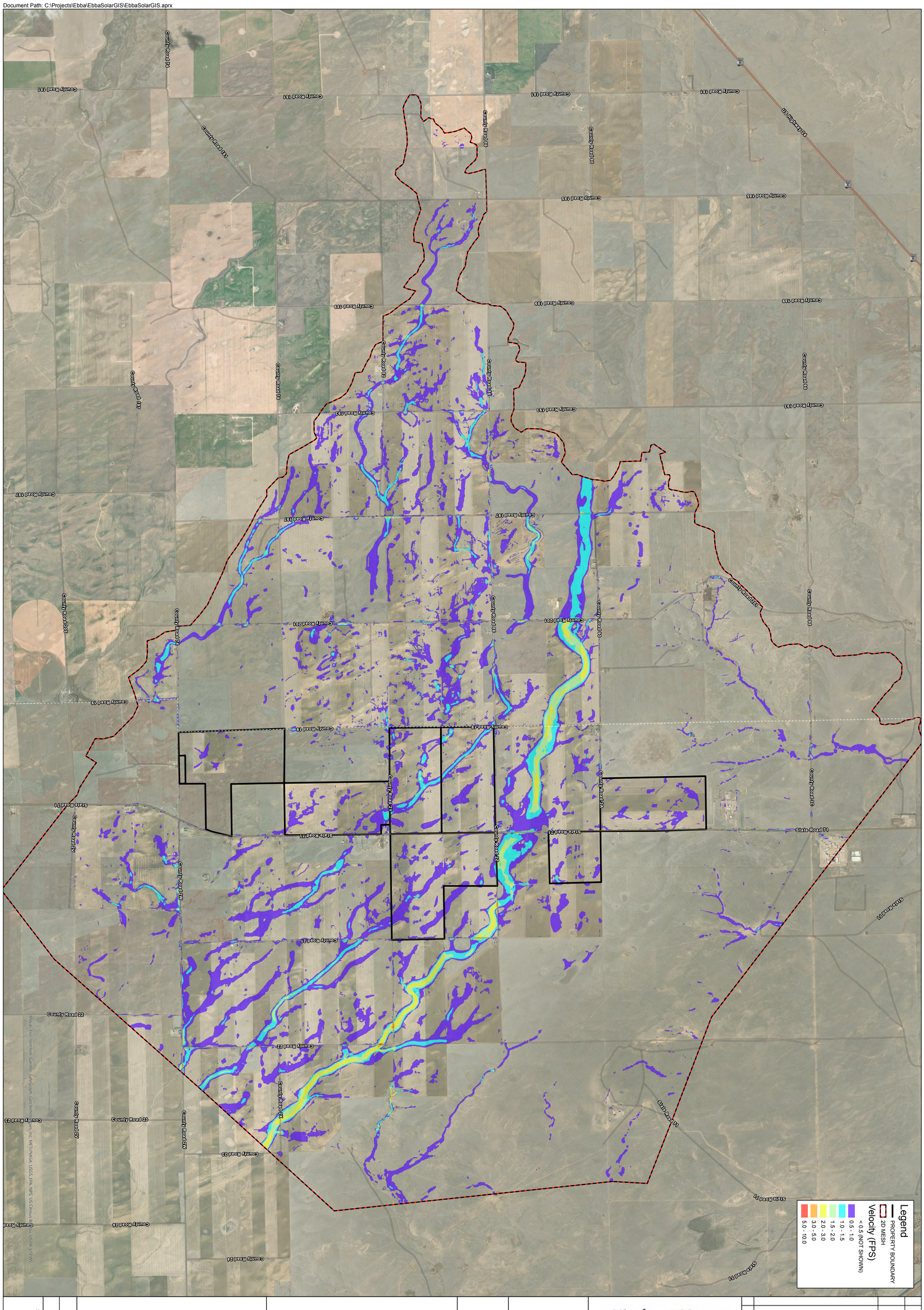

SHEET NUMBER 4	PROJECT NO. 069927116	DATE FEBRUARY 2024	100-YEAR VELOCITY MAP	EBBA SOLAR LINCOLN COUNTY, COLORADO	1 Inch = 2,000 feet	Kimley»Horn 1400 WOODLOCH FOREST DRIVE, SUITE 225 THE WOODLANDS, TX 77380 PHONE: 281-475-2816

DESIGN:	AAT	
DRAWN:	AAT	
REVIEW:	BWP	

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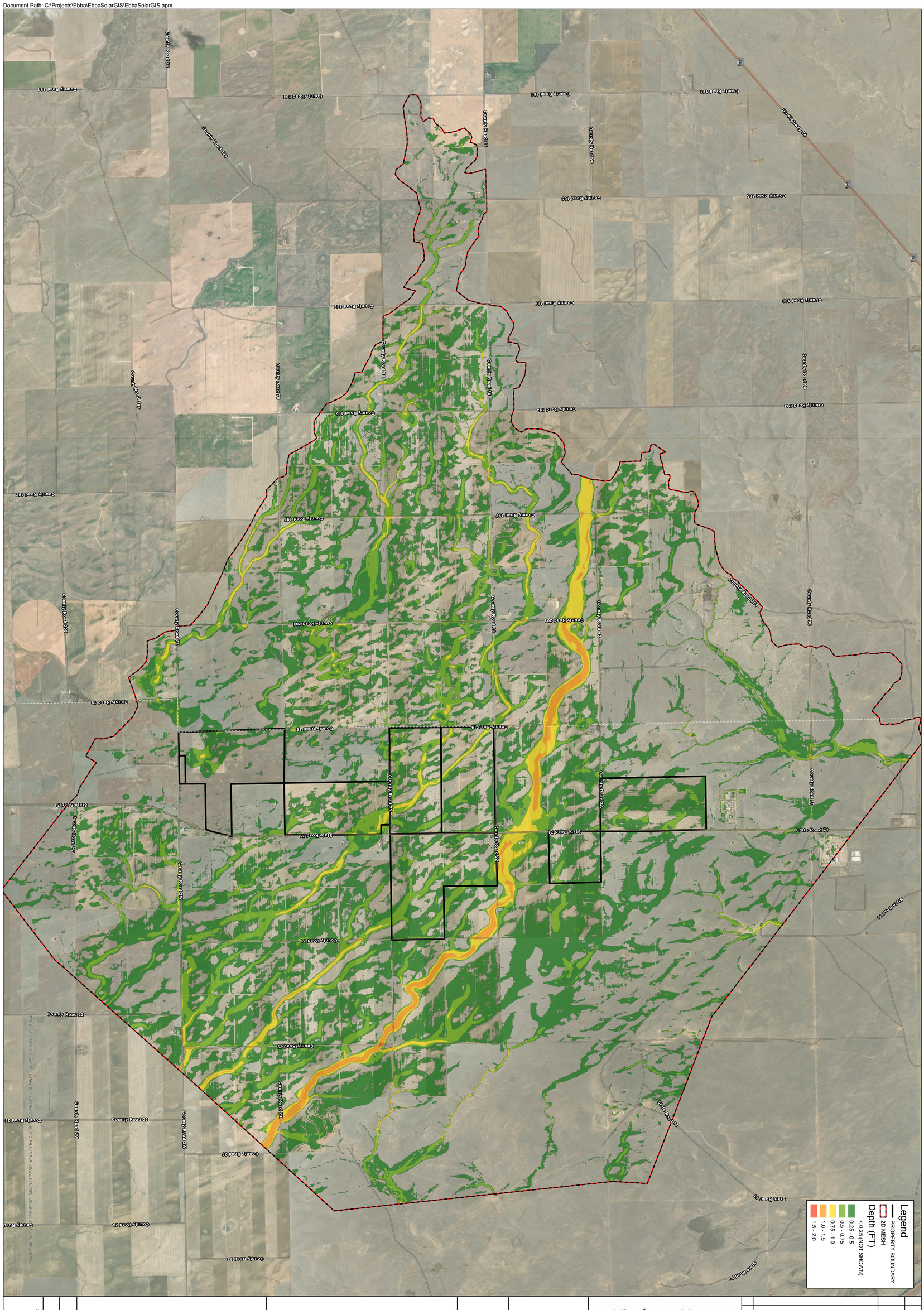

5	100-YEAR SCOUR MAP	EBBA SOLAR LINCOLN COUNTY, COLORADO	1 Inch = 2,000 feet	Kimley»Horn 1400 WOODLOCH FOREST DRIVE, SUITE 225 THE WOODLANDS, TX 77380 PHONE: 281-475-2816	DESIGN: AAT DRAWN: AAT REVIEW: BWP	

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