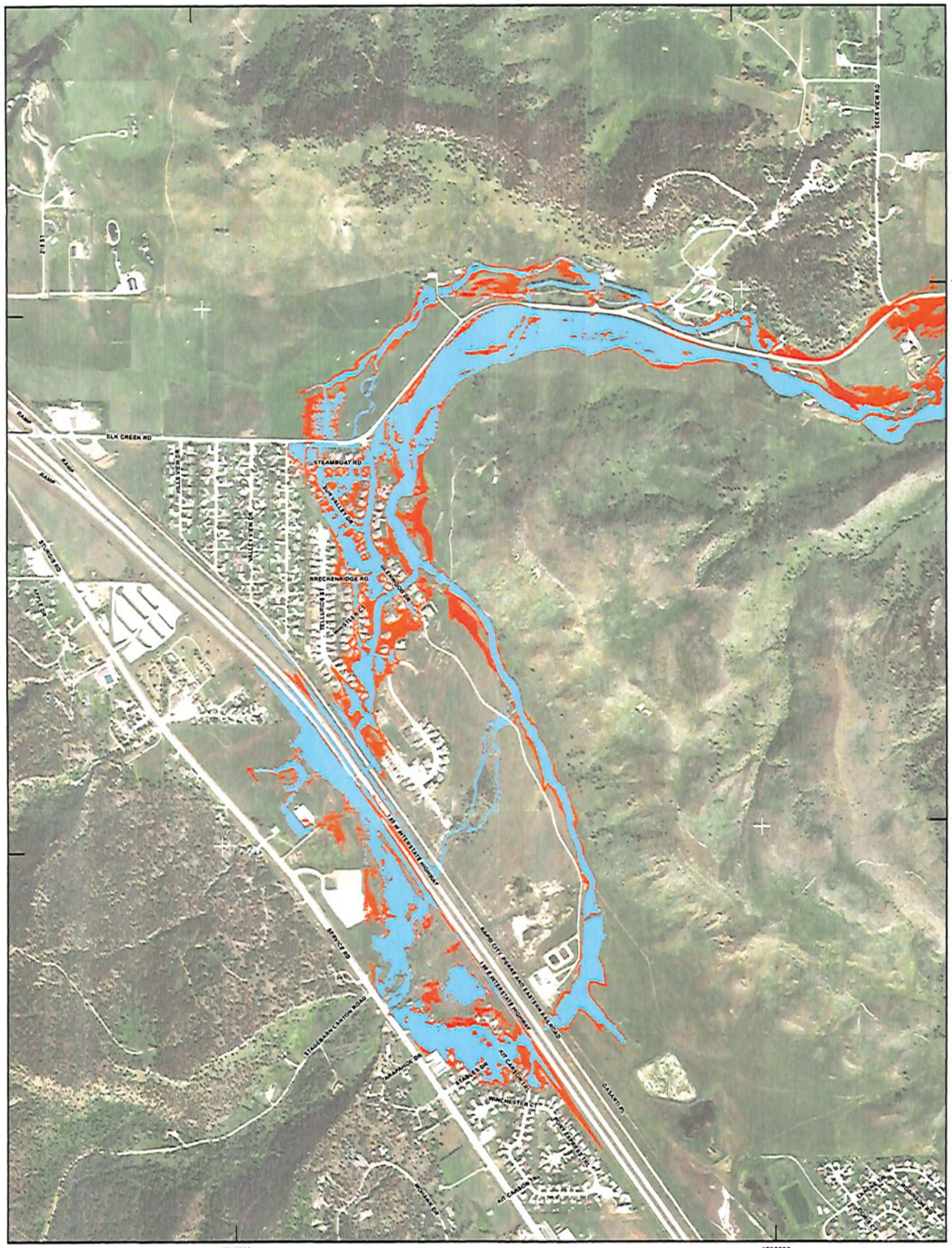
NOTES TO USERS

This map has been prepared in association with the Black Hills Flood Demonstration South Dakota Silver Jacket Project, and identifies the 1% and 0.2% annual chance exceedance floodplain. This map is authored by the United States Army Corps of Engineers – Omaha District Flood Risk and Floodplain Management Section (USACE). The information presented may not reflect the view of the Federal Emergency Management Agency. It should not for use in administering the National Flood Insurance Program.

The projection used in the preparation of this map was South Dakota State Plane Coordinate North System of 1983, FIPS 4001. The horizontal datum was NAD 1983. Differences in datum, spheroid, projections, or state zone used in the production of FIRM's for adjacent jurisdiction boundaries may result in slight positional differences in map features across jurisdiction boundaries. These differences do not affect the accuracy of this map.

If you have questions about this map, please call the USACE-Omaha District, Floodplain Management Section, (402) 995-2326.



Legend

100-Year Inundation

500-Year Inundation

MAP SCALE 1" = 500'

250 0 250 500 1000 FEET

150 0 150 300 METERS

INUNDATION PANEL 1

FLOOD RISK IDENTIFICATION MAP

- Inundation Areas -

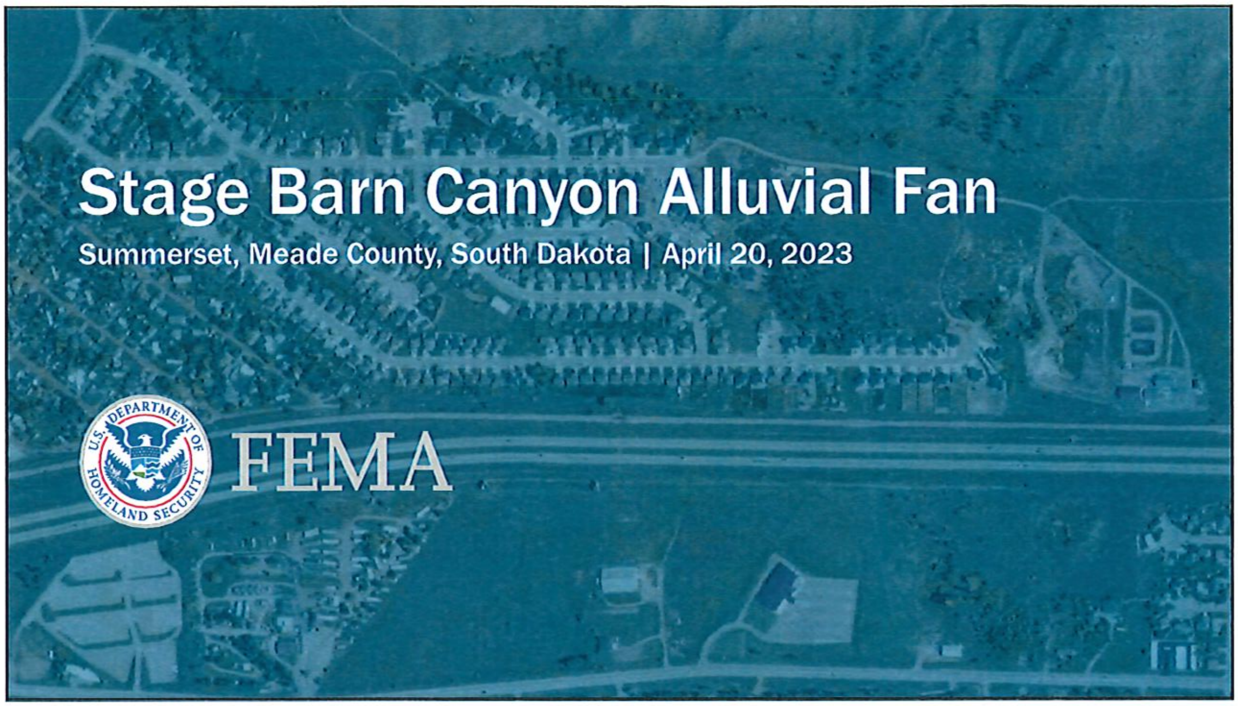
Stagebarn Canyon Drainage Inundation Areas for 100-Year and 500-Year Flood Events

CITY OF SUMMERSET, MEADE COUNTY SOUTH DAKOTA

PANEL 1 OF 2

US Army Corps of Engineers ® Omaha District

DATE:03/30/2018



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Agenda

- Introductions
- Mapping Study
  - History
  - Methodology
  - Results
  - Conclusions
- Next Steps Discussion

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Mapping Study: History

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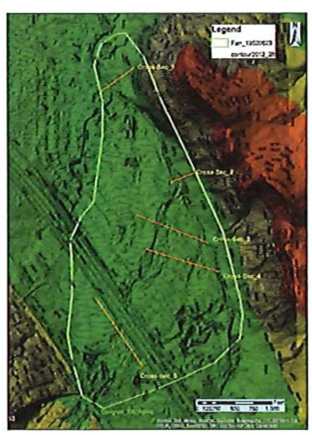
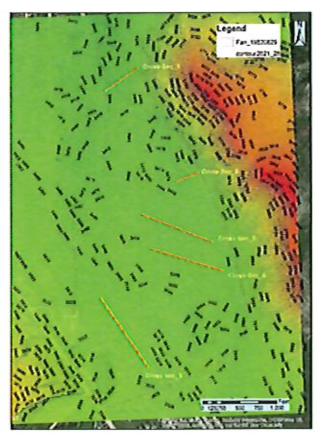
Analyzing Available Terrains: Active or Inactive Alluvial Fan?

1953 Terrain



2012 Terrain*



2017 Terrain + 2021 survey

FEMA

** Polygon shows the limits of the active alluvial fan.*

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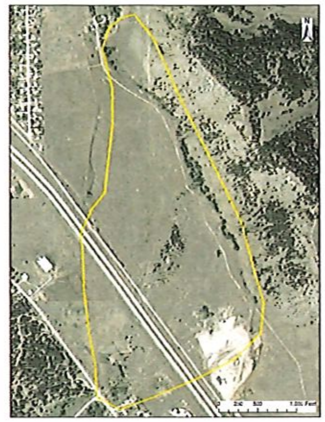
Comparing Historical Aerial Imageries: Active or Inactive Alluvial Fan?

June 29, 1952

August 2, 1971

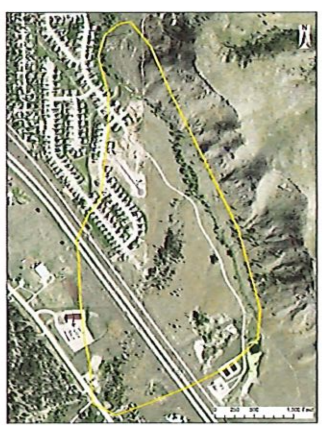


July 25, 2004

FEMA ** Polygon shows the limits of the active alluvial fan.*

Development at a Glance

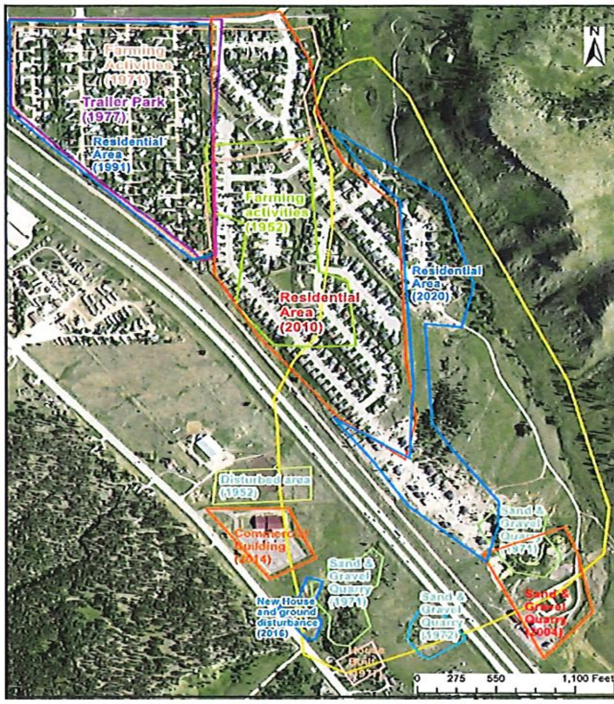
July 31, 2010



September 19, 2016

August 6, 2020

FEMA ** Polygon shows the limits of the active alluvial fan.*



Manmade Disturbance Since 1952

- Farming
- Mining
- Development occurred mostly in recent 20 years.
- A large residential area was built on the alluvial fan before 2010.
- The residential area is still expanding within the alluvial fan area.

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Mapping Study: Methodology

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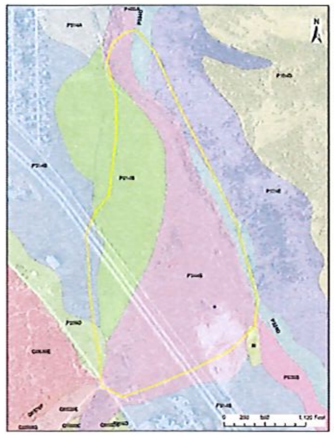
Soil Survey

- Performed 14 soil samplings.
- The area is mainly covered by two types of soils.
- Rapidcreek very cobbly sandy loam (P344B): mixed alluvium derived from sedimentary and igneous sources.
- Altvan loam (P014B): sand or gravelly sand.



Soil Map

Soil Sampling

FEMA

** Polygon shows the limits of the active alluvial fan.*

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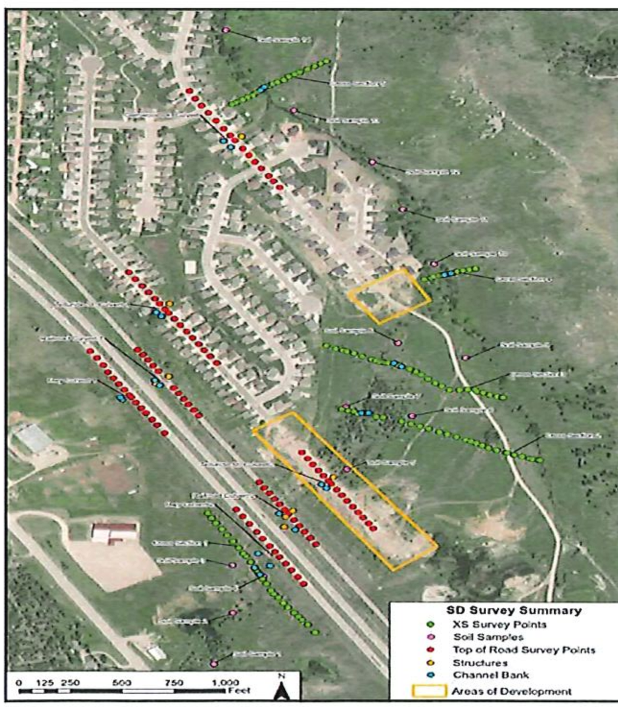

Field Survey of Structures and Natural Channels

- Surveyed major structures (culverts and bridges).
- Surveyed cross sections along streams.
- Surveyed channel banks.
- Surveyed new development not shown on aerial imagery.

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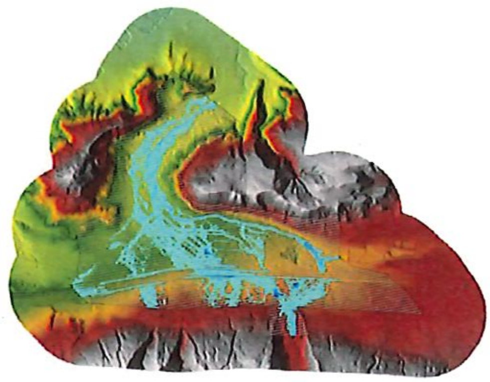
Flood Simulation using Detailed 2D Model

- Hydraulics analysis performed using the latest version of **HEC-RAS 2D** (6.3).
- **2D mesh**: Fine **Cell size of 20 ft** for developed areas, active alluvial fan area, and near streams. 50-ft cell size away from the area of interest.



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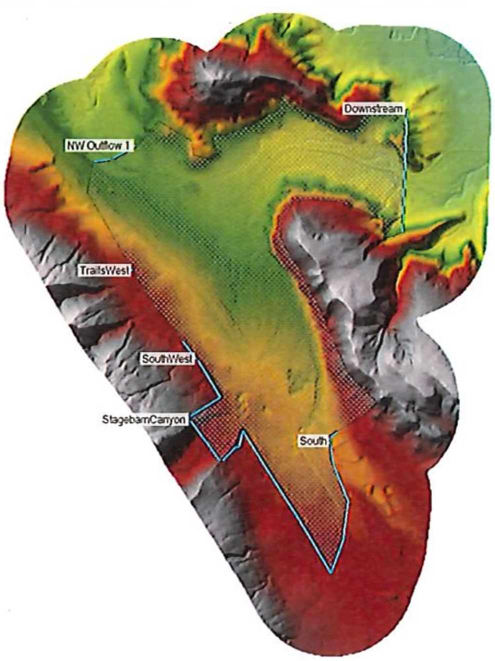

Flooding Sources

- Studied 10-yr, 25-yr, 50-yr, 100-yr, 100-yr+, and 500-yr floods.

Boundary Condition	Hydrograph Peak Flows (cfs) for Modeled Events					
	10-yr	25-yr	50-yr	100-yr	100-yr+	500-yr
Stagebarn Canyon	398	840	1,420	2,230	3,657	5,590
Southwest	48.2	102	171	267	438	667
South	144	284	458	690	1,131	1,560
TrailsWest	67.1	142	240	375	615	944

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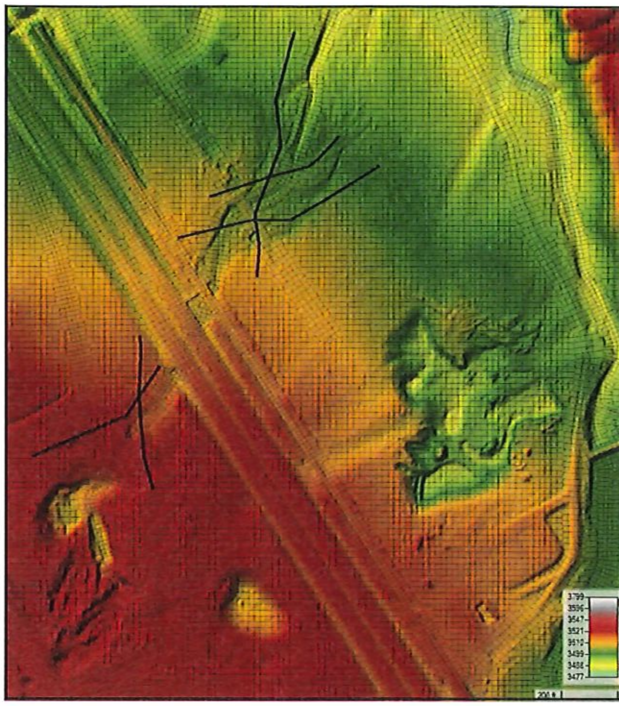

Alluvial Fan Analysis

- **Existing conditions:** performed using existing terrain based on most recent LiDAR and field survey.
- **Future conditions:** impacts of alluvial fan flow path uncertainty examined using **eight hypothetical scenarios** (different combinations of blocked flow paths shown on the figure).
- **Floodplain mapping:** based on the **highest water surface elevation** (worst case scenario) out of eight scenarios.

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Mapping Study: Results

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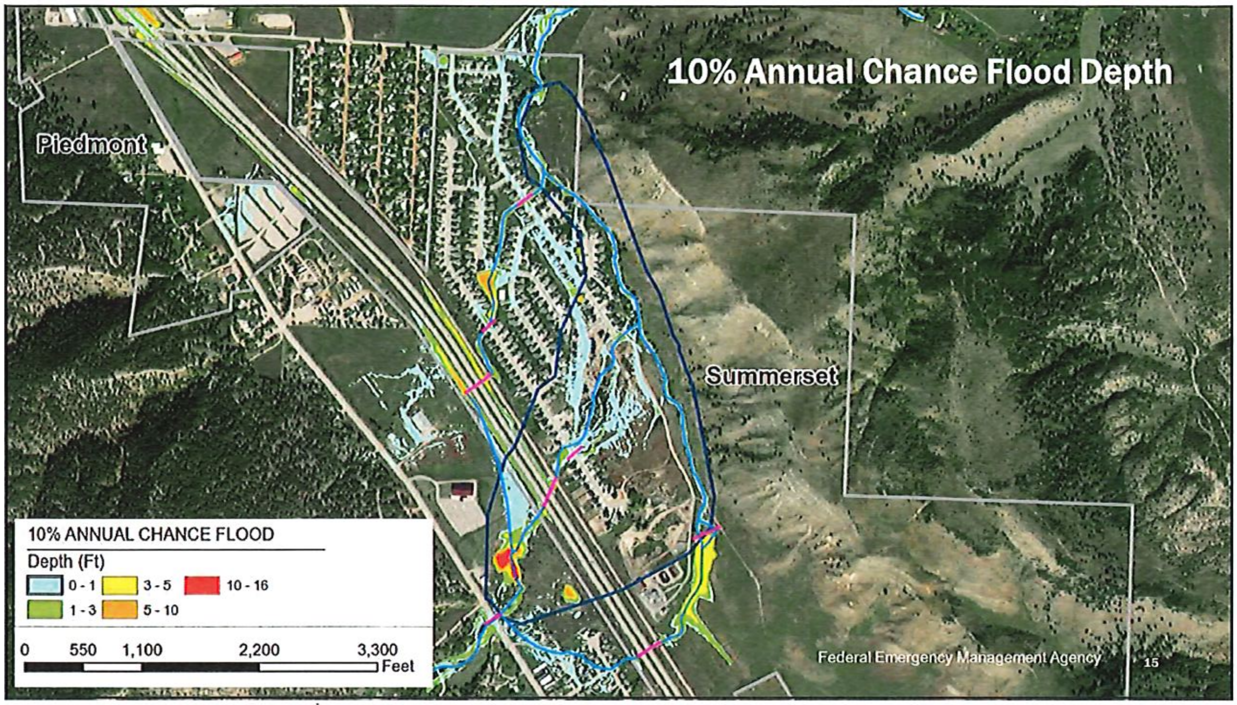
10% Annual Chance Flood Depth
Piedmont
Summerset
10% ANNUAL CHANCE FLOOD
Depth (Ft)
0 - 1
3 - 5
10 - 16
1 - 3
5 - 10
0 550 1,100 2,200 3,300 Feet
Federal Emergency Management Agency
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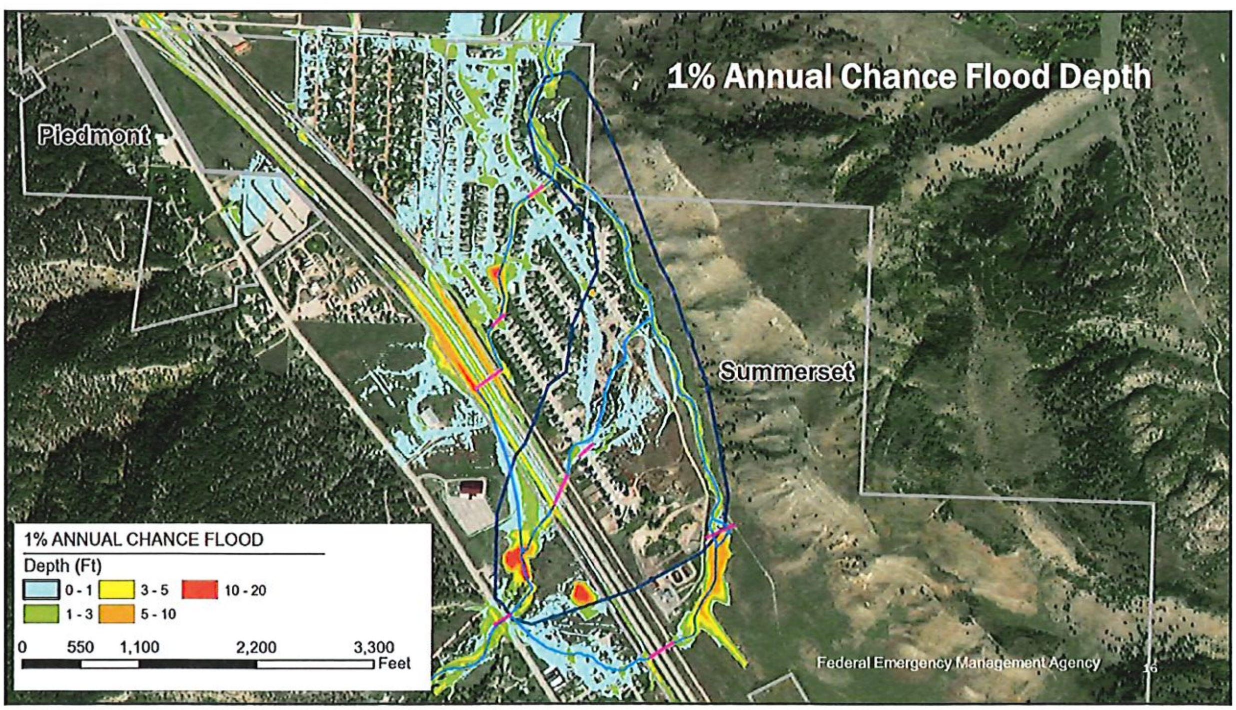
1% Annual Chance Flood Depth
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5 - 10
0 550 1,100 2,200 3,300 Feet
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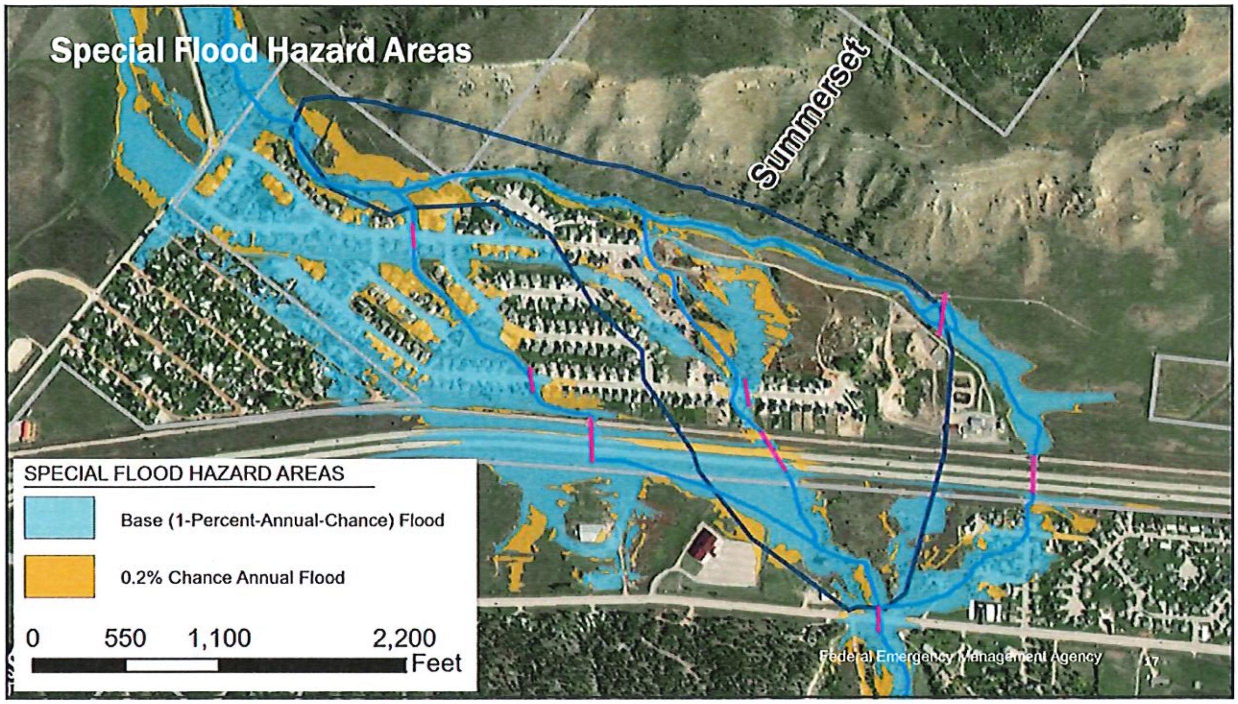

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Mapping Results: Conclusion

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Conclusions

- Stagebarn alluvial fan is active.
- This study provides flood mapping based on analysis of alluvial fan uncertainty.
- Residential area is developed within the floodplain of the active alluvial fan.
- Alluvial fan floodplain mapping is provided for 10-yr, 100-yr and 500-yr floods.

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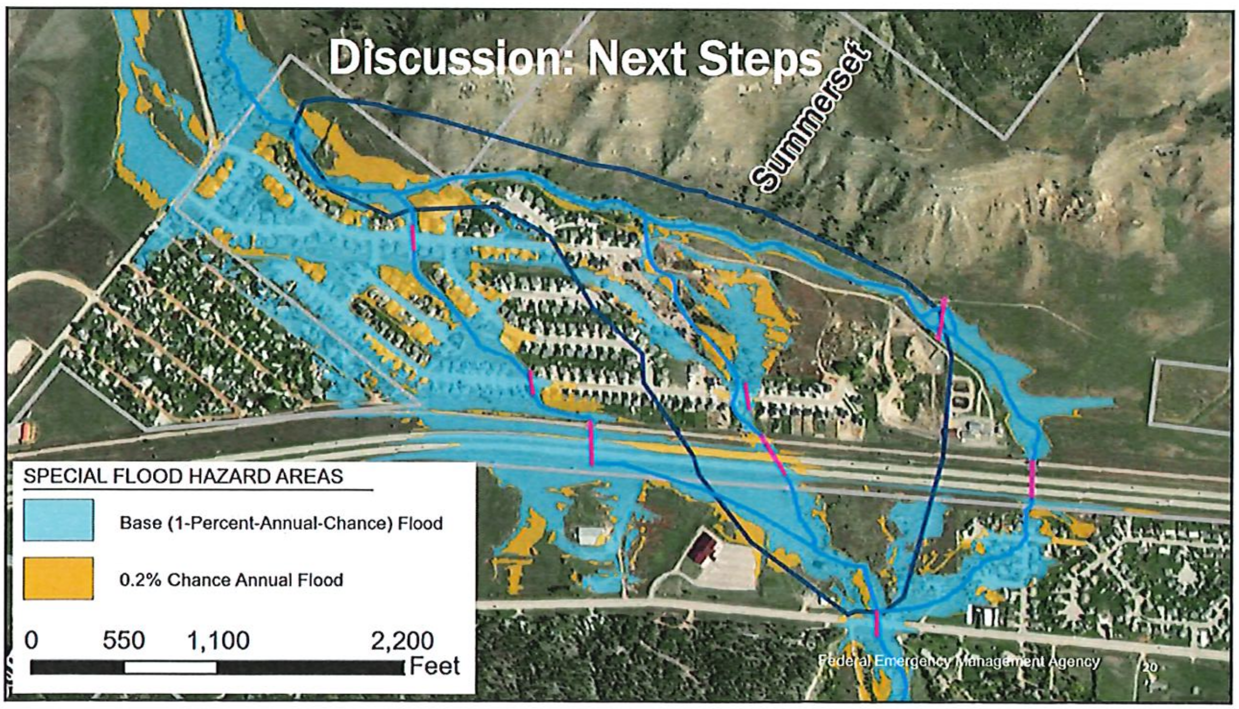

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Memo

Date: Wednesday, July 26, 2023

Project: FEMA Flood Model/Map Review

To: City of Summerset, SD

From: HDR

Subject: Summary Mapping and Map Development Comments – Summerset, SD

HDR was hired by the City of Summerset to review and comment on the *Hydraulic Study Report – Meade County, South Dakota – Stagebarn Canyon Alluvial Fan.*, dated June 2023.

Summary of Findings

The hydraulic study and preliminary floodplain mapping products developed as part of "Hydraulic Study Report – Meade County, South Dakota – Stagebarn Canyon Alluvial Fan" (COMPASS 2023) were given a limited review by HDR based only on the information provided. This memorandum summarizes the findings from that review but should not be considered an exhaustive set of comments since not all of the necessary technical information was provided. The information provided for this review included the following:

- Stagebarn Canyon Alluvial Fan hydraulic model which includes a portion of the City of Summerset (Stagebarn.prj)
- Task Documentation including:
    - "Hydraulic Study Report – Meade County, South Dakota – Stagebarn Canyon Alluvial Fan" (StageBarnFan_SD_Hydraulics_Report_final.pdf)
    - "Black Hills Flood Risk Demonstration Project, City of Summerset, Meade County, South Dakota" (Revised_March_2018_Black_Hills_Flood_Demonstration.pdf)
- April 2023 Meeting Presentation Slides: (Stage Barn Alluvial Fan Mapping Mtg Presentation 042023.pdf)

From a review the above listed analyses, it appears the City of Summerset does have flood risk resulting from Stagebarn Canyon flood flows. The intended use for the commentary provided in this memo is to advance these analyses for potential future applications which could include mapping and communication of flood risk, guiding regulatory changes, and/or exploration of mitigation alternatives. Below is a brief summary of the major findings of the review and the remaining portions of the memo provide additional details:

- This study (COMPASS 2023) represents an expansion of a previous flood risk study performed by USACE (2018). It retains the previously developed hydrology, refines the hydraulics, and provides mapping products in accordance with FEMA specifications. The study can be used by the City (City of Summerset) as best available data regarding flood risk, or the City can choose to have FEMA proceed with the process to make these maps a regulatory product.

- Terrain data is not the highest resolution that is available and terrain development could benefit by an approach to include bathymetric data that assumes connectivity. Additional survey data may be needed to properly define bathymetry through the area.
- No clear identification of the survey (structure or bathymetry) data accuracy was provided, and some appears to be approximated. Pending the intended level of detail for future mapping, additional refinement may be necessary using supporting data like field survey, as-builts, or design plans that are confirmed in the field.
- The hydrologic analysis developed peak flow estimates using a regional regression analysis and scaled hydrographs from historical events at nearby stream gages to those peak flows. It is unclear if this analysis falls within FEMA (2019) guidelines. If it is an appropriate approach, it requires additional verification.
- Hydraulic model inputs have been advanced from previous analysis, but may require refinement and enhancement throughout the domain, including the terrain, structure/bathymetric survey, roughness, and breakline additions to the numerical grid better capturing topographic features.
- Alluvial fan identification approach generally follows FEMA (2016) methodology but does require some clarification. The approach to 1% inundation mapping including the blocked flow path methodology requires verification that this is a FEMA approved mapping approach, and if so the description on approach needs to be expanded.

1.0 Hydrology

Flows in the model were determined as part of multiple previous studies as described in USACE (2018). The approach used peak flow estimates from a USGS report (2016) and scaled hydrographs from historical events at nearby stream gages to those peak flows (USACE 2017).

Peak flows were determined by the USGS as described in the report (USGS 2016), "Documentation of Peak-Flow Information for the Black Hills Flood Risk Demonstration Project." The USGS used StreamStats 3.0 to delineate drainage basins, derive basin characteristics, and the compute peak flow estimates. Peak flow estimates were determined for four drainage basins which enter the hydraulic area along various boundaries. Sando (1998) was used to determine peak flows, this set of regression equations uses stream slope and drainage area to estimate peak flows. The primary inflow point is to the west of Summerset entering west of Sturgis Road draining 17.2 sq miles (Figure 1). The two largest basins entering the hydraulic modeling domain have basin characteristics (area and slope) which are within applicable range for extrapolation, the other three smaller drainage areas do not. Two historical peaks were observed at a location just upstream of the primary inflow point in Stagebarn Canyon, in 1972 of 4,100 cfs, and in 2007 of 1,600 cfs. The return period of these peak flows is unclear but compares well to the computed 100-year peak flow of 2,230 cfs, as shown in Figure 2.

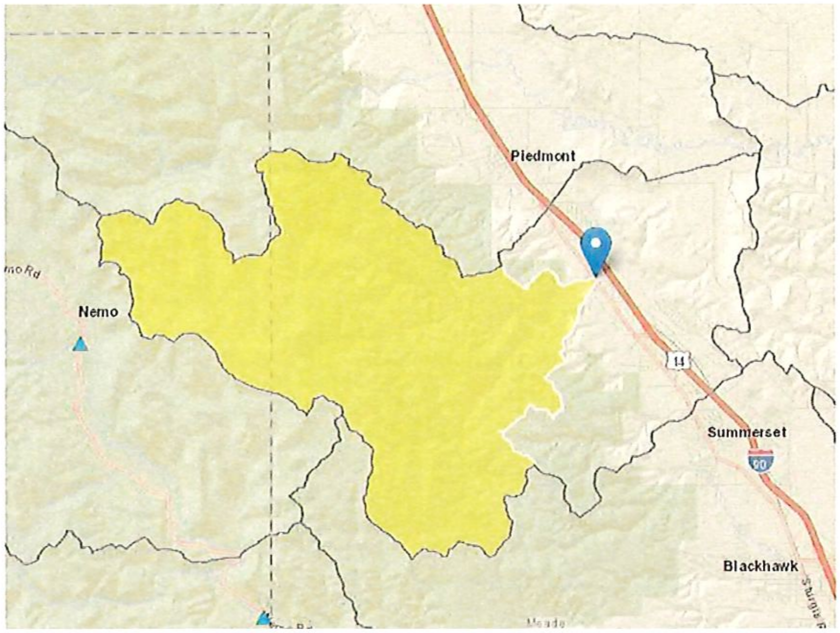


Figure 1. USGS StreamStats screen shot of the primary watershed entering from Stagebarn Canyon

Table 2. Summary of peak-flow computations for the Stagebarn Canyon sub-basin of primary interest.

Flow threshold		Flow estimate (cubic feet per second)	
Annual exceedance probability	Recurrence interval (years)	From StreamStats	From paleoflood scaling
0.5	2	55.3	Not applicable
0.2	5	197	Not applicable
0.01	10	398	Not applicable
0.04	25	840	1,520
0.02	50	1,420	2,810
0.01	100	2,230	5,070
0.05	200	Not applicable	8,940
0.002	500	5,590	18,300
Maximum paleoflood		Not applicable	49,600

Figure 2. Caption from USGS 2016 table 2 of the primary drainage basin entering the hydraulic modeling area

Inflow hydrographs were developed by using regional stream gages to produce a hydrograph scaled to regional regression equations (USACE 2017). USACE (2017) describes the typical approaches to determine inflows and why the scale hydrograph approach was selected:

"In the absence of stream gages in the basin, it is often preferred to utilize a hydrologic model with physically based or regionally informed runoff transform parameters to generate hydrographs. An alternative method, adopted for this case study due to limited resources, is to utilize regional gage data to produce a scaled hydrograph to match a peak flow determined by

regional regression equations. It is important to note that this approach is more approximate but less effort-intensive than other state of practice hydrologic techniques for generating statistically representative hydrographs. The scaling technique assumes that basins of similar drainage areas in a region respond to precipitation events in the same manner (e.g., duration-volume relationships for events of similar frequency are maintained)."

USACE (2017) recommended scaling of the Whitewood Creek at Deadwood, SD (USGS gage 06436170) event from May of 1995 for use in flood risk assessment as it would result in the most conservative flood inundation.

1.1 Hydrology Comment

USACE (2017) notes that typically a hydrologic model with physically based or regionally informed runoff transform parameters would be developed to generate hydrographs. FEMA (2019) continues that rainfall-runoff models are applicable and necessary for studies where a flood hydrograph is required, and in studies where storage behind road embankments may be significant in determining flow and stage. Why was a regional regression-based approach selected instead of a model-based approach?

1.2 Hydrology Comment

The hydrograph was developed using a Whitewood Creek 1995 flood hydrograph which was scaled to the peak flows calculated via regional regression. Is this hydrologic method listed in the approved FEMA methods or defined by FEMA guidance for developing a 2D modeling hydrograph?

1.3 Hydrology Comment

Stagebarn Canyon appears to be completely within the "Loss zone and artesian spring" as shown in Figure 3 (red). Sando (2008) indicates that loss zones only exhibit active discharge when upstream channel flows exceed the areas channel infiltration capacity. This results in limited response to frequent events and a reduction of peak flows in the downstream direction. However, these effects may be less prevalent for large events. The crystalline core area in Figure 3 exhibits a larger peak flow potential and more direct response to short-term precipitation. The blue circle (Figure 3) shows the approximate location of Whitewood Creek. The 1995 event at Whitewood Creek was selected due to its conservatism regarding duration and flood inundation. This location may not result in a similar response to the Stagebarn Canyon. Additionally, this site is 45 sq. miles in drainage area, is this hydrograph appropriate for application to all (or any) of the four inflow locations?

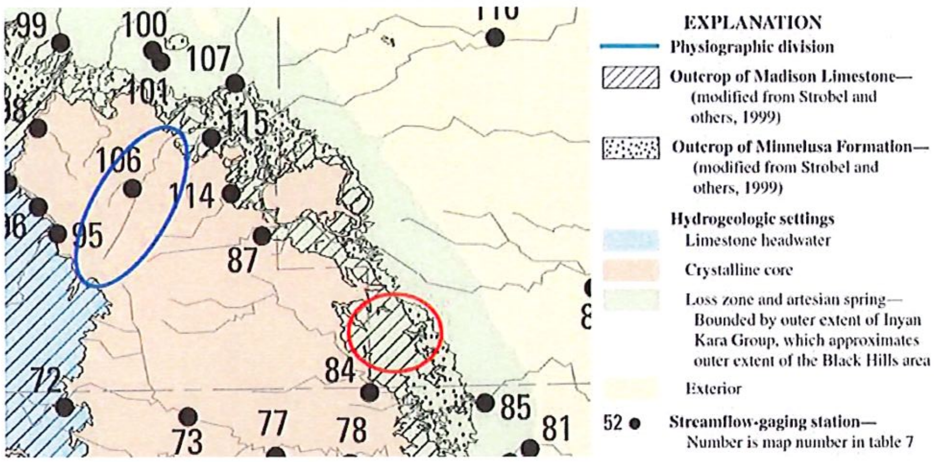


Figure 3. Hydrogeologic settings for the Black Hills region (excerpt from Sando et al. (2008))

1.4 Hydrology Comment

Is it likely that all four drainage basins respond coincidently? Or should they be evaluated independently?

1.5 Hydrology Comment

Sando (1998) notes that peak flows in the Black Hills are high variable and difficult to regionalize. Peak flows were calculated using regression equations developed with data from between 1929 and 1994 (Sando 1998). Since development of this report an additional 28 years of record have become available. Additionally, two reports Sando et al. (2008) and Harden et al. (2011) have expanded flood-frequency analyses in the Black Hills Area. Consider using the more recent data and studies.

1.6 Hydrology Comment

Please clarify how the paleoflood information in the report was used in the analysis.

2.0 Terrain

Terrain data used in the hydraulic analysis includes a combination of LiDAR based Digital Elevation Model (DEM) supplemented with survey. The LiDAR dataset used was 2017 USGS SD FY17 NRCS. NOAA U.S. Interagency Elevation inventory (https://coast.noaa.gov/inventory/) lists this data source as having a vertical accuracy of 3.7 cm RMSEz, point spacing of 0.7 m, and of QL2 data quality, which meets the minimum mapping standard. These data were supplemented with survey data of eight hydraulic structure (bridges and culverts) and five natural cross sections (COMPASS 2023).

A combined surface, LiDAR and survey, was created by converting the LiDAR DEM (1 meter resolution) into points and overriding the DEM points within 5 or 10 feet of the survey cross sections. COMPASS (2023) notes several iterations of the process were used to create the final terrain.

Twelve terrain modifications were included in the HEC-RAS model. The terrain modifications are named "Channels", "Channel Sturgis Rd", and "SB_23_US". These are located upstream and downstream of select roadway crossings of water features.

2.1 Terrain Comment

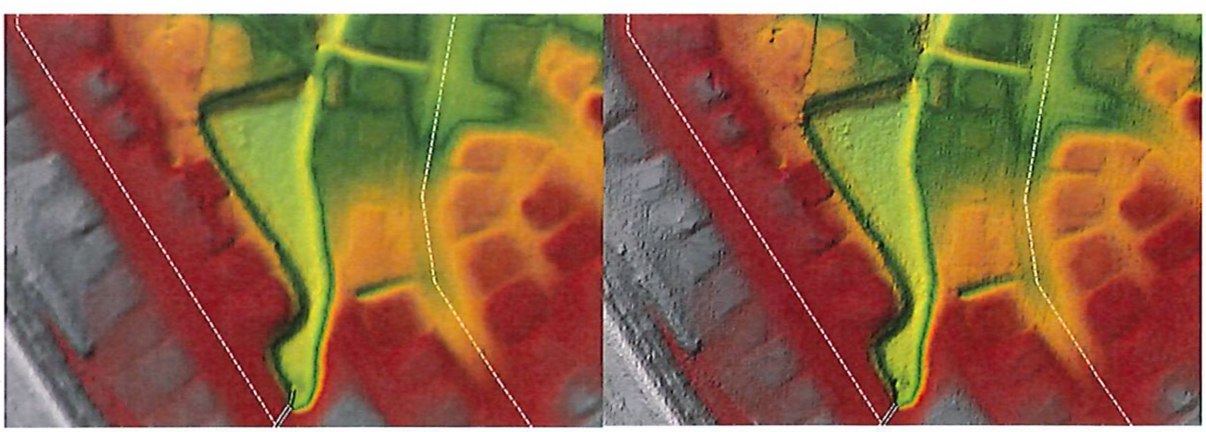
Development of the terrain (LiDAR and channel bathymetry) did not create a continuous bathymetric surface, rather each cross section was included independently into the terrain. By assuming cross sections are connected and a stream is continuous, an interpolation surface can be created connecting all of the cross sections along a water feature. This allows for representation of bathymetry for an entire reach. Why were cross sections used independently instead of together?

2.2 Terrain Comment

When creating a combined surface, the report notes the DEM at one meter resolution was converted to points at the center of each pixel and then survey points were integrated with the DEM points. The original LiDAR dataset is a point cloud of data, points falling within the same one-meter grid were averaged to create a one-meter resolution DEM. If there were interest in including survey points independently of the cross section/reach approach, the original LiDAR point cloud of data should have been used instead of the DEM cell centers. This approach would maintain the accuracy and resolution of the original dataset and eliminate additional averaging which occurs from re-sampling the data multiple times.

2.3 Terrain Comment

Through the HEC-RAS "Download Terrain Data" tool and selecting "USGS" terrain products published by the USGS can directly be downloaded. For this location both the one-meter resolution data or a finer 0.5-meter resolution (noted as original resolution) can be downloaded. Application of the 0.5-meter resolution terrain data would improve representation of hydraulic conveyance and improve inundation mapping. Figure 4 provides a comparison between the 0.5-meter resolution LiDAR product and the combined 1-meter surface used as part of the 2023 study.



COMPASS 2023 Terrain 1 meter — USGS Downloaded Terrain 0.5 meter

Figure 4. LiDAR DEM comparison

2.4 Terrain Comment

Twelve terrain modifications were used but there is no documentation for their purpose (example shown in Figure 5). Do surveyed cross sections support modification of the elevations upstream and/or downstream of the structures?

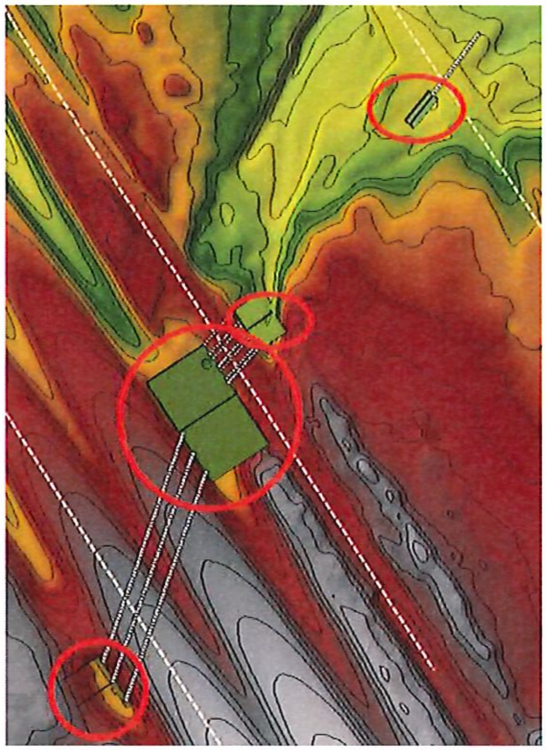


Figure 5. Terrain Modification Example

2.5 Terrain Comment

Guidance for Flood Risk Analysis and Mapping: Hydraulics: Two-Dimensional Analysis (FEMA 2020a). Identifies that at a minimum topographic data of the channel (including bathymetry) and floodplain is required for two-dimensional analysis. This point is confirmed in the Guidance for Flood Risk Analysis and Mapping: General Hydraulics Considerations (FEMA 2020b), which states, "the geometry of the channel bathymetry should be considered in enhanced studies." Is bathymetry available for the entire study area? Survey data should be included to adequately represent structures, and channel conveyance capacity.

3.0 Hydraulic Model Geometry and Set Up

Inflows were provided at four locations along the west and south boundaries and three outflow locations were provided to the north and east boundaries of the 2D area as shown in Figure 6. Stage Barn Canyon and Main Outflow are the primary inflow and outflow locations.

Cell sizes were nominally 50 ft X 50 ft, refined to 20 ft x 20 ft in the active alluvial fan area, refined to 15 ft x 15 ft in the stream corridor and along transportation features. Breaklines were included to define prominent topographic features such as roadway embankments and/or to refine cell sizes near stream channels as shown in Figure 8.

Roughness coefficients (Figure 7) provided in the USACE (2018) study were updated to represent new development areas. Buildings were included as an increased roughness value (n=10) as shown in red in Figure 8.

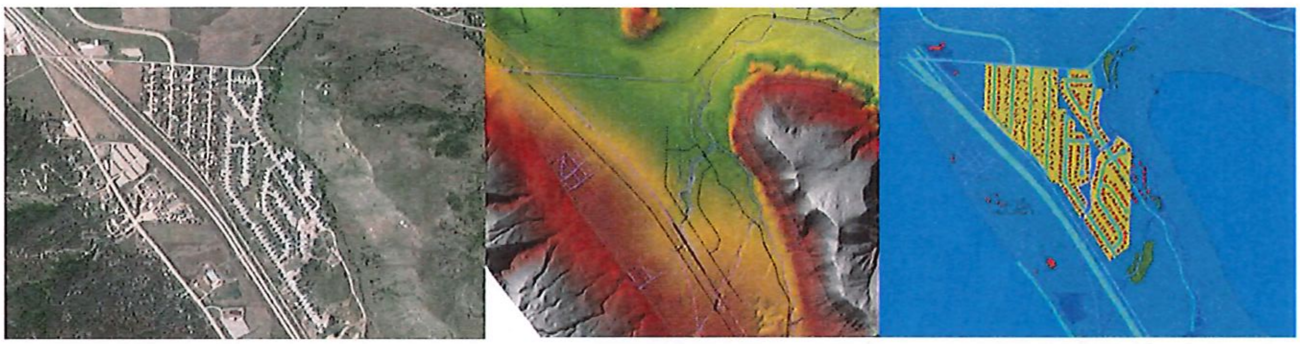
Twelve (12) 2D/SA connections were included in the model. These are typically used to represent bridges/culverts or surveyed roadway/levee embankments in the modeling domain. Survey was obtained for eight stream crossings (COMPASS 2023). The remaining structures included in the model used the structure data from the USACE 2D model (USACE 2018). USACE (2018) notes that all structures were include as culverts, and sizes and descriptions were based on a site visit. No survey was mentioned in the USACE (2018) report. No survey was performed at Sturgis Road crossing (COMPASS 2023).

Figure 4: Stagebarn Zone AE Model Domain and Boundary Conditions (Inflows and Outflow)

Figure 6. Hydraulic Modeling Boundary Condition Locations, clip from COMPASS (2023)

Name	ManningsN
NoData	
Channel	0.038
Grass - Short	0.035
Home Rural	0.04
Homes	0.2
Road	0.017
Trees	0.06

Figure 7. Manning's roughness applied to 2D area



Aerial Model Layout Roughness

Figure 8. Overview of spatial data for model set up

3.1 Hydraulics Comment

Manning's Roughness Coefficient of 0.038 for all channels is appropriate for some but overly conservative for others. Figure 9 and Figure 10 provide a few examples through the development that would likely be more efficient than 0.038 especially in flood flows.

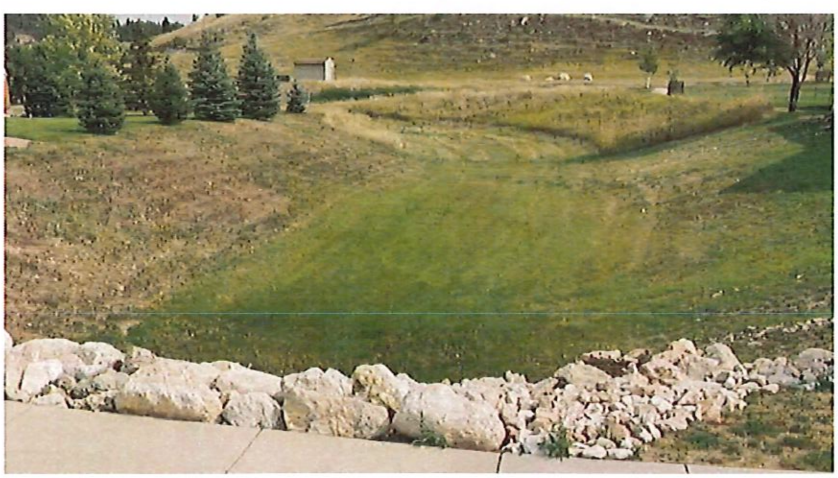


Figure 9. Roughness exampled from Glenwood Drive crossing looking northeast

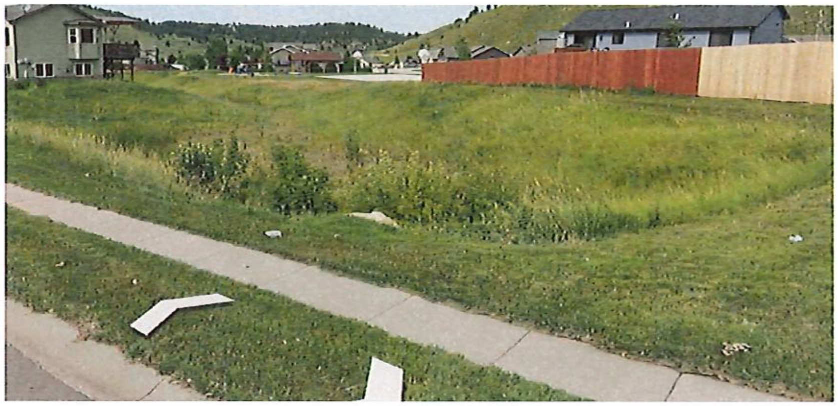


Figure 10. Roughness exampled from Telluride Street crossing looking northeast

3.2 Hydraulics Comment

Manning's roughness polygons targeted at describing buildings do not capture all structures as shown in Figure 11. The area in blue is described as "grass-short" and has an efficient roughness of 0.035. Consider adjusting the roughness value to represent the areas where there are buildings.

Figure 11. Omitted buildings from roughness

3.3 Hydraulics Comment

Where buildings are included as high roughness areas through development, the grassed space around the buildings are represented as 0.07 (Figure 12, yellow area). These areas may be better characterized with a short grass roughness value.

Figure 12. Roughness in developed area

3.4 Hydraulics Comment

Typically, 2D/SA connections are used to represent stream crossings (bridges and culverts), or high features not reflected in the terrain (e.g., a proposed levee). The stagebarn canyon model includes five 2D/SA connections to represent roadways or a dam feature without a bridge or culvert through the connection. However, it is unclear how the overtopping elevations on these structures were selected, or if they were surveyed. It appears as if many were carried forward from previous modeling efforts, which the USACE (2018) report does not provide documentation for how the elevation data was selected. USACE (2018) does not document the source terrain data for the 2D modeling, however the LiDAR data used in the COMPASS (2023) study became available after publication of the USACE 2018 study. These 2D/SA connections and breaklines from previous modeling efforts should not be accepted into the updated modeling without review and modification. Provide documentation for the source of the connection data.

3.5 Hydraulics Comment

I90-S 2D/SA connection (Figure 13, blue line) includes three independent reach crossings (red circles). Although the model configuration used in this analysis allows flow to pass appropriately, the headwater/tailwater and discharge dynamics for all the structures are merged together and diff icult to disaggregate. Splitting these into three crossings allows for improved understanding of capacity and backwater caused by each structure and improves the capability for mitigation planning.

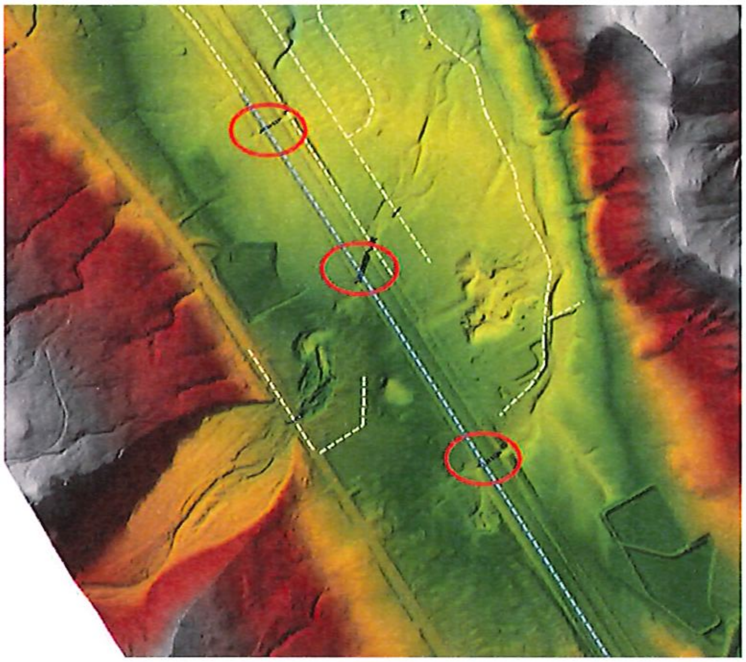


Figure 13. I90-S 2D/SA connection multiple crossings

3.6 Hydraulics Comment

2D/SA connections and breaklines occasionally are not located appropriately to capture the high point, resulting in premature overtopping of high point features. Blue line represents a better placement of the connection. Adjust the 2D/SA connections and breaklines to better represent the overtopping.

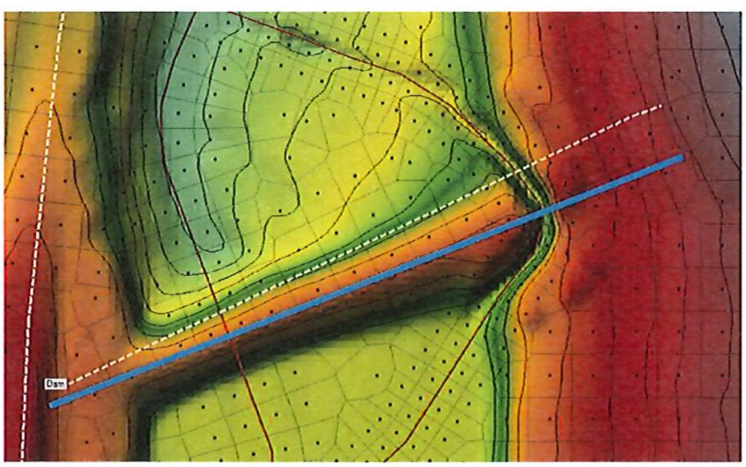


Figure 14. 2D/SA connection at the dam location requiring re-location

3.7 Hydraulics Comment

A number of elevated topographic features which will have a hydraulic impact on hydraulic conveyance and inundation extent are not captured with the current breakline and 2D/SQ connection configuration. Figure 15, Figure 16, and Figure 17 provide a few examples of topographic features that should be captured by breaklines, or locations where the actual high point was not captured with a current breakline. Refine the breaklines to capture the elevated topographic features.

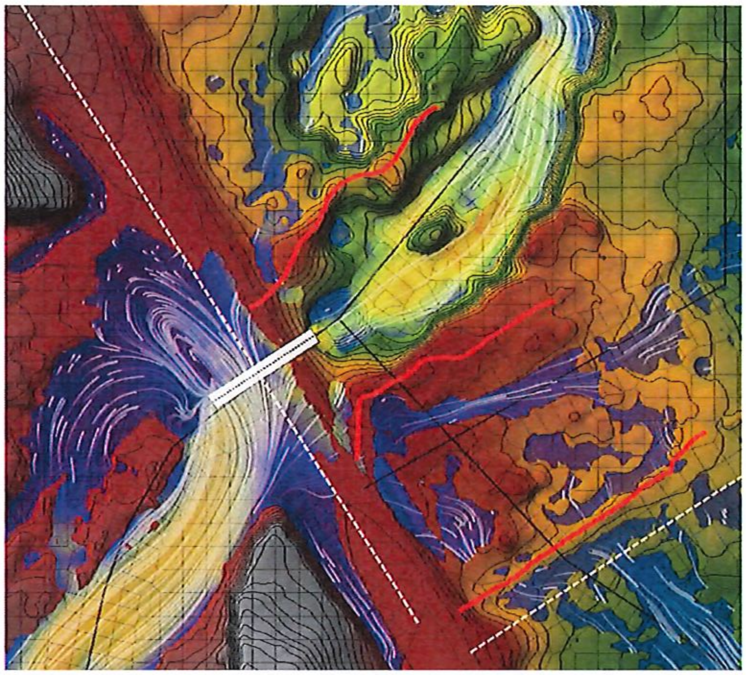


Figure 15. Breakline refinement to contain premature overtopping flows

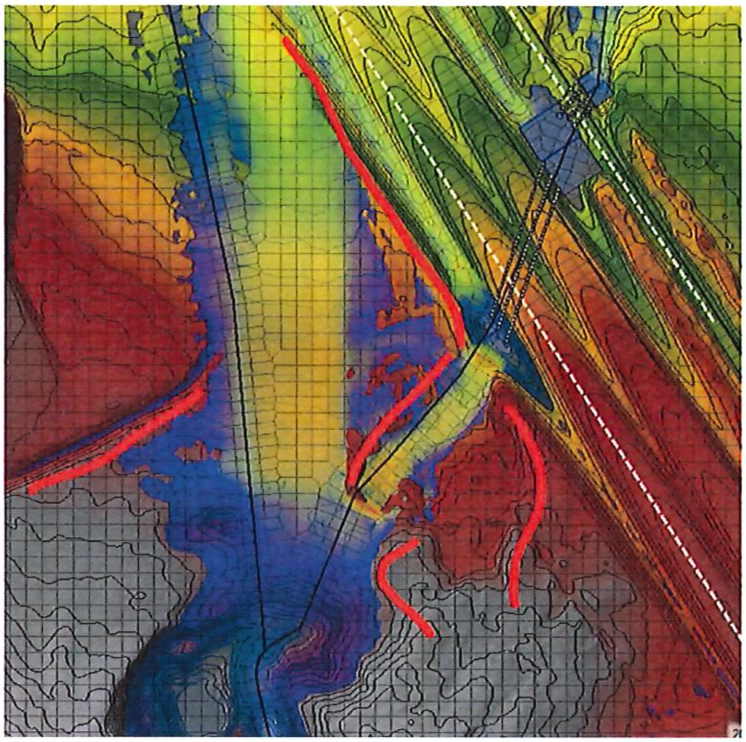


Figure 16. Breakline refinement to contain premature overtopping flows

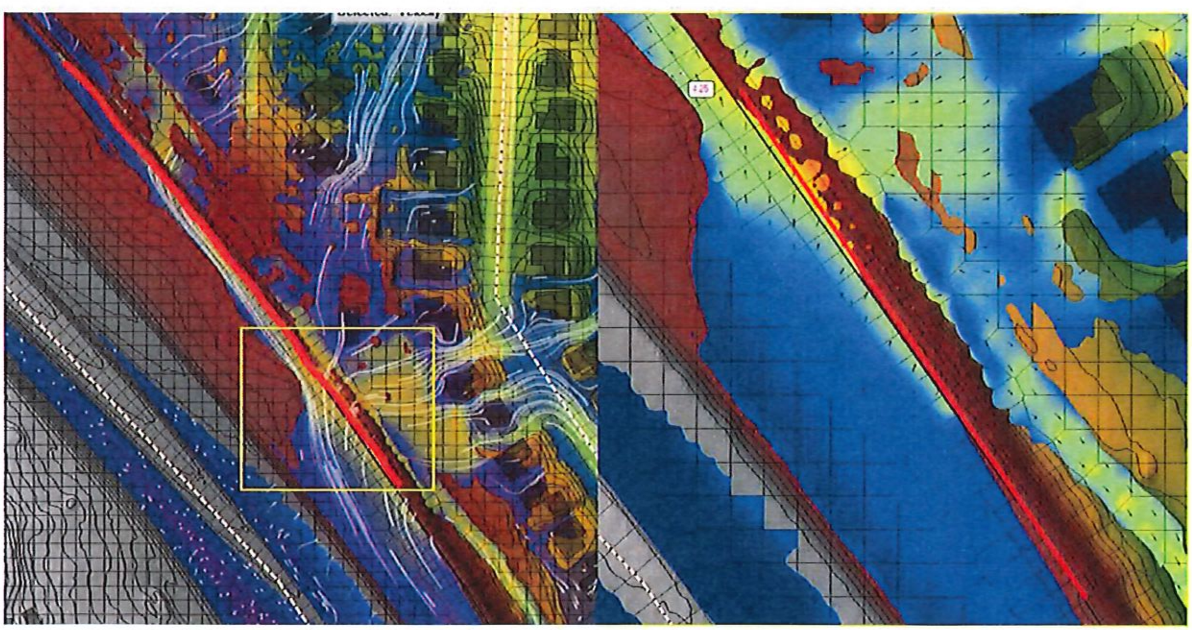


Figure 17. Breakline refinement to contain premature overtopping flows

4.0 Alluvial Fan and Mapping Comments/Questions

The 4-20-2023 meeting presentation and report appendices (COMPASS 2023) appear to generally follow the FEMA *Guidance for Flood Risk Analysis and Mapping – Alluvial Fans, November 2016* which provides the following three stage approach:

- Stage 1 – Recognizing and characterizing alluvial fan landforms
- Stage 2 – Defining the nature of the alluvial fan environment and identifying active and inactive areas of the fan
- Stage 3 – Defining and characterizing the 1-percent-annual-chance (100-year) flood within the defined areas

4.1 Alluvial Fan Step 1 Comments and Questions

The first step in the FEMA Guidance is characterizing the alluvial fan which requires geologic map review and field reconnaissance to determine whether the landform is composed of alluvium and use topographic info and aerial photos to assess whether flow paths radiate outward. The following comments and questions are in the order listed in the FEMA alluvial fan guidance:

4.1.1 – The alluvial fan apex has been identified in the 4-20-2023 meeting presentation. A separate hydrologic apex was not identified. Does this mean there is not a separate hydrologic apex? Interstate 90 is defined as a dividing line within the fan is this a separate topographic or hydrologic apex?

4.1.2 - The extent/toe/lateral boundary of the alluvial fan is defined in the 4-20-2023 meeting presentation and appendix (COMPASS 2023), but the boundaries cross low areas and defined flow paths. Why does the alluvial fan boundary cross low areas and why are there mapped flow paths outside limits of the alluvial fan boundary? Is the provided boundary the limits of the active alluvial fan and outside of this boundary the inactive portion of the alluvial fan?

4.1.3 - The geologic information used to define the alluvial fan is provided in the appendix (COMPASS 2023). Are multiple alluvial fans present in the study area, or just the Stagebarn Canyon alluvial fan?

4.2 Alluvial Fan Step 2 Comments and Questions

The second step is to define the active and inactive areas of the alluvial fan/fans. The historic aerials and soil type information were provided.

4.2.1 - Are there any other historic records from the highway department or railroad identifying washouts due to active alluvial fan flooding?

4.2.2 - Are the areas outside the defined flood hazard areas considered inactive areas?

4.3 Alluvial Fan Step 3 Comments and Questions

The third step of the FEMA guidance document provides methods to define the 1-percent annual chance flood including the limitations and recommended applications for various methods.

4.3.1 - The hydraulic analytical methods, such as HEC-RAS, are recommended for entrenched stable channel networks. Define the entrenched areas where the analytical methods are most applicable.

4.3.2 - According to the Stagebarn Canyon Study report (COMPASS 2023) and 4-20-2023 meeting presentation the flood profiles are based on HEC-RAS 2D modeling of an estimated 100-year flood hydrograph, and the model includes 8 blocked flow paths to force flow into different channels. Is this blocked flow path method defined in the FEMA guidance?

4.3.3 - The 4-20-2023 presentation materials state the floodplain mapping is the worst-case water surface elevation based on mapping of the 8 blocked flow path scenarios. Is the 1% chance area of inundation different than the worst-case scenario?

4.3.4 - The volume of the design flow hydrograph has a significant impact on the area being flooded. If the method used to develop the hydrograph changes, then the area of inundation will change as well.

5.0 Conclusion

HDR agrees the City of Summerset has flood risk due to Stagebarn Canyon flood flows. The questions related to hydrology, terrain, hydraulics, and alluvial fan mapping have the potential to adjust the areas of mapped flood risk, but the proposed adjustments will not eliminate the areas at risk of flooding. We look forward to continuing the collaborative effort between the City, FEMA, and Compass to define the flood risk for the community.

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compass
Identify, Interpret, Integrate

Hydraulic Study Report

Meade County, South Dakota - Stagebarn Canyon Alluvial Fan

Contract #HSFE60-15-D-0003
Task Order #70FBR821F00000021
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Prepared for:

US Department of Homeland Security
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APPROVALS

This document requires the approval of the following persons:

Role	Name	Phone Extension	Title (CLIN/RMC)	Review Date	Approved Date
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CLIENT DISTRIBUTION

Name	Title/Organization	Location
Margaret Doherty	Regional Project Monitor/ FEMA Region VIII	Denver, CO

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Acronyms

cfs	Cubic Feet Per Second
DEM	Digital Elevation Model
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
HEC-RAS	Hydrologic Engineering Center - River Analysis System
MIP	Mapping Information Platform
USACE	U.S. Army Corps of Engineers
USGS	United States Geological Service
WSEL	Water Surface Elevation

01 Introduction

1.1 Introduction and Background

This report presents the hydraulic study for the flooding sources within the Stagebarn Canyon Alluvial Fan study area in the southwestern portion of Meade County, South Dakota. Compass prepared this document in accordance with the Federal Emergency Management Agency (FEMA) Contract #HSFE60-15-D-0003, Task Order 70FBR821F00000021.

The project study area is shown in Figure 1. The analysis was performed in accordance with FEMA's Guidelines and Standards for Flood Risk Analysis and Mapping.

Figure 1. Stagebarn Canyon Study Area

1.2 Task Scope of Work

The purpose of this study is to investigate the existence and severity of flood hazards for Stagebarn Alluvial Fan. A fast-growing residential zone is situated on or in close proximity to the alluvial fan at the mouth of Stagebarn Canyon. Since the year 2000, numerous new residences have been constructed on or near the alluvial fan. Currently, there are no existing floodplain maps for this area, despite its history of flash floods and the occurrence of relatively frequent and larger paleofloods, which have been supported by geological evidence (Driscoll, Huft, & O'Connor, 2012).

Compass was tasked to perform the hydraulic analyses to determine water surface elevations (WSELs) for the 10-, 4-, 2-, 1-, and 0.2-percent-annual-chance flood events, as well as the 1-percent plus. The scope includes 2.43 miles of detailed study (Zone AE) stream.

A summary of the scope and study limits for the project area is shown in Table 1.

Table 1: Study Stream

Flooding Source	Upstream Study Limit	Downstream Study Limit	Study Mileage (miles)	Hydraulic Study Method
Stagebarn Canyon	0.2 miles upstream of Sturgis Road	0.1 miles downstream of Sturgis Road	2.4	2D Zone AE

1.3 Type of Flooding

The entire study area is riverine without any tidal influences. However, the study area is impacted by an active alluvial fan as discussed below.

1.4 Alluvial Fan

According to the FEMA Alluvial Fan Guidance (FEMA, 2016), the active alluvial fan is defined to be the portion of an alluvial fan where deposition, erosion, and unstable flow paths are possible. The guidance states that if flooding and deposition have occurred on a part of an alluvial fan in the past 100 years, clearly that part of the fan can be considered to be active.

The historic terrain data from 1953, 2012, 2017, and the Compass survey data gathered in 2021 were analyzed to assess the deposition and erosion of sediment across the alluvial fan area around Summerset, South Dakota. According to the analysis, the sediment transports are very active in the Stagebarn alluvial fan area since 1953. Large quantity of sedimentation has been transported from upstream canyon through the Stagebarn Canyon Creek to Elk Creek. It caused the increase of terrain elevation up to 12 feet within the alluvial fan. The change of stream course is possible as the sediment deposits are mounting across the fan. Historical record also showed at least one flood event, 1972 Black Hill flood, which is greater than the 100-year recurrence frequency for the alluvial fan area. The aerial maps showed the significant ground condition changes on Stagebarn alluvial fan since 1953. The soil type of the site also showed evidence of active sediment transport activities on the fan in the past 70 years. The geologic map also showed that the geologic structure in the alluvial fan area has a thick layer of alluvium deposit across the entire study site. Following the FEMA Alluvial Fan Guidance, based on the sediment activity and the flood record, it can be concluded that Stagebarn alluvial fan is active. In addition, the active area should cover the entire fan. The active area is shown in Figure 2. In the figure, the active area is the area where the sediment transport is significantly active during the past 100 years as a condition specified by the guidance. Based on the original alluvial fan domain and the terrain change history in additional to the land development history, the active area was delineated for the alluvial fan as shown in Figure 1. Part of the residential area was included as the active area because of its proximity to the natural stream path and the potential risk of mudflow from upstream canyon. The I-90 highway may have certain protective effect like a levee for the downstream area against flood from the canyon. However, in the event of mudflow or debris flow, the flood can still overtop I-90 and move downstream. The residential area near the stream will be in its path.

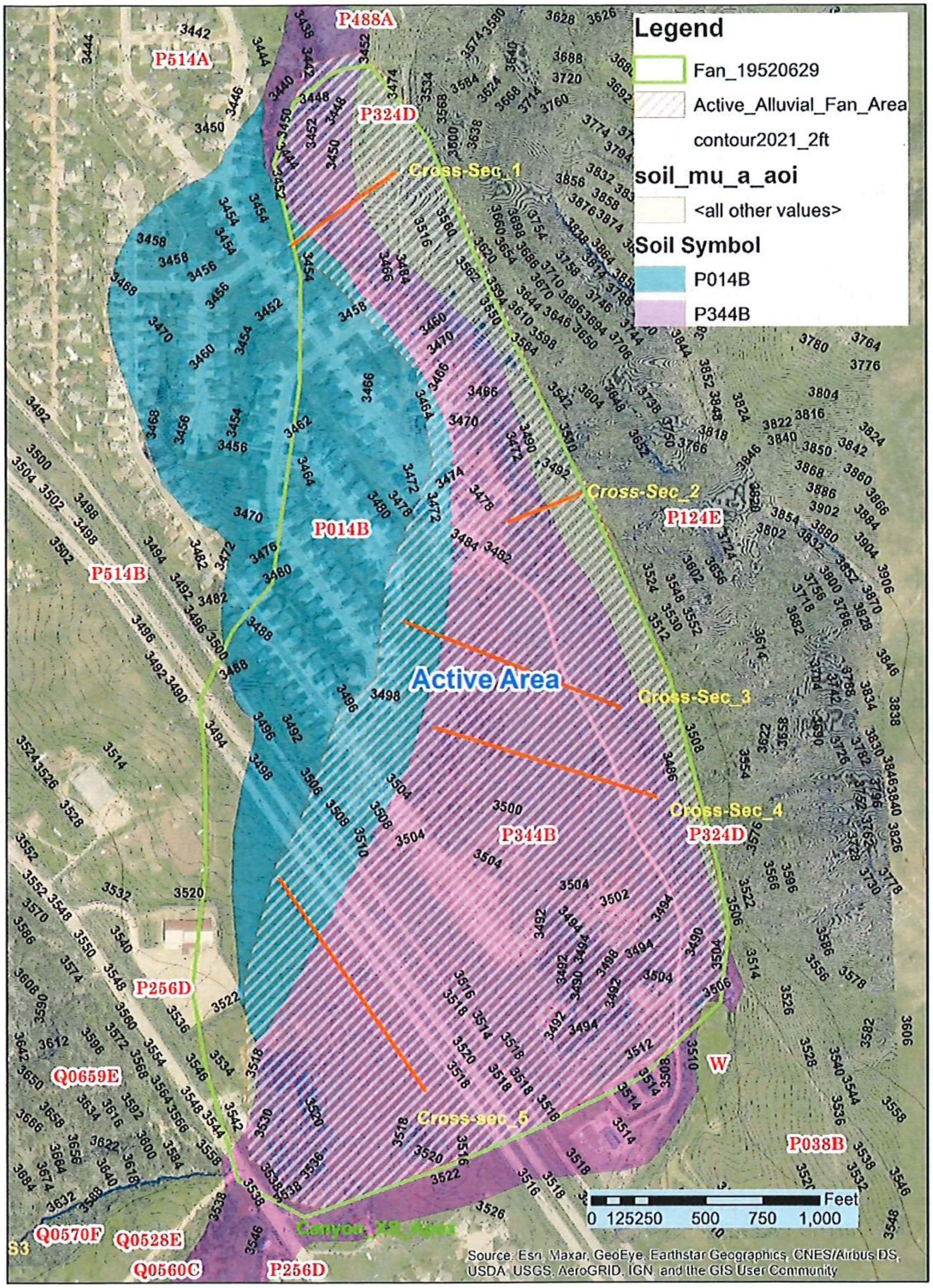

Figure 2: Active area for Stagebarn Alluvial Fan

1.5 Flooding History

The Black Hills area, that is the headwater of Stagebarn Canyon, has a history of destructive flash floods primarily caused by intense thunderstorms that produce heavy rainfall. One well-known example is the devastating storm that occurred on June 9-10, 1972. This particular event led to the most severe flooding ever recorded in several major drainage areas near Rapid City, resulting in the loss of 238 lives and 3,057 injuries (Carter et al., 2002).

Another notable flooding took place on August 17, 2007, when a series of severe thunderstorms caused substantial precipitation and flash flooding in and around the towns of Hermosa and Piedmont (Holm and Smith, 2008). The 2007 storm caused some of the most significant flooding in the Black Hills region since 1972. Along Battle Creek near Hermosa, the peak flow during the 2007 flood was only slightly smaller than the record flood experienced at the same location in 1972.

The year 1907 stands out as a significant period for flooding in the Black Hills area. The presence of wet conditions was initially indicated by an article in the Deadwood Pioneer Times on May 19, 1907, which recounted the 1883 flooding in the Deadwood region. Subsequent articles described widespread disruptions to rail services and a rapid rise in the Belle Fourche River at Belle Fourche, reaching its highest level since 1883. On May 26, 1907, another article in the Deadwood Pioneer Times reported a record late snowfall of at least 2.5 feet in the Deadwood area following heavy rain over a period of 60 hours. A June 1, 1907, article in the Rapid City Journal reported very high water levels and flooding of a "government gauge" on the lower Cheyenne River. According to the records from the National Weather Service office in Rapid City (station 396947), 8.09 inches of precipitation were recorded in May 1907, with a total of 6.11 inches occurring during May 23-25 (South Dakota State University, 2009). Unfortunately, the closest available United States Geological Service (USGS) streamflow data for 1907 is for the Little Missouri River at Medora, North Dakota (station 06336000), which recorded a peak flow of 29,000 cubic feet per second (ft^3/s) on June 24. Several news articles indicated that the June 1907 storm likely produced heavy rainfall over an area north and west of Rapid City. Based on these accounts, the severity and scale of the 1907 storm and flooding may have approached that of the 1972 event. Detailed descriptions by Honerkamp (1978) suggested that the storm activity was centered, at least in part, over the drainage area for Stagebarn Canyon, where flooding was particularly severe.

At station 06422500 (Boxelder Creek near Nemo), located just south of the headwaters of Stagebarn Canyon, Little Elk Creek, and Elk Creek, a peak flow of 16,000 ft^3/s occurred on June 12, 1907. This indicates heavy precipitation upstream from this station. An article in the Black Hills Press on June 19, 1907, described a "wall of water" estimated to be fifteen feet high flowing down Stagebarn Canyon (Driscoll et al., 2010). This report aligns with Honerkamp's (1978) account of flood debris found 18.5 feet above the floor of Stagebarn Canyon, indicating a significant peak flow.

Flooding in the Piedmont region was localized. On August 18, 2007, the highest recorded flow at the USGS streamflow-gauging station 06425100, located near Rapid City on Elk Creek, was only 68 cubic feet per second (cfs). This station is situated approximately 10 miles downstream from Piedmont. The drainage area for this particular station covers 211 square miles and encompasses a significant portion of the Piedmont area affected by the 2007 storm. Field inspections revealed that numerous small drainages in the Piedmont region experienced flows well above 68 cfs. Notably, Stagebarn Canyon (with a drainage area of 17.2 sq. mi) recorded a flow of 1,600 cfs (Driscoll et al., 2010). Hence, it appears that as the floodwaters moved downstream from Piedmont through extensive channel networks with substantial alluvial deposits, significant reduction or attenuation of localized flood peaks took place.

1.6 Existing Hydraulic Studies

There is no current effective study for Stagebarn Canyon.

02 Resources

While there is no current effective study for Stagebarn Canyon, a recent study by U.S. Army Corps of Engineers (USACE) (USACE, 2018) has been performed for Stagebarn Alluvial Fan area. The extent of this study is from Sturgis Road to about 0.1 miles upstream of confluence with Elk Creek. This study includes regression hydrology, survey for structures, and 2D hydraulics. The data from this study was leveraged for the current study. These studies will be in the Supplemental folder on the Mapping Information Platform (MIP) case for this project. Subsequently, FEMA Region 8 authorized Compass to complete a Stage-1 analysis of the alluvial fan before this project which had not been done before. During this project a Stage-2 and Stage-3 analysis were also completed. The Stage-1 and Stage-2 analyses are in Appendices 1 and 2 in this report document.

03 Methodology and Modeling

Hydraulic analyses consisted of determining WSELs for the 10-, 4-, 2-, 1-, and 0.2-percent-annual-chance exceedance events for all streams, as well as the 1-percent-plus for all scoped streams.

3.1 Methodology

The hydraulic model used for this flood study is the USACE Hydrologic Engineering Center – Hydrologic Modeling System (HEC-RAS), version 6.3. The hydraulic model represent 2D unsteady state flow conditions.

The horizontal projection for this study is NAD_1983_CORS96_StatePlane_South_Dakota_North _FIPS_4001_Ft_US and the vertical datum is the horizontal projection and North American Vertical Datum of 1988.

3.2 Topography

Compass leveraged the best available data that is the 2017 USGS SD FY17 NRCS Lidar 1-meter Digital Elevation Model (DEM). This topographic data source was used, and the survey data was incorporated to create a blended terrain. The survey data was collected in September 2021 and was submitted as part of the Survey Data Capture Stagebarn Canyon, South Dakota, Alluvial Fan – 01 task. The blended terrain consisting of the 2017 bare earth 1-meter DEM and the survey data make up the final bare earth 1-meter DEM used to conduct the 2D hydraulic analyses needed to create and publish regulatory Special Flood Hazard Areas (SFHAs) for the Stagebarn alluvial fan.

The 2017 USGS SD FY17 NRCS Lidar 1-meter DEM was projected to North American Datum of 1983 State Plane South Dakota South Federal Information Processing Series (4002) feet and elevations units converted to feet. To develop a blended terrain consisting of survey data and the 2017 USGS SD FY17 NRCS Lidar 1-meter DEM for ground points, the 1-meter DEM was converted to points and imported to a feature dataset within a File Geodatabase. The September 2021 survey point data was also imported into the feature dataset, as well as a bounding polygon for the study area. An ESRI terrain was created from the 1-meter points and survey points. A buffer area between 5 to 10 feet was set around the survey cross sections to remove or "turn off" the 1-meter points from the terrain surface allowing the survey points to capture the elevations at cross sections. The Engineering team performed quality control checks throughout the workflow. There were several iterations of the blended ground and survey terrain surface to correct steep slopes and better capture road features within the terrain surface. The figure below depicts DEM and surveyed data along the Stagebarn alluvial fan.

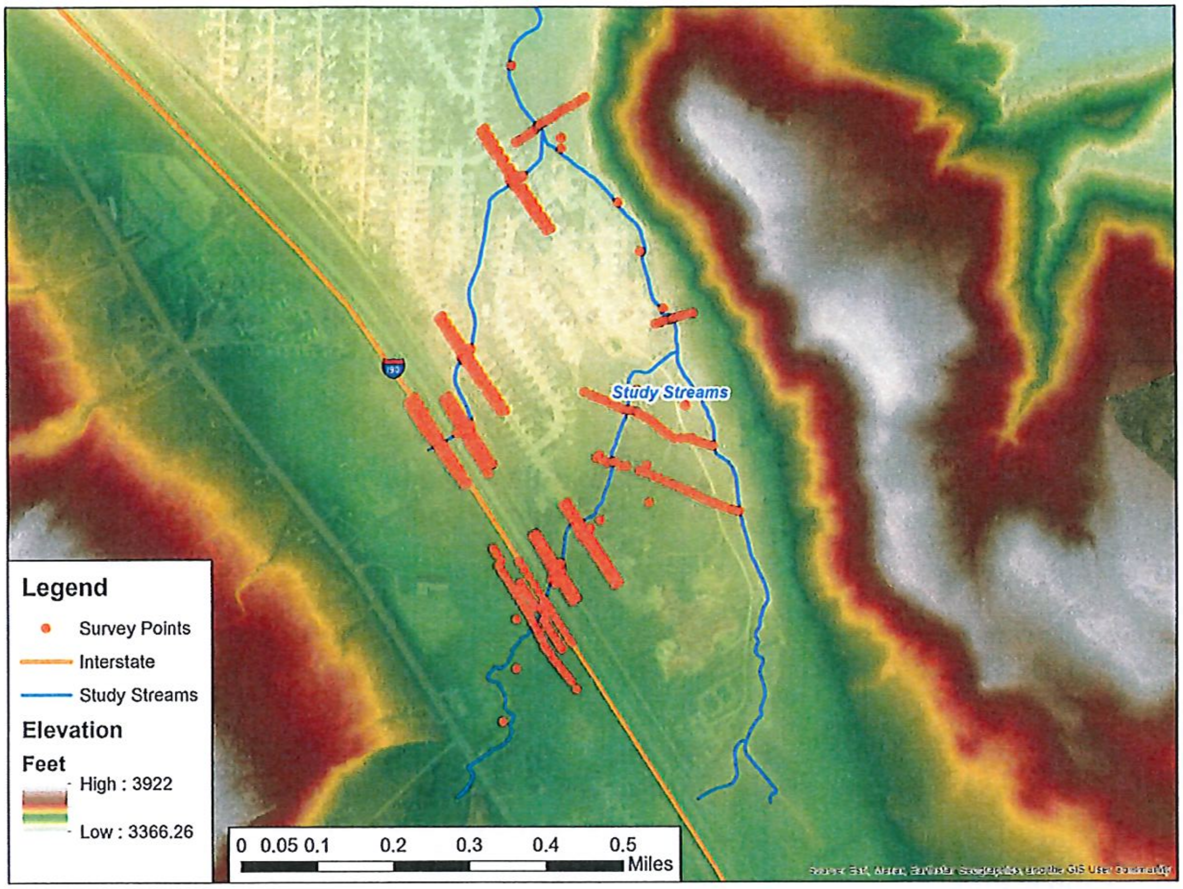

Figure 3: Stagebarn Elevation Data

3.3 Survey

For this Task Order, the surveyors performed eight detailed structure and five natural cross section field surveys.

Surveyed items for bridges include the deck, low chord, parapet, opening widths, rail heights and lengths, pier dimensions, and channel sections at the upstream and downstream faces. Surveyed items for culverts include the culvert dimensions, soffit, inverts, top of road, and channel sections at the upstream and downstream faces. Photos were taken of each surveyed structure.

In addition to the above survey data, the structure data from the USACE model for Stagebarn (USACE, 2018) was leveraged and used for the 2D model of this study.

3.4 Model Domain and Parameters

The 2D model domain covers an extended area of the alluvial fan from 0.2 miles upstream of Sturgis Road to 0.1 miles downstream of Elk Creek Road (see Figure 4). The Stagebarn alluvial fan was studied as a fluvial model using inflows leveraged from regression hydrology of USACE study (USACE, 2018).

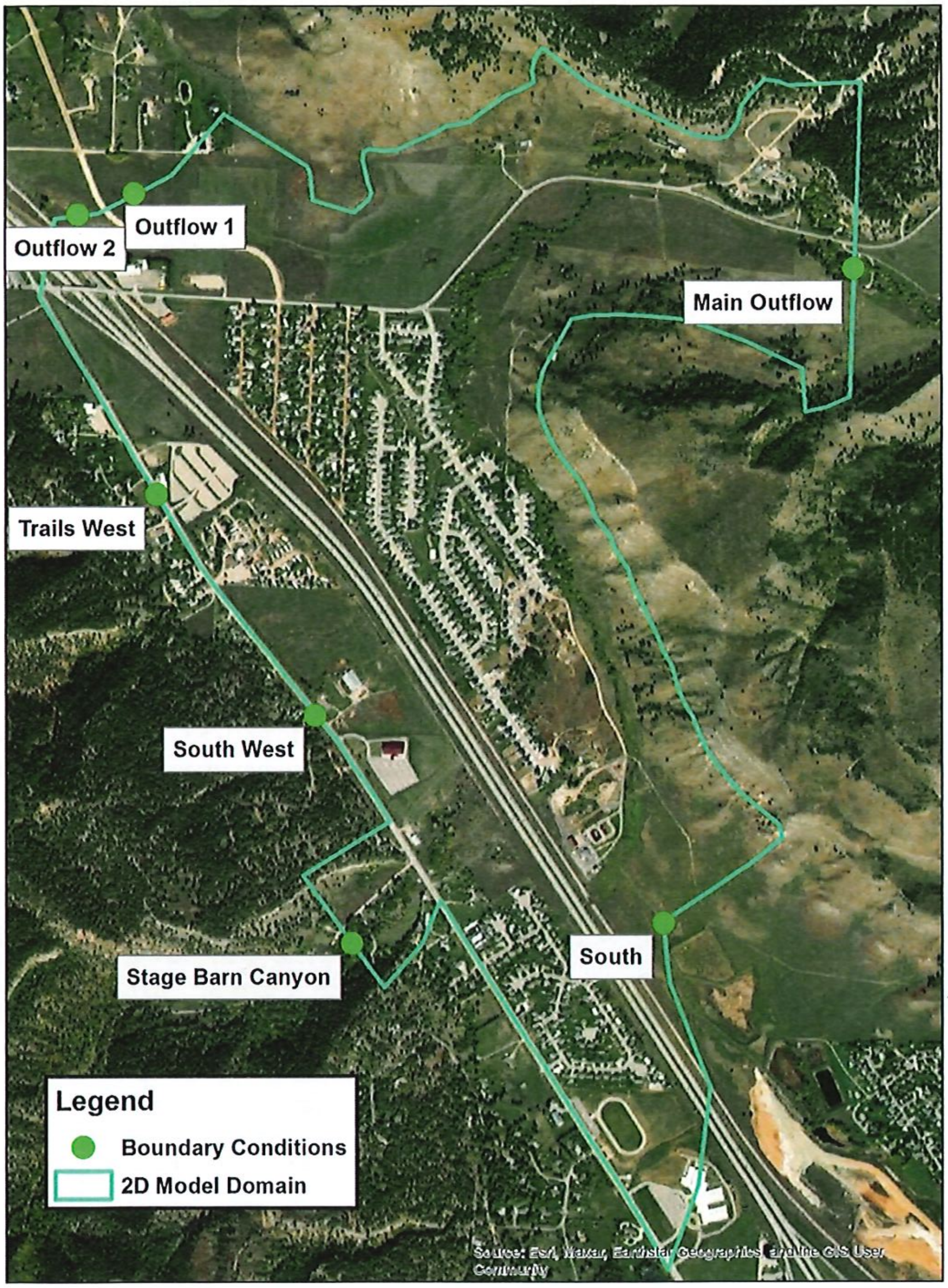

Figure 4: Stagebarn Zone AE Model Domain and Boundary Conditions (Inflows and Outflow)

3.4.1 Model Parameters

The 2D model was run using HEC-RAS 6.3 with the Full Momentum, Shallow Water Equations, Eulerian-Lagrangian Method (SWE-ELM). Table 2 shows a summary of the methodology and settings used for the 2D model.

Table 2: Summary of Model Parameters

Model Settings	BLE Methodology used
Software	• HEC-RAS Version 6.3
Equation	• SWE-ELM
Initial Conditions	• Start Completely Dry
Time Step	• 1 Second
Nominal Mesh	• 50-foot x 50-foot cell size • 4-sided
Mesh Refinement	• Alluvial Fan Active Area (20-foot) • Stream Corridor (15-foot) • Transportation features and embankment (15-foot)

3.5 Hydrology

For the hydrology portion of this study, flows have already been computed by the USACE in 2018. The Hydrology Report of this Compass study describes details of the analysis to confirm the applicability of USACE flows for the 10%, 2%, 1%, 1%+, and 0.2% events and the methodology to include the 4% flow. Peak flows were also computed at the inflow locations shown in Figure 4 using StreamStats 3.0. To better represent inflow conditions, the peak flows were converted into unsteady flow hydrographs by scaling a nearby inflow hydrograph along Whitewood Creek. Table 3 summarizes the inflows to the 2D model of this study.

Table 3: Summary of Hydrologic Methods

Boundary Condition	Hydrograph Peak Flows (cfs) for Modeled Events					
	10% Annual Chance	4% Annual Chance	2% Annual Chance	1% Annual Chance	1%+ Annual Chance	0.2% Annual Chance
Stagebarn Canyon	398	840	1,420	2,230	3,657	5,590
Southwest	48.2	102	171	267	438	667
South	144	284	458	690	1,131	1,560
TrailsWest	67.1	142	240	375	615	944

3.6 Hydraulics

3.6.1 Manning's Roughness Values

Manning's n-values were updated and enhanced for the new development area from the USACE study. Available resources including building footprints and aerial imageries were used to define buildings in the 2D model. For the buildings, an extremely high n-value of 10 was used to represent zero conveyance at these locations.

3.6.2 Structures

Most structures along the streams were included in the USACE model based. Compass field survey (discussed above) was utilized to add additional structures or update existing structures as needed. All structures were represented in the models as internal connections utilizing the measurements from field survey. Structure settings for entrance and exit loss coefficients, and bridge modeling approaches were determined based on the HEC-RAS Hydraulic Reference Manual (USACE, 2016). Survey structure information provides a detailed analysis of the impacts of structures on flooding. For hydraulic simulations, bridges and culverts were assumed to remain fully functional and have unobstructed flows.

3.6.3 Mesh Refinement

The 2D area mesh was refined in the active area of the alluvial fan and the newly developed area. All transportation features and other embankments were represented with breaklines to capture the high ground in the terrain that may impact flow. Additionally, breaklines were added for stream channels to increase cell density and represent channel banks within these areas.

3.6.4 Alluvial Fan Modeling

Alluvial fans are landforms with a gently sloping, fan-like shape that develop gradually as sediment eroded from higher areas is deposited over time. During a flood event, especially torrential rainfalls, soils and rocks can be washed off from mountain slopes and carried to the alluvial fan at downstream of the valley. Flood from upstream slopes normally carries high density of sediments. The sediments will start settling and deposit on the ground surface when flow becomes slow. Some old deposit on the ground surface could be eroded and moved downstream when flow from upstream is strong enough to cause erosion (National Research Council, 1996). According to the regulations of the National Flood Insurance Program, alluvial fan flooding is defined as "flooding occurring on the surface of an alluvial fan or similar landform which originates at the apex and is characterized by high-velocity flows; active processes of erosion, sediment transport and deposition; and unpredictable flow paths." Alluvial fan flooding is characterized by a high level of uncertainty regarding the flow path of the floodwaters, which is so significant that it cannot be disregarded when assessing flood risk or implementing effective mitigation measures (National Research Council, 1996). To account for uncertainty of the flow path, eight hypothetical scenarios for potential sediment deposition were developed based on the flow characteristics of the 1% annual chance flood under existing conditions. These scenarios define where sediment deposition may occur in future and consequently change the flow path. Figure 5 shows the identified potential location of sediment deposition. The hydraulics models for these scenarios were developed by raising the terrain at the sediment deposition locations.

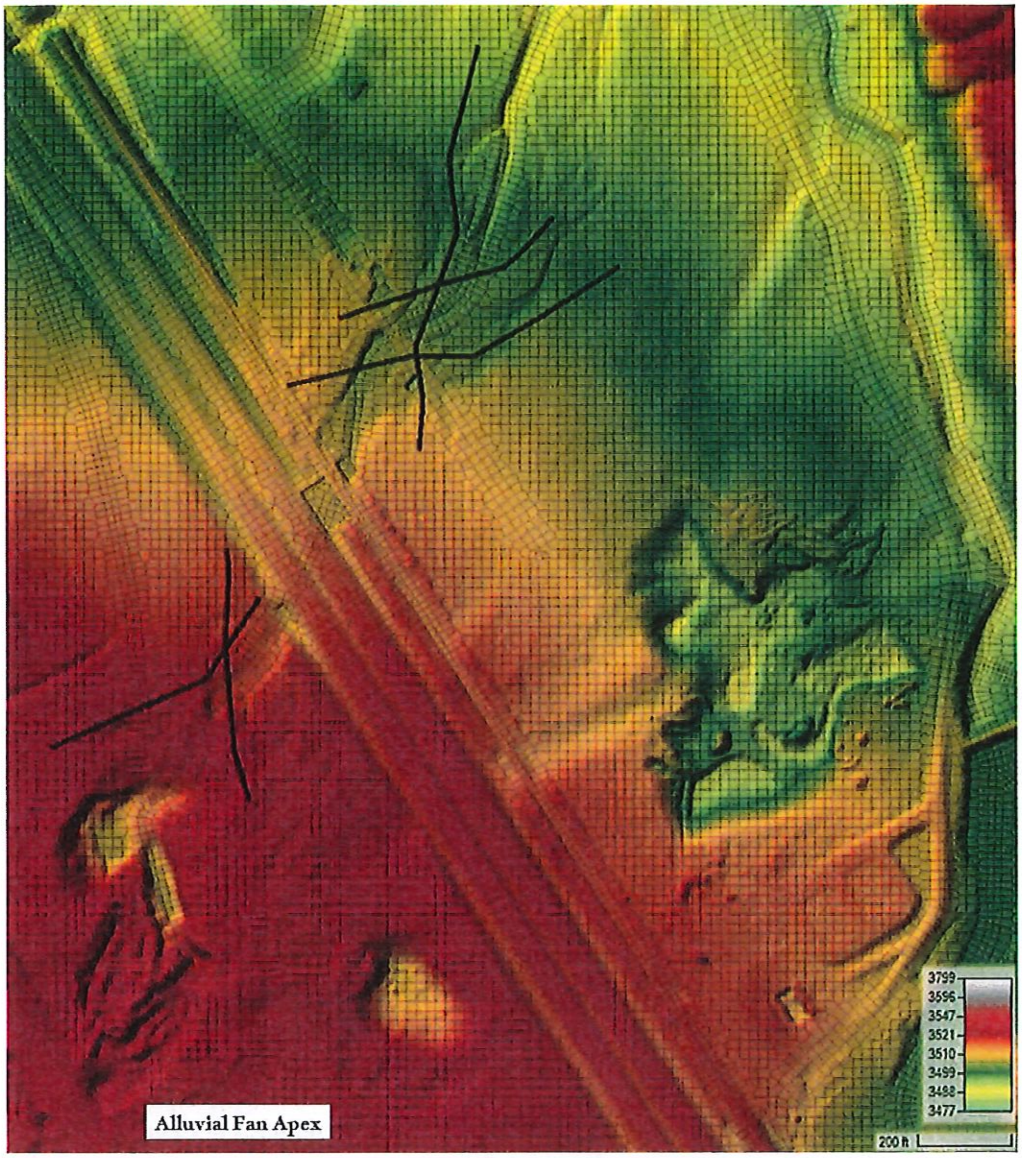

Figure 5: Identified Potential Location (Black Lines) of Sediment Deposition

3.7 Modeling Assumptions

1. Manning's roughness coefficients were based on the USACE model and revised for the recent developments. Manning's roughness coefficients are identical for all modeling scenarios.
2. The structure at Sturgis Road was not surveyed, and the required data for modeling was determined from the available resources including DEM, imagery, and street view.
3. The scenarios (future conditions) of the alluvial fan are hypothetical representations of potential flow path changes. The simulation of flow path changes is beyond the scope of this study due to the complexity and uncertainty of the alluvial fan development.

3.8 Floodway

No floodway included in the study.

3.9 Floodplain Boundaries

Floodplain boundaries for each flood frequency were defined using maximum WSEL (worst case scenario) out of eight alluvial fan scenarios explained above. Figures below show the flood depth for 10% and 1% annual chance flood.

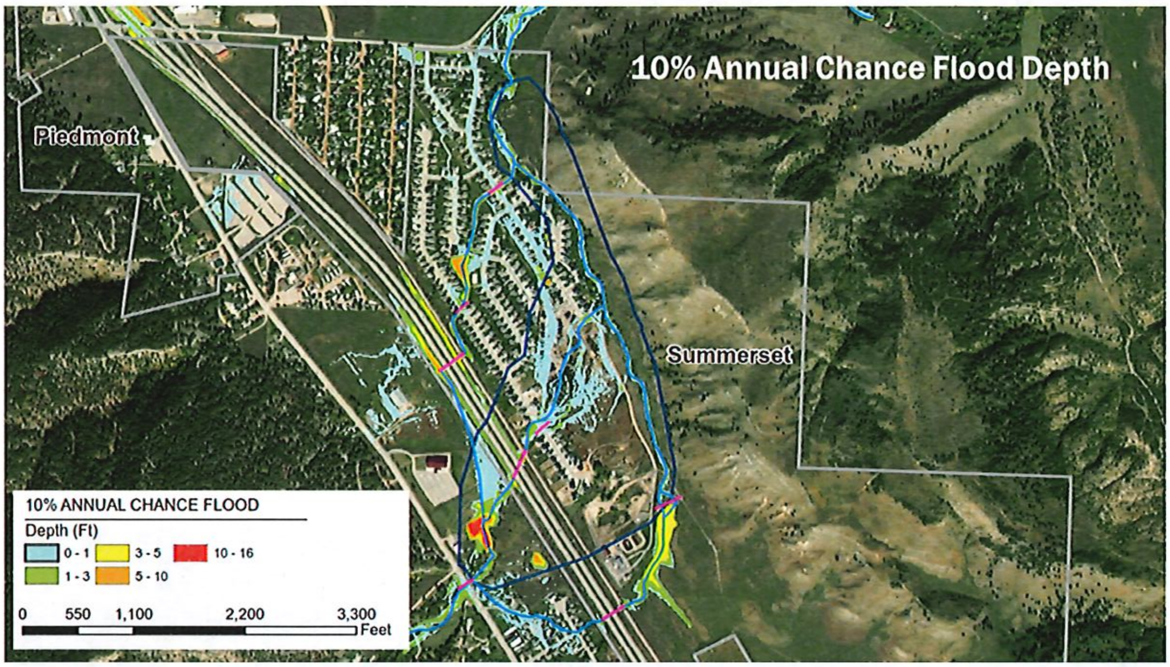

Figure 6: 10% Annual Chance Flood Depth. The dark blue line defines the active alluvial fan area.

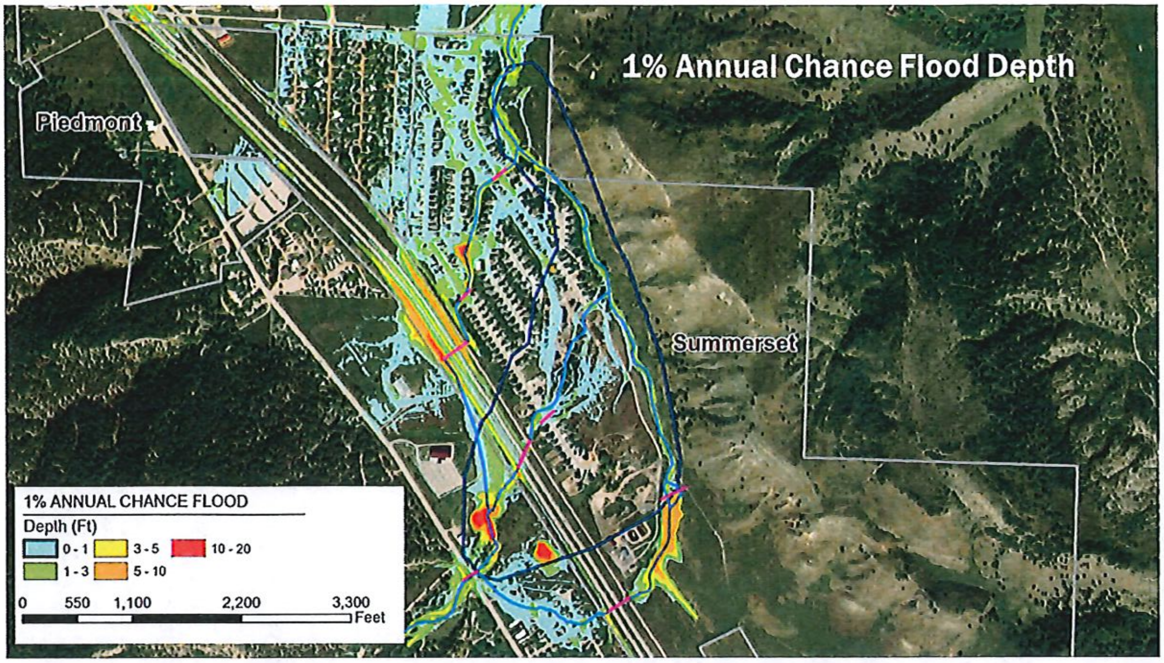

Figure 7: 1% Annual Chance Flood Depth. The dark blue line defines the active alluvial fan area.

Figure 8 illustrates the SFHAs developed based on the worst case scenario.

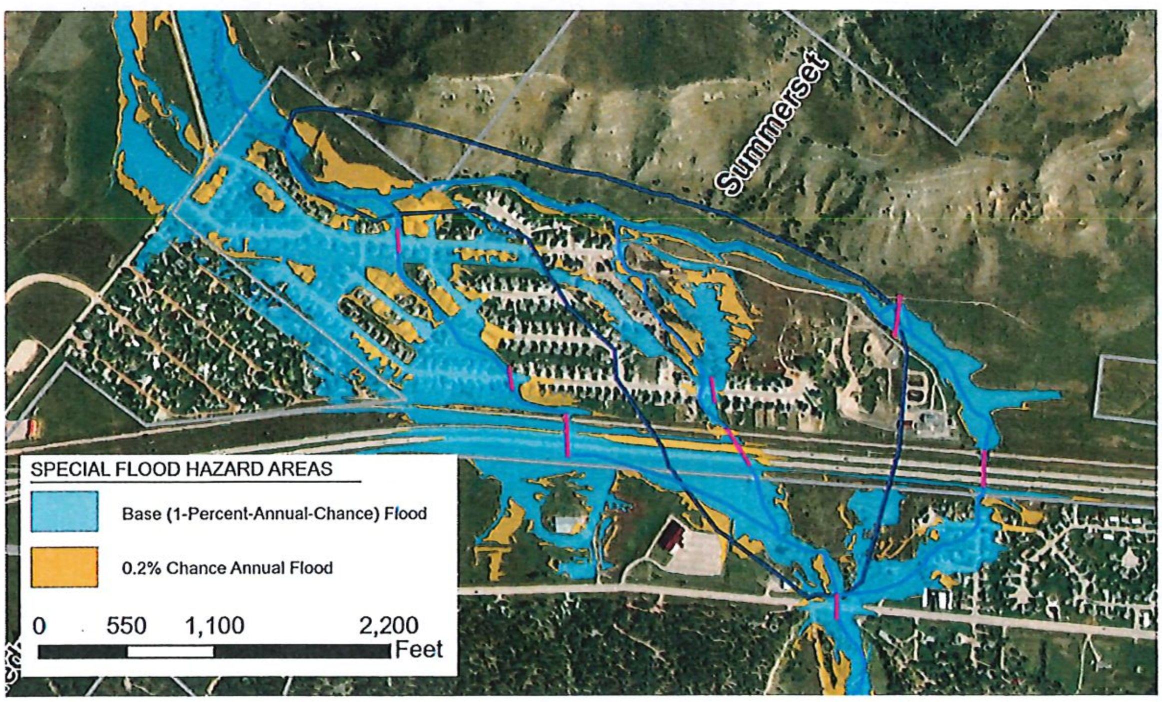

Figure 8: Special Flood Hazard Areas. The dark blue line defines the active alluvial fan area.

3.10 Quality Check

The hydraulics model was reviewed by Compass partners to assure the model is consistent with the general FEMA requirements and specifically with the Guidance for Flood Risk Analysis and Mapping Hydraulics: Two-Dimensional Analysis 2016.

3.11 Special Consideration

No special consideration for this study.

04 Other Supporting Documentation

No active Letters of Map Revisions or Levees were identified along any of our detailed studied flooding sources.

05 Results and Effective Water Surface Elevation Comparison

No effective study available for the stream of this study.

06 Conclusions

This report documents the hydraulic methodology and analyses used to determine WSEL values for the 10-, 4-, 2-, 1, and 0.2-percent-annual-chance events, as well as the 1-percent-plus. The computed WSELs were used to generate the floodplain boundary extents for the studied streams for the 1- and 0.2-percent-annual-chance events. All hydraulic calculations, models used, and modeling methodology meet FEMA specifications to be used for Flood Insurance Rate Map (FIRM) production.

Hydraulic spatial files and model input and output files, where applicable, were developed in accordance with FEMA's *Data Capture Technical Reference* (FEMA, 2018a) and *FIRM Database Technical Reference* (FEMA, 2018b). The data is included in the MIP submittal package along with a digital copy of this report.

The Floodplain Mapping was performed to refine the engineering floodplains generated under the Hydraulics task according to FEMA specifications.

07 References

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