South Dayton Valley Area Drainage Master Plan

Technical Support Data Notebook

June 2020

prepared for

Lyon County | Carson Water Subconservancy District

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Table of Contents

1 Introduction 1

1.1 Project Purpose 1

1.2 Project Location 1

1.3 Previous Studies 3

1.3.1 Subdivision Drainage Reports 3

1.3.2 Flood Insurance Studies 4

1.3.3 U.S. Army Corps of Engineers Alluvial Fan Mapping 6

1.4 Historical Flowpath Assessment 9

1.4.1 Aerial Photography 9

1.4.2 Summary 9

2 Hydrologic and Hydraulic Modeling 13

2.1 Method Description 13

2.2 Model Development 13

2.2.1 Spatial Reference System 13

2.2.2 Model Domains 13

2.2.3 Grid Size 15

2.2.4 Grid Element Elevations 15

2.2.5 Model Inflow/Outflow 17

2.2.6 Precipitation Development 19

2.2.7 Infiltration Development 20

2.2.8 Grid Element Roughness (Manning's n Values) 25

2.2.9 Hydraulic Structures 28

2.2.10 Buildings (as Flow Obstructions) 31

2.2.11 Model Adjustments 32

2.2.12 Model Control Parameters 34

2.3 Model Results 35

2.3.1 Floodplain Cross-Sections 35

2.3.2 Depth and Discharge Results 40

2.3.3 Animations 40

2.4 Verification of Results 47

2.4.1 Comparison with USGS Regression Equations 47

2.4.2 Additional USGS Data 50

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2.4.3 Historical Flooding Documentation 52
2.4.4 Eldorado Canyon Dam 57
2.5 Summary 59
3 Sedimentation Analyses 61
3.1 Sediment Sampling and Transport Analysis 61
3.1.1 Sediment Sampling 61
3.1.2 Sediment Transport Analyses 65
3.2 Results 66
4 Flood Hazard Classification 70
4.1 Purpose 70
4.2 Flooding Hazards to Pedestrians 70
4.3 Flooding Hazards to Passenger Vehicles 73
4.4 Flooding Hazards to Structures 78
4.5 Building Inundation Assessment 81
4.5.1 Methodology 81
4.5.2 Base Conditions 81
4.6 HAZUS Analyses 83
4.6.1 Methodology and Purpose 83
4.6.2 Base Conditions 84
4.7 Summary 84
5 Regional Flood Mitigation Alternatives 85
5.1 Introduction 85
5.2 Mitigation Alternatives 86
5.2.1 Alternative 1 86
5.2.2 Alternative 1a 86
5.2.3 Alternative 1b 87
5.2.4 Summary 87
5.3 Selected Regional Mitigation Alternative 92
5.4 Ranchos Drainage Improvement Assessment 95
5.4.1 Introduction 95
5.4.2 Methodology and Results 98
5.5 Selected Regional Alternative Conceptual 15% Design Plans 103
5.6 Benefits Summary 104
5.6.1 Buildings Benefit 104

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5.6.2 Flood Risk Area Reduction Benefit 106
5.6.3 Flood Depth Reduction Benefit 106
5.7 Future Design Considerations 115
6 ADMP Mitigation Prioritization 116
6.1 Potential Funding Sources 118
6.2 ADMP Limitations 121
7 References 122

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List of Figures

Figure 1-1. Study area vicinity map 2
Figure 1-2. Effective FEMA Floodplains 5
Figure 1-3. Distribution of relative risk rankings by watershed, from Floyd (2017) 7
Figure 1-4. USACE alluvial fan risk ranking 8
Figure 1-5. 1948 aerial photography 10
Figure 1-6. 2017 aerial photography 11
Figure 1-7. Historical flowpath comparison 12
Figure 2-1. Modeling domains used in the South Dayton Valley ADMP 14
Figure 2-2. Limits of topographic mapping data 16
Figure 2-3. Hydrograph flow transfer between FLO-2D models 18
Figure 2-4. Comparison of 6- and 24-hour hyetographs used in the SDVADMP (with comparison to DVADMP) 20
Figure 2-5. Hydrologic Soil Group (HSG) classifications in the South Dayton Valley ADMP, from NRCS (2019) 21
Figure 2-6. Cover type delineation used in selection of curve numbers 23
Figure 2-7. Spatial distribution of curve numbers used in the FLO-2D modeling 24
Figure 2-8. Example of typical watercourse in the upper piedmont areas 26
Figure 2-9. Surface classification used to assign grid element roughness in the FLO-2D model 27
Figure 2-10. Locations of all modeled hydraulic structures (storm drains and culverts) 29
Figure 2-11. Comparison of water surface elevations at the upstream/downstream inlet and outlet cell location with (left) and without (right) box culverts. 30
Figure 2-12. Locations and types of model adjustments 33
Figure 2-13. Example of typical vegetation and rock cover in the upper piedmont areas 35
Figure 2-14. Floodplain cross-section locations 36
Figure 2-15. Existing conditions 25-year, 24-hour flow depth results 41
Figure 2-16. Existing conditions 100-year, 6-hour flow depth results 42
Figure 2-17. Existing conditions 100-year, 24-hour flow depth results 43
Figure 2-18. Existing conditions 25-year, 24-hour discharge results 44
Figure 2-19. Existing conditions 100-year, 6-hour discharge results 45
Figure 2-20. Existing conditions 100-year, 24-hour discharge results 46

Figure 2-21. Comparison of FLO-2D results with the relations between 100-year peak discharge and drainage area and plot of maximum peak discharge of record and drainage area for gaged sites in the Eastern Sierras Region 5, adapted from USGS (1997). 48
Figure 2-22. Drainage basins used for comparison of FLO-2D results to the USGS 100-year regression equations 49
Figure 2-23. Drainage area statistics for USGS crest stage sites 50
Figure 2-24. Location and drainage areas of USGS crest stage sites 51
Figure 2-25. Comparison of FLO-2D results, 1997 100-year regression equation, and peak flow estimates from crest stage sites 52
Figure 2-26. Verification for 108 Rancho Road 53
Figure 2-27. Verification for 130 Nugget Lane 54
Figure 2-28. Verification for Dayton Valley Road near Gold Creek Drive 55
Figure 2-29. Verification for Sutro Road near Dayton Valley Road 56
Figure 2-30. Current elevation-storage curves for Eldorado Canyon Dam based on USGS QL1 LiDAR and FLO-2D cell elevations 57
Figure 2-31. Comparison of FLO-2D and HEC-RAS maximum water surface elevations for the 100-year 24-hour event 59
Figure 3-1. Example of sediment deposition at culvert 61
Figure 3-2. Sediment sampling locations labeled with ID 62
Figure 3-3. Gradation curves for the twelve sediment samples 63
Figure 3-4. Total accumulated sediment transport capacity by the Yang methodology for the 100-year, 24-hour event 67
Figure 3-5. Cumulative sediment transport profile for the primary overland flow path throughout the 100-year 24-hour event 69
Figure 4-1. Depth-Velocity flood danger level relationship for children, from USBR (1988) 71
Figure 4-2. USBR criteria flooding hazards to pedestrians based on the 100-year, 24-hour results 72
Figure 4-3. Depth-Velocity flood danger level relationship for passenger vehicles, from USBR (1988) 73
Figure 4-4. USBR criteria flooding hazards to vehicles based on the 100-year, 24-hour results 75
Figure 4-5. Hazardous road crossings during a 100-year, 24-hour storm (USBR criteria) 76
Figure 4-6. Hazardous road crossings during a 25-year, 24-hour storm (USBR criteria) 77
Figure 4-7. Depth-Velocity flood danger level relationship for structures built on foundations, from USBR (1988) 78
Figure 4-8. USBR criteria flooding hazards to buildings based on the 100-year, 24-hour results 80
Figure 4-9. Building inundation assessment (100-Year, 24-Hour) result example 82
Figure 5-1. Development process for the regional flood mitigation alternatives for the ADMP 85
Figure 5-2. Conceptual layout of Alternative 1 89
Figure 5-3. Conceptual layout of Alternative 1a 90
Figure 5-4. Conceptual layout of Alternative 1b 91
Figure 5-5. Selected mitigation system 93
Figure 5-6. Examples of typical driveway culverts in study area (note sediment clogging and available headwater depth). 96
Figure 5-7. Ranchos area vicinity map 97
Figure 5-8. Drainage improvement concepts for the Ranchos area 99
Figure 5-9. Typical section required for a new channel in the Ranchos 100
Figure 5-10. Example of cross-section with slight overtopping (see left bank) 101

Figure 5-11. Approximate flow discharges and channel slope calculations 102
Figure 5-12. Example 15% design plan sheet for Basin #2 104
Figure 5-13. Potential flood risk area reduction benefit: 25-Yr Alt System, 25-Yr, 24-Hr storm 107
Figure 5-14. Potential flood risk area reduction benefit: 25-Yr Alt System, 100-Yr, 24-Hr storm 108
Figure 5-15. Potential flood risk area reduction benefit: 100-Yr Alt System, 25-Yr, 24-Hr storm 109
Figure 5-16. Potential flood risk area reduction benefit: 100-Yr Alt System, 100-Yr, 24-Hr storm 110
Figure 5-17. Potential flow depth reduction benefit: 25-Yr Alt System, 25-Yr, 24-Hr storm 111
Figure 5-18. Potential flow depth reduction benefit: 25-Yr Alt System, 100-Yr, 24-Hr storm 112
Figure 5-19. Potential flow depth reduction benefit: 100-Yr Alt System, 25-Yr, 24-Hr storm 113
Figure 5-20. Potential flow depth reduction benefit: 100-Yr Alt System, 100-Yr, 24-Hr storm 114
Figure 6-1. Potential mitigation construction phasing 117

List of Tables

Table 1-1. Collected subdivision drainage reports 3
Table 1-2. Flood Insurance Studies 4
Table 1-3. FEMA flood zones within the study area 4
Table 2-1. FLO-2D model domain areas and number of grid elements 15
Table 2-2. LiDAR flight parameters, reproduced from DAS (2018b) 17
Table 2-3. Maximum NOAA14 point rainfall estimates (in inches) by recurrence interval and model domain 19
Table 2-4. Runoff curve numbers for arid and semiarid rangelands, from NRCS (2004) 22
Table 2-5. Final runoff curve numbers used in the FLO-2D modeling 25
Table 2-6. Surface classification and corresponding Manning's n value 25
Table 2-7. Full flow versus "D" line pipe capacity used in the FLO-2D modeling 31
Table 2-8. Recommended n values for deep ponded areas, from FCDMC (2016) 34
Table 2-9. Peak flow and volume results from the FLO-2D floodplain cross-sections 37
Table 2-10. Comparison with 100-year USGS regression equation 48
Table 3-1. Major characteristics of the sediment within the lower watershed 64
Table 4-1. Building flooding hazard classification results 79
Table 4-2. Buildings that are impacted by various depths (base conditions) 81
Table 4-3. Summary of flood damage estimates (base conditions) 84
Table 5-1. Alternative comparison summary 88
Table 5-2. Sediment design volumes 95
Table 5-3. Drainage improvement concept cost estimates 103
Table 5-4. Summary of buildings removed from potential inundation 105
Table 5-5. Summary of flood damage estimates and potential benefits 105
Table 5-6. Potential flood risk area reduction benefit 106
Table 6-1. Potential mitigation construction phasing cost 118
Table 6-2. Potential grant funding sources 119

Appendices

Appendix A – USGS LiDAR Report

Appendix B – Concept Design Sheets, Construction Cost Estimates, and Life-Cycle Cost Estimates

Appendix C – Supporting Data (Digital)

1 INTRODUCTION

1.1 PROJECT PURPOSE

The South Dayton Valley Area Drainage Master Plan (SDVADMP) was developed to meet three primary objectives:

1. Evaluate and identify flooding and sedimentation hazards within the project area by completion of a technical study that includes data collection, review of previous studies, information gathering from public agencies and residents, hydrologic and hydraulic modeling, geomorphic assessments, and field surveys.
2. Develop a series of alternatives to either partially or wholly mitigate the hazards identified in the first objective.
3. Provide stakeholder coordination and public outreach of the project through a series of public meetings to inform of the existing hazards and to present the mitigation alternatives.

Each major task of the project is presented herein with a description of the technical approach, analysis results, interpretation of results, and applicability to the overall project purpose. The results of this study can be used as a planning tool and as input to the design of potential future drainage infrastructure and flood mitigation measures that are appropriate for the physical environment for both existing and future development.

1.2 PROJECT LOCATION

The SDVADMP study area is 97 square miles and is located on the northern slopes of the Pine Nut Mountains, approximately 15 miles east of Carson City (Figure 1-1). Most of the study area spans Lyon County, with smaller portions of the upper watershed extending into Carson City and Douglas Counties. The percent study area by county is: Lyon County (75%), Carson City County (16%), and Douglas County (9%). The primary focus area of the SDVADMP is the lower watershed area downstream of the mountains, also shown on Figure 1-1.

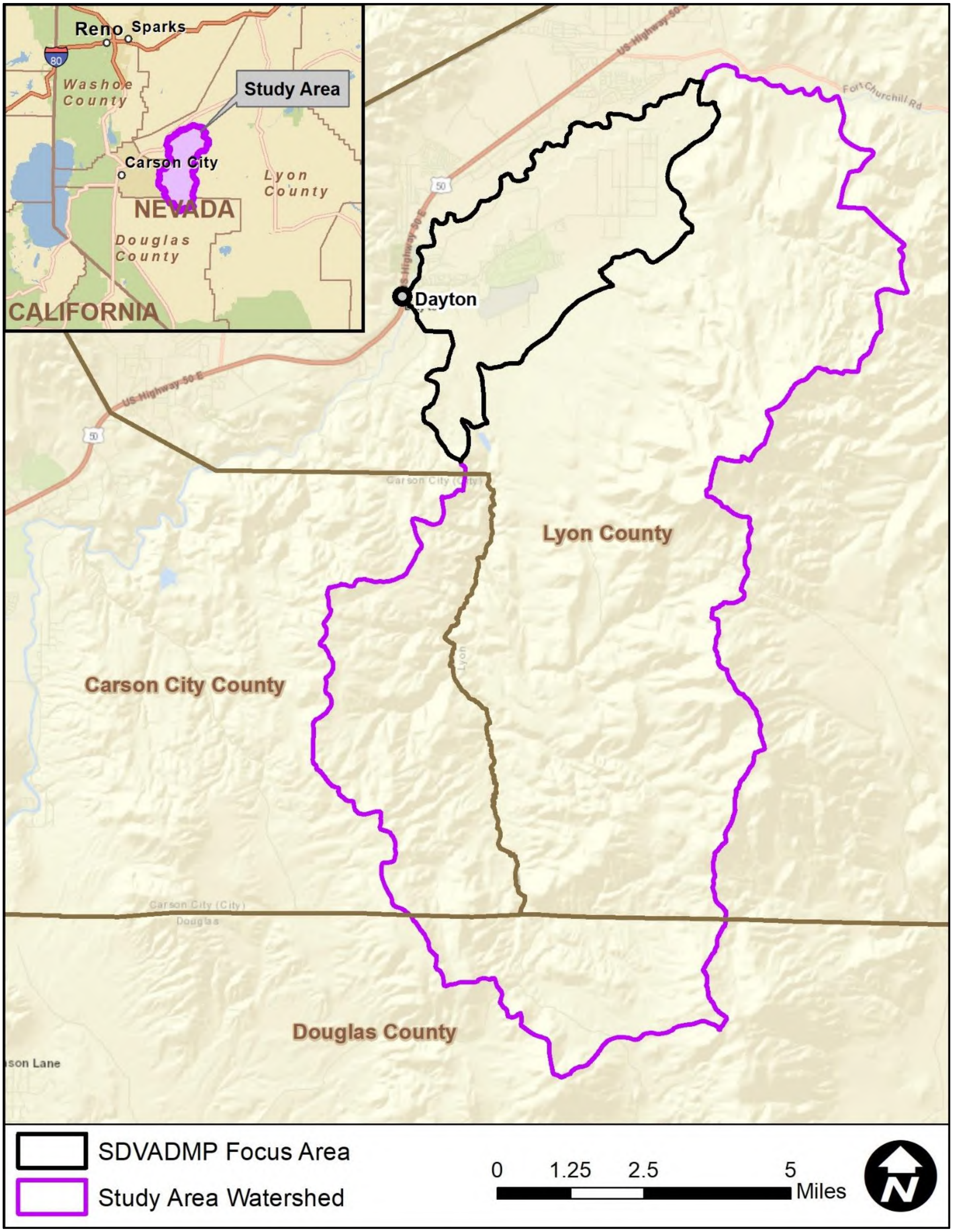


Figure 1-1. Study area vicinity map

1.3 Previous Studies

An early phase of the study included research and collection of previous reports and studies relevant to the ADMP area. These included drainage reports for local subdivisions, flood insurance studies (FIS), and geologic reports. A summary of the different types of reports are summarized in the following sections.

1.3.1 Subdivision Drainage Reports

Several drainage reports and drainage studies were collected from the county agencies and included information that was used directly in the development of the existing conditions hydraulic model (Section 2). The documents provided information on the location and design for drainage facilities within the individual subdivisions. All the collected drainage reports are included in the digital data appendix (Appendix C). Table 1-1 lists the collected documents.

Table 1-1. Collected subdivision drainage reports

Title	Author	Date	Subdivision
Drainage Reports and Drainage Studies			
Dayton Valley Country Club	Summit Engineering	August 2000	Dayton Valley Country Club
Final Drainage Study for Riverpark Unit 20	HEC Civil Engineering Consultants	August 2005	Riverpark Unit 20
Drainage Report for Webstaurant Building Expansion	Tectonics Design Group	September 2015	Airpark
Conceptual Drainage Analysis for the Gold Canyon Estates Phase 2	Western Engineering & Surveying Services	July 2004	Gold Canyon Estates
Technical Drainage Study for Granite Pointe Subdivision	R.O. Anderson Engineering, Inc.	December 2016	Granite Pointe
Hydrologic Drainage Report for Gallery Phase 3A Residential Development	Manhard Consulting	December 2017	Gallery Phase 3A
Hydrologic Drainage Report for Point Legado Phase 2 Residential Development	Manhard Consulting	February 2018	Point Legado
Drainage Study for the Holley Ranch Estates Tentative Map	Lumos & Associates	August 2018	Holley Ranch Estates
Hydrologic Drainage Report for Gallery Phase 3A Residential Development	Manhard Consulting	September 2018	Gallery

1.3.2 Flood Insurance Studies

Federal Emergency Management Agency (FEMA) Flood Insurance Studies (FIS) for Lyon County were collected and reviewed for historical flooding records and regulatory discharge estimates for watercourses in the study area. Table 1-2 lists the collected studies and derived information. Although the goal of this study is not to "match" the FIS discharge estimates, they do provide a base-level comparison for the hydraulic model results (see Section 2.3). The consistency of discharges between years in Table 1-2 suggests that there has been no revision to the hydrology for FEMA regulatory studies since at least 1998.

Table 1-2. Flood Insurance Studies

Study Date	County	SDVADMP Watercourses	10-year Discharge (cfs)	50-year Discharge (cfs)	100-year Discharge (cfs)
January 1998	Lyon	Eldorado Canyon	-	-	5,265
February 2000	Lyon	Eldorado Canyon	-	-	5,265
January 2009	Lyon	Eldorado Canyon	-	-	5,265
January 2016	Lyon (current effective)	Eldorado Canyon	-	-	5,265

1.3.2.1 Effective FEMA Floodplain Mapping

As of the date of this study Eldorado Canyon is the only watercourse in the study area with FEMA regulatory floodplains (Figure 1-2). Table 1-3 lists the descriptions for each flood zone within the study area. Like FIS data, FEMA floodplain mapping provides a base-level comparison of flood risk for the hydraulic modeling results from this study.

Table 1-3. FEMA flood zones within the study area

Flood Zone	Definition	Flooding Type	Recurrence Interval
A	No base flood elevation is provided	Riverine	1% chance
AE	Base flood elevation (BFE) is provided	Riverine	1% chance
AE with Floodway	BFE and Floodway is provided	Riverine	1% chance
X	Flooding outside the SFHA	Riverine, Other	0.2% chance
X	Area of minimal flood hazard	Riverine, Other	-

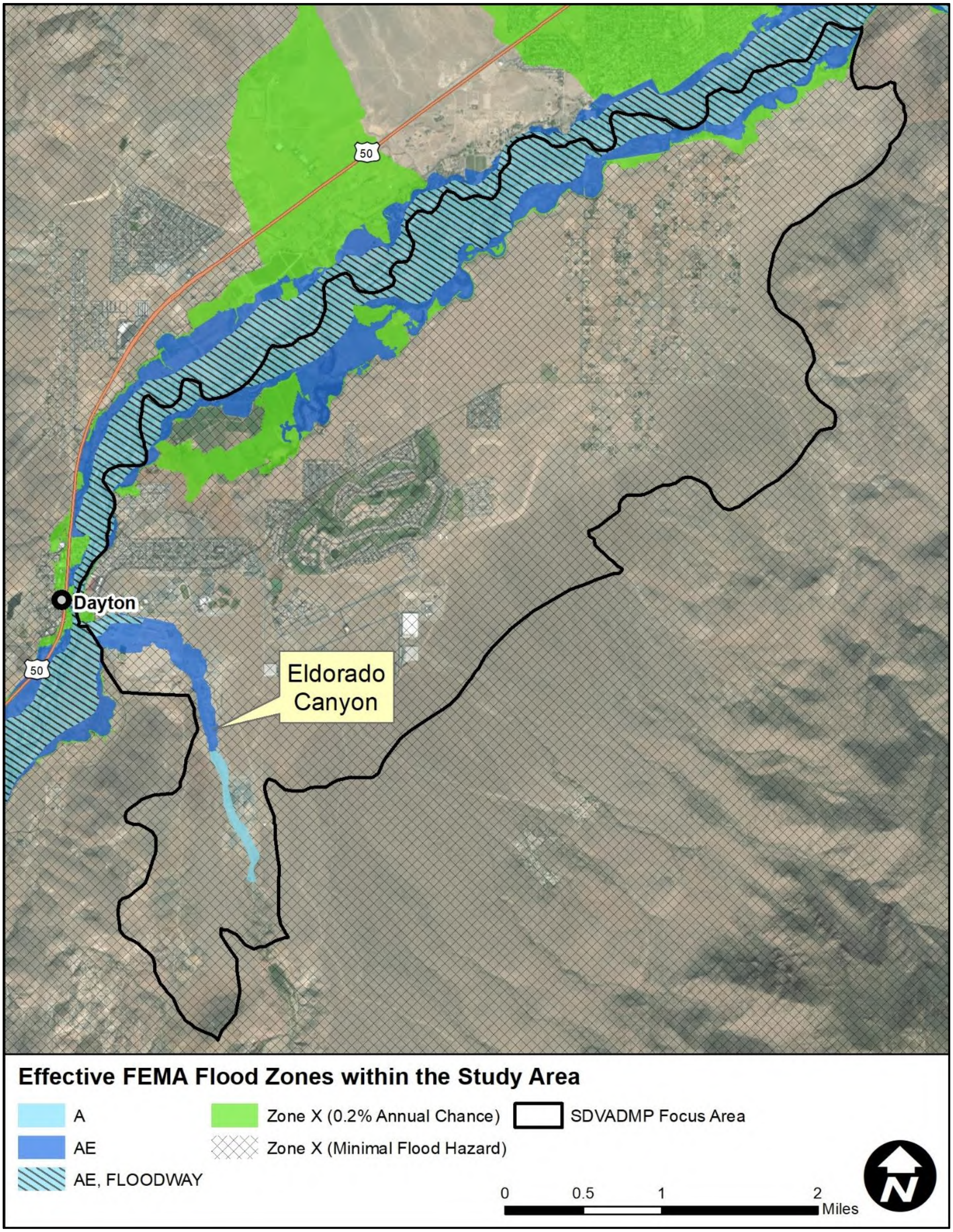


Figure 1-2. Effective FEMA Floodplains

1.3.3 U.S. Army Corps of Engineers Alluvial Fan Mapping

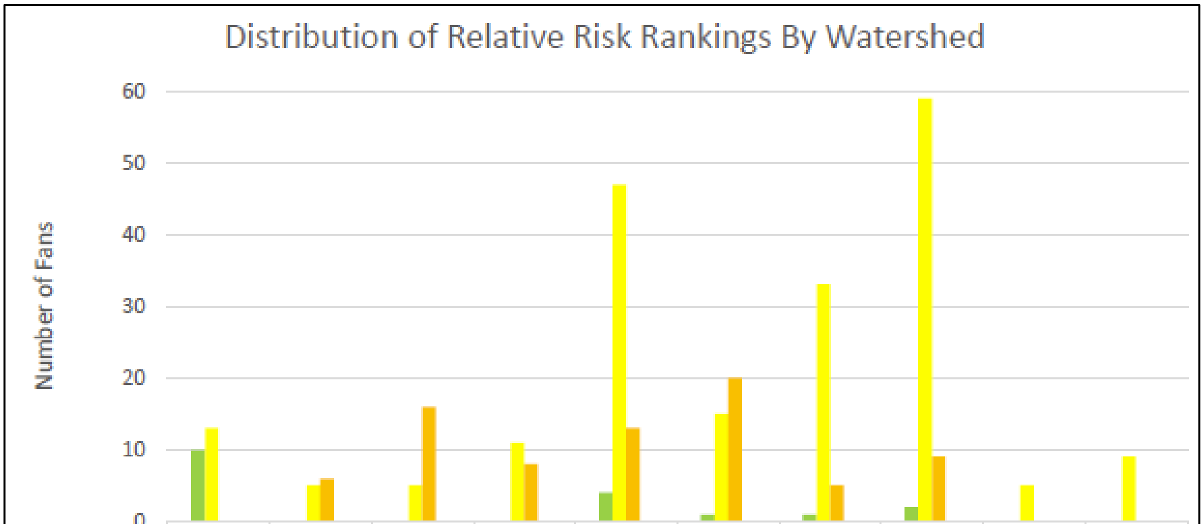
In December 2017 the U.S. Army Corps of Engineers (USACE), Sacramento District, published a study titled *Alluvial Fan Mapping for the Carson River Watershed Methodology* (Floyd, 2017) which included the SDVADMP study area. The purpose of the mapping study was to classify the relative risk of alluvial fan landforms within the Carson River Watershed. Alluvial fan landforms were identified and assigned a risk ranking based on the following categories:

- Appearance of active or inactive
- Existence of disturbances
- Presence of infrastructure

Within each category, a series of risk factors were examined. For example, the Active/Inactive category included four risk factors:

  - Soil Development
  - Alluvium
  - Unconfined Flow
  - Incised Channels

The risk factors were assigned a relative score and summed to derive an overall hazard ranking by watershed. Figure 1-3 from the report depicts the distribution of relative risk rankings by watershed. Figure 1-4 shows the identified alluvial fan landforms within the SDVADMP study area and their assigned risk.



	Upper East Fork Carson River	Middle East Fork Carson River	West Fork Carson River	Lower East Fork Carson River	Carson Valley-Carson River	Town of Dayton-Carson River	Mineral Canyon-Carson River	Lahontan Reservoir -Carson River	Soda Lake-Carson River	Carson Sink
Very Low	0	0	0	0	0	0	0	0	0	0
Low	10	0	0	0	4	1	1	2	0	0
Moderate	13	5	5	11	47	15	33	59	5	9
High	0	6	16	8	13	20	5	9	0	0
Very High	0	0	0	0	0	0	0	0	0	0
Total	23	11	21	19	64	36	39	70	5	9

Figure 1-3. Distribution of relative risk rankings by watershed, from Floyd (2017)

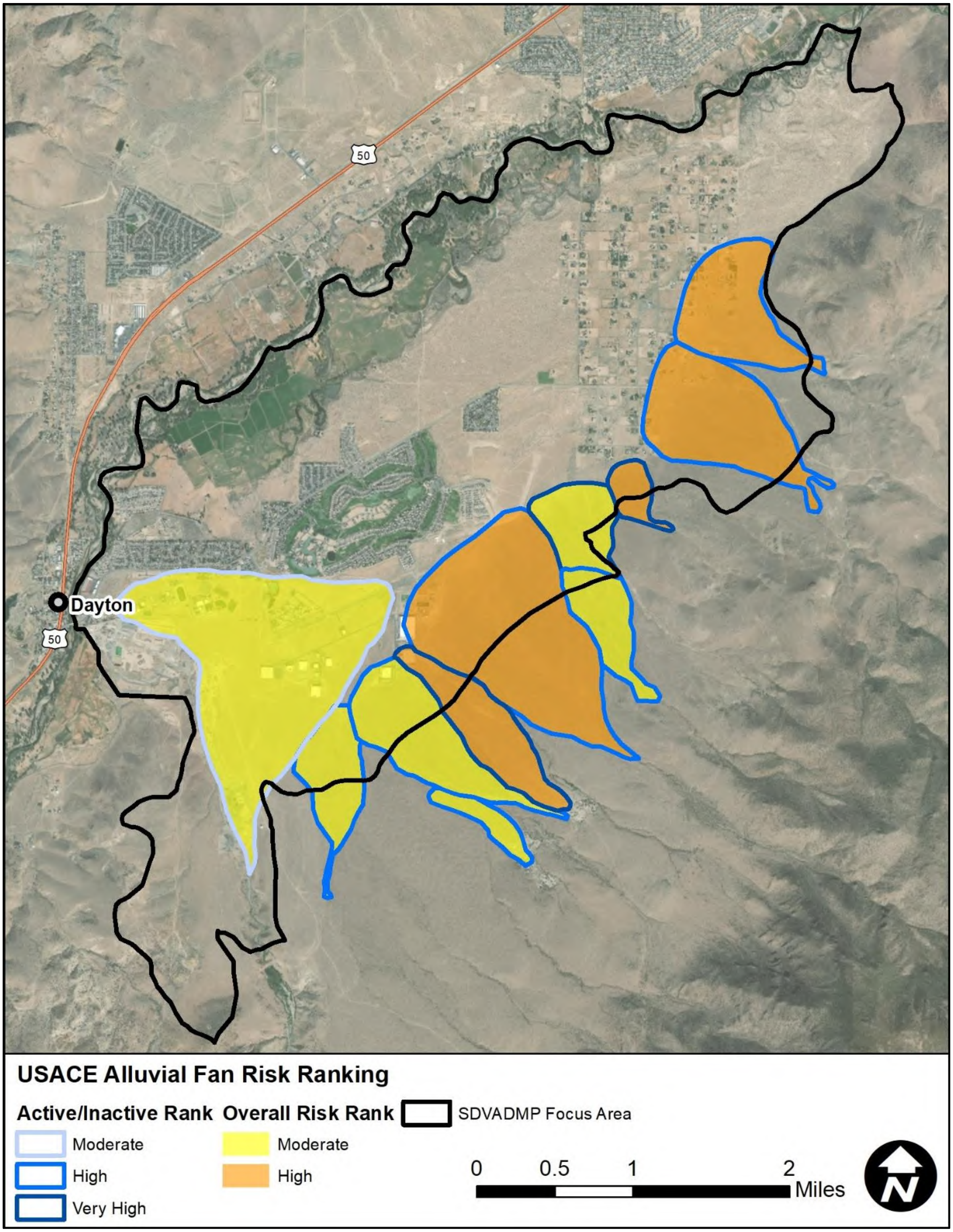


Figure 1-4. USACE alluvial fan risk ranking

1.4 Historical Flowpath Assessment

Understanding the historical evolution of a geomorphic system is critical to understanding present-day processes and predicting future trends. Natural systems can take hundreds of thousands of years to develop, and their morphology is a direct reflection of this long-development period. Anthropogenic changes to a natural system often result in abrupt changes that can be managed for a brief period, but quite often the disturbed system will trend back to its natural condition, despite efforts to change and maintain it.

A historical flowpath assessment was conducted for the DVADMP study area to assess the natural flowpaths of the study watercourses with the goal that understanding the natural flowpaths will aid in understanding the current flooding patterns and potential future flooding trends.

1.4.1 Aerial Photography

Historical aerial photography from 1948 (earliest year available) and 1953 were collected and semi-rectified using ArcGIS software tools. The 1948 photography was not available for the entire focus area, so the next available year of photography (1953) was used to complete the dataset. The natural flowpaths for the project watercourses were identified and delineated from the photography. Figure 1-5 shows the 1948/1953 aerial photography and Figure 1-6 the modern aerial photography (2018) for the ADMP focus area. The 1948/1953 photographs pre-date much of the development within the focus area and shows the landforms in a (mostly) natural condition. The locations of the dominant flowpaths for the major drainage channels were interpreted and delineated from the 1948/1953 photographs to compare with the present-day locations.

1.4.2 Summary

The most significant changes in flowpath alignment since 1948/1953 have occurred due to manmade channel realignments (Figure 1-7). Both the historical and modern aerial photography indicate evidence of distributary and active alluvial fan drainage patterns within the project focus area, but many of the main drainage channels have remained laterally stable for at least the past 70 years. This suggests that there may not have been a flood event of sufficient magnitude since at least 1948 to cause major channel avulsions. The major watercourses were investigated during the field verification phase of the ADMP and were not found to be incised or laterally confined within the lower project focus area. In other words, there are no physical constraints that should have prevented historical channel avulsions since 1948, which further suggests that there hasn't been a flood event with sufficient energy to cause a major channel avulsion. As such, flowpath uncertainty scenarios are not recommended for this study area as they were in the Dayton Valley ADMP.

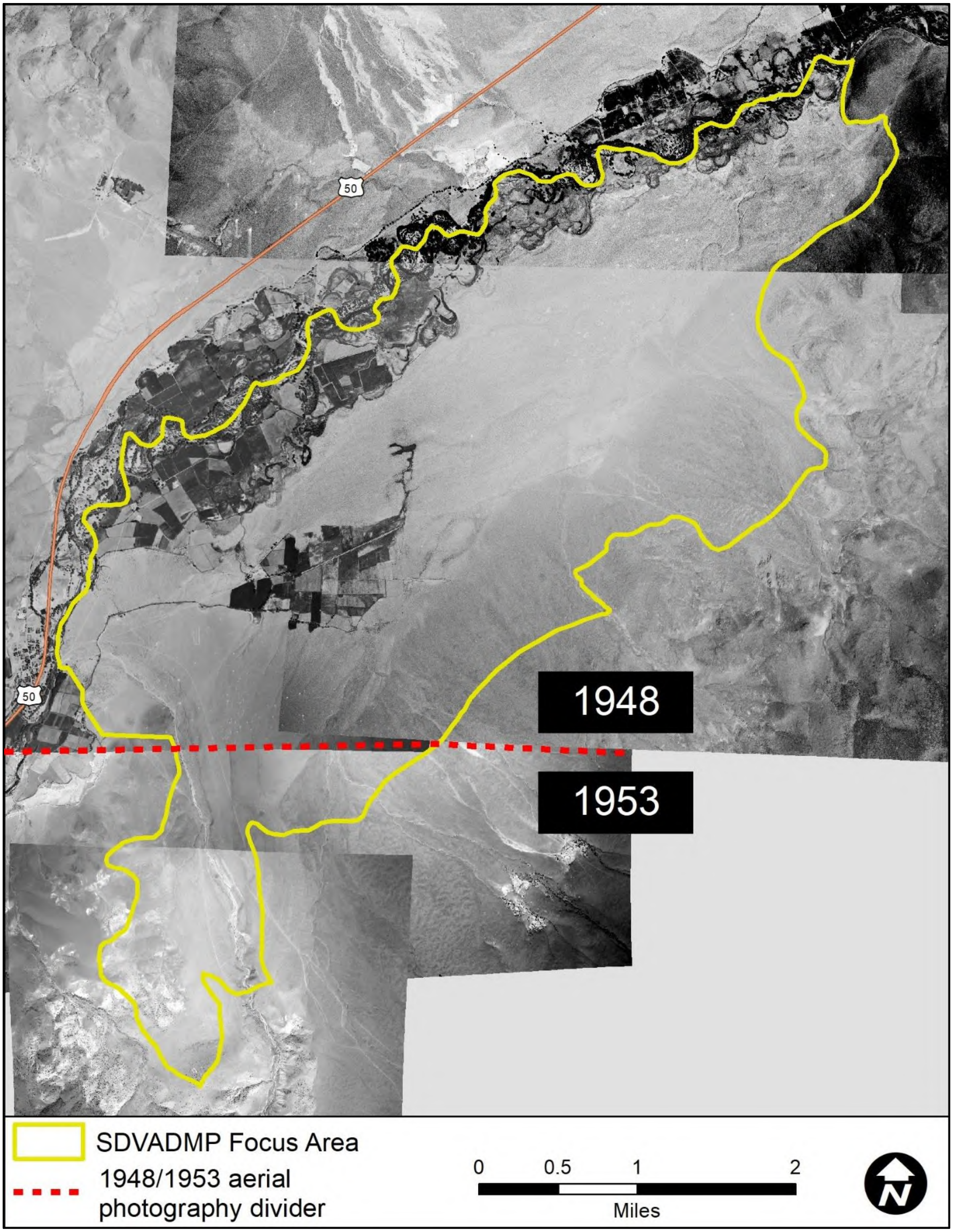


Figure 1-5. 1948 aerial photography

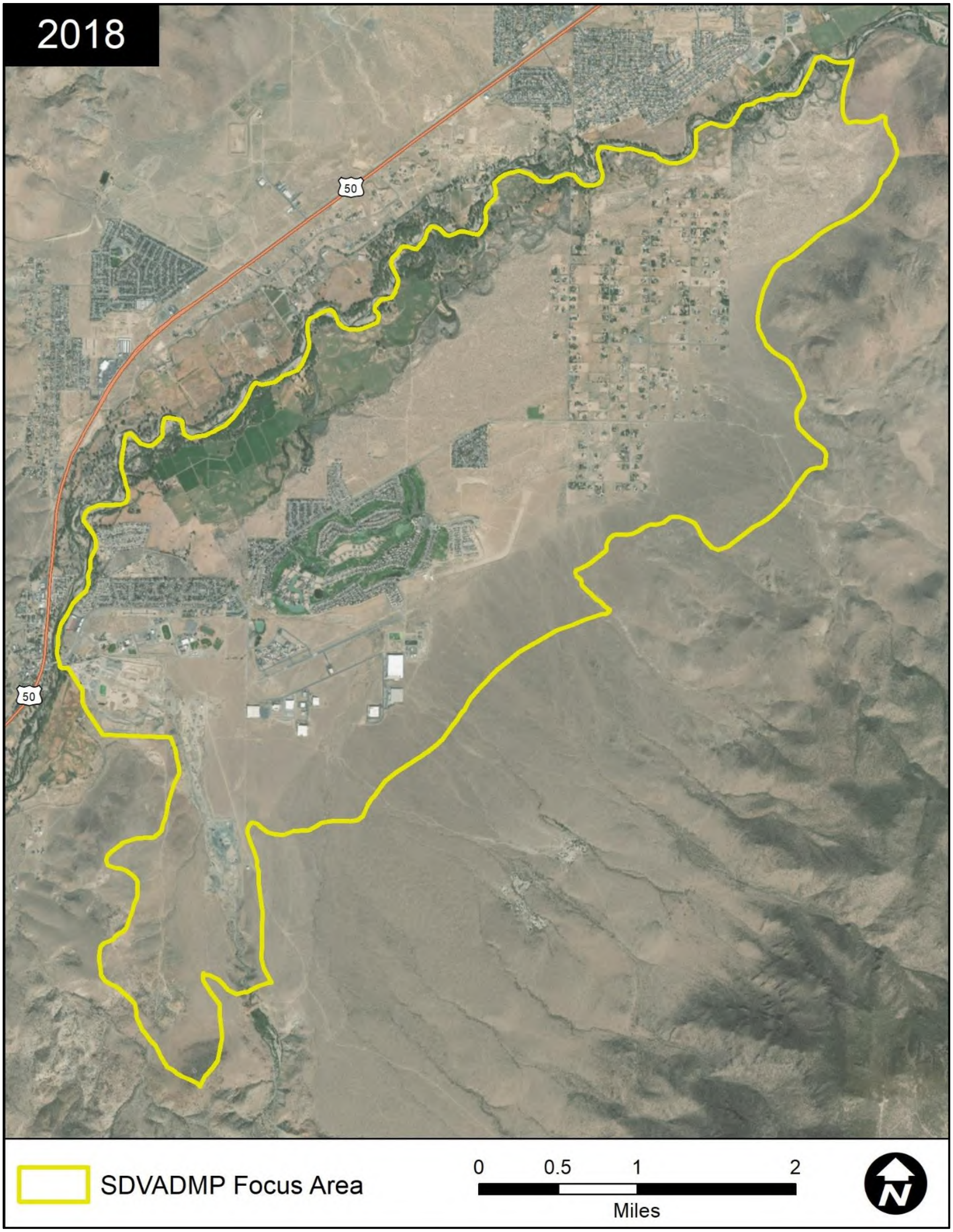


Figure 1-6. 2017 aerial photography

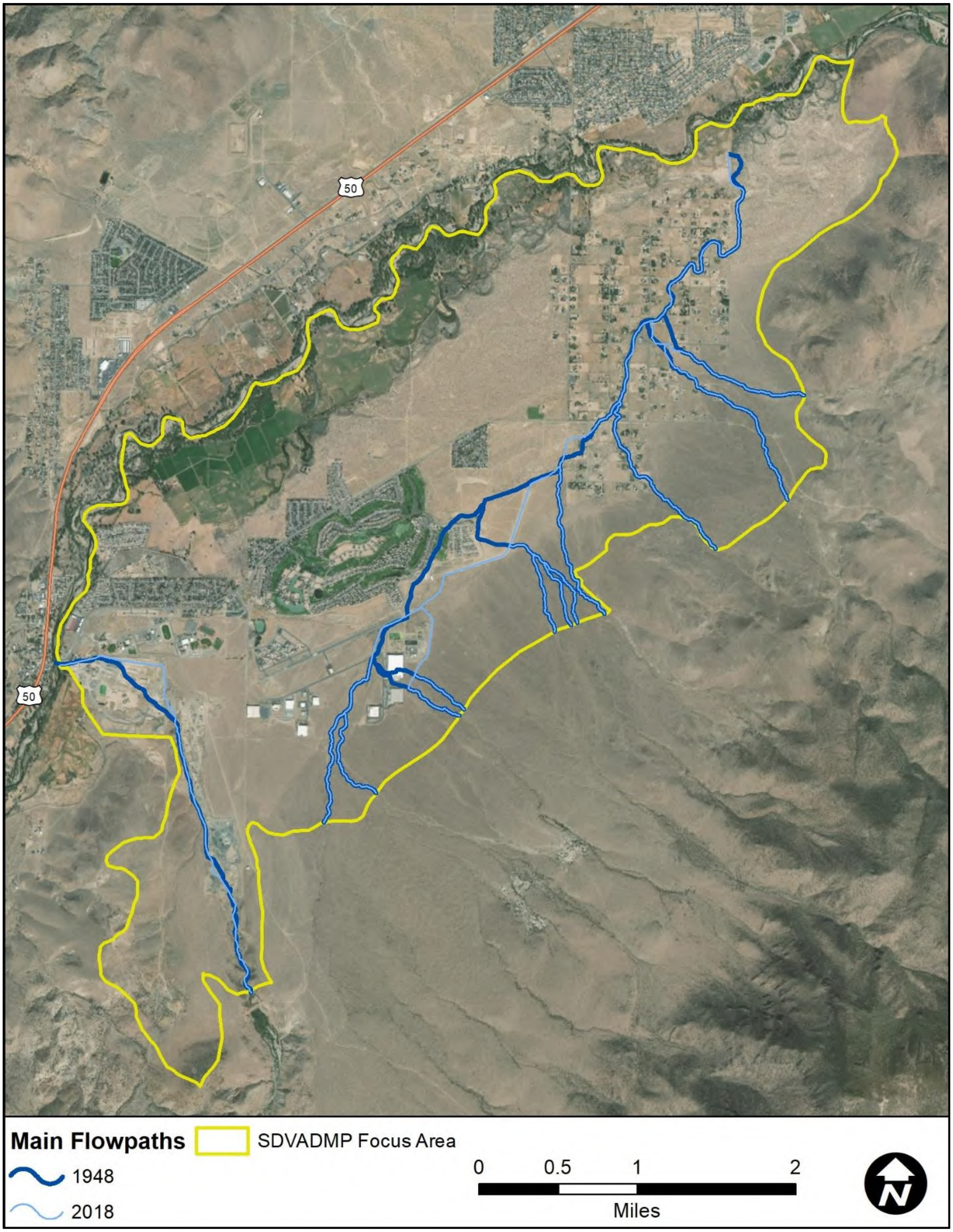


Figure 1-7. Historical flowpath comparison

2 HYDROLOGIC AND HYDRAULIC MODELING

2.1 METHOD DESCRIPTION

To maintain consistency with the adjacent Dayton Valley Area Drainage Master Plan (DVADMP), the same general procedures were used in model development. The procedures that were used for hydrology and infiltration for the SDVADMP are as follows:

- Infiltration was simulated using runoff curve number (CN) methodology per the Lyon County Drainage Guidelines (2018).
- Rainfall depths were based on the NOAA Atlas 14 (NOAA14) precipitation estimates.
- The hyetograph for the 6-hour storm was based on the balanced mass curve, while the hyetographs for the 24-hour storms were based on the Nevada Department of Transportation (NDOT) 90th percentile maximum intensity with smoothing by the generalized logistic equation (GLE) (NDOT, 2015).

All modeling, both hydrologic and hydraulic, was done using the FLO-2D Pro software[1] package, Build No. 16.06.16 with an executable dated February 28, 2017. This version has been used for multiple area drainage master studies and has functioned adequately. FLO-2D was selected for the SDVADMP due to the following: 1) to maintain method consistency with other ADMPs and drainage studies in the area (Manhard, 2012; JEF, 2019), 2) to streamline model development since there are many small subbasins that would require individual analysis if a lumped parameter model, such as HEC-HMS were used, and 3) FLO-2D is a combined rainfall-runoff model (i.e., both hydrologic and hydraulic processes are simulated within the model).

2.2 MODEL DEVELOPMENT

2.2.1 Spatial Reference System

All data that was generated for the SDVADMP used the horizontal control of the Nevada Coordinate System, West Zone, NAD83; while the vertical datum was the North American Vertical Datum of 1988 (NAVD 88). The units of measurement were US survey feet.

2.2.2 Model Domains

The boundaries of the modeling domains are shown in Figure 2-1. The upper watershed areas (Eldorado and Upper) were modeled to provide inflow hydrographs to the detailed modeling area, labeled as "Lower" in the figure. The upper watershed areas may also be referred to as "off-site areas" throughout this report since the detailed model area is the focus of the flood hazard identification and mitigation alternative development.

Since FLO-2D is a combined rainfall-runoff model, off-site modeling was completed using less detailed models (by surface classification and culvert/storm drain modeling), with inflow hydrographs from these upstream FLO-2D models being transferred to the upstream boundary of the detailed FLO-2D model.

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[1] https://www.flo-2d.com/

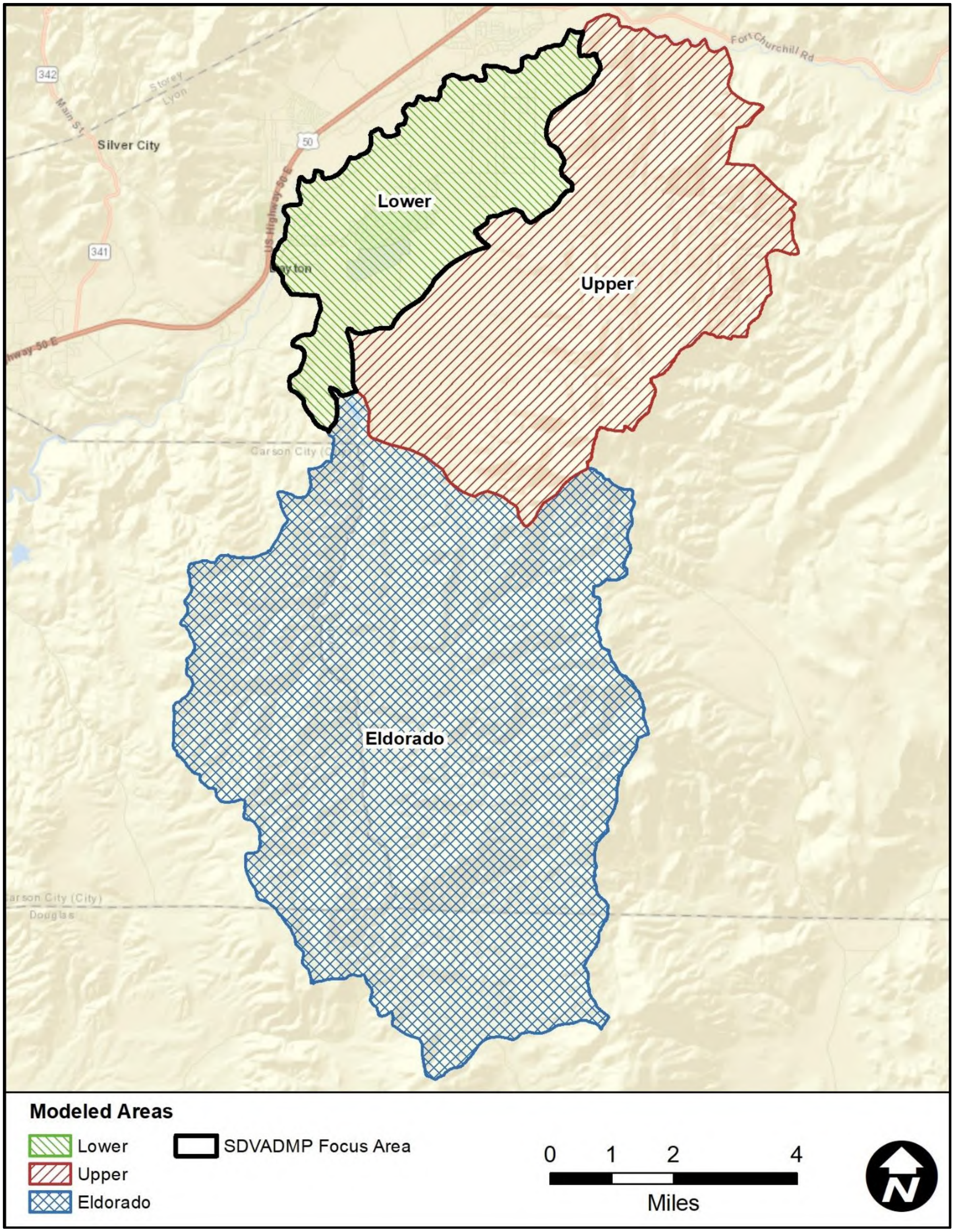

Figure 2-1. Modeling domains used in the South Dayton Valley ADMP

2.2.3 Grid Size

The South Dayton Valley watersheds contain many small drainage features that need to be adequately captured in the model to provide the most accurate results. Some of these features include small 18-inch storm drains and minor drainage ditches. A high-resolution, 10-foot grid-size was selected to provide the necessary detail to model these features in the Lower model, while a lower resolution grid size of 20-feet was selected for the two off-site model domains (Eldorado and Upper). The coarser grid size was selected to reduce model run times given the large contributing watersheds. The domain area and the number of grid cells in each model are shown in Table 2-1.

Table 2-1. FLO-2D model domain areas and number of grid elements

Model Domain	Domain Area (sq. miles)	Number of Grid Elements
Lower	13.5	3,764,732
Upper	29.4	2,054,509
Eldorado	54.4	3,799,432

2.2.4 Grid Element Elevations

The limits of all the topographic mapping sources used in the FLO-2D modeling are shown in relation to the model domains on Figure 2-2. There were three mapping sources:

- QL1 LiDAR
- QL2 LiDAR
- NEXTMap 5-meter DTM

All three mapping sources are discussed in detail below.

2.2.4.1 United State Geological Survey (USGS) LiDAR

As a part of the 3D Elevation Program[2], the USGS collected high resolution LiDAR data for a large portion of Carson City and Washoe, Storey, and Lyon counties in Nevada through a contract with Digital Aerial Solutions, LLC (DAS) – Contract Number: G16PC00044. This data was collected at two specifications, QL1 and QL2. The flight parameters and point densities for both datasets are listed in Table 2-2. LiDAR collection began on September 19, 2017 and was completed on October 27, 2017 (DAS, 2018b). The original LiDAR data was collected with elevations in meters, a horizontal spatial reference of UTM Zone 11 N, Meters, NAD83, and a vertical spatial reference of NAVD 88. The DAS LiDAR reports are included in Appendix A.

[2] https://www.usgs.gov/core-science-systems/ngp/3dep

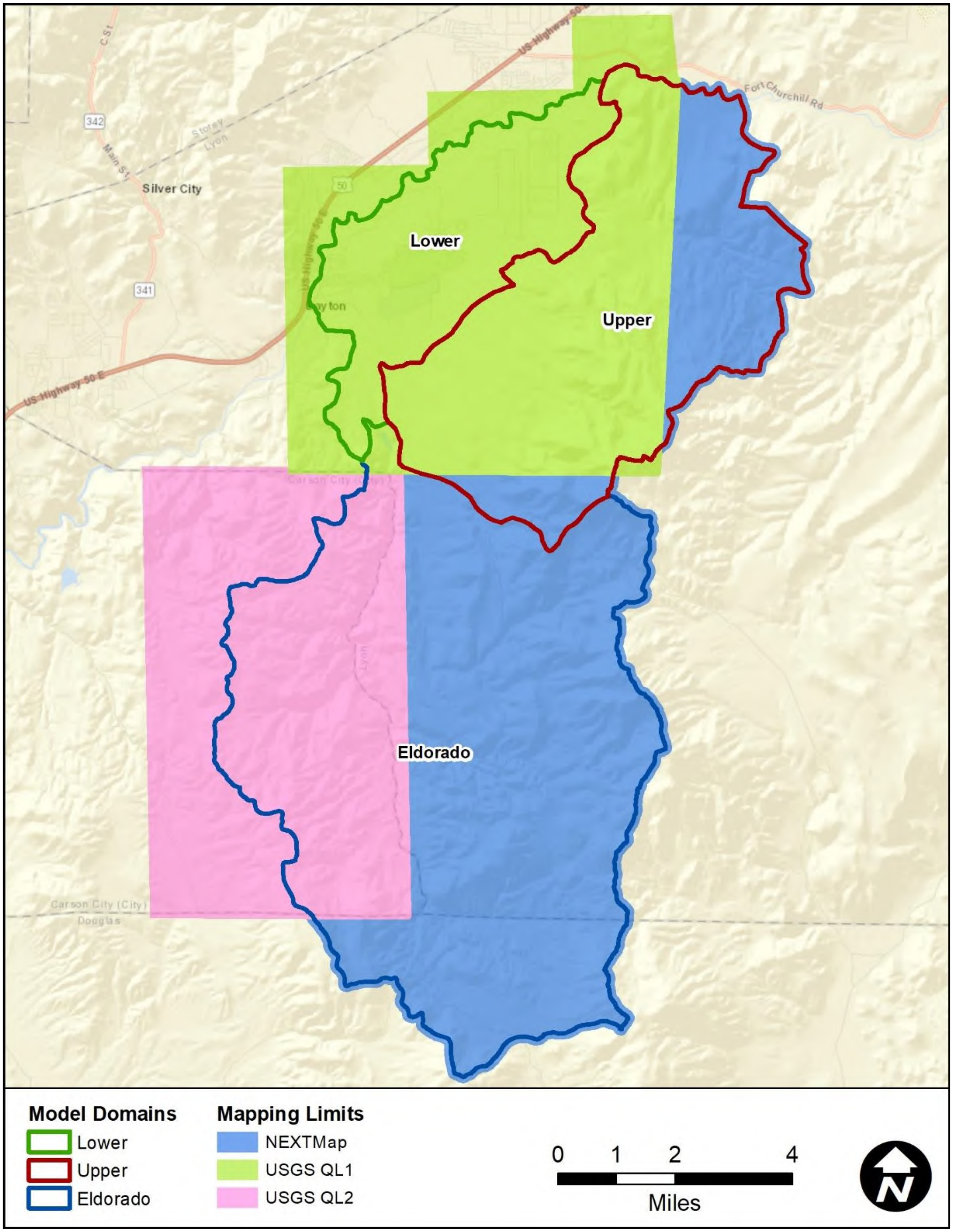

Figure 2-2. Limits of topographic mapping data

Table 2-2. LiDAR flight parameters, reproduced from DAS (2018b)

Parameter	QL1	QL2
Flying Height Above Ground Level:	8,609 feet	9,072 feet
Nominal Sidelap:	60%	30%
Nominal Speed Over Ground:	155 Knots	155 Knots
Field of View:	15°	24°
Laser Rate:	220.2 kHz	206.2 kHz
Scan Rate:	65.2 Hz	49.2 Hz
Maximum Cross Track Spacing:	1.22 meters	1.62 meters
Maximum Along Track Spacing:	0.61 meters	0.81 meters
Average point Spacing:	0.50 meters	0.67 meters

2.2.4.2 NEXTMap Data

Approximately 46 square miles of the off-site areas (outside of the SDVADMP focus area) was not included in the USGS LiDAR mapping area. Topographic data (DTM) was purchased from Intermap[3] for this area. This DTM product (referred to as NEXTMap) has a 5-meter resolution with elevation values in meters, a horizontal spatial reference of GCS North American 1983, and a vertical spatial reference of NAVD 88. Initial FLO-2D results from the NEXTMap data were reasonable and compared well with observed flow patterns on aerial photography.

2.2.4.3 Combined FLO-2D Data

Since the LiDAR and NEXTMap data were both in meters and in a different horizontal coordinate system than the DVADMP, the data was first converted to feet and the Nevada Coordinate System, West Zone, NAD83 and combined into a single raster. This single raster had a grid resolution of 1-foot to maintain accuracy of the LiDAR data even though the NEXTMap data has a courser resolution. This high-resolution raster was resampled to 10-foot and 20-foot rasters that reflect the average grid elevations that are used in the actual FLO-2D models. The 10-foot grid was used in the Lower model domain, while the 20-foot grid was used in the Eldorado and Upper model domains. The three topographic sources and their relation to the FLO-2D model domains are shown in Figure 2-2.

2.2.5 Model Inflow/Outflow

In general, outflow nodes were placed along the entire boundary of the all model domains to let water free-flow out of the domain. For model boundaries that were coincident to a downstream model (i.e., Upper to Lower and Eldorado to Lower), the outflow hydrographs were read from the outflow node and applied to the lower model as an inflow hydrograph. Since the two upper watersheds have a coarser grid spacing than the lower model, the outflow hydrograph was sometimes spit across two inflow elements with the outflow hydrograph being divided by two before being applied as an inflow hydrograph. Note that some outflow elements do not have any outflow; and therefore, a corresponding inflow element does not exist. Also, the model boundary between the Upper and Eldorado models was set along a watershed divide so that there is no flow transfer between these models. A schematic of the flow transfer between models is shown as Figure 2-3.

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[3] http://www.intermap.com/

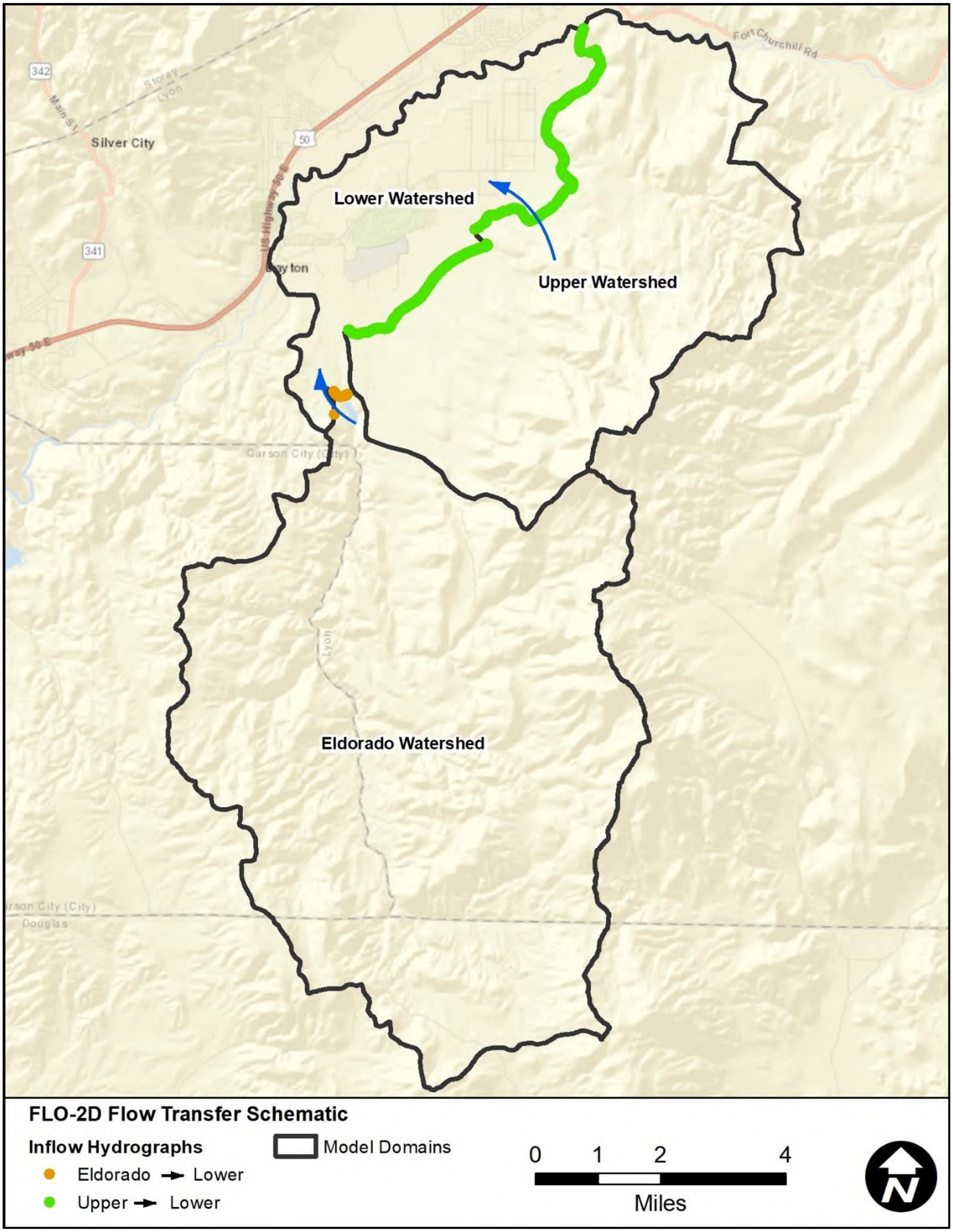

Figure 2-3. Hydrograph flow transfer between FLO-2D models

2.2.6 Precipitation Development

As a part of the SDVADMP, three design storms were simulated:

- 25-year, 24-hour
- 100-year, 24- hour
- 100-year, 6-hour

The 24-hour durations were chosen to be consistent with Lyon County's drainage regulations, while the 6-hour duration was chosen because this higher intensity duration usually results in higher peak flow estimates for smaller (i.e., < 20 square miles) drainage areas.

2.2.6.1 Precipitation Depths

NOAA Atlas 14 (NOAA14) precipitation depth estimates were downloaded from the National Weather Service (NWS) website (2018) as raster images, then used to apply the spatially varied rainfall estimate for each grid element in the model. This means that the point statistics are used at each grid cell in the FLO-2D model, which is different than the typical centroid-based precipitation estimates that are used in lumped parameter (e.g., HEC-HMS or HEC-1) modeling. Point rainfall statistics were selected because:

1) using point rainfall has been the general procedure for other ADMP studies in the southwest
2) using point statistics results in reasonable but conservative flow estimates. The maximum rainfall point values for each submodel are shown in Table 2-3.

Table 2-3. Maximum NOAA14 point rainfall estimates (in inches) by recurrence interval and model domain

Model Domain	Storm Event		
	25Y24H	100Y6H	100Y24H
Lower	2.268	1.755	2.884
Upper	3.902	2.273	5.046
Eldorado	4.482	2.450	5.819

2.2.6.2 Hyetographs

As mentioned in Section 2.1, this ADMP followed the procedures that were developed during the DVADMP. This means that the NDOT (2015) hyetograph for this region was be used for the 24-hour storms, while the "balanced storm" hyetograph (developed with HEC-HMS frequency storm option) was used for the 6-hour duration. Since this area also shows a large increase in precipitation depth when the duration increases from 6 to 24 hours (see Table 2-3), the use of the hyetographs is appropriate. A comparison of the final two temporal distributions that were used in the SDVADMP is shown in Figure 2-4. The hyetographs from the DVADMP are included for reference.

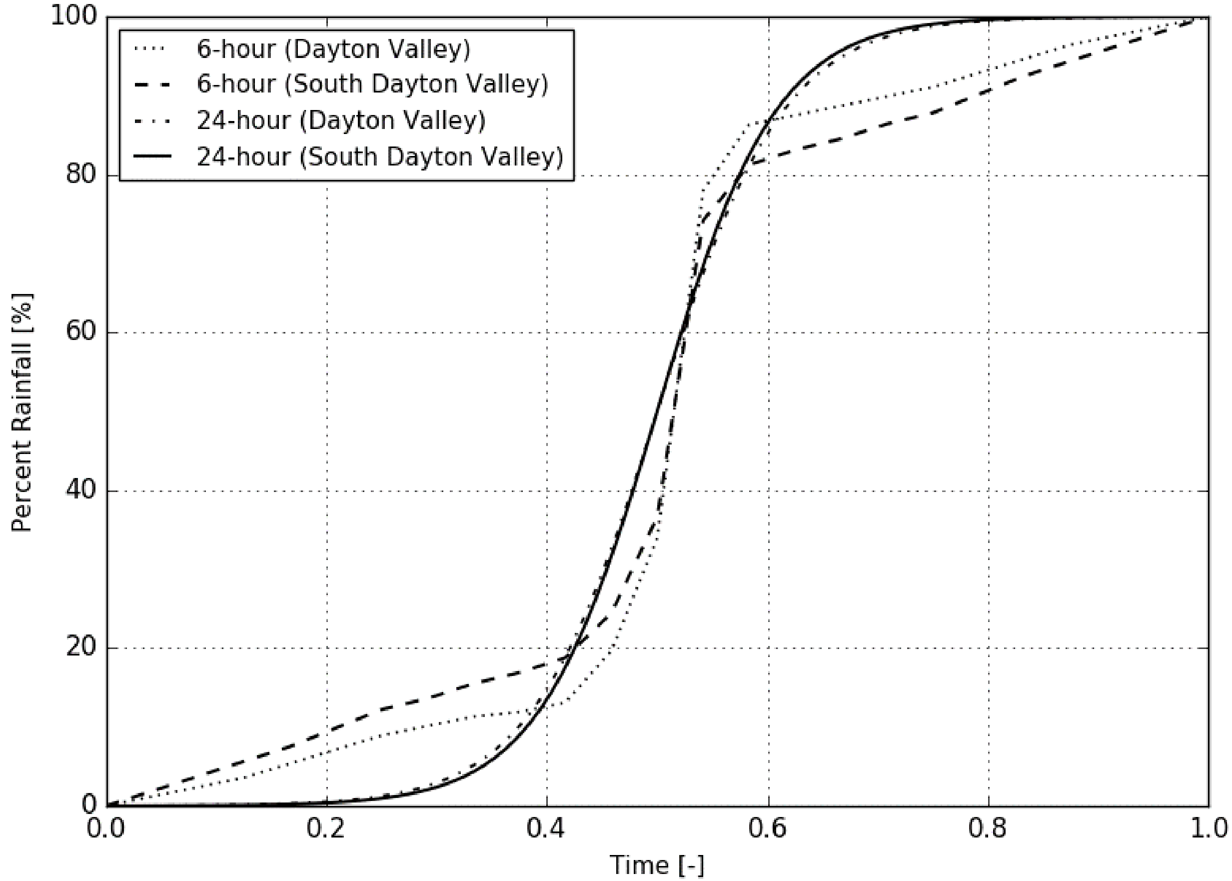

Figure 2-4. Comparison of 6- and 24-hour hyetographs used in the SDVADMP (with comparison to DVADMP)

2.2.7 Infiltration Development

As mentioned in Section 2.1, the curve number methodology was used to calculate infiltration for this study. Curve numbers were extracted from the NRCS National Engineering Handbook (2004) which relates hydrologic soil group (HSG) and vegetation coverage type (Table 2-4). The HSG was developed from the Soil Survey Geographic (SSURGO) data from the National Resource Conservation Service (NRCS), which was downloaded from the web soil survey (NRCS, 2019). The spatial variability of the HSG is shown in Figure 2-5.

Initially, curve numbers were assigned using the same procedure that was used in the Dayton Valley ADMP. However, these values produced unreasonable peak flows within the Eldorado modeling domain. Therefore, a more refined delineation of cover type (Pinyon-juniper or Sage-grass) was developed. This delineation is shown as Figure 2-6. Reasonable curve numbers were then selected based on this delineation, Table 2-4, the HSG of the soils, and an adjustment to account for surface imperviousness of pavement (or buildings). The final curve numbers selected for use in the FLO-2D models are shown in Figure 2-7 and listed in Table 2-5.

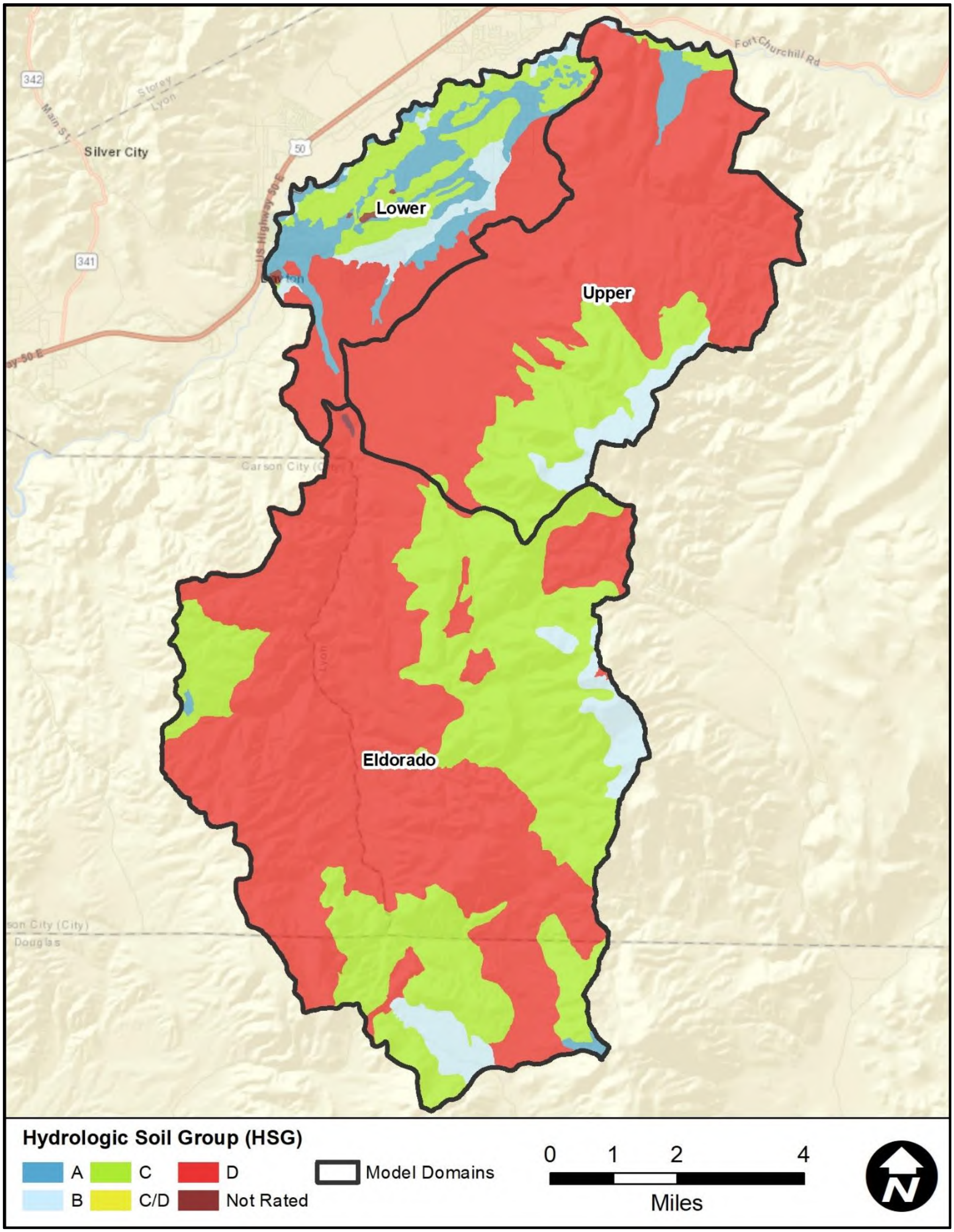

Figure 2-5. Hydrologic Soil Group (HSG) classifications in the South Dayton Valley ADMP, from NRCS (2019)

Table 2-4. Runoff curve numbers for arid and semiarid rangelands, from NRCS (2004)

Cover description: cover type	hydrologic condition [2]	Hydrologic soil group: A [3]	B	C	D
Herbaceous—mixture of grass, weeds and low-growing brush, with brush the minor element	Poor		80	87	93
	Fair		71	81	89
	Good		62	74	85
Oak-aspen—mountain brush mixture of oak brush, aspen, mountain mahogany, bitter brush, maple, and other brush	Poor		66	74	79
	Fair		48	57	63
	Good		30	41	48
Pinyon-juniper—pinyon, juniper, or both; grass understory	Poor		75	85	89
	Fair		58	73	80
	Good		41	61	71
Sage-grass—sage with an understory of grass	Poor		67	80	85
	Fair		51	63	70
	Good		35	47	55
Desert shrub—major plants include saltbush, greasewood, creosotebush, blackbrush, bursage, paloverde, mesquite, and cactus	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84

1/ Average runoff condition, and $I_a = 0.2s$. For range in humid regions, use table 9–1.

2/ Poor: <30% ground cover (litter, grass, and brush overstory).
Fair: 30 to 70% ground cover.
Good: >70% ground cover.

3/ Curve numbers for group A have been developed only for desert shrub.

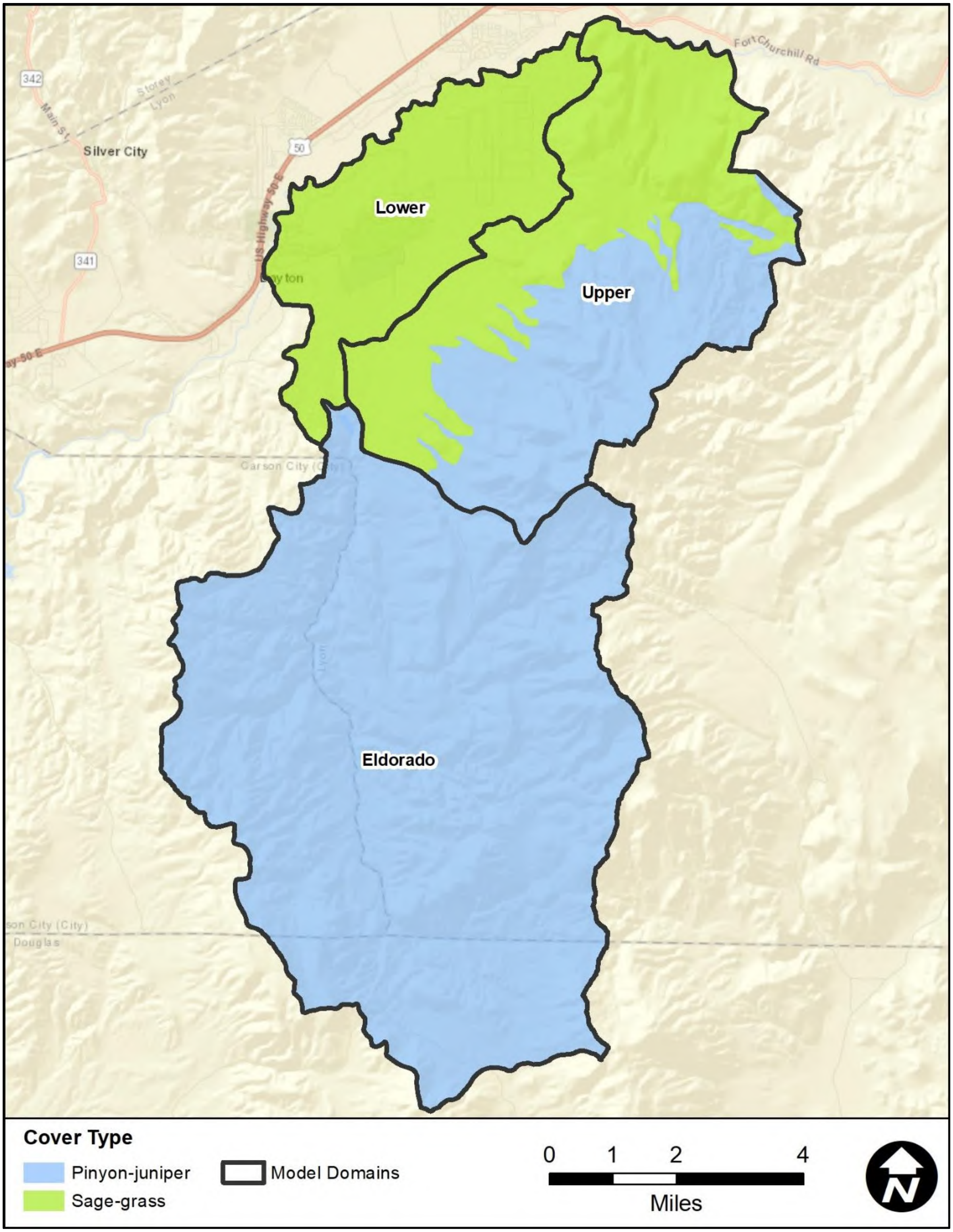

Figure 2-6. Cover type delineation used in selection of curve numbers

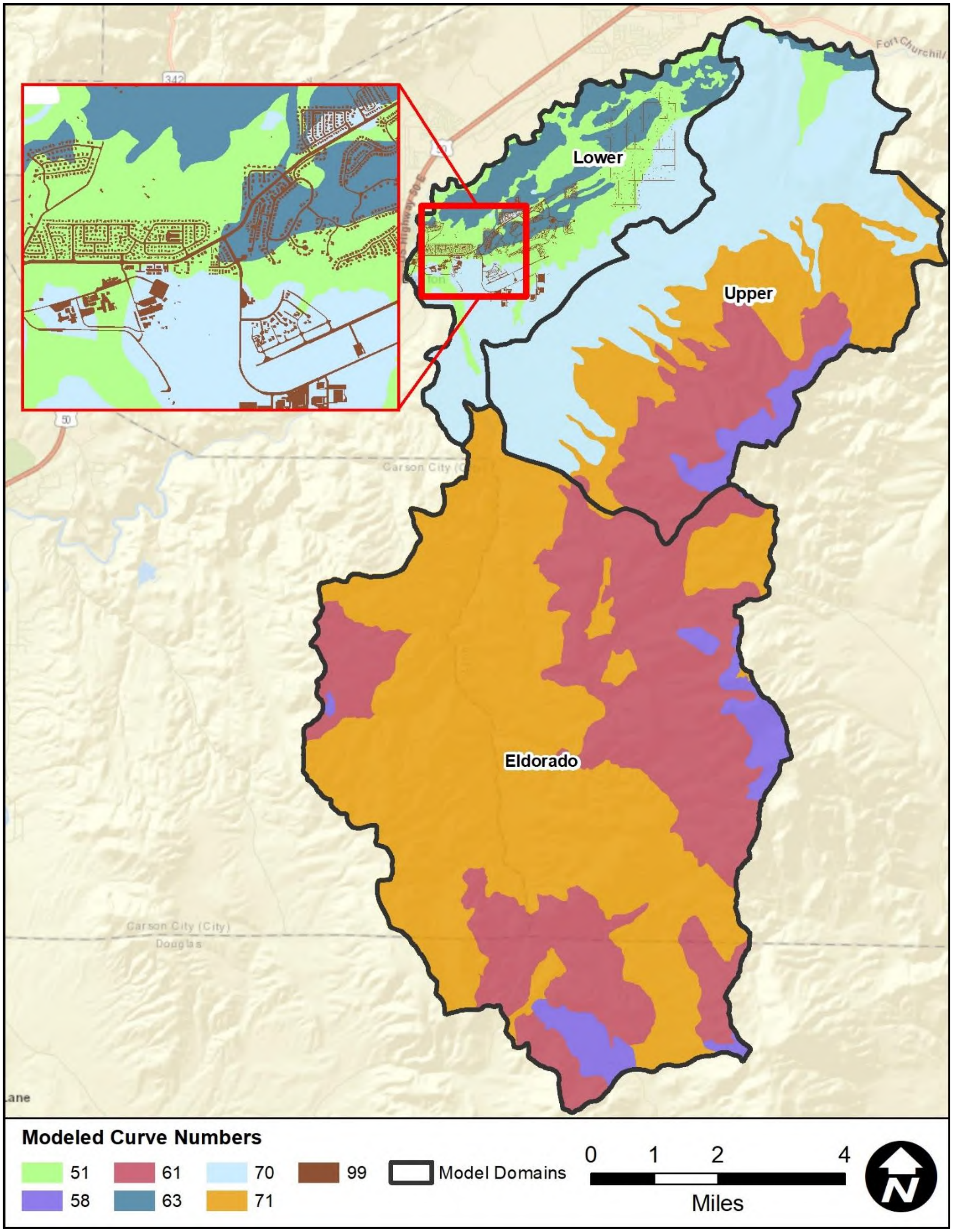

Figure 2-7. Spatial distribution of curve numbers used in the FLO-2D modeling

Table 2-5. Final runoff curve numbers used in the FLO-2D modeling

Cover Type	Hydrologic Soil Group	Curve Number
Pinyon-juniper	A	58
Sage-grass	A	51
Pinyon-juniper	B	58
Sage-grass	B	51
Pinyon-juniper	C	61
Sage-grass	C	63
Pinyon-juniper	D	71
Sage-grass	D	70
Pinyon-juniper	Pavement/Rooftops	99
Sage-grass	Pavement/Rooftops	99

2.2.8 Grid Element Roughness (Manning's n Values)

The FLO-2D model uses Manning's n value to estimate roughness on each grid. Each grid element is assigned an average n value based on the underlying surface conditions. For this study, a detailed surface feature classification was developed by refining land use data provided by Lyon County and adding more detail in areas where the initial delineations were too generalized. For example, major areas of pavement (parking lots and roads) and wash corridors were delineated in the modeling area since these features can act as major conveyances. Buildings and other structures were also added based on the latest available aerials (see Section 2.2.10).

Table 2-6 lists the surface classification and its corresponding Manning's n values that were used in this analysis. Higher values were used for the lower watershed and wash classifications than what was used in the Dayton Valley ADMP due to the increased roughness that was found in South Dayton watersheds (see example in Figure 2-8). The spatial distribution of the surface classification is shown in Figure 2-9.

Table 2-6. Surface classification and corresponding Manning's n value

Surface Classification	Manning's N
Upper Watershed	0.060
Lower Watershed	0.050
Maintained Grass	0.040
Pavement	0.020
Buildings	0.050
Washes	0.045
Water	0.040

Figure 2-8. Example of typical watercourse in the upper piedmont areas

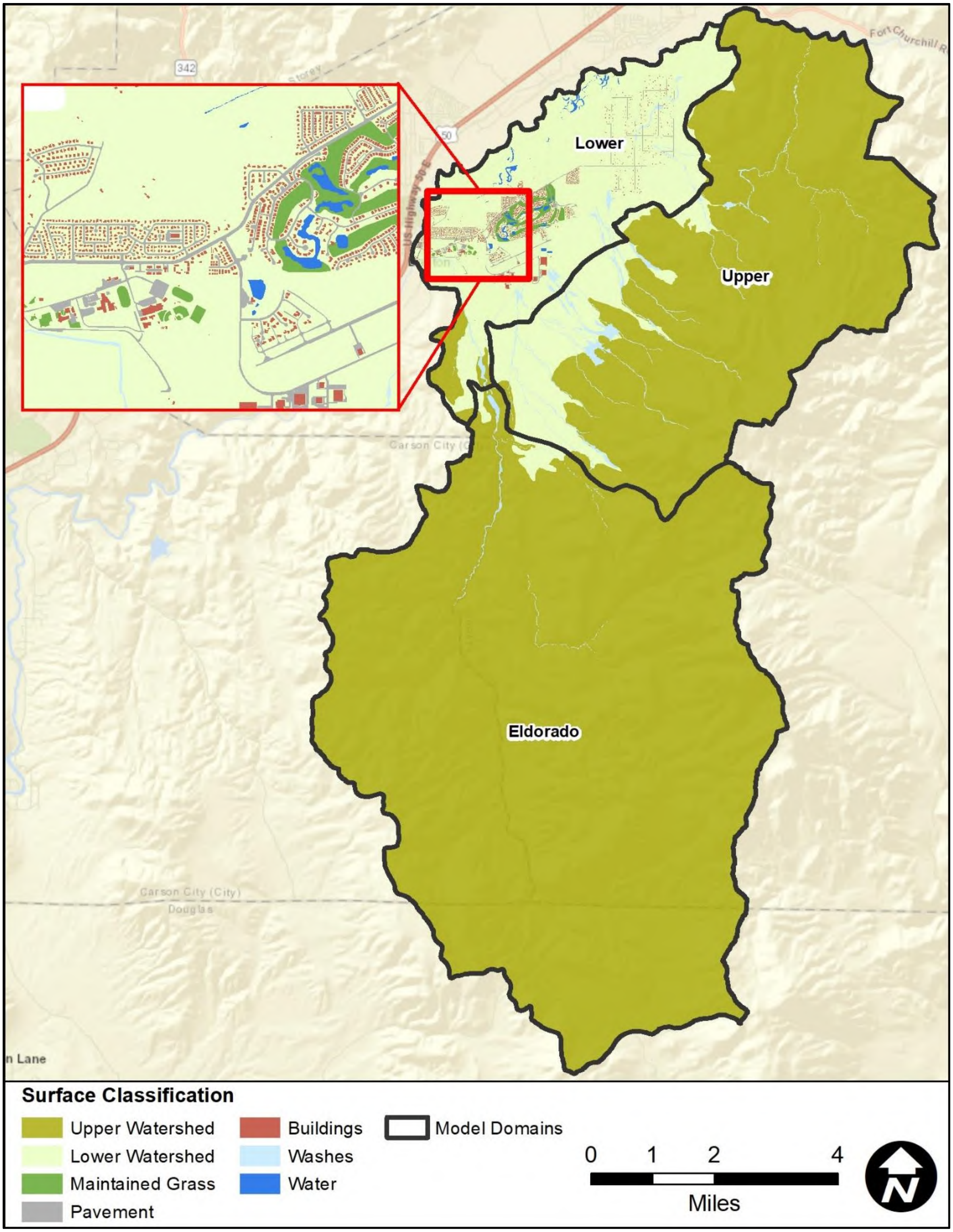

Figure 2-9. Surface classification used to assign grid element roughness in the FLO-2D model

2.2.9 Hydraulic Structures

Both culverts and minor storm drains in the study area were simulated with the hydraulic structure routine within the FLO-2D software. Please see the FLO-2D Data Input Manual (FLO-2D Software, Inc., 2016) and the FLO-2D Reference Manual (FLO-2D Software, Inc., 2017) for more details on the application of this routine and its associated modeling options for this build of the FLO-2D software. All structures (culverts and storm drains) that were modeled as a part of this ADMP are shown in Figure 2-10. Lyon County provided the consultant team with plan sheets which included the location and size of most structures within master planned communities. Additionally, JEF staff conducted two field verification visits to the study area (March 2019 and August 2019) to both locate additional structures and verify the information developed from the plan sheets (e.g. locations, sizes, overall condition, etc.).

2.2.9.1 Culverts

In 2016, the Flood Control District of Maricopa County (FCDMC) produced a comprehensive FLO-2D verification report in which recommendations on modeling hydraulic structures were provided. Per those recommendations, the generalized culvert equation option in FLO-2D was used in the South Dayton Valley ADMP models for single barrel box and circular culverts as a first option. If there were multiple barrels, a rating table was developed assuming inlet control for the culvert. The modeling options that were used to model culverts are summarized in the list below.

1) Generalized culvert equations used for single barrel boxes and circular culverts with no tailwater influence (i.e., INOUTCONT parameter set to 0).
2) If multiple barrel, a rating table developed based on inlet control.
3) If significant sediment blockage, most times a rating table developed based on inlet control with a reduced discharge based on the percent clogged. In one case, the height was reduced on a single barrel box culvert to account for sediment deposition.
4) If culvert had an irregular shape (i.e., ellipse or arch), a rating table was developed based on a simplified EPA-SWMM model (and the flow reduced if there was significant sediment blockage).
5) If tailwater conditions could affect flow, a rating table was used and the INOUTCONT parameter in FLO-2D was set to 2.

2.2.9.1.1 Clogging Factors

If a culvert was observed to have significant sediment blockage during a field investigation, an appropriate reduction in flow was applied to the rating table or the open area (i.e., if a culvert was blocked by 50%, the flow or open area was reduced by 50%).

For the detailed on-site modeling (i.e., the Lower model), smaller culverts (<36 inches) used a 50% clogging factor. Larger culverts (≥ 36 inches and box culverts) did not have a clogging factor except where sediment deposition was observed at the culvert or in the watersheds that exhibited high sediment transport rates. The larger culverts that used a clogging factor were denoted by adding a “clog” or “clg” to the name of the structure in the FLO-2D HYSTRUC.DAT input file.

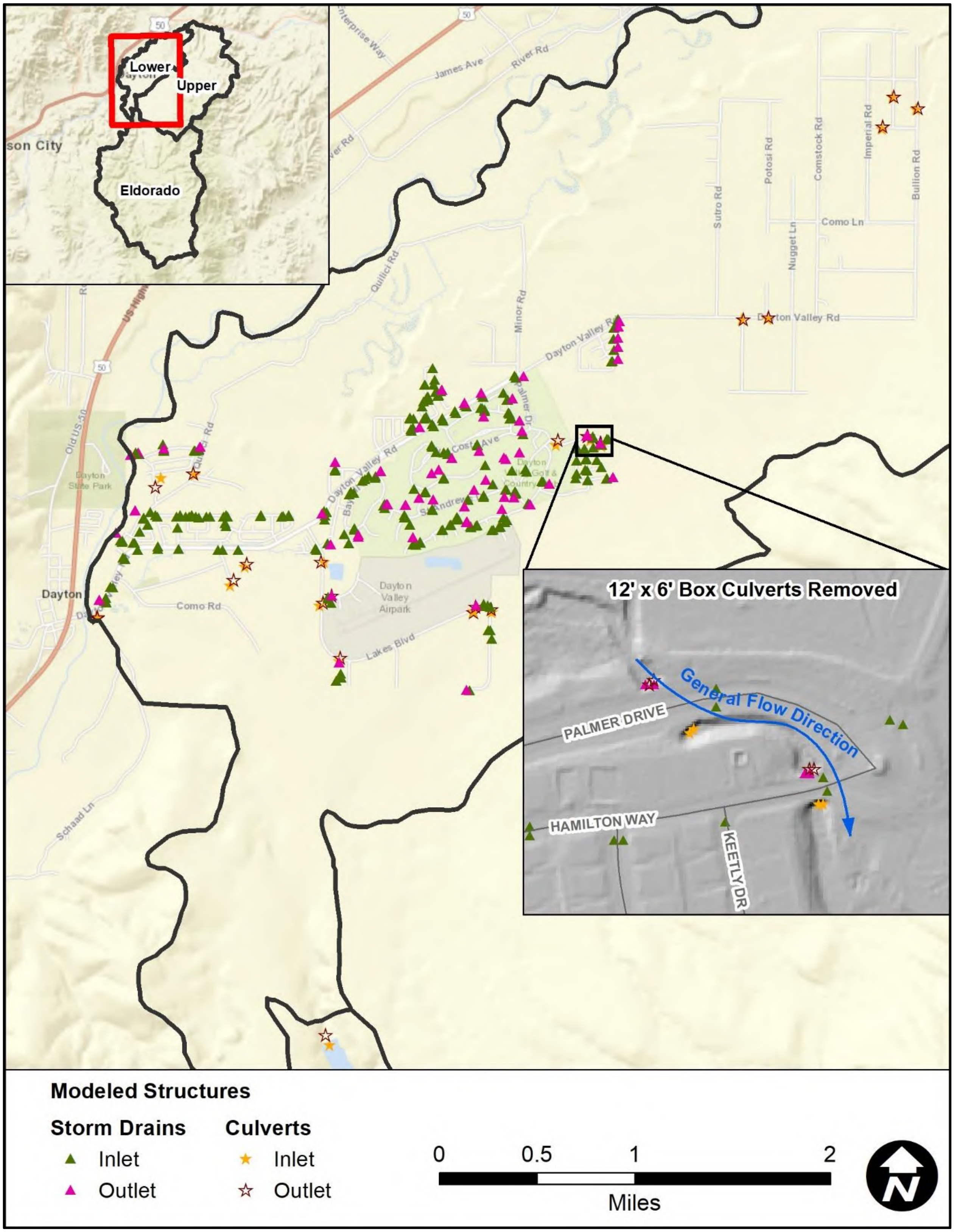

Figure 2-10. Locations of all modeled hydraulic structures (storm drains and culverts)

2.2.9.1.2 Special Problems

Four 12-ft by 6-ft box culverts (within the Lakes at Dayton Valley Village 9 subdivision, see inset map on Figure 2-10) showed erroneous depth results during initial simulations. This area was reviewed, and it was found that water flanks these culverts and enters the incomplete downstream channel first before flowing through these culverts to the upstream channel/basin. Since this water is basically in a ponded condition, an INOUTCONT value of 2 was used for these culverts to allow for reverse flow. However, the box culvert with cell numbers (or ID) 2073538 and 2098000 showed severe oscillations in water surface elevation (WSEL) – see left chart in Figure 2-11. These oscillations appeared to cause a higher depth in the northernmost section of this channel/basin. Consequently, these culverts were removed, and cells lowered to allow for the overland flow routine within FLO-2D to calculate the hydraulics through the open area of these culverts (see Section 2.2.11 for other model adjustments). A comparison of the water surface elevations at the four cell locations (inlet and outlet of two culverts) between the "with" and "without" box culverts scenarios is shown as Figure 2-11. The "without" box culvert scenario shows much more reasonable results when compared with the "with" culverts scenario. Therefore, the final Lower models do not contain the four 12-ft by 6-ft box culverts.

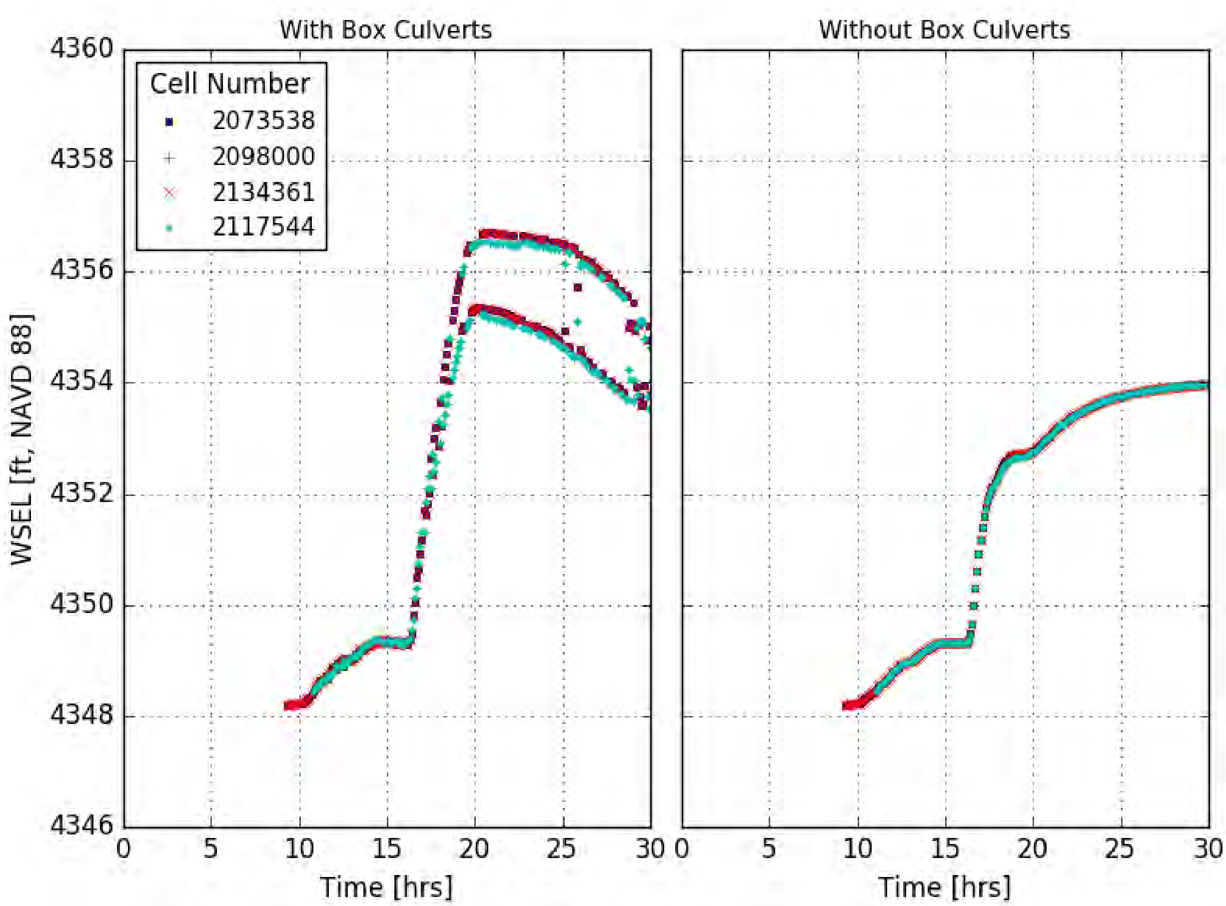

Figure 2-11. Comparison of water surface elevations at the upstream/downstream inlet and outlet cell location with (left) and without (right) box culverts.

2.2.9.2 Storm Drains

Since the study area has a relatively small number of minor storm drains (i.e., 12- to 36-inch trunk lines with about 2 to 10 total inlets per trunk line), rating tables were developed to simulate these structures. The rating tables were developed based on the inlet geometry and the connector pipe. This means that at low depths the curb/grate opening controlled flow, but at higher depths the connector pipe capacity controlled. Finally, if multiple inlets were connected to one trunk line outlet, the "D" line functionality that limits the total flow in the storm drain system to a user-specified discharge was used to limit the flow to the trunk line capacity. This capacity was determined by calculating the normal depth full flow of the trunk line and estimated a 20-50% increase in flow to account for some pressure flow. The limited pipe capacities that were used in the FLO-2D modeling are shown in Table 2-7.

Table 2-7. Full flow versus "D" line pipe capacity used in the FLO-2D modeling

Pipe Diameter	Full Flow (normal depth)	Pipe Capacity in FLO-2D
inches	**cfs**	**cfs**
12	6	9
15	10	15
18	17	25
21	25	33
24	36	48
30	65	78
36	105	126

2.2.10 Buildings (as Flow Obstructions)

As a part of the OpenStreetMap project, the Microsoft Bing Maps team developed techniques to automatically digitize building footprints from aerials[4]. These automated routines were used to create building coverages for all 50 US states. The buildings shapefile for Nevada was downloaded from Microsoft's GitHub site[5], and this shapefile was updated by the consultant team using the latest available aerials (dated late 2018) to reflect the most current conditions.

This updated shapefile was used to create a global area-weighted 10-foot blocked obstruction raster. The raster was then used to extract the percentage of area obstructed by buildings and assigned to area reduction factors (ARF) for each grid in each sub-model. The totally blocked grid element routine ("T Line") was not used to simplify file development. Totally blocked grids were rather assigned 1 in the partially blocked grid attribute (i.e., the IDG column). Similarly, to ease file development, width reduction factors (WRF) were not used in this study and were assigned a 0 value in the ARF.DAT file. The buildings that were modeled with the ARF functionality are shown in Figure 2-9.

[4] https://blogs.bing.com/maps/2018-06/microsoft-releases-125-million-building-footprints-in-the-us-as-open-data
[5] https://github.com/Microsoft/USBuildingFootprints

It should be noted that other flow obstructions, such as block walls, exist within the study area. One example is within the Dayton Valley Country Club, were substantial block wall exist. However, these walls were not modeled because they were not designed as engineered flood walls; and, as such, would not meet FEMA's criteria for a levee.

2.2.11 Model Adjustments

Manual cell elevation and Manning's n value adjustments were made in a few locations to better reflect physical conditions in the watershed. Both the elevation and n value adjustments are discussed in more detail below. All areas where the model was adjusted are shown in Figure 2-12.

2.2.11.1 Cell Elevations

The cell elevations that were adjusted fell into two main categories. These were:

1) Adjustments at culverts to obtain better hydraulics, and
2) Adjustment of the NEXTMap data to allow for better flow transfer off the LiDAR data to the NEXTMap data.

The adjustments at culverts occurred at three locations – the invert of the box culvert on Lakes Boulevard upstream of the airport was lower to show a more accurate elevation, the cell elevations that represent the roadway at the Ricci Road box culvert on Eldorado Canyon were adjusted to show the roadway elevation since the LiDAR data removed the roadway, and the cell elevations at the box culverts (discussed in Section 2.2.9.1.2) were lowered to represent the almost flat slope of the culverts.

The NEXTMap adjustment was only necessary where water flowed from the LiDAR data to the NEXTMap data. This situation only occurred in the flat area downstream of the mountains in the northwest area of the Upper model (shown in Figure 2-12). Other topography seam areas (between the LiDAR and NEXTMap) were handled by raising the NEXTMap data 10 feet to remove the potential for erroneous ponding.

2.2.11.2 Manning's n values

Areas, such as gravel mines or retention basins, that contain a large depth of ponded water can cause model runtimes to become extremely long due to excessive time step decrements. A relatively high Manning's n value is assigned to these areas to help alleviate this issue. The adjusted n value for deep ponded grid elements was chosen based on the recommended table of ponded n values shown as Table 2-8. However, a lower n value was generally used to ensure that the hydraulics weren't erroneously affected in some areas (e.g., at the Eldorado Canyon Dam).

For this study, the primary areas where n values were adjusted were:

1) The deep gravel mines along Eldorado Canyon (adjusted n value = 0.15),
2) The flood pool of Eldorado Canyon (adjusted n value = 0.08).
3) The lakes that function as retention basins within the golf course (adjusted n value = 0.08).

The cells where the elevations were adjusted to account for the removal of the box culverts also used an n value of 0.08.

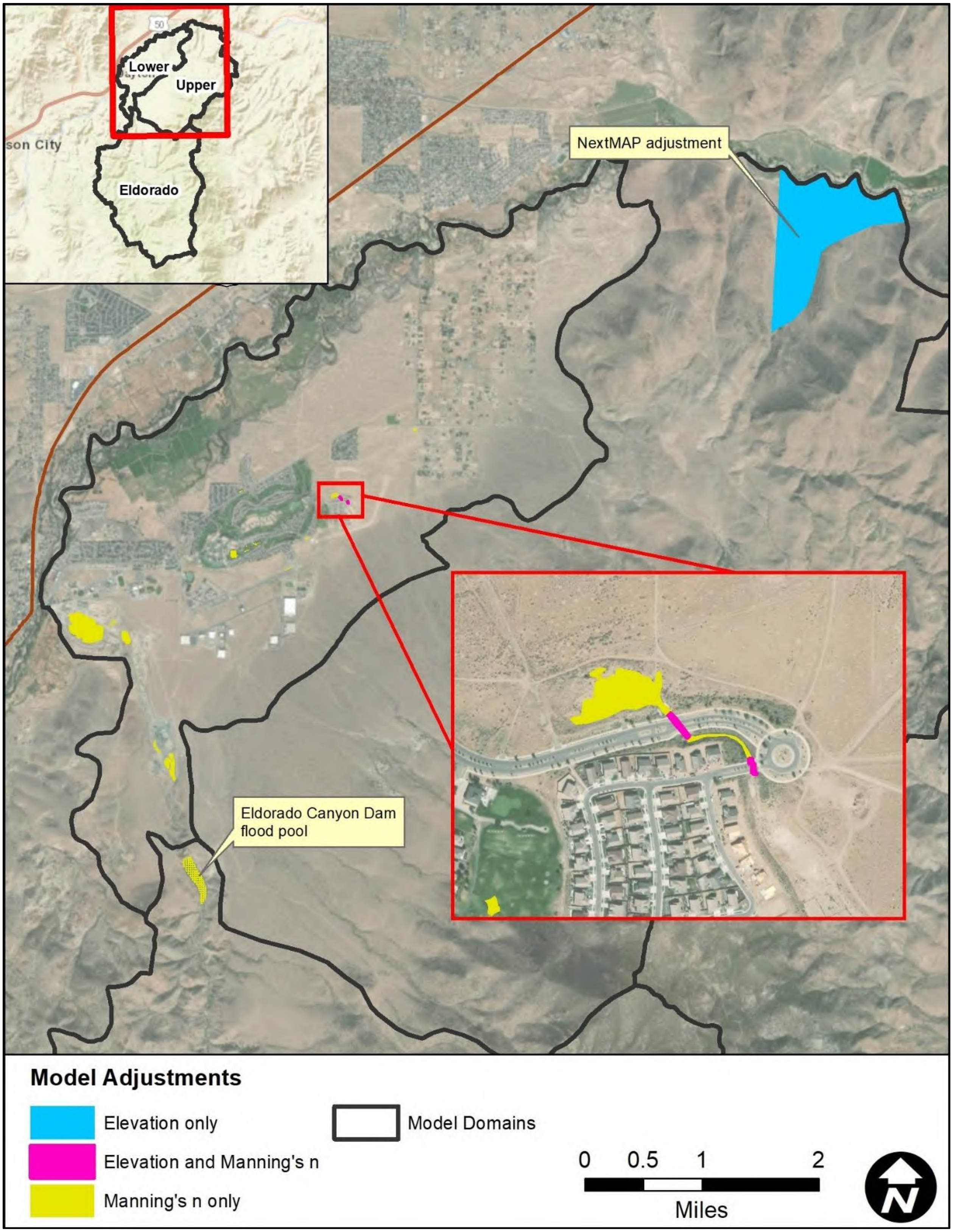

Figure 2-12. Locations and types of model adjustments

Table 2-8. Recommended n values for deep ponded areas, from FCDMC (2016)

Depth (feet)	n value
5 - 8	0.08
8 - 10	0.10
10 - 15	0.20
> 15	0.30

2.2.12 Model Control Parameters

CONT.DAT and TOLER.DAT contain numerical stability and simulation controls for the FLO-2D model. The CONT.DAT file controls simulation time, output report time interval, some numerical controls and model switches, such as infiltration and rain. The total simulation time was set to 15 hours for the 6-hour storm, while the total simulation time was set to 30 hours for the 24-hour storms. These times were sufficient to ensure that the bulk of the floodwave has traveled through the entire study area and keeping total model runtime reasonable (e.g., about 120 hours for the Lower model 100-year 24-hour simulation).

In the CONT.DAT file, the global Manning's n value adjustment factor (AMANN) and the limiting Froude number (FROUDL) were the numerical controls that were used in the South Dayton Valley ADMP study. For this study, these controls were set to:

- AMANN = 0 (depth integrated roughness is used with the SHALLOWN parameter)
- FROUDL = 1.5 (Off-site areas), 1.1 (detailed model area)
- SHALLOWN = 0.20 (Off-site areas), 0.15 (detailed model area)

For the limiting Froude number, a value of 1.5 was used in the off-site, upper watershed areas (Eldorado and Upper modeling domains) due to the presence of mountainous and piedmont areas where high flow velocities are possible since slopes can be greater than 20%. In the detailed model area, the limiting Froude number was set to 1.1 to account for the general reduction in slope in comparison to the higher slopes found in the upper watersheds. Similarly, the SHALLOWN was set to 0.20 for the upper watershed areas to account for the increased roughness due to large boulders and rocks, while the lower detailed model (Lower domain) used a value of 0.15. The relatively high SHALLOWN values were chosen due to the rocky terrain and surface cover that is found in the study watersheds (see Figure 2-8 and Figure 2-13).

The TOLER.DAT file contains the numerical tolerance settings specified for the model. These settings are: the flow exchange tolerance (TOL), percent allowed change in flow depth (DEPTOL), dynamic wave stability criteria (WAVEMAX), and Courant-Friedrich-Lewy numerical stability parameter for floodplain grid element flow exchange (COURANTFP). For the South Dayton Valley models, the settings applied were:

- TOL = 0.004 feet (the depth at which FLO-2D begins to route flow)
- DEPTOL = 0 (not used, model uses Courant number as stability criteria)
- WAVEMAX = 0 (not used, model uses Courant number as stability criteria)
- COURANTFP = 0.6 (main stability criterion used by FLO-2D)

These values have been used in similar studies, which yielded reasonable results. For this project, these values have produced good model stability and reasonable results.

Figure 2-13. Example of typical vegetation and rock cover in the upper piedmont areas

2.3 Model Results

2.3.1 Floodplain Cross-Sections

Floodplain cross-sections were developed and included in the FPXSEC.DAT file to query flow hydrographs, peak discharges, and flow volumes from the FLO-2D model at key locations, such as:

- Major flow concentration locations,
- Areas near potential mitigation sites, and
- Areas of interest to Lyon County

Major floodplain cross-section locations are shown on Figure 2-14. Hydrograph plots at the floodplain-cross-sections for each storm event are included in Appendix C. The peak flow and volume for each floodplain cross-section are shown in Table 2-9.

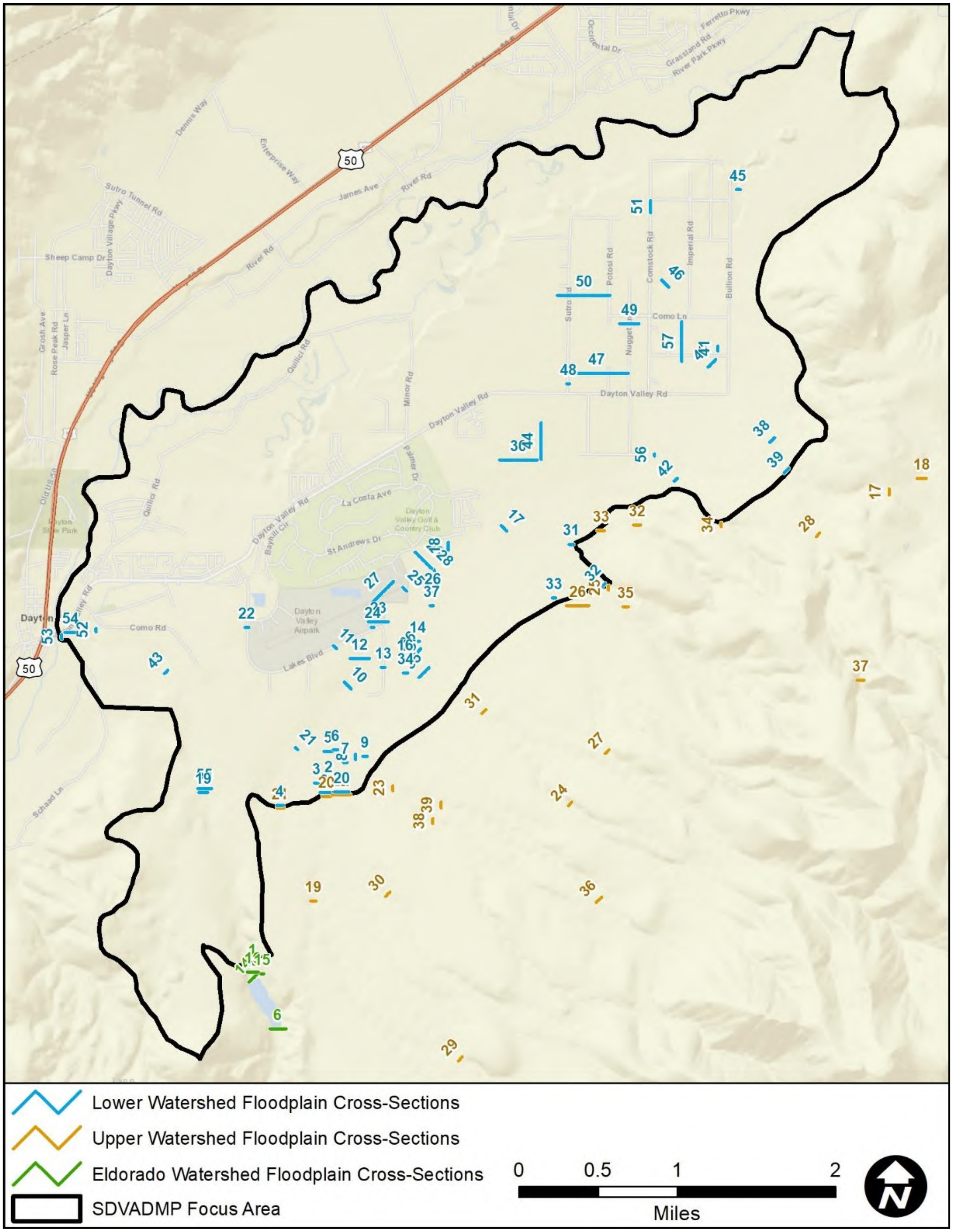

Figure 2-14. Floodplain cross-section locations

Table 2-9. Peak flow and volume results from the FLO-2D floodplain cross-sections

ID	100Y24H		100Y6H		25Y24H	
	Peak Flow	Volume	Peak Flow	Volume	Peak Flow	Volume
	cfs	ac-ft	cfs	ac-ft	cfs	ac-ft
Note: Volumes shown below may not contain the entire hydrograph volume due to extreme model runtimes when modeling ponded conditions. Please verify correct volume is used for any design.						
Lower Watershed Model						
1	523.6	160.8	47.0	15.9	267.2	83.1
2	522.5	160.8	46.9	15.9	267.3	83.1
3	1.0	0.2	0.1	0.0	0.2	0.0
4	11.8	4.7	1.6	0.8	4.5	2.2
5	479.4	155.8	47.0	15.7	265.6	82.9
6	43.3	7.1	0.3	0.1	3.6	1.1
7	74.7	27.0	9.9	3.5	41.4	14.8
8	458.9	141.2	42.6	13.7	243.6	73.4
9	3.4	0.4	0.0	0.0	0.0	0.0
10	1057.6	343.5	92.5	33.7	545.0	177.0
11	8.6	5.0	11.3	2.1	5.7	3.2
12	1064.5	349.8	93.6	34.3	549.5	180.8
13	15.4	6.8	2.8	0.9	5.9	3.3
14	202.4	67.5	22.8	7.7	104.6	35.5
15	120.4	45.1	17.8	5.9	68.9	25.3
16	8.0	1.5	0.0	0.0	0.6	0.1
17	624.0	301.8	101.5	38.6	334.2	179.7
18	549.7	260.6	99.0	39.5	325.2	163.2
19	13205.3	4295.5	1147.9	369.0	6746.3	2436.8
20	68.8	23.4	9.5	3.2	40.3	13.4
21	22.3	9.8	2.7	1.4	7.9	4.4
22	2.3	0.4	0.2	0.0	0.1	0.1
23	1091.8	363.7	94.1	38.0	530.5	185.0
24	364.3	215.6	93.0	37.1	324.5	159.7
25	253.9	168.8	90.1	35.4	234.4	129.9
26	212.5	72.8	24.4	8.2	107.7	37.7
27	535.8	123.3	1.7	0.8	171.3	35.5
28	47.8	44.8	33.8	18.7	43.9	38.4
29	710.0	267.8	68.7	23.7	381.6	145.2
30	905.0	409.7	93.3	26.1	444.6	222.0
31	168.1	45.6	33.5	7.6	90.9	23.9
32	162.2	41.8	29.9	7.1	85.8	22.1
33	214.5	67.8	16.3	4.7	131.1	36.4

ID	100Y24H		100Y6H		25Y24H	
	Peak Flow	Volume	Peak Flow	Volume	Peak Flow	Volume
	cfs	ac-ft	cfs	ac-ft	cfs	ac-ft
34	17.7	6.6	1.6	0.9	7.1	3.2
35	138.6	45.4	20.7	5.8	80.9	25.2
36	57.9	14.7	3.0	1.0	24.3	6.3
37	211.8	71.9	24.4	8.1	107.8	37.4
38	414.6	139.6	42.0	15.4	208.9	74.6
39	416.6	139.9	42.3	15.5	208.9	74.7
40	416.4	141.4	42.7	15.3	210.2	75.3
41	44.3	13.8	8.0	2.2	20.1	6.2
42	28.1	8.4	6.8	1.5	14.6	4.1
43	14064.6	4417.5	1127.3	360.7	6745.4	2430.4
44	883.7	407.7	81.4	21.3	425.3	220.4
45	494.4	329.7	26.4	9.0	161.1	111.9
46	490.7	297.1	39.3	14.3	162.7	124.8
47	851.8	385.4	0.3	0.1	319.3	156.5
48	5.0	0.6	0.0	0.0	0.0	0.0
49	391.9	189.4	3.6	1.2	114.0	69.1
50	314.4	178.3	0.1	0.0	109.9	47.1
51	187.9	87.2	0.1	0.0	0.1	0.0
52	4108.4	1968.6	1114.7	353.5	2650.7	1428.8
53	1814.0	1345.1	1087.3	348.5	1652.7	1124.0
54	393.6	146.4	17.3	2.0	252.4	91.4
55	14260.5	4433.4	1148.0	368.9	6744.5	2437.5
56	10.8	3.6	2.0	0.6	5.0	1.7
57	463.7	157.1	49.3	17.5	230.5	82.1
Upper Watershed Model						
1	970.9	328.2	165.5	41.0	510.8	170.1
2	794.1	245.6	141.7	33.3	433.6	131.4
3	238.0	76.8	20.9	7.5	100.2	36.3
4	959.8	324.8	162.6	41.0	504.2	168.7
5	70.2	20.1	10.9	3.1	31.5	8.7
6	932.2	324.5	161.5	39.6	511.9	169.6
7	74.0	18.7	7.0	2.1	21.0	6.6
8	87.2	25.1	18.4	4.1	43.8	11.7
9	58.7	17.0	12.4	2.8	32.1	8.1
10	79.1	24.2	16.4	3.7	37.7	11.1
11	5.6	1.8	0.8	0.2	2.7	0.7
12	69.2	21.9	7.5	2.4	21.8	8.2
13	989.1	333.8	169.5	41.7	521.1	172.7

ID	100Y24H		100Y6H		25Y24H	
	Peak Flow	Volume	Peak Flow	Volume	Peak Flow	Volume
	cfs	ac-ft	cfs	ac-ft	cfs	ac-ft
14	903.8	317.5	166.8	40.6	511.4	169.9
15	11.7	2.4	0.1	0.0	0.9	0.2
16	36.4	5.1	0.0	0.0	0.5	0.1
17	139.4	51.8	17.4	6.8	79.1	30.4
18	114.0	31.1	2.8	1.3	45.7	13.0
19	376.8	123.4	33.8	12.2	203.3	64.9
20	508.6	162.4	46.1	16.1	260.0	83.2
21	11.7	4.6	1.7	0.8	4.6	2.2
22	70.6	24.3	10.0	3.4	43.6	13.9
23	456.2	140.8	42.3	13.8	242.6	73.1
24	137.4	42.9	14.5	4.5	76.5	22.6
25	139.5	41.8	31.8	7.0	78.5	22.1
26	254.5	68.4	19.5	5.9	117.7	33.1
27	316.6	94.4	22.9	5.4	168.2	47.6
28	268.8	81.2	29.7	8.2	137.8	41.5
29	254.2	77.1	21.5	5.9	140.2	40.3
30	128.9	40.7	16.5	4.8	68.5	21.5
31	180.8	56.2	22.5	6.4	96.7	29.5
32	32.2	9.2	7.7	1.6	16.6	4.6
33	5.4	1.7	1.3	0.3	2.6	0.8
34	22.8	7.0	5.1	1.2	12.3	3.5
35	119.9	36.2	23.9	6.1	68.0	19.4
36	240.4	71.9	17.2	4.0	130.4	36.4
37	150.5	44.4	7.8	2.1	76.2	21.6
38	115.1	36.1	17.9	5.0	62.7	19.3
39	326.5	98.9	25.3	8.1	175.9	51.1
Eldorado Model						
1	14161.8	4538.4	1144.9	374.9	7901.3	2568.8
2	1937.5	617.3	145.2	52.6	1131.7	349.7
3	5166.0	1719.1	602.4	185.6	2982.9	1004.4
4	3752.8	1240.6	403.2	122.7	2138.8	717.0
5	2230.4	702.8	207.8	61.1	1261.1	391.8
6	14083.6	4620.1	1435.1	484.5	8023.8	2643.6
7	13816.8	4540.4	1427.9	481.7	7914.0	2604.5
8	13382.6	4402.7	1401.6	469.1	7690.5	2533.1
9	10775.2	3569.1	1182.9	395.2	6219.5	2069.5
10	2561.4	811.5	228.0	73.4	1435.3	452.4
11	9538.5	3167.9	1060.6	347.8	5529.6	1846.1

ID	100Y24H		100Y6H		25Y24H	
	Peak Flow	Volume	Peak Flow	Volume	Peak Flow	Volume
	cfs	ac-ft	cfs	ac-ft	cfs	ac-ft
12	889.0	282.9	152.2	39.0	523.1	165.5
13	8678.8	2882.2	948.6	308.9	5021.5	1679.1
14	3782.8	522.4	0.2	0.0	131.9	6.8
15	10245.8	3919.4	1088.7	335.4	7578.7	2461.9
16	3845.8	601.8	56.2	40.2	187.4	81.2

2.3.2 Depth and Discharge Results

Flow depth and discharge results from the existing conditions FLO-2D modeling are shown on Figure 2-15 through Figure 2-20. These figures are for general illustrative purposes and not practical for obtaining detailed information at site-specific locations. For more detailed information, please see the digital data in Appendix C, which includes the grid-based results for maximum flow depth, maximum peak discharge, maximum velocity, and other FLO-2D output.

2.3.3 Animations

Google Earth animations of the Lower model have been included with the digital model results (see Appendix C). These animations are helpful for visualizing the dynamic nature of the flooding as it moves through the study area.

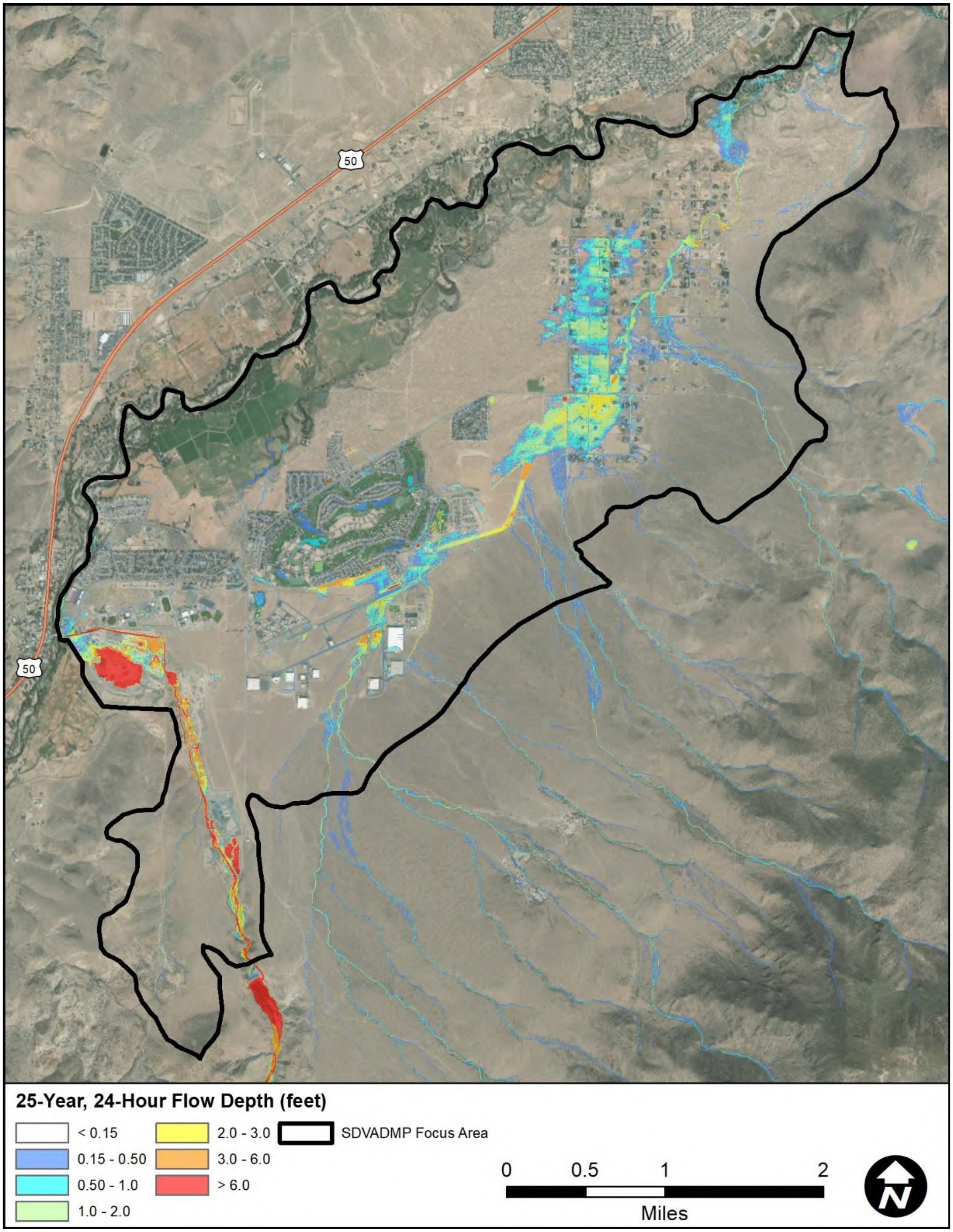

Figure 2-15. Existing conditions 25-year, 24-hour flow depth results

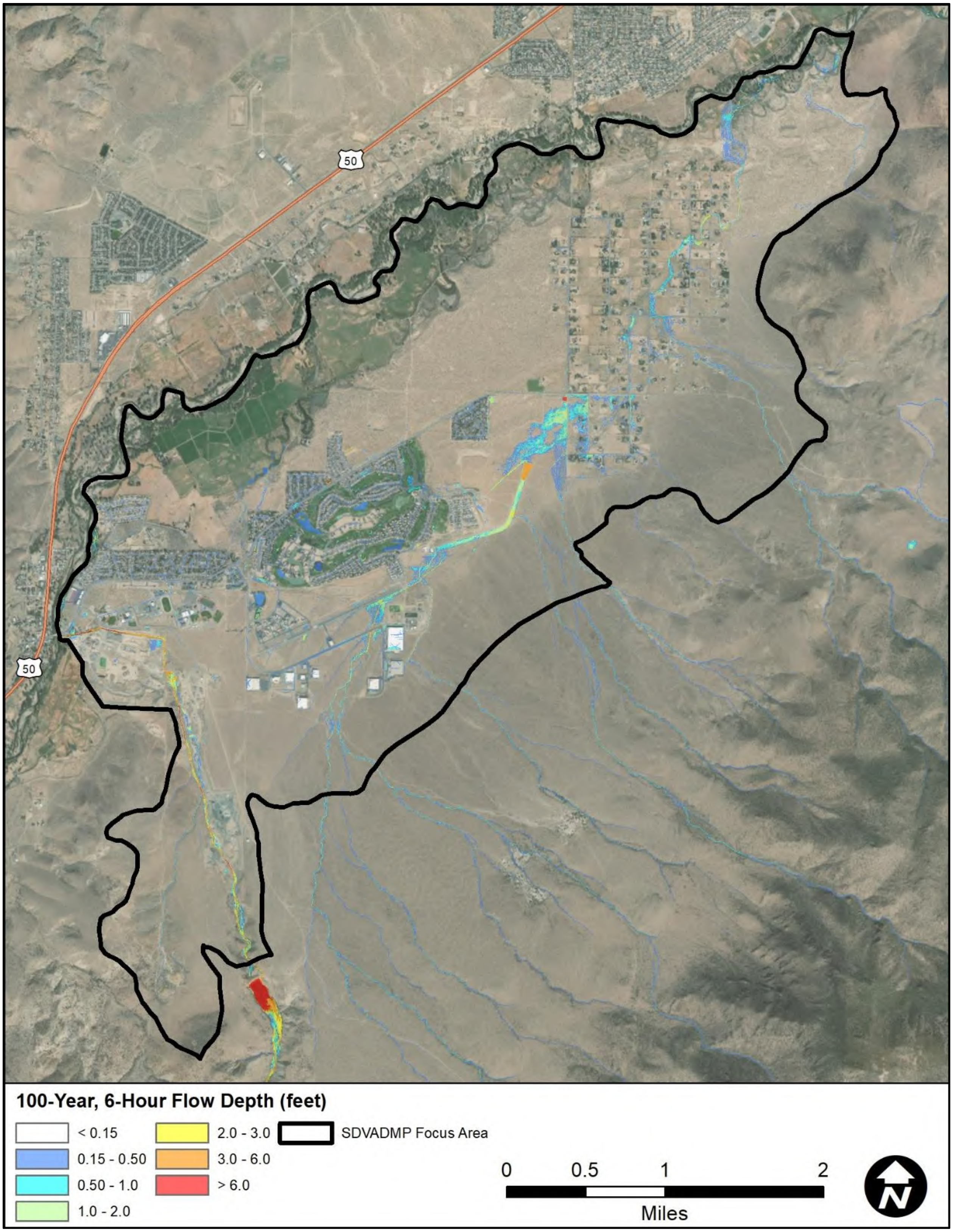

Figure 2-16. Existing conditions 100-year, 6-hour flow depth results

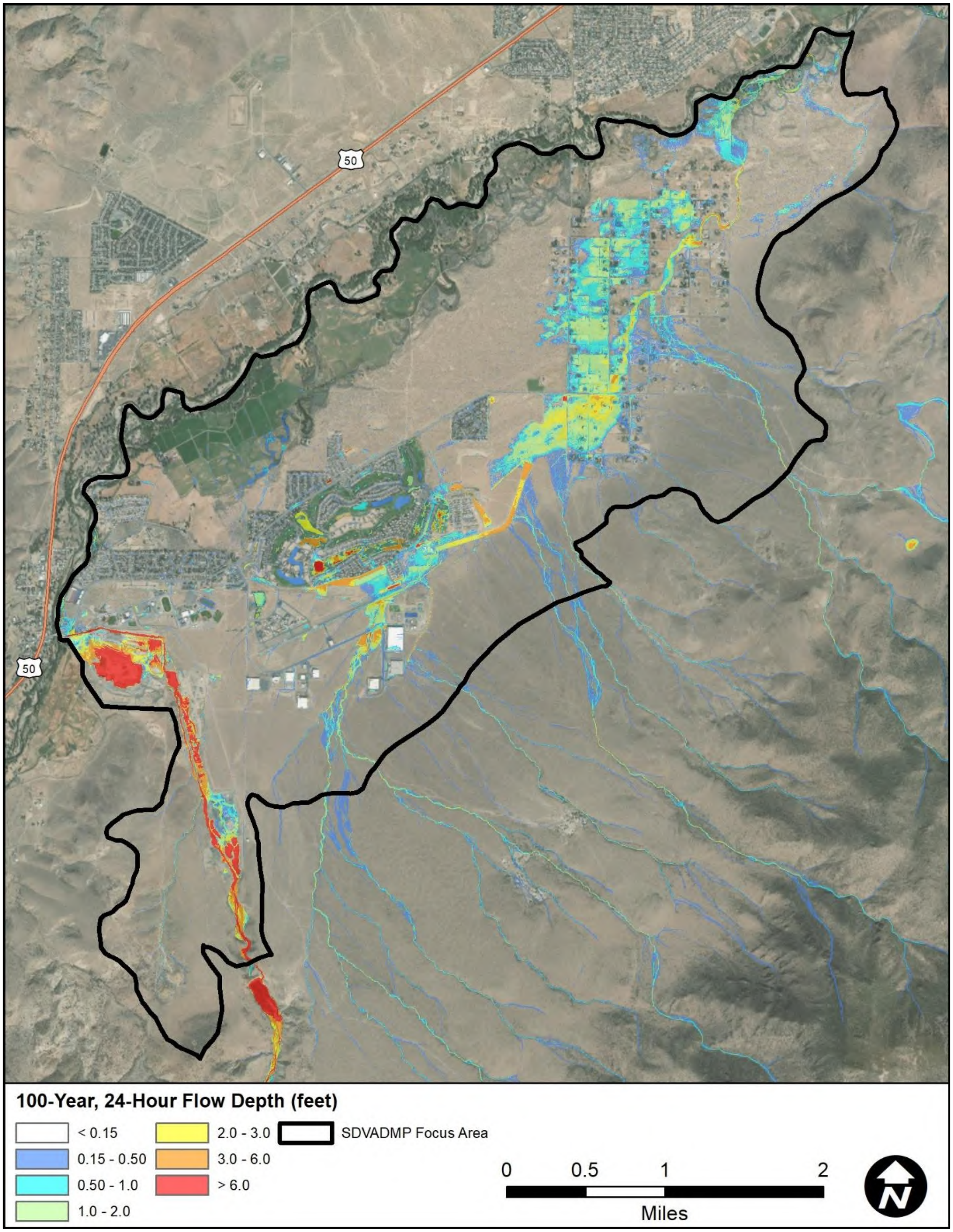

Figure 2-17. Existing conditions 100-year, 24-hour flow depth results

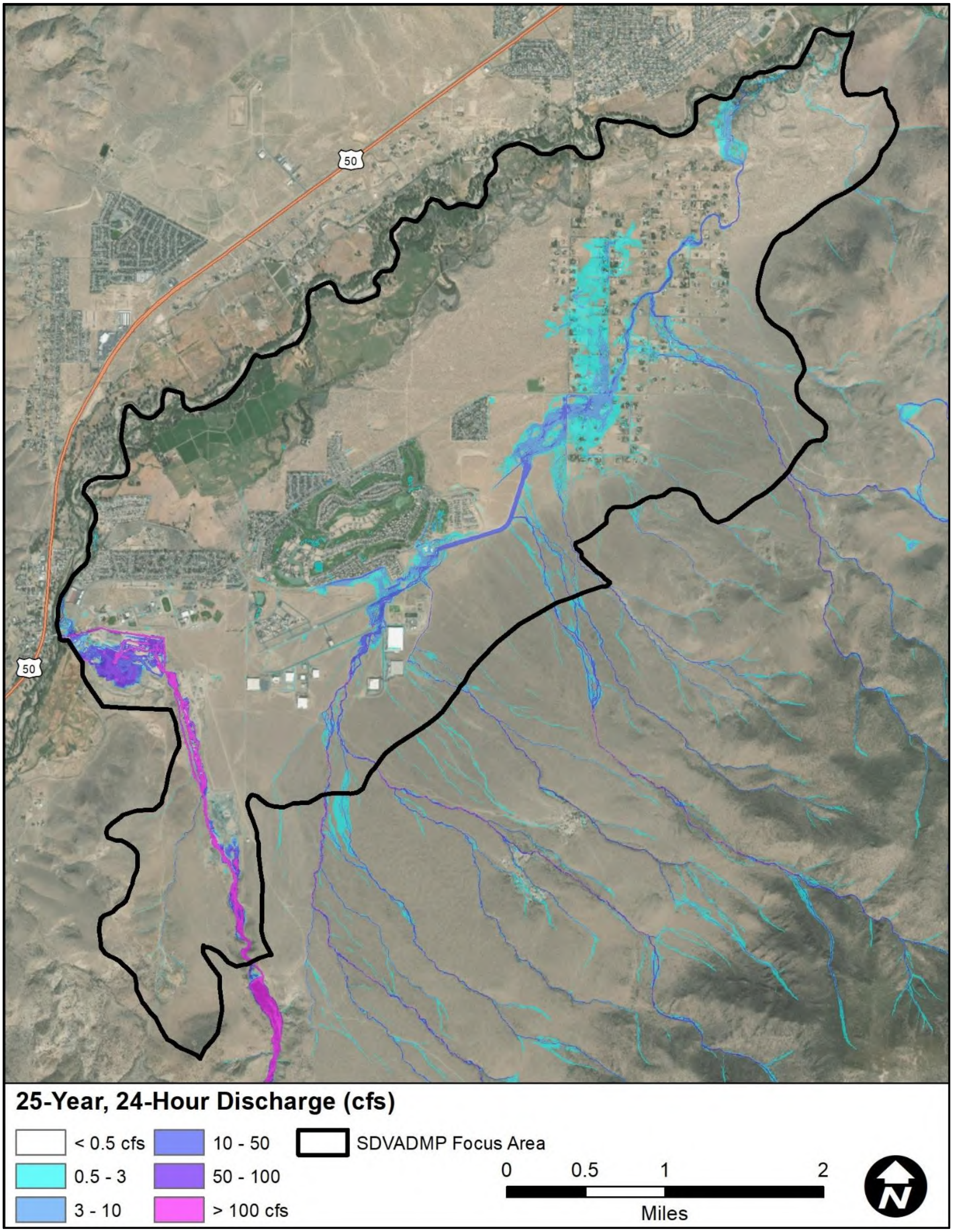

Figure 2-18. Existing conditions 25-year, 24-hour discharge results

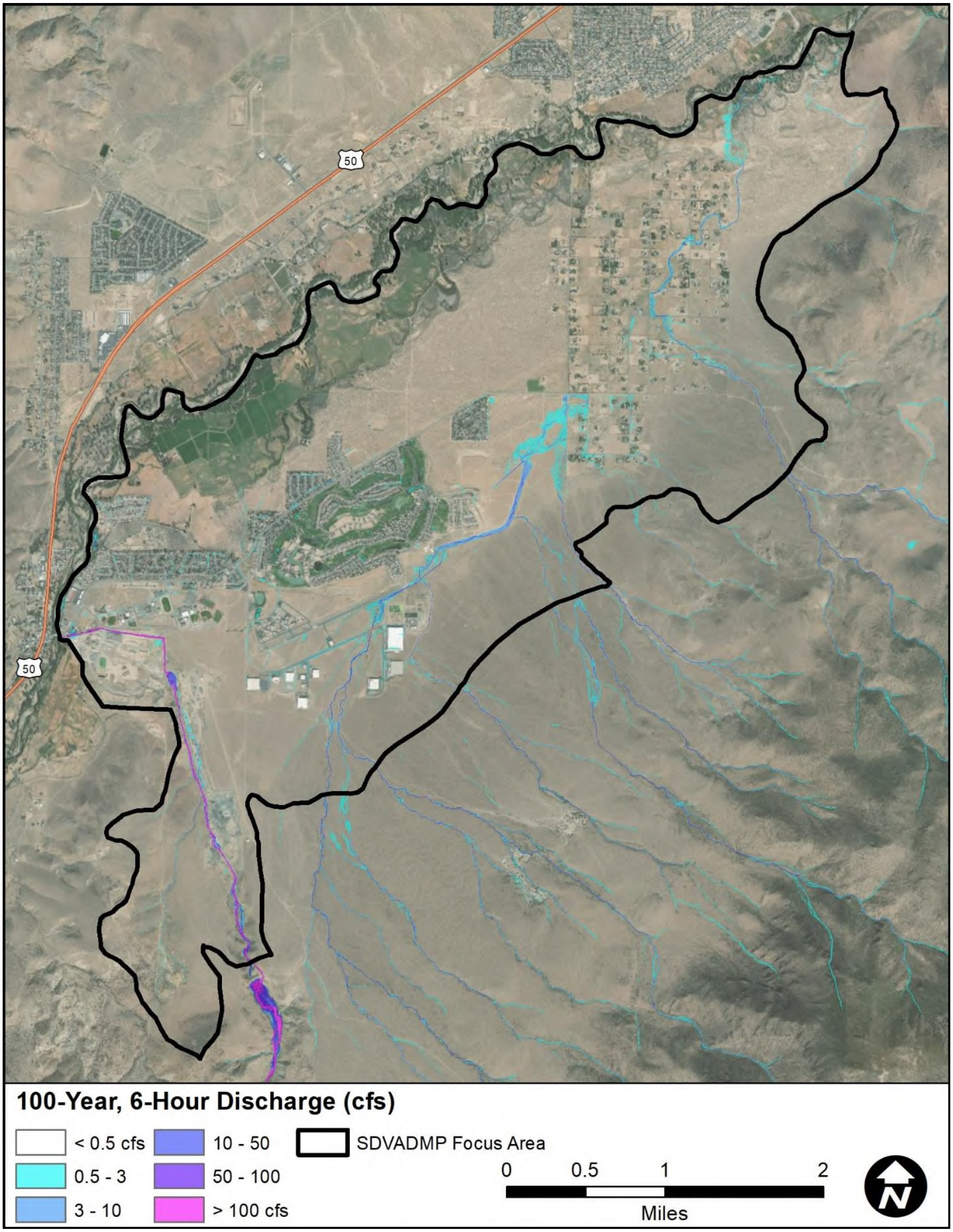

Figure 2-19. Existing conditions 100-year, 6-hour discharge results

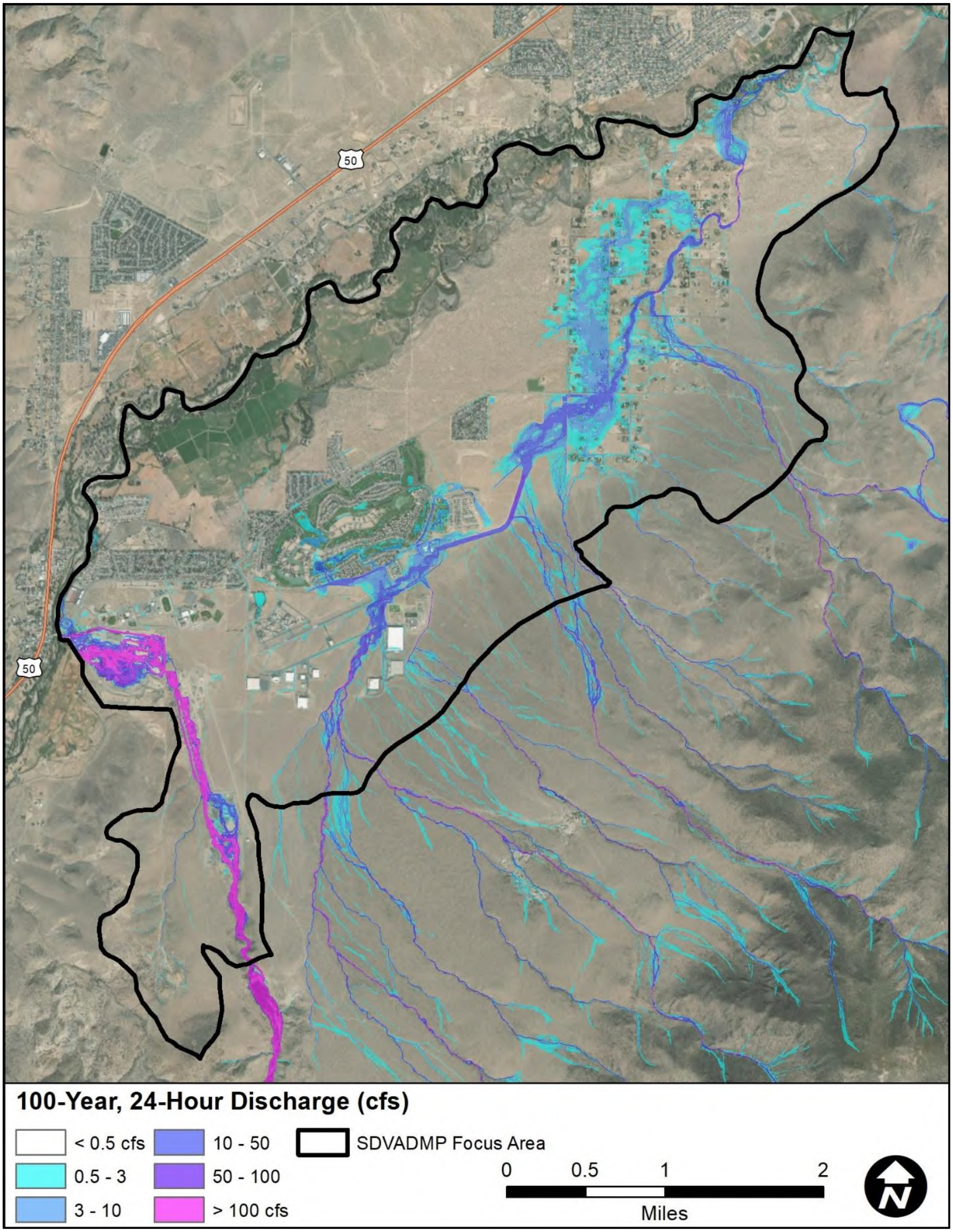

Figure 2-20. Existing conditions 100-year, 24-hour discharge results

2.4 VERIFICATION OF RESULTS

2.4.1 Comparison with USGS Regression Equations

As a verification of model results, the 100-year 6- and 24-hour results at seven drainage basins were compared with the 100-year USGS regression equation, shown as Equation (1), for the Eastern Sierras Region 5 (USGS, 1997).

$$Q_{100} = 7000AREA^{0.782}(ELEV/1000)^{-2.18}(LAT-28)^{4.6} \quad (1)$$

Where:

- Q_{100} is the 100-year peak discharge (cfs)
- *AREA* is the drainage area (square miles)
- *ELEV* is mean basin elevation (ft)
- *LAT* is the latitude of site (decimal degrees)

The results from this comparison are shown in Table 2-10 and Figure 2-21, while the basin locations used for this comparison are shown in Figure 2-22.

Table 2-10shows both the 100-year 6-hour (labeled as 100Y6H) and the 100-year 24-hour (labeled as 100Y24H) peak flow results from the FLO-2D modeling compared with the 100-year flow from the regression equation. The unit discharges for each basin and the median values are also calculated and shown in the table.

The comparison indicates that the FLO-2D results for the entire study area are generally reasonable. In Figure 2-21, all results fall below the USGS envelope curve and within the cloud of values. However, 100-year 24-hour storm falls below the low- to middle-elevation study area line (which includes USGS Regression Regions 2-16, not just Region 5) for smaller drainage areas with the results from larger drainage areas rising above the line, while the results from the 100-year 6-hour storm fall below the line for all drainage areas.

When compared with the 100-year discharge relation for Region 5, the results are similar. The 100-year 24-hour storm follows the line for small drainage areas but diverges above the line as drainage area increases. Conversely, the 100-year 6-hour storm falls below the line at small drainage area and approaches the line as the drainage area increases. However, it should be noted that the USGS used mean values for variables other than drainage area when plotting this line. Therefore, this plot may not appear to fit the data.

Finally, since the 100-year 24-hour storm is the controlling storm, this comparison indicates that the FLO-2D results may be conservative (i.e., higher) for larger drainage basins (e.g., > 5 square miles), such as the Eldorado Canyon watershed (Basin ID: 1). However, the unit discharge comparison in Table 2-10 indicate the 100-year 24-hour median unit discharge are reasonable when compared with those generated from Equation (1). Additionally, the only basins that are larger than 5 square miles are contained within the Eldorado Canyon watershed, and that watercourse is contained within its channel as it flows through the focus area. Therefore, the results that impact the focus area of the SDADMP are reasonable Since the Eldorado Canyon watershed is a special case, it and the Eldorado Canyon Dam are discussed in more detail in Section 2.4.4

Table 2-10. Comparison with 100-year USGS regression equation

Basin ID	Basin Area	Regression Peak Flow	Regression Unit Discharge	100Y6H Peak Flow	100Y6H Unit Discharge	100Y24H Peak Flow	100Y24H Unit Discharge
	mi^2	cfs	cfs/mi^2	cfs	cfs/mi^2	cfs	cfs/mi^2
1	54.20	4,859	90	1,435	26	14,084	260
2	6.35	767	121	145	23	1,938	305
3	4.63	890	192	142	31	794	172
4	3.53	644	182	152	43	889	252
5	2.58	540	209	42	16	456	177
6	1.31	276	210	22	16	254	194
7	0.98	194	198	8	8	151	154
8	0.80	225	281	15	18	137	172
9	0.79	352	446	11	14	70	89
10	0.65	243	374	12	19	59	90
11	0.30	144	480	8	26	32	107
		Median:	**209**	**-**	**19**	**-**	**172**

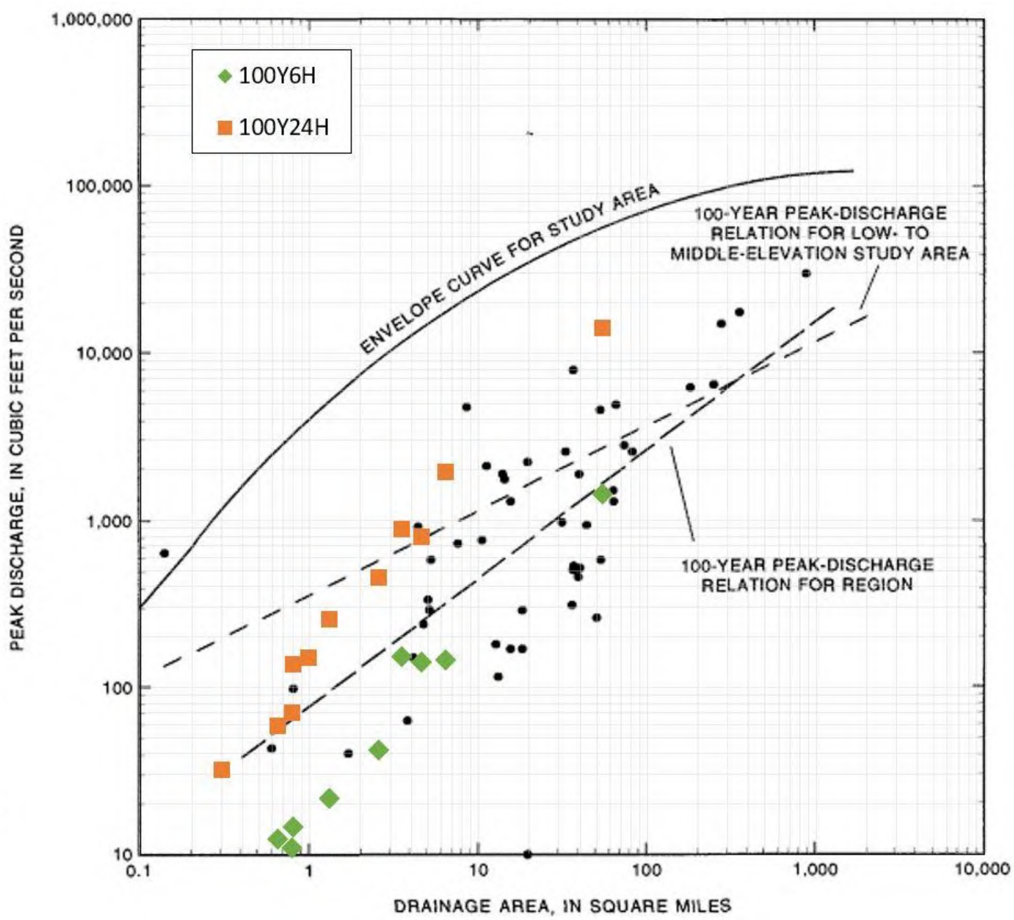

Figure 2-21. Comparison of FLO-2D results with the relations between 100-year peak discharge and drainage area and plot of maximum peak discharge of record and drainage area for gaged sites in the Eastern Sierras Region 5, adapted from USGS (1997).

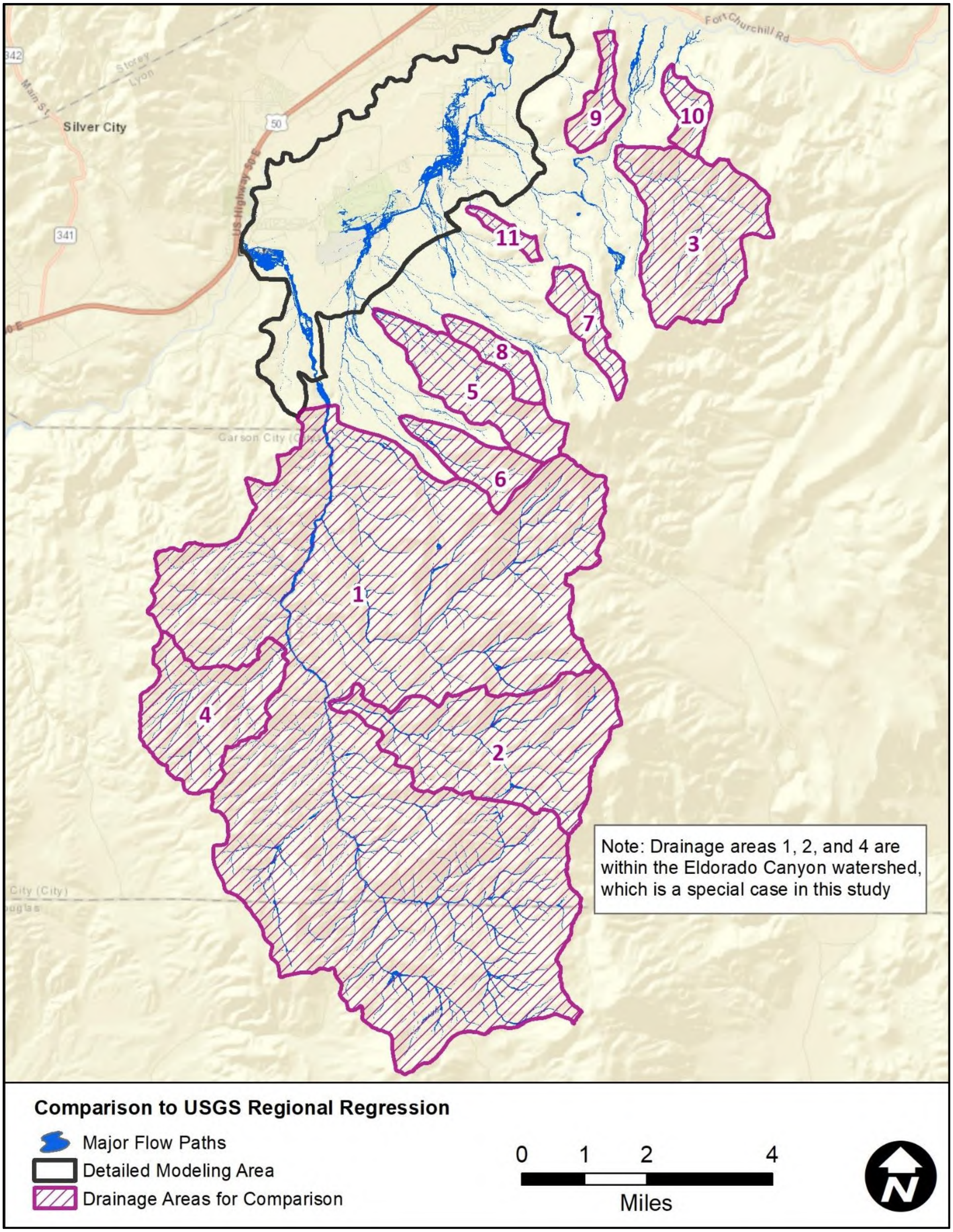

Figure 2-22. Drainage basins used for comparison of FLO-2D results to the USGS 100-year regression equations

2.4.2 Additional USGS Data

As part of another hydrology update project, NDOT recently obtained peak flow estimates for both inactive and active crest stage sites. Since these were crest gages, they contained only peak flow estimates rather than entire hydrographs.

The maximum peak of record for each gage was parsed from the USGS data peak flow data, while the drainage area was collected from each gage's site description on the USGS website. However, not all gages listed the drainage area in the site description. Of the 216 total sites, forty-five did not list the drainage area, and these sites were excluded from the comparison to the SVADMP peak results. A summary of the drainage area statistics for all 216 sites is shown in Figure 2-23, and the spatial location of the sites is shown in Figure 2-24.

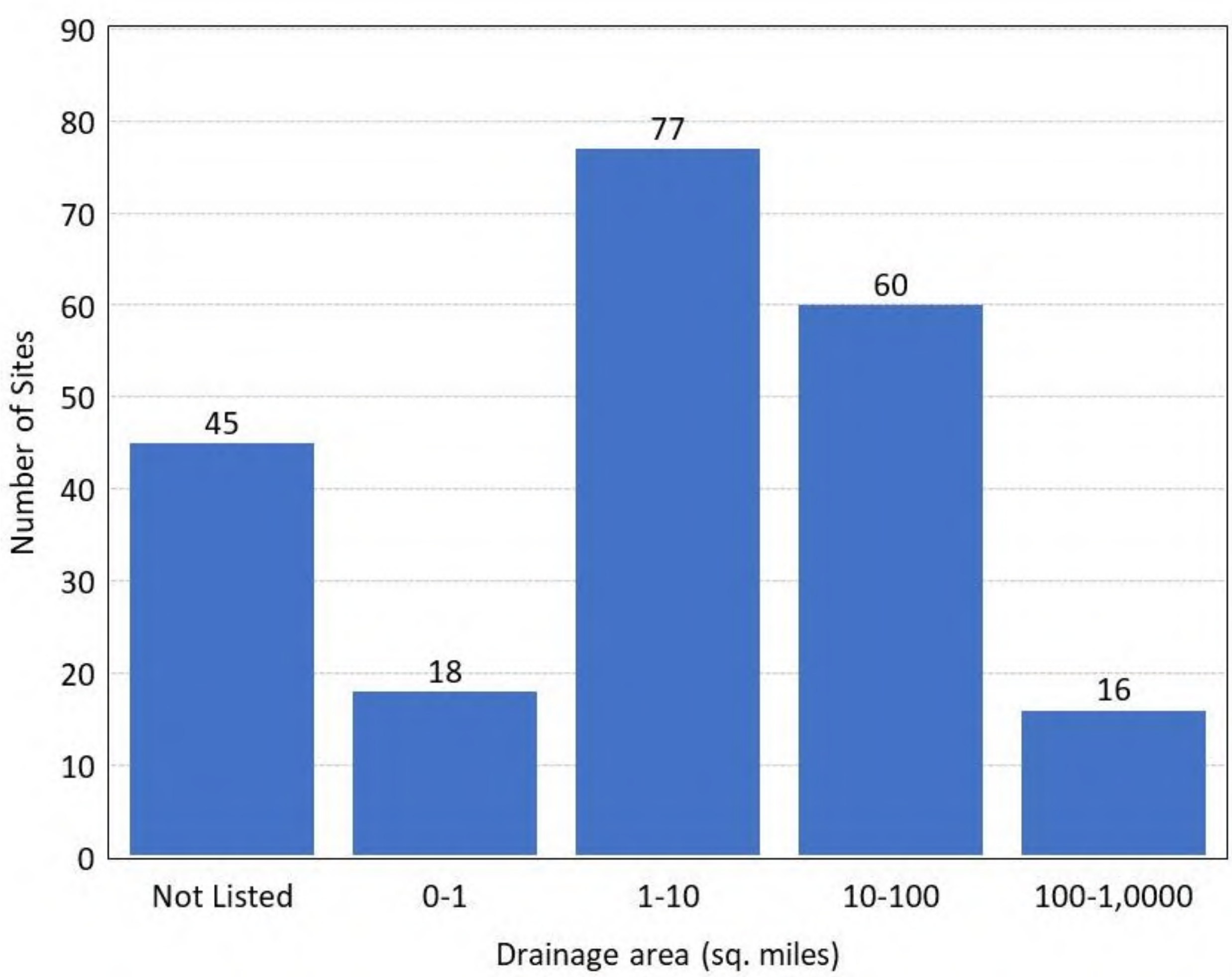

Figure 2-23. Drainage area statistics for USGS crest stage sites

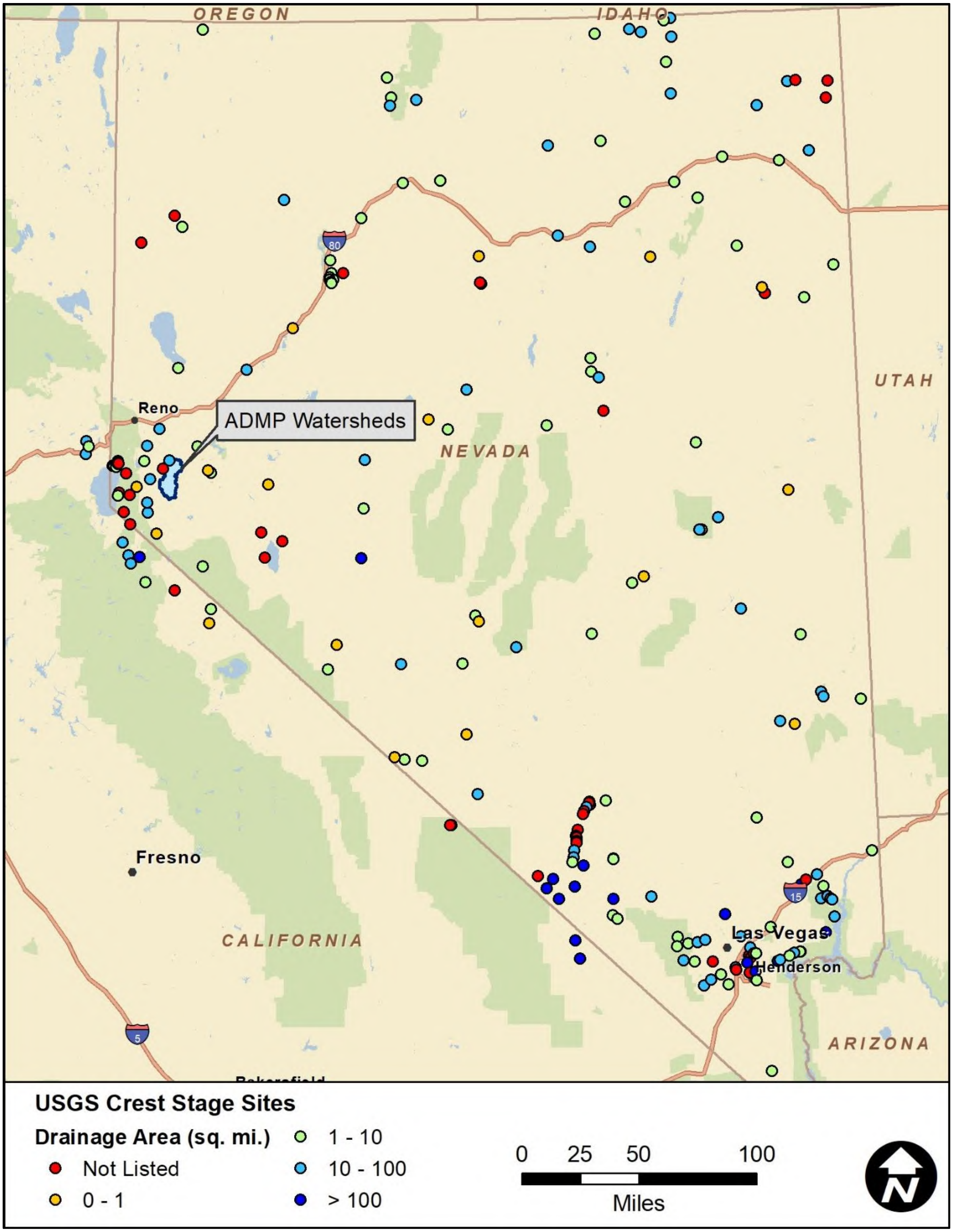

Figure 2-24. Location and drainage areas of USGS crest stage sites

As an additional verification of the peak flow estimates in the SDVADMP, the crest stage flow peak estimates were compared with the 100-year, 24-hour and 100-year, 6-hour FLO-2D results and peak flow estimates from the 1997 100-year regression equation (Equation 1). This comparison is shown as Figure 2-25. As before, both the FLO-2D and the 1997 100-year regression estimates fall within the cloud of data, which provides another indicator that the SDVADMP results are reasonable.

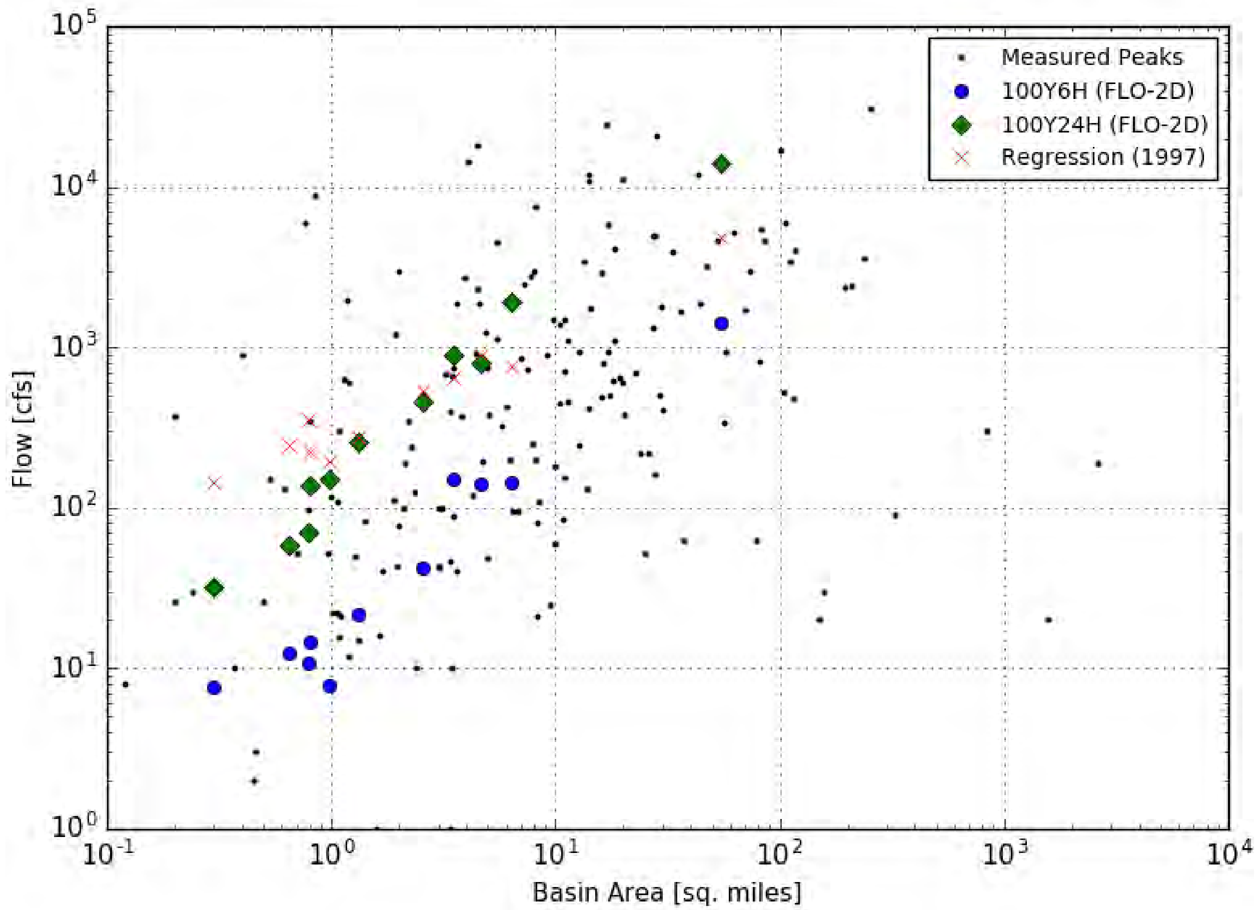

Figure 2-25. Comparison of FLO-2D results, 1997 100-year regression equation, and peak flow estimates from crest stage sites

2.4.3 Historical Flooding Documentation

As a part of the public outreach effort, the consultant team collected photographs, videos, and anecdotal information of historical flooding from residents within the ADMP study area. This information was used to help verify and adjust the FLO-2D model if needed. In general, the model results corresponded well with the historical information. Information from four locations within the study area were submitted by residents. The four locations are listed below and are illustrated in Figure 2-26 through Figure 2-29 to show the correlation between model results and actual flooding accounts.

- 108 Rancho Road
- 130 Nugget Lane
- Near Gold Creek Drive and Dayton Valley Road
- Sutro Road south of Bonnie Court

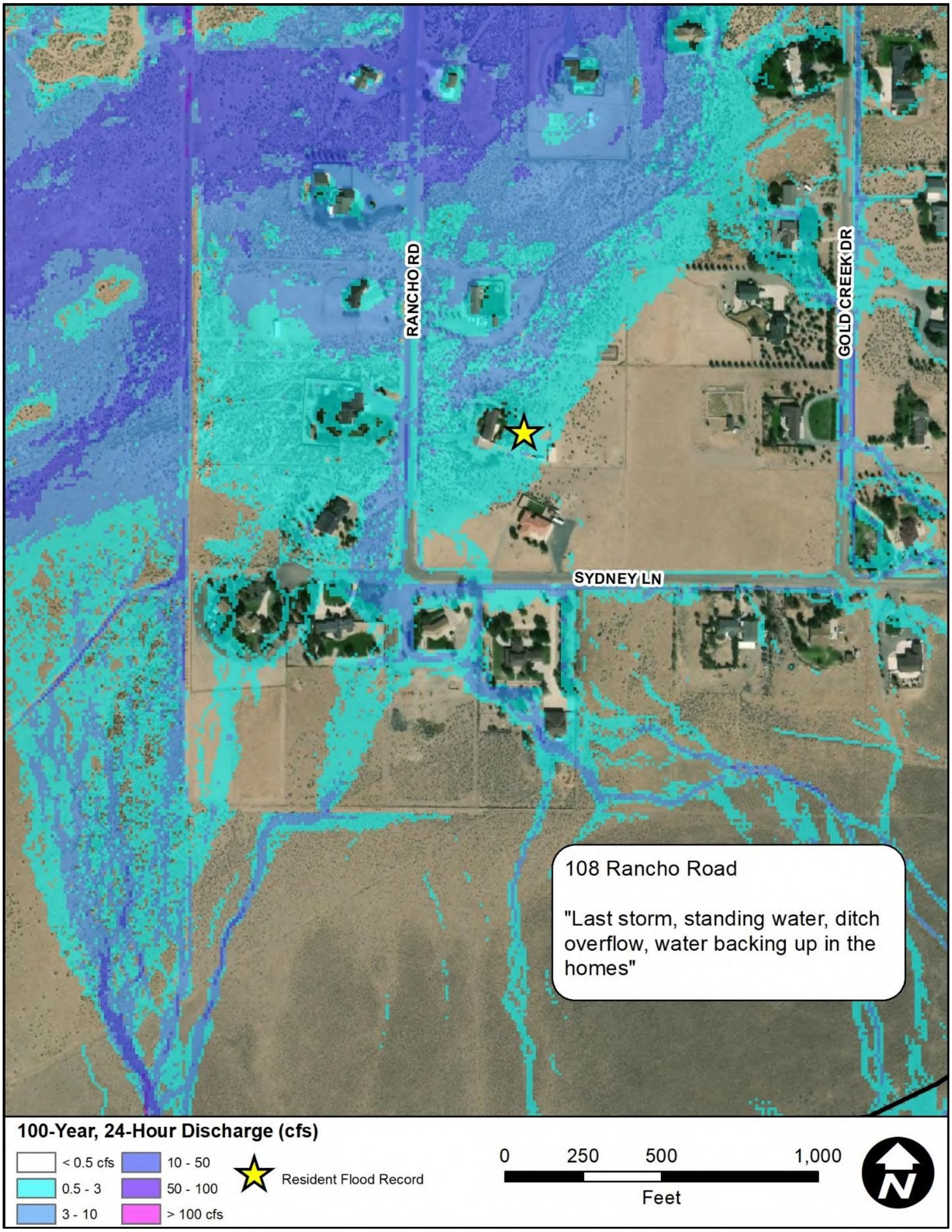

Figure 2-26. Verification for 108 Rancho Road

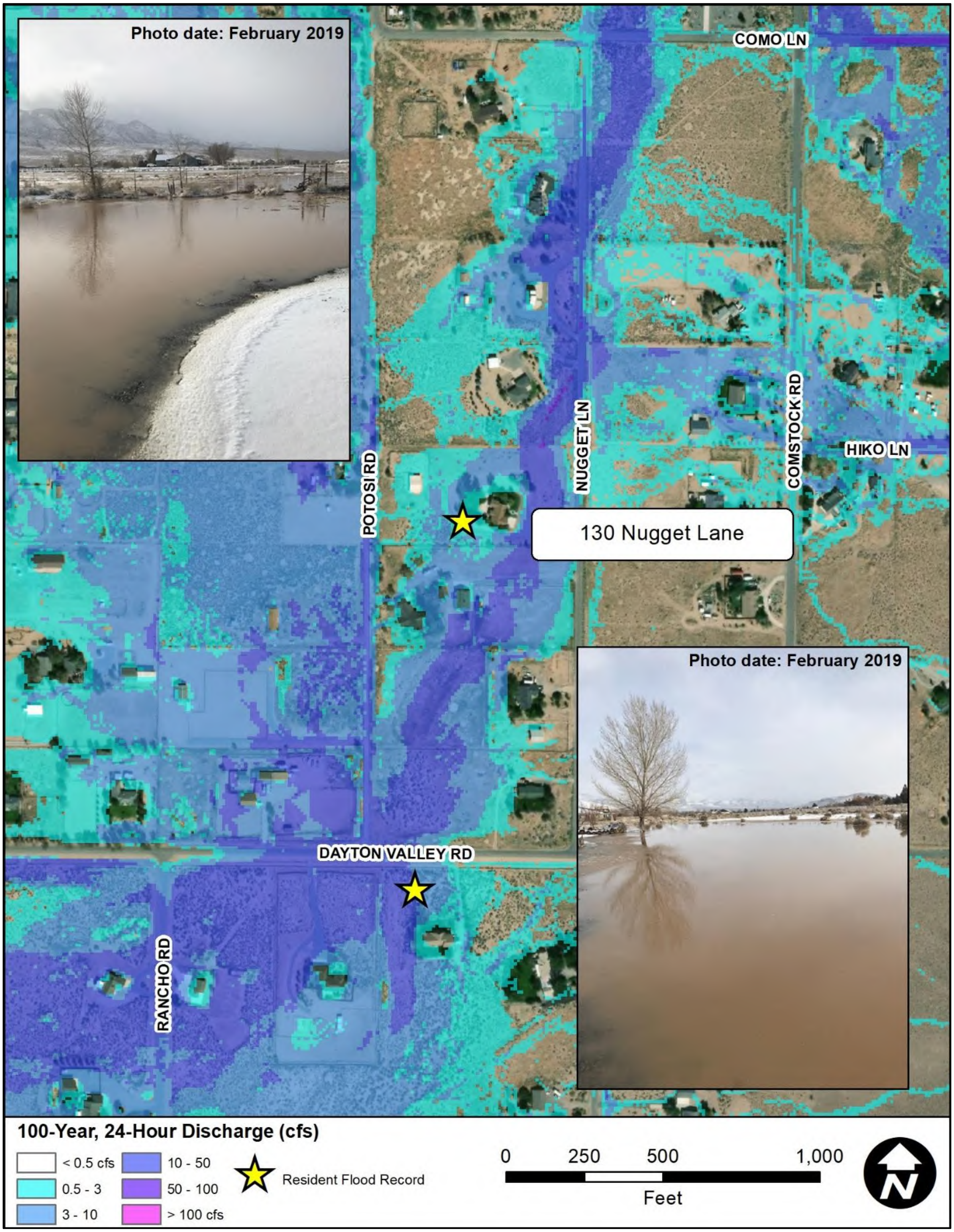

Figure 2-27. Verification for 130 Nugget Lane

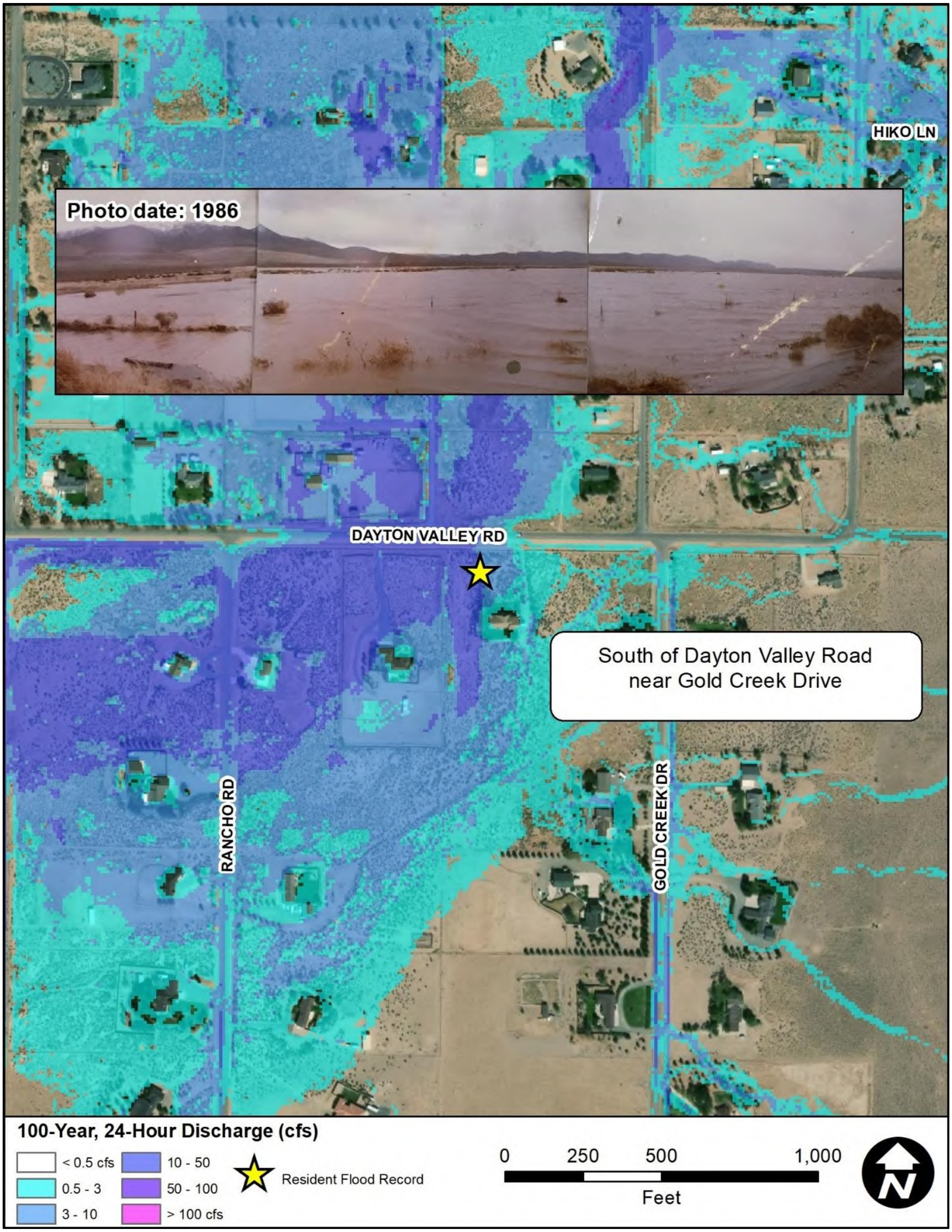

Figure 2-28. Verification for Dayton Valley Road near Gold Creek Drive

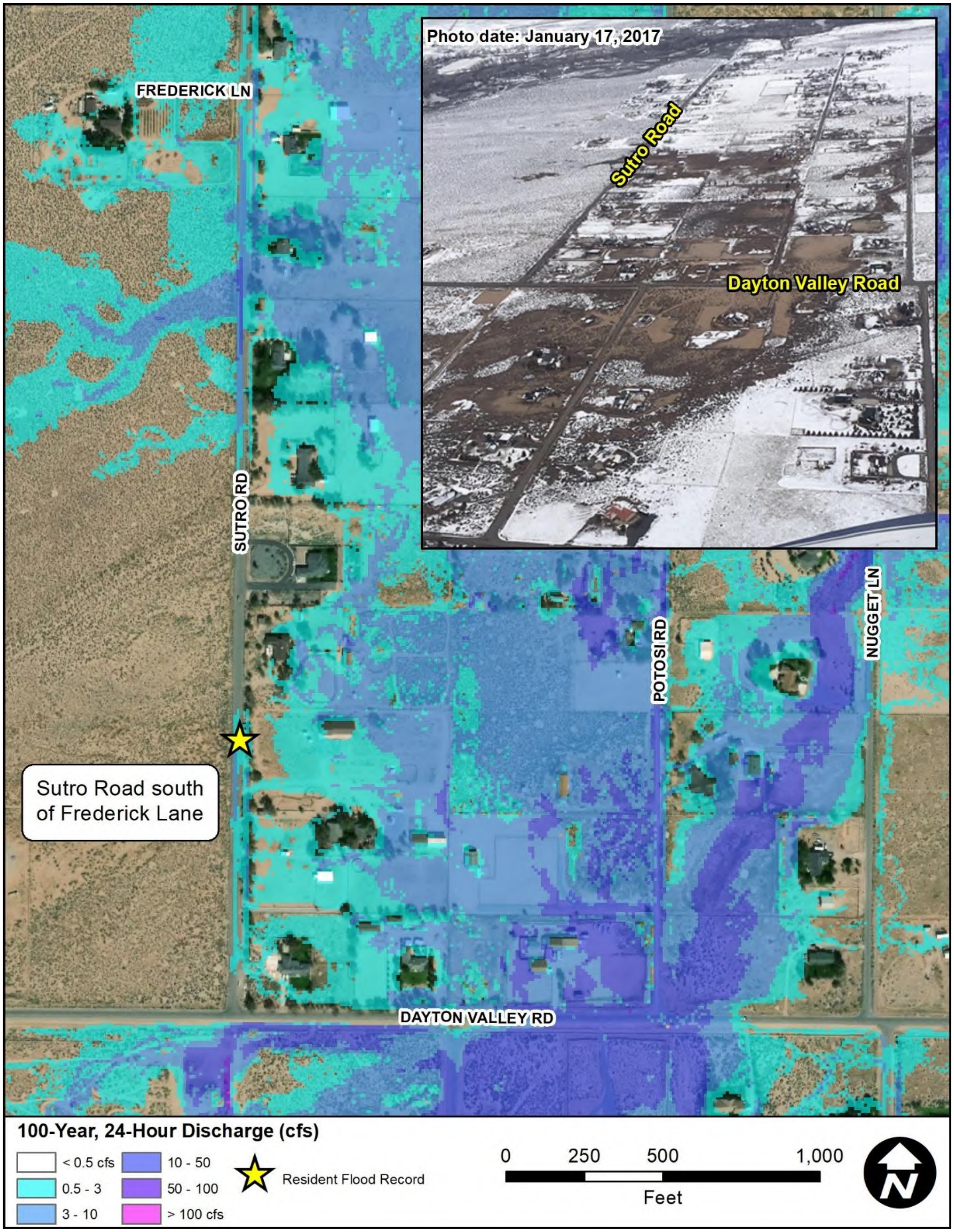

Figure 2-29. Verification for Sutro Road near Dayton Valley Road

2.4.4 Eldorado Canyon Dam

The Eldorado Canyon Dam is a Bureau of Land Management (BLM) dam that was built in 1972 and modified in 1995 (USDI BLM, 2018) with a primary purpose of irrigation per the National Inventory of Dams[6]. Since this dam provides some control on the largest watercourse within the study area, the results in this area were reviewed in detail. In addition, the 100-year 24-hour peak flow rate from FLO-2D is 14,084 cfs upstream of the dam while the probable maximum flood (PMF) is 44,150 cfs, per the Nevada Division of Water Resources.

First, the current elevation-storage rating curve was computed from both the 2017 LiDAR data and the FLO-2D cell elevations (see Figure 2-30). This comparison gave confidence that the FLO-2D model approximated the correct storage volume based on the latest topographical information. However, the crest and spillway elevations show differences when compared with what is shown in the latest inspection report (USDI BLM, 2018). For example, the crest elevation is approximately 4705 feet (NAVD88) in the LiDAR data, while the minimum crest elevation per the inspection report is 4708.2 feet. Even though there is this elevation difference, no changes were made in the FLO-2D model because the elevations were derived from the latest USGS LiDAR data, which is the best, most comprehensive mapping in the vicinity of the Eldorado Canyon Dam flood pool. The FLO-2D cell elevations within the flood pool were derived only from the LiDAR data. Note that at the spillway elevation, the storage is approximately 85 ac-ft; while at the crest, storage is approximately 330 ac-ft. These volumes are much smaller than the 4500 ac-ft that is generated during the 100-year 24-hour event.

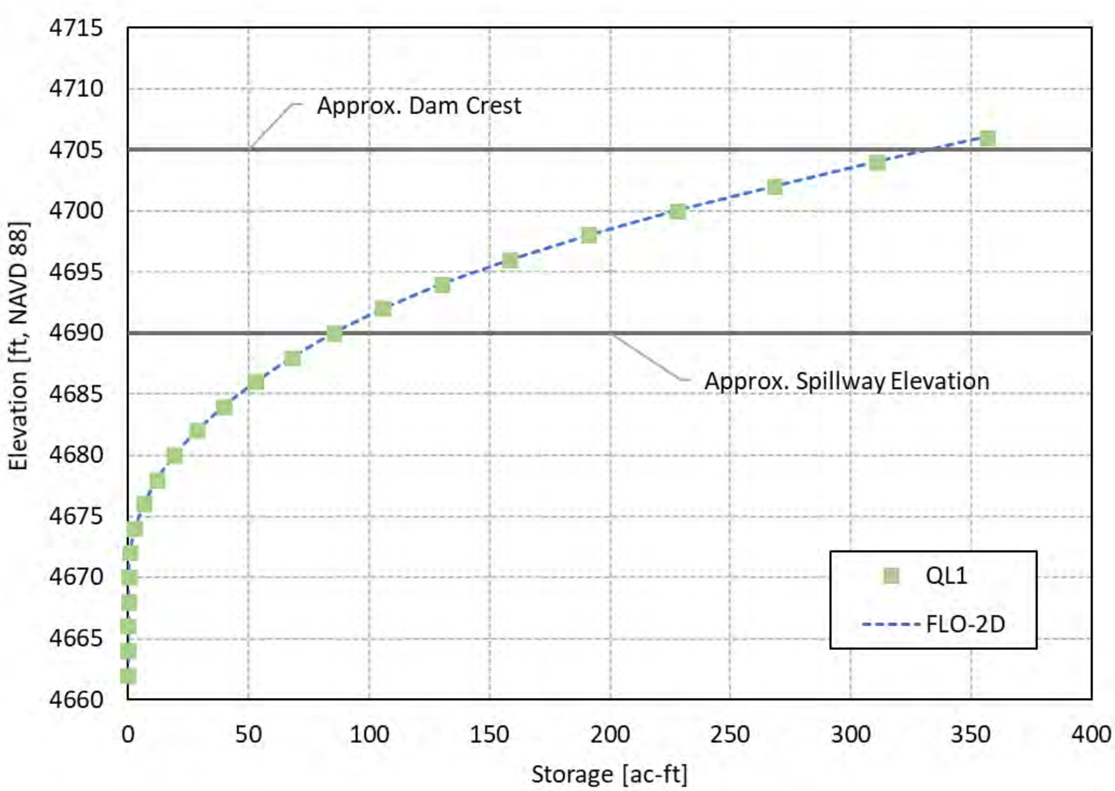

Figure 2-30. Current elevation-storage curves for Eldorado Canyon Dam based on USGS QL1 LiDAR and FLO-2D cell elevations

[6] https://nid.sec.usace.army.mil/ords/f?p=105:1::::::

Second, an HEC-RAS 2D (RAS2D) model was developed to verify the FLO-2D results because the 100-year 24-hour event showed water overtopping the dam crest. Additionally, three FLO-2D scenarios (Base, Courant = 0.05, Limiting Froude = 3) were developed, and the results compared with the results from the RAS2D model. These scenarios were developed because with the base settings (i.e., those used in the SDVADMP) of FLO-2D the results are not directly comparable to RAS2D since FLO-2D has computational limiters, such as the limiting Froude number, and the numerical scheme is different. Similarly, FLO-2D also discretizes the physical surface differently than RAS2D. FLO-2D uses a regular square mesh (i.e., the grid size is constant and uniform in a single model), while RAS2D can use an irregular mesh with breaklines to enforce a cell boundary at a physical feature, such as a levee crest.

A comparison between the FLO-2D and RAS2D model results for the maximum water surface elevation (WSEL) sampled along a profile through the flood pool is shown in Figure 2-31. All FLO-2D scenarios produce essentially the same WSEL results, while RAS2D is consistently lower and does not show overtopping of the dam crest. However, all models showed that there was no attenuation during the 100-year 24-hour event. Approximately 14,000 cfs entered the flood pool and 14,000 cfs left. This is unsurprising considering the differences between the available storage volume and flood volume.

The differences in the WSEL results between models is likely due to differences in numerical scheme and discretization of the surface. A slightly higher n value was used in the FLO-2D model (0.08 in FLO-2D, 0.06 in RAS2D) because FLO-2D can become unstable when the depth is much larger than the cell size. In these scenarios, the maximum depth was greater than 35 feet, while the cell size is 20 feet.

Finally, the results from the FLO-2D modeling were acceptable for the SDVADMP for two principal reasons:

1) Eldorado Canyon Dam provides almost no attenuation to the 100-year 24-hour storm event (the controlling storm) in both the HEC-RAS and FLO-2D models.
2) The flow is contained within the main channel and gravel mines of Eldorado Canyon within the focus area of the study.

However, the hydraulics at the dam itself appear to be better resolved with the HEC-RAS model. This model is included in Appendix C.

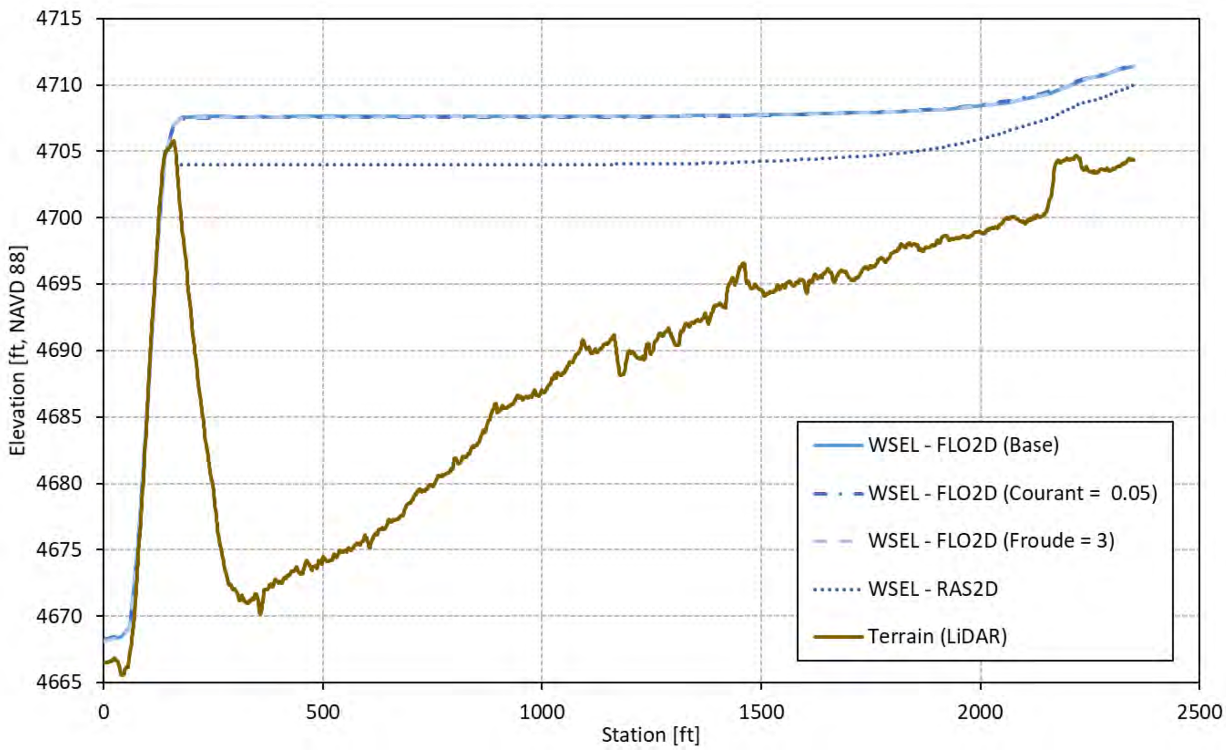

Figure 2-31. Comparison of FLO-2D and HEC-RAS maximum water surface elevations for the 100-year 24-hour event

2.5 Summary

The existing conditions FLO-2D models were created using the best available information for land cover, land use, topography, and hydrology. Every effort was made to ensure the models represented existing conditions as of the date of the LiDAR survey and the NEXTMap data. However, the NEXTMap did not provide near the resolution of the LiDAR data, and areas along the LiDAR/NEXTMap seam were smoothed to prevent erroneous ponding. Therefore, flow patterns and peak discharges in areas within the NEXTMap limits should be verified before being used for future projects.

Photographs and anecdotal information collected from both Lyon County and the residents within the community were used to help calibrate and verify the modeling results. Like all models, the SDVADMP FLO-2D models are a simulation of potential conditions that could occur during a range of storm events. The models cannot exactly duplicate actual, observed storm events at all locations within the community due to the vast number of variables that change with each unique storm event.

The modeling results reflect the complex flooding and sedimentation hazards that exist within the South Dayton Valley study area. The results provide valuable, quantitative, detailed information from which future planning and development decisions can be based. The existing conditions models also serve as a foundation from which potential mitigation alternatives can be assessed (Section 5).

Although the ADMP FLO-2D modeling effort was not intended to replicate an actual historical flood event, the comparison of the modeling results with USGS regression equations, anecdotal flood information, and independent hydraulic calculations indicate the project FLO-2D models suitably depict storm runoff conditions – indicating that the underlying input parameters are reasonable. Given the distributary nature of the flooding within the community, and the high sediment transport rates (see Section 5), flooding characteristics (e.g., depth, discharge, location) are likely to change from one flood event to the next. Even small anthropogenic changes to the landscape (e.g. dirt piles, berms, construction of outbuildings, landscaping debris piles, etc.) will result in sediment accumulation, channel scour, and changes in flowpath directions that may not be represented in the project FLO-2D modeling. In other words, the results of the modeling represent potential flooding conditions as of the date of the project topographic mapping. Updated mapping and FLO-2D modeling are recommended if major changes to the landscape occur in the future.

3 SEDIMENTATION ANALYSES

3.1 SEDIMENT SAMPLING AND TRANSPORT ANALYSIS

3.1.1 Sediment Sampling

Since the SDVADMP study area has known sedimentation issues (see example of sediment deposition at a culvert in Figure 3-1), twelve sediment samples were collected in August 2019 by JEF staff to help classify the type of sediment being transported to (and through) the detailed model area. The sampling locations are shown along with the sample IDs in Figure 3-2. Due to the size of the sediment in some of the watercourses, nine of the twelve sediment samples were evaluated by the pebble count method (Wolman, 1954). The other three were processed via mechanical sieve procedures to compute the sediment gradation. The gradation curves from each of these samples are shown in Figure 3-3, while major characteristics of the sediment are tabulated in Table 3-1.

Figure 3-1. Example of sediment deposition at culvert

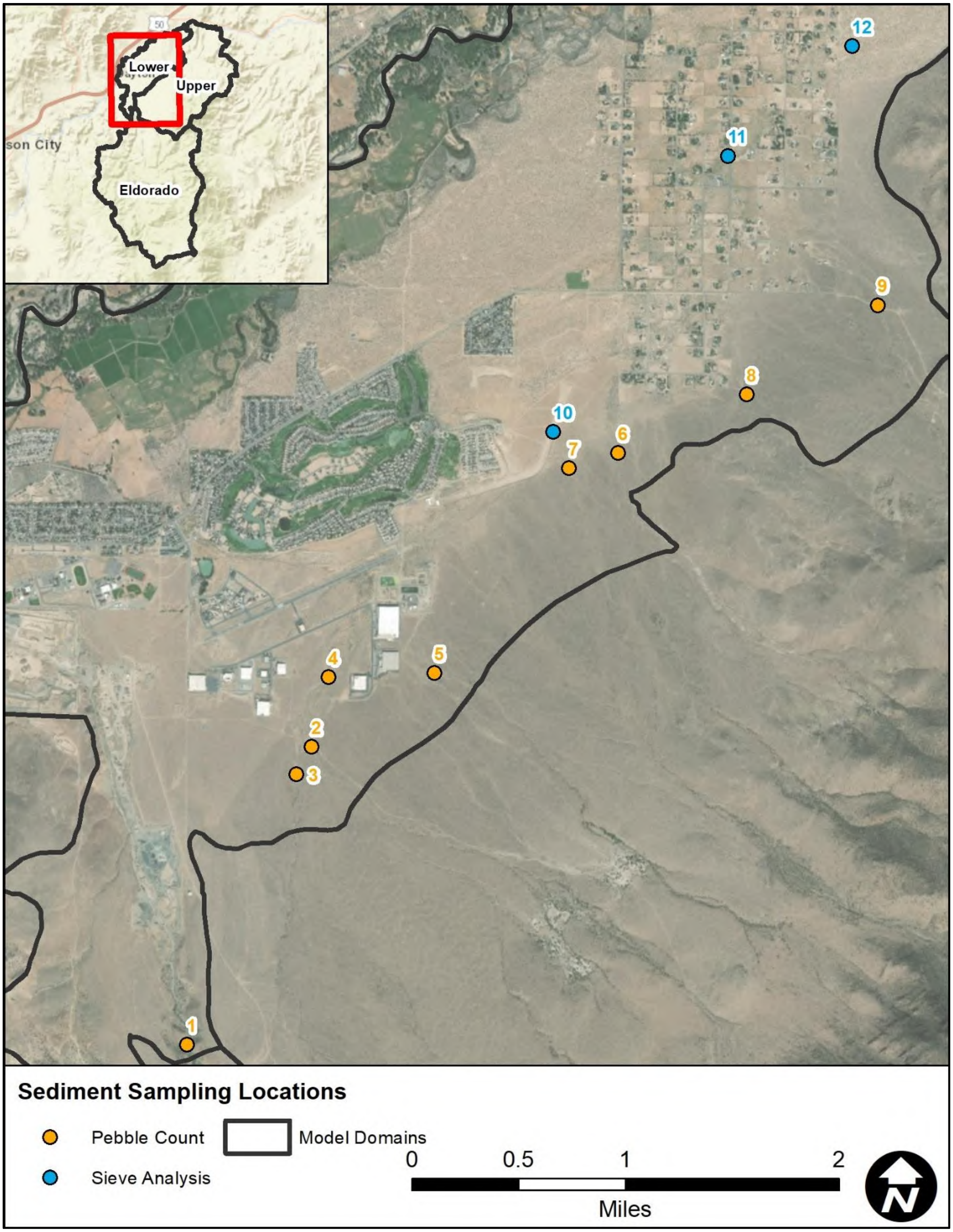

Figure 3-2. Sediment sampling locations labeled with ID

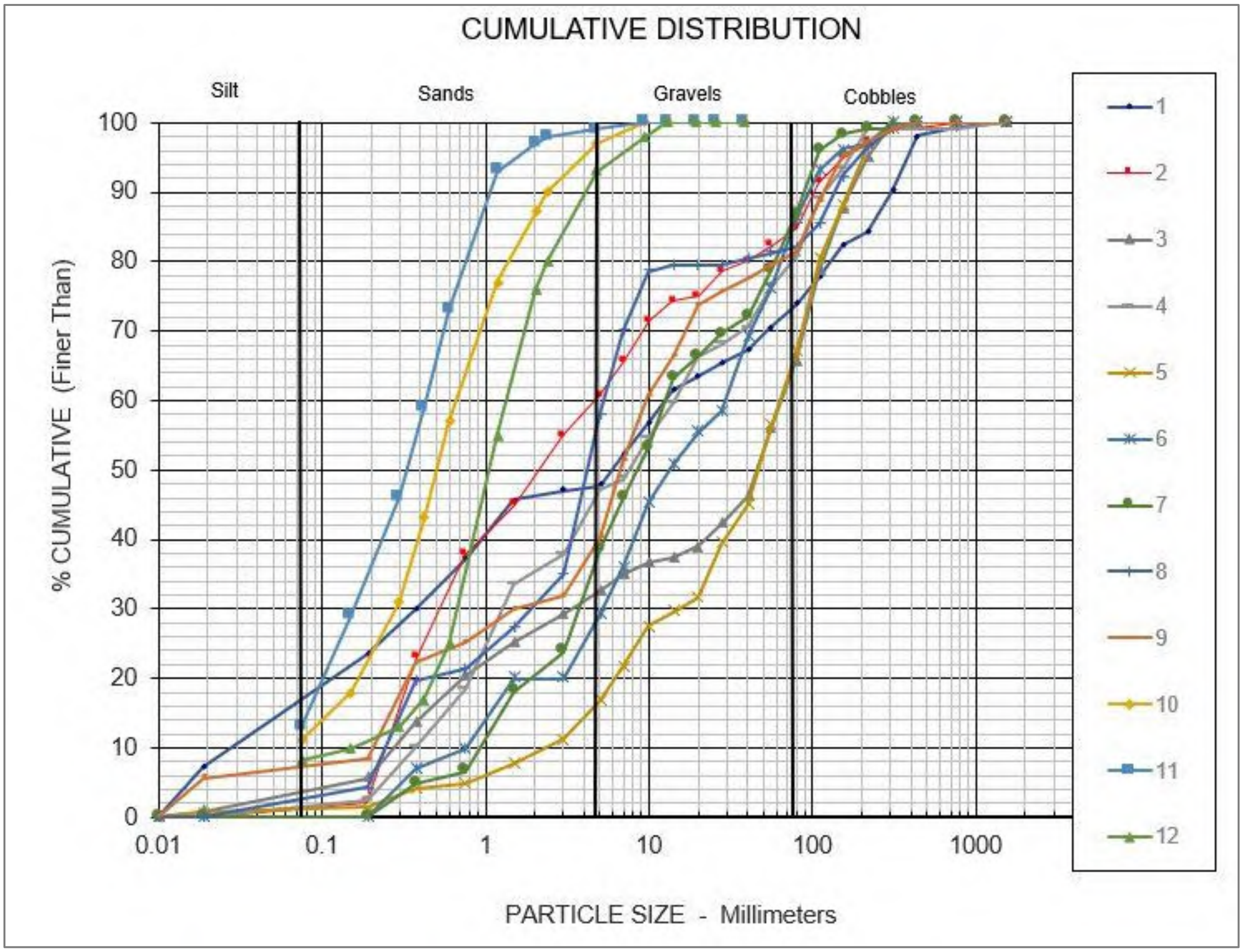

Figure 3-3. Gradation curves for the twelve sediment samples

Table 3-1. Major characteristics of the sediment within the lower watershed

ID	Type	D16 (mm)	D50 (mm)	D84 (mm)	G
1	Pebble Count	0.110	6.000	207.760	71.338
2	Pebble Count	0.313	2.250	71.600	31.209
3	Pebble Count	0.501	46.000	134.855	75.798
4	Pebble Count	0.638	7.661	91.393	19.150
5	Pebble Count	4.679	47.000	130.623	10.259
6	Pebble Count	1.200	13.429	74.831	13.411
7	Pebble Count	1.367	8.667	71.552	11.677
8	Pebble Count	0.330	4.296	96.530	28.390
9	Pebble Count	0.289	6.750	90.440	29.404
10	Sieve Analysis	0.128	0.508	1.757	5.942
11	Sieve Analysis	0.088	0.335	0.922	5.247
12	Sieve Analysis	0.389	1.091	3.112	4.526
Median	-	0.360	6.375	82.636	16.281
Average	-	0.836	11.999	81.281	25.529

3.1.2 Sediment Transport Analyses

The FLO-2D hydraulic modeling was used to assess the trends of both flooding and sedimentation throughout the study area. Hydraulic data from FLO-2D inherently includes both discharge and flow depth at each grid element. This hydraulic data was used to estimate sedimentation using the Yang sediment transport equation (1973, 1984) on a cell-by-cell scale. For this study, only the Yang equation was calculated based on the results of the analyses from the previous Dayton Valley ADMP. The median values from Table 3-1 were used in the sediment calculations.

For each modeled storm event, the total accumulated (i.e., throughout the entire storm event) sediment transport capacities were calculated at each cell. These accumulated capacities can identify areas where deposition or scour may be expected. The detailed results will be discussed in Section 3.2.

3.1.2.1 Yang Equation

Sediment transport was calculated using the Yang sediment transport methodology. This approach followed the calculation outline found in the HEC-RAS Hydraulic Reference Manual (USACE, 2016). The grain size distribution was discretized into three equal mass components where sediment transport capacity was computed separately for each compartment and the results were combined while weighting the capacity of each compartment by its relative mass contribution. The governing equation for estimating sediment concentration for each grain size using the Yang approach is as follows:

$$\log C_t = 5.435 - 0.286 \log \frac{\omega d_m}{v} - 0.457 \log \frac{u_*}{\omega} + \left(1.799 - 0.409 \log \frac{\omega d_m}{v} = 0.314 \log \frac{u_*}{\omega}\right) \log \left(\frac{VS}{\omega} - \frac{V_{cr}S}{\omega}\right) \qquad (2)$$

$$\log C_t = 6.681 - 0.633 \log \frac{\omega d_m}{v} - 4.816 \log \frac{u_*}{\omega} + \left(2.874 - 0.305 \log \frac{\omega d_m}{v} = 0.282 \log \frac{u_*}{\omega}\right) \log \left(\frac{VS}{\omega} - \frac{V_{cr}S}{\omega}\right) \qquad (3)$$

Where:

- C_t is the total sediment concentration (ppm)
- ω is the particle fall velocity (ft/s)
- d_m is the median particle diameter (ft)
- v is the kinematic viscosity (ft^2/s)
- u_* is the shear velocity (ft/s)
- V is the average channel velocity (ft/s)
- S is the energy gradient (ft/ft)

Equation (2) is used for sand with a median diameter < 2mm, while Equation (3) is for gravel with a median diameter is ≥ 2mm. Within a model spanning 2-dimensions in plan-view, such as FLO-2D, the Yang methodology differentiates itself through application of vectorized parameters – average channel velocity and slope, notably. Using time-varying output from FLO-2D, the direction of maximum velocity at each time step was determined and the terms utilized in the Yang equation were applied in that direction. This method allows the sediment transport capacity analysis to adapt to changes in peak flow direction which is especially valuable in areas of flowpath uncertainty such as coalescing alluvial fans and areas subject to varied flooding sources.

3.2 RESULTS

3.2.1.1 Sediment Rasters

Since the total accumulated transport is calculated at each cell, an overall map of the study area with sediment transport capacities can be produced similar to the FLO-2D results presented in Section 3. Since the 100-year, 24-hour storm produces the largest amount of flow and sediment, it is used as a representative example. The relative total accumulated sediment transport within the focus area calculated with the Yang equation is shown in Figure 3-4. Note - The colors in both these figures represent relative transport capacity to each other, so green is relatively low compared to red, but green is higher than areas without color.

In general, the results are straightforward. Higher sediment transport rates appear in the channels, while lower rates appear as the flow spreads out over the piedmont. Unsurprisingly, the Eldorado Canyon produces the most sediment because it has the largest drainage area with the longest drain time. Finally, since these sediment results are based on hydraulic conditions, off-site inflows are considered because inflow hydrographs have been input at all major watercourses through the upstream FLO-2D modeling (see Figure 2-3).

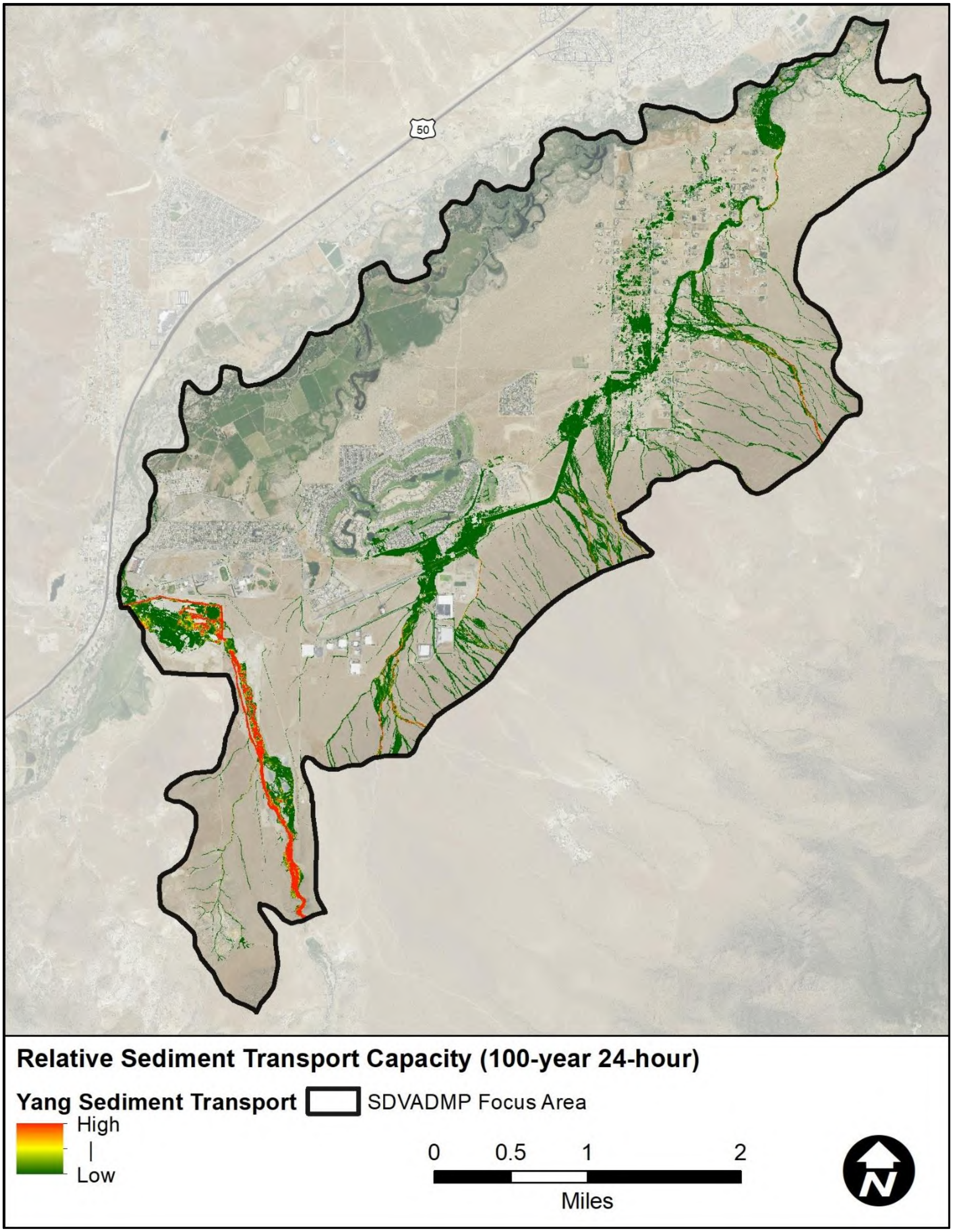

Figure 3-4. Total accumulated sediment transport capacity by the Yang methodology for the 100-year, 24-hour event

3.2.1.2 Sediment Profiles

A sediment transport profile was developed for the major overland flow path within SDVADMP focus area because alternatives will most likely be developed to control this overland flow. Conversely, since Eldorado Canyon is contained within its channel throughout the focus area and does not cause major flooding problems, a profile was not developed for this watercourse. As before, the 100-year 24-hour event is used as the representative example.

To develop these profiles, the total accumulated sediment transport through each station (or cross-section) over the entire storm event was calculated for the Yang equation. This transport profile was plotted and is shown in Figure 3-5.

In this study, these profiles were used in two ways. First, the profiles can be used to identify areas where sediment transport is not in equilibrium or out of balance. This is important because when the sediment transport is out of balance, erosion (degradation) or deposition (aggradation) is occurring within the wash. When sediment transport is increasing (i.e., the slope change is positive), the wash is gathering sediment through degradation. Conversely, when the sediment transport profile is decreasing, and the slope change is negative, the wash is losing sediment through aggradation.

Areas where there can be significant erosion or deposition are highlighted on the profile. The leftmost (or upstream) depositional area occurs where flow exits the confined mountain channels and distributes over a larger area on the piedmont. Below this area, sediment transport significantly decreases until the main flow path becomes confined again near station 5000. Downstream of station 5000, flow spreads out over an agricultural field where sediment transport decreases. These results are consistent with what would be expected given those hydraulic conditions.

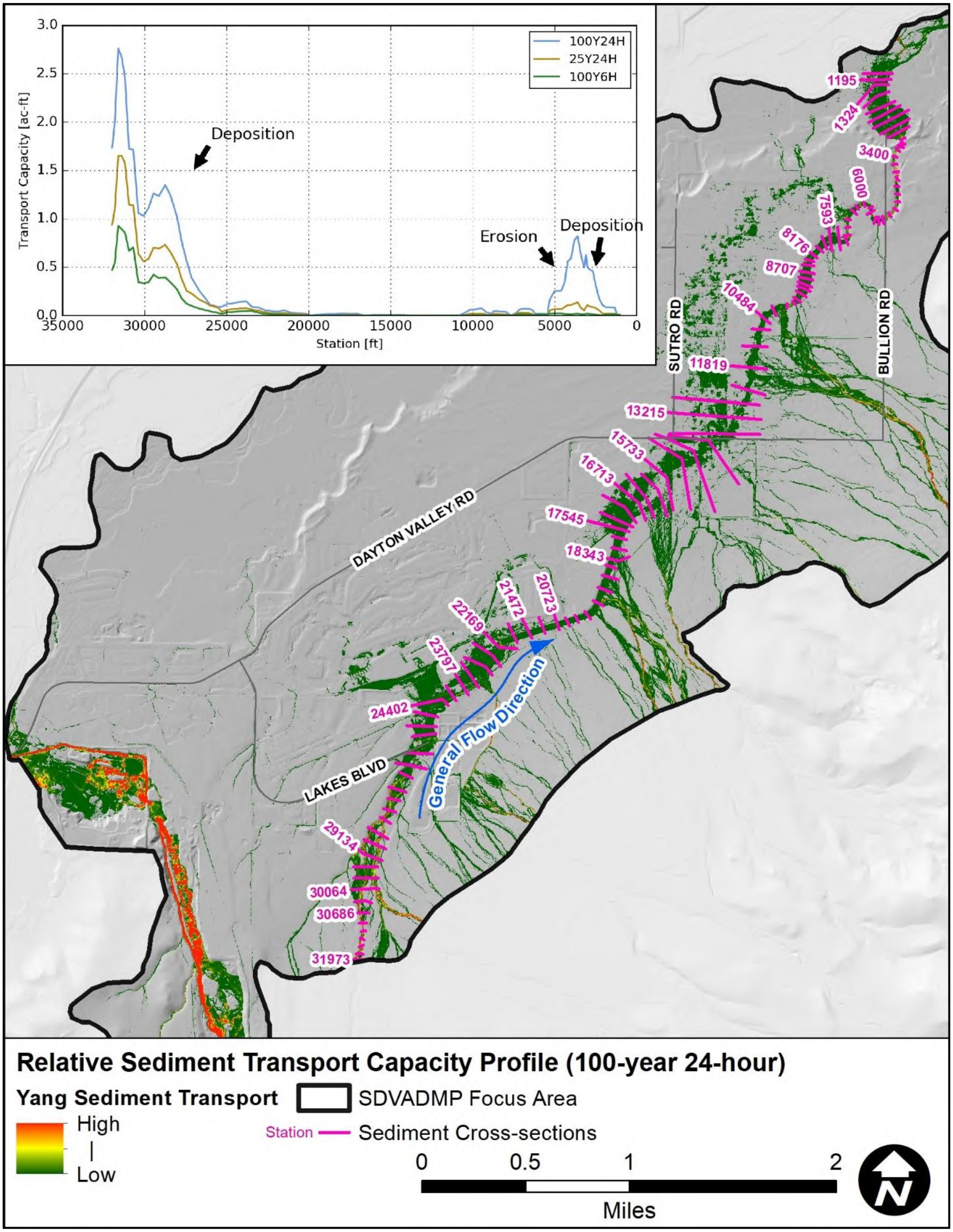

Figure 3-5. Cumulative sediment transport profile for the primary overland flow path throughout the 100-year 24-hour event

4 FLOOD HAZARD CLASSIFICATION

4.1 PURPOSE

During a severe storm event, flood waters flow throughout the South Dayton Valley ADMP study watershed. However, not all flood hazards pose a risk to people or to their properties. Flood risk depends on the presence of both a flood hazard and a person (or their property). As an example, flow in a constructed flood control channel does not present a risk until someone enters the channel. Identifying areas where flood waters may cause risks that potentially harm people (or property) is an important objective of the ADMP. Identification of potential flood risks in the study area helps the consultant team prioritize which flood problems should be addressed and in what order.

For the purposes of this study, flood hazards were defined based on the physical characteristics of the flood water – that is, the location, depth, and velocity associated with those flood waters. The hydrology and hydraulic modeling results were used to define flood hazards for three storms:

- The 25-year, 24-hour event,
- The 100-year, 24-hour event, and
- The 100-year, 6-hour event.

The flood risk assessment involved selecting criteria and quantifying flood risks throughout the study watershed using the FLO-2D model results. Three types of potential flood risks were assessed – flooding risks to pedestrians, passenger vehicles, and structures.

In addition to the flooding risks, two other types of flood consequence assessments were conducted:

- Building Inundation Assessment, and
- HAZUS Event-Based Analysis.

The building inundation and HAZUS assessments are planning level analyses to estimate the number of habitable structures and associated damage costs by flow depths greater than six inches. Since this analysis will be done for both the base (i.e., existing) and the with-alternatives conditions (see Section 5), it gives a quantitative estimate of the effectiveness of the potential alternative structures. Both analyses were performed for all three storm events.

The following sections describe the flood classification criteria, methodology, and description of provided electronic files for each potential flooding assessment.

4.2 FLOODING HAZARDS TO PEDESTRIANS

Pedestrian flood hazards were classified using the depth-velocity relationship outlined in the United States Bureau of Reclamation (USBR) Technical Memorandum 11 (TM 11) (1988). The depth-velocity relationships presented in TM 11 are a good basis for flood hazard classification since the criteria are widely accepted. TM 11 presents two possible classifications for pedestrians; flood danger levels for adults and for children. It was decided to use the flood danger classification for children throughout the entire watershed to simplify the methodology and to be conservative. The depth-velocity flood danger level relationship from TM 11 is shown as Figure 4-1.

The following three categories exist for pedestrian flood hazards:

- *Low*: These are areas with depths and velocities corresponding to the Low Danger Zone as shown in Figure 4-1. Low pedestrian hazards are not displayed on the map exhibits because, per TM11, low hazard zones do not present a threat to children of almost any size (excluding infants) and cover all areas not classified with a higher flood hazard.
- *Moderate*: Areas with depths and velocities corresponding to the Judgment Zone in Figure 4-1 have been labeled as having a moderate potential flood hazard to pedestrians.
- *High*: Areas with depths and velocities corresponding to the High Danger Zone in Figure 4-1 have been labeled as having a high potential flood hazard to pedestrians.

The flood hazards to pedestrians have been digitized in GIS in the form of a raster. The rasters generated for the risk analysis coincide with the FLO-2D grid elements with a 10-foot by 10-foot pixel size. The raster contains values of 1, 2, and 3 which correlates to a low, moderate, and high hazard classification, respectively. Since the 100-year, 24-hour storm produces the largest peak runoff for most areas (see Table 2-9), the flooding hazard from this storm event is shown as Figure 4-2.

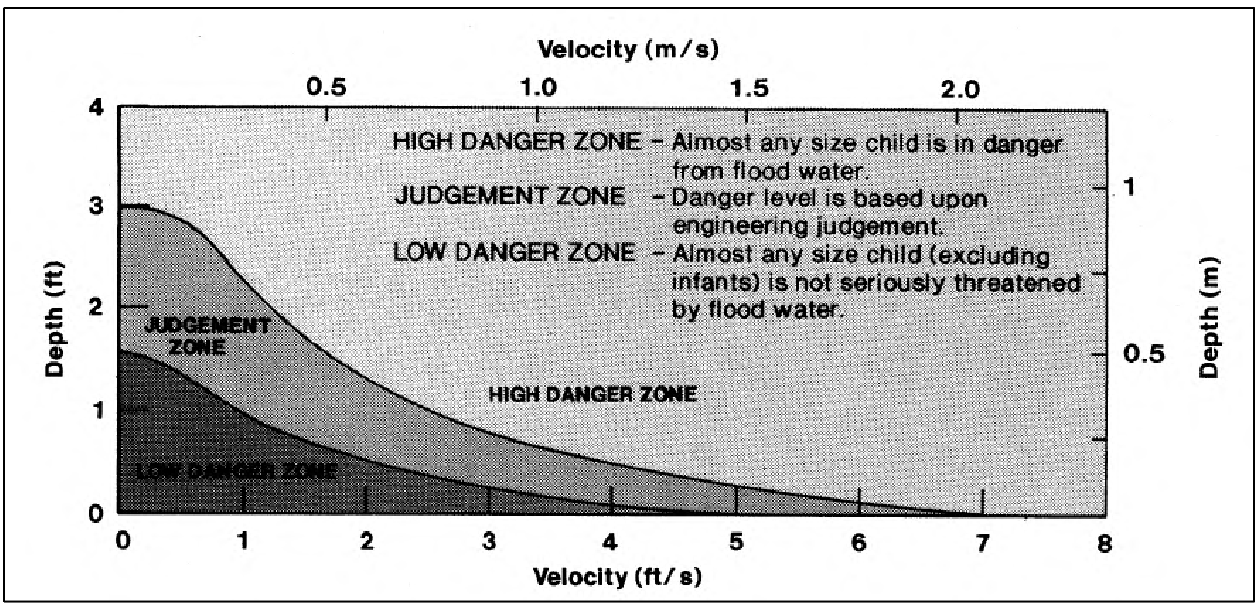

Figure 4-1. Depth-Velocity flood danger level relationship for children, from USBR (1988)

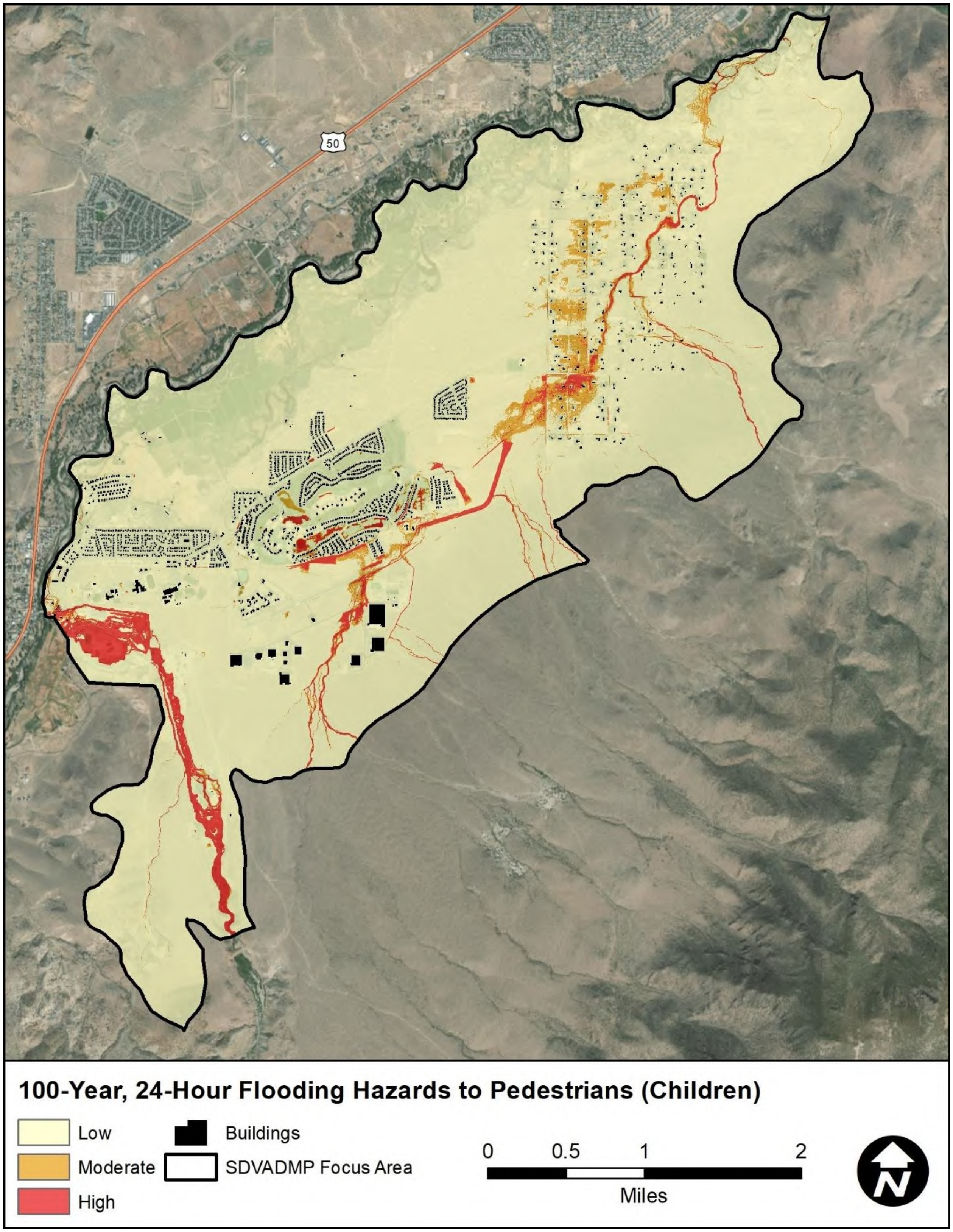

Figure 4-2. USBR criteria flooding hazards to pedestrians based on the 100-year, 24-hour results

4.3 FLOODING HAZARDS TO PASSENGER VEHICLES

Potential hazards to passenger vehicles were classified using a combination of minimum depth criteria and the depth-velocity relationship in TM 11 as shown in Figure 4-3. The following four categories exist for passenger vehicle flood hazards:

- *Low*: This hazard category is based solely on minimum depth criteria and is for roadway crossings with depths less than half a foot. Low passenger vehicle hazards are not displayed on the map exhibits because low hazard zones indicate areas where vehicles "are not seriously in danger" and, as such, almost any size passenger vehicle can safely pass. Also, this hazard classification covers all areas not classified with a higher flood hazard. This classification is not explicitly shown in the Figure 4-3.
- *Moderate*: This hazard category is based on a combination of minimum depth criteria and the depth-velocity relationship in TM 11. Specifically, these are roadway crossings with depths and velocities falling into the Low Danger Zone (as shown in Figure 4-3) that also have greater than a half a foot of depth. The threshold depth of half a foot was chosen because half a foot of water will reach the bottom of most passenger cars and can cause loss of control and possible stalling.
- *High*: Roadway crossings with depths and velocities corresponding to the Judgment Zone in have been labeled as having a high potential flood hazard for passenger vehicles.
- *Very High*: Roadway crossings with depths and velocities corresponding to the High Danger Zone in Figure 4-3 have been labeled as having a very high potential flood hazard for passenger vehicles.

The flood hazards to passenger vehicles have also been digitized in GIS in the form of a raster. The raster contains values of 1, 2, 3, and 4. These values correlate to low, moderate, high, and very high classification, respectively. The TM 11 flooding hazards to vehicles for the 100-year, 24-hour storm is shown in Figure 4-4.

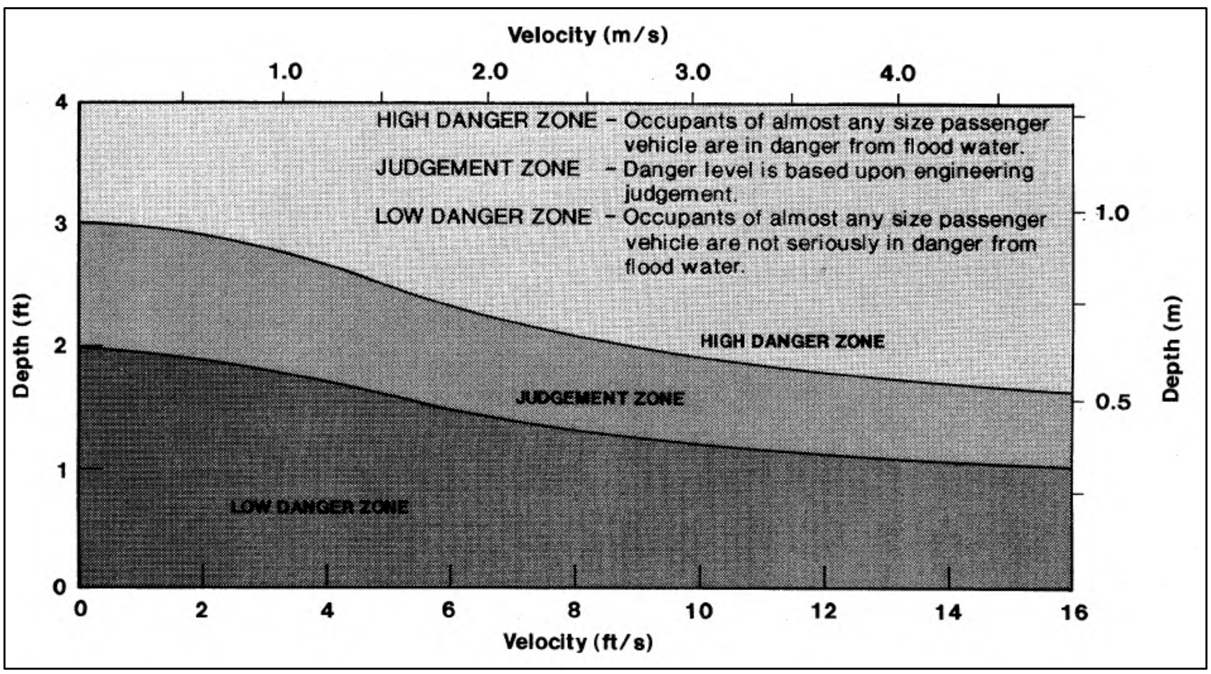

Figure 4-3. Depth-Velocity flood danger level relationship for passenger vehicles, from USBR (1988)

To isolate the actual risk to vehicles, the street centerlines GIS layer was intersected with the hazards zones to produce a "Potential Risk to Passenger Vehicles" map. This isolates the road crossings that pose a risk to vehicles during a storm event. Only the 100-year 24-hour and the 25-year 24-hour storm produce conditions of "High" risk using the USBR criteria. There were no locations of "Very High" risk from any of the three storm events modeled. The "High" risk road crossing locations for the 100-year, 24-hour and 24-year, 24-hour storms are shown in Figure 4-5 and Figure 4-6, respectively.

During the two storm events there are eleven (11) distinct crossing areas with a "High" hazard classification which are numbered below and shown in Figure 4-5 and Figure 4-6.

Rancho Area

1. Como Lane between Comstock Road and Imperial Road
2. Imperial Road and Ione Lane
3. Nugget Lane between Hiko Lane and Como Lane
4. Nugget Lane between Hiko Lane and Como Lane
5. Ophir Road between Ione Lane and Eureka Lane
6. Potosi Road between Dayton Valley Road and Hiko Lane
7. Potosi Road and Dayton Valley Road
8. Sutro Road between Dayton Valley Road and Frederick Lane

Dayton Valley Golf Course Area

9. Grayhawk Drive between Grayhawk Court and Lythm Court
10. Grayhawk Drive and Lythm Court
11. Lakeview Drive north of Moore Avenue

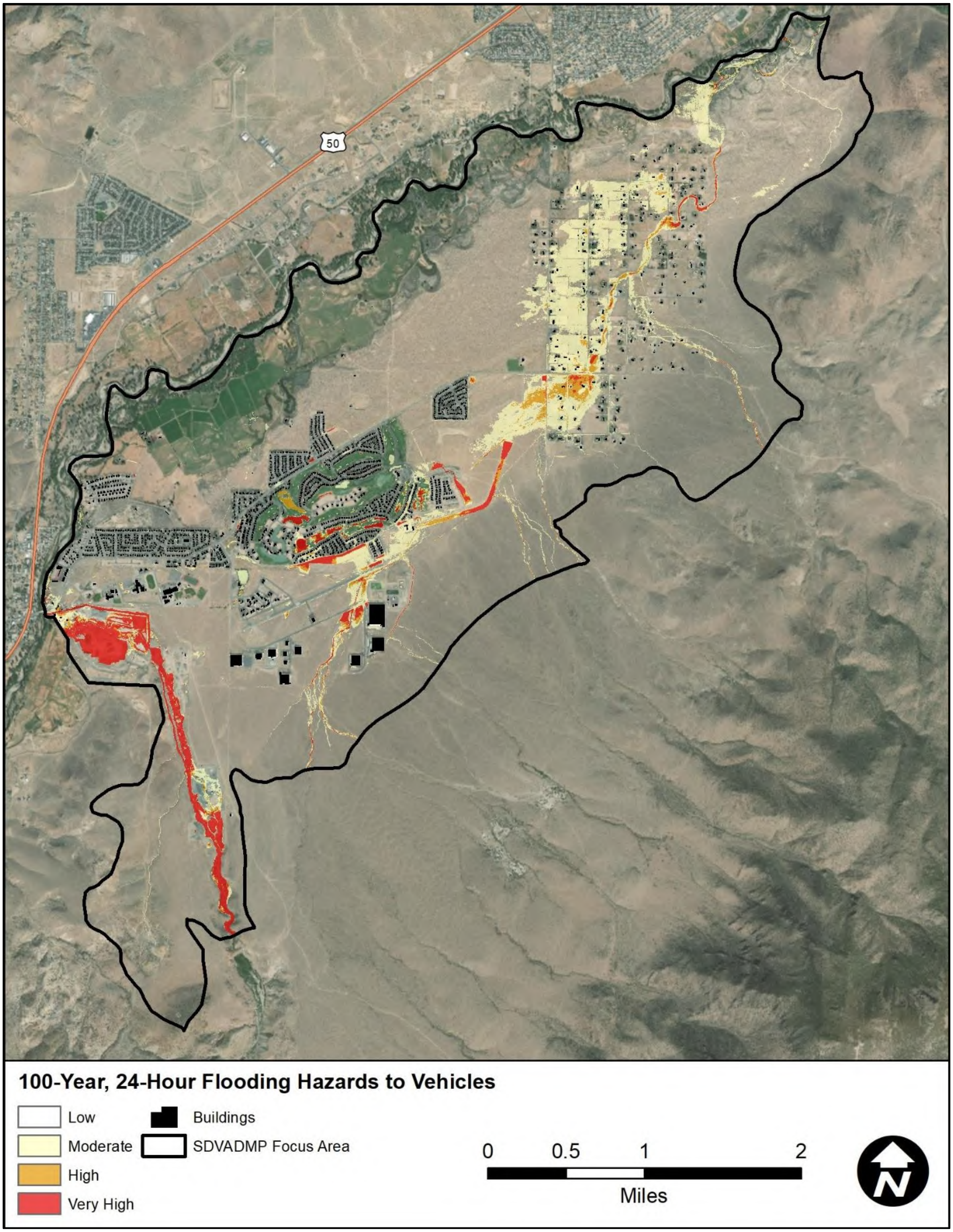

Figure 4-4. USBR criteria flooding hazards to vehicles based on the 100-year, 24-hour results

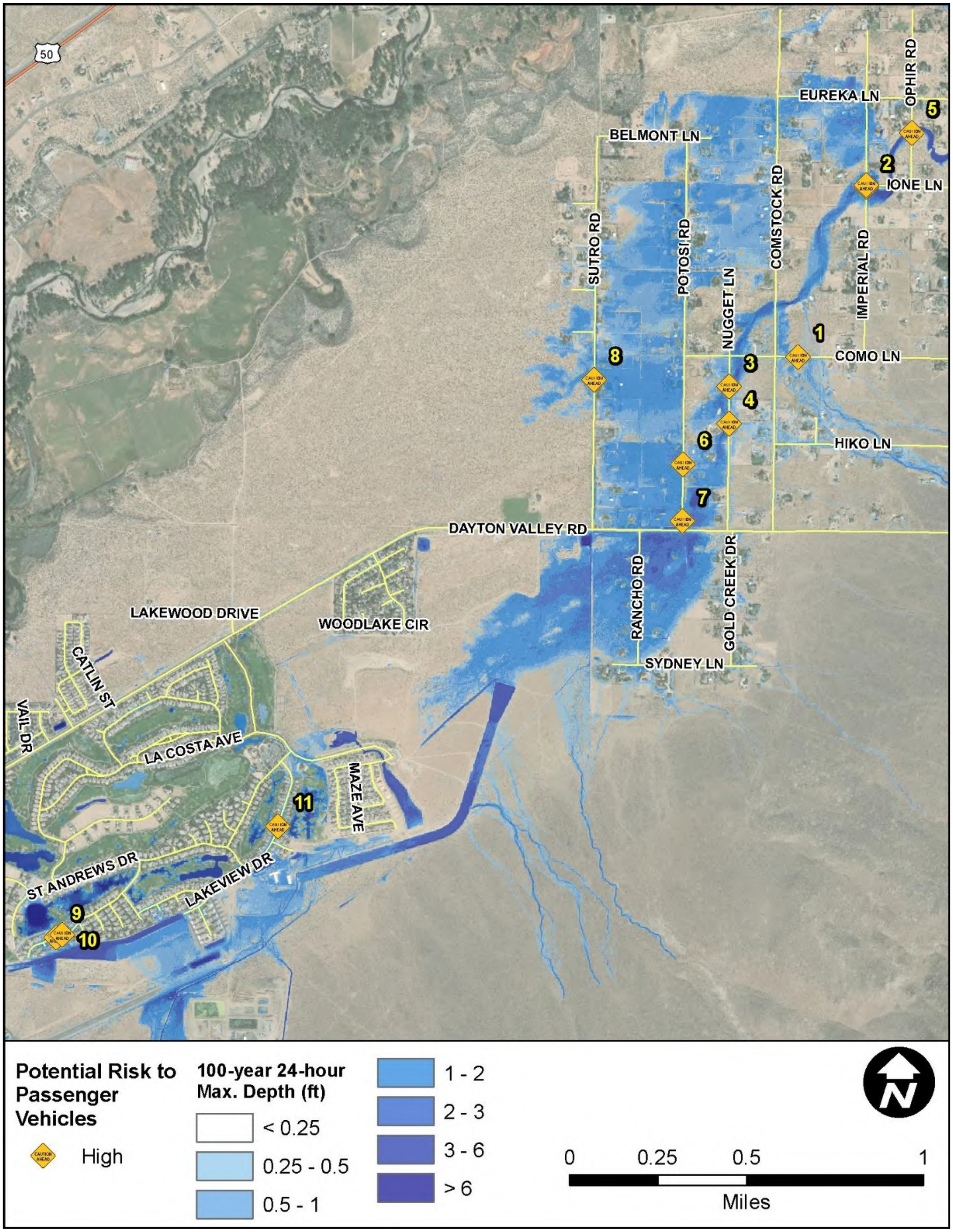

Figure 4-5. Hazardous road crossings during a 100-year, 24-hour storm (USBR criteria)

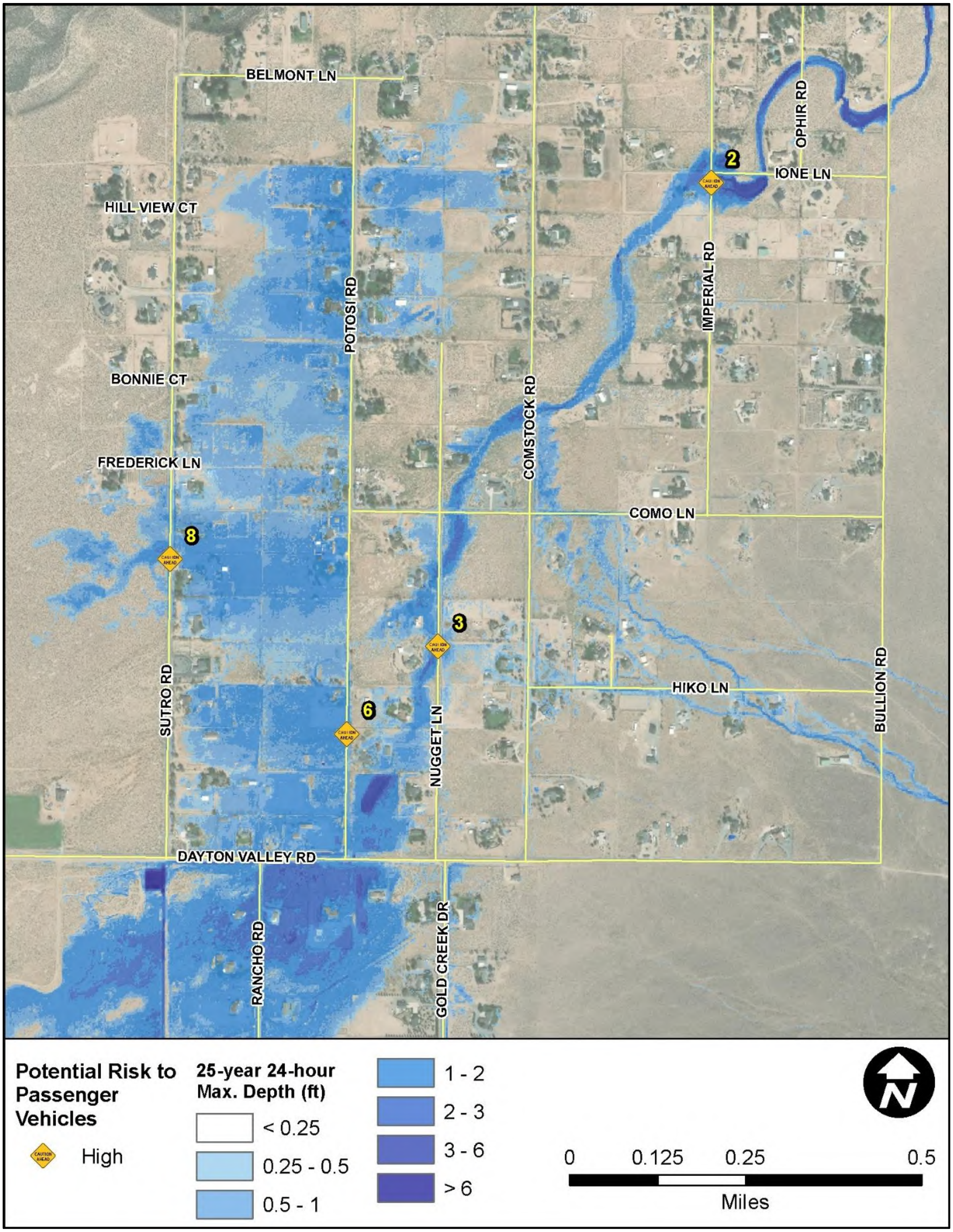

Figure 4-6. Hazardous road crossings during a 25-year, 24-hour storm (USBR criteria)

4.4 Flooding Hazards to Structures

Potential hazards to buildings were classified using the depth-velocity relationship from TM 11. The depth-velocity relationship from TM 11 is shown as Figure 4-7. The following three categories exist for potential flood hazards to structures:

- *Low*: Buildings that have contact with at least one FLO-2D grid element that has a depth-velocity relationship corresponding to the low danger zone in Figure 4-7 have been designated as having a low potential flood hazard.
- *Moderate*: Buildings that have contact with at least one FLO-2D grid element that has a depth-velocity relationship corresponding to the judgment danger zone in Figure 4-7 have been designated as having a moderate potential flood hazard.
- *High*: Buildings that have contact with at least one FLO-2D grid element that has a depth-velocity relationship corresponding to the high danger zone in Figure 4-7 have been designated as having a high potential flood hazard.

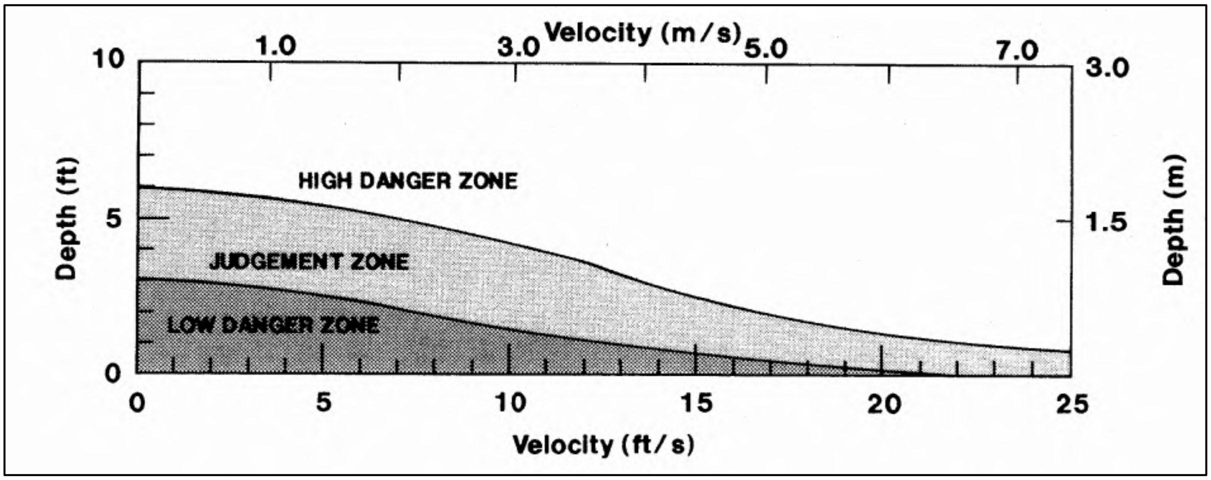

Figure 4-7. Depth-Velocity flood danger level relationship for structures built on foundations, from USBR (1988)

To create the building flood hazard classification, the building polygon shapefile is intersected with the flood hazard layer using GIS software tools. When multiple grid cells from the flood hazard layer intersect one building polygon, the maximum hazard classification is assigned to the building. Buildings with less than 600 square feet (e.g., unattached garages or sheds) were not considered because they were assumed to be uninhabited due to their size. The result is a building polygon shapefile with a hazard attribute classifying low, moderate, or high flood hazards.

The tabulated building hazard results are shown in Table 4-1. Due to the relatively shallow flooding in the project area, there are no buildings with a high or moderate hazard classification based on the TM 11 criteria. The 100-year 24-hour flooding hazards to buildings raster is shown in Figure 4-8.

Table 4-1. Building flooding hazard classification results

Base Conditions				
Recurrence Interval	Building Count	Building Count	Building Count	Total Building Count
	Low	Moderate	High	
25Y24H	2,105	1	0	**2,106**
100Y24H	2,105	1	0	**2,106**
100Y6H	2,106	0	0	**2,106**

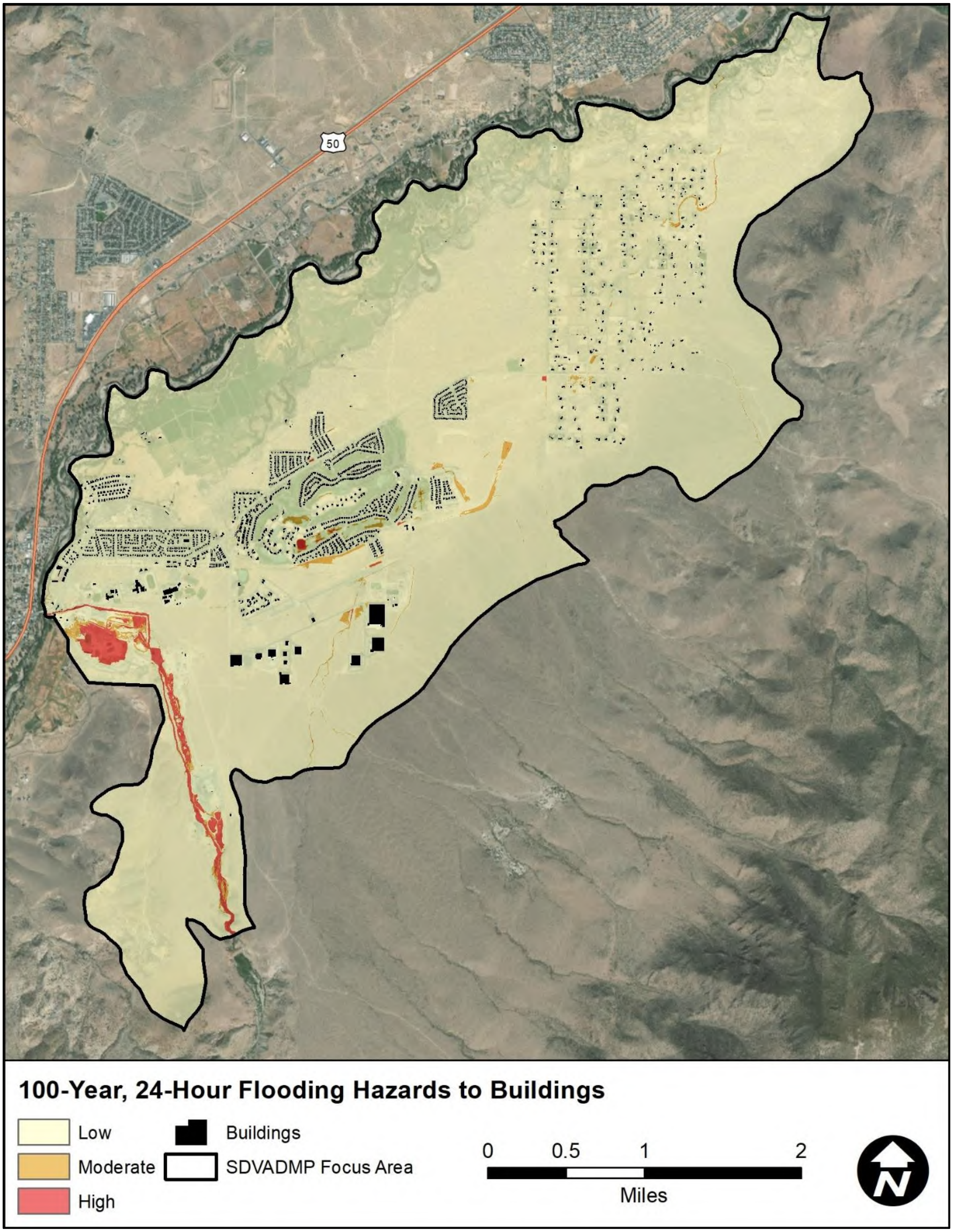

Figure 4-8. USBR criteria flooding hazards to buildings based on the 100-year, 24-hour results

4.5 BUILDING INUNDATION ASSESSMENT

4.5.1 Methodology

The USBR TM 11 procedures are commonly used within the engineering community for assessing flood risk. However, TM 11 was developed for conditions downstream of a dam failure. As such, lower flood depths may produce a "Low" risk classification for buildings with TM 11 but may be of a sufficient depth to justify a higher risk classification. To both verify the TM 11 results and to provide a lower threshold risk assessment, a separate building impact analysis was run using the building footprint data and the maximum depth results from the FLO-2D modeling for the base conditions. The maximum depth layers only consider the maximum depth that occurred during the model simulation.

From the building footprint data, there are 2,150 structures within the HAZUS study area; however, not all these structures are habitable structures (e.g. - water tanks or sheds). For this analysis, the same 600 square foot filter that was used in the "flooding hazard to structures" analysis (see Section 4.4) was applied. After applying this filter, there are 2,106 structures in the study area.

In this section, the documentation will focus on the base conditions analyses, while the with-alternatives results will be presented later in Section 5.

4.5.2 Base Conditions

Each building was classified based on the maximum depth that fell within the structure outline. The structures were tabulated into four groups:

1) 0.25 ft < Depth (h) ≤ 0.5 ft – Low
2) 0.5 ft ≤ Depth (h) ≤ 1.0 ft – Moderate
3) 1.0 ft < Depth (h) – High
4) 0.25 ft < Depth (h) (inclusive of groups 1 through 3 above)

The results for existing conditions are tabulated in Table 4-2, while the results for the 100-year 24-hour storm are shown in Figure 4-9.

Table 4-2. Buildings that are impacted by various depths (base conditions)

Base Conditions				
Recurrence Interval	**Building Count Flow Depth**	**Building Count Flow Depth**	**Building Count Flow Depth**	**Total Building Count**
	0.25' < h ≤ 0.5'	**0.5'< h ≤ 1'**	**1' < h**	**0.25' < h**
25Y24H	329	79	37	**445**
100Y24H	371	118	91	**580**
100Y6H	437	54	8	**499**

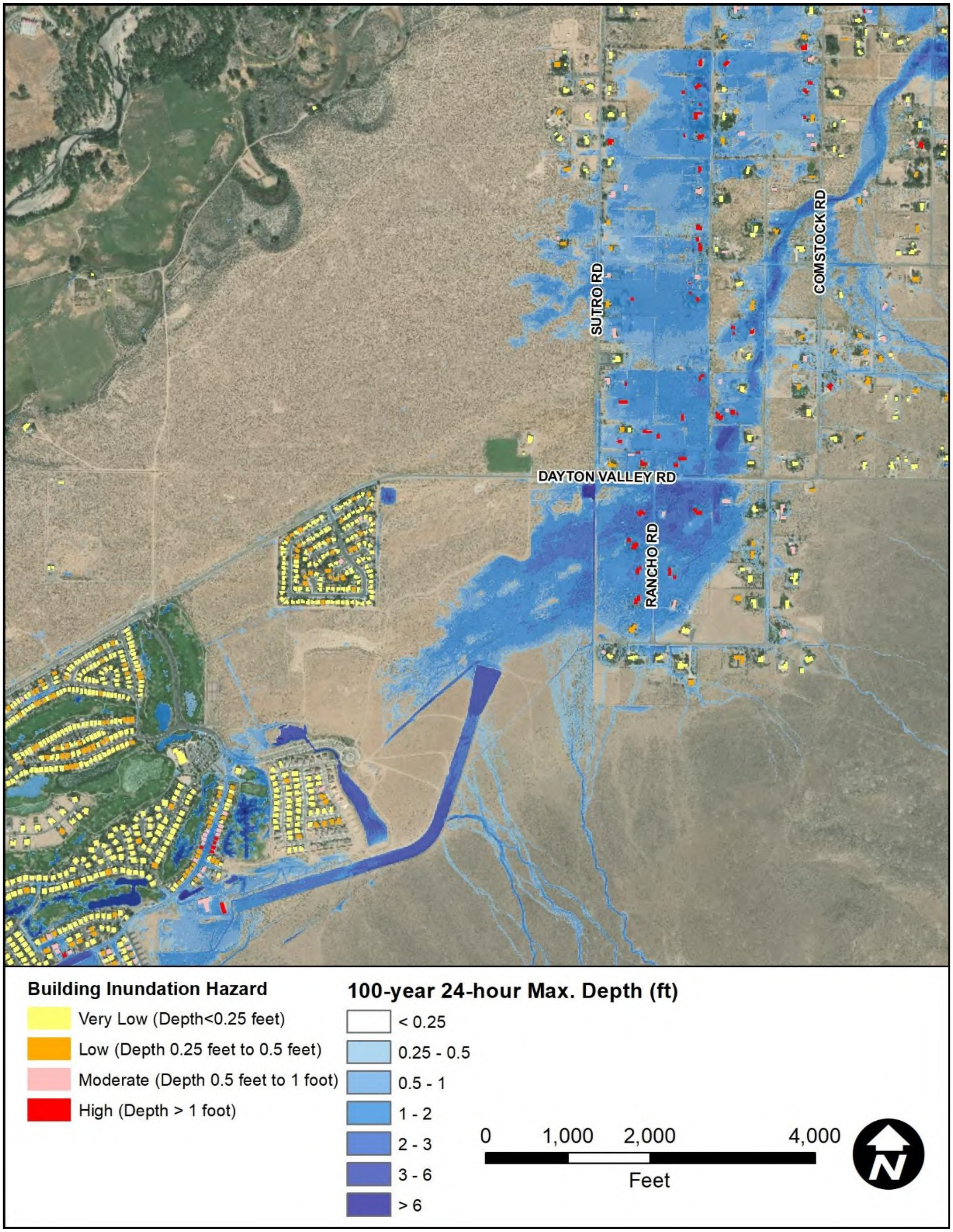

Figure 4-9. Building inundation assessment (100-Year, 24-Hour) result example

4.6 HAZUS ANALYSES

4.6.1 Methodology and Purpose

FEMA's HAZUS program[7] is a standardized computer software package that automates FEMA's methodology for estimating potential economic losses and human displacement due to natural disasters such as earthquakes, floods and hurricanes. For flood related losses, HAZUS has the capability to perform varying levels of analyses that are distinguished primarily on the amount of user provided data. A Level 1 analysis is primarily based on generalized data provided with the software and rudimentary estimations of hydrology and flood depths to estimate flood risk. A Level 2 analysis blends user generated data with software data. A Level 3 analysis primarily uses all user generated input data. The analysis performed in this study would be considered a simple Level 2 since more detailed flood risk data (flood depth grids from FLO-2D) has been generated external to the model and imported for use in conducting the loss analyses.

In HAZUS, the flood depth grids are analyzed against a general building stock (GBS) database that is spatially tied to the 2010 Census blocks. The HAZUS analysis also considers single location essential facilities (e.g. – fire stations, hospitals, etc.). Both data sets contain attributes that represent an estimate of the number of buildings, building type, population, building replacement costs and so forth. However, the GBS data are generalized to the level of a census block. Since these estimates are based on the resolution of census blocks, the loss estimates are considered valid for a planning level of analysis. For a more complete explanation of the HAZUS modeling package, see the link provided in the footnote below.

Flood hazard loss estimates for the base and with-project conditions were calculated for the SDVADMP study using HAZUS 4.2 with the Service Pack 01 (SP01) update. In the 4.2 release of HAZUS, an erroneous multiplier was removed from the business interruption calculations that will significantly increase the economic losses from business interruptions. This correction should be recognized when comparing results from older versions of HAZUS. Additionally, the state databases were updated with 2018 valuations with the SP01 update. However, for this study, the business interruption estimates were not included because they were estimated in the hundreds of millions of dollars; and, as such, completely overwhelmed the direct building losses.

The purpose of the HAZUS analyses is to quantify the economic benefit from reduced flood damages that may be realized with the construction of all or part of the alternatives. The HAZUS default damage curves were used for all types of structures, with two exceptions. The United States Army Corps of Engineers (USACE) New Orleans District depth-damage curve (ID 143) was used for one story slab foundation residential structures, while the USACE New Orleans depth-damage curve (ID 57) was used for the contents of those same structures. With these curves, more reasonable estimates of the economic damages were calculated.

As before, the documentation in this section will focus on the base conditions analyses, while the with-project results will be presented after the alternatives are discussed. The two scenarios will be compared in that section.

[7] HAZUS-MH 4.2 (https://msc.fema.gov/portal/resources/hazus)

4.6.2 Base Conditions

These estimates only include direct building loss. According to HAZUS literature (FEMA, 2015), “the direct building losses are the estimated costs to repair or replace the damage caused to the building and its contents.” In these tables, the total property column includes residential, commercial, industrial and miscellaneous other structures. Therefore, the total property represents the sum of other four categories. Finally, all estimates are based on the HAZUS GBS database, which is tied to 2010 census data and 2018 dollars.

A results summary is presented as Table 4-3. From these results, the 100-year 24-hour storm event causes significantly more damage than the other storms. Based on the results, the 25-year 24-hour event causes slightly more damage than the 100-year 6-hour storm, which is surprising but not unreasonable given the magnitudes of the precipitation in this region (see Table 2-3). These results show the same general trends as the Dayton Valley ADMP. However, the 100-year 6-hour results are much lower on relative basis than in that study. The differences in magnitude between the South Dayton Valley and Dayton Valley results are most likely due to the size difference between focus areas (13.5 square miles SDVADMP versus 18.3 square miles for the DVADMP) and the location, type, and density of development.

Table 4-3. Summary of flood damage estimates (base conditions)

Base Conditions					
Recurrence Interval	**Direct Building Economic Loss**				
	Residential	**Commercial**	**Industrial**	**Others**	**Total Property**[1]
	$ millions	**$ millions**	**$ millions**	**$ millions**	**$ millions**
25Y24H	2.68	0.21	0.45	0.43	3.77
100Y24H	5.93	0.36	0.69	0.67	7.65
100Y6H	0.78	0.05	0.08	0.06	0.97
1. May not be additive due to rounding in internal HAZUS calculations					

4.7 Summary

In this section, the methodologies and results from five separate hazard assessments were presented. These included:

- Flood hazards to children
- Flood hazards to vehicles
- Flood hazards to buildings
- Building inundation assessment
- HAZUS analyses

These analyses help identify areas that have a higher risk of flooding and which property and infrastructure are most susceptible to damage. Having this information helps focus the mitigation alternative to areas where they are most needed. Additionally, the last two analyses (the building inundation assessment and the HAZUS analysis) help show if the proposed alternatives are reasonable and cost-effective. The HAZUS analysis is a standard FEMA methodology for estimating potential economic losses.

5 Regional Flood Mitigation Alternatives

5.1 Introduction

The development of the regional alternatives comprised the following elements:

1) Drainage improvement assessment for the Ranchos area
2) Flood hazard identification
3) Alternative formulation/evaluation
4) Development of conceptual 15% design plans and cost estimates for the selected mitigation alternative

JE Fuller (JEF) served as the lead on the flood hazard identification and alternative formulations with assistance from Lumos and Associates (Lumos), who were the lead in the development of the 15% design plans and cost estimates for the selected mitigation alternative. Figure 5-1 summarizes the process for developing the regional alternatives.

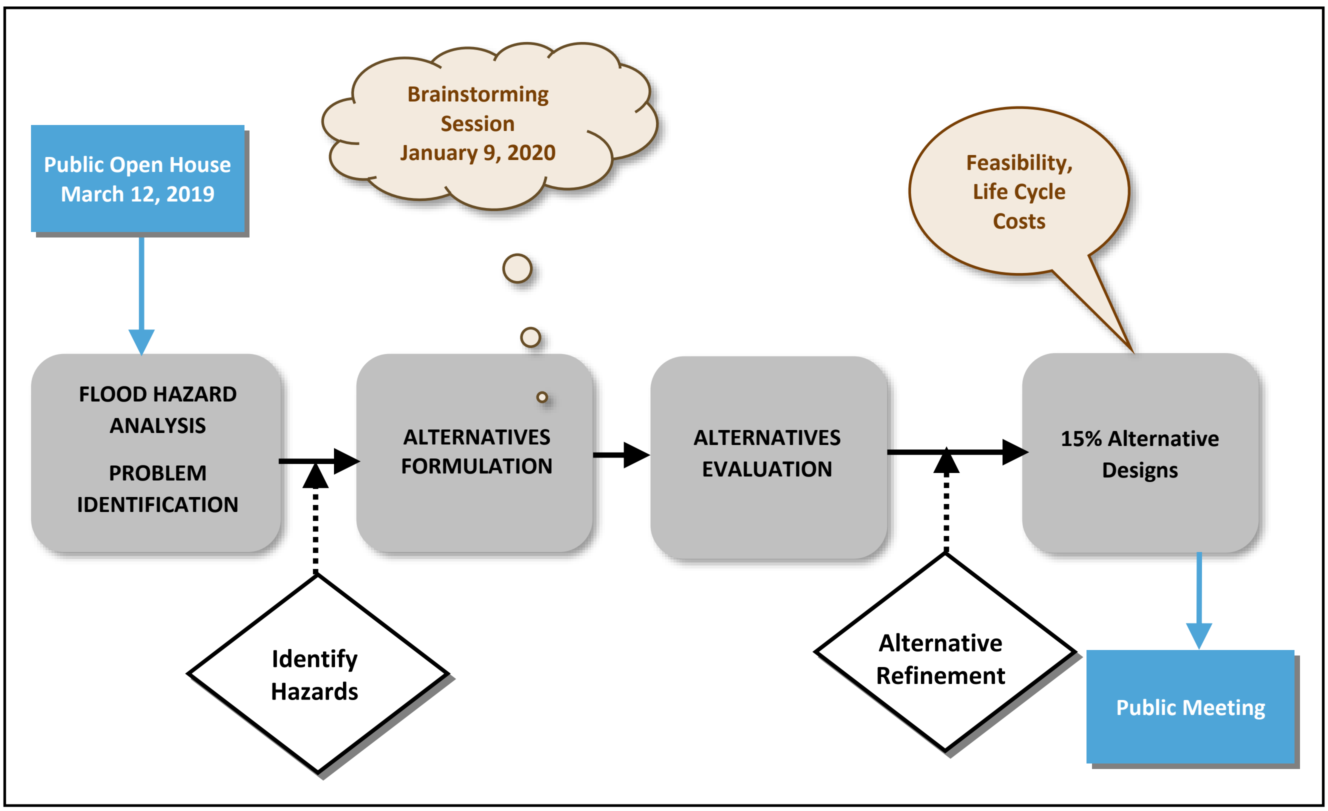

Figure 5-1. Development process for the regional flood mitigation alternatives for the ADMP

5.2 Mitigation Alternatives

On January 9, 2020, the consultant team (JEF and Lumos) conducted a brainstorming session to develop initial mitigation concepts and verify their feasibility. The meeting resulted in the conceptualization of several regional mitigation systems. On January 21, 2020, the consultant team met with the client team to present and discuss the mitigation system options. The system options were comprised of the following structure elements:

- Detention basins
- Collector channels
- Conveyance channels
- Culverts
- Existing channel improvements
- Existing detention basin improvements

Through the Alternatives Formulation and Alternatives Evaluation process, the consultant team developed three mitigation alternative systems that were presented to Lyon County. Each system was comprised of a series of sediment/detention basins and collector/conveyance channels in various configurations that would result in significant mitigation of offsite flooding to the South Dayton community. Each alternative system is described in the following sections and summarized in Table 5-1.

5.2.1 Alternative 1

Alternative 1 was initially proposed as six sediment/detention basins located at the major offsite drainage channels on the lower piedmont. The basins would be connected to a collector/conveyance channel that spanned the entire length of the piedmont and drained to the Carson River east of the South Dayton community (Figure 5-2).

5.2.2 Alternative 1a

Alternative 1a is comprised of five sediment/detention basins, a series of collector/conveyance channels, and proposed improvements to existing drainage infrastructure (Figure 5-3). Three basins would be located south of the airport commercial district and would collect and pass offsite runoff to a conveyance channel that would flow to the northwest and empty into the main channel of El Dorado Canyon. A separate collector channel would be constructed southeast of the airport commercial district and would be incorporated into the existing drainage channel to the east of the commercial district. The existing channel would need to be improved to collect and convey the storm runoff. A new conveyance channel would need to extend from the existing channel to the existing regional detention basin east of the Dayton Valley Golf Course community. The existing basin would also need to be improved to safely detain and convey the storm runoff. A new conveyance channel would extend from the existing basin outlet across Dayton Valley Road and north to the Carson River.

To mitigate offsite flows from east of the Ranchos area, a single sediment/detention basin would be located on the main drainage corridor and would connect to a collector/conveyance channel that would extend directly north and connect to the existing channel that exists the Ranchos development. The existing channel would require improvements to convey the storm runoff directly north to the Carson River.

5.2.3 Alternative 1b

Alternative 1b incorporates all the structure elements of 1a except for the conveyance system downstream of the existing regional basin. The 1b system includes a conveyance channel from the basin outlet to Dayton Valley Road, then extends south of the road to the existing drainage channel that flows through the Ranchos development (Figure 5-4). A new culvert at Dayton Valley Road would allow the flow to pass beneath the road to the existing channel. The ADMP hydraulic modeling results indicate a section of the existing channel does not have capacity to convey the offsite flow, thus channel improvements would be necessary. The existing channel alignment through the Ranchos intersects many individual private parcels.

5.2.4 Summary

Figure 5-2 through Figure 5-4 illustrate the conceptual layout of each alternative system. Land ownership within the alternative areas is either Private or Bureau of Land Management (BLM). The land ownership boundaries are shown in the figures.

Table 5-1 provides a summary of the alternatives and the key opportunities and constraints that were presented to Lyon County to aid in their decision in selecting a preferred alternative system to advance to the conceptual design phase of the ADMP.

Table 5-1. Alternative comparison summary

Alternative System	Structure Elements	Opportunities	Constraints	Preliminary Cost Estimates
1	• New Sediment/Detention Basins • New Collector/Conveyance Channel	• Regional mitigation solution • Minimal private land right-of-way acquisition needed • Construction/design with regional future bypass road could result in significant cost savings	• Coordination with BLM • Coordination and approval needed from 6 private parcel owners	25-yr: $28.2 million 100-yr: $44.0 million
1a	• New Sediment/Detention Basins • New Collector/Conveyance Channels • Improvements to existing drainage channels • Improvements to existing regional detention basin	• Regional mitigation solution • Utilizes existing drainage infrastructure	• Coordination with BLM • Significant private right-of-way area needed • Coordination and approval needed from 20 private parcel owners	25-yr: $33.5 million 100-yr: $37.3 million
1b	• New Sediment/Detention Basins • New Collector/Conveyance Channels • Improvements to existing drainage channels • Improvements to existing regional detention basin • Upgrade 8 existing culverts	• Regional mitigation solution • Utilizes existing drainage infrastructure	• Coordination with BLM • Significant private right-of-way area needed • Coordination and approval needed from 52 private parcel owners	25-yr: $30.5 million 100-yr: $34.9 million

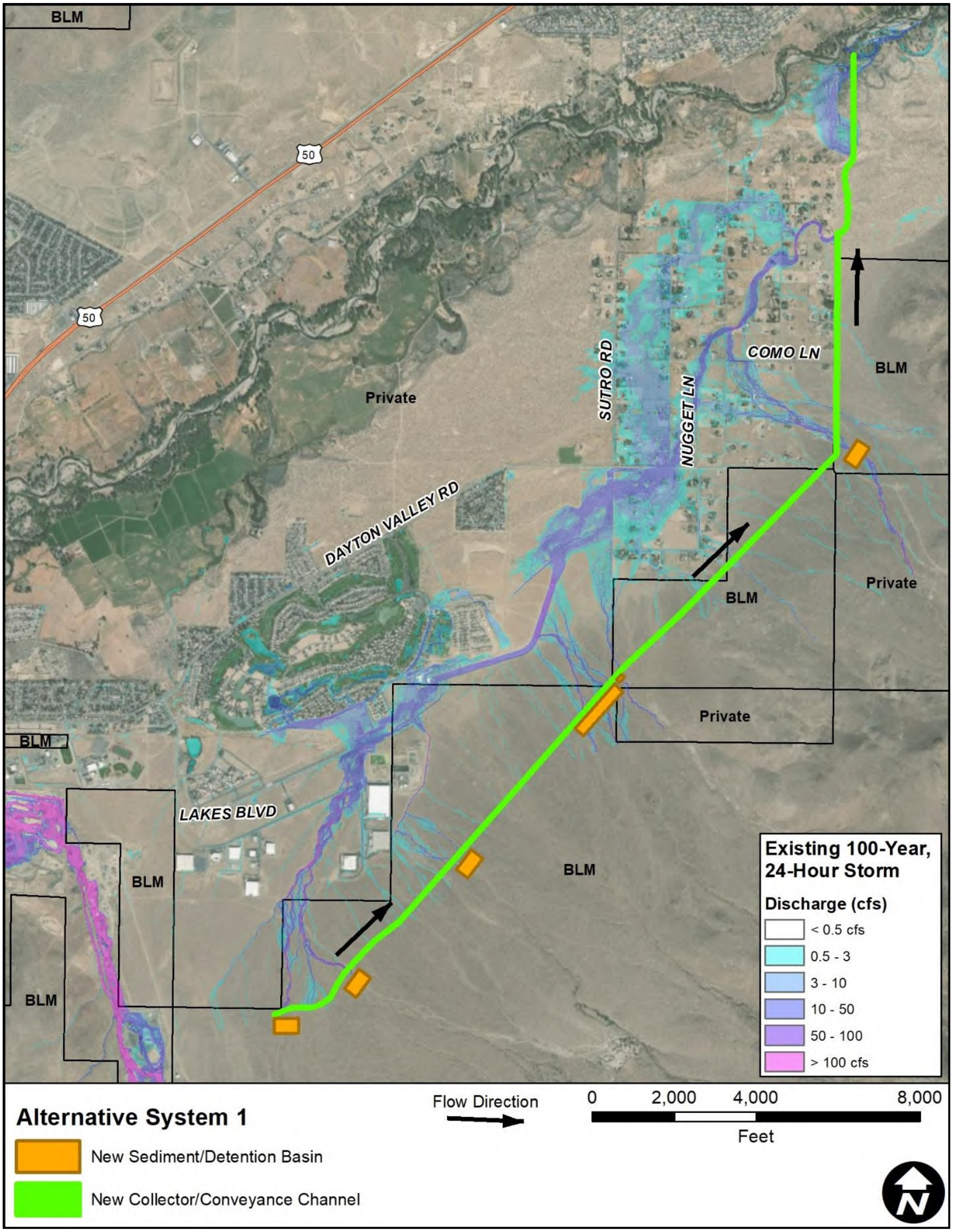

Figure 5-2. Conceptual layout of Alternative 1

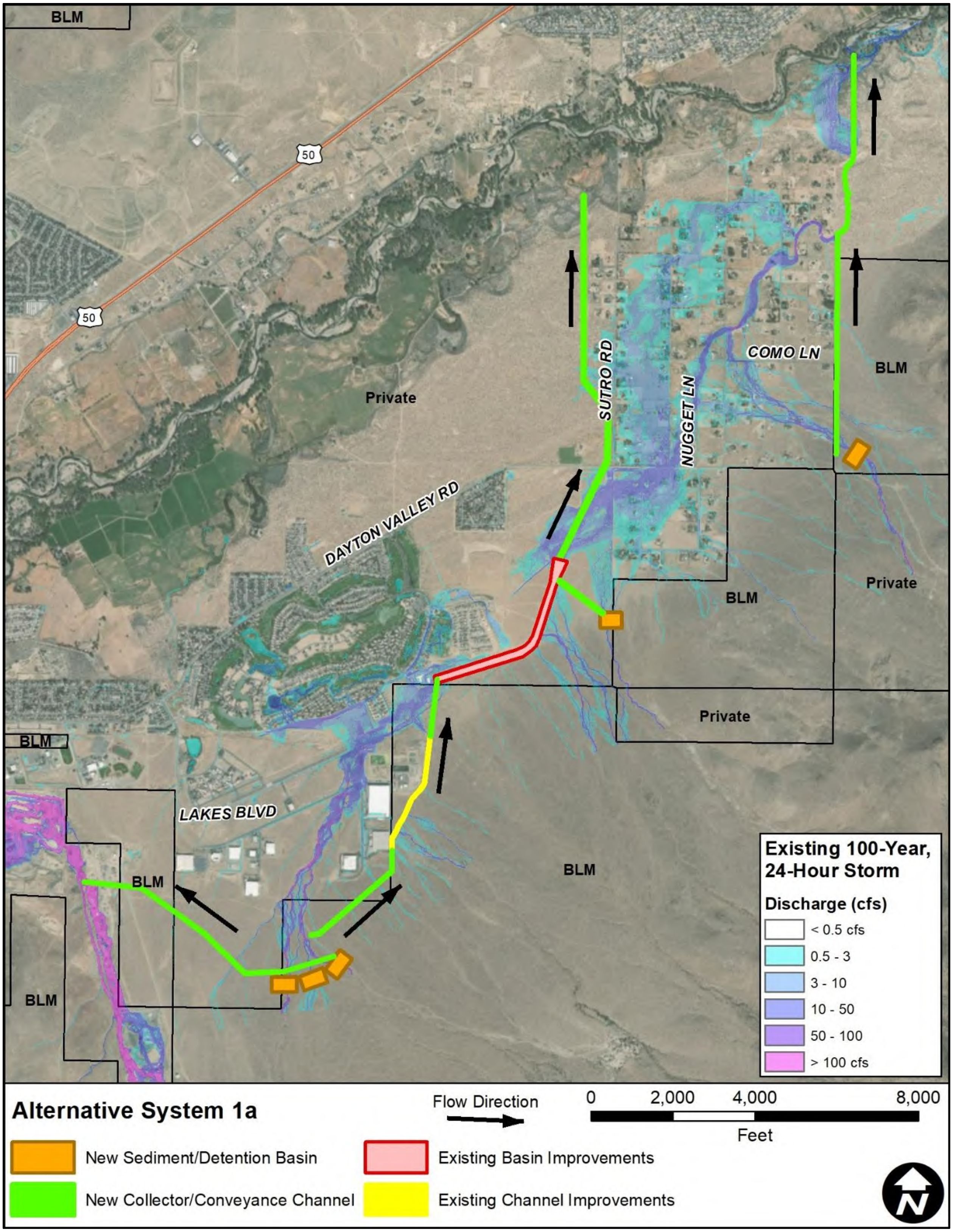

Figure 5-3. Conceptual layout of Alternative 1a

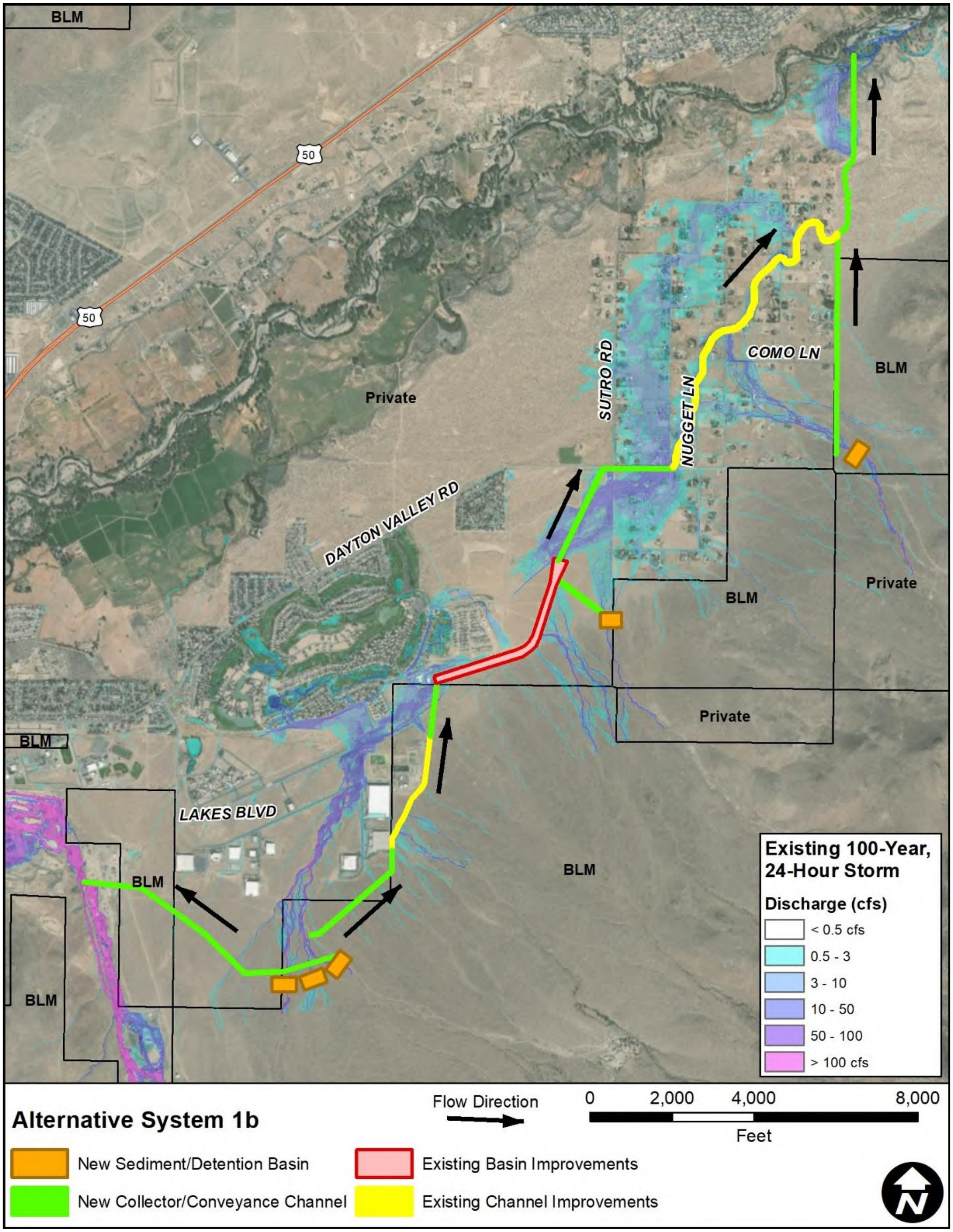

Figure 5-4. Conceptual layout of Alternative 1b

5.3 Selected Regional Mitigation Alternative

Lyon County selected Alternative System 1 to advance to the concept phase of the ADMP. The final system concept is comprised of six sediment/detention basins and one collector/conveyance channel that spans the length of most of the Pine Nut Mountain piedmont that drains to South Dayton (Figure 5-5). The consultant team developed proposed mitigation structures for both the 100-year and 25-year storms to assess which would provide the most overall benefit. There were many considerations that led to the selection of the alternative system. A few of the most significant are:

- Provides a regional solution that mitigates most of the offsite flood risk to the South Dayton community.
- The Lyon County Comprehensive Master Plan[8] includes a proposed South Dayton Bypass Road that could parallel the proposed conveyance channel, resulting in significant cost savings if constructed concurrently with mitigation system; or at least each project is designed and constructed with the other project in mind.
- The basins and channel are located primarily on public land which would minimize the number of private landowners involved in acquiring property right-of-way to construct and maintain the system.

[8] https://www.lyon-county.org/773/Comprehensive-Master-Plan

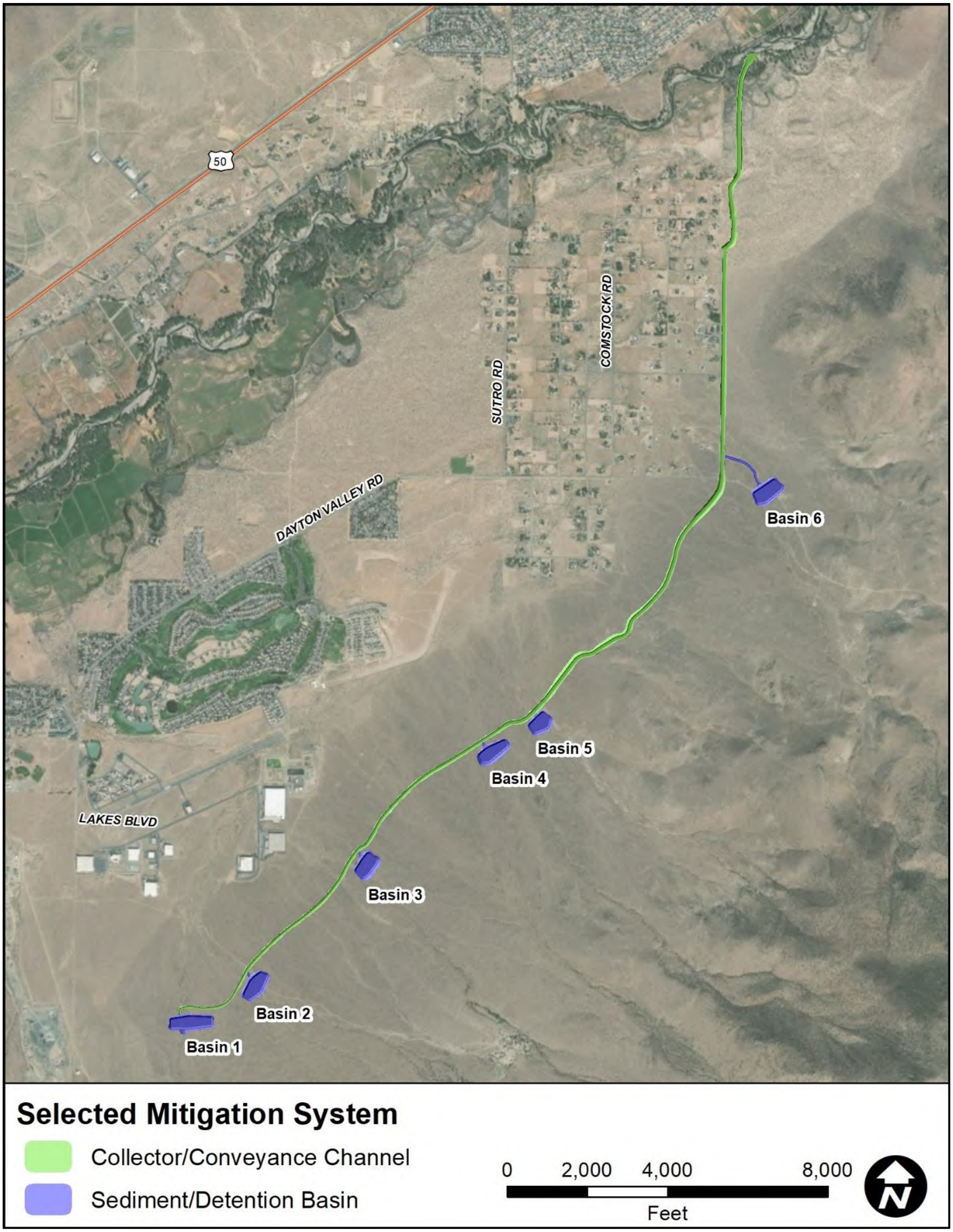

Figure 5-5. Selected mitigation system

5.3.1.1 Sediment Considerations for Proposed Alternatives

The primary function of the proposed basins is to trap sediment to prevent the conveyance channel from depositing sediment that is presently distributed across the piedmont to one outlet point on the Carson River.

An estimate of sediment delivery volumes is beneficial when assessing proposed infrastructure locations and designs. Unlike scour, long-term sediment deposition is a common issue for infrastructure and often cannot be mitigated through on-site improvements. Common examples of sediment deposition challenges for infrastructure include culvert sedimentation and loss of storage volume in detention basins due to deposition. To assist in the design of proposed infrastructure improvements, sediment yield was calculated for the contributing watersheds.

Sediment transport capacity calculations were performed as described previously in Section 3 with the Yang method. Sediment transport capacity rates were integrated over time at pre-defined FLO-2D floodplain cross-section locations to calculate total sediment transport volumes at each cross-section for the suite of storms modeled. Sediment transport volumes per storm were then probabilistically composited based upon likelihood of occurrence within a 100-year span following guidance outlined in SLA (1985) with the following relationship:

$$\text{annual probabilistic value} = 0.4 * (\text{2-year value}) + 0.2 * (\text{5-year value}) + 0.08 * (\text{10-year value}) + 0.04 * (\text{25-year value}) + 0.015 * (\text{100-year value}) + 0.002 * (\text{500-year value}) \quad (4)$$

Equation (4) calculates an annualized average value based upon a non-continuous storm recurrence range for commonly analyzed storm frequencies.

Yang sediment transport equations yield results in concentration as parts per million (ppm). The maximum concentrations per grid were converted from a mass per volume result to a volume per volume relationship to determine the maximum sediment concentrations for flow bulking due to sediment. Flow bulking is a useful method for accounting for extra flood volume due to entrained sediment in flood flows.

The Yang sediment transport estimates were used in the development of the 15% design alternatives. Three times the annual sediment transport volume plus one design event (100-year or 25-year) sediment transport volume was used as the total sediment volume for each basin. The total sediment design volumes for the proposed flood mitigation basins are summarized in Table 5-2.

Finally, it should be noted that sediment throughput calculations exhibit wide variability based on the transport equation used, grain size of the sediment, watershed slope, and many other variables. Similarly, since the hydraulic calculations are the backbone of any sediment calculation, infiltration volumes and Manning’s n values also affect total sediment volumes. Therefore, most analyses in this study were taken on a relative basis – that is the absolute values are not precise. However, the sediment basins need a calculated design volume; and, in this case, appropriate safety factors were incorporated in the analyses. Nonetheless, detailed analysis of a basin’s specific watershed is recommended to refine the expected sediment volumes for final design.

Table 5-2. Sediment design volumes

Basin Name*	25-Year Sediment Storage Volume (ac-ft)	100-Year Sediment Storage Volume (ac-ft)
Basin 1	0.8	1.2
Basin 2	0.6	1.0
Basin 3	0.7	0.8
Basin 4	0.5	0.9
Basin 5	0.2	0.3
Basin 6	1.8	2.5
*The basins listed in this table represent proposed mitigation structures that are part of the selected mitigation alternative		

5.4 Ranchos Drainage Improvement Assessment

5.4.1 Introduction

Initially, the ADMP scope of work included a driveway culvert assessment since the main drainage infrastructure throughout the Ranchos area are small roadside ditches designed to convey local (or on-site) runoff from the adjacent road and right-of-way from frequent recurrence interval storms (e.g., 2-year, 5-year, 10-year, etc.). Residents generally access their property via a driveway that crosses a roadside ditch, and these driveways typically have small culverts that are designed to allow passage of runoff along the ditches (Figure 5-6).

However, after completing the existing conditions modeling, JEF determined that due to the infiltration methodology (SCS curve number) being applied in the study, the FLO-2D models were indicating minimal local runoff within the Ranchos area. That is, most of the localized on-site rainfall was absorbed through the selected curve numbers. Therefore, this task was modified to provide a concept drainage improvement assessment specific to the Ranchos area (Figure 5-7). This analysis included major roadway crossing improvements (excluding driveway culverts) within the Ranchos area that could potentially reduce offsite flood risk to the community even if the regional mitigation alternatives were not implemented.

Figure 5-6. Examples of typical driveway culverts in study area (note sediment clogging and available headwater depth).

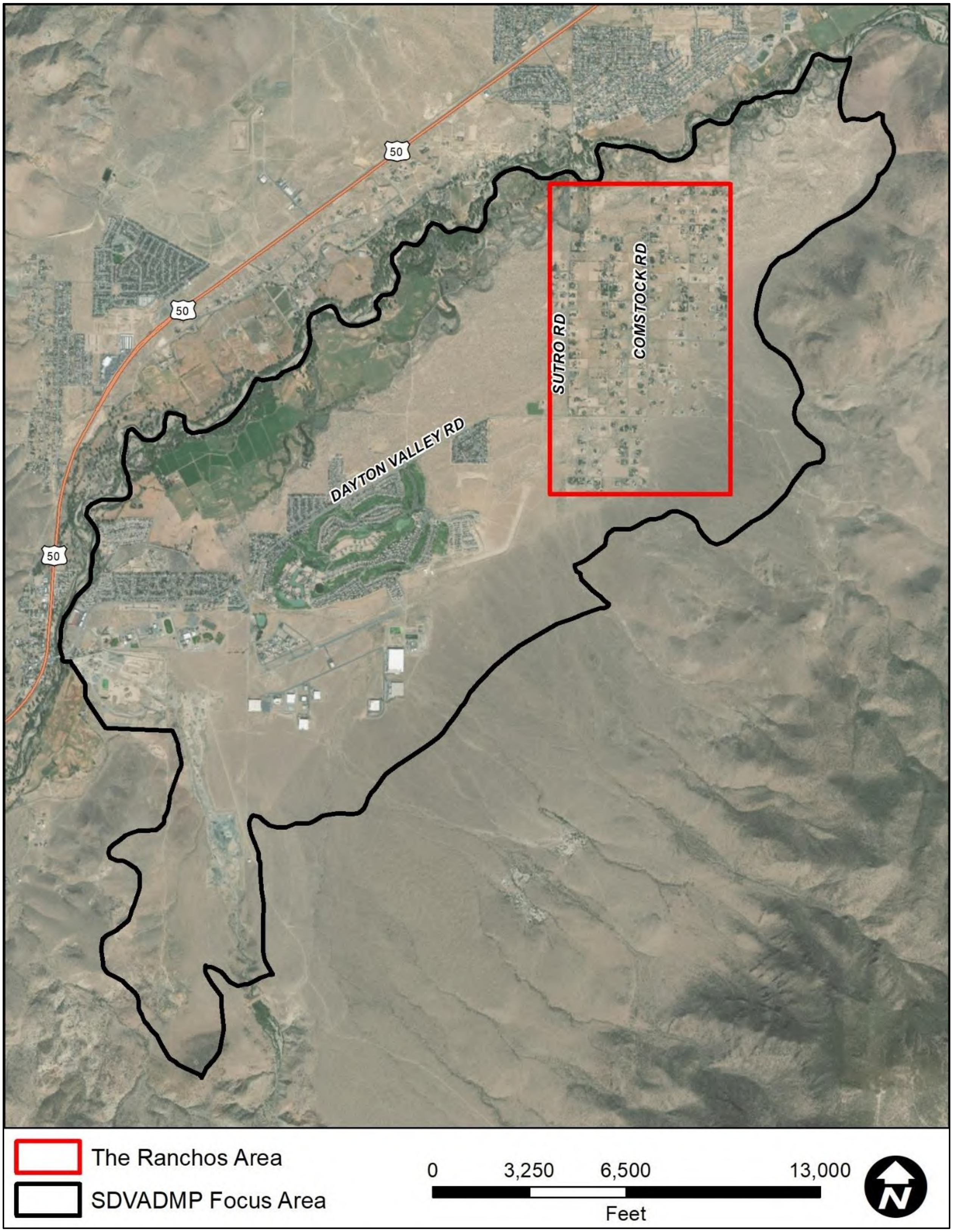

Figure 5-7. Ranchos area vicinity map

5.4.2 Methodology and Results

Prior to the development of the South Dayton area, runoff from the Pine Nut Mountain piedmont collected in a single drainage channel that flowed through what is now the Ranchos to the Carson River (see Section 1.4). Development of the Ranchos area encroached on the natural floodplain of the channel corridor. Although the historical alignment of the channel is mostly preserved, reaches of the present channel do not have capacity to convey the 100-year, 24-hour storm runoff without overtopping and flooding adjacent properties. In addition, the road crossing culverts do not have the capacity to pass either the 25-year or 100-year storm runoff without overtopping. As part of the ADMP, the consultant team prepared a concept that would improve drainage through the Ranchos community, exclusive of the regional mitigation structures in the selected alternative. The concept elements are described below and are shown spatially in Figure 5-8.

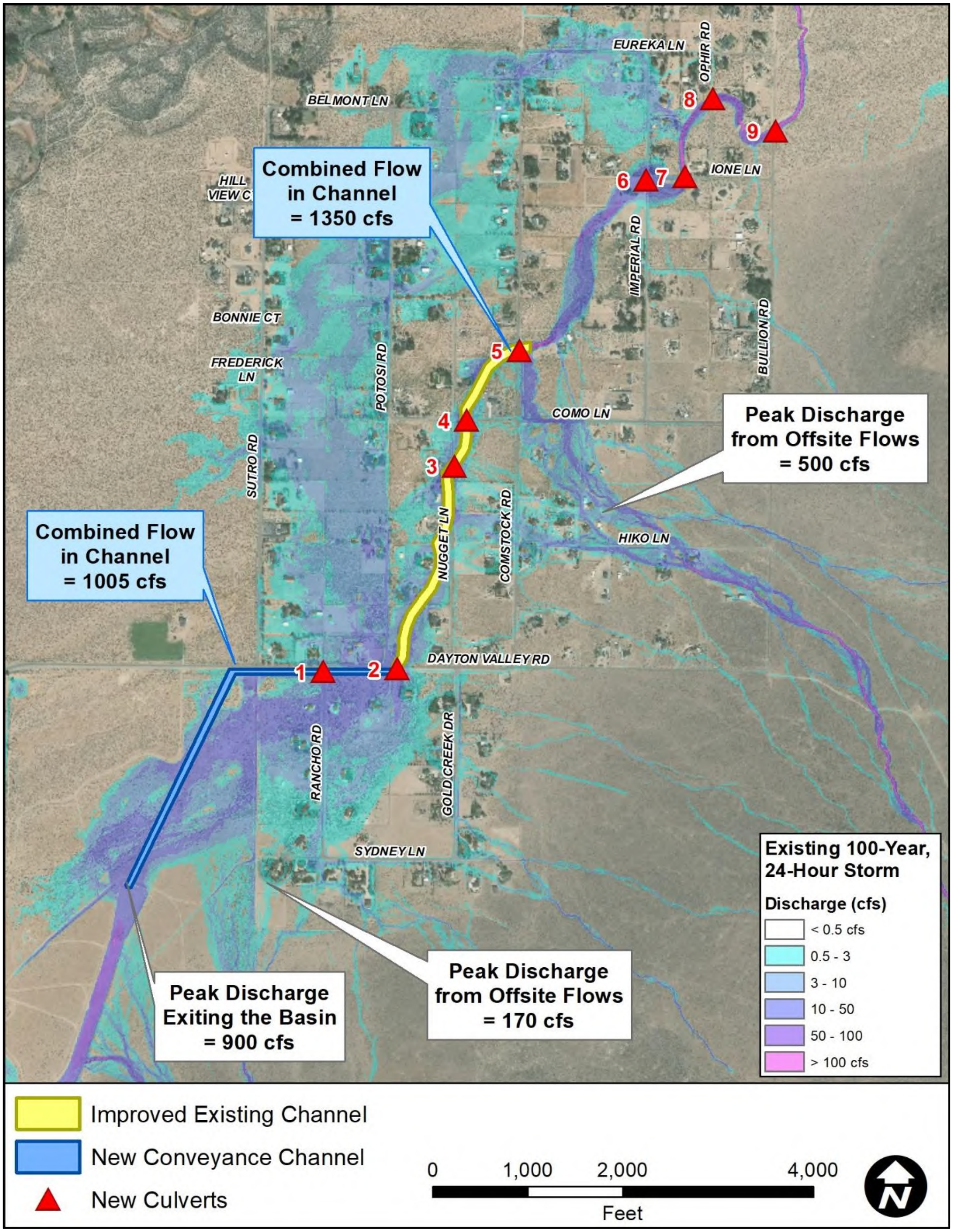

Figure 5-8. Drainage improvement concepts for the Ranchos area

5.4.2.1 Basin Conveyance Channel

The existing 4,500-foot long basin that is located immediately east of the Dayton Valley Golf Course community releases stormwater upstream of the Ranchos. To better control this release, a new conveyance channel is recommended from the basin outlet to Dayton Valley Road. The conveyance channel would then need to extend east along Dayton Valley Road between Rancho Road and Gold Creek Drive, then through a new culvert beneath Dayton Valley Road. The ADMP FLO-2D modeling results indicate the outflow discharge from the basin is approximately 900 cfs for the 100-year, 24-hour storm and increases to 1,350 cfs within the Ranchos development due to additional inflows from both the south and east. However, the design flow rate for the new conveyance channel is 1,005 cfs since the major eastern inflows reach the channel downstream of the new channel (see Figure 5-8). Figure 5-9 shows a typical section for the new conveyance channel that would convey the 100-year discharge from the basin outlet to the new culvert at Dayton Valley Road. It should be noted that the basin outflow would increase if the outlet elevation was lowered. This analysis did not consider that possibility.

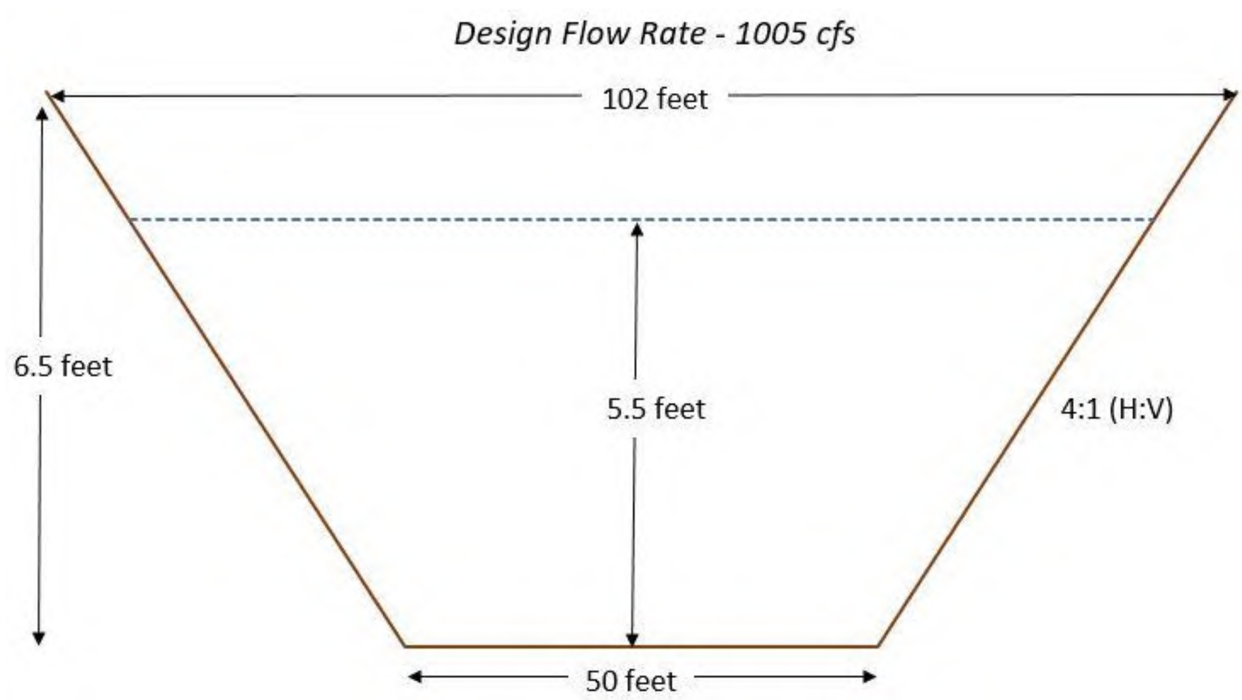

Figure 5-9. Typical section required for a new channel in the Ranchos

5.4.2.2 Existing Channel Improvements

The existing drainage channel within the Ranchos needs to be improved from Dayton Valley Road to downstream of Comstock Road to convey the runoff through the community for the 100-year storm. It is recommended that the existing channel be improved to the dimensions in the typical section shown in Figure 5-9. The ADMP modeling results and channel slope calculations indicate the existing channel from downstream of Comstock Road to Bullion Road generally has the capacity to convey the 100-year discharge; however, some sections show areas that would overtop by approximately 6 inches (see Figure 5-10). In addition, the culverts at major road crossings would need to be upgraded to pass the 100-year discharge without overtopping the road and causing adverse flooding to adjacent properties (Figure 5-11).

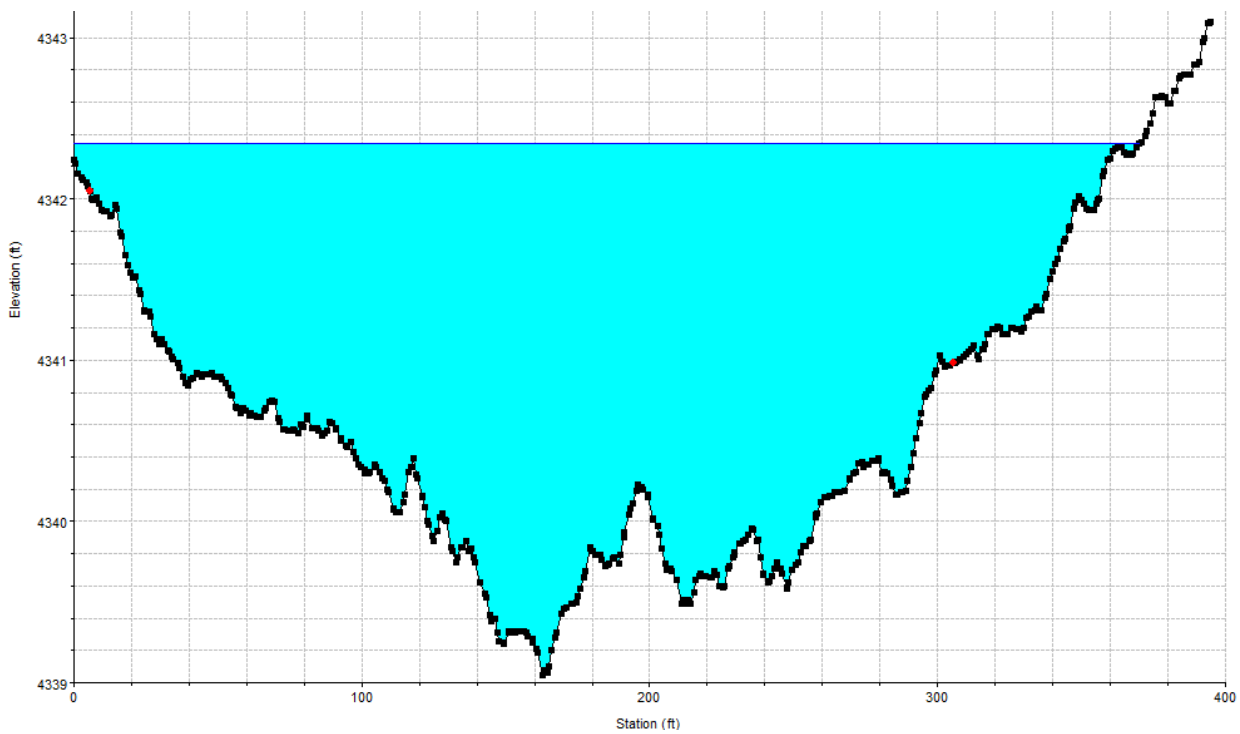

Figure 5-10. Example of cross-section with slight overtopping (see left bank)

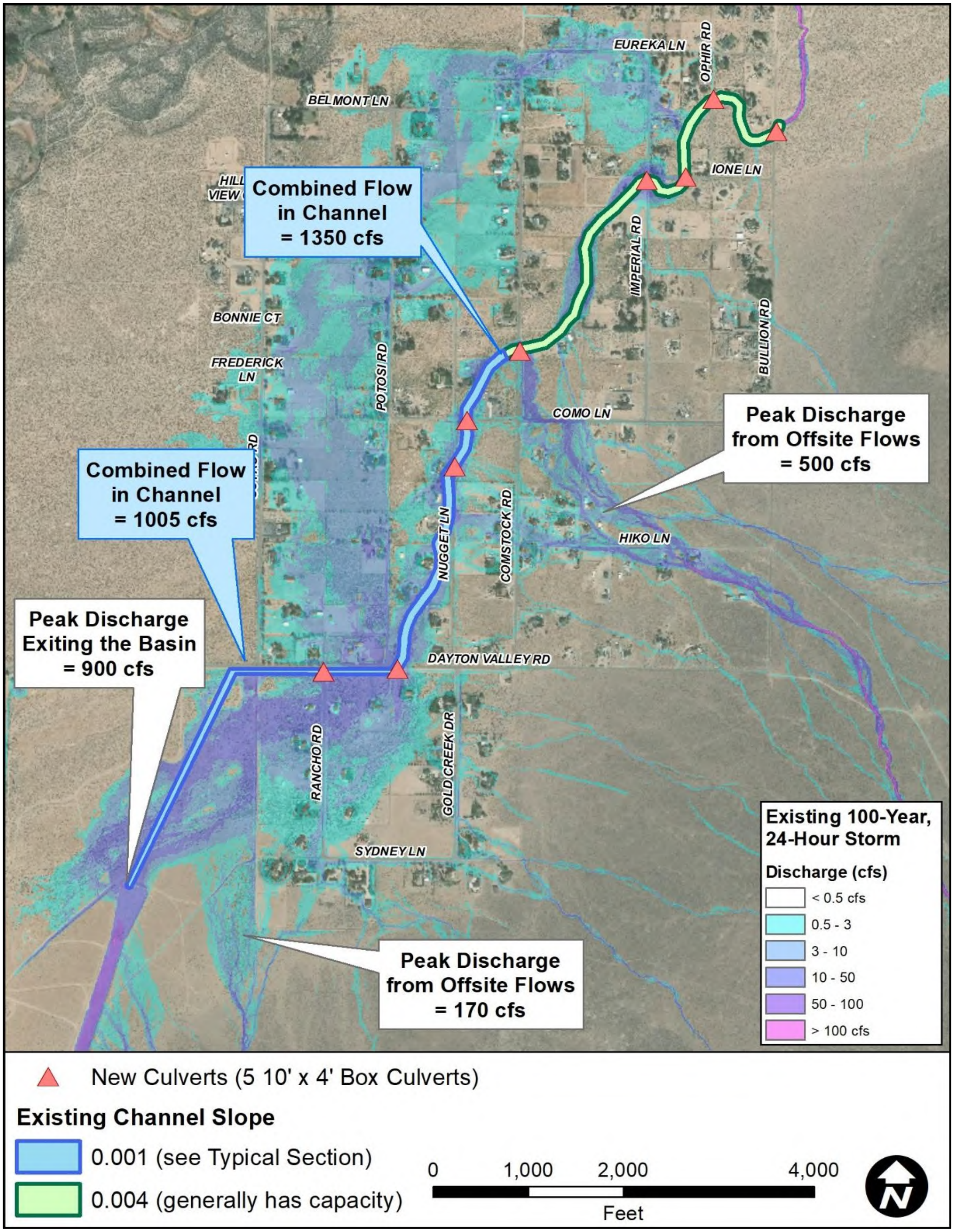

Figure 5-11. Approximate flow discharges and channel slope calculations

5.4.2.3 Culverts

The new drainage system would necessitate construction of culverts at major road crossings that would allow for access to the development during a 100-year storm event. The recommended culvert locations are listed below in upstream to downstream order and shown spatially in Figure 5-8:

1. Ranchos Road
2. Dayton Valley Road
3. Nugget Lane
4. Como Lane
5. Comstock Road
6. Imperial Road
7. Ione Lane
8. Ophir Road
9. Bullion Road

The recommended culverts would allow passage of runoff without overtopping the roadway. A 5-barrel 10' x 4' box culvert at each road crossing would convey the 100-year discharge safely through the Ranchos community to the Carson River. This size of culvert crossing was chosen to keep the design headwater elevation less than 6 feet.

5.4.2.4 Cost Estimates

Approximate cost estimates for each of the concept elements are listed in Table 5-3. These costs were developed based on the cost per lineal foot basis that Lumos developed for use on the regional alternatives (see Appendix B). Therefore, this estimate does not consider the cost of right-of-way (ROW) acquisition or drainage easements.

Table 5-3. Drainage improvement concept cost estimates

Mitigation Concept	100-Year Storm Cost Estimate
New Conveyance Channel & Existing Channel Improvements	$6,100,000
New Culverts (9 total)	$1,300,000
Total	**$7,400,000**

5.5 Selected Regional Alternative Conceptual 15% Design Plans

Lumos was tasked with developing conceptual, 15% design plans for the mitigation alternative for the 25-year and 100-year storms. The Lumos plan sets and accompanying technical report are included in Appendix B. An example design plan excerpt is shown in Figure 5-12. These concept designs are meant to outline costs and general characteristics of the proposed structures to allow for recommendation and prioritization. The design volumes, structure alignments, and other characteristics should be refined during final design. There may be constraints such as utility conflicts uncovered during Final Design that are outside the scope of this study.

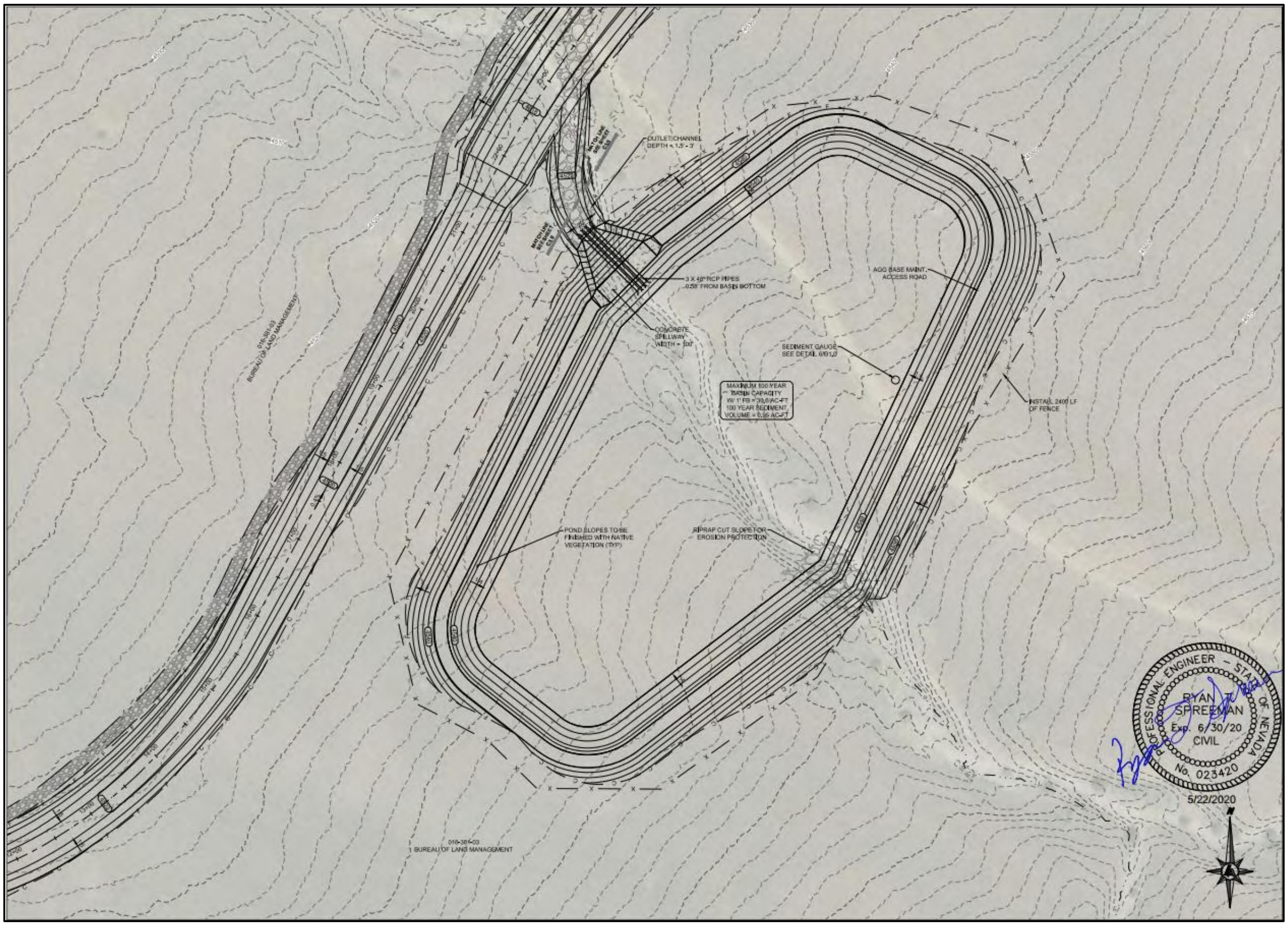

Figure 5-12. Example 15% design plan sheet for Basin #2

5.6 BENEFITS SUMMARY

5.6.1 Buildings Benefit

The depth and HAZUS analyses that were performed for existing conditions (Section 4) were repeated for the proposed conditions model results. The analyses were run using two scenarios for each of the three storm events for a total of six proposed conditions models. The scenarios were:

1) All 25-year proposed structures in place, and
2) All 100-year proposed structures in place

The proposed conditions building flood risk and HAZUS analyses are summarized in Table 5-4 and Table 5-5. The last column in the tables show the estimated benefit for each storm event when compared to existing base conditions for that same storm event.

Table 5-4. Summary of buildings removed from potential inundation

Recurrence Interval Storm	Proposed Conditions Building Counts				Existing Conditions Building Count[1]	Buildings Removed (Benefit)
	Building Count Flow Depth	Building Count Flow Depth	Building Count Flow Depth	Total Building Count		
	0.25' < h ≤ 0.5'	0.5'< h ≤ 1'	1' < h			
Proposed Conditions (25-year System)						
25Y24H	314	47	12	**373**	**445**	**72**
100Y24H	351	80	27	**458**	**580**	**122**
100Y6H	432	53	7	**492**	**499**	**7**
Proposed Conditions (100-year System)						
25Y24H	314	47	12	**373**	**445**	**72**
100Y24H	345	62	15	**422**	**580**	**158**
100Y6H	432	53	7	**492**	**499**	**7**

1. From Table 4-2.

Table 5-5. Summary of flood damage estimates and potential benefits

Recurrence Interval Storm	Direct Building Economic Loss					
	Residential	Commercial	Industrial	Others	Total Property[1]	Total Benefit
	$ millions	$ millions	$ millions	$ millions	$ millions	$ millions
Base Conditions						
25Y24H	2.68	0.21	0.45	0.43	3.77	-
100Y24H	5.93	0.36	0.69	0.67	7.65	-
100Y6H	0.78	0.05	0.08	0.06	0.97	-
Proposed Conditions (25-year System)						
25Y24H	1.19	0.07	0.09	0.01	1.36	**2.41**
100Y24H	2.53	0.22	0.39	0.35	3.49	**4.16**
100Y6H	0.56	0.04	0.03	0	0.63	**0.34**
Proposed Conditions (100-year System)						
25Y24H	1.16	0.07	0.07	0.01	1.32	**2.45**
100Y24H	1.76	0.13	0.13	0.08	2.11	**5.54**
100Y6H	0.56	0.04	0.03	0	0.63	**0.34**

1. May not be additive due to rounding in internal HAZUS calculations

5.6.2 Flood Risk Area Reduction Benefit

The selected alternative would result in a significant reduction in flood risk area throughout South Dayton. To quantify this benefit, the total flood risk area for depths of 0.25 feet and greater was computed from the existing conditions FLO-2D model results for both the 25-year and 100-year storms and subtracted from the inundation area resulting from the selected alternative models. The results are listed in Table 5-6 and shown in Figure 5-13 through Figure 5-16.

Table 5-6. Potential flood risk area reduction benefit

Recurrence Interval Storm	Flood Risk Inundation Area	Total Benefit
	Acres	Acres Removed from Flood Risk (depth < 0.25 feet)
Base Conditions		
25Y24H	770	-
100Y24H	1,165	-
Proposed Conditions (25-year System)		
25Y24H	347	**423**
100Y24H	751	**414**
Proposed Conditions (100-year System)		
25Y24H	337	**433**
100Y24H	501	**664**

5.6.3 Flood Depth Reduction Benefit

The selected alternative would also result in a significant reduction in flood depths throughout the South Dayton area. To illustrate this benefit, Figure 5-17 through Figure 5-20 show the reduction in flood depth for the 25-year and 100-year storms considering both the 25-year and 100-year mitigation systems.

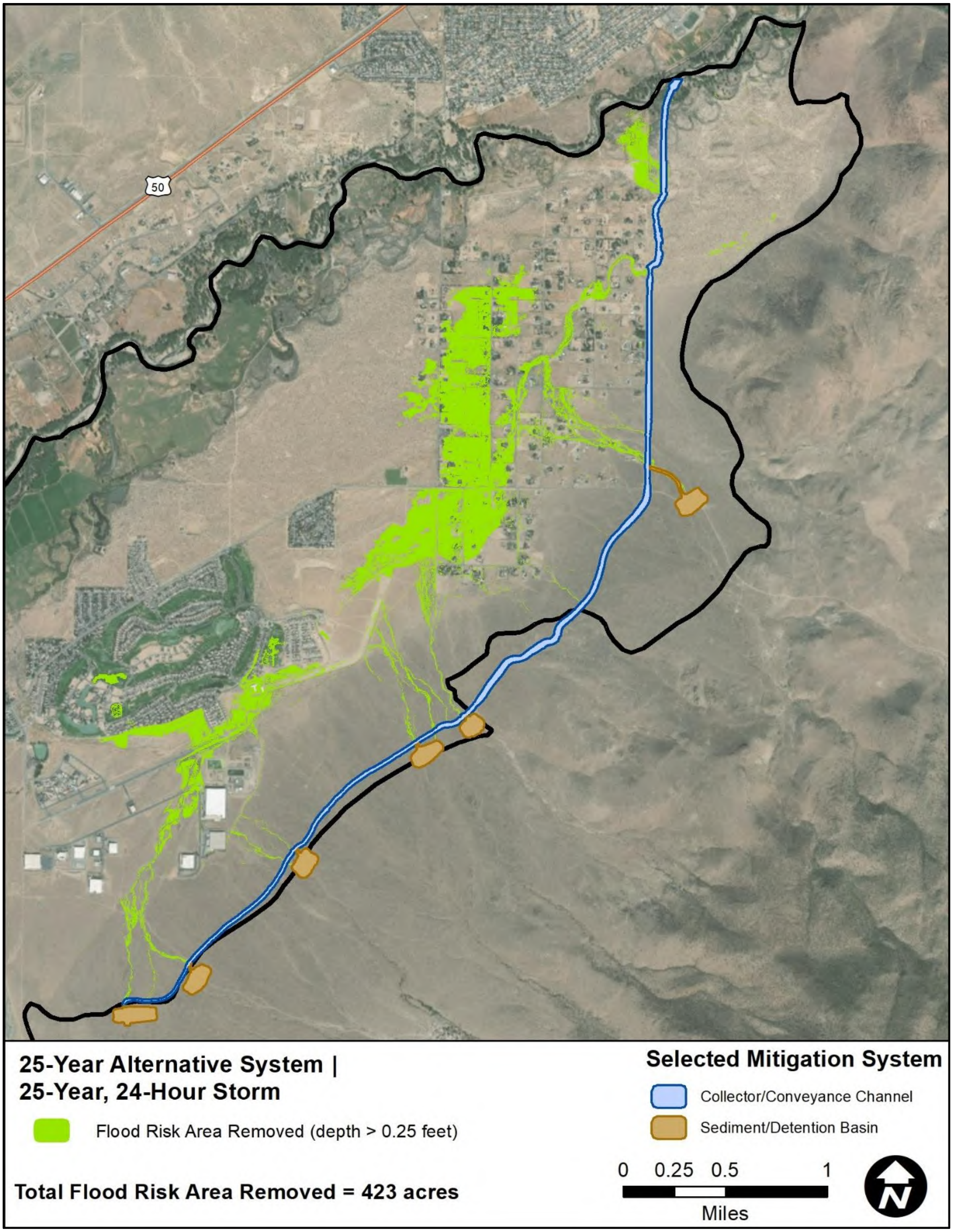

Figure 5-13. Potential flood risk area reduction benefit: 25-Yr Alt System, 25-Yr, 24-Hr storm

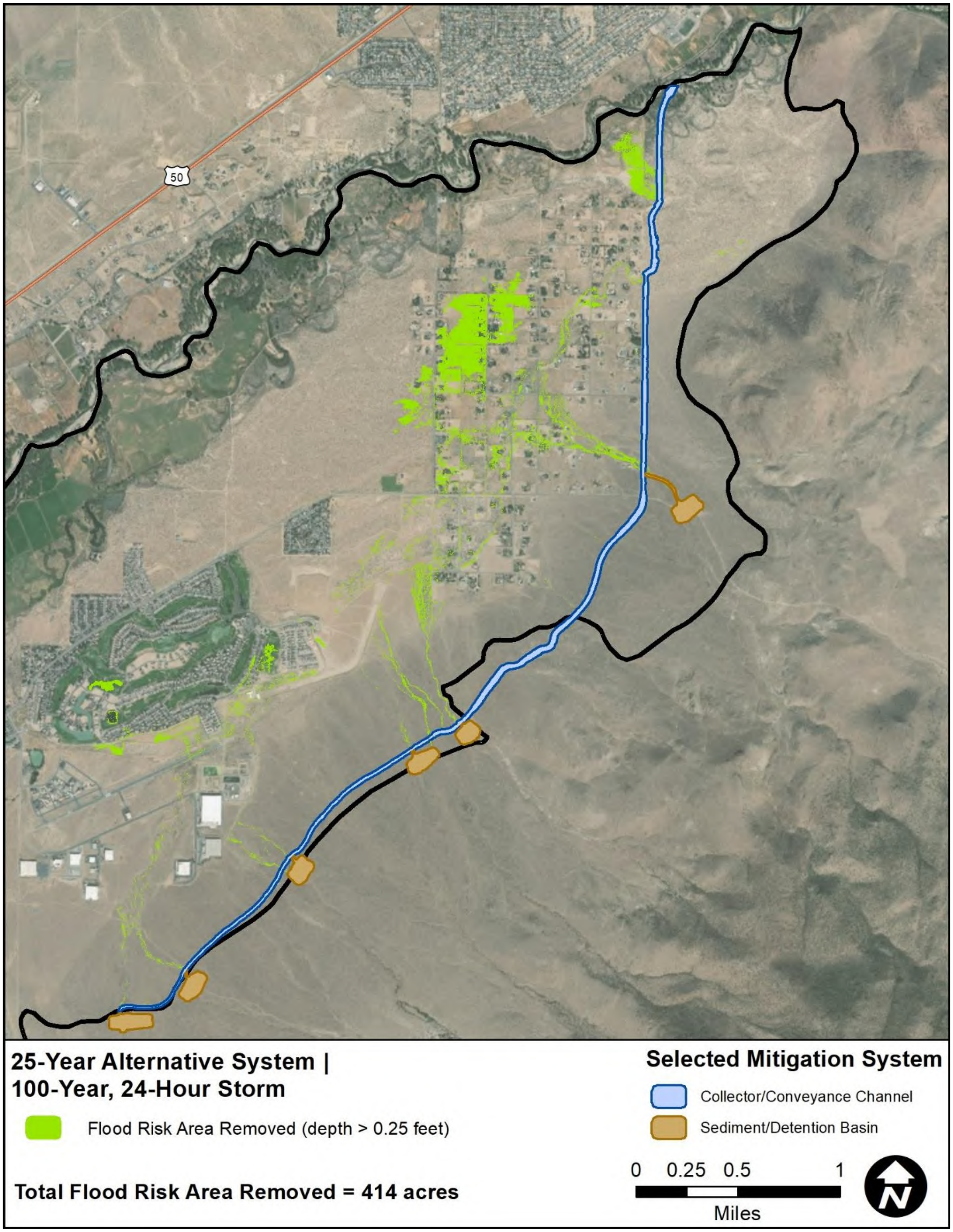

Figure 5-14. Potential flood risk area reduction benefit: 25-Yr Alt System, 100-Yr, 24-Hr storm

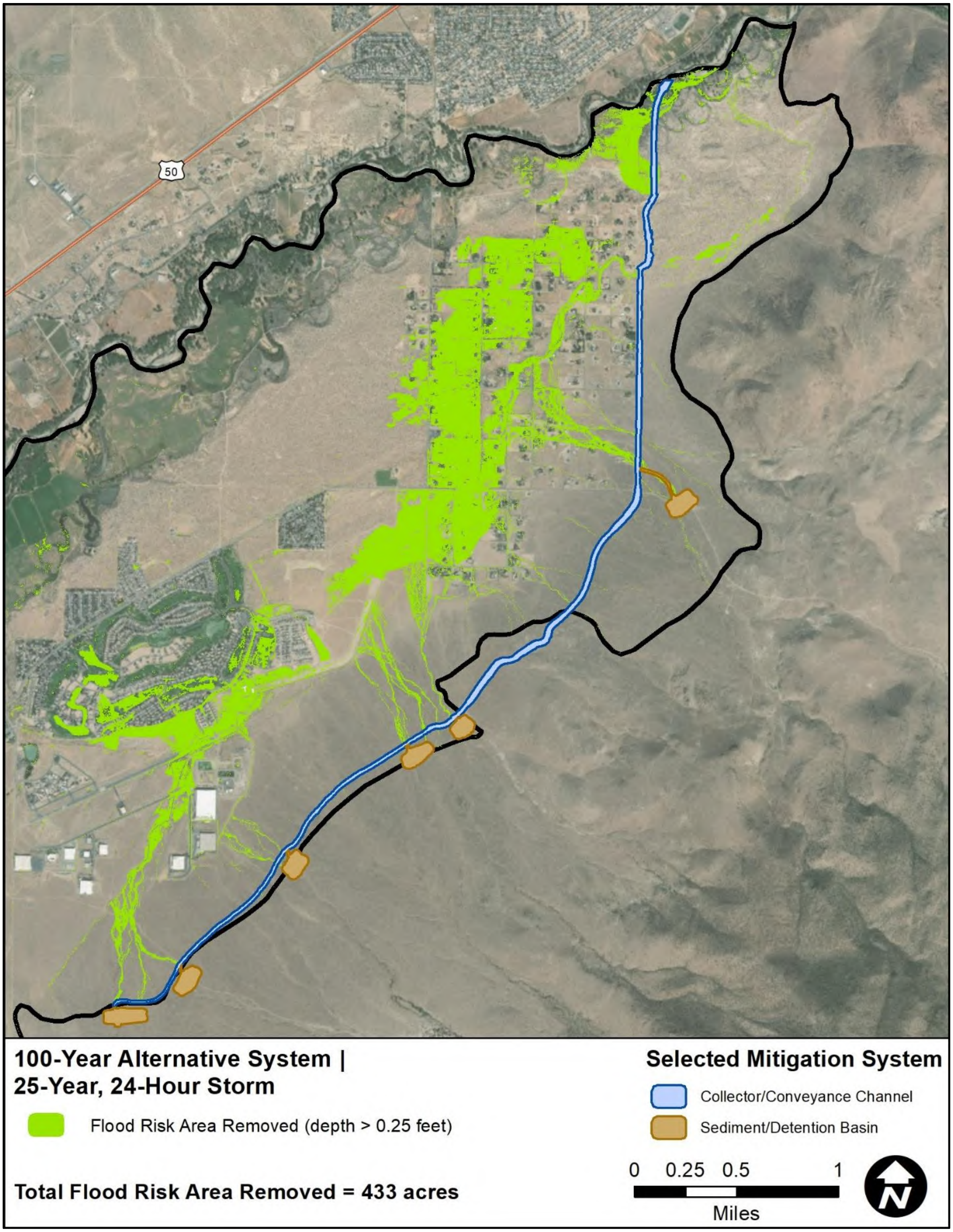

Figure 5-15. Potential flood risk area reduction benefit: 100-Yr Alt System, 25-Yr, 24-Hr storm

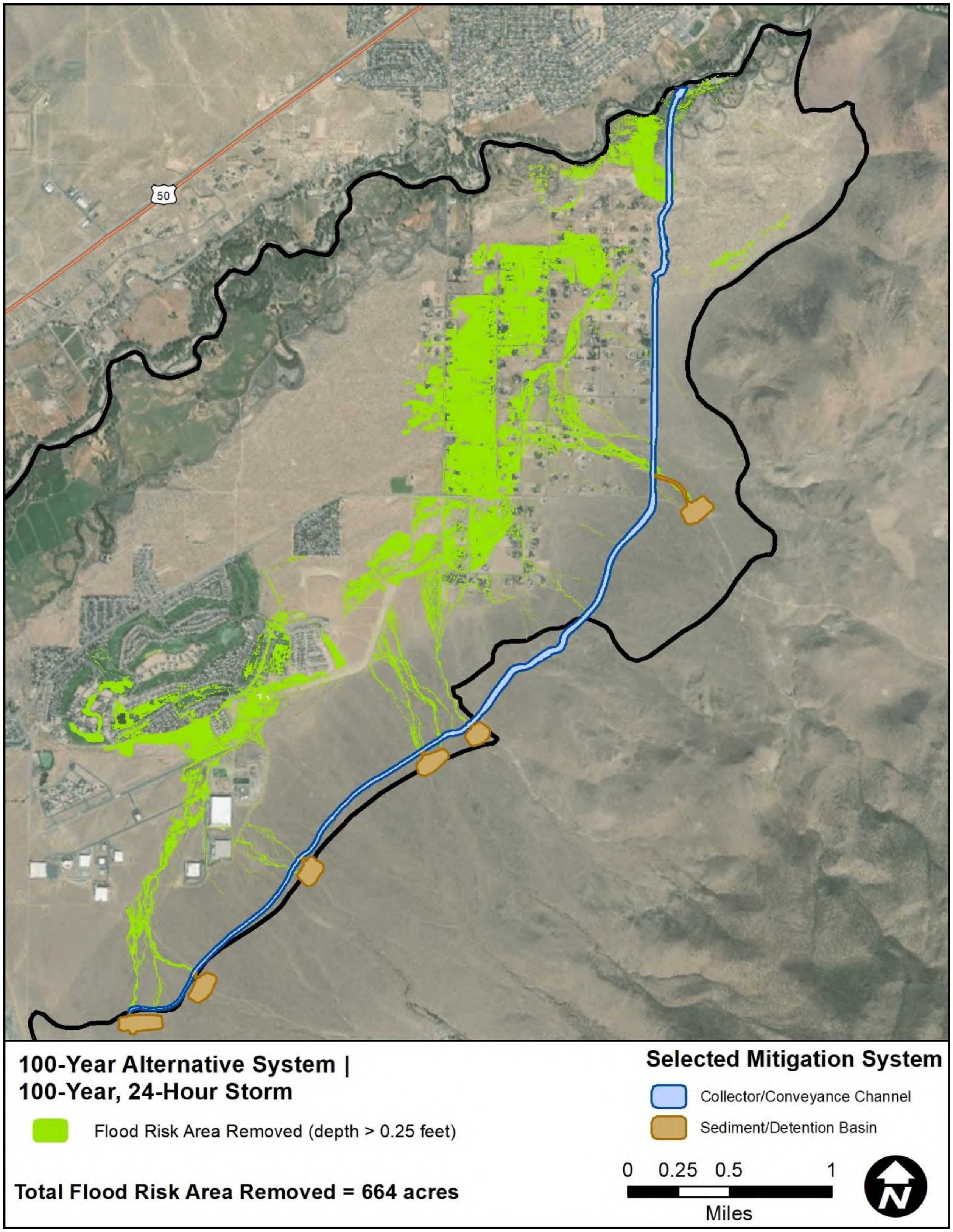

Figure 5-16. Potential flood risk area reduction benefit: 100-Yr Alt System, 100-Yr, 24-Hr storm

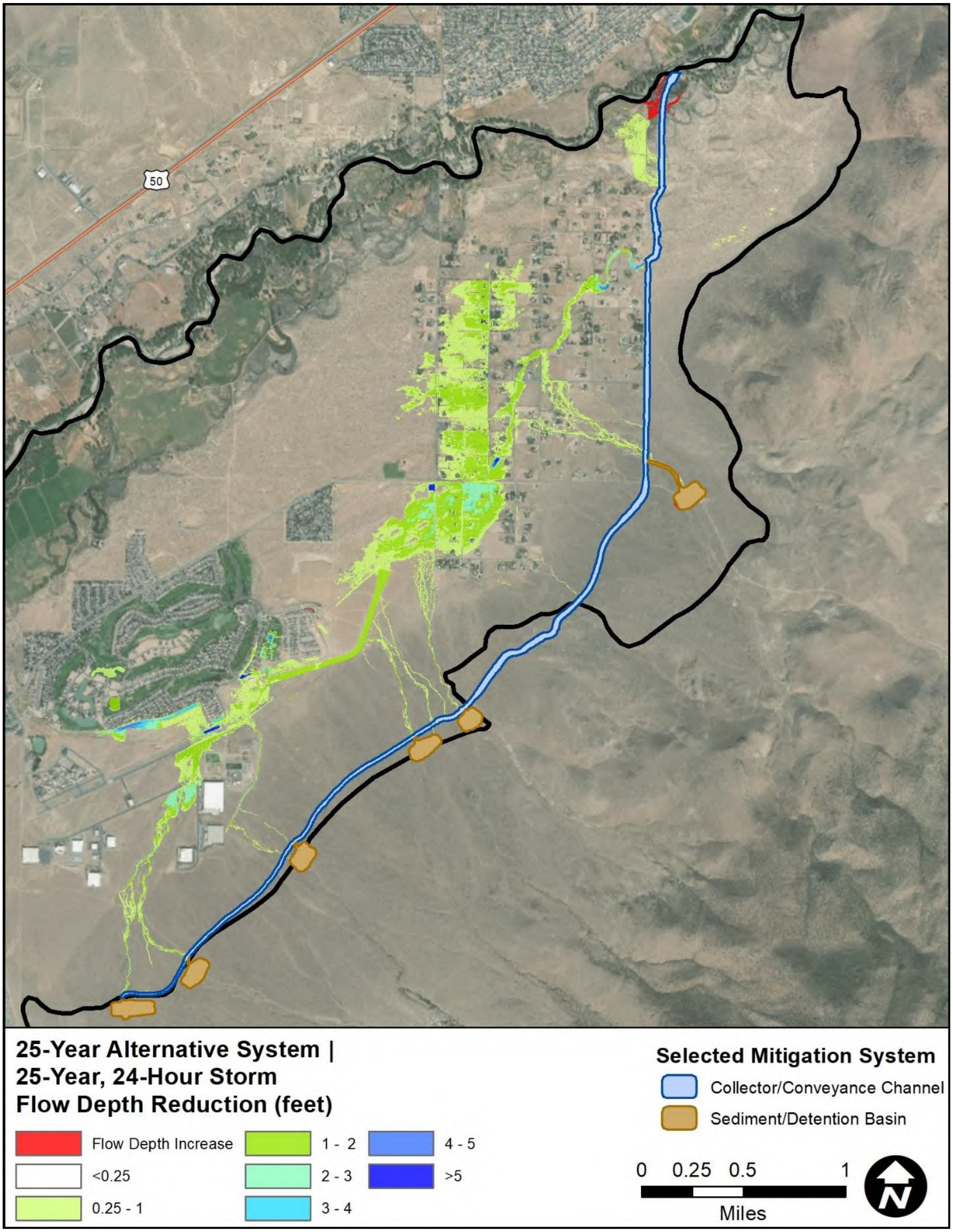

Figure 5-17. Potential flow depth reduction benefit: 25-Yr Alt System, 25-Yr, 24-Hr storm

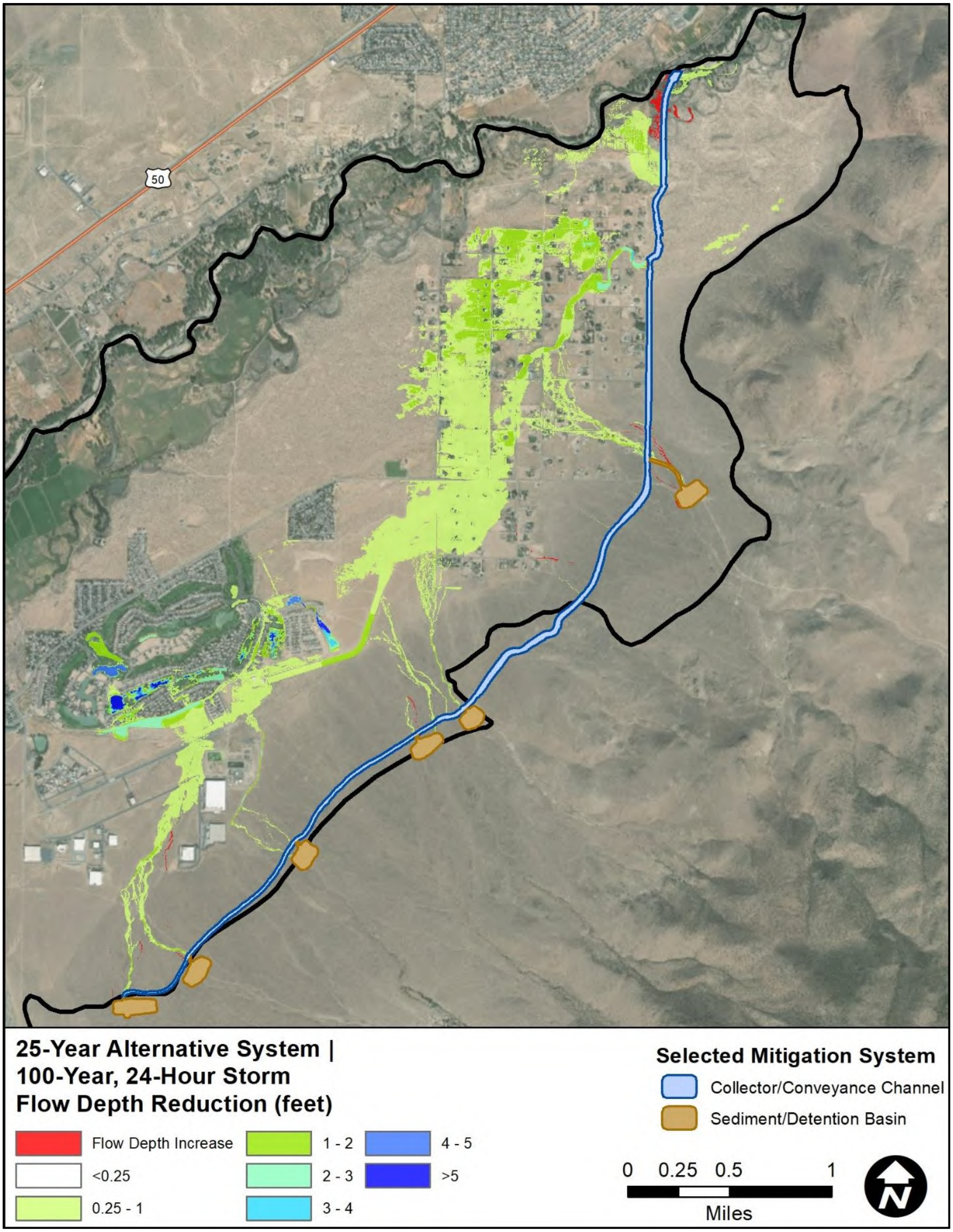

Figure 5-18. Potential flow depth reduction benefit: 25-Yr Alt System, 100-Yr, 24-Hr storm

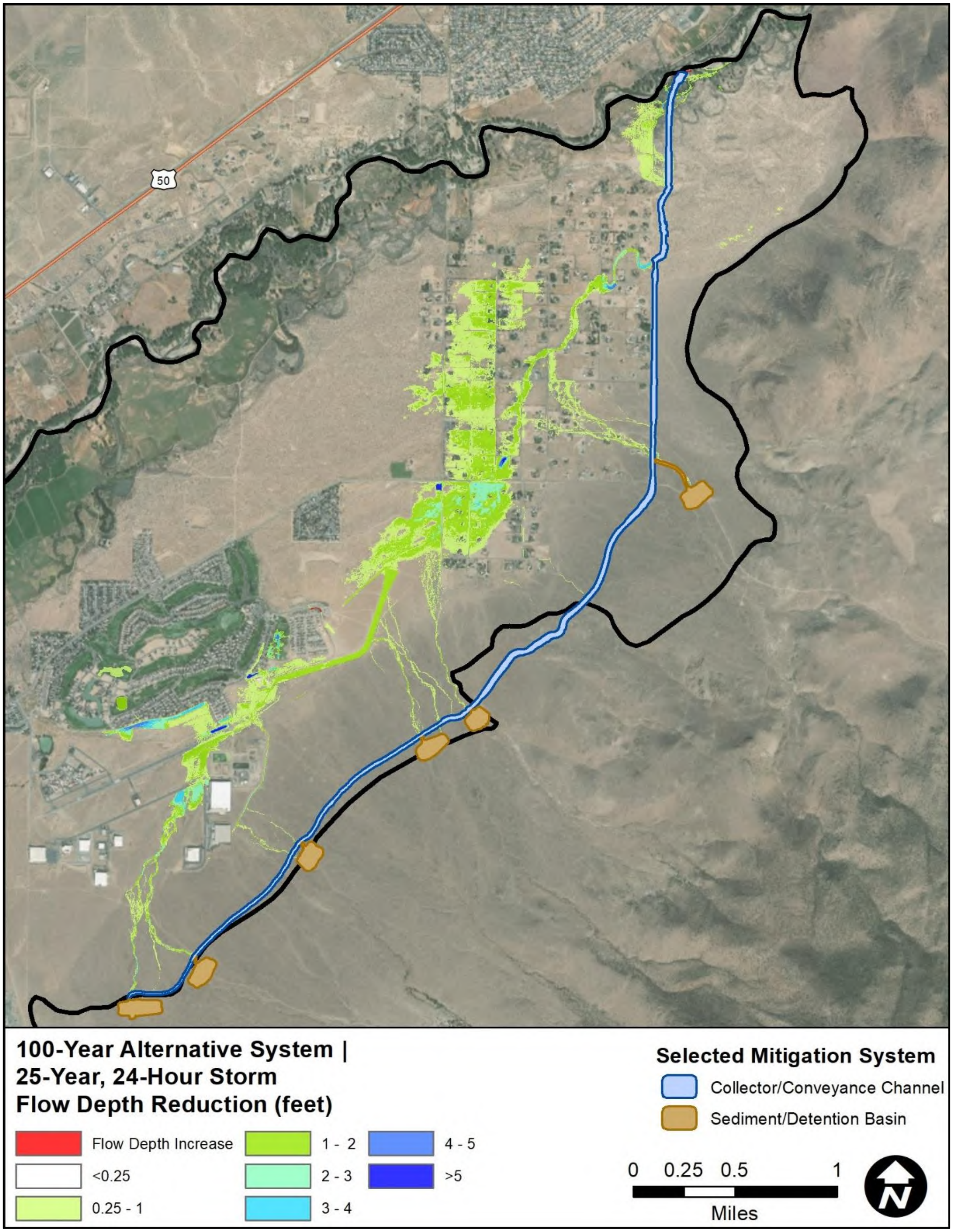

Figure 5-19. Potential flow depth reduction benefit: 100-Yr Alt System, 25-Yr, 24-Hr storm

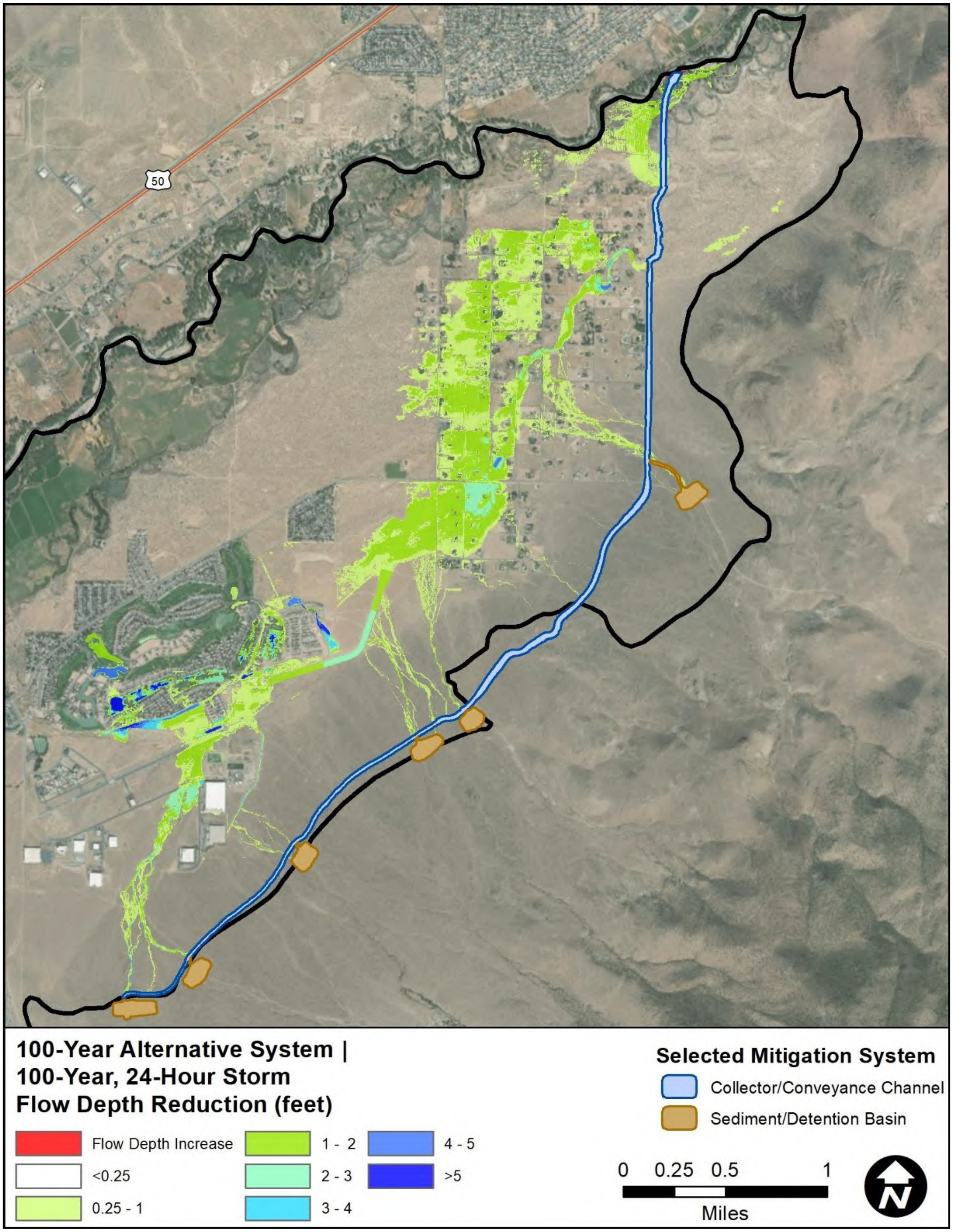

Figure 5-20. Potential flow depth reduction benefit: 100-Yr Alt System, 100-Yr, 24-Hr storm

5.7 Future Design Considerations

Preliminary FLO-2D modeling of the 15% design alternatives yielded items to be considered during final design:

- The dynamic nature of the upstream topography. Channels may shift, and new inlet locations may be needed.
- The overall sediment delivery to the Carson River should be analyzed in detail to ensure that the point source sediment delivery from the conveyance channel does not cause any adverse impacts.
- The sediment calculations used in this study were regional in nature and are generally applicable to channels with sandy bedload sediment. Some channels in the watershed were observed with coarser bedload sediment. A more site-specific sediment analysis is recommended for each structure during the final design process.
- If any mitigation system is implemented, the emergency spillways need to be carefully evaluated and designed to ensure that adverse impacts do not occur during larger events.

6 ADMP MITIGATION PRIORITIZATION

The regional alternative structures presented in this report can be designed and constructed in phases as funding sources are identified and/or become available. Construction should occur beginning furthest downstream so as not to cause adverse flooding conditions due to point-source releases of stormwater. Other phasing strategies could be considered, but interim spillways and/or basins should be implemented to avoid adverse impacts until the full project is built.

Figure 6-1 shows a potential construction phasing strategy that could be implemented by Lyon County, while Table 6-1 lists a possible phasing schedule with associated costs. Note that the phasing cost for the conveyance channel was computed by dividing the total channel cost by the number of phases. The actual costs of each phase of channel construction may vary from those in Table 6-1 due to variability in channel geometry and erosion protection and that if phased into multiple construction contracts, certain bid items such as mobilization will be increased

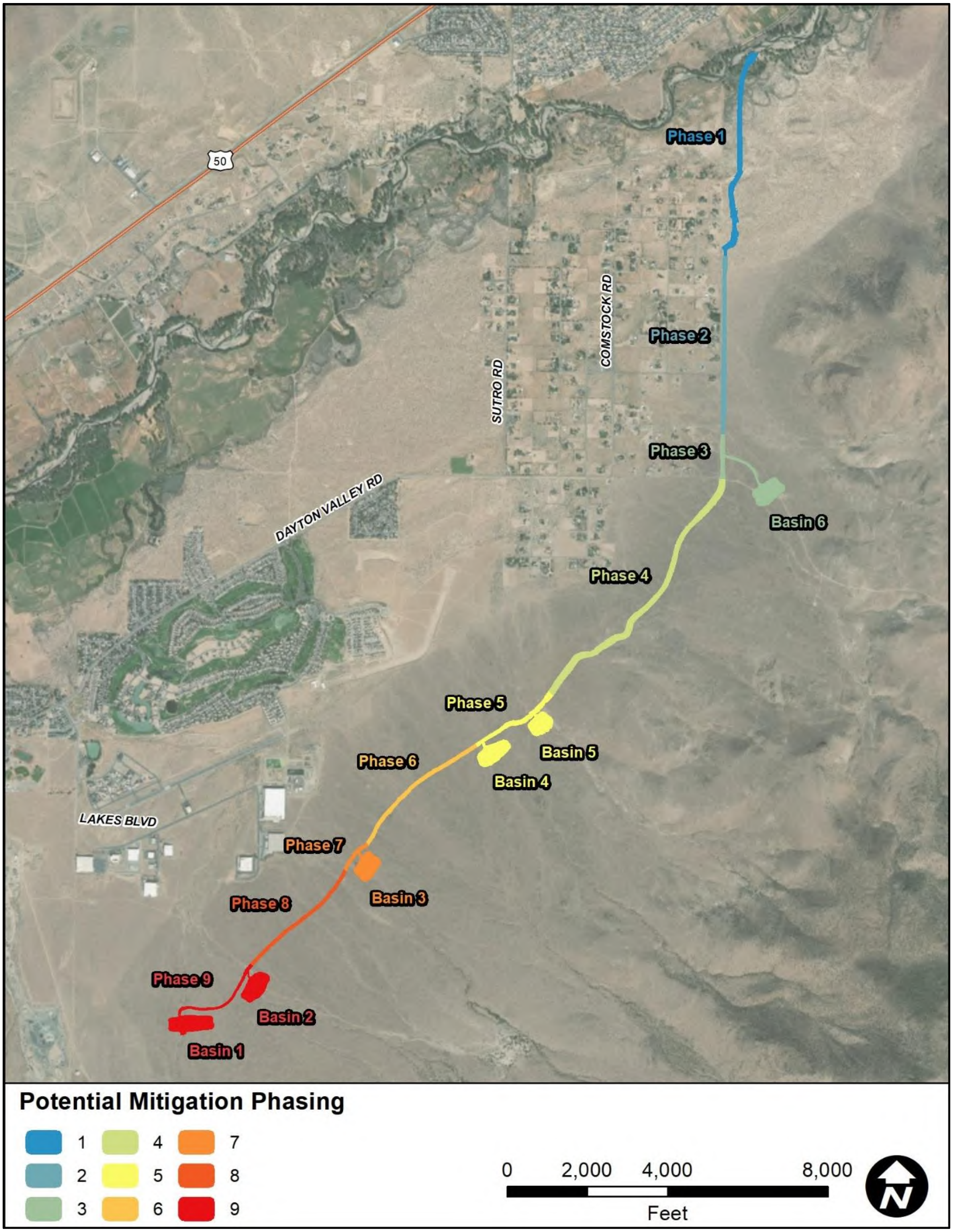

Figure 6-1. Potential mitigation construction phasing

Table 6-1. Potential mitigation construction phasing cost

Phase	Structure Elements	25-Year Structure Cost Estimate[2]	100-Year Structure Cost Estimate[2]
Phase 1	Conveyance Channel (5,200 LF[1])	$3,030,000	$4,500,000
Phase 2	Conveyance Channel (4,500 LF)	$2,600,000	$3,800,000
Phase 3	Conveyance Channel (1,100 LF) Basin #6	$700,000 $2,400,000	$970,000 $2,800,000
Phase 4	Conveyance Channel (7,200 LF)	$4,200,000	$6,100,000
Phase 5	Conveyance Channel (2,300 LF) Basin #5 Basin #4	$1,350,000 $1,100,000 $3,100,000	$2,000,000 $2,200,000 $4,400,000
Phase 6	Conveyance Channel (3,700 LF)	$2,200,000	$3,200,000
Phase 7	Conveyance Channel (900 LF) Basin #3	$515,000 $2,000,000	$760,000 $3,200,000
Phase 8	Conveyance Channel (3,300 LF)	$1,950,000	$3,000,000
Phase 9	Conveyance Chanel (2,500 LF) Basin #2 Basin #1	$1,500,000 $2,000,000 $2,600,000	$2,200,000 $2,200,000 $3,000,000

1. LF = linear feet (approximate)
2. Construction costs have been rounded for simplification. See Appendix B for a detailed breakdown of cost estimates.

6.1 Potential Funding Sources

There are numerous potential grant sources that could be explored by the South Dayton community and Lyon County to partially or fully fund the alternatives presented in this study. Some examples of grants that can be obtained are shown in Table 6-2.

Table 6-2. Potential grant funding sources

Grant	Funding Agency	Qualifications	Description
Building Resilient Infrastructure and Communities (BRIC) *[formerly Pre-Disaster Mitigation (PDM)]*	FEMA	FEMA approved Hazard Mitigation Plan[1].	Funds the planning, design and construction of mitigation projects and provides opportunities for raising public awareness about reducing future losses before disaster strikes. BRIC grants are awarded to projects that show a net benefit, i.e. a benefit cost ration greater than 1.
Flood Mitigation Assistance (FMA)	FEMA	Must protect National Flood Insurance Program (NFIP) insured properties/structures. Requires a FEMA approved Hazard Mitigation Plan that must include Flood as one of the hazards[1].	Funds awarded to projects and planning efforts that reduce or eliminate long-term risk of flood damage to structures insured under the NFIP. Includes the Repetitive Loss Program.
Hazard Mitigation Grant Program (HMGP)	FEMA	Requires a Presidential Major Disaster Declaration. 25% cost share from applicant. FEMA approved Hazard Mitigation Plan[1].	Funding for projects listed in the community's Hazard Mitigation Plan. Funds are only released if there is a Federally declared disaster.

Grant	Funding Agency	Qualifications	Description
Planning Assistance to States (PAS)	USACE	None Application for PAS is typically started through consultation with the regional USACE District office. Planning only – no construction. (Difficult to obtain and usually over-prescribed)	Upon request and funding availability, USACE will cooperate with non- federal public sponsors in the preparation of plans for the development, utilization and conservation of water and related land resources located within the boundaries of the state. Assistance is given within the limits of available appropriations, but $2,000,000 is the maximum federal funding available annually to any state or tribe. A 50-percent cost share is required by the non-federal sponsor.
Continuing Authorities Program (CAP) Section 205 — Small Flood Risk Management Projects. Authorized by Section 205 of the Flood Control Act of 1948, as amended.	USACE	None Application for PAS is typically started through consultation with the USACE District office. (Difficult to obtain and usually over-prescribed)	Work under this authority provides for local protection from flooding by the construction or improvement of flood control works such as levees, channels, and dams. Non-structural alternatives are considered and may include measures such as installation of flood warning systems, raising and/or flood proofing of structures, and relocation of flood prone facilities. The feasibility study phase is federally funded up to $100,000. Study costs in excess of $100,000 are shared 50 percent Federal and 50 percent by the project sponsor. The project sponsor will be required to sign a feasibility cost-sharing agreement when study costs exceed $100,000.

Grant	Funding Agency	Qualifications	Description
Watershed and Flood Prevention Operations	USDA – NRCS	Some General and Sponsor Eligibility Requirements (see Description) Apply to State NRCS Office Program has limited authorization for a period of 5-years with application periods in each of FY17-FY21	There are several general requirements and limitations as follows: • The Sponsor must meet eligibility requirements. • The Sponsor is ready, willing and able to commence with the construction project. • The request is for $25 million or less in NRCS funds. • The project must demonstrate agricultural benefits, including those to rural communities • The project will have an authorized PL 83-566 Watershed Plan. • The project does not exceed 250,000 acres in size • The project does not include any single structure that provides more than 12,500 acre-feet of floodwater detention capacity. • The project provides no more than 25,000 acre-feet of total capacity.
1. https://www.lyon-county.org/DocumentCenter/View/8670/Lyon-County-MJHMP--FINALDec-10-2018			

6.2 ADMP Limitations

While the results are based on detailed topography, hydrology, and hydraulic modeling, they represent the existing conditions as of the date of the LiDAR mapping. Because of the unique landform and sediment characteristics of the watershed, the topography and distribution of flow can be very dynamic (i.e., small culverts or drainage channels can quickly fill with sediment causing water to change course from what it was previously). Therefore, during final design of any of the alternatives, or prior to any future development within the project area, a detailed assessment of upstream flow distribution should be undertaken.

Furthermore, this study did not analyze rain on snow events, flooding recurrence intervals greater than 100-year, or post-wildfire flooding events. These types of events are considered outside the scope of the typical area drainage master plan process. The hydrology used in this study was state of the art, engineering design storms based on recent NDOT research. These atypical events could create hydraulic conditions that exceed these design storms.

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APPENDIX A

USGS LiDAR Report

LiDAR Project Report

G17PD01257, NV Reno Carson City Urban

Prepared For:

United States Geological Survey

Prepared By:

Digital Aerial Solutions, LLC

CONTRACT: # G16PC00044
CONTRACTOR: DIGITAL AERIAL SOLUTIONS
TASK ORDER: # G17PD01257

Project Report
LiDAR Collection, Processing, and QA/QC

G17PD01257, NV Reno Carson City
Urban

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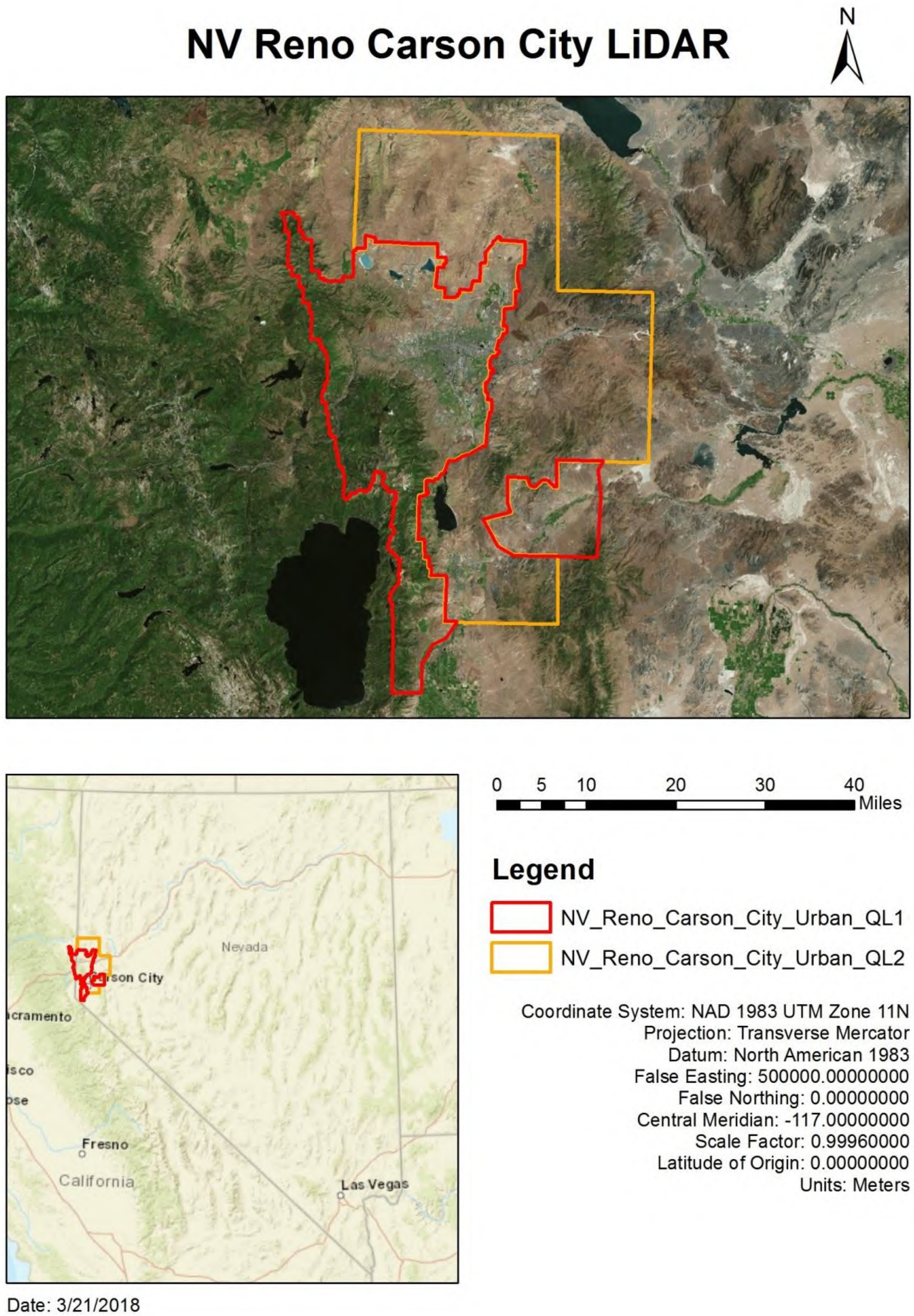


Image 1: NV Reno Carson City Urban LiDAR AOI

Table of Contents

1 Introduction and Specifications 5
2 Spatial Reference System 5
3 LiDAR Acquisition 6
3.1 Survey Area 6
3.2 Acquisition Parameters 6
3.3 Acquisition Mission 7
3.4 Airborne GPS/IMU 7
4 LiDAR Processing 8
4.1 Acquisition Post-Processing 8
4.2 Geometric Calibration 9
4.3 Point Cloud Classification 11
4.4 Breakline Collection 11
4.5 DEM Generation 12
5 Quality Control 12
5.1 Point Clouds 12
5.2 Breaklines 15
5.3 Digital Elevation Models 15
Appendix A. Flight Logs 16
Appendix B. Vertical Accuracy Calculations 55

1 Introduction and Specifications

Digital Aerial Solutions, LLC (DAS) was tasked to collect and process a Light Detection And Ranging (LiDAR) derived elevation dataset for the G17PD01257, NV Reno Carson City Urban LiDAR. The area encompasses approximately 1534 square miles Aerial LiDAR data was collected utilizing a Leica ALS80. The ALS80 is a discrete return topographic LiDAR mapping system manufactured by Leica Geosystems. LiDAR data collected for the G17PD01257, NV Reno Carson City Urban LiDAR survey has an Aggregate Nominal Pulse (ANPS) spacing of (QL1 0.35 meters) and (QL2 0.7 meters), and includes up to 4 discrete returns per pulse, along with intensity values for each return.

LiDAR datasets were post processed to generate elevation point cloud swaths for each flight line. Deliverables include the point cloud swaths, tiled point clouds classified by land cover type, breaklines to support hydro-flattening of digital elevation models (DEM)s, intensity tiles, and bare-earth DEM tiles. The point cloud deliverables are stored in the LAS version 1.4, point data record format 6. The tiling scheme for tiled deliverables is a 1000 meter x 1000 meter grid. Tile number is the appropriate cell number values found in the USNG index. All deliverables were generated in conformance with the U.S. Geological Survey National Geospatial Program Guidelines and Base Specifications, Version 1.3.

2 Spatial Reference System

The spatial reference of the data is as follows:

Horizontal Spatial Reference

- Coordinates: UTM Zone 11 N, Meters (to 2 decimal places)
- Datum: North American Datum 1983 (2011), Meters (to 2 decimal places)

Vertical Spatial Reference

All datasets are available with orthometric elevation; point cloud datasets are also available with ellipsoid heights.

- Datum: North American Vertical Datum of 1988 (GEOID12B)

3 LiDAR Acquisition

3.1 Survey Area

The NV Reno Carson City Urban LiDAR survey covers approximately 676 square miles for the QL1 area of interest and 858 square miles for the QL2 area of interest. Totaling 1534 square miles covering all of Washoe, Storey, Carson City and Lyon counties in NV. The flight plan consisted of 610 survey lines and 4 control lines.

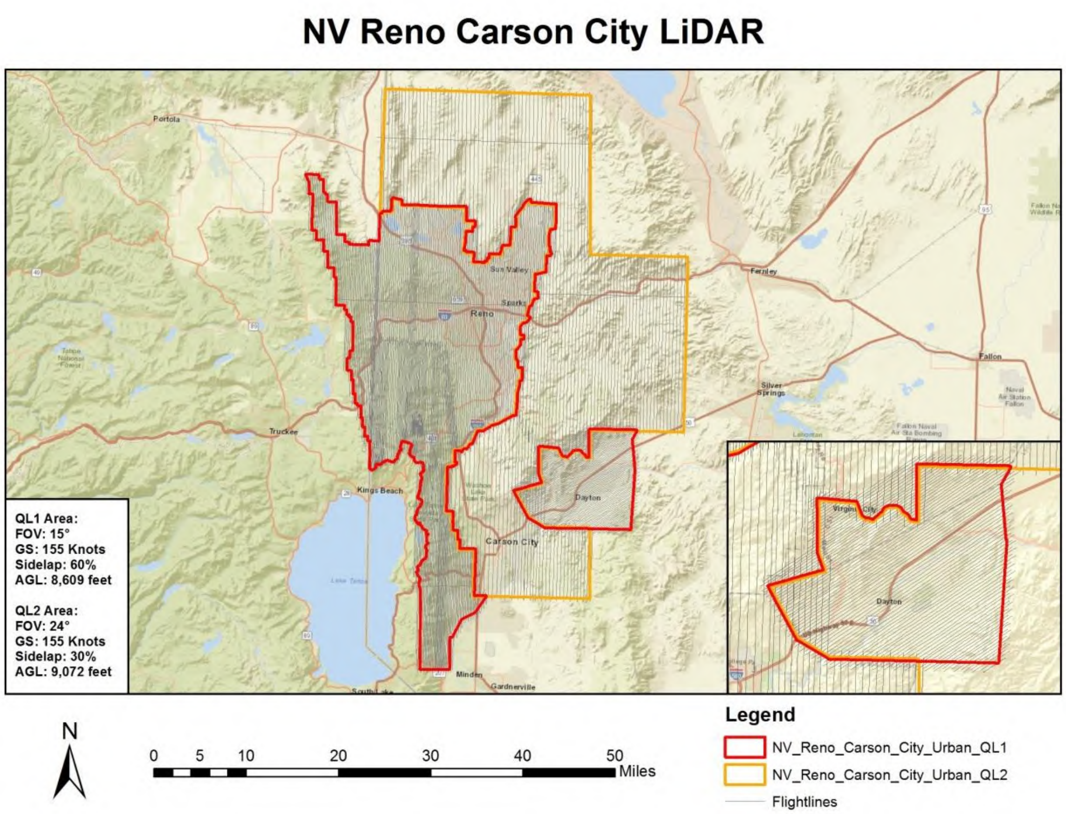


Image 2: NV Reno Carson City Urban LiDAR Flightlines

3.2 Acquisition Parameters

Acquisition parameters include the sensor configuration and the flight plan characteristics, and are selected based on a number of project specific criteria. Criteria reviewed include the required accuracies for the final dataset, the land cover types within the project survey area, and the required nominal pulse spacing. Aggregate Nominal Pulse Density (ANPD) for QL1 AOIs are no less than 8ppsm and for the QL2 AOIs are no less than 2ppsm. The project parameters are summarized below.

Parameter	QL1	QL2
Flying Height Above Ground Level:	8,609 feet	9,072 feet
Nominal Sidelap:	60%	30%
Nominal Speed Over Ground:	155 Knots	155 Knots
Field of View:	15°	24°
Laser Rate:	220.2 kHz	206.2 kHz
Scan Rate:	65.2 Hz	49.2 Hz
Maximum Cross Track Spacing:	1.22 meters	1.62 meters
Maximum Along Track Spacing:	0.61 meters	0.81 meters
Average point Spacing:	0.50 meters	0.67 meters

Table 1: Flight Parameters

3.3 Acquisition Mission

The acquisition mission for the G17PD01257, NV Reno Carson City Urban LiDAR survey was coordinated for optimal collection conditions and was acquired within 6 weeks. Collection began on September 19, 2017 and was completed on October 27, 2017.

3.4 Airborne GPS/IMU

Airborne global positioning system (GPS) and inertial measurement unit (IMU) data was collected on the aircraft during the acquisition mission, providing sensor position and orientation information for geo- referencing the LiDAR data. Airborne GPS observations were collected at a frequency of 2Hz, and IMU observations are collected at a frequency of 200Hz.

Aircraft	Sensor	GPS Lever Arm (m)	IMU Lever Arm (m)
C421-N12RF	ALS80 SN# 8137	X: -0.153, Y: -0.055, Z: -1.361	X: -0.219, Y: 0.297, Z: 1.192

Table 2: Aircraft and Lever Arms

GPS data was collected with ground base stations during the acquisition missions, providing corrections to support differential post-processing of the airborne GPS. Base stations were setup at

Minden-Tahoe Airport NV. Ground GPS observations were collected at a frequency of 2Hz. The use of three CORS stations was also employed to support data acquisition for the project area. The following table's list the positions used in to post-process the airborne GPS.

Name	Latitude	Longitude	Ellipsoid (m)
Minden-Tahoe Airport – KMEV	38° 59' 52.40797"	-119° 45' 22.01331"	1409.811
Minden-Tahoe Airport – KMEV1	38° 59' 52.32560"	-119° 45' 22.16652"	1409.803
CORS – COF1	39° 36' 18.05072"	-119° 14' 26.22857"	1252.459
CORS – DOT1	39° 09' 22.30087"	-119° 45' 48.33047"	1416.299
CORS – P143	38° 45' 36.58657"	-119° 45' 53.35851"	1734.123

Table 3: Base Stations locations

4 LiDAR Processing

4.1 Acquisition Post-Processing

For each mission, airborne GPS was differentially corrected using the ground base station GPS for the corresponding day in Leica's IPAS software. The resulting solution is check to assure an accuracy of +/- 3 cm combined separation for north, east and height position difference between the forward and reverse processing solutions.

Differentially corrected airborne GPS data was merged with the airborne IMU dataset in Leica's IPAS software through Kalman filtering techniques. IPAS applies the reference lever arms for the GPS and IMU measurement systems during processing to determine the trajectory (position and orientation) of the LiDAR sensor during the acquisition mission. Estimated lever arm values reported posteriori validate the measurements made during sensor installation in the aircraft.

Raw LiDAR sensor ranging data and the final sensor trajectory from IPAS were processed in Leica's ALSPP software to produce the LiDAR elevation point cloud swaths for each flight line, stored in LAS version 1.2 file format. Quality control of the swath point clouds was performed to validate proper function of the sensor systems, full coverage of the project AOI, and point density consistent with the planned nominal pulse spacing.

Swath point clouds were assigned a unique File Source ID within the LAS file format before further processing. Swath files for the G17PD01257, NV Reno Carson City Urban LiDAR project were numbered in chronological order of acquisition.

4.2 Geometric Calibration

Geometric and positional accuracy of the LiDAR swath point clouds is highly dependent on accurate calibration of the various subsystems within the LiDAR sensor system. Sensor calibration parameters fall into two categories, one being those parameters proprietary to the manufacturer's sensor design, and the other being parameters common to most commercial airborne LiDAR sensors, the IMU to laser reference system alignment angles (bore-site), and mirror deformation constants (scaling).

The manufacturer specific calibration parameters are applied in Leica's ALSPP software for the Leica ALS80 sensor system. Terrasolid's Terramatch software was used to calculate the IMU bore-site and mirror scale parameters for the G17PD01257, NV Reno Carson City Urban LiDAR. Within the TerraMatch software, the Tie- line workflow was used to solve for the parameters. The Tie-line workflow involves automated selection of numerous 'tie-lines', which represent a linear segment fit to the data that should have the same slope, azimuth, position and elevation, within the overlap sections of the survey lines and control lines. The tie- lines provide observations for algorithms within TerraMatch to solve for the bore-site and mirror scale parameters for the lift.

The Tie-line workflow is dependent upon well distributed tie-lines throughout the swath point clouds to effectively solve for bore-site and mirror scale parameters with the automated algorithms.

Manual estimation of the bore-site and mirror scale parameters was performed using the observed tie-lines in overlap areas.

The final step of geometric calibration is to determine elevation (z) offset corrections to be applied to the swath point clouds. The Z values calculated during the course of the acquisition mission can vary at the centimeter level as the GPS satellite constellation observed in the survey area changes with satellites moving through their orbits over the course of the mission. Baseline length from the ground base station GPS to the airborne GPS can also impact the z values calculated for the swath point clouds. The Z offset corrections are calculated in two steps; a relative step, where individual lines are corrected one to another using the adjusted tie-lines from the bore-site and mirror scale calculation step; and an absolute step, where groups of lines are leveled to project ground control.

For G17PD01257, NV Reno Carson City Urban LiDAR project, the control lines were used to determine relative z offset corrections in areas of discernible ground. The ground control points listed below were used to adjust the LiDAR by an average of -0.180 cm.

Point Id	Easting	Northing	Orth. Height
04.GCP.BG.01	620192.726	5064157.33	891.6397
08.GCP.BG.01	625950.124	5081209.372	920.0333
08.GCP.BG.01A	602777.4524	5031062.218	1066.0656
GCP.BG.01	260969.099	4338273.65	1423.118
GCP.BG.10	277392.198	4356378.341	1648.38
GCP.BG.11	277392.199	4356378.343	1648.371
GCP_NVA.BG.02	256020.902	4329290.092	1528.339
GCP_NVA.BG.03	250244.158	4318040.241	2163.541
GCP_NVA.BG.04	272152.037	4347496.544	1554.815
GCP_NVA.BG.06	271231.517	4353733.3	1907.229
GCP_NVA.BG.07	271263.717	4359012.689	2074.733
GCP_NVA.BG.11	252561.759	4358148.771	2308.951
GCP.HP.01	258003.661	4344308.104	1550.248
GCP.HP.02	272445.392	4375771.769	1338.888
GCP.HP.11	282521.926	4353104.002	1323.601
GCP.HP.12	257558.262	4403563.812	1563.345
GCP_NVA.HP.03	259189.646	4332992.955	1480.408
GCP_NVA.HP.06	263293.752	4332298.771	1438.997
GCP_NVA.HP.08	270245.594	4344174.034	1481.727
GCP_NVA.HP.09	256091.814	4362654.773	1771.648
GCP_NVA.HP.16	260442.59	4341638.183	1442.508
GCP_NVA.HP.24	280973.185	4381806.092	1308.072
GCP_NVA.LV.10	261848.55	4352267.561	1569.989
GCP.PS.01	248807.55	4392717.7	1520.357
GCP.PS.02	256445.016	4416808.361	1513.873
GCP_NVA.PS.04	256325.956	4333359.564	1631.584
GCP_NVA.PS.06	252854.437	4332996.338	1824.366
GCP_NVA.PS.08	265773.119	4332626.121	1415.375
GCP_NVA.PS.13	265301.972	4372050.22	1347.786
GCP_NVA.PS.18	252471.425	4400483.183	1575.459
GCP_NVA.PS.28	264254.101	4412809.06	1476.773
GCP_NVA.PS.30	269039.062	4400110.38	1434.329
GCP_NVA.PS.31	267592.54	4391765.602	1372.906

Table 5: Ground Control Points

The final geometrically calibrated swath point clouds were compared to the bare-earth profile survey data. The data fit the profile surveys within the vertical accuracy tolerance specified for the project. Full documentation of the vertical accuracy checks maybe found in section 5.1.

4.3 Point Cloud Classification

Georeference information was applied to the swath point cloud LAS files. Geometrically calibrated swath point clouds were cut into USNG index, 1000 meter x 1000 meter LAS 1.2 format tiles for point cloud classification and derived in LAS 1.4 format for product creation.

Tiled point cloud data was processed in Terrasolid's Terrascan software to assign initial classification values. The Terrascan software provides a number of routines to algorithmically detect and assign points to their appropriate class. Points left unclassified by the algorithmic routine remain as Class 1

– Processed, but unclassified. Automated classification routines assigned points to one of the following classes:

```
Class 1 – Processed, but unclassified
Class 2 – Bare-earth ground
Class 7 – Low Noise (low, manually identified, if necessary)
Class 9 — Water
Class 17 — Bridge Decks
Class 18 – High Noise (high, manually identified, if necessary)
Class 20 — Ignored Ground (Breakline Proximity)
```

Automated classification results were reviewed for each tiled point cloud, and manual edits made where necessary to correct for misclassified points. Points remaining in Class 1 after the automated classification routines were run were left in Class 1. Points falling outside of a 100 meter buffer of the project AOI polygon were excluded from the tiled point clouds.

4.4 Breakline Collection

Manual breakline collection was performed to support the hydro-flattening requirements of the project's DEM deliverables. Breaklines were collected directly from the classified point clouds and from triangulated irregular network (TIN) surface models built from the classified point clouds, in Terrasolid's Terrascan and Terramodeler software. Breakline features were collected as design file elements in Bentley's Microstation software. Breaklines were converted to ESRI 3D shapefile format for the breakline deliverable, and tiled to USNG index.

The data collected for the G17PD01257, NV Reno Carson City Urban LiDAR survey maintained significant point density in the water, marsh, and swamp, limiting the usefulness of point density as guiding factor in breakline placement.

Points classified as Class 2 – Bare-earth ground, falling within a one meter buffer of the collected breaklines, were reassigned to Class 20 – Ignored Ground. These points are excluded from the surface model during DEM generation to preserve the hydro-flattening characteristics of the breaklines.

4.5 DEM Generation

The final classified point clouds and collected breaklines were reviewed for completeness and conformance to the task order scope of work. Within the Terramodeler software, points in Class 2 – Bare- earth ground and the breaklines were combined to generate TIN elevation models for each tile, from which the bare-earth DEM tiles were interpolated and exported as ERDAS Imagine 32-bit floating point raster format ".img" format.

5 Quality Control

5.1 Point Clouds

Accuracy and completeness of the LiDAR point clouds directly impacts the quality of all other derived LiDAR derived products. Ensuring a quality LiDAR dataset begins with proper mission planning and execution. Ground GPS base stations are located such that GPS baselines between the ground and airborne receivers do not exceed 30km. For the G17PD01257, NV Reno Carson City Urban LiDAR project, two base stations were run to meet this requirement, one at the field operations airport and one within the survey area. Static alignment is performed both before take-off and after landing to allow for GPS integer ambiguity resolution. Sensor operators carefully monitor the LiDAR unit and its various subsystems during the acquisition mission to ensure proper function. Airborne GPS positional dilution of precision (PDOP) estimates are monitored to ensure they remain less than 3.The optical system is monitored to ensure there are no ranging errors encountered during the flight lines.

During acquisition post-processing estimates of the trajectory data accuracy are reviewed to ensure they will support the required accuracies of the point cloud data. The trajectory accuracy is a function of the differentially corrected GPS data and the IMU data.

The raw swath point clouds generated from ALSPP are reviewed as another check for proper sensor function. The point clouds are reviewed for full coverage of the AOI, required point density and nominal pulse spacing, clustering, proper intensity values, full swath coverage within the planned field of view, and planned survey line overlap.

Geometric calibration quality control validates that the positional accuracy requirements of the project are met, and includes relative accuracy assessments for intra-swath (within) and inter-swath (between) accuracy, along with absolute accuracy assessments against project ground control.

Image 3: NV Reno Carson City Urban LiDAR QL1 Intensity Image

Relative vertical accuracy assessments are normally made using the tie-lines generated in the Terramatch software, as these lines provide positional observations throughout the extent of individual swaths, and between neighboring swaths.

This data set was produced to meet ASPRS "Positional Accuracy Standards for Digital Geospatial Data" (2014) for a 22.6 (cm) RMSEx / RMSEy Horizontal Accuracy Class which equates to Positional Horizontal Accuracy =+/- 78.3 cm at a 95% confidence level.

Estimated LiDAR Horizontal:	(cm)
Error Per Point ($RMSE_R$)	32.0
Error Per Point ($RMSE_X$/$RMSE_Y$)	22.6
Per Point at 95% confidence level	78.3

Table 6: Estimated LiDAR Horizontal Accuracy

Absolute vertical accuracy assessments for the point cloud data are made against ground check point data. For the G17PD01257, NV Reno Carson City Urban LiDAR, ground check point data consisted of the ground GPS base station and real-time kinematic (RTK) GPS techniques.

Check point locations were collected at 1 – second intervals during the RTK survey. Points collected during the static pre-initialization and post-initialization was removed from the assessment so as not to bias the assessment.

Local TIN models of the elevation points are built around each ground check points. The tin model elevation is sampled at the horizontal position of the ground check point. The TIN model elevation and ground check point survey elevation values were used to calculate the Non-vegetated Vertical Accuracy (NVA) of the swath point clouds. The NVA of the TIN tested RMSEz 0.051 meters and 0.100 meters at the 95% confidence level in open terrain. NVA of the DEM tested at an RMSEz of 0.053 meters and 0.104 meters at the 95% confidence level in open terrain. The full calculations for all check points can be found in Appendix B.

NVA of TIN		
$RMSE_Z$ =	0.051	meters
NSSDA =	0.100	meters

Table 7: Tested NVA of tin from Classified Point Cloud.

NVA of DEM		
$RMSE_Z$ =	0.053	meters
NSSDA =	0.104	meters

Table 7: Tested NVA of Digital Elevation Model.

The tiled point cloud products were reviewed for full coverage of the AOI and proper classification. As part of the QC process, TINs are built in the Terramodeler software for each tile using the ground class and the hydro-flattening breaklines. The TINs are reviewed for non-ground features, and edited where necessary to remove any remaining non-ground features. Points were also reviewed for absolute elevation, and points falling below the selected orthometric elevation for water were removed from the ground class.

5.2 Breaklines

The final breaklines in ESRI 3D shapefile format were reviewed for topological consistency and correct elevation. Breaklines features are continuous and do not have overlaps or dangles.

5.3 Digital Elevation Models

Digital elevation models (DEMs) were reviewed for conformance with the SOW and the Base Mapping Specification version 1.3 guidelines. DEM files were loaded in the Global Mapper software and inspected visually for edge matching between tiles, void areas within the project AOI, and proper coding of the NODATA values. DEM file naming was verified for consistency with the USNG index.

Appendix A. Flight Logs

Leica ALS80 Flight Log

Project:	NV_ Reno						Sensor Operator/s
							Jackson Beebe
Date/Julian:	9/20/2018	ALS80 SN# 8137	Disk Drive MM70	Flight Plan(s):			Pilot/s
Hobbs End	3301.6			NV_Reno			Keith Morrel
Hobbs ST	3297.1	LIFT		TARGET AIRSPD (KNTS)	BASE PID:	Base Height	Aircraft / Airport Idnt:
Flight Time	4.5	A		155	TEMP	1.500	C421-N13RF / KMEV (Minden, NV)

Lift	#	Flight Line	Mission Line	UTC time:		GPS Altitude: ASL:	Direction	Speed: kts:	Available	S/Vs:	Position Acc.		Comments and Conditions:
				Begin:	End:				MM Space		PDOP	HDOP	
A		312	170920_004726	:47	:54	13793	346°	159	745	23	1	0.5	
		313	170920_010019	1:00	1:07	13791	166°	151	743	23	1	0.5	
		314	170920_011622	1:16	1:24	13790	346°	146	741	21	1.1	0.6	
		311	170920_012838	1:28	1:34	13850	166°	164	738	19	1.3	0.6	
		310	170920_014105	1:41	1:47	13842	346°	164	737	20	1.3	0.6	
		309	170920_015252	1:52	1:59	13842	166°	161	735	20	1.2	0.6	
		308	170920_020503	2:05	2:11	13861	346°	159	733	21	1.2	0.7	
		307	170920_021710	2:17	2:23	14027	166°	162	731	21	1.2	0.7	
		306	170920_023059	2:30	2:35	14063	346°	159	730	21	1.2	0.7	
		305	170920_024137	2:41	2:45	14210	166°	160	729	21	1.2	0.7	
		304	170920_025045	2:50	2:53	14192	346°	169	728	21	1.2	0.7	
		303	170920_025942	2:59	3:02	14200	166°	165	726	21	1.3	0.7	
		302	170920_030957	3:09	3:12	14176	346°	163	725	21	1.3	0.7	
		301	170920_031800	3:18	3:19	14176	166°	170	725	21	1.3	0.6	
		315	170920_032857	3:28	3:35	13852	346°	161	724	22	1.1	0.6	
		316	170920_034043	3:40	3:47	13835	166°	168	722	21	1.2	0.6	
		317	170920_035208	3:52	3:59	13853	346°	152	720	22	1.2	0.6	

Leica ALS80 Flight Log

Project:	NV_ Reno							Sensor Operator/s
								Jackson Beebe
Date/Julian:	9/24/2018	ALS80 SN# 8137	Disk Drive MM70	Flight Plan(s):				Pilot/s
Hobbs End	3306			NV_Reno				Keith Morrel
Hobbs ST	3301.6	LIFT		TARGET AIRSPD (KNTS)	BASE PID:	Base Height	Aircraft	Airport Idnt:
Flight Time	4.4	A		155	TEMP	1.500	C421-N13RF	KMEV (Minden, NV)

Lift	#	Flight Line	Mission Line	UTC time: Begin:	UTC time: End:	GPS Altitude: ASL:	Direction	Speed: kts:	Available MM Space	S/Vs:	Position Acc. PDOP	Position Acc. HDOP	Comments and Conditions:
A		300	170924_021626	2:16	2:19	13256	166°	157	696	20	1.3	0.7	
		301	170924_022411	2:24	2:27	13310	346°	155	696	21	1.2	0.7	
		302	170924_023302	2:33	2:35	13265	166°	154	695	21	1.2	0.7	
		303	170924_024056	2:40	2:43	13225	346°	155	695	21	1.2	0.7	
		304	170924_025040	2:50	2:53	13326	166°	154	694	22	1.2	0.7	
		305	170924_025950	2:59	3:02	13400	346°	155	6393	22	1.2	0.6	
		306	170924_030749	3:07	3:10	13519	166°	154	692	22	1.2	0.6	
		307	170924_031549	3:15	3:18	13569	346°	155	691	21	1.1	0.6	
		308	170924_032319	3:23	3:26	13522	166°	155	690	20	1.2	0.6	
		309	170924_033055	3:30	:33	13525	346°	154	689	20	1.2	0.6	
		310	170924_033816	3:38	3:41	13404	166°	153	688	21	1.1	0.6	
		311	170924_034613	3:46	3:42	13361	346°	156	688	22	1	0.6	
		299	170924_035723	3:57	4:00	13407	166°	155	687	21	1	0.6	
		298	170924_040638	4:06	4:09	1338	346°	157	686	23	1	0.6	
		486	170924_041836	4:18	4:21	13074	41°	152	685	22	1.1	0.6	
		487	170924_042629	4:26	4:29	12082	221°	158	684	22	1	0.6	
		488	170924_043526	4:35	4:38	12697	41°	153	683	21	1	0.6	
		489	170924_044300	4:43	4:45	12658	221°	155	682	20	1.1	0.6	
		490	170924_045113	4:51	4:53	12708	41°	156	681	20	1.1	0.6	
		491	170924_045823	4:58	5:00	12764	221°	155	681	21	1.1	0.6	
		492	170924_050608	5:06	5:08	12769	41°	155	680	19	1.1	0.6	
		493	170924_051334	5:13	5:15	12928	221°	155	679	19	1.2	0.6	
		494	170924_052045	5:20	5:22	13130	41°	152	678	18	1.2	0.7	
		495	170924_052821	5:28	5:30	13207	221°	155	678	18	1.4	0.7	
		496	170924_053547	5:35	5:37	13330	41°	155	677	17	1.3	0.7	
		497	170924_054300	5:43	5:44	13407	221°	157	676	17	1.3	0.7	

Leica ALS80 Flight Log

		498	170924_055026	5:50	5:51	13623	41°	152	675	18	1.2	0.7	
		499	170924_055743	5:57	5:59	13886	221°	154	675	12	1.2	0.3	

Leica ALS80 Flight Log

DAS Digital Aerial Solutions

Project:	**NV_ Reno**					**Sensor Operator/s**
						Jackson Beebe
Date/Julian:	9/28/2018	ALS80 SN# 8137	**Disk Drive MM70**	**Flight Plan(s):**		**Pilot/s**
Hobbs End	3309.2			NV_Reno		Keith Morrel
Hobbs ST	3307.7	**LIFT**		**TARGET AIRSPD (KNTS)**	**BASE PID:** / **Base Height:**	**Aircraft** / **Airport Idnt:**
Flight Time	1.5	**A**		155	TEMP / 1.500	C421-N13RF / KMEV (Minden, NV)

Lift	#	Flight Line	Mission Line	UTC time:		GPS Altitude: ASL:	Direction	Speed: kts:	Available	S/Vs:	Position Acc.		Comments and Conditions:
				Begin:	End:				MM Space		PDOP	HDOP	
A		289	170928_212255	21:22	21:29	13186	0°	154	673	17	1.1	0.74	
		290	170928_213551	21:35	21:42	13188	180°	153	671	21	0.9	0.6	
		291	170928_214756	21:47	21:54	13200	0°	154	669	20	1	0.6	
		292	170928_215952	21:59		13160	180°	152	667	20	1	0.6	BACK REFLECTION ERROR

Leica ALS80 Flight Log

Project:	NV_ Reno				Sensor Operator/s
					Jackson Beebe
Date/Julian:	10/11/2018	ALS80 SN# 8137	Disk Drive MM70	Flight Plan(s):	Pilot/s
Hobbs End	3336.3			NV_Reno	Keith Morrel

Hobbs ST	3334.2		LIFT		TARGET AIRSPD (KNTS)	BASE PID:	Base Height:	Aircraft	Airport Idnt:
Flight Time	2.1		A		155	TEMP	1.500	C421-N13RF	KMEV (Miden, NV)

Lift	#	Flight Line	Mission Line	UTC time:		GPS Altitude: ASL:	Direction	Speed: kts:	Available	S/Vs:	Position Acc.		Comments and Conditions:
				Begin:	End:				MM Space		PDOP	HDOP	
A													
	1	569	171011_153622	15:36	15:37	13104	347°	142	658	19	1.1	.	
	2	568	171011_154237	15:42	15:43	13106	167°	151	657	191	1.1		
	3	567	171011_154824	15:48	13:49	13072	347°	155	657	19	1.2	0.6	
	4	566	171011_155508	15:54	15:55	13042	167°	152	657	19	1.1	0.6	
	5	565	171011_160100	16:01	16:01	13102	166°	155	657	18	1.1	0.6	
	6	564	171011_160840	16:08	16:08	13069	347°	152	657	18	1.2	0.7	
	7	563	171011_162249	16:22	16:23	13082	167°	151	657	18	1.1	0.6	
	8	562	171011_162842	16:28	16:31	13126	347°	150	656	18	1.2	0.6	
	9	561	171011_163731	16:37	16:40	13078	167°	156	655	18	1.2	0.6	
	10	562	171011_164745	16:47	16:48	13020	347°	154	654	19	1.2	0.6	
	11	84	171011_165641	16:56	17:03	13183	347°	154	654	18	1.4	0.7	
	12	85	171011_170939	17:09	17:16	13097	167°	150	652	19	1.2	0.7	
	13												
	14												
	15												
	16												
	17												
	18												
	19												
	20												
	21												
	22												
	23												
	24												
	25												

Leica ALS80 Flight Log

Project:	NV_ Reno					Sensor Operator/s
						Jackson Beebe
Date/Julian:	10/12/2018	ALS80 SN# 8137	Disk Drive MM70	Flight Plan(s):		Pilot/s
Hobbs End	3340.1			NV_Reno		Keith Morrel
Hobbs ST	3336.3	LIFT		TARGET AIRSPD (KNTS)	BASE PID:	Base Height:	Aircraft	Airport Idnt:
Flight Time	3.8	A		155	TEMP	1.500	C421-N13RF	KMEV (Minden, NV)

Lift	#	Flight Line	Mission Line	UTC time: Begin:	UTC time: End:	GPS Altitude: ASL:	Direction	Speed: kts:	Available MM Space	S/Vs:	Position Acc. PDOP	Position Acc. HDOP	Comments and Conditions:
A													
	1	86	171012_052825	5:28	5:34	13104	347°	155	650	16	1.2	0.7	
	2	87	171012_054002	5:40	5:41	13012	167°	150	648	16	1.3	0.7	Brieft Low R 12 mi South
	3	88	171012_055054	5:50	5:56	13089	347°	152	646	16	1.3	0.7	
	4	89	171012_060213	6:02	6:08	13091	167°	157	644	17	1.3	0.7	
	5	90	171012_061308	6:13	6:17	13079	347°	150	643	18	1.2	0.6	
	6	560	171012_062402	6:24	6:26	13189	167°	156	641	19	1.1	0.7	
	7	559	171012_063106	6:31	6:33	13209	347°	155	640	18	1.1	0.7	
	8	558	171012_063800	6:38	6:40	13196	167°	150	639	18	1.2	0.8	
	9	557	171012_064458	6:44	6:47	132007	347°	151	639	17	1.4	0.8	
	10	556	171012_065158	6:51	6:54	13200	167°	151		17	1.4	0.8	
	11	555	171012_065900	6:59	7:01	13149	347°	155	637	17	1.4	0.8	
	12	554	171012_070602	7:06	7:08	13132	167°	152	636	17	1.5	0.7	
	13	553	171012_071311	7:13	7:16	13147	347°	152	635	18	1.3	0.7	
	14	552	171012_072025	7:20	7:23	13113	167°	157	634	18	1.3	0.7	
	15	551	171012_072749	7:27	7:30	13165	347°	151	633	18	1.3	0.7	
	16	550	171012_073503	7:35	7:38	13138	167°	159	632	18	1.3	0.7	
	17	549	171012_074312	7:43	7:46	13146	347°	152	631	17	1.4	0.7	
	18	548	171012_075116	7:51	7:55	13142	167°	157	630	18	1.4	0.6	
	19	547	171012_075929	7:59	8:03	13120	347°	152	629	18	1.2	0.6	
	20	546	171012_080757	8:07	8:12	13131	167°	156	628	19	1.1	0.6	
	21	545	171012_081624	8:16	8:20	13140	347°	156	626	20	1.1	0.6	
	22	544	171012_082447	8:24	8:30	13143	167°	155	625	19	1.1	0.6	
	23	543	171012_083445	8:34	8:40	13143	347°	152	623	20	1.2	0.6	
	24	542	171012_084525	8:45	8:51	13078	167°	157	622	20	1.2	0.6	
	25	541	171012_085554	8:55	9:01	13137	347°	157	620	21	1.1	6	

Leica ALS80 Flight Log

	26	540	171012_090618	9:06	9:12	13096	167°	157	618	23	1	0.5	

Leica ALS80 Flight Log

Project:	NV_ Reno					Sensor Operator/s
						Jackson Beebe
Date/Julian:	10/12/2018	ALS80 SN# 8137	Disk Drive MM70	Flight Plan(s):		Pilot/s
Hobbs End	3344.9			NV_Reno		Keith Morrel
Hobbs ST	3340.1	LIFT		TARGET AIRSPD (KNTS)	BASE PID:	Base Height:	Aircraft	Airport Idnt:
Flight Time	4.8	B		155	TEMP	1.500	C421-N13RF	KMEV (Minden, NV)

Lift	#	Flight Line	Mission Line	UTC time: Begin:	UTC time: End:	GPS Altitude: ASL:	Direction	Speed: kts:	Available MM Space	S/Vs:	Position Acc. PDOP	Position Acc. HDOP	Comments and Conditions:
B													
		539	171012_175429	17:54	18:00	13127	347°	151	616	21	1.1	0.6	
		538	171012_180816	18:08	18:15	13118	167°	154	614	22	1.1	0.6	
		537	171012_182020	18:20	18:28	13136	347°	155	611	20	1.1	0.6	
		536	171012_183246	183:23	15:40	10600	167°	159	609	19	1.2	0.6	
		535	171012_184525	18:45	18:53	10733	347°	150	607	20	1.1	0.6	
		534	171012_185712	18:57	19:04	10687	167°	156	605	21	1	0.6	
		533	171012_190932	19:09	19:17	10730	347°	155	603	19	1.2	0.7	
		532	171012_192108	19:21	19:28	10823	167°	156	602	19	1.2	0.7	
		531	171012_193325	19:33	19:41	11017	347°	153	600	16	1.4	0.7	
		530	171012_194544	19:45	19:53	11043	167°	155	598	16	1.4	0.7	
		529	171012_195807	19:58	20:04	11100	347°	153	596	16	1.4	0.7	
		528	171012_201026	20:10	20:18	11208	167°	158	594	16	1.3	0.7	
		527	171012_202239	20:22	20:30	11309	347°	156	593	17	1.2	0.7	
		526	171012_203619	20:36	20:43	13916	167°	157	591	19	1	0.6	
		525	171012_204849	20:48	20:56	14046	347°	160	588	19	1	0.6	
		524	171012_210050	21:00	21:08	14236	167°	156	586	18	1.1	0.7	
		523	171012_211312	21:13	21:20	14300	347°	153	583	18	1.1	0.6	Brief IMU erro Afterline
		522	171012_212621	21:26	21:34	14467	167°	153	581	18	1.1	0.6	

Leica ALS80 Flight Log

Project:	**NV_ Reno**					**Sensor Operator/s**
						Jackson Beebe
Date/Julian:	10/12/2018	ALS80 SN# 8137	**Disk Drive MM70**	**Flight Plan(s):**		**Pilot/s**
Hobbs End	3396.4			NV_Reno		Keith Morrel
Hobbs ST	3394.9	**LIFT**	**TARGET AIRSPD (KNTS)**	**BASE PID:**	**Base Height:**	**Aircraft** / **Airport Idnt:**
Flight Time	1.5	**C**	155	TEMP	1.500	C421-N13RF / KMEV (Minden, NV)

Lift	#	Flight Line	Mission Line	UTC time: Begin:	UTC time: End:	GPS Altitude: ASL:	Direction	Speed: kts:	Available MM Space	S/Vs:	Position Acc. PDOP	Position Acc. HDOP	Comments and Conditions:
C													
		521	171012_233310	23:33	23:40	14622	347°	155	578	22	1.1	0.6	
		520	171012_234537	23:45	23:53	14732	167°	150	575	22	1.1	0.6	
		519	171012_235755	23:57	:5	14883	347°	152	573	20	1.3	0.6	Broke 10 mi North/High
		518	171013_001017	:1		14892	167°	145	570	22	1.1	0.6	Pulled due to Turb
		239	171013_002151	:21	:21		41°		569				Too Fast / Refly

Leica ALS80 Flight Log

Project:	**NV_ Reno**												**Sensor Operator/s**
													Jackson Beebe
Date/Julian:	10/12/2018	ALS80 SN# 8137		**Disk Drive MM70**			**Flight Plan(s):**						**Pilot/s**
Hobbs End	3396.4						NV_Reno						Keith Morrel
Hobbs ST	3394.9		**LIFT**				**TARGET AIRSPD (KNTS)**		**BASE PID:**		**Base Height:**	**Aircraft**	**Airport Idnt:**
Flight Time	1.5		**B**				155		TEMP		1.500	C421-N13RF	KMEV (Minden, NV)

Lift	#	Flight Line	Mission Line	UTC time:		GPS Altitude: ASL:	Direction	Speed: kts:	Available	S/Vs:	Position Acc.		Comments and Conditions:
				Begin:	End:				MM Space		PDOP	HDOP	
B													
		519	171014_204152	20:41	20:49	14800	347°	153	569	22	0.9	0.6	
		517	171014_205410	20:54	21:01	14935	187°	153	567	19	1	0.6	
		516	171014_210624	21:06	21:14	14927	347°	153	564	18	1.1	0.6	
		515	171014_211838	21:18	21:26	14921	167°	153	561	18	1.1	0.6	
		514	171014_213106	21:31	21:38	15003	347°	155	559	16	1.3	0.7	
		518	171014_214308	21:43	21:50	14888	167°	156	556	17	1.3	0.7	
		513	171014_215500	21:55	22:02	15067	347°	154	554	17	1.4	0.8	
		512	171014_220709	22:07	22:14	15157	167°	150	551	15	1.6	0.8	
		511	171014_221939	22:19	22:29	15277	347°	155	549	18	1.2	0.7	
		510	171014_223208	22:32	22:39	15488	167°	155	546	20	1	0.6	
		509	171014_224458	22:44	22:51	15529	347°	155	544	19	1.1	0.6	
		508	171014_225627	22:56	23:01	15437	167°	155	541	21	1	0.6	
		507	171014_230603	23:06	23:10	15524	347°	156	540	22	1	0.6	
		506	171014_231539	23:15	23:19	15492	167°	154	538	22	1	0.6	
		505	171014_232419	23:24	23:28	15370	347°	150	537	21	1.1	0.6	
		504	171014_233435	23:34	23:35	15815	167°	156	536	21	1.1	0.6	

Leica ALS80 Flight Log

Project:	**NV_ Reno**				**Sensor Operator/s**
					Jackson Beebe
Date/Julian:	10/14/2018	ALS80 SN# 8137	**Disk Drive MM70**	**Flight Plan(s):**	**Pilot/s**
Hobbs End	3355.7			NV_Reno	Keith Morrel

Hobbs ST	3351.2	**LIFT**	**TARGET AIRSPD (KNTS)**	**BASE PID:**	**Base Height**	**Aircraft**	**Airport Idnt:**
Flight Time	4.5	**B**	155	TEMP	1.500	C421-N13RF	KMEV (Minden, NV)

Lift	#	Flight Line	Mission Line	UTC time: Begin:	UTC time: End:	GPS Altitude: ASL:	Direction	Speed: kts:	Available MM Space	S/Vs:	Position Acc. PDOP	Position Acc. HDOP	Comments and Conditions:
B													
		503	171015_003548	:35	:36	13883	347°	152	535	19	1.2	0.6	
		502	171015_004116	:41	:42	13893	167°	151	535	19	1.2	0.6	
		501	171015_004706	:47	:48	13880	347°	151	535	18	1.4	0.7	
		500	171015_005306	:53	:55	13886	167°	152	534	19	1.3	0.6	
		499	171015_005931	:59	1:01	13868	347°	151	534	20	1.1	0.6	
		498	171015_010618	1:06	1:08	13847	167°	151	533	20	1.1	0.6	
		497	171015_011331	1:13	1:16	14039	347°	148	532	20	1.1	0.6	
		496	171015_012106	1:21	1:24	14214	167°	150	531	20	1.2	0.7	
		495	171015_012910	1:29	1:32	14276	347°	146	530	20	1.2	0.7	
		494	171015_013719	1:37	1:41	14315	167°	156	529	20	1.2	0.7	
		493	171015_014621	1:46	1:50	14324	347°	153	527	20	1.3	0.7	
		492	171015_015529	1:55	2:00	14100	167°	153	526	20	1.2	0.7	
		491	171015_020445	2:04	2:09	14071	347°	149	525	20	1.1	0.7	
		490	171015_021351	2:13	2:18	14096	167°	157	523	21	1.1	0.7	
		489	171015_022313	2:23	2:27	14110	347°	150	522	21	1.1	0.6	
		488	171015_023227	2:32	2:37	14242	167°	155	520	20	1.1	0.6	
		487	171015_024300	2:43		11690	346°	155	519	18	1.1	0.6	Pulled Due to EyeSafe Shut Off
		487	171015_025219	2:52	2:58	11716	167°	151	518	15	1.1	0.6	
		486	171015_030124	3:01	3:06	11730	346°	158	517	17	1.2	0.6	
		485	171015_031052	3:10	3:15	11825	166°	148	516	18	1.2	0.6	
		484	171015_031955	3:19	3:24	11766	346°	154	515	17	1.1	0.6	
		483	171015_032904	3:29	3:33	12025	166°	150	514	18	1.2	0.6	
		482	171015_033803	3:38	3:42	12222	346°	159	513	17	1.3	0.7	
		481	171015_034958	3:49	3:54	14883	166°	156	512	17	1.4	0.6	
		480	171015_035913	3:59	4:03	14001	346°	155	511	15	1.4	0.7	

Leica ALS80 Flight Log

		479	171015_040843	4:08	4:13	14987	166°	155	509	15	1.4	0.8	
		478	171015_041807	4:18	4:22	14978	346°	153	507	16	1.3	0.7	
		477	171015_042716	4:27	4:32	14815	166°	153	506	16	1.1	0.7	
		4	171015_043938	4:39	4:40	13414	274°	150	504	16	1.2	0.7	Cross Strip

Leica ALS80 Flight Log

Project:	NV_ Reno				Sensor Operator/s
					Jackson Beebe
Date/Julian:	10/15/2018	ALS80 SN# 8137	Disk Drive MM70	Flight Plan(s):	Pilot/s
Hobbs End	3360.5			NV_Reno	Keith Morrel

Hobbs ST	3355.7		LIFT		TARGET AIRSPD (KNTS)	BASE PID:	Base Height:	Aircraft	Airport Idnt:
Flight Time	4.8		A		155	TEMP	1.500	C421-N13RF	KMEV (Minden, NV)

Lift	#	Flight Line	Mission Line	UTC time: Begin:	UTC time: End:	GPS Altitude: ASL:	Direction	Speed: kts:	Available MM Space	S/Vs:	Position Acc. PDOP	Position Acc. HDOP	Comments and Conditions:
A													
		476	171015_173400	17:34	17:38	14702	346°	159	503	21	1.1	0.6	
		475	171015_174639	17:46	17:51	11871	166°	150	502	21	1.1	0.6	
		474	171015_175549	17:55	18:00	11756	346°	157	501	21	1.1	0.6	
		473	171015_180500	18:05	18:09	11694	166°	152	500	21	1	0.6	
		472	171015_181404	18:14	18:18	11691	346°	157	499	19	1.1	0.6	
		471	171015_182315	18:23	18:27	11704	166°	150	597	19	1.1	0.6	
		470	171015_183233	18:32	18:37	11708	346°	153	596	19	1.1	0.6	
		469	171015_184201	18:42	18:46	11684	166°	156	495	20	1	0.6	
		468	171015_185107	18:51	18:55	11775	346°	156	494	21	0.9	0.6	
		467	171015_190031	19:00	19:03	11829	166°	157	493	19	1.1	0.6	
		466	171015_191000	19:10	19:14	11831	346°	154	492	19	1.2	0.7	
		465	171015_191935	19:19	19:24	11800	166°	156	491	17	1.4	0.7	
		464	171015_192850	19:28	19:33	11958	346°	159	490	16	1.5	0.7	
		463	171015_193820	19:38	19:42	12108	166°	157	489	16	1.5	0.7	
		462	171015_194716	19:47	19:51	12317	346°	156	488	16	1.4	0.7	
		461	171015_195639	19:56	20:01	12525	166°	156	487	16	1.3	0.7	
		460	171015_200547	20:05	20:10	12519	346°	154	486	16	1.3	0.7	
		459	171015_201440	20:14	20:19	12518	166°	154	485	17	1.1	0.7	
		458	171015_202405	20:24	20:28	12416	346°	160	484	19	1	0.6	
		457	171015_203343	20:33	20:32	12394	166°	156	483	21	0.9	0.6	
		456	171015_204211	20:42	20:46	12493	346°	154	482	20	0.9	0.6	
		455	171015_205112	20:51	20:55	12388	166°	154	481	19	1	0.6	
		454	171015_210010	21:00	21:04	12430	346°	160	480	18	1	0.6	
		453	171015_210934	21:09	21:13	12529	166°	156	479	18	1.1	0.6	
		452	171015_211835	21:18	21:22	12552	346°	160	478	18	1.1	0.7	

Leica ALS80 Flight Log

		451	171015_212800	21:28	21:32	12515	166°	155	477	16	1.3	0.7	
		450	171015_213722	21:37	21:41	12532	346°	156	476	16	1.4	0.7	
		449	171015_214703	21:47	21:51	12499	166°	150	475	17	1.4	0.7	

Leica ALS80 Flight Log

Project:	NV_ Reno				Sensor Operator/s
					Jackson Beebe
Date/Julian:	10/15/2018	ALS80 SN# 8137	Disk Drive MM70	Flight Plan(s):	Pilot/s
Hobbs End	3364.9			NV_Reno	Keith Morrel

Hobbs ST	3360.5		LIFT		TARGET AIRSPD (KNTS)	BASE PID:	Base Height:	Aircraft	Airport Idnt:
Flight Time	4.4		C		155	TEMP	1.500	C421-N13RF	KMEV (Minden, NV)

Lift	#	Flight Line	Mission Line	UTC time: Begin:	UTC time: End:	GPS Altitude: ASL:	Direction	Speed: kts:	Available MM Space	S/Vs:	Position Acc. PDOP	Position Acc. HDOP	Comments and Conditions:
C													
		448	171015_233111	23:31	23:35	12592	346°	154	474	21	1.1	0.6	
		447	171015_234107	23:41	23:45	12604	166°	150	473	19	1.3	0.7	
		446	171015_235014	23:50	23:54	13256	346°	157	472	19	1.3	0.7	
		421	171016_000307	:3	:8	11251	166°	151	470	20	1.2	0.7	
		422	171016_001249	:12	:17	11251	346°	157	469	20	1.2	0.7	
		423	171016_002251	:22	:27	11231	166°	154	468	21	1.1	0.7	
		424	171016_003300	:33	:37	11272	346°	158	462	20	1.2	0.7	
		425	171016_004307	:43	:48	11253	166°	149	466	19	1.2	0.7	
		426	171016_005254	:52	:58	11260	346°	148	464	19	1.2	0.7	
		427	171016_010249	1:02	1:07	11247	166°	152	463	20	1.3	0.7	
		428	171016_011234	1:12	1:17	11133	346°	157	462	18	1.2	0.7	
		429	171016_012236	1:22	1:27	11108	166°	149	461	20	1.3	0.6	
		430	171016_013225	1:32	1:37	11146	346°	159	460	20	1.2	0.6	
		431	171016_014222	1:42	1:47	11140	166°	150	457	19	1.3	0.7	
		432	171016_015211	1:52	1:57	11157	346°	159	458	20	1.2	0.6	
		433	171016_020208	2:02	2:06	11289	166°	158	457	20	1.1	0.6	
		434	171016_021201	2:12	2:16	11390	346°	159	456	20	1.1	0.7	
		435	171016_022159	2:21	2:26	11509	166°	151	454	20	1.1	0.6	
		436	171016_023144	2:31	2:36	11709	346°	161	453	19	1	0.6	
		437	171016_024127	2:41	2:46	11787	166°	152	452	20	1	0.6	
		438	171016_025108	2:51	2:57	11998	316°	154	451	19	1	0.6	
		439	171016_030148	3:01	3:06	14804	166°	158	450	17	1.1	0.7	
		440	171016_031137	3:11	3:16	14950	346°	155	449	17	1.1	0.7	
		441	171016_032112	3:21	3:26	15112	166°	153	447	17	1.1	0.7	

Leica ALS80 Flight Log

Project:	NV_ Reno				Sensor Operator/s
					Jackson Beebe
Date/Julian:	10/16/2018	ALS80 SN# 8137	Disk Drive MM70	Flight Plan(s):	Pilot/s
Hobbs End	3369.6			NV_Reno	Keith Morrel

Hobbs ST	3364.9		LIFT		TARGET AIRSPD (KNTS)	BASE PID:	Base Height:	Aircraft	Airport Idnt:
Flight Time	4.7		A		155	TEMP	1.500	C421-N13RF	KMEV (Minden, NV)

Lift	#	Flight Line	Mission Line	UTC time:		GPS Altitude: ASL:	Direction	Speed: kts:	Available	S/Vs:	Position Acc.		Comments and Conditions:
				Begin:	End:				MM Space		PDOP	HDOP	
A													
		445	171016_173416	17:34	17:38	15260	346°	151	445	20	1.1	0.6	
		444	171016_174345	17:43	17:48	15420	166°	158	444	20	1.1	0.6	
		443	171016_175337	17:53	17:58	15425	346°	148	443	20	1	0.6	
		442	171016_180310	18:03	18:07	15297	166°	159	4441	19	1.1	0.6	
		420	171016_181343	18:13	18:21	13769	346°	159	440	19	1.1	0.6	
		419	171016_182624	18:26	18:33	13741	166°	156	437	19	1.1	0.6	
		418	171016_183830	18:38	18:46	13757	346°	154	435	21	1	0.5	
		417	171016_185100	18:51	18:58	13765	166°	154	433	18	1.1	0.6	
		416	171016_190329	19:03	19:11	13887	346°	153	430	19	1	0.6	
		415	171016_191553	19:15	19:23	13942	166°	156	428	17	1.3	0.7	
		414	171016_192825	19:28	19:36	13930	346°	147	426	16	1.4	0.7	
		413	171016_194119	19:41	19:48	13935	166°	155	423	16	1.4	0.7	
		412	171016_195338	19:53	20:07	13944	346°	156	421	16	1.3	0.7	
		411	171016_200556	20:05	20:12	13907	166°	156	419	17	1.1	0.7	
		410	171016_201754	20:17	20:25	13972	346°	157	416	19	1.1	0.7	
		409	171016_203020	20:30	20:36	14014	166°	158	414	20	0.9	0.6	
		408	171016_204145	20:41	20:48	13994	346°	157	412	19	0.9	0.6	
		407	171016_205318	20:53	20:54	14018	166°	157	410	17	1.1	0.6	
		406	171016_210406	21:04	21:10	14188	346°	158	408	17	1.1	0.6	
		405	171016_211456	21:14	21:21	14324	166°	154	406	17	1.1	0.7	
		404	171016_212546	21:25	21:31	14353	346°	154	404	15	1.4	0.7	
		403	171016_213555	213:35	21:41	14525	166°	157	403	16	1.4	0.7	

Leica ALS80 Flight Log

DAS Digital Aerial Solutions

Project:	NV_ Reno														Sensor Operator/s
															Jackson Beebe
Date/Julian:	10/16/2018		ALS80 SN# 8137		Disk Drive MM70			Flight Plan(s):							Pilot/s
Hobbs End	3373.8							NV_Reno							Keith Morrel
Hobbs ST	3369.6			LIFT				TARGET AIRSPD (KNTS)		BASE PID:		Base Height	Aircraft		Airport Idnt:
Flight Time	4.2			B				155		TEMP		1.500	C421-N13RF		KMEV (Minden, NV)
Lift	#	Flight Line	Mission Line	UTC time: Begin:	UTC time: End:	GPS Altitude: ASL:	Direction	Speed: kts:	Available MM Space	S/Vs:	Position Acc. PDOP	Position Acc. HDOP	Comments and Conditions:		
B		402	171016_232606	23:26	23:31	14502	346°	154	401	24	1	0.6			
		401	171016_233636	23:36	23:41	15493	166°	152	399	21	1.3	0.6			
		400	171016_234609	23:46	23:51	1425	346°	152	397	22	1.3	0.6			
		399	171016_235547	23:55	:	14712	166°	152	396	21	1.3	0.7			
		398	171017_000535	:5	:10	14807	346°	1524	394	22	1.1	0.6			
		397	171017_001515	:15	:20	14932	166°	149	393	22	1.1	0.6			
		396	171017_002631	:26	:29	15039	346°	154	391	22	1.1	0.6			
		395	171017_003448	:34	:37	14996	166°	150	390	22	1.1	0.6			
		394	171017_004220	:42	:45	15024	346°	156	382	21	1.2	0.6			
		393	171017_005026	:50	:53	14930	166°	155	389	21	1.3	0.6			
		392	171017_005817	:58	1:01	14734	346°	150	387	21	1.1	0.7			
		391	171017_010532	1:05	1:09	14351	166°	150	386	21	1.1	0.6			
		390	171017_011422	1:14	1:18	14374	346°	152	385	21	1.3	0.6			
		389	171017_012336	1:23	1:25	14371	1666°	150	384	21	1.3	0.7			
		388	171017_013229	1:32	1:35	14360	346°	156	383	21	1.3	0.6			
		387	171017_014152	1:41	1:44	14438	166°	150	381	21	1.1	0.6			
		386	171017_014951	1:49	1:52	14431	346°	153	380	21	1.1	0.6			
		385	171017_015818	1:58	2:00	14526	160°	145	379	21	1.1	0.6			
		384	171017_020547	2:05	2:08	14505	346°	154	379	22	1	0.6			
		383	171017_021415	2:14	2:15	14512	166°	148	378	21	1	0.6			
		382	171017_022207	2:22	2:25	14655	346°	160	377	22	1	0.6			
		381	171017_023038	2:30	2:34	14122	166°	156	376	23	1	0.6			
		380	171017_023940	2:39	2:42	14160	346°	152	395	23	1.9	0.6			
		379	171017_024741	2:47	2:50	14150	166°	148	374	22	1.1	0.6			
		378	171017_025520	2:55	2:58	14230	346°	148	373	21	1	0.6			
		377	171017_030326	3:03	3:06	14224	166°	163	372	19	1.1	0.7			

Leica ALS80 Flight Log

Project:	NV_ Reno								Sensor Operator/s
									Jackson Beebe
Date/Julian:	10/17/2018	ALS80 SN# 8137		Disk Drive MM70	Flight Plan(s):				Pilot/s
Hobbs End	3382.9				NV_Reno				Keith Morrel
Hobbs ST	3378.4		LIFT		TARGET AIRSPD (KNTS)	BASE PID:	Base Height:	Aircraft	Airport Idnt:
Flight Time	4.5		A		155	TEMP	1.500	C421-N13RF	KMEV (Minden, NV)

Lift	#	Flight Line	Mission Line	UTC time: Begin:	UTC time: End:	GPS Altitude: ASL:	Direction	Speed: kts:	Available MM Space	S/Vs:	Position Acc. PDOP	Position Acc. HDOP	Comments and Conditions:
A		376	171017_180802	18:07	18:10	14315	346°	152	1118	20	1.1	0.6	
		375	171017_181740	18:17	18:20	14324	166°	156	1117	20	1.1	0.6	
		374	171017_182515	18:25	18:27	14475	346°	151	1116	20	1	0.6	
		373	171017_183302	18:33	18:35	14320	166°	151	1115	20	1	0.6	
		372	171017_184022	18:40	18:42	14649	346°	154	1114	21	1	0.6	
		371	171017_184754	18:47	18:49	14741	166°	150	1113	21	1	0.6	
		370	171017_185443	18:54	18:56	14852	346°	153	1113	19	1	0.7	
		369	171017_190152	19:01	19:04	15025	166°	149	1112	19	1.2	0.7	
		368	171017_190942	19:09	19:10	14948	346°	153	1111	19	1.2	0.7	
		367	171017_191544	19:15	19:16	14914	166°	151	1111	18	1.3	0.7	
		366	171017_192125	19:21	19:22	14932	346°	150	1111	17	1.4	0.7	
		365	171017_192706	19:27	19:27	14935	166°	157	1110	17	1.4	0.7	
		240	171017_193538	19:35	19:46	13412	166°	154	1110	17	1.4	0.7	
		241	171017_194535	19:45	19:50	13420	346°	152	1109	19	1.3	0.7	
		242	171017_195518	19:55	20:00	13380	166°	153	1108	17	1.3	0.7	
		243	171017_200455	20:04	20:09	13443	346°	155	1106	17	1.2	0.7	
		244	171017_201454	20:14	20:19	13357	166°	151	1104	19	1	0.6	
		245	171017_202418	20:24	20:29	13373	346°	157	1103	21	0.9	0.6	
		246	171017_203407	20:34	20:39	13355	166°	155	1101	20	1	0.6	
		247	171017_204346	20:43	20:49	13358	346°	154	1099	17	1.1	0.6	
		248	171017_205405	20:54	20:59	133367	166°	155	1098	17	1.1	0.6	
		249	171017_210434	21:04	21:09	133341	346°	152	1096	17	1.1	0.6	
		250	171017_211444	21:14	21:20	13395	166°	150	1094	16	1.2	0.7	
		251	171017_212514	21:25	21:30	13342	346°	156	1093	15	1.4	0.7	
		252	171017_213516	21:35	21:40	13389	166°	155	1091	16	1.3	0.7	
		253	171017_214532	21:45	21:50	13325	346°	152	1089	16	1.4	0.8	

Leica ALS80 Flight Log

		254	171017_215537	21:55	21:60	13389	166°	158	1088	15	1.5	0.8	

Leica ALS80 Flight Log

DAS Digital Aerial Solutions

Project:	NV_ Reno				Sensor Operator/s
					Jackson Beebe
Date/Julian:	10/18/2018	ALS80 SN# 8137	Disk Drive MM70	Flight Plan(s):	Pilot/s
Hobbs End	3387.6			NV_Reno	Keith Morrel

Hobbs ST	3382.9		LIFT		TARGET AIRSPD (KNTS)	BASE PID:	Base Height	Aircraft	Airport Idnt:
Flight Time	4.7		A		155	TEMP	1.500	C421-N13RF	KMEV (Minden, NV)

Lift	#	Flight Line	Mission Line	UTC time: Begin:	UTC time: End:	GPS Altitude: ASL:	Direction	Speed: kts:	Available MM Space	S/Vs:	Position Acc. PDOP	Position Acc. HDOP	Comments and Conditions:
A		280	171017_233821	23:38	23:43	13126	346°	157	1086	20	1.1	0.6	
		279	171017_234820	23:48	23:53	13156	166°	150	1084	19	1.3	0.7	
		278	171017_235835	23:58	:3	13140	346°	152	1083	21	1.1	0.6	
		277	171018_000845	:8	:13	13181	166°	150	1081	22	1.1	0.6	
		276	171018_001854	:18	:24	13161	346°	146	1079	21	1.1	0.6	
		275	171018_002900	:29	:34	13189	166°	158	1078	21	1.1	0.6	
		274	171018_003906	:39	:44	13154	346°	154	1076	21	1.2	0.6	
		273	171018_004859	:48	:54	13195	166°	158	1074	21	1.1	0.6	
		272	171018_005909	:59	1:04	13181	346°	152	1073	22	1.1	0.6	
		271	171018_010930	1:09	1:14	13183	166°	157	1071	21	1.2	0.6	
		270	171018_011958	1:19		10637	346°	146	1070	21	1.2	0.6	EyeSafe/Refly
		269	171018_013152	1:31	1:37	10661	166°	150	1069	20	1.2	0.6	
		270	171018_014218	1:42	1:47	10620	346°	156	1068	20	1.2	0.6	
		268	171018_015218	1:52	1:57	10676	166°	154	1067	21	1.1	0.6	
		267	171018_020215	2:02	2:07	10637	346°	148	1066	22	1	0.6	
		266	171018_021142	2:11	2:16	10629	166°	155	1064	21	1	0.6	
		265	171018_022128	2:21	2:26	10642	346°	148	1063	22	1	0.6	
		264	171018_023123	2:31	2:36	10692	166°	156	1062	22	1	0.6	
		263	171018_024315	2:43	2:48	13185	346°	157	1061	21	1	0.6	
		262	171018_025333	2:53	2:58	13242	166°	158	1057	20	1	0.6	
		261	171018_030346	3:03	3:09	13231	346°	155	1058	19	1.1	0.7	
		260	171018_031358	3:13	3:19	13151	166°	156	1056	20	1.1	0.6	
		259	171018_032356	3:23	3:29	13204	346°	158	1054	19	1.2	0.6	
		258	171018_033419	3:34	3:34	13199	166°	154	1052	18	1.2	0.7	

Leica ALS80 Flight Log

Project:	NV_ Reno								Sensor Operator/s
									Jackson Beebe
Date/Julian:	10/18/2018	ALS80 SN# 8137		Disk Drive MM70	Flight Plan(s):				Pilot/s
Hobbs End	3387.6				NV_Reno				Keith Morrel
Hobbs ST	3382.9		LIFT		TARGET AIRSPD (KNTS)	BASE PID:	Base Height:	Aircraft	Airport Idnt:
Flight Time	4.7		A		155	TEMP	1.500	C421-N13RF	KMEV (Minden, NV)

Lift	#	Flight Line	Mission Line	UTC time: Begin:	UTC time: End:	GPS Altitude: ASL:	Direction	Speed: kts:	Available MM Space	S/Vs:	Position Acc. PDOP	Position Acc. HDOP	Comments and Conditions:
A		257	171018_171238	17:12	17:18	13222	346°	153	371	20	1.1	0.6	
		256	171018_172319	17:23	17:28	13247	166°	147	369	20	1.1	0.6	
		255	171018_173336	17:33	17:39	13267	346°	153	368	20	1.1	0.6	
		364	171018_174739	17:47	17:48	13530	166°	156	366	21	1	0.6	
		363	171018_175220	17:52	17:54	1368	346°	154	366	21	1	0.6	
		362	171018_175930	17:59	18:01	13306	166°	151	365	20	1.1	0.6	
		361	171018_180642	18:06	18:08	31246	346°	152	364	19	1.2	0.6	
		360	171018_181352	18:13	18:16	13044	166°	158	364	20	1.1	0.6	
		359	171018_182145	18:21	18:24	13061	346°	154	363	20	1	0.6	
		358	171018_182944	18:29	18:32	13059	166°	155	362	20	1	0.6	
		357	171018_183727	18:37	18:40	13067	346°	155	361	22	0.9	0.5	
		356	171018_184516	18:45	18:48	13036	166°	152	360	18	1.2	0.5	
		355	171018_190006	19:00	19:03	13074	346°	153	357	19	1.2	0.5	
		354	171018_190852	19:08	19:12	13058	166°	150	356	17	1.4	0.7	
		353	171018_191735	19:17	19:21	1300	346°	154	355	16	1.4	0.7	
		352	171018_192648	19:26	19:30	12962	166°	141	354	16	1.4	0.7	
		351	171018_193555	19:35	19:37	13078	346°	156	352	16	1.4	0.7	
		350	171018_194516	19:45	19:49	12902	166°	154	351	16	1.3	0.7	
		349	171018_195546	19:55	20:00	12912	346°	157	350	16	1.2	0.7	
		348	171018_200620	20:06	20:11	12893	166°	150	357	17	1.1	0.7	
		347	171018_201641	20:16	20:21	12987	346°	153	350	20	1	0.6	
		346	171018_202721	20:27	20:34	12900	166°	151	347	20	0.9	0.6	
		345	171018_203934	20:39	20:46	12926	346°	157	345	18	1	0.6	
		344	171018_205151	20:51	20:58	12924	166°	156	343	18	1.1	0.6	
		343	171018_210426	21:04	21:12	12941	346°	158	341	18	1.1	0.6	
		342	171018_211755	21:17	21:25	12920	166°	155	339	16	1.3	0.7	

Leica ALS80 Flight Log

Project:	NV_ Reno				Sensor Operator/s
					Jackson Beebe
Date/Julian:	10/18/2018	ALS80 SN# 8137	Disk Drive MM70	Flight Plan(s):	Pilot/s
Hobbs End	3391.9			NV_Reno	Keith Morrel

Hobbs ST	3387.6		LIFT		TARGET AIRSPD (KNTS)	BASE PID:	Base Height:	Aircraft	Airport Idnt:
Flight Time	4.3		B		155	TEMP	1.500	C421-N13RF	KMEV (Minden, NV)

Lift	#	Flight Line	Mission Line	UTC time:		GPS Altitude: ASL:	Direction	Speed: kts:	Available	S/Vs:	Position Acc.		Comments and Conditions:
				Begin:	End:				MM Space		PDOP	HDOP	
B		156	171018_231806	23:18	23:18	15128	41°	159	336	20	1.1	0.6	
		157	171018_232421	23:24	23:23	14905	221°	147	336	19	1.3		
		158	171018_233027	23:30	23:30	14563	41°	155	335	19	1.3		
		159	171018_233647	23:36	23:37	14128	221°	145	3335	19	1.3		
		160	171018_234204	23:42	23:42	13907	41°	156	335	20	1.2		
		161	171018_234758	23:47	23:48	13834	221°	152	335	19	1.3		
		162	171018_235343	23:53	23:54	13803	41°	154	336	19	1.2		
		163	171019_000027	:	:1	13716	221°	155	334	20	1.1		
		164	171019_000629	:6	:8	13450	41°	157	334	21	1		
		165	171019_001426	:14	:17	13383	221°	154	333	20	2.1		
		166	171019_002207	:22	:24	13326	41°	156	332	20	1.1		
		167	171019_002956	:29	:32	13211	221°	151	3331	19	1.2		
		168	171019_003735	:37	:40	13191	41°	152	330	18	1.2		
		169	171019_004550	:45	:48	13095	221°	150	329	18	1.2		
		170	171019_005350	:53	:56	13145	41°	154	328	18	1.2		
		171	171019_010211	1:02	1:06	13060	221°	152	327	20	1.2		
		172	171019_011116	1:11	1:16	13002	41°	158	326	20	1.2		
		173	171019_012142	1:21	1:26	12950	221°	154	324	20	1.2		
		174	171019_013056	1:30	1:35	12885	41°	154	323	19	1.2		
		341	171019_014829	1:48	1:56	12935	346°	152	321	21	1.1		
		340	171019_020153	2:01	2:10	12919	166°	153	319	21	1		
		339	171019_021501	2:15	2:23	12917	346°	158	316	20	1		
		338	171019_022848	2:28	2:36	12901	166°	155	314	22	0.9		
		337	171019_024204	2:42	2:50	12927	346°	156	311	19	1		
		336	171019_025549	2:55	3:03	12875	160°	155	309	18	1		

Leica ALS80 Flight Log

Project:	NV_ Reno												**Sensor Operator/s**
													Jackson Beebe
Date/Julian:	10/22/2018	ALS80 SN# 8137		**Disk Drive MM70**			**Flight Plan(s):**						**Pilot/s**
Hobbs End							NV_Reno						Keith Morrel
Hobbs ST	3392.8		**LIFT**				**TARGET AIRSPD (KNTS)**		**BASE PID:**		**Base Height:**	**Aircraft**	**Airport Idnt:**
Flight Time			**A**				155		TEMP		1.500	C421-N13RF	KMEV (Minden, NV)

Lift	#	Flight Line	Mission Line	UTC time:		GPS Altitude: ASL:	Direction	Speed: kts:	Available	S/Vs:	Position Acc.		Comments and Conditions:
				Begin:	End:				MM Space		PDOP	HDOP	
A		334	171022_155331	15:22	16:01	12875	346°	150	305	19	1.1	0.6	BREAKER TRIP

Leica ALS80 Flight Log

Project:	**NV_ Reno**							**Sensor Operator/s**	
								Jackson Beebe	
Date/Julian:	10/22/2018	ALS80 SN# 8137		**Disk Drive MM70**	**Flight Plan(s):**			**Pilot/s**	
Hobbs End	3397.5				NV_Reno			Keith Morrel	
Hobbs ST	3392.8		**LIFT**		**TARGET AIRSPD (KNTS)**	**BASE PID:**	**Base Height:**	**Aircraft**	**Airport Idnt:**
Flight Time	4.7		**B**		155	TEMP	1.500	C421-N13RF	KMEV (Minden, NV)

Lift	#	Flight Line	Mission Line	UTC time:		GPS Altitude: ASL:	Direction	Speed: kts:	Available	S/Vs:	Position Acc.		Comments and Conditions:
				Begin:	End:				MM Space		PDOP	HDOP	
B		334	171022_155331	15:53	16:01	12876	166°	160	304	19	1.3	0.7	
		333	171022_160641	16:06	16:14	12938	346°	153	301	19	1.3	0.7	
		332	171022_162016	16:20	16:27	12929	166°	157	299	18	1.5	0.7	
		331	171022_163300	16:33	16:40	12921	346°	153	297	20	1.3	0.7	
		330	171022_164623	16:46	1:53	12930	166°	154	294	22	1	0.6	
		329	171022_165902	16:59	17:05	12936	346°	152	292	21	1.1	0.6	
		328	171022_171123	17:11	17:18	12941	166°	154	290	21	1.1	0.6	
		327	171022_172353	17:23	17:30	12943	346°	158	288	22	1	0.6	
		326	171022_173637	17:36	17:43	12949	166°	156	286	22	1.1	0.6	
		325	171022_174900	17:49	17:55	129630	346°	159	284	19	1.2	0.6	
		324	171022_180127	18:01	18:08	12950	166°	160	282	20	1.1	0.6	
		323	171022_181315	18:13	18:19	12959	346°	156	280	21	1	0.6	
		322	171022_182515	18:25	18:31	12936	166°	159	278	22	1	0.6	
		321	171022_183713	18:37	18:44	12885	346°	158	276	19	1.2	0.7	
		320	171022_184909	18:49	18:55	12876	166°	158	273	19	1.2	0.7	
		319	171022_190017	19:00	19:06	12855	346°	157	271	16	1.3	0.7	
		318	171022_191210	19:12	19:18	12907	166°	156	269	16	1.4	0.7	
		317	171022_192353	19:23	19:30	12902	346°	152	267	16	1.4	0.7	
		316	171022_193540	19:35	19:42	12919	166°	155	265	16	1.3	0.7	

Leica ALS80 Flight Log

Project:	NV_ Reno				Sensor Operator/s
					Jackson Beebe
Date/Julian:	10/22/2018	ALS80 SN# 8137	Disk Drive MM70	Flight Plan(s):	Pilot/s
Hobbs End	3397.5			NV_Reno	Keith Morrel

Hobbs ST	3392.8		LIFT		TARGET AIRSPD (KNTS)	BASE PID:	Base Height:	Aircraft	Airport Idnt:
Flight Time	4.7		C		155	TEMP	1.500	C421-N13RF	KMEV (Minden, NV)

Lift	#	Flight Line	Mission Line	UTC time: Begin:	UTC time: End:	GPS Altitude: ASL:	Direction	Speed: kts:	Available MM Space	S/Vs:	Position Acc. PDOP	Position Acc. HDOP	Comments and Conditions:
C		315	171022_212704	21:27	21:34	12950	346°	150	263	16	1.4	0.8	
		314	171022_213912	21:39	21:45	12906	166°	154	260	17	1.6	0.8	
		313	171022_215147	21:51	21:58	12941	346°	153	255	19	1.1	0.6	
		312	171022_220347	22:03	22:10	12936	166°	153	256	20	1.1	0.6	
		311	171022_221623	22:16	22:25	12935	346°	157	254	19	1.2	0.7	
		310	171022_223008	22:30	22:38	12946	166°	160	251	24	1	0.6	
		309	171022_224346	22:43	22:52	12937	346°	152	249	24	1	0.6	
		308	171022_225752	22:57	23:06	12939	166°	157	246	23	1.1	0.6	
		307	171022_231202	23:12	23:20	12957	346°	154	243	20	1.3	0.6	
		306	171022_232631	23:26		13031	166°	158	241	20	1.3	0.7	Red Error/ GPS/Air Start
		306	171022_235137	23:51	24:00	13056	346°	154	239	23	1.1	0.6	
		305	171023_000554	:5	:15	12995	166°	153	236	22	1.1	0.6	
		304	171023_002130	:21	:36	13056	346°	152	233	21	1.1	0.6	
		303	171023_003616	:36	:45	13021	166°	154	231	20	1.1	0.6	

Leica ALS80 Flight Log

Project:	**NV_ Reno**						**Sensor Operator/s**
							Jackson Beebe
Date/Julian:	10/22/2018	ALS80 SN# 8137		**Disk Drive MM70**	**Flight Plan(s):**		**Pilot/s**
Hobbs End					NV_Reno		Keith Morrel
Hobbs ST	3392.8		**LIFT**		**TARGET AIRSPD (KNTS)**	**BASE PID:**	**Base Height:**	**Aircraft**	**Airport Idnt:**
Flight Time			**D**		155	TEMP	1.500	C421-N13RF	KMEV (Minden, NV)

Lift	#	Flight Line	Mission Line	UTC time:		GPS Altitude: ASL:	Direction	Speed: kts:	Available	S/Vs:	Position Acc.		Comments and Conditions:
				Begin:	End:				MM Space		PDOP	HDOP	
D		306	171022_235137	23:51	24:00	13056	346°	154	239	23	1.1	0.6	
		305	171023_000554	:5	:15	12995	166°	153	236	22	1.1	0.6	
		304	171023_002130	:21	:36	13056	346°	152	233	21	1.1	0.6	
		303	171023_003616	:36	:45	13021	166°	154	231	20	1.1	0.6	

Leica ALS80 Flight Log

DAS Digital Aerial Solutions

Project:	NV_ Reno					Sensor Operator/s
						Jackson Beebe
Date/Julian:	10/23/2018	ALS80 SN# 8137	Disk Drive MM70	Flight Plan(s):		Pilot/s
Hobbs End	3406			NV_Reno		Keith Morrel
Hobbs ST	3401.3	LIFT		TARGET AIRSPD (KNTS)	BASE PID:	Base Height:	Aircraft	Airport Idnt:
Flight Time	4.7	A		155	TEMP	1.500	C421-N13RF	KMEV (Minden, NV)

Lift	#	Flight Line	Mission Line	UTC time: Begin:	UTC time: End:	GPS Altitude: ASL:	Direction	Speed: kts:	Available MM Space	S/Vs:	Position Acc. PDOP	Position Acc. HDOP	Comments and Conditions:
A		302	171023_014820	1:48	1:57	12992	346°	150	228	21	1	0.6	
		301	171023_020310	2:03	2:12	13054	166°	157	225	22	1	0.6	
		300	171023_021753	2:17	2:27	13041	346°	157	223	21	1	0.6	
		299	171023_023233	2:32	2:41	13048	166°	154	219	220	1	0.6	
		298	171023_024803	2:48	2:57	13062	346°	151	216	190	1.2	0.7	
		297	171023_030238	3:02	3:11	13107	166°	154	213	20	1.1	0.6	
		296	171023_031808	3:18	3:26	13062	346°	152	210	18	1.2	0.7	
		295	171023_033206	3:32	3:40	13065	166°	150	208	17	1.4	0.7	
		294	171023_034626	3:46	3:54	13075	346°	154	206	17	1.3	0.7	
		293	171023_035940	3:59	4:00	13085	166°	161	203	18	1.1	0.7	
		292	171023_041341	4:13	4:20	13096	346°	152	200	17	1.3	0.8	
		291	171023_042606	4:26	4:32	13082	166°	153	198	19	1.1	0.7	
		290	171023_043859	4:38	4:45	13092	346°	153	196	20	1.1	0.7	
		289	171023_045048	4:50	4:56	13106	166°	154	194	19	1.2	0.7	Brief IMU Error Refresh
		288	171023_050247	5:02	5:08	13106	346°	155	192	18	1.3	0.7	
		287	171023_051335	5:13	5:18	13116	166°	158	190	19	1.2	0.7	
		286	171023_052357	5:23	5:29	13103	346°	151	189	20	1.2	0.7	
		285	171023_053433	5:34	5:36	13123	166°	157	187	20	1.2	0.7	
		284	171023_054517	5:45	5:50	13125	346°	150	185	20	1.1	0.6	
		283	171023_055526	5:55	6:03	13125	166°	154	183	21	1.1	0.6	

Leica ALS80 Flight Log

Project:	NV_ Reno						Sensor Operator/s
							Jackson Beebe
Date/Julian:	10/23/2018	ALS80 SN# 8137	Disk Drive MM70	Flight Plan(s):			Pilot/s
Hobbs End	3410.9			NV_Reno			Keith Morrel
Hobbs ST	3406	LIFT		TARGET AIRSPD (KNTS)	BASE PID:	Base Height:	Aircraft / Airport Idnt:
Flight Time	4.9	B		155	TEMP	1.500	C421-N13RF / KMEV (Minden, NV)

Lift	#	Flight Line	Mission Line	UTC time: Begin:	UTC time: End:	GPS Altitude: ASL:	Direction	Speed: kts:	Available MM Space	S/Vs:	Position Acc. PDOP	Position Acc. HDOP	Comments and Conditions:
B		282	171023_173352	17:33	17:39	13116	346°	153	182	20	1.1	0.6	
		281	171023_174355	17:43	17:49	13162	166°	155	180	20	1.1	0.6	
		3	171023_180018	18:00	18:08	13225	76°	155	178	21	1	0.6	
		335	171023_181845	18:18	18:26	12914	166°	158	176	21	0.9	0.6	
		81	171023_183342	18:33	18:40	13182	166°	158	174	18	1.2	0.7	
		239	171023_184743	18:47	18:48	15092	41°	152	172	16	1.5	0.7	
		238	171023_185353	18:53	18:54	15314	221°	159	171	16	1.5	0.7	
		237	171023_190022	19:00	19:00	150064	41°	157	171	16	1.5	0.7	
		236	171023_190632	19:06	19:07	14736	221°	157	171	16	1.4	0.7	
		235	171023_191303	19:13	19:14	14530	41°	157	171	16	1.4	0.7	
		234	171023_191933	19:19	19:20	14388	221°	155	170	16	1.3	0.7	
		233	171023_192632	19:26	19:27	14171	41°	150	170	16	1.3	0.7	
		218	171023_193458	19:34	19:37	12670	221°	154	169	16	1.3	0.7	
		217	171023_194313	19:43	19:46	12661	41°	155	168	17	1.1	0.7	
		216	171023_195142	19:51	19:54	12593	221°	155	167	19	1	0.6	
		215	171023_200016	20:00	20:03	12553	41°	149	166	20	0.9	0.6	
		214	171023_200857	20:08	20:12	12488	221°	153	165	19	0.9	0.6	
		213	171023_201736	20:17	20:21	12429	41°	151	164	18	1	0.6	
		212	171023_202612	20:26	20:29	12431	221°	155	163	18	1	0.6	
		211	171023_203508	20:35	20:39	12360	41°	154	162	17	1.1	0.6	
		210	171023_204423	20:44	20:48	12378	221°	157	160	17	1.1	0.7	
		209	171023_205329	20:53	20:57	12361	41°	153	159	15	1.3	0.7	
		208	171023_210249	21:02	21:07	12395	221°	156	158	15	1.4	0.7	
		207	171023_211231	21:12	21:16	1295	41°	154	157	16	1.4	0.7	
		206	171023_212143	21:21	21:26	12279	221°	153	155	16	1.4	0.8	
		205	171023_213126	21:31	21:35	12289	41°	155	153	16	1.5	0.8	

Leica ALS80 Flight Log

		204	171023_214055	21:40	214:54	12328	221°	158	152	16	1.5	0.8	
		203	171023_215029	21:50	21:53	12301	41°	152	150	18	1.2	0.7	
		202	171023_215955	21:59	22:04	12278	221°	150	149	19	1.1	0.6	

Leica ALS80 Flight Log

DAS Digital Aerial Solutions

Project:	NV_ Reno				Sensor Operator/s
					Jackson Beebe

Date/Julian:	10/24/2018	ALS80 SN# 8137		Disk Drive MM70	Flight Plan(s):			Pilot/s	
Hobbs End	3415.5				NV_Reno			Keith Morrel	
Hobbs ST	3410.9		LIFT		TARGET AIRSPD (KNTS)	BASE PID:	Base Height:	Aircraft	Airport Idnt:
Flight Time	4.6		A		155	TEMP	1.500	C421-N13RF	KMEV (Minden, NV)

Lift	#	Flight Line	Mission Line	UTC time:		GPS Altitude: ASL:	Direction	Speed: kts:	Available	S/Vs:	Position Acc.		Comments and Conditions:
				Begin:	End:				MM Space		PDOP	HDOP	
A		201	171023_235715	23:57	:1	12297	41°	148	147	23	1.2	0.6	
		200	171024_000703	:7	:11	12324	221°	144	146	21	1.3	0.7	
		199	171024_001630	:16	:20	12283	41°	149	144	21	1.3	0.7	
		198	171024_002608	:26	:30	12300	221°	159	143	23	1.2	0.6	
		197	171024_003547	:35	:40	12339	41°	150	141	22	1.2	0.6	
		196	171024_004544	:45	:50	12324	221°	155	139	22	1.2	0.6	
		195	171024_005546	:55	1:00	12333	41°	152	138	22	1.2	0.6	
		194	171024_010523	1:05	1:10	12341	221°	159	136	21	1.2	0.6	
		193	171024_011519	1:15	11:20	12340	41°	154	135	21	1.1	0.6	
		192	171024_012458	1:24	1:29	12342	221°	158	133	21	1.1	0.6	
		191	171024_013521	1:35	1:40	13342	41°	152	131	21	1.1	0.6	
		190	171024_014533	1:45	1:50	12355	221°	157	130	21	1	0.6	
		189	171024_015618	1:56	2:01	12343	41°	152	128	23	1	0.6	
		188	171024_020633	2:06	2:11	12420	221°	158	126	24	0.9	0.6	
		187	171024_021610	2:16	2:21	12322	41°	154	124	23	0.9	0.6	
		186	171024_022612	2:26	2:31	12451	221°	154	123	21	1	0.7	
		185	171024_023644	2:36	2:42	12431	41°	153	121	20	1.1	0.7	
		184	171024_024652	2:46	2:52	12397	221°	159	119	20	1.1	0.7	
		183	171024_025648	2:56	3:02	12422	41°	150	117	19	1.1	0.6	
		182	171024_030641	3:06	3:11	12523	221°	158	116	19	1.1	0.6	
		181	171024_031708	3:17	3:22	12525	41°	153	114	18	1.2	0.7	
		180	171024_032654	3:26	3:31	12670	221°	156	112	17	1.4	0.7	
		179	171024_033720	3:37	3:42	12665	41°	155	111	17	1.3	0.7	
		178	171024_034646	3:46	3:51	12783	221°	160	109	18	1.1	0.7	
		177	171024_035630	3:56	4:01	12757	41°	159	108	17	1.2	0.7	
		176	171024_040622	4:06	4:11	12801	221°	159	106	16	1.3	0.7	

Leica ALS80 Flight Log

Project:	NV_ Reno						Sensor Operator/s
							Jackson Beebe
Date/Julian:	10/24/2018	ALS80 SN# 8137	Disk Drive MM70	Flight Plan(s):			Pilot/s
Hobbs End	3419.9			NV_Reno			Keith Morrel
Hobbs ST	3415.5	LIFT		TARGET AIRSPD (KNTS)	BASE PID:	Base Height:	Aircraft	Airport Idnt:
Flight Time	4.4	B		155	TEMP	1.500	C421-N13RF	KMEV (Minden, NV)

Lift	#	Flight Line	Mission Line	UTC time:		GPS Altitude: ASL:	Direction	Speed: kts:	Available	S/Vs:	Position Acc.		Comments and Conditions:
				Begin:	End:				MM Space		PDOP	HDOP	
B		175	171024_174829	17:48	17:53	12809	41°	160	310	20	1.1	0.6	
		155	171024_180021	18:00	18:07	13120	346°	156	308	20	1.1	0.6	
		154	171024_181140	18:11	18:18	13158	166°	152	308	22	0.9	0.5	
		153	171024_182300	18:23	18:29	13139	346°	154	304	19	1.1	0.6	
		152	171024_183500	18:35	18:41	13166	166°	154	302	20	1	0.6	
		151	171024_184641	18:46	18:53	13158	346°	154	300	17	1.4	0.7	
		150	171024_185801	18:58	19:04	13120	166°	149	298	17	1.4	0.7	
		149	171024_190930	19:09	19:16	13149	346°	159	298	17	1.4	0.7	
		148	171024_192106	19:21	19:27	13137	166°	150	294	17	1.3	0.7	
		147	171024_193231	19:32	19:39	13225	346°	155	293	17	1.2	0.7	
		146	171024_194406	19:44	19:50	13232	166°	153	291	18	1.1	0.7	
		145	171024_195533	19:55	20:02	13232	346°	154	289	21	1	0.6	
		144	171024_200708	20:07	20:13	13214	166°	154	287	21	0.9	0.6	
		143	171024_201847	20:18	20:25	13209	346°	156	285	19	1	0.6	
		142	171024_203031	20:30	20:37	13185	166°	156	283	18	1.1	0.6	
		141	171024_204211	20:42	20:48	13205	346°	155	281	18	1.1	0.7	
		140	171024_205404	20:54	21:00	13225	166°	156	279	16	1.4	0.7	
		139	171024_210528	21:05	21:12	13207	346°	155	277	17	1.4	0.7	
		138	171024_211656	21:16	21:23	13232	166°	156	274	16	1.6	0.8	
		137	171024_212836	21:28	21:35	13245	346°	155	273	16	1.6	0.8	
		136	171024_214023	21:40	21:46	13225	166°	156	271	17	1.5	0.8	

Leica ALS80 Flight Log

Project:	NV_ Reno						Sensor Operator/s
							Jackson Beebe
Date/Julian:	10/25/2018	ALS80 SN# 8137		Disk Drive MM70	Flight Plan(s):		Pilot/s
Hobbs End	3424.4				NV_Reno		Keith Morrel

Hobbs ST	3419.9		LIFT		TARGET AIRSPD (KNTS)	BASE PID:	Base Height:	Aircraft	Airport Idnt:
Flight Time	4.5		A		155	TEMP	1.500	C421-N13RF	KMEV (Minden, NV)

Lift	#	Flight Line	Mission Line	UTC time: Begin:	UTC time: End:	GPS Altitude: ASL:	Direction	Speed: kts:	Available MM Space	S/Vs:	Position Acc. PDOP	Position Acc. HDOP	Comments and Conditions:
A		135	171024_235828	23:58	:5	13184	346°	155	269	20	1.1	0.6	
		134	171025_000945	:9	:16	13193	166°	158	267	19	1.2	0.6	
		133	171025_002132	:21	:28	13231	346°	154	265	20	1.1	0.6	
		132	171025_003331	:33	:40	13219	166°	154	263	20	1.1	0.6	
		131	171025_004523	:45	:51	13212	346°	153	262	21	1.2	0.6	
		130	171025_005654	:56	1:03	13234	166°	155	260	21	1.2	0.6	
		129	171025_010838	1:08	1:15	12315	346°	151	258	20	1.2	0.6	
		128	171025_012015	1:20	1:27	13216	166°	153	256	21	1.1	0.6	
		127	171025_013300	1:33	1:40	13217	346°	153	253	22	1	0.6	
		126	171025_014520	1:45	1:52	13213	166°	152	251	21	1	0.6	
		125	171025_015805	1:58	2:05	13235	346°	152	249	21	1	0.6	
		124	171025_021058	2:10	2:18	13240	166°	153	249	21	1	0.6	
		123	171025_022333	2:23	2:31	13214	346°	148	245	18	1.1	0.7	
		122	171025_023557	2:35	2:43	13232	166°	155	242	17	1.2	0.8	
		121	171025_024845	2:48	2:56	13212	346°	153	240	17	1.1	0.7	
		120	171025_030145	3:01	3:09	13288	166°	158	238	18	1.1	0.7	
		119	171025_031429	3:14	3:22	13323	346°	155	236	15	1.3	0.8	
		118	171025_032712	3:27	3:34	13304	166°	154	234	15	1.3	0.8	
		117	171025_033957	3:39	3:47	13310	346°	156	231	15	1.4	0.8	
		116	171025_035226	3:52	3:59	13318	166°	156	229	14	1.6	0.9	

Leica ALS80 Flight Log

Project:	NV_ Reno						Sensor Operator/s
							Jackson Beebe
Date/Julian:	10/25/2018	ALS80 SN# 8137	Disk Drive MM70	Flight Plan(s):			Pilot/s
Hobbs End	3429.2			NV_Reno			Keith Morrel
Hobbs ST	3424.4	LIFT		TARGET AIRSPD (KNTS)	BASE PID:	Base Height:	Aircraft / Airport Idnt:
Flight Time	4.8	B		155	TEMP	1.500	C421-N13RF / KMEV (Minden, NV)

Lift	#	Flight Line	Mission Line	UTC time:		GPS Altitude: ASL:	Direction	Speed: kts:	Available	S/Vs:	Position Acc.		Comments and Conditions:
				Begin:	End:				MM Space		PDOP	HDOP	
B		105	171025_173037	17:30	17:34	13359	346°	152	226	18	1.2	0.6	
		106	171025_173847	17:38	17:42	13359	166°	152	225	18	1.2	0.6	
		107	171025_174652	17:46	17:53	13356	346°	153	224	19	1.1	0.6	
		108	171025_175727	17:57	18:03	13338	166°	159	223	20	1	0.6	
		109	171025_180850	18:08	18:15	13391	346°	140	221	20	1	0.6	
		110	171025_182005	18:20	18:26	13370	166°	1458	219	18	1.1	0.6	
		111	171025_183139	18:31	18:37	13379	346°	157	217	18	1.2	0.7	
		112	171025_184346	18:43	18:51	13333	166°	153	215	16	1.4	0.7	
		113	171025_185532	18:55	19:02	13374	346°	153	213	16	1.4	0.7	
		114	171025_190841	19:08	19:16	13363	166°	156	211	16	1.4	0.7	
		115	171025_192139	19:21	19:29	13365	346°	153	209	16	1.3	0.7	
		5	171025_193738	19:37	19:43	125723	346°	158	207	17	1.1	0.7	
		6	171025_194858	19:48	19:55	12602	166°	156	205	21	0.9	0.6	
		7	171025_200106	20:01	20:07	12598	346°	154	203	20	0.9	0.6	
		8	171025_201303	20:13	20:19	12472	166°	153	201	18	1.1	0.6	
		9	171025_202414	20:24	20:30	12470	346°	156	199	18	1.1	0.6	
		10	171025_203540	20:35	20:41	12471	166°	151	197	18	1.1	0.6	
		11	171025_204702	20:47	20:53	12463	346°	149	195	16	1.3	0.7	
		12	171025_205819	20:58	21:04	12489	166°	154	193	17	1.3	0.7	
		13	171025_210930	21:09	22:14	12496	346°	153	191	17	1.4	0.7	
		14	171025_212054	21:20	21:27	1244	166°	150	189	16	1.5	0.8	
		15	171025_213241	21:32	21:38	12527	346°	154	187	18	1.2	0.7	
		16	171025_214409	21:44	21:50	12450	166°	155	185	19	1.1	0.6	

Leica ALS80 Flight Log

Project:	NV_ Reno												Sensor Operator/s
													Jackson Beebe
Date/Julian:	10/25/2018	ALS80 SN# 8137		Disk Drive MM70			Flight Plan(s):						Pilot/s
Hobbs End	3433.3						NV_Reno						Keith Morrel
Hobbs ST	3429.2		LIFT				TARGET AIRSPD (KNTS)		BASE PID:		Base Height:	Aircraft	Airport Idnt:
Flight Time	4.1		C				155		TEMP		1.500	C421-N13RF	KMEV (Minden, NV)

Lift	#	Flight Line	Mission Line	UTC time:		GPS Altitude: ASL:	Direction	Speed: kts:	Available	S/Vs:	Position Acc.		Comments and Conditions:
				Begin:	End:				MM Space		PDOP	HDOP	
C		17	171025_235307	23:53	23:59	12411	345°	151	183	21	1.1	0.6	
		18	171026_000436	:4	:10	12445	165°	159	181	20	1.2	0.6	
		19	171026_001714	:17	:21	12440	345°	151	180	20	1.1	0.6	
		20	171026_002634	:26	:31	12435	165°	154	178	20	1.1	0.7	
		21	171026_003612	:36	:40	12432	345°	151	177	16	1.5	1	High PDOP/HDOP
		22	171026_004546	:45	:50	12428	165°	150	176	18	1.4	0.9	
		23	171026_005510	:55	:59	12429	345°	155	174	20	1.2	0.7	
		24	171026_010448	1:04	1:10	12446	165°	153	173	19	1.2	0.7	
		25	171026_011428	1:14	1:19	12509	345°	152	171	20	1.1	0.6	
		26	171026_012411	1:24	1:29	12492	165°	154	170	20	1.1	0.6	
		27	171026_013414	1:34	1:40	12697	345°	150	168	20	1	0.6	
		28	171026_014458	1:44	1:52	12927	165°	160	166	20	1.1	0.7	
		29	171026_015625	1:56	2:02	12934	345°	156	164	18	1.1	0.7	
		30	171026_020744	2:07	2:13	13052	165°	156	162	19	1.1	0.6	
		31	171026_021857	2:18	2:25	13052	346°	154	160	18	1.1	0.6	
		32	171026_023028	2:30	2:36	13084	165°	156	158	19	1.2	0.7	
		33	171026_024208	2:42	2:48	13050	345°	155	156	18	1.2	0.7	
		34	171026_025344	2:53	3:00	13183	165°	155	154	17	1.2	0.6	
		35	171026_030513	3:05	3:11	13189	345°	159	152	16	1.3	0.7	
		36	171026_031642	3:16	3:23	13180	165°	159	150	15	1.4	0.7	

Leica ALS80 Flight Log

Project:	NV_ Reno				Sensor Operator/s
					Jackson Beebe
Date/Julian:	10/26/2018	ALS80 SN# 8137	Disk Drive MM70	Flight Plan(s):	Pilot/s
Hobbs End	3438			NV_Reno	Keith Morrel

Hobbs ST	3433.3		LIFT		TARGET AIRSPD (KNTS)	BASE PID:	Base Height:	Aircraft	Airport Idnt:
Flight Time	4.7		A		155	TEMP	1.500	C421-N13RF	KMEV (Minden, NV)

Lift	#	Flight Line	Mission Line	UTC time: Begin:	UTC time: End:	GPS Altitude: ASL:	Direction	Speed: kts:	Available MM Space	S/Vs:	Position Acc. PDOP	Position Acc. HDOP	Comments and Conditions:
A		37	171026_170355	17:03	17:10	13128	345°	150	284	18	1.1	0.6	
		38	171026_171455	17:14	17:21	13164	166°	152	282	20	1	0.6	
		39	171026_172514	17:25	17:31	13125	345°	152	280	18	1.1	0.6	
		40	171026_173622	17:36	17:40	13137	166°	156	278	17	1.2	0.7	
		41	171026_174556	17:45	17:50	13146	345°	154	276	18	1.1	0.6	
		42	171026_175509	17:55	17:59	13150	166°	158	275	19	1	0.6	
		43	171026_180430	18:04	18:09	13142	345°	156	274	20	0.9	0.6	
		44	171026_181349	18:13	18:18	13275	165°	153	272	17	1.2	0.7	
		45	171026_182330	18:23	18:28	13273	345°	148	271	18	1.2	0.7	
		46	171026_183249	18:32	18:37	13777	166°	156	269	17	1.3	0.7	
		47	171026_184240	18:42	18:47	13304	345°	154	268	17	1.3	0.7	
		48	171026_185207	18:52	18:56	13017	166°	155	267	16	1.4	0.7	
		49	171026_190147	19:01	19:06	13028	345°	154	265	16	1.4	0.7	
		50	171026_191120	19:11	19:15	13030	166°	153	264	16	1.3	0.7	
		51	171026_192042	19:20	19:25	13003	343°	153	262	16	1.2	0.7	
		52	171026_193007	19:30	19:34	13012	165°	160	261	17	1.1	0.7	
		53	171026_193943	19:39	19:44	13028	345°	155	259	19	1.1	0.6	
		54	171026_194908	19:49	19:53	13028	165°	155	258	19	1	0.6	
		55	171026_195852	19:58	20:03	13042	345°	155	257	19	0.9	0.6	
		56	171026_200801	20:08	20:12	13034	165°	153	255	17	1	0.6	
		57	171026_201702	20:17	20:21	13231	345°	154	254	17	1.1	0.6	
		58	171026_202652	20:26	20:31	13314	165°	154	252	17	1.1	0.6	
		59	171026_203643	20:36	20:41	13306	345°	155	251	17	1.1	0.6	
		60	171026_204627	20:46	20:57	13311	165°	157	250	15	1.3	0.7	
		61	171026_205630	20:56	21:01	13228	345°	157	248	16	1.3	0.7	

Leica ALS80 Flight Log

DAS Digital Aerial Solutions

Project:	**NV_ Reno**						**Sensor Operator/s**	
							Jackson Beebe	
Date/Julian:	10/26/2018	ALS80 SN# 8137		**Disk Drive MM70**	**Flight Plan(s):**		**Pilot/s**	
Hobbs End	3442.5				NV_Reno		Keith Morrel	
Hobbs ST	3438		**LIFT**		**TARGET AIRSPD (KNTS)**	**BASE PID:**	**Base Height:**	**Aircraft**	**Airport Idnt:**
Flight Time	4.5		**A**		155	TEMP	1.500	C421-N13RF	KMEV (Minden, NV)

Lift	#	Flight Line	Mission Line	UTC time: Begin:	End:	GPS Altitude: ASL:	Direction	Speed: kts:	Available MM Space	S/Vs:	Position Acc. PDOP	HDOP	Comments and Conditions:
		1	171026_225618	22:56	23:04	13733	76°	151	246	21	1.3	0.6	cross/strip
		2	171026_231717	23:17	23:23	13613	256°	150	244	22	1.2	0.6	cross/strip
		R05	171026_233106	23:31		14343	166°		242				
		R02	171026_233321	23:33									
		R01	171026_233831	23:38									
		R08	171026_234332	23:43									
		R06	171026_234910	23:49									
		R37	171026_235446	23:54									
		R38	171027_000023	:									
		R39	171027_000614	:6									
		R40	171027_001237	:12	:13								
		R41	171027_001839	:18	:19								
		R36	171027_002430	:24	:25								
		R35	171027_003032	:30	:31								
		R34	171027_003605	:36									
		R33	171027_004212	:42									
		R32	171027_004824	:48									
		R31	171027_005422	:54									
		R30	171027_010025	1:00	1:01								
		R23	171027_010616	1:06									
		R17	171027_011104	1:11									
		R18	171027_011642	1:16									
		R16	171027_012233	1:22									
		R15	171027_012847	1:28									
		R14	171027_013416	1:34									
		R13	171027_014014	1:40									

Leica ALS80 Flight Log

		R12	171027_014541	1:45									
		R11	171027_015142	1:51									
		R10	171027_015727	1:57									
		R09	171027_020350	2:03									
		R07	171027_020949	2:09									
		R24	171027_021348	2:13									
		R20	171027_021532	2:15									
		R04	171027_022053	2:20									
		R29	171027_022614	2:26									
		R28	171027_023210	2:32									
		R19	171027_023306	2:33									
		R26	171027_024011	2:40									
		R25	171027_024428	2:44									
		R22	171027_024929	2:49									

Leica ALS80 Flight Log

Project:	NV_ Reno								Sensor Operator/s
									Jackson Beebe
Date/Julian:	10/26/2018	ALS80 SN# 8137		Disk Drive MM70	Flight Plan(s):				Pilot/s
Hobbs End	3443.2				NV_Reno				Keith Morrel
Hobbs ST	3442.5		LIFT		TARGET AIRSPD (KNTS)	BASE PID:	Base Height:	Aircraft	Airport Idnt:
Flight Time	0.7		C		155	TEMP	1.500	C421-N13RF	KMEV (Minden, NV)

Lift	#	Flight Line	Mission Line	UTC time:		GPS Altitude: ASL:	Direction	Speed: kts:	Available	S/Vs:	Position Acc.		Comments and Conditions:
				Begin:	End:				MM Space		PDOP	HDOP	
C		R27	171027_180434	18:04			348°		232				
		R21	171027_180917	18:09									
		R03	171027_181514	18:15									

Appendix B. Vertical Accuracy Calculations

Project Information

Prepared By: Kenneth L Coffey
Project Name: NV Reno Carson City
Sensor Info: Leica ALS80
Required Nominal Pulse Spacing: 0.35
Vendor Name: Digital Aerial Solutions .LLC
Units: Meters
Percent of Extent Tolerance: Extents Not Checked
Date of Aquisition: Start: 9/19/2017 Finish: 10/27/2017

Metadata Information

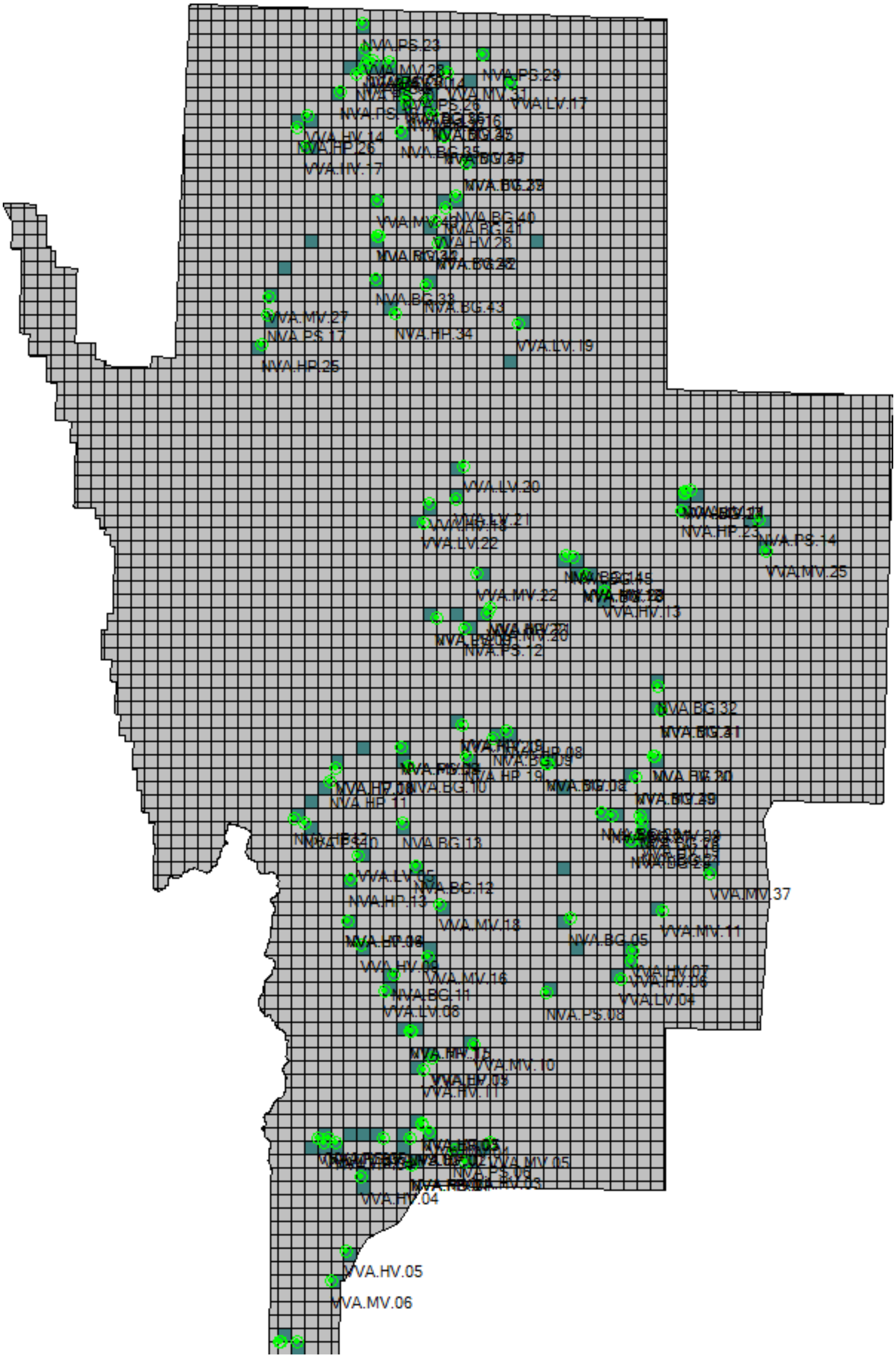
Tile Index:
- Filename: CLIP_NV_1K_LAS_Tiles.shp
- Number of Polys: 0

Intensity:
- Tile Index Attribute: Not Specified
- Data Filename: Not Specified

DEM:
- Tile Index Attribute: NAME
- Data Filename: Clipped

LAS:
- Tile Index Attribute: NAME
- Data Filename: LAS

Tiled-Data Area



LiDAR Accuracy Assessment Summary

LC Type	# of Points	NVA	VVA	
LAS				
Bare Ground	32	0.098		
Hard Pavement	20	0.112		
High Vegetation	17		0.110	
Low Vegetation	18		0.073	
Medium Vegetation	32		0.093	
Pack Sand	19	0.089		
Total	138			
DEM				
Bare Ground	32	0.100		
Hard Pavement	20	0.119		
High Vegetation	17		0.148	
Low Vegetation	18		0.104	
Medium Vegetation	32		0.106	
Pack Sand	19	0.094		
Total	138			

Units: Meters

Coordinates and Offsets of Analyzed Locations

		ID					
			Survey X	Survey Y	Z1	Z DEM	Z LAS
					LC Type	ΔZ DEM	ΔZ LAS
1)	☑	**NVA.BG.03A**					
			250244.122	4318038.929	2163.561	2163.484	2163.508
					Bare Ground	-0.077	-0.053
2)	☑	**NVA.BG.05**					
			271973.423	4349694.748	1560.549	1560.535	1560.528
					Bare Ground	-0.014	-0.021
3)	☑	**NVA.BG.08**					
			270241.281	4361309.801	1934.795	1934.726	1934.72
					Bare Ground	-0.069	-0.075
4)	☑	**NVA.BG.09**					
			266248.56	4363224.658	1481.683	1481.622	1481.6
					Bare Ground	-0.061	-0.083
5)	☑	**NVA.BG.10**					
			259795.06	4361167.423	1838.814	1838.798	1838.802
					Bare Ground	-0.016	-0.012
6)	☑	**NVA.BG.11**					
			258724.86	4345532.127	1543.781	1543.749	1543.744
					Bare Ground	-0.032	-0.037
7)	☑	**NVA.BG.12**					
			260353.727	4353643.357	1552.69	1552.714	1552.715
					Bare Ground	0.024	0.025

Coordinates and Offsets of Analyzed Locations (Continued)

		ID					
			Survey X	Survey Y	Z1	Z DEM	Z LAS
					LC Type	ΔZ DEM	ΔZ LAS
8)	☑	**NVA.BG.13**					
			259421.284	4356882.446	1547.528	1547.527	1547.532
					Bare Ground	-0.001	0.004
9)	☑	**NVA.BG.14**					
			271607.062	4376914.191	1354.109	1354.085	1354.09
					Bare Ground	-0.024	-0.019
10)	☑	**NVA.BG.15**					
			272251.052	4376819.247	1331.011	1331.008	1331.023
					Bare Ground	-0.003	0.012
11)	☑	**NVA.BG.16**					
			273058.573	4375480.444	1345.184	1345.164	1345.18
					Bare Ground	-0.02	-0.004
12)	☑	**NVA.BG.17**					
			280558.528	4381665.727	1304.147	1304.105	1304.109
					Bare Ground	-0.042	-0.038
13)	☑	**NVA.BG.24**					
			277346.7	4355681.048	1537.208	1537.307	1537.295
					Bare Ground	0.099	0.087
14)	☑	**NVA.BG.25**					
			276571.055	4355540.406	1558.04	1558.068	1558.051
					Bare Ground	0.028	0.011

Coordinates and Offsets of Analyzed Locations (Continued)

		ID					
			Survey X	Survey Y	Z1	Z DEM	Z LAS
					LC Type	ΔZ DEM	ΔZ LAS
15)	☑	**NVA.BG.26**					
			277323.692	4356988.818	1736.75	1736.742	1736.766
					Bare Ground	-0.008	0.016
16)	☑	**NVA.BG.27**					
			275141.375	4357400.1	1778.342	1778.356	1778.35
					Bare Ground	0.014	0.008
17)	☑	**NVA.BG.28**					
			274341.871	4357659.906	1931.523	1931.503	1931.505
					Bare Ground	-0.02	-0.018
18)	☑	**NVA.BG.29**					
			276948.999	4360293.082	1837.21	1837.22	1837.223
					Bare Ground	0.01	0.013
19)	☑	**NVA.BG.30**					
			278296.379	4361923.176	1793.652	1793.612	1793.636
					Bare Ground	-0.04	-0.016
20)	☑	**NVA.BG.31**					
			278800.915	4365322.289	1758.492	1758.362	1758.37
					Bare Ground	-0.13	-0.122
21)	☑	**NVA.BG.32**					
			278601.896	4367091.565	1714.901	1714.756	1714.764
					Bare Ground	-0.145	-0.137

Coordinates and Offsets of Analyzed Locations (Continued)

		ID					
			Survey X	Survey Y	Z1	Z DEM	Z LAS
					LC Type	ΔZ DEM	ΔZ LAS
22)	☑	**NVA.BG.33**					
			257416.204	4397686.049	1543.609	1543.614	1543.622
					Bare Ground	0.005	0.013
23)	☑	**NVA.BG.34**					
			257536.856	4400939.036	1675.732	1675.773	1675.783
					Bare Ground	0.041	0.051
24)	☑	**NVA.BG.35**					
			259328.032	4408701.385	1579.476	1579.474	1579.47
					Bare Ground	-0.002	-0.006
25)	☑	**NVA.BG.36**					
			259678.057	4411293.895	1616.269	1616.329	1616.341
					Bare Ground	0.06	0.072
26)	☑	**NVA.BG.37**					
			261661.994	4410052.846	1627.899	1627.902	1627.894
					Bare Ground	0.003	-0.005
27)	☑	**NVA.BG.38**					
			262545.573	4408347.662	1746.511	1746.539	1746.54
					Bare Ground	0.028	0.029
28)	☑	**NVA.BG.39**					
			264149.326	4406305.152	1543.064	1543.045	1543.056
					Bare Ground	-0.019	-0.008

Coordinates and Offsets of Analyzed Locations (Continued)

		ID					
			Survey X	Survey Y	Z1	Z DEM	Z LAS
					LC Type	ΔZ DEM	ΔZ LAS
29)	☑	**NVA.BG.40**					
			263437.076	4403900.184	1562.443	1562.497	1562.471
					Bare Ground	0.054	0.028
30)	☑	**NVA.BG.41**					
			262593.578	4403012.766	1598.613	1598.628	1598.658
					Bare Ground	0.015	0.045
31)	☑	**NVA.BG.42**					
			262060.194	4400355.207	1549.99	1550.033	1550.058
					Bare Ground	0.043	0.068
32)	☑	**NVA.BG.43**					
			261180.16	4397202.348	1551.117	1551.157	1551.147
					Bare Ground	0.04	0.03
33)	☑	**NVA.HP.01**					
			260090.266	4331304.003	1501.797	1501.813	1501.816
					Hard Pavement	0.016	0.019
34)	☑	**NVA.HP.02**					
			259930.611	4333245.923	1454.073	1454.099	1454.1
					Hard Pavement	0.026	0.027
35)	☑	**NVA.HP.04**					
			254432.307	4332876.681	1708.791	1708.847	1708.833
					Hard Pavement	0.056	0.042

Coordinates and Offsets of Analyzed Locations (Continued)

		ID					
			Survey X	Survey Y	Z1	Z DEM	Z LAS
					LC Type	ΔZ DEM	ΔZ LAS
36)	☑	NVA.HP.05					
			260856.059	4334298.574	1445.82	1445.791	1445.788
					Hard Pavement	-0.029	-0.032
37)	☑	NVA.HP.07					
			251482.829	4317967.107	2075.945	2075.817	2075.816
					Hard Pavement	-0.128	-0.129
38)	☑	NVA.HP.08					
			267162.876	4363743.27	1642.658	1642.58	1642.607
					Hard Pavement	-0.078	-0.051
39)	☑	NVA.HP.10					
			254431.015	4361015.03	1849.759	1849.662	1849.656
					Hard Pavement	-0.097	-0.103
40)	☑	NVA.HP.11					
			253952.746	4359955.868	1906.247	1906.203	1906.159
					Hard Pavement	-0.044	-0.088
41)	☑	NVA.HP.13					
			255477.844	4352644.52	1549.053	1548.977	1549.023
					Hard Pavement	-0.076	-0.03
42)	☑	NVA.HP.14					
			255258.558	4349548.263	1541.022	1540.94	1540.956
					Hard Pavement	-0.082	-0.066

Coordinates and Offsets of Analyzed Locations (Continued)

		ID				
			Survey X	Survey Y	Z1	Z DEM	Z LAS
					LC Type	ΔZ DEM	ΔZ LAS
43)	☑	NVA.HP.17					
			259991.982	4341231.157	1450.091	1450.076	1450.08
					Hard Pavement	-0.015	-0.011
44)	☑	NVA.HP.19					
			264174.186	4361930.152	1413.747	1413.753	1413.772
					Hard Pavement	0.006	0.025
45)	☑	NVA.HP.20					
			263855.503	4364228.647	1390.093	1390.087	1390.085
					Hard Pavement	-0.006	-0.008
46)	☑	NVA.HP.22					
			265964.295	4372987.633	1364.119	1364.16	1364.156
					Hard Pavement	0.041	0.037
47)	☑	NVA.HP.23					
			280396.462	4380333.896	1310.768	1310.73	1310.739
					Hard Pavement	-0.038	-0.029
48)	☑	NVA.HP.25					
			248838.345	4392713.852	1519.603	1519.552	1519.567
					Hard Pavement	-0.051	-0.036
49)	☑	NVA.HP.26					
			251494.758	4409036.363	1759.634	1759.573	1759.615
					Hard Pavement	-0.061	-0.019

Coordinates and Offsets of Analyzed Locations (Continued)

		ID					
			Survey X	Survey Y	Z1	Z DEM	Z LAS
					LC Type	ΔZ DEM	ΔZ LAS
50)	☑	NVA.HP.34					
			258876.235	4395146.386	1509.969	1509.929	1510.003
					Hard Pavement	-0.04	0.034
51)	☑	NVA.HP12					
			251311.849	4357262.871	2515.081	2514.976	2514.969
					Hard Pavement	-0.105	-0.112
52)	☑	VVA.HP.15					
			261606.381	4339243.81	1423.046	1423.045	1423.045
					Hard Pavement	-0.001	-0.001
53)	☑	NVA.PS.01					
			260077.748	4331270.429	1499.361	1499.378	1499.405
					Pack Sand	0.017	0.044
54)	☑	NVA.PS.02					
			257949.35	4333225.197	1534.277	1534.321	1534.334
					Pack Sand	0.044	0.057
55)	☑	NVA.PS.05					
			253843.07	4333261.732	1763.536	1763.508	1763.511
					Pack Sand	-0.028	-0.025
56)	☑	NVA.PS.06					
			263283.818	4332312.137	1439.166	1439.088	1439.113
					Pack Sand	-0.078	-0.053

Coordinates and Offsets of Analyzed Locations (Continued)

		ID					
			Survey X	Survey Y	Z1	Z DEM	Z LAS
					LC Type	ΔZ DEM	ΔZ LAS
57)	☑	**NVA.PS.08**					
			270232.562	4344152.078	1481.648	1481.603	1481.622
					Pack Sand	-0.045	-0.026
58)	☑	**NVA.PS.09**					
			259304.563	4362515.291	1673.398	1673.414	1673.424
					Pack Sand	0.016	0.026
59)	☑	**NVA.PS.11**					
			261949.149	4372209.098	1352.894	1352.941	1352.943
					Pack Sand	0.047	0.049
60)	☑	**NVA.PS.12**					
			264091.47	4371438.505	1373.478	1373.512	1373.501
					Pack Sand	0.034	0.023
61)	☑	**NVA.PS.14**					
			286148.928	4379619.688	1376.758	1376.75	1376.742
					Pack Sand	-0.008	-0.016
62)	☑	**NVA.PS.17**					
			249279.308	4394940.003	1549.494	1549.465	1549.468
					Pack Sand	-0.029	-0.026
63)	☑	**NVA.PS.19**					
			254736.826	4411680.533	1609.864	1609.874	1609.865
					Pack Sand	0.01	0.001

Coordinates and Offsets of Analyzed Locations (Continued)

		ID					
			Survey X	Survey Y	Z1	Z DEM	Z LAS
					LC Type	ΔZ DEM	ΔZ LAS
64)	☑	NVA.PS.20					
			255956.585	4413033.566	1575.988	1576.051	1576.053
					Pack Sand	0.063	0.065
65)	☑	NVA.PS.21					
			256466.575	4413504.973	1561.61	1561.667	1561.628
					Pack Sand	0.057	0.018
66)	☑	NVA.PS.22					
			256684.262	4413982.568	1552.958	1552.982	1552.983
					Pack Sand	0.024	0.025
67)	☑	NVA.PS.23					
			256429.905	4416791.861	1514.027	1514.052	1514.053
					Pack Sand	0.025	0.025
68)	☑	NVA.PS.26					
			259511.422	4412301.519	1603.816	1603.853	1603.868
					Pack Sand	0.037	0.052
69)	☑	NVA.PS.27					
			259741.516	4410771.315	1624.1	1624.116	1624.124
					Pack Sand	0.016	0.024
70)	☑	NVA.PS.29					
			265439.212	4414492.122	1408.449	1408.498	1408.51
					Pack Sand	0.049	0.061

		ID					
			Survey X	Survey Y	Z1	Z DEM	Z LAS
					LC Type	ΔZ DEM	ΔZ LAS
71)	☑	NVA.PS10					
			252100.416	4356929.867	2413.397	2413.272	2413.284
					Pack Sand	-0.125	-0.113
72)	☑	VVA.HV.03					
			264053.116	4331467.387	1413.68	1413.77	1413.743
					High Vegetation	0.09	0.063
73)	☑	VVA.HV.04					
			256327.202	4330313.766	1571.086	1571.253	1571.196
					High Vegetation	0.167	0.11
74)	☑	VVA.HV.05					
			255144.678	4324824.1	1448.548	1448.696	1448.649
					High Vegetation	0.148	0.101
75)	☑	VVA.HV.06					
			276516.238	4346526.834	1327.67	1327.647	1327.669
					High Vegetation	-0.023	-0.001
76)	☑	VVA.HV.07					
			276669.651	4347338.265	1321.574	1321.651	1321.71
					High Vegetation	0.077	0.136
77)	☑	VVA.HV.08					
			254408.565	4361040.25	1850.649	1850.658	1850.672
					High Vegetation	0.009	0.023

Coordinates and Offsets of Analyzed Locations (Continued)

		ID					
			Survey X	Survey Y	Z1	Z DEM	Z LAS
					LC Type	ΔZ DEM	ΔZ LAS
78)	☑	**VVA.HV.09**					
			256290.205	4347719.943	1543.684	1543.65	1543.643
					High Vegetation	-0.034	-0.042
79)	☑	**VVA.HV.11**					
			260946.977	4338375.064	1424.562	1424.535	1424.556
					High Vegetation	-0.027	-0.006
80)	☑	**VVA.HV.12**					
			273066.04	4375519.736	1344.23	1344.307	1344.265
					High Vegetation	0.077	0.035
81)	☑	**VVA.HV.13**					
			274508.97	4374275.62	1370.766	1370.807	1370.795
					High Vegetation	0.041	0.029
82)	☑	**VVA.HV.14**					
			252236.994	4409888.614	1677.846	1677.863	1677.863
					High Vegetation	0.017	0.017
83)	☑	**VVA.HV.17**					
			252114.228	4407548.112	1766.893	1766.962	1766.978
					High Vegetation	0.069	0.084
84)	☑	**VVA.HV.18**					
			261410.453	4380811.423	1353.853	1353.771	1353.775
					High Vegetation	-0.082	-0.078

Coordinates and Offsets of Analyzed Locations (Continued)

		ID					
			Survey X	Survey Y	Z1	Z DEM	Z LAS
					LC Type	ΔZ DEM	ΔZ LAS
85)	☑	VVA.HV.19					
			277397.356	4356344.905	1645.479	1645.47	1645.52
					High Vegetation	-0.009	0.041
86)	☑	VVA.HV.20					
			278279.178	4361935.702	1794.376	1794.246	1794.29
					High Vegetation	-0.13	-0.086
87)	☑	VVA.HV.27					
			264170.594	4406300.763	1542.25	1542.272	1542.267
					High Vegetation	0.022	0.017
88)	☑	VVA.HV.28					
			261825.682	4401955.08	1589.923	1590.029	1589.988
					High Vegetation	0.106	0.065
89)	☑	VVA.LV.01					
			259940.397	4333201.911	1454.564	1454.59	1454.594
					Low Vegetation	0.026	0.03
90)	☑	VVA.LV.02					
			253498.44	4332973.635	1740.606	1740.603	1740.605
					Low Vegetation	-0.003	-0.001
91)	☑	VVA.LV.03					
			260858.66	4334330.938	1446.07	1446.06	1446.073
					Low Vegetation	-0.01	0.003

Coordinates and Offsets of Analyzed Locations (Continued)

		ID					
			Survey X	Survey Y	Z1	Z DEM	Z LAS
					LC Type	ΔZ DEM	ΔZ LAS
92)	☑	VVA.LV.04					
			275740.261	4345190.586	1330.834	1330.856	1330.868
					Low Vegetation	0.022	0.034
93)	☑	VVA.LV.05					
			256089.83	4354472.255	1556.336	1556.298	1556.291
					Low Vegetation	-0.038	-0.045
94)	☑	VVA.LV.06					
			255272.953	4349568.976	1539.967	1539.955	1539.979
					Low Vegetation	-0.012	0.012
95)	☑	VVA.LV.07					
			261655.447	4339236.857	1422.16	1422.149	1422.143
					Low Vegetation	-0.011	-0.018
96)	☑	VVA.LV.08					
			258033.599	4344308.81	1550.807	1550.801	1550.812
					Low Vegetation	-0.006	0.005
97)	☑	VVA.LV.09					
			261929.033	4372226.508	1353.061	1353.093	1353.107
					Low Vegetation	0.032	0.046
98)	☑	VVA.LV.11					
			281000.312	4381820.762	1307.682	1307.651	1307.651
					Low Vegetation	-0.031	-0.031

Coordinates and Offsets of Analyzed Locations (Continued)

		ID					
			Survey X	Survey Y	Z1	Z DEM	Z LAS
					LC Type	ΔZ DEM	ΔZ LAS
99)	☑	VVA.LV.14					
			258406.485	4413882.723	1541.97	1541.94	1541.953
					Low Vegetation	-0.03	-0.017
100)	☑	VVA.LV.16					
			261156.124	4411042.802	1599.527	1599.631	1599.584
					Low Vegetation	0.104	0.057
101)	☑	VVA.LV.17					
			267569.48	4412428.563	1316.993	1317.036	1317.036
					Low Vegetation	0.043	0.043
102)	☑	VVA.LV.19					
			268087.132	4394276.469	1386.738	1386.85	1386.788
					Low Vegetation	0.112	0.05
103)	☑	VVA.LV.20					
			263977.132	4383624.562	1391.741	1391.7	1391.683
					Low Vegetation	-0.041	-0.058
104)	☑	VVA.LV.21					
			263370.479	4381176.125	1347.699	1347.616	1347.626
					Low Vegetation	-0.083	-0.073
105)	☑	VVA.LV.22					
			260908.054	4379408.603	1353.934	1353.884	1353.87
					Low Vegetation	-0.05	-0.064

Coordinates and Offsets of Analyzed Locations (Continued)

		ID					
			Survey X	Survey Y	Z1	Z DEM	Z LAS
					LC Type	ΔZ DEM	ΔZ LAS
106)	☑	VVA.LV.28					
			262075.273	4400359.356	1549.826	1549.898	1549.907
					Low Vegetation	0.072	0.081
107)	☑	VVA.MV.01					
			260123.163	4331257.599	1502.811	1502.917	1502.904
					Medium Vegetation	0.106	0.093
108)	☑	VVA.MV.03					
			253103.693	4333306.699	1794.299	1794.315	1794.303
					Medium Vegetation	0.016	0.004
109)	☑	VVA.MV.04					
			261453.963	4333719.388	1439.973	1439.998	1440.01
					Medium Vegetation	0.025	0.037
110)	☑	VVA.MV.05					
			265944.636	4332937.55	1418.247	1418.296	1418.281
					Medium Vegetation	0.049	0.034
111)	☑	VVA.MV.06					
			254068.118	4322510.346	1460.026	1460.136	1460.126
					Medium Vegetation	0.11	0.1
112)	☑	VVA.MV.08					
			250189.547	4318008.106	2166.073	2166.106	2166.074
					Medium Vegetation	0.033	0.001

Coordinates and Offsets of Analyzed Locations (Continued)

		ID					
			Survey X	Survey Y	Z1	Z DEM	Z LAS
					LC Type	ΔZ DEM	ΔZ LAS
113)	☑	VVA.MV.10					
			264764.773	4340278.581	1412.03	1411.953	1411.958
					Medium Vegetation	-0.077	-0.072
114)	☑	VVA.MV.11					
			278855.283	4350324.596	1326.654	1326.722	1326.729
					Medium Vegetation	0.068	0.075
115)	☑	VVA.MV.12					
			270277.978	4361313.335	1932.919	1932.881	1932.84
					Medium Vegetation	-0.038	-0.079
116)	☑	VVA.MV.14					
			259321.83	4362521.322	1672.985	1673.022	1673.012
					Medium Vegetation	0.037	0.027
117)	☑	VVA.MV.15					
			260036.705	4341230.108	1448.416	1448.557	1448.5
					Medium Vegetation	0.141	0.084
118)	☑	VVA.MV.16					
			261250.282	4346845.995	1549.494	1549.544	1549.492
					Medium Vegetation	0.05	-0.002
119)	☑	VVA.MV.18					
			262230.859	4350800.154	1561.104	1561.159	1561.166
					Medium Vegetation	0.055	0.062

Coordinates and Offsets of Analyzed Locations (Continued)

		ID				
			Survey X	Survey Y	Z1	Z DEM	Z LAS
					LC Type	ΔZ DEM	ΔZ LAS
120)	☑	VVA.MV.19					
			263874.341	4364265.688	1389.309	1389.324	1389.349
					Medium Vegetation	0.015	0.04
121)	☑	VVA.MV.20					
			265801.209	4372569.162	1386.607	1386.652	1386.688
					Medium Vegetation	0.045	0.081
122)	☑	VVA.MV.21					
			265983.351	4372995.75	1365.034	1365.091	1365.085
					Medium Vegetation	0.057	0.051
123)	☑	VVA.MV.22					
			265023.936	4375571.919	1338.797	1338.869	1338.891
					Medium Vegetation	0.072	0.094
124)	☑	VVA.MV.23					
			273103.663	4375508.195	1345.511	1345.534	1345.554
					Medium Vegetation	0.023	0.043
125)	☑	VVA.MV.24					
			280543.625	4381675.251	1304.599	1304.571	1304.608
					Medium Vegetation	-0.028	0.009
126)	☑	VVA.MV.25					
			286709.35	4377289.998	1457.819	1457.78	1457.776
					Medium Vegetation	-0.039	-0.043

Coordinates and Offsets of Analyzed Locations (Continued)

		ID					
			Survey X	Survey Y	Z1	Z DEM	Z LAS
					LC Type	ΔZ DEM	ΔZ LAS
127)	☑	VVA.MV.27					
			249355.773	4396343.949	1578.84	1578.85	1578.875
					Medium Vegetation	0.01	0.035
128)	☑	VVA.MV.28					
			256604.726	4414894.456	1546.168	1546.222	1546.229
					Medium Vegetation	0.054	0.061
129)	☑	VVA.MV.30					
			257149.992	4413997.34	1546.964	1546.987	1546.997
					Medium Vegetation	0.023	0.033
130)	☑	VVA.MV.31					
			262784.504	4413127.863	1531.308	1531.359	1531.37
					Medium Vegetation	0.051	0.062
131)	☑	VVA.MV.37					
			282521.392	4353137.669	1322.79	1322.824	1322.812
					Medium Vegetation	0.034	0.022
132)	☑	VVA.MV.39					
			277274.264	4357491.917	1773.836	1773.82	1773.848
					Medium Vegetation	-0.016	0.012
133)	☑	VVA.MV.40					
			276930.14	4360314.501	1835.441	1835.451	1835.466
					Medium Vegetation	0.01	0.025

Coordinates and Offsets of Analyzed Locations (Continued)

		ID					
			Survey X	Survey Y	Z1	Z DEM	Z LAS
					LC Type	ΔZ DEM	ΔZ LAS
134)	☑	VVA.MV.41					
			278801.133	4365338.805	1758.597	1758.539	1758.566
					Medium Vegetation	-0.058	-0.031
135)	☑	VVA.MV.42					
			257564.889	4400938.394	1676.647	1676.667	1676.728
					Medium Vegetation	0.02	0.081
136)	☑	VVA.MV.43					
			257515.177	4403556.876	1563.513	1563.554	1563.575
					Medium Vegetation	0.041	0.062
137)	☑	VVA.MV.45					
			261651.638	4410039.138	1627.872	1627.877	1627.892
					Medium Vegetation	0.005	0.02
138)	☑	VVA.MV.47					
			262558.096	4408354.54	1746.299	1746.344	1746.353
					Medium Vegetation	0.045	0.054

LAS

Nonvegetated Vertical Accuracy
LandCover Type: Bare Ground, Hard Pavement, Pack Sand

Minimum DZ: -0.137

Maximum DZ: 0.087

Mean DZ: -0.006

Mean Magnitude DZ: 0.198

Number Observations: 71

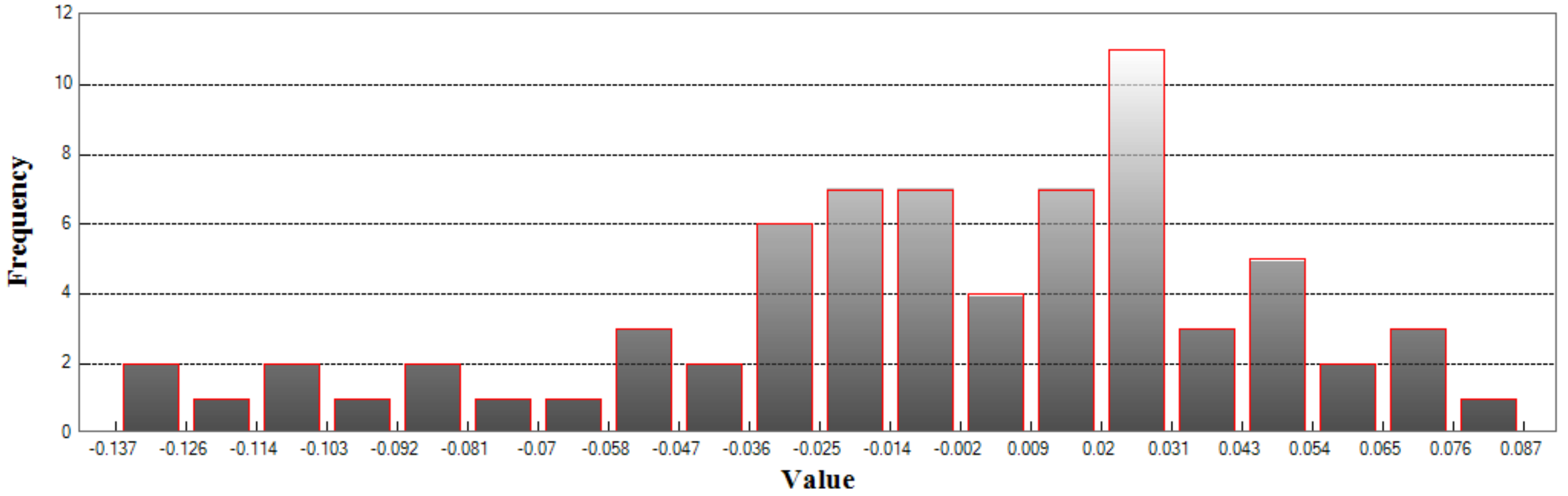
Standard Deviation DZ: 0.051

RMSE Z: 0.051

95% Confidence Level Z: 0.1

Units: Meters

Histogram



Min: -0.137

Max: 0.087

Number Of Bins: 20

Bin Interval: 0.011

LAS (Continued)

Vegetated Vertical Accuracy

LandCover Type: High Vegetation

Minimum DZ: -0.086

Maximum DZ: 0.136

Mean DZ: 0.03

Mean Magnitude DZ: 0.234

Number Observations: 17

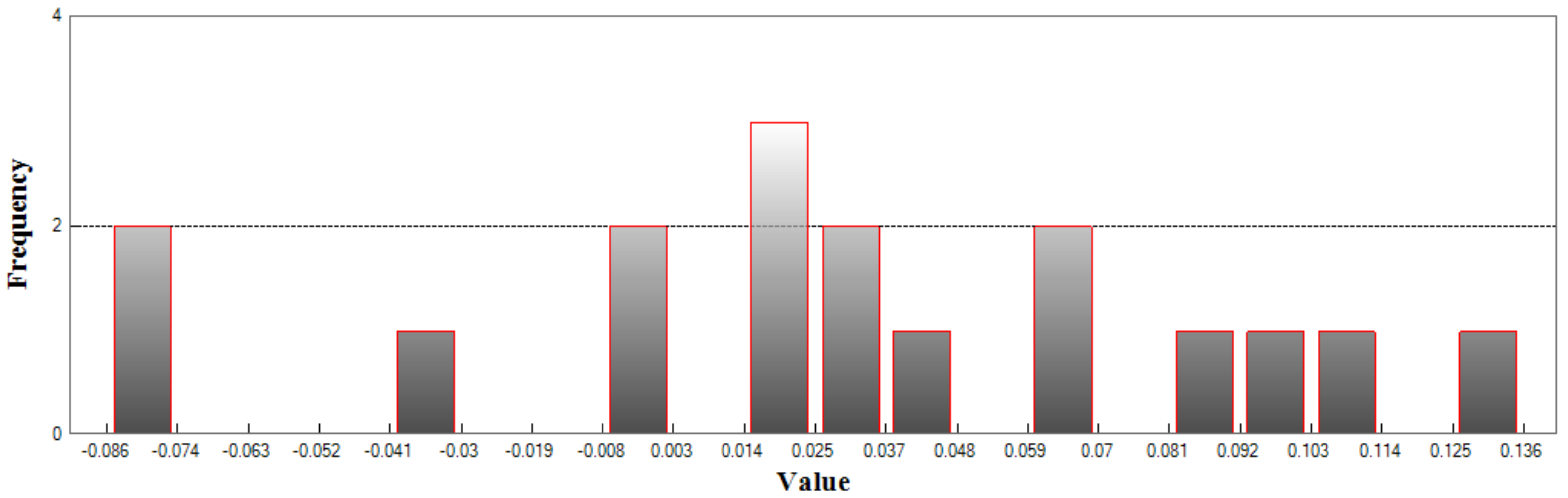
Standard Deviation DZ: 0.062

RMSE Z: 0.067

95th Percentile: 0.11

Units: Meters

Histogram



Min: -0.086

Max: 0.136

Number Of Bins: 20

Bin Interval: 0.011

LAS (Continued)

Vegetated Vertical Accuracy

LandCover Type: Low Vegetation

Minimum DZ: -0.073

Maximum DZ: 0.081

Mean DZ: 0.003

Mean Magnitude DZ: 0.192

Number Observations: 18

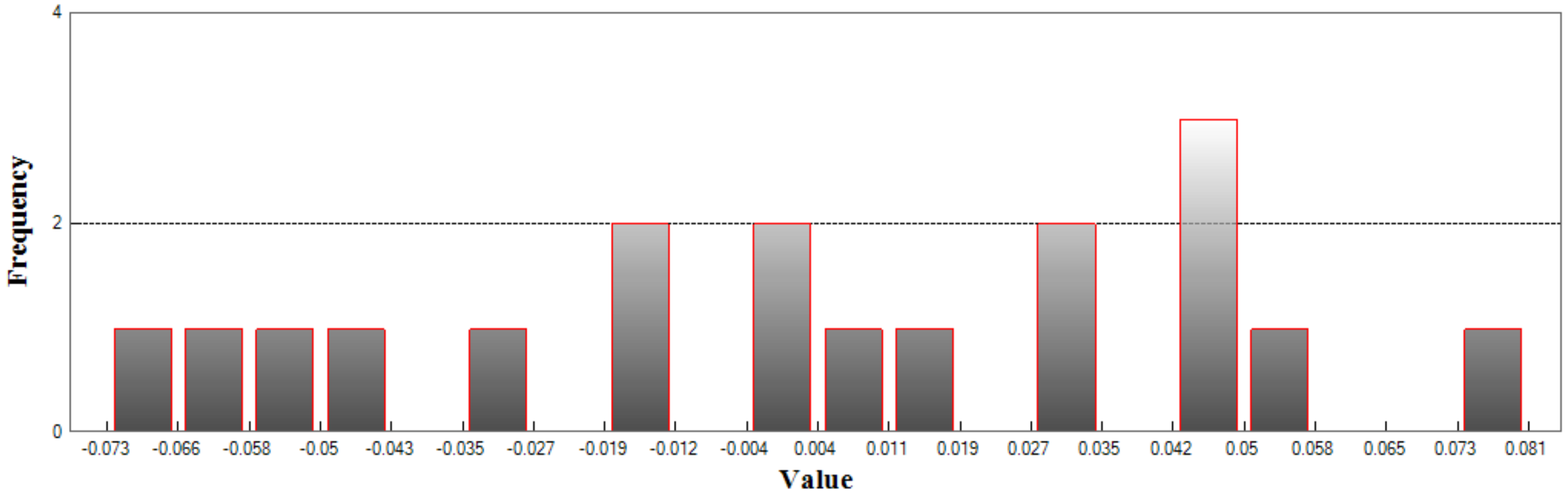
Standard Deviation DZ: 0.045

RMSE Z: 0.044

95th Percentile: 0.073

Units: Meters

Histogram



Min: -0.073

Max: 0.081

Number Of Bins: 20

Bin Interval: 0.008

LAS (Continued)

Vegetated Vertical Accuracy

LandCover Type: Medium Vegetation

Minimum DZ: -0.079

Maximum DZ: 0.1

Mean DZ: 0.034

Mean Magnitude DZ: 0.219

Number Observations: 32

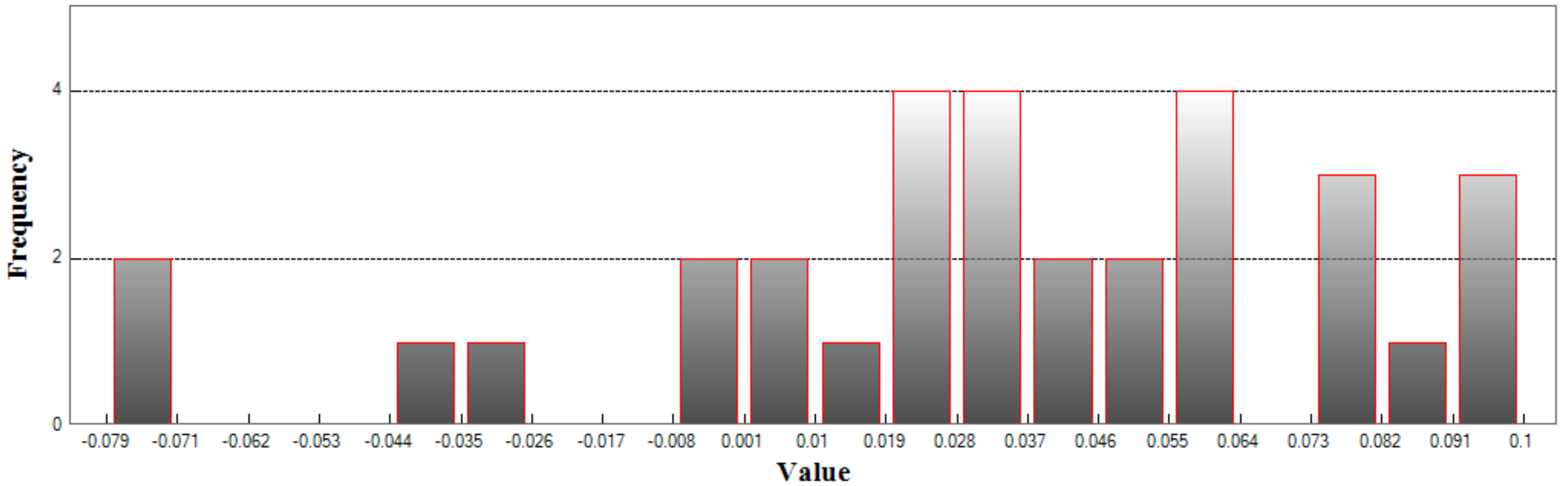
Standard Deviation DZ: 0.045

RMSE Z: 0.056

95th Percentile: 0.093

Units: Meters

Histogram



Min: -0.079

Max: 0.1

Number Of Bins: 20

Bin Interval: 0.009

DEM

Nonvegetated Vertical Accuracy
LandCover Type: Bare Ground, Hard Pavement, Pack Sand

Minimum DZ: -0.145

Maximum DZ: 0.099

Mean DZ: -0.012

Mean Magnitude DZ: 0.203

Number Observations: 71

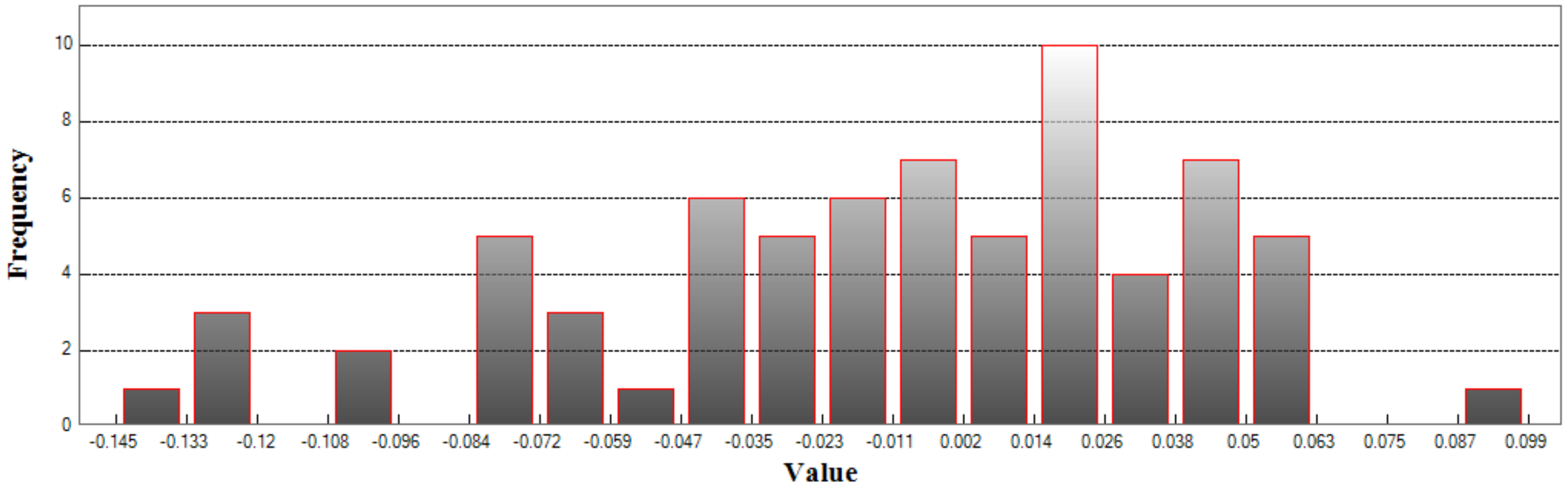
Standard Deviation DZ: 0.052

RMSE Z: 0.053

95% Confidence Level Z: 0.104

Units: Meters

Histogram



Min: -0.145

Max: 0.099

Number Of Bins: 20

Bin Interval: 0.012

DEM (Continued)

Vegetated Vertical Accuracy

LandCover Type: High Vegetation

Minimum DZ: -0.13

Maximum DZ: 0.167

Mean DZ: 0.03

Mean Magnitude DZ: 0.257

Number Observations: 17

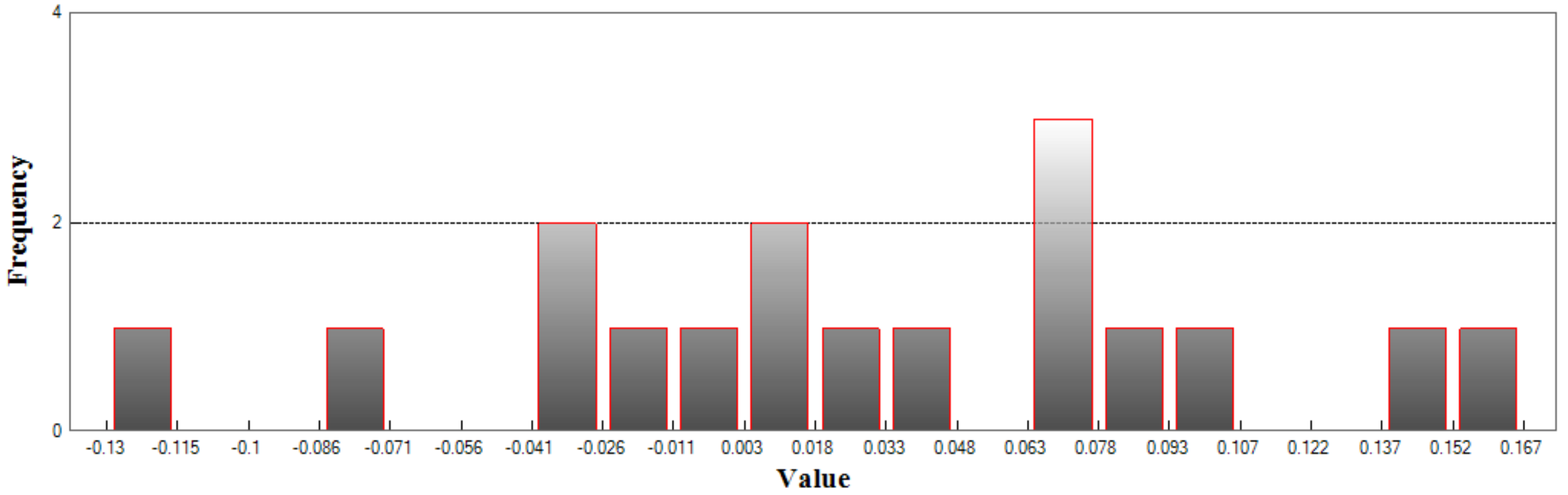
Standard Deviation DZ: 0.078

RMSE Z: 0.082

95th Percentile: 0.148

Units: Meters

Histogram



Min: -0.13

Max: 0.167

Number Of Bins: 20

Bin Interval: 0.015

DEM (Continued)

Vegetated Vertical Accuracy

LandCover Type: Low Vegetation

Minimum DZ: -0.083

Maximum DZ: 0.112

Mean DZ: 0.005

Mean Magnitude DZ: 0.201

Number Observations: 18

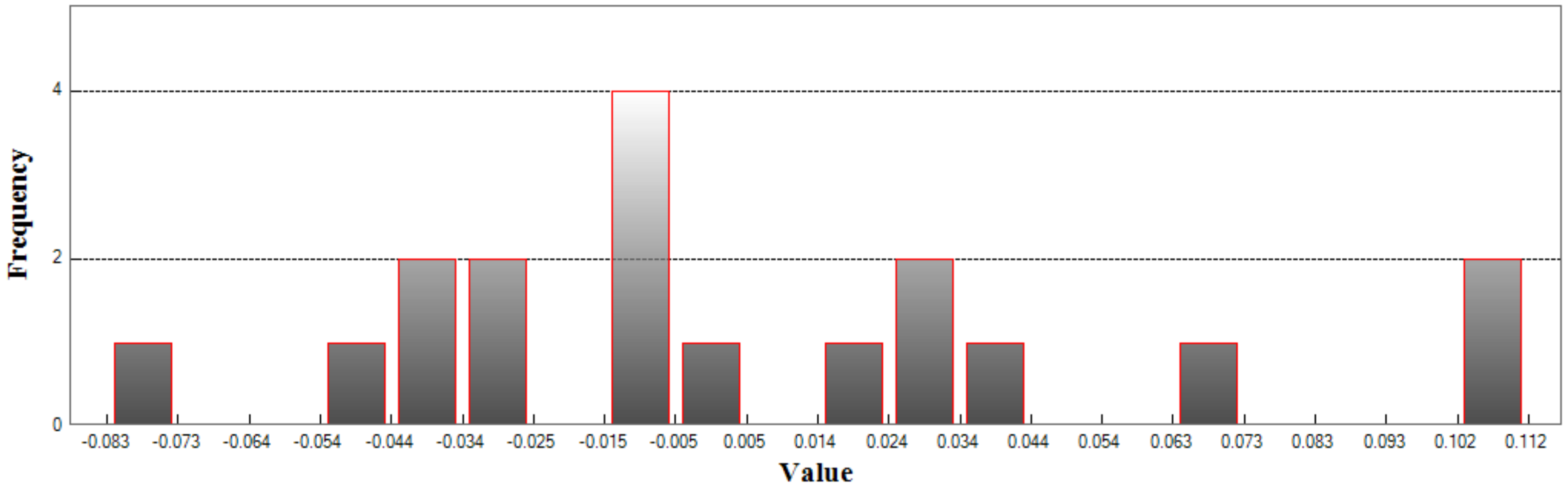
Standard Deviation DZ: 0.052

RMSE Z: 0.051

95th Percentile: 0.104

Units: Meters

Histogram



Min: -0.083

Max: 0.112

Number Of Bins: 20

Bin Interval: 0.01

DEM (Continued)

Vegetated Vertical Accuracy

LandCover Type: Medium Vegetation

Minimum DZ: -0.077

Maximum DZ: 0.141

Mean DZ: 0.029

Mean Magnitude DZ: 0.213

Number Observations: 32

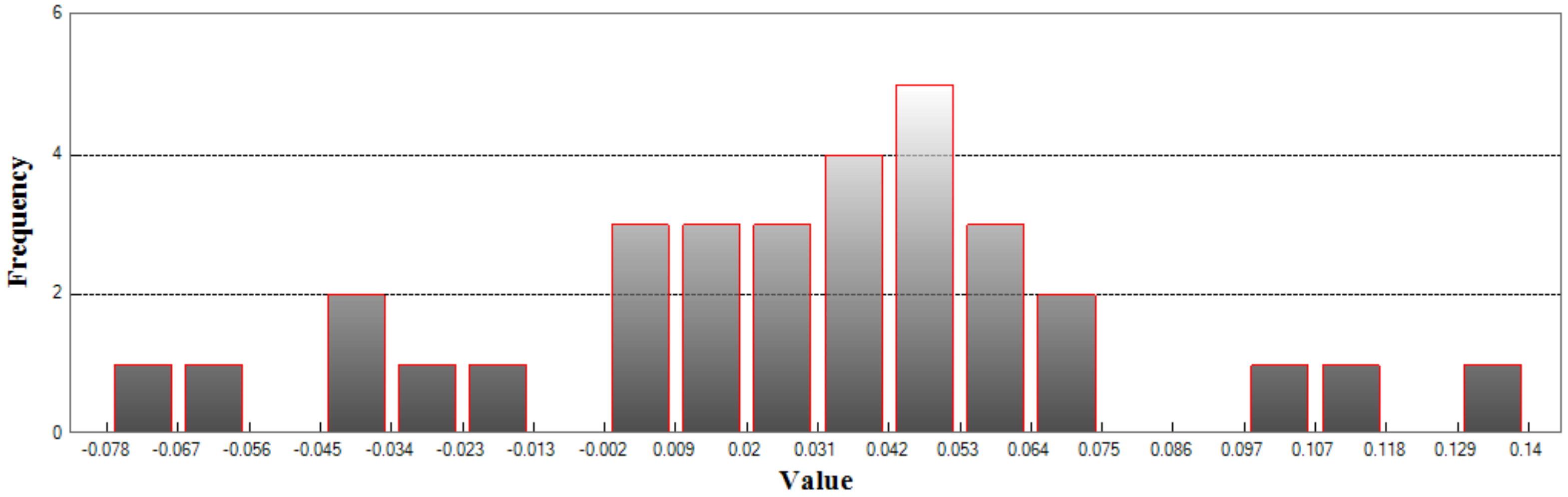
Standard Deviation DZ: 0.047

RMSE Z: 0.055

95th Percentile: 0.106

Units: Meters

Histogram



Min: -0.077

Max: 0.141

Number Of Bins: 20

Bin Interval: 0.011