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Vermont Department of Environmental Conservation *Agency of Natural Resources*
Water Investment Division
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MEMORANDUM

TO:	Town of Glover Selectboard, care of Brian Carroll, Selectman - Dam Owner
FROM:	Benjamin Green, PE, Dam Safety Program (DSP), Engineer
DATE:	December 8, 2021
SUBJECT:	DSS-Wise Lite Dam Failure Analysis and Flood Inundation Maps Shadow Lake Dam, Glover, Vermont State ID No: 81.02 | National ID No: VT00070

This memorandum discusses the methods, assumptions, and results of dam failure and downstream flood inundation analysis using the Decision System for Water Infrastructural Security (DSS-Wise Lite) model for the Shadow Lake Dam. Shadow Lake Dam and its floodway are in the Town of Glover and downstream communities along the Barton River. The following attachments are included:

- ***Attachment A:*** Dam Failure Flood Inundation Maps
- ***Attachment B:*** DSS-Wise Lite Simulation Results Final Report
- ***Attachment C:*** DSS-Wise Lite Human Consequences Final Report
- ***Attachment D:*** ACER Technical Memorandum No. 11 – USBR, Depth-Velocity Flood Danger Relationships

It should be noted that ***Attachments B*** and ***C*** are automatically generated reports by the DSS-Wise Lite Program.

Purpose:
The analysis was performed to investigate the hazard potential classification of the dam and potential downstream consequences in the event of a dam failure.

Dam Overview:
Shadow Lake Dam is an earth embankment dam with a principal spillway and concrete auxiliary spillway. The dam is currently classified as a SIGNIFICANT hazard potential dam. According to file information, the dam is approximately 130 feet long with a structural height of about 13 feet. The upstream face of the dam consists of a riprap armored slope and granite block wall. The dam crest is about 8 feet wide and surfaced with grass. The downstream slope is earthen, inclined at approximately 3H:1V, and surfaced with grass. The principal spillway is a cast-in-place concrete drop inlet-style spillway with a single, upstream stoplog section that controls the lake elevation. Flow over the stoplogs is released through a 36-inch diameter slide gate that is generally maintained in the open position. The stoplogs and slide gate are housed in a timber building near the right abutment. The auxiliary spillway is a concrete and ogee-style weir chute spillway with a width of 15 feet and a chute length of approximately 33.5 feet. The drainage area of the dam is reportedly 5.3 square miles. Shadow Lake at normal pool is approximately 220 acres. The normal and maximum storage capacities of the dam are approximately 1,709 acre-feet and 2,866 acre-feet, respectively, based on recent computations by Dubois & King, Inc. The values were reportedly estimated by using available bathometric mapping below normal pool levels and available LIDAR mapping above normal pool levels.

The dam's original construction dates to the 1800s and the auxiliary spillway was reportedly constructed to its current configuration circa 1929. The dam was originally used in the timber trade and is now used for recreation. The dam's configuration, while reportedly advantageous for its original purpose, results in an inflow versus outflow imbalance during storm/high runoff events such that more flood waters are stored in the reservoir area than are discharged downstream. This results in elevated reservoir levels and lower than natural (restricted) outflows below the dam. While not designed or intended for this purpose, the dam does provide a measure of flood storage and protection to properties and infrastructure downstream while having prolonged, elevated reservoir pools upstream.

Downstream Conditions:
The Shadow Lake Dam discharges into the Shadow Lake Brook, a steeply graded stream that flows easterly along Shadow Lake Road to its confluence with the Barton River approximately 1 mile downstream. From this confluence, the Barton River flows northerly along Route 16 through downtown Glover approximately 4.5 miles downstream of the dam. The Barton River then extends further north, flowing under Interstate Highway Route 91 approximately 7.8 miles downstream of the dam, just upstream of a portion of the Town of Barton. The Barton River continues to flow northerly approximately 21 miles from the dam through Barton and Orleans to its confluence with the South Bay of Lake Memphremagog. It appears that a dam failure could potentially impact road crossings, homes, and businesses.

Previous Study:
A Dam Break Flood Analysis was performed circa 1991for Shadow Lake Dam by D&K under contract with the Army Corps of Engineers, New York District, whose assistance had been requested by the DSP. The purpose of the work was to determine the hazard potential classification of the dam and provide some information for the dam owner to develop an Emergency Action Plan (EAP). It should be noted that the hazard potential classification definitions in place in 1991 are now antiquated and no longer in use. One notable discrepancy between the old and new definitions is how the potential for loss of life from a dam failure impacts classification. In the current system, any probable loss of human life dictates a dam be classified as a HIGH hazard potential, whereas the old system allowed for “few” loss of life at the SIGNIFICANT hazard potential level. In the past, the DSP interpreted “few” to mean approximately two homes, and assuming an average of three people per house, potential loss of approximately six lives or less could be considered a SIGNIFICANT hazard potential dam. Accordingly, with the adoption of the new hazard potential classification system, some dams previously classified as SIGNIFICANT hazard potential are being reclassified as HIGH hazard potential dams despite no changes to land development or uses downstream.

The 1991 study considered a dam failure flood wave under sunny day (normal weather conditions and lake levels) and storm day (during the flood event associated with the ½ Probable Maximum Flood) conditions. The limits of the study were from the dam along the Shadow Lake Brook to its confluence with the Barton River to Perron Hill Road, approximately 3 miles downstream. The study concluded that one to two houses could be subject to inundation on the order of up to 7 feet deep and up to four roadways could be subject to overtopping depths up to 9 feet deep. Due to the potential for downstream damages, the dam was classified as a SIGNIFICANT hazard potential dam using the old classification system. The study did not offer a clear picture of the difference in downstream damages caused by just the storm flows during the storm day failure, versus the incremental damages caused by the dam failure flows. It should be noted that during the storm day dam failure scenario, approximately 60% of the downstream flood flow was attributed to the dam failure and 40% of the flood flow was attributed to flows from the storm.

Methods:
The DEC DSP prepared a DSS-Wise Lite model of the Shadow Lake Dam and the downstream area. DSS-Wise Lite is a publicly available flood modeling and consequence analysis tool developed by The National Center for Computational Hydroscience and Engineering at the University of Mississippi. DSS-Wise Lite is a web-based program that allows the user to setup an automated two-dimensional dam breach model with minimal inputs and provides results including inundation maps, flood arrival times, hydrographs, and other life consequence information. As noted in program literature, DSS-Wise Lite is a simplified analysis producing rough, approximate results that are not intended to replace more detailed modeling/programs. The following limitations of DSS-Wise Lite should be considered:

- While an inflow flood hydrograph can be manually input into DSS-Wise Lite to simulate a storm day dam failure, the program does run most reliably under sunny day failure scenarios. For this reason, a sunny dam failure during maximum pool conditions (water level at the dam crest) was modeled. This scenario is possible assuming the principal spillway was clogged, and the water level were to rise to the dam crest. This approach also assumes normal, base flow in the downstream channel, allowing for a more easily understood incremental impact of dam breach flooding than would be present during a storm event. The failure is assumed to occur rapidly and completely to model a worst-case scenario.

- The model defaults to the use of publicly available digital elevation models (DEMs). For the area of this project, the resolution of the DEMs used in the model is reportedly 1 meter (3.281 feet).
- The program does not allow for the modeling of culverts at downstream road crossings and embankments. Bridges can be input but are modeled as an opening with no deck. Select culverts were modeling using this same technique to try to roughly account for some flow capacity through them.

Model Inputs:
The model inputs are summarized in ***Attachment B***. Based on the GPS survey by D&K in 2019, the following elevation and storage data was used (all elevations reference the North American Vertical Datum of 1988, NAVD88, in feet):

- Principal Spillway Crest/Top of Stoplogs (Normal Pool) — El. 1,394.6
- Normal Pool Storage — 1,709 acre-feet
- Auxiliary Spillway Crest — El. 1,396.2
- Dam Crest (Maximum Pool) — El. 1,399.8
- Maximum Pool Storage — 2,866 acre-feet

Within the DSS-Wise Lite platform, the hydrograph dam failure mode was used. In this method, the dam failure outflow hydrograph is provided by the user. To develop this hydrograph, a simplified dam failure simulation was run in another hydraulic modeling software package (HEC-HMS) assuming the storages and elevations noted above. Assumed dam breach parameters were applied, including a dam failure breach bottom width of 45 feet, side slopes of 0.7H:1V, and breach development time of 1 hour. Refer to the ***Attachment B*** for the hydrograph.

Several challenges are present when performing dam breach and flood inundation analyses/mapping at Shadow Lake Dam.

- According to the most current bathometry map of Shadow Lake (dated 6/1/2019), the approach area upstream of the dam, which is in a small cove on the eastern side of the lake, ranges in depth from approximately 4 to 8 feet deep. It is not clear that in the event of a dam failure if this approach channel would reduce the amount of water that releases from the dam or if it would scour and release more of the full pool held by the dam.
- Approximately 250 feet downstream from the dam is the Stone Shore Road embankment. The crest elevation of this roadway embankment is similar to the dam crest. The performance of this embankment and hydraulic conveyance structure could impact the dam failure flood wave. If the conveyance structure plugs and the roadway overtops and fails, the full brunt of the dam failure flows will be transferred downstream. In the event the roadway either does not fail or only partially fails, it could act to throttle flood flows and reduce downstream impacts. For the purpose of this analysis and to study a worst-case scenario, which is necessary to explore hazard potential classification, it was assumed the roadway embankment fails or does not provide any meaningful flood flow reduction or attenuation.
- The downstream floodway along the Barton River is a combination of rural and developed areas with multiple roadway crossings. The downstream flow areas are complex, and the analysis overall would benefit from a more detailed model in these areas. Flooding impacts were identified downstream of Glover in the Towns of Barton and Orleans. For the purposes of this study, these additional impacts, which are unlikely to impact the hazard potential classification, were not carefully studied.

Model Results:
The DSS-Wise Lite model results are summarized in ***Attachments A*** through ***C***. The estimated inundation limits were overlain on a ANR Atlas satellite image map. The following table provides estimated dam failure flood flow depths and velocities at select locations downstream of the dam (also refer to the ***Attachment A: Dam Failure Flood Inundation Maps***).

TABLE 1: Dam Failure Flood Flow Depths, Velocities, and Peak Arrival Time at Select Locations

LEGEND

(1) Not applicable, (2) Not calculated, *Vulnerable population, **Mobile Home

Blue Text = All or portion of range is in the USBR ACER 11 "Judgment Zone" (buildings, only)

Red Text = All or portion of range is in USBR ACER 11 "High Danger Zone" (buildings, only)

Black Text = Range is in the "Low Danger Zone" (buildings only)

Location	Dist. Downstream From Dam (miles)	Max. Estimated Flood Depth (ft)	Max. Est. Flood Flow Velocity (ft/s)	Est. Arrival Time of Peak Flood (hours)
At Dam	0.0	NA[1]	NC[2]	NA
Stone Shore Road Crossing	*.05 (250 feet)*	*1 to 4*	*5 to 10*	*0.3*
Driveway-274 Shadow Lake Rd.	0.8	8 to 10	10 to 12	0.5
181 Shadow Lake Drive		1 to 3	<2	0.8
Route 16 Crossing near Confluence with Barton River	*1.0*	*<2*	*<2*	*1.0*
Drinell Drive Crossing	*1.1*	*6 to 8*	*6 to 8*	*0.6*
Perron Hill Road Crossing	*3.1*	*1 to 3*	*5 to 8*	*1.5*
123 Perron Hill		2 to 4	2 to 4	1.5
Aldrich Lane Crossing	*3.7*	*2 to 4*	*3 to 5*	*1.8*
Still Hill Road Crossing	*4.7*	*1 to 3*	*4 to 8*	*2.0*
21 Still Hill		1 to 3	3 to 5	2.0
3122, 3130, 3132 Glover Street		2 to 4	3 to 5	2.0
3153 Glover Street		<1	<1	2.0
3127 Glover Street		<1	<1	2.0
3103 Glover Street		<1	<1	2.0
3086 Glover Street – Union House Nursing Home*		<1	1 to 3	2.0
3074 Glover Street – Church		1 to 5	1 to 3	2.0
3050 Glover Street		1 to 3	2 to 3	2.0
3032 Glover Street		1 to 4	2 to 3	2.0
3018 Glover Street		2 to 6	3 to 5	2.0
3008 Glover Street		2 to 6	3 to 5	2.0
2984 Glover Street – Currier Market and Post Office		2 to 6	6 to 9	2.0
School Street Crossing	*4.9*	*2 to 3*	*5 to 8*	*2.0*
2972 Glover Street		1 to 2	5 to 7	2.1
2956 Glover Street		2 to 3	3 to 5	2.1
2944 Glover Street		3 to 5	3 to 5	2.1
9 Bean Hill Road		5 to 7	4 to 7	2.1
Bean Hill Road Crossing	*5.0*	*1 to 3*	*5 to 7*	*2.1*
23 Dexter Mountain Road – Senior Housing*		1 to 2	2 to 4	2.1
33 Mill Place		1 to 3	3 to 6	2.1
2894 Glover Street – Red Sky Trading		4 to 8	3 to 5	2.1
2880 Glover Street		3 to 6	3 to 6	2.1
2864 Glover Street		1 to 3	3 to 5	2.1
2861 Glover Street – Self-Storage		1 to 3	4 to 8	2.1
Route 16 Crossing	*5.1*	*1 to 3*	*2 to 7*	*2.1*
26 Talbot Lane**		6 to 8	3 to 5	2.1
Talbot Lane Crossing	*5.4*	*2 to 4*	*6 to 10*	*2.2*
2653, 2637, 2615 Glover Street		Flooding of rear, attached outbuildings		
Sargent Lane Crossing	*5.5*	*2 to 4*	*4 to 6*	*2.2*
9 Sargent Lane – Labour of Love Landscaping		<2	1 to 3	2.2
2581 Glover Street		<2	<2	2.2
2575 Glover Street		1 to 4	1 to 3	2.2
2561 Glover Street**		1 to 2	1 to 3	2.2
2529 Glover Street**		4 to 7	3 to 5	2.2
2513 Glover Street		4 to 8	3 to 6	2.2
2510 Glover Street		1 to 2	2 to 4	2.2
2421 Glover Street		1 to 3	2 to 5	2.2
Route 16 Crossing	*5.7*	*<2*	*3 to 6*	*2.2*
2269 Glover Street		<2	<1	2.4
2197 Glover Street – Self-Storage		<2	1 to 3	2.4
Glover/Barton Town Line	6.0	Flooding of low-lying areas in Barton & Orleans anticipated. For purposes of this study, these areas were not carefully evaluated.		

Hazard Potential Classification:
As noted above, this dam is currently rated as a SIGNIFICANT hazard potential based on the 1991 study. The current hazard potential classification definitions from the Vermont Dam Safety Rule are provided below:

TABLE 2: HAZARD POTENTIAL CLASSIFICATION DEFINITIONS

Classification	General Definition
HIGH	Dams where failure or mis-operation will probably cause loss of human life.
SIGNIFICANT	Dams where failure or mis-operation results in no probable loss of human life but can cause economic loss, environment damage, disruption of lifeline facilities, or impact other concerns. Significant hazard potential classification dams are often located in predominantly rural or agricultural areas but could be located in areas with population and significant infrastructure.
LOW	Dams where failure or mis-operation results in no probable loss of human life and low economic and environmental losses.
MINIMAL	A dam that meets the LOW hazard definition, above, but is only capable of impounding less than 500,000 cubic feet.

In the assessment of a dam's hazard potential classification, the four potential loss types are systematically assessed in the following order: life, property, lifeline, and environmental losses.

The Hazard Consequence Model (HCom) estimated the Population at Risk (PAR) resulting from the simulated dam failure of Shadow Lake Dam. The PAR is the estimated number of people within the estimated inundation limits of a simulated dam failure. The HCom estimated a Nighttime PAR of 219 and a Daytime PAR of 394. The daytime and nighttime PAR vary based on the number of homes where people are typically at night, versus business, churches, or schools, where people are typically during the day. PAR estimates provided by the HCom should be reviewed as property and census data that the program relies on may be out-of-date and in rural areas with large parcels, potential flooding of a portion of a parcel may not necessarily include the home or inhabited dwellings, therefore lessening potential for loss of life and/or economic losses.

The two potential risk drivers/consequences appear to be associated with the flooding of homes and businesses related to potential for loss of life and economic damages and for flooding/overtopping of roads/bridges and associated economic damages:

- Homes/Businesses: In general, once the potential exists for homes and businesses that are occupied to be flooded due to dam failure flows above first floor elevations, the minimum hazard potential classification of that dam becomes SIGNIFICANT. From there, the depths and velocities of the dam failure flows and the potential susceptibility of the population impacted are evaluated to determine if the dam's hazard potential classification should be elevated to HIGH.

  Based on this simulation, approximately 30 homes and 5 businesses could be flooded above their first-floor levels in Glover due to a dam failure. Of particular interest are structures that may be exposed to depths and velocity combinations that plot in the "judgement zone" and "high danger zone" on the danger level plots for homes/buildings on foundations and mobile homes per ACER Technical Memorandum 11 by the Bureau of Reclamation (***Attachment D***). Approximately five to ten buildings may be exposed to depth and velocity combinations in each the judgment zone and high danger zone in Glover. In addition, there may be potential for some flooding of low-lying properties near the Barton River downstream in Barton and Orleans.

- Flooding of roads/bridges: In general, overtopping of a road/bridge due to a dam failure flow implies damage. Roadways are assigned a functional classification by VTrans, whereas the higher the functional classification, the more important the roadway and the greater potential to impact the public should it be damaged. Approximately ten roadways/bridges were identified as potentially being overtopped and flooded in Glover due to a dam failure. Based on the simulation results, the highest functional classification road overtopped by the dam failure according to this simulation is Route 16, which appears to be overtopped several times. Route 16 is classified by VTrans as a Minor Arterial roadway with an average annual daily traffic (AADT, according to 2018 VTrans study) of approximately 2,300. The road is an important north-south route in this area of Vermont, the loss of which would lead to costly road closures, detours, and construction to replace. Accordingly, a minimum hazard potential classification based on potential damages to downstream roadways, only, is SIGNIFICANT. While damages to smaller local roads and collectors such as Shadow Lake Road, Bean Hill Road, Stone Shore Road, Perron Hill Road, and others are anticipated, their damage would not be grounds to elevate the hazard potential classification above SIGNIFICANT based on current guidance and methods.

- Since the potential for loss of life and economic losses drive the hazard potential classification for Shadow Lake Dam, evaluation of lifeline losses and environmental losses is not necessary and has not been performed.

Conclusions:
As noted above, DSS-Wise Lite is a simplified dam failure flood and consequence analysis program. With regards for the potential loss of life, PAR estimates in the 200 to 400 range do highlight life safety concerns. In addition, several homes and businesses may be subjected to flooding with combination flood flow depths and velocities that could be life threatening. Also, two of the buildings within the inundation zone house vulnerable populations (nursing home and senior living facility). Accordingly, a hazard potential classification of HIGH may be warranted. Given the results of this work, with the potential for economic losses associated with bridge/roadway damage and home/business and private property damages, a hazard classification of no less than SIGNIFICANT is appropriate with respect to those losses. With the technical challenges identified in using the DSS-Wise Lite platform, a more rigorous and detailed analysis is recommended to confirm the hazard potential classification. It is recommended that the recently completed Hydrologic and Hydraulic Study of Shadow Lake Dam be used as the basis of a more detailed dam failure study and downstream consequence analysis. This work would also be helpful to understand the potential downstream impacts of proposed dam improvements that alter dam outflows under normal and storm conditions.

It is recommended that an updated Emergency Action Plan (EAP) for the dam be developed, and the flood inundation mapping generated during this study be used until more detailed mapping can be generated. The DSP would be happy to assist in the development of an EAP and can share our template. The EAP would include the flood inundation maps attached here-in, pre-planned actions in the case of a dam incident or failure, and identification of key emergency personnel as well as potential evacuees.

Y:\WID_DamSafety\Dams\S\ShadowLake\Hazard Verification\Shadow Lake Dam (No. 81.02) - 2021 DSS Wise Lite Dam Flood Mapping.docx

Attachment A: Dam Failure Flood Inundation Maps

SHADOW LAKE DAM
DAM FAILURE FLOOD INUNDATION OVERVIEW MAP (1 of 4)

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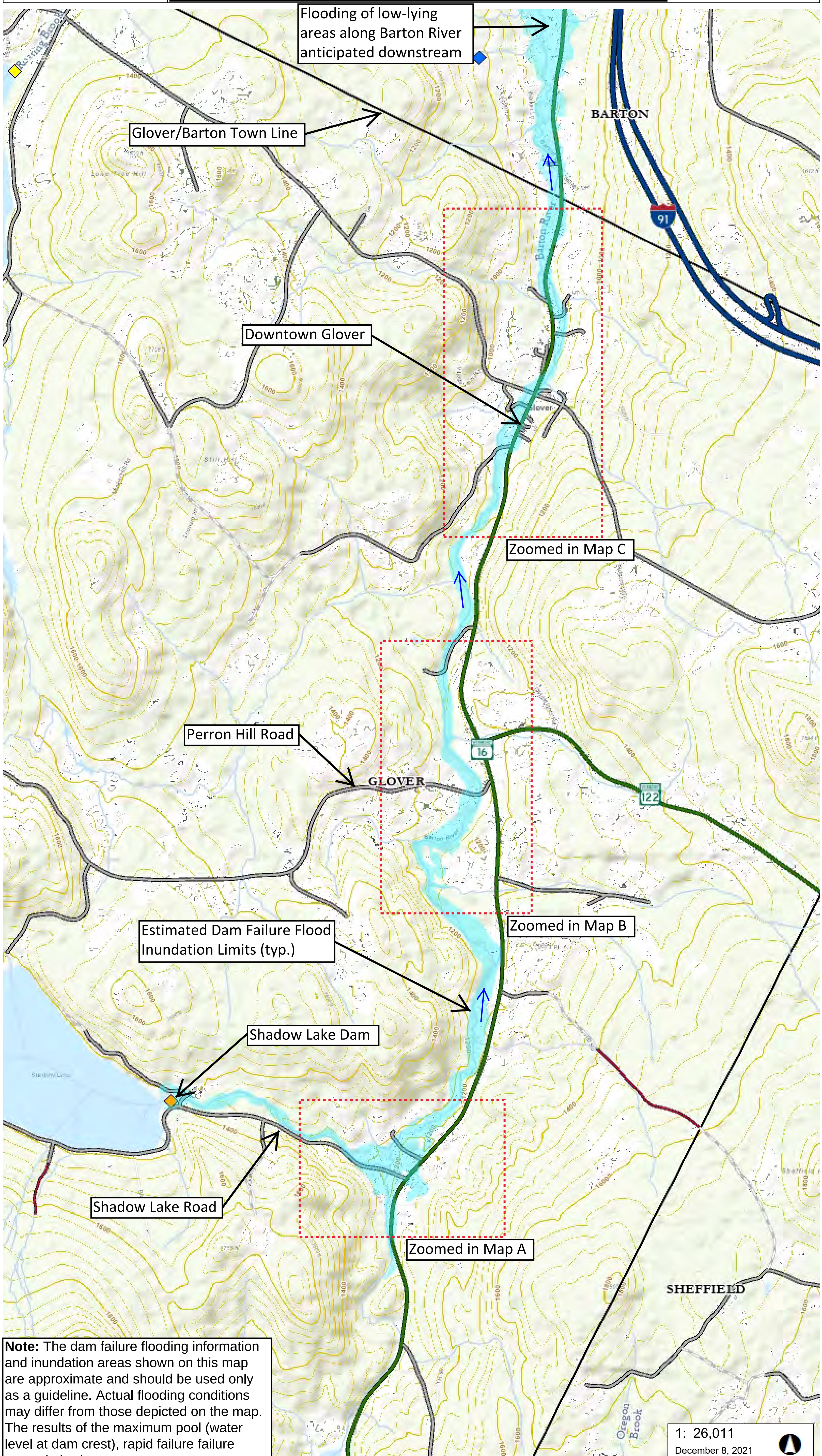

Note: The dam failure flooding information and inundation areas shown on this map are approximate and should be used only as a guideline. Actual flooding conditions may differ from those depicted on the map. The results of the maximum pool (water level at dam crest), rapid failure failure scenario is shown.

LEGEND

Hazard Class
- High Hazard Potential
- Significant Hazard Potential
- Low Hazard Potential
- Undetermined Hazard Potential

Historical Dam Location

Roads
- Interstate
- US Highway; 1
- State Highway
- Town Highway (Class 1)
- Town Highway (Class 2,3)
- Town Highway (Class 4)
- State Forest Trail
- National Forest Trail
- Legal Trail
- Private Road/Driveway
- Proposed Roads

Stream/River
- Stream
- Intermittent Stream

Town Boundary

Flow Direction

Created by VT Dam Safety Program, 12/8/21

NOTES

Map created using ANR GIS mapping technology.

1,321.0 0 660.00 1,321.0 Meters

WGS_1984_Web_Mercator_Auxiliary_Sphere 1" = 2168 Ft. 1cm = 260 Meters

THIS MAP IS NOT TO BE USED FOR NAVIGATION

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SHADOW LAKE DAM
DAM FAILURE FLOOD INUNDATION - ZOOMED IN MAP A (2 of 4)

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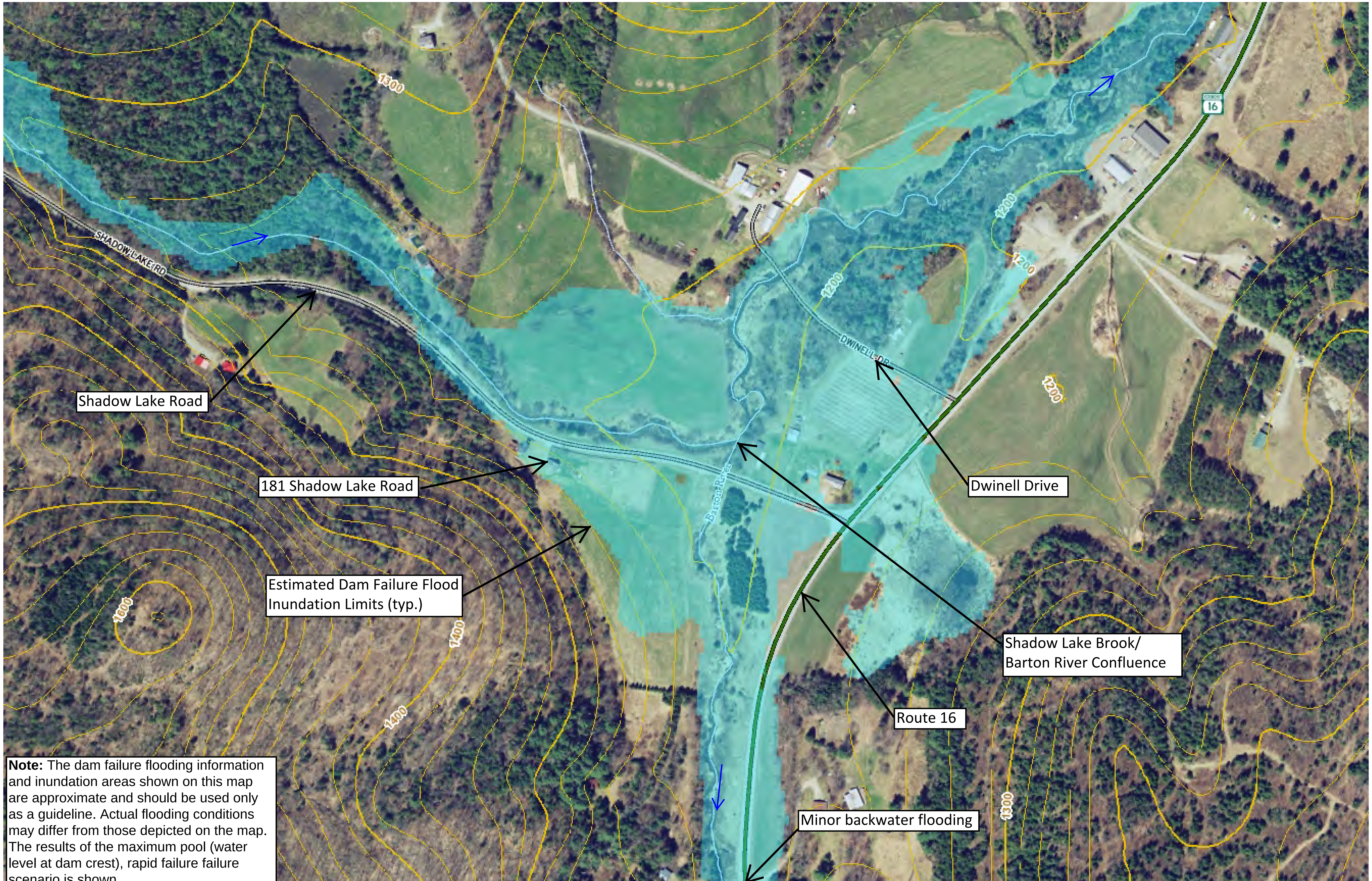
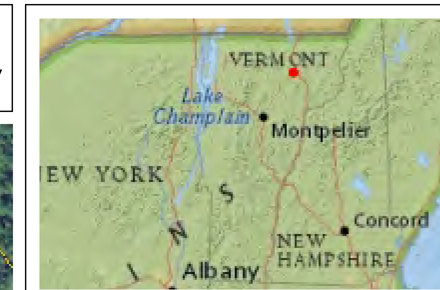


Note: The dam failure flooding information and inundation areas shown on this map are approximate and should be used only as a guideline. Actual flooding conditions may differ from those depicted on the map. The results of the maximum pool (water level at dam crest), rapid failure failure scenario is shown.



LEGEND

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- State Forest Trail
- National Forest Trail
- Legal Trail
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- Proposed Roads

Stream/River
- Stream
- Intermittent Stream

Town Boundary

Flow Direction

1: 3,907

1in = 326 ft.
1cm = 39 meters

198.0 0 99.00 198.0 Meters

WGS_1984_Web_Mercator_Auxiliary_Sphere

NOTES

Map created using ANR's Natural Resources Atlas

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SHADOW LAKE DAM
DAM FAILURE FLOOD INUNDATION - ZOOMED IN MAP B (3 of 4)

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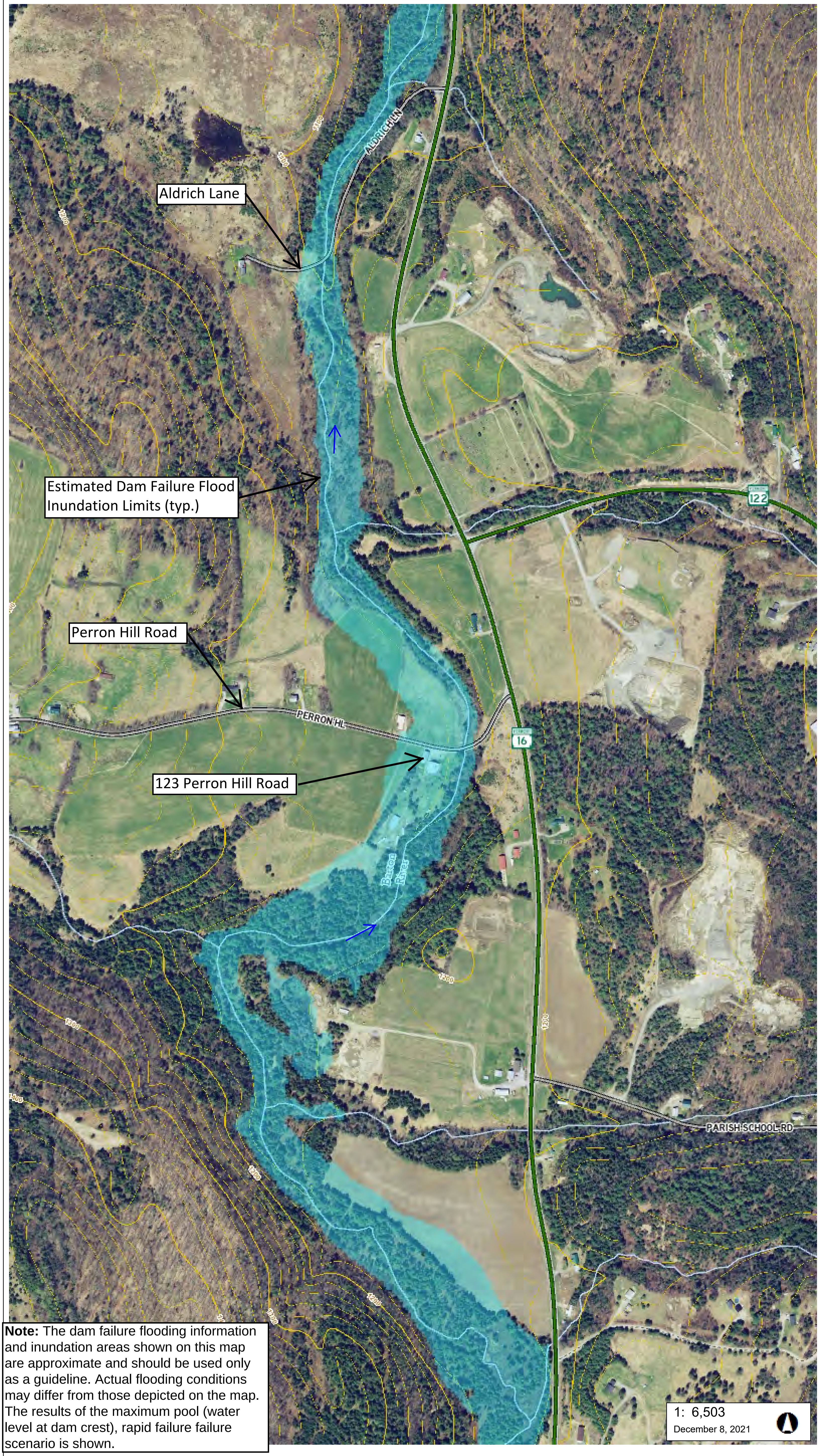

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1: 6,503

December 8, 2021

LEGEND

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- Undetermined Hazard Potential

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- Interstate
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- State Highway
- Town Highway (Class 1)
- Town Highway (Class 2,3)
- Town Highway (Class 4)
- State Forest Trail
- National Forest Trail
- Legal Trail
- Private Road/Driveway
- Proposed Roads

Stream/River
- Stream
- Intermittent Stream

Town Boundary

Flow Direction

NOTES

Map created using ANR GIS mapping technology.

330.0 0 165.00 330.0 Meters

WGS_1984_Web_Mercator_Auxiliary_Sphere

1" = 542 Ft. 1cm = 65 Meters

THIS MAP IS NOT TO BE USED FOR NAVIGATION

DISCLAIMER: This map is for general reference only. Data layers that appear on this map may or may not be accurate, current, or otherwise reliable. ANR and the State of Vermont make no representations of any kind, including but not limited to, the warranties of merchantability, or fitness for a particular use, nor are any such warranties to be implied with respect to the data on this map.

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SHADOW LAKE DAM
DAM FAILURE FLOOD INUNDATION - ZOOMED IN MAP C (4 of 4)

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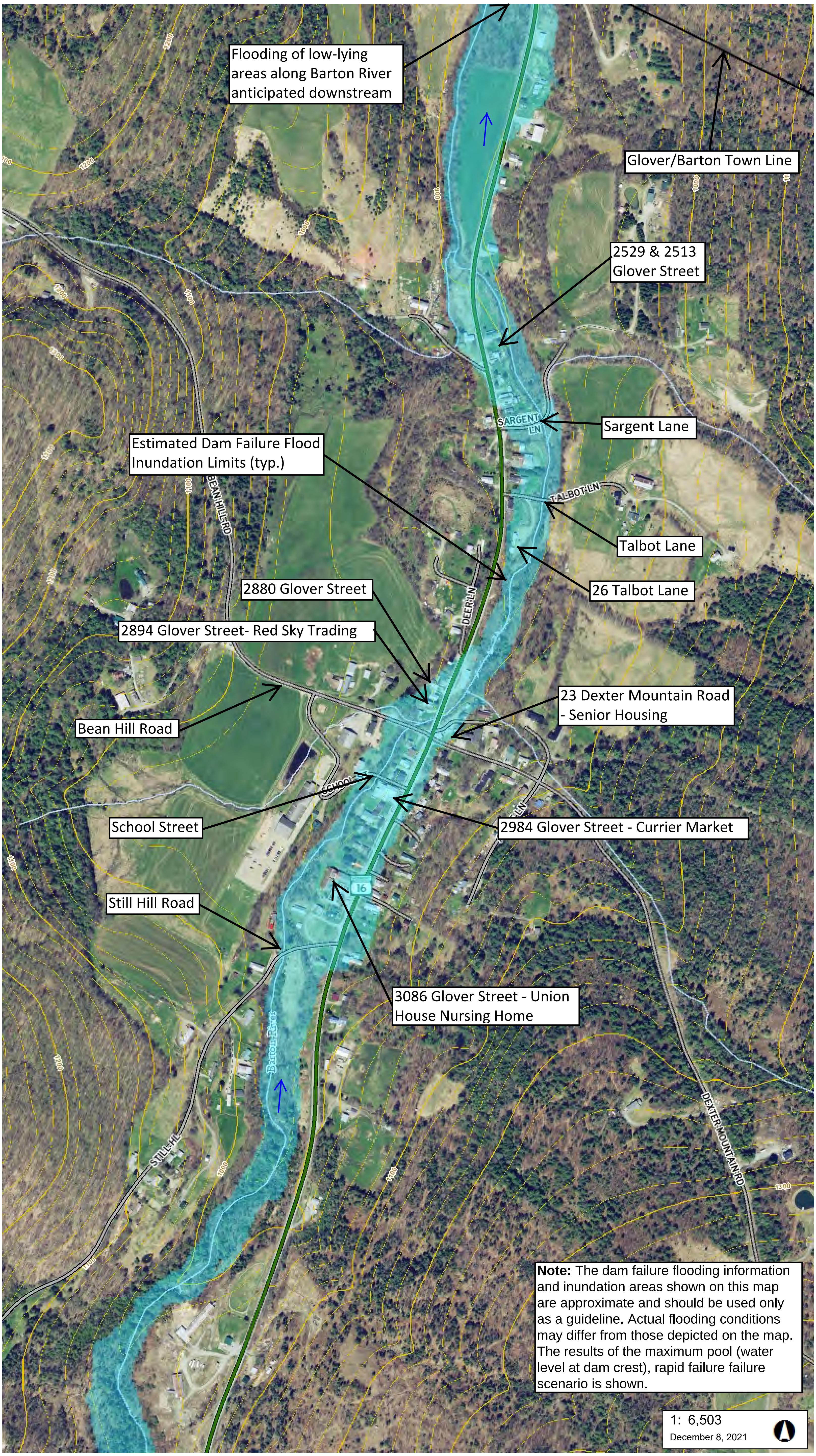

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330.0 0 165.00 330.0 Meters

WGS_1984_Web_Mercator_Auxiliary_Sphere
1" = 542 Ft. 1cm = 65 Meters

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Attachment B: DSS-Wise Lite Simulation Results Final Report

National Center for Computational Hydroscience and Engineering (NCCHE)

The University of Mississippi

DSS-WISE™ Lite Flood Simulation Report

Hydrograph-type, sudden and complete br
each

SHADOW LAKE

VT00070

December 07, 2021

Contact Information:

DSS-WISE™ Lite modeling questions: admin@dsswiseweb.ncche.olemiss.edu

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Table of Contents

1.0 Overview

The Decision Support System for Water Infrastructure Security (DSS-WISE™) is an integrated software package combining 2D numerical flood modeling capabilities with a series of GIS-based decision support tools. It was developed by the National Center for Computational Hydroscience and Engineering (NCCHE) at the University of Mississippi and was initiated by the US Department of Homeland Security (DHS) Science and Technology Directorate through the Southeast Region Research Initiative (SERRI) Program.

A simplified, and fully automated, version of the DSS-WISE™ software suite (DSS-WISE™ Lite Ver 1.0) was developed on behalf of the US Army Corps of Engineers (USACE) Critical Infrastructure Protection and Resilience (CIPR) Program and the DHS Office of Infrastructure Protection. This simplified dam break flood modeling capability was available to interested parties through the Dams Sector Analysis Tool (DSAT) secure web portal until November 2014. An updated version with more features was developed on behalf of Federal Emergency Management (FEMA) and is available at dsswiseweb.ncche.olemiss.edu.

The DSS-WISE™ Lite software suite, running on NCCHE servers, automatically processes input files for dam-break modeling scenarios submitted by an user. DSS-WISE™ Lite further simplifies simulations by making several general overarching assumptions in an effort to streamline data preparation and computations.

The results produced by this simplified dam-break flood simulation tool represent a rough approximation. They are not intended to replace more detailed flood inundation modeling and mapping products or capabilities developed by hydraulic and hydrologic engineers and GIS professionals.

The user is, therefore, warned that professional engineering judgment should be used in the interpolation of the results generated by this simplified and automated dam-break flood analysis.

To learn more about DSS-WISE™ and DSS-WISE™ Lite visit us at:
`https://dsswiseweb.ncche.olemiss.edu`

Disclaimer

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Elevation Datum

All reported elevations use the North American Vertical Datum of 1988 (NAVD 88).

2.0 Modeling Parameters and Conditions

2.1 Project Information

Project Name:	SHADOW LAKE
Scenario Name:	Hydrograph-type, sudden and complete br each
NIDID:	VT00070
Scenario Description:	1 active reservoir 1 active impounding structure hydrograph-type, sudden and c omplete breach of SHADOW LAKE
User e-mail:	benjamin.green@vermont.gov

2.2 Simulation Parameters

Simulation distance requested (miles):	22.7
Simulation cell size requested (ft):	15.0
Simulation duration requested (days):	3

2.3 Impounding Structure(s) Characteristics

Number of Structures: 1

Structure Name:	SHADOW LAKE
Structure Type:	Embankment
Hydraulic Height (ft):	13.0
Crest Elevation (ft):	1399.8
Length (ft):	466.333277115

2.4 Bridge(s) to be Removed

Number of Bridges: 6

Bridge Name:	Stone Shore Road

Length(ft):	50.0
Coordinates (Latitude/Longitude):	44.6666956296/-72.215207384
Bridge Name:	Dwinell Drive
Length(ft):	16.0
Coordinates (Latitude/Longitude):	44.6642573172/-72.1980030333
Bridge Name:	I-91 US
Length(ft):	60.0
Coordinates (Latitude/Longitude):	44.7365921972/-72.1859943785
Bridge Name:	I-91 DS
Length(ft):	60.0
Coordinates (Latitude/Longitude):	44.7367735822/-72.1857712187
Bridge Name:	RR 1
Length(ft):	60.0
Coordinates (Latitude/Longitude):	44.7599474313/-72.19599031
Bridge Name:	RR2
Length(ft):	60.0
Coordinates (Latitude/Longitude):	44.7626325449/-72.2003111963

2.5 User-Specified Breach Hydrograph

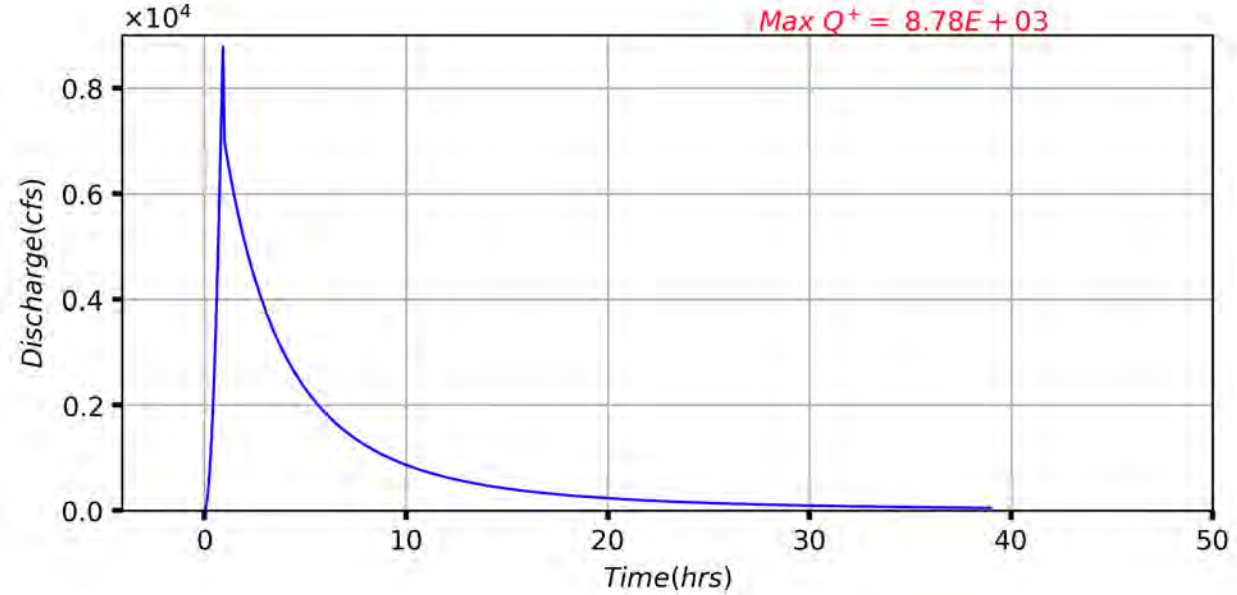

Figure 1. Breach inflow hydrograph for: SHADOW LAKE.

2.6 Reservoir Characteristics

Number of Reservoirs: 1

Reservoir Name:	SHADOW LAKE Reservoir
Selected Reservoir Point (Latitude/Longitude):	44.6662124119/-72.218348505
Pool Elevation @ Max Storage (ft):	1399.8
Maximum Storage Volume (ac-ft):	2866.0
Pool Elevation @ Normal Storage (ft):	1394.6
Normal Storage Volume (ac-ft):	1709.0

2.7 Failure Conditions

Structure Name:	SHADOW LAKE
Structure Type:	Embankment
Failure Mode:	Total Dam Breach
Breach Location (Latitude/Longitude):	44.6666069353/-72.2159368972

3.0 Automated Data Preparation and Job Flow Summary

3.1 Job Flow Summary

1. Prepare Digital Elevation Model (DEM) and Land Use/Land Cover (LULC) tiles for the Area of Interest (AOI) based on requested cellsize and maximum downstream distance.
2. Burn U.S. Army Corps of Engineers (USACE) levee lines into DEM for the AOI.
3. Assign Manning's coefficients based on LULC classifications.
4. Validate user provided simulation input parameters.
5. Remove user identified bridges from the DEM.
6. Estimate reservoir bathymetry.
7. Extend impounding structures if the specified reservoir level cannot be contained.
8. Fill reservoir to specified failure elevation.
9. Prepare boundary condition and all input data for simulation.

3.2 Reservoir Bathymetry and Filling

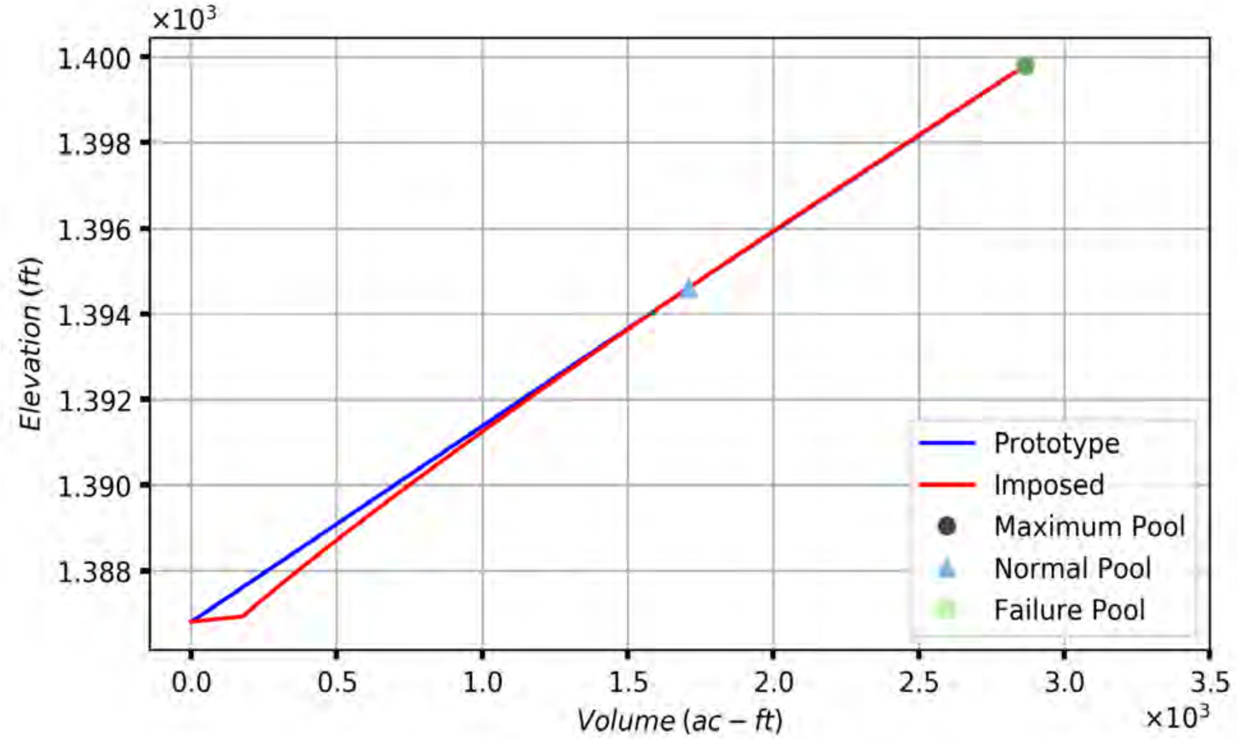

Figure 2. Stage-Volume Curve for Reservoir: SHADOW LAKE Reservoir.

Prototype: Theoretical cubic Hermite spline curve generated from user-provided reservoir elevation and volume information.
Imposed: Measured from reservoir bathymetry after filling to the failure elevation.

The reservoir water surface was detected to be in the DEM, so bathymetry estimation was performed using the prototype stage-volume curve shown above.
User-given Storage Volume at Failure (ac-ft): 2866.0
Imposed Storage Volume at Failure (ac-ft): 2866.0
After filling to the failure elevation, the imposed reservoir volume matched 100.0% of the prototype volume.

3.3 Data Sources

1. Digital Elevation Models

   Sources: USGS 2018 National Elevation Dataset, NOAA, DEM provided by group.

   Resolutions: 2, 1, 1/3, 1/9, 0.15 arc-seconds, 1 meter, and 10 feet based on availability

   Vertical Datum: NAVD88

   Horizontal Datum: NAD83

2. National Land Use/Land Cover Data

   Source: USGS 2016 National Land Cover Database

   Resolution: 30 m

3. National Levee Database

   Source: USACE

3.4 Digital Elevation Model

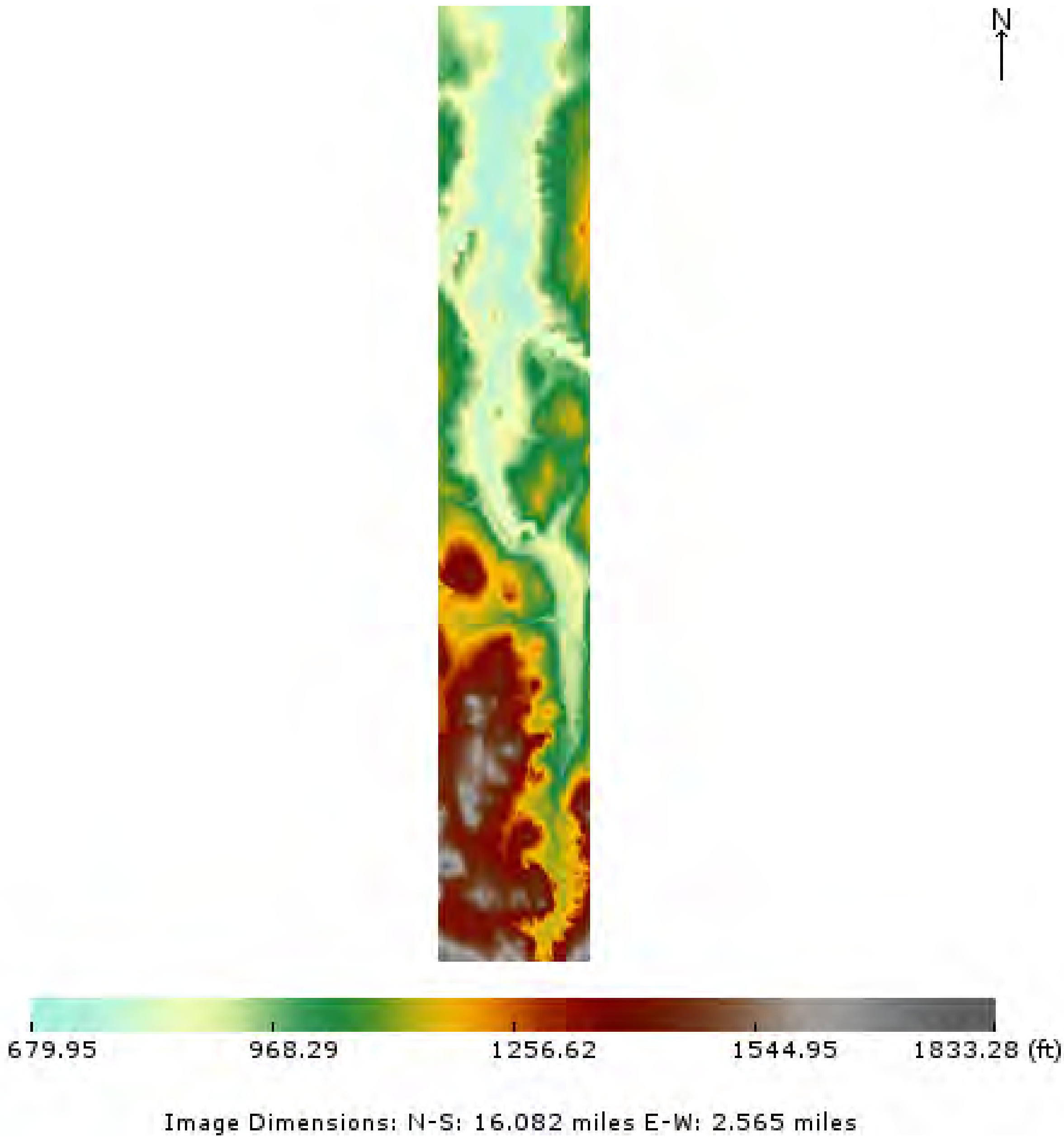

Figure 3. Map of Digital Elevation Model with Levees for AOI.

3.5 Reservoir Boundary and Breaching Structure

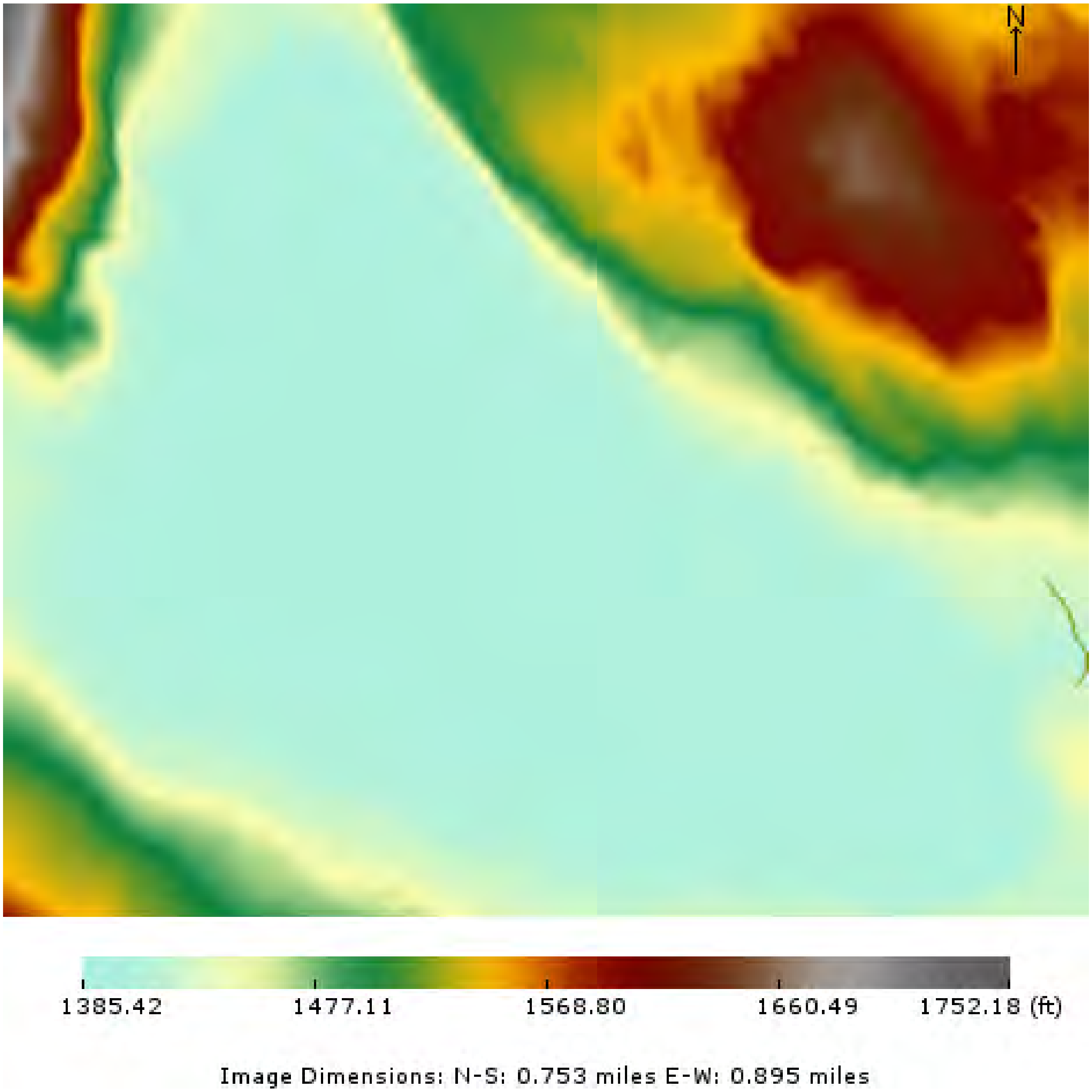

Figure 4. Map of Reservoir Boundary and Breached Structure.

3.6 Reservoir Initial Depth Profile

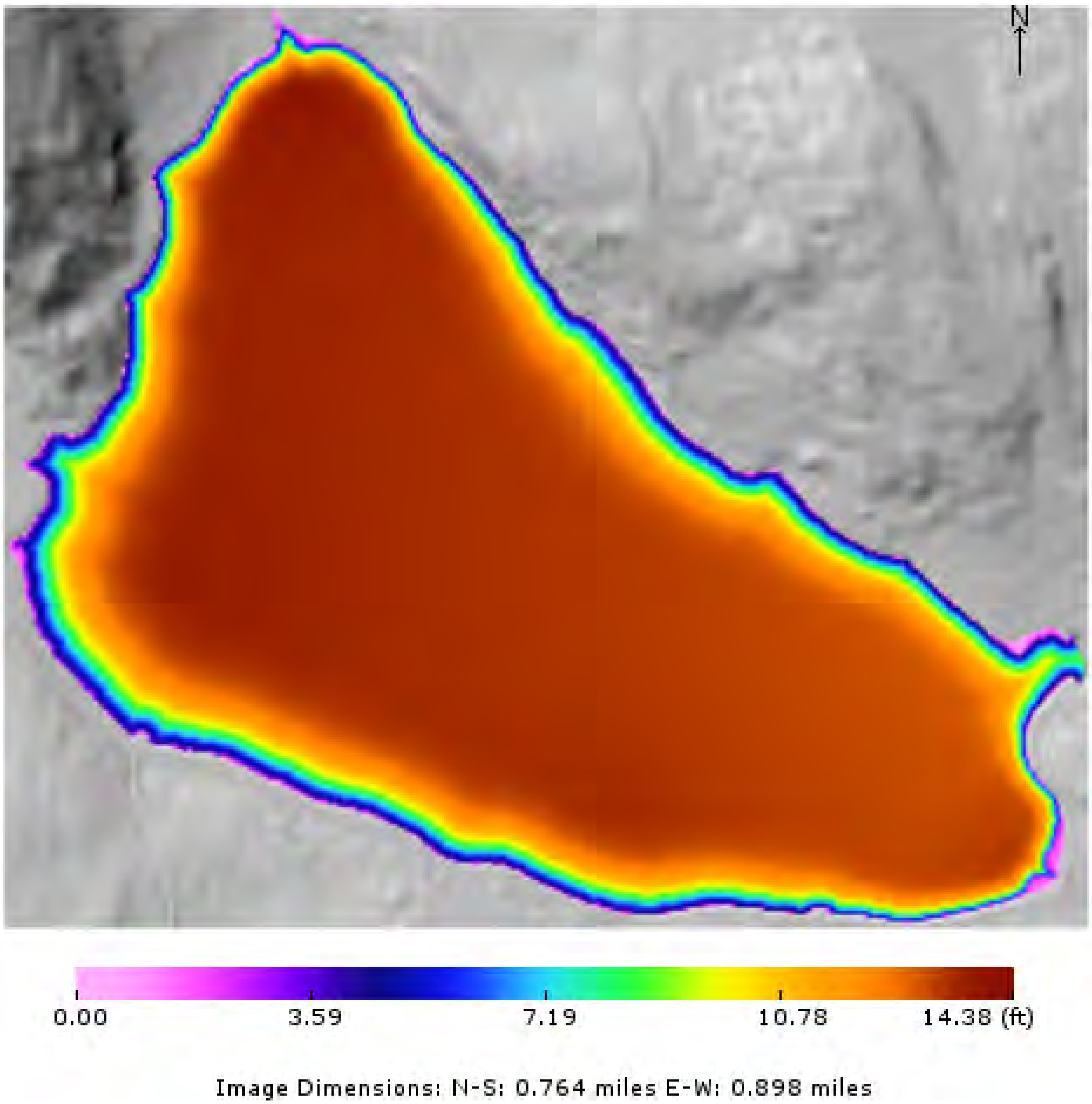

Figure 5. Map of Initial Depths in Reservoir at Failure Conditions.

3.7 Land Use/Land Cover

Figure 6. Map of Land Use for AOI.

4.0 Simulation Results

4.1 Simulation Summary

Simulation Request Received:	01:14 PM CST (12/07/2021)
Simulation Start Time:	01:15 PM CST (12/07/2021)
Simulation End Time:	03:55 PM CST (12/07/2021)
DEM resolution used for simulation (ft):	15.0
DEM resolution requested (ft):	15.0
Final distance reached downstream (miles):	15.4
Maximum downstream distance requested (miles):	22.7
Elapsed simulation time after breach initiation (hrs):	72.0
Termination condition:	Simulation end time reached(72.0 hours).

4.2 Land Use and Manning's Roughness Coefficient for Inundated Area

Land Use Description	% of Inundated Area	n-Value($m^{-1/3}s$)	Code	Color
Woody Wetlands	38.23	0.1500	90	
Hay/Pasture	27.10	0.0350	81	
Emergent Herbaceous Wetlands	8.52	0.1825	95	
Developed, Low Density	6.34	0.0678	22	
Mixed Forest *	4.49	0.1200	43	
Evergreen Forest *	4.22	0.1000	42	
Cultivated Crops	2.79	0.0700	82	
Developed, Medium Density	2.59	0.0678	23	
Developed, Open Space	2.44	0.0404	21	
Deciduous Forest *	1.33	0.1000	41	
Open Water	0.78	0.0330	11	
Developed, High Density	0.74	0.0404	24	
Grassland/Herbaceous	0.20	0.0400	71	
Shrub/Scrub	0.10	0.0400	52	
Barren Land	0.04	0.0113	31	
Unclassified	0.00	0.0350	0	
Perennial Snow/Ice	0.00	0.0100	12	
Dwarf Scrub *	0.00	0.0350	51	
Sedge/Herbaceous *	0.00	0.0350	72	
Lichens *	0.00	0.0350	73	
Moss *	0.00	0.0350	74	

Note: * indicates an n-value estimated by NCCHE. ** indicates an n-value given by the user. Other values are taken from literature.

4.3 Coverage and Sources of DEM Raster Datasets

Figure 7. Coverage of DEM Raster Datasets in the Inundation Area.

DEM Source	Source Resolution	Source Dataset	Color
USGS	1 arc-second	usgs_1as	
USGS	1/3 arc-seconds	usgs_13as	
USGS	1 meter	usgs_utm_z18_1m	
USGS	1 meter	usgs_utm_z19_1m	

Note: The DEM for this job was created from the source DEM raster datasets listed above. These DEM raster datasets were resampled and reprojected to the user defined cell size and UTM zone, respectively. Resampled and projected DEM raster datasets were then stacked in the order specific to the group under which this simulation was submitted.

4.4 Maximum Flood Depth

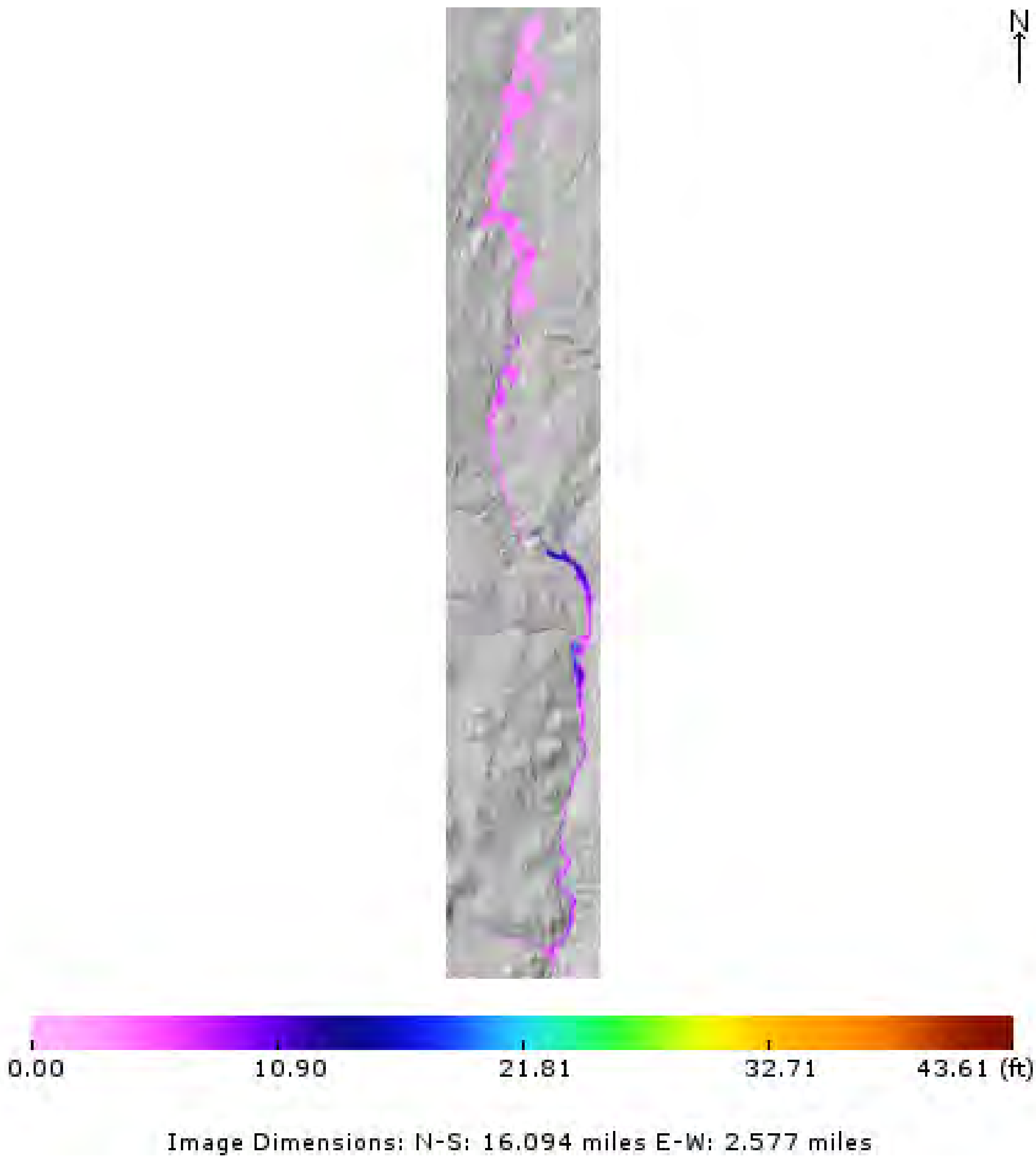

Figure 8. Maximum Flood Depth Map.

4.5 Flood Arrival Time

Flood arrival time is measured from the beginning of the simulation.

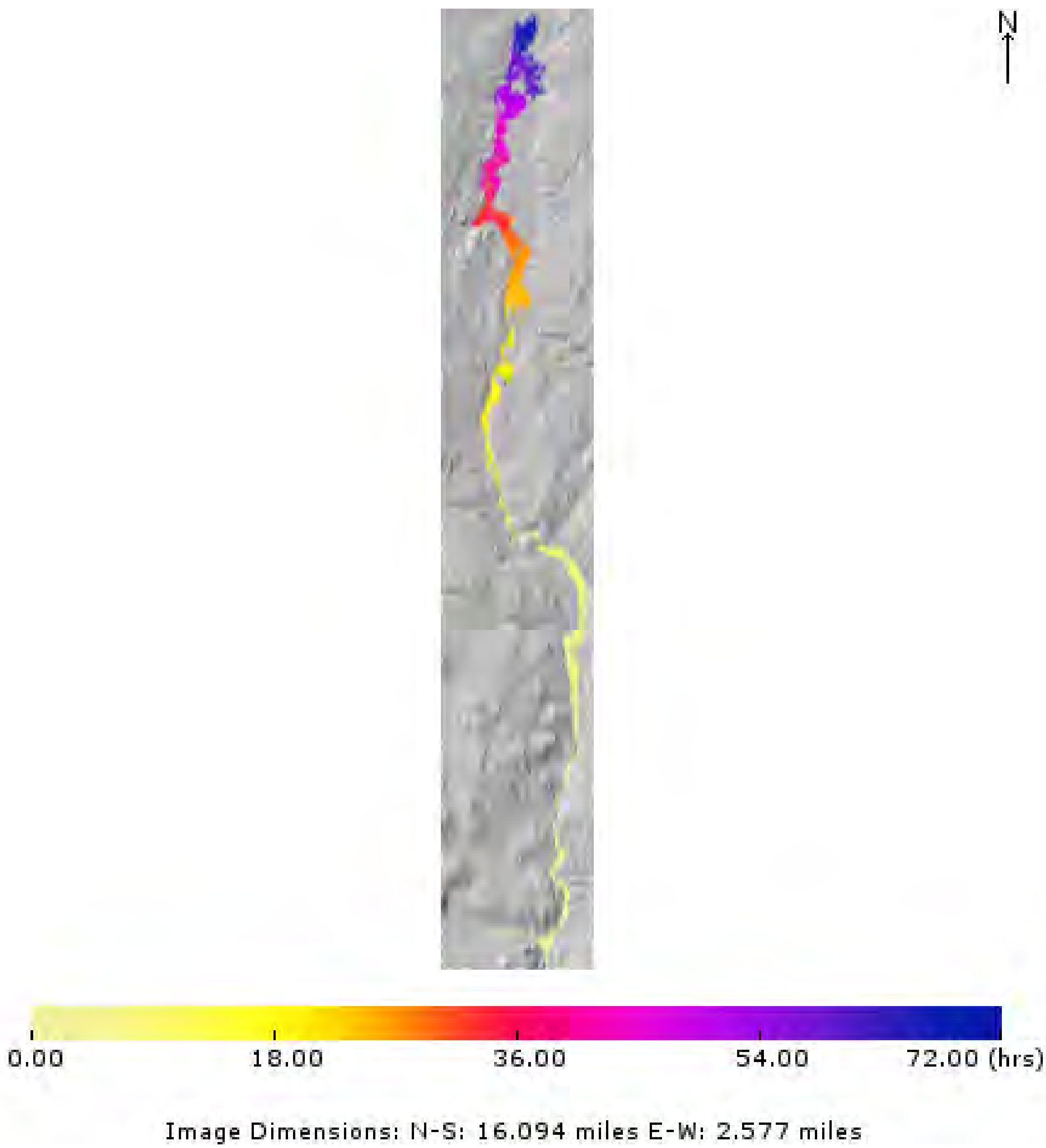

Figure 9. Flood Arrival Time Map.

4.6 Downloading Simulation Results

The simulation results can be accessed at the following web address:

`https://dsswiseweb.ncche.olemiss.edu/download`

Job ID: 42726

Attachment C: DSS-Wise Lite Human Consequences Final Report

National Center for Computational Hydroscience and Engineering (NCCHE)

The University of Mississippi

DSS-WISE™ HCOM
HUMAN CONSEQUENCE REPORT

SHADOW LAKE

Hydrograph-type, sudden and complete breach

VT00070

December 07, 2021

DSS-WISE Lite Simulation ID: 42726

FOR OFFICIAL USE ONLY

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Table of Contents

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EXECUTIVE SUMMARY

This document reports the human consequences assessment for the DSS-WISE Lite simulation ID: **42726**

INUNDATION EXTENT

Total inundated area (acres)(see figure 1): 1613.44

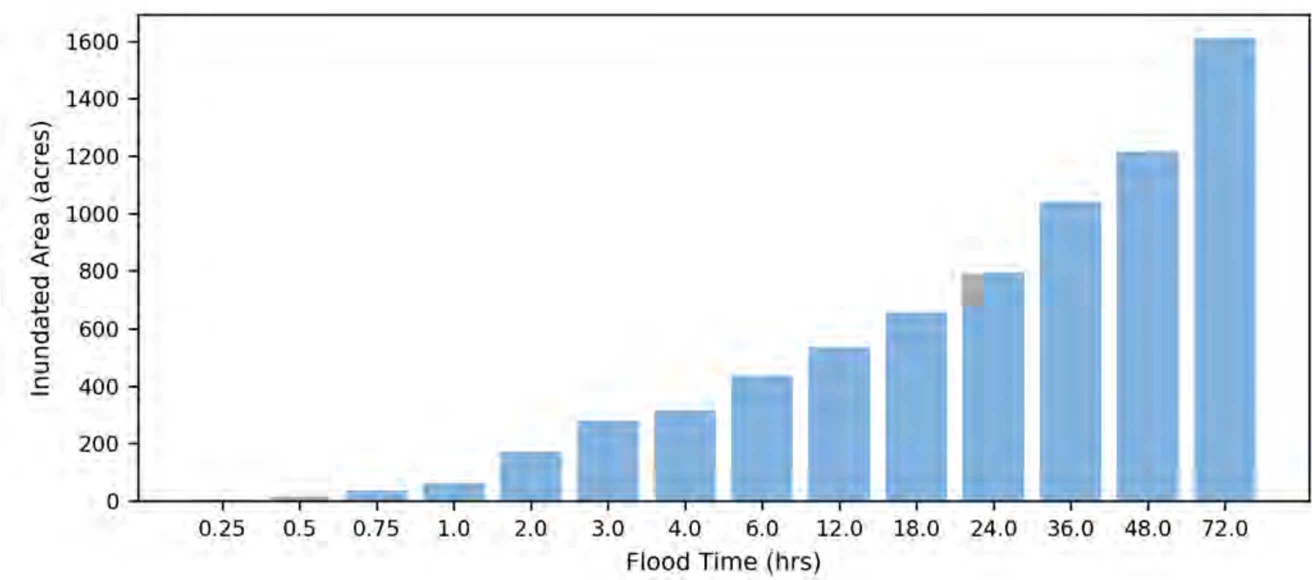

Figure 1. Evolution of total inundated area as a function of time.

ANALYSIS BASED ON CENSUS BLOCK DATA

Population in completely or partially inundated census blocks:	1690
Housings in completely or partially inundated census blocks:	967
Number of states in inundated area:	1
Number of counties in inundated area:	1
Number of census blocks in inundated area:	180

ANALYSIS BASED ON GRIDDED LANDSCAN USA DATA

Total Nighttime PAR in inundated area (see figure 2):	219
Total Daytime PAR in inundated area (see figure 3):	394

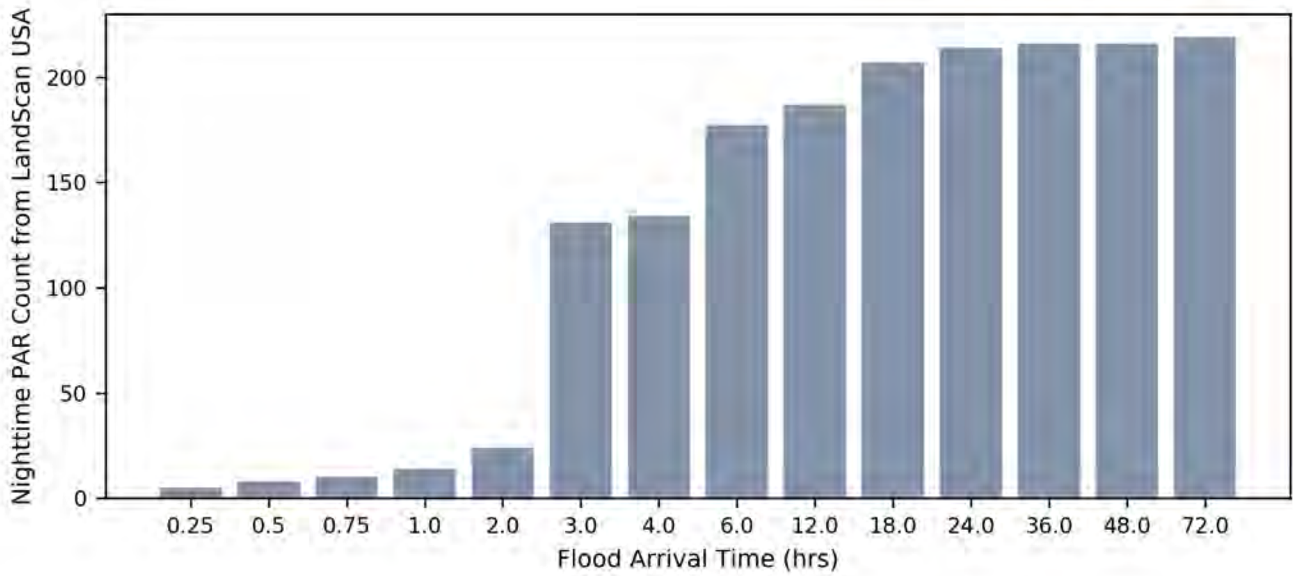

Figure 2. Evolution of nighttime PAR as a function of time.

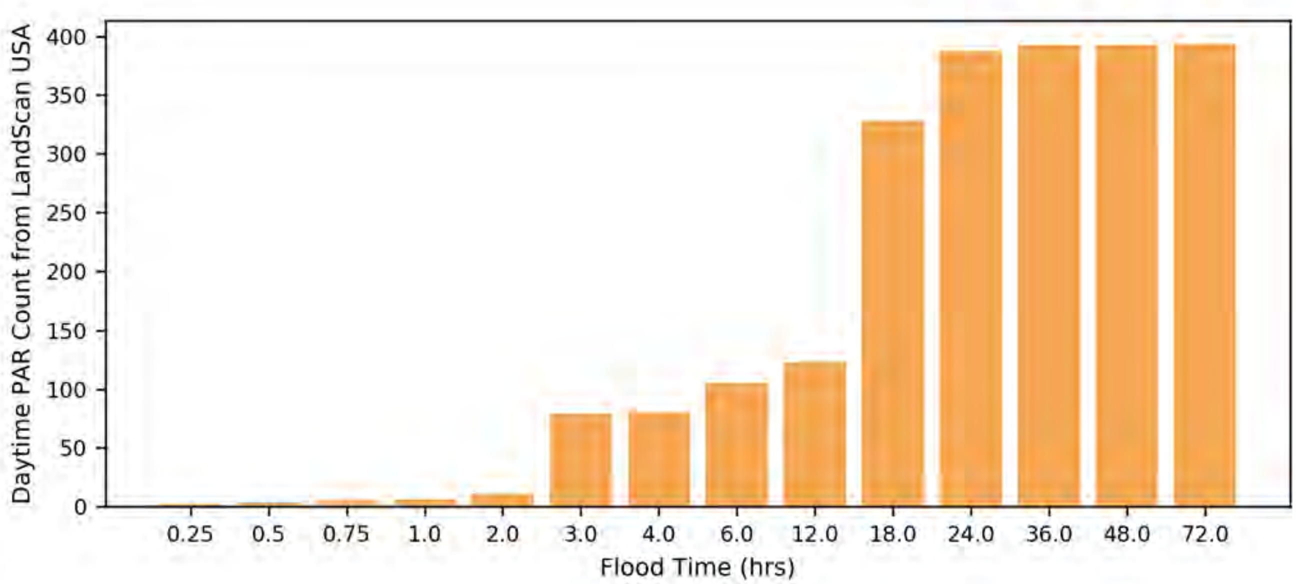

Figure 3. Evolution of daytime PAR as a function of time.

1.0 Overview

This report is produced DSS-WISE HCOM, which is part of the DSS-WISE Web system developed by the National Center for Computational Hydroscience and Engineering, at the University of Mississippi. Funding for DSS-WISE HCOM was provided by the U.S. Federal Emergency Management Agency (FEMA) through a contract with Argonne National Laboratory (ANL).

The results provided to the user by DSS-WISE HCOM include the following:

- the present report,
- a Microsoft Excel file containing data, results and plots, and
- a series of geospatial results files (in the form of polygon shapefiles).

These files can be used for further analysis and decision making for preparedness or during the response to an emergency. The files can also be used for hazard classification, risk prioritization preparing Emergency Actions Plans (EAPs).

DSS-WISE HCOM interfaces two-dimensional flood simulation results provided by DSS-WISE Lite with the population data provided by the U.S. Census Bureau and LandScan USA.

Please send any questions or suggestions to
admin@dsswiseweb.ncche.olemiss.edu

2.0 List of Abbreviations

ft	feet
hrs	hours
ft^2/s	Unit discharge, feet-squared per second
m^2/s	Unit discharge, meters squared per second
ft/s	feet per second
$ft.lb.$	foot-pounds
$m.kg.$	Meter-kilograms
D_{max}	Maximum depth
DV	Depth times velocity, unit discharge
DV_{max}	Maximum depth times velocity, maximum unit discharge
q_{max}	Maximum unit discharge, also called DV_{max}
DSS-WISE	Decision Support System for Water Infrastructural Security
DSS-WISE Web	Decision Support System for Water Infrastructural Security Web, the web-based system housing DSS-WISE Lite and other tools
DSS-WISE Lite	Decision Support System for Water Infrastructural Security Lite, the web-based version of DSS-WISE dam-break and flood modeling software
HCOM	Human Consequence Module
NCCHE	National Center for Computational Hydroscience and Engineering
PLFZ	Potentially Lethal Flood Zones
PAR	Population At Risk
EAP	Emergency Action Plan
NIDID	National Inventory of Dams (NID) Identifier
USCB	United States Census Bureau, or officially the Bureau of the Census
FEMA	Federal Emergency Management Agency
ANL	Argonne National Laboratory
ORNL	Oak Ridge National Laboratory
ESRI	Environmental Systems Research Institute
LSM	Life Safety Model

3.0 HCOM DATA SETS

3.1 DSS-WISE Lite Results Files

The human consequence analysis in this report are provided by DSS-WISE HCOM based on the raster results files for the following dam-break flood modeling simulation with DSS-WISE Lite:

DSS-WISE Lite simulation ID:	42726
Project Name:	SHADOW LAKE
Scenario Name:	Hydrograph-type, sudden and complete breach
NIDID:	VT00070
Scenario Description:	1 active reservoir 1 active impounding structure hydrograph-type, sudden and complete breach of SHADOW LAKE
Simulation distance requested (*miles*):	22.7
Simulation cell size (*ft*):	15.0
Simulation duration requested (*days*):	3.0

Table 1. DSS-WISE Lite results files used by DSS-WISE HCOM.

File Name	Type	Units	Description
42726_Hmax_ft_upto_final.tif	Raster	ft	Maximum flood depth
42726_Arrival_Time_hr_upto_final.tif	Raster	hrs	Flood Arrival Time
42726_Vmax_ftps_upto_final.tif	Raster	ft/s	Maximum flood velocity
42726_DVmax_ft2ps_upto_final.tif	Raster	ft^2/s	Magnitude of the maximum specific discharge
42726_DVmax_ft2ps_upto_final.tifArrivalTime	Raster	hrs	Arrival time of the maximum value of specific discharge

3.2 Population Data Sets Used by DSS-WISE HCOM

DSS-WISE HCOM uses two different sets of population data to estimate the Population at Risk (PAR) potentially affected by the flood:

1. 2010 Census Block data provided by the United States Census Bureau (USCB), which is federal government agency in charge of producing data about the people and economy of the U.S. A census block is the smallest geographic unit for which USCB collects data from all the houses in the unit (rather than a sample of houses). Census Blocks are bounded by visible features such as streets, roads, streams and nonvisible features such as property lines and limits of city, township, school district, and counties, etc. They are defined as polygons in a shapefile covering the entire territory of the U.S. including Puerto Rico and the Island areas. The attributes of the census block polygons include 2010 Census Housing Unit Count and 2010 Census Population Count. The latter should be considered as 2010 nighttime population data.

2. LandScan USA gridded population data developed and maintained by the Oak Ridge National Laboratory (ORNL) located in Oak Ridge, TN. LandScan USA (https://landscan.ornl.gov/) is a collection of gridded nighttime and daytime population datasets developed by the Oak Ridge National Laboratory (ORNL), Department of Energy. These gridded population datasets are available as raster files with a resolution of 3 arc-second ($90m$ or $295.28ft.$). They were developed by combining satellite remote sensing data, geospatial infrastructure datasets, and demographic data from USCB. Researchers at ORNL used "Intelligent" dasymetric modeling method to assign the population counts to the grid cells (Dobson et al. 2000 and Bhaduri et al. 2007) by defining a habitability index and by maintaining the total count of cells in a census block to be equal to the total population of the census block. The LandScan USA datasets used in this report are projections for 2016 (McKee et al. 2014). Daytime data is generated using specially developed techniques for population dynamics (Bhaduri 2007).

Detailed explanations on the methodologies used by DSS-WISE HCOM are provided in the technical manual, which can be downloaded from documentation page of the DSS-WISE Web website.

4.0 FLOOD HAZARD MAPPING

Flood-hazard mapping consists of partitioning the inundation extent into zones of predefined potential danger classes for humans. The resulting map is an ESRI shapefile of polygon type. The polygons correspond to different levels of potential danger for humans caught outdoors and indoors.

The potential danger classes are identified based on the ranges of the value of the maximum specific discharge, DV_{max}. The ranges of $q_{max} \equiv DV_{max}$ values are different for persons caught outdoors or indoors.

4.1 Potential Flood Hazard for Humans Caught Outdoors

For humans caught outdoors, the ranges of DV_{max} corresponding to five potential hazard (or danger) levels identified by different color codes are summarized in Table 2, which is adapted from Cox et al. (2010). The potential hazard levels are:

1. "Very Low Hazard: Shallow flow or deep standing water";
2. "Low Hazard: Dangerous to children";
3. "Moderate Hazard: Dangerous to some adults";
4. "Significant Hazard: Dangerous to most adults"; and
5. "Extreme Hazard: Dangerous to all".

The three rightmost columns of Table 2 correspond to the interpretation of five potential hazard levels by Cox et al. (2010) for three population categories defined by an index value corresponding to the product of height (H) and mass (M) of the individual as listed at the bottom of Table 2.

1. "Infants and small Children",
2. "Children", and
3. "Adults";

The five polygons corresponding to the five potential flood hazard levels for people caught outdoors as listed in Table 2 are provided as an ESRI shapefile of polygon type.

Cox et al. (2010) notes that the limits of DV_{max} in Table 2 correspond loosely to the loss of stability of different population categories. However, it is important to note that the ranges of DV_{max} given in Table 2 should not be considered as strict limits. Various other factors may influence the stability of individuals caught outdoors by the flood, such as:

- Bottom conditions (uneven surface, slippery surface, visible or invisible obstacles);
- Flow conditions (floating debris, low temperature, poor visibility, unsteady flow and flow aeration);
- Human subject (standing or moving, experience and training, clothing and footwear, physical attributes, such as height, mass and muscular development, disabilities, and psychological factors); and
- Other factors (strong wind, poor lighting, feeling unsafe or complete loss of footing).

Table 2. Potential flood hazard levels for humans caught outdoors by the flood (adapted from Cox et al. 2010).

<table>
<tr><th colspan="4">DV_{max}</th><th rowspan="3">Potential Hazard Category</th><th colspan="3">Explanation</th></tr>
<tr><th colspan="2">m^2/s</th><th colspan="2">ft^2/s</th><th rowspan="2">Adults</th><th rowspan="2">Children</th><th rowspan="2">Infants, Small Children and Frail/Older Persons</th></tr>
<tr><th>from</th><th>to</th><th>from</th><th>to</th></tr>
<tr><td>0.0</td><td>0.4</td><td>0.0</td><td>4.3</td><td>HZ01
Very Low Hazard: Shallow flow or deep standing water</td><td rowspan="2">Low Hazard</td><td>Low Hazard</td><td rowspan="5">Extreme Hazard Dangerous to all Infants, small Children and Frail/Older Persons</td></tr>
<tr><td>0.4</td><td>0.6</td><td>4.3</td><td>6.5</td><td>HZ02
Low Hazard: Dangerous to Children</td><td rowspan="2">Significant Hazard; Dangerous to most Children</td></tr>
<tr><td>0.6</td><td>0.8(2)</td><td>6.5</td><td>8.6(2)</td><td>HZ03
Moderate Hazard: Dangerous to some adults</td><td>Moderate Hazard: Dangerous to some adults</td></tr>
<tr><td>0.8</td><td>1.2(3)</td><td>8.6</td><td>13(3)</td><td>HZ04
Significant Hazard: Dangerous to most adults</td><td>Significant Hazard: Dangerous to most adults</td><td rowspan="2">Extreme Hazard: Dangerous to all children</td></tr>
<tr><td>1.2(3)</td><td></td><td>13(3)</td><td></td><td>HZ05
Extreme Hazard: Dangerous to all</td><td>Extreme Hazard: Dangerous to all</td></tr>
<tr><td colspan="8">1) Small children, children and adult categories are defined based on $height(H) \times mass(M)$
Small children: $H \times M \leq 25l(m.kg.)$ $H \times M \leq 181(ft.lb.)$
Children: $25 < H \times M(m.kg.) \leq 50$ $181 < H \times M(m.kg.) \leq 362$
Adult: $50 < H \times M(m.kg.)$ $362 < H \times M(ft.lb.)$</td></tr>
<tr><td colspan="8">2) Recommended upper limit of tolerable working flow regime for trained safety workers or experience and well-equipped persons</td></tr>
<tr><td colspan="8">3) Above this value, the hazard is extreme according to majority of the past studies.</td></tr>
</table>

Results file package of DSS-WISE HCOM contains an ESRI shapefile of polygon type containing up to five polygons (see Table 6) corresponding to the five potential flood hazard levels for humans caught outdoors by the flood, which are listed in Table 2. For convenience, Map 09 of this report shows the inundation extent colored by the five potential flood hazard levels listed in Table 2.

4.2 Flood Hazard for Humans Caught Indoors

For people caught indoors by the flood, it is assumed that the potential danger is associated with the collapses of the building (see FEMA 2011, p.43). This implicitly assumes that the people indoors are in potential danger of loss of life if the building collapses due to inundation by floodwaters.

Table 3 list the DV_{max} values for the potential collapse of different types of buildings, which are taken from the technical report of the Life Safety Model (LSM) developed by British Columbia Hydro (BCH 2006).

Table 3. Potential flood hazard levels for humans caught indoors based on the BC Hydro LSM Building Stability Criteria.

DV_{max}		Color Code	Building Type
(m^2/s)	(ft^2/s)		
≥5	≥54		HZ06: Poorly constructed building
≥10	≥108		HZ07: Well-built timber building
≥15	≥161		HZ08: Well-built masonry building
≥20	≥215		HZ09: Concrete building
≥35	≥377		HZ10: Large concrete building

Results file package of DSS-WISE HCOM contains an ESRI shapefile of polygon containing up to five stacked polygons (see Table 6) corresponding to the five potential flood hazard levels for humans caught indoors by the flood, which are listed in Table 3. For convenience, Map 10 of this report shows the inundation extent colored by the five potential flood hazard levels listed in Table 3.

5.0 MAPPING POTENTIALLY LETHAL FLOOD ZONES (PLFZs) FOR CHILDREN AND ADULTS

The mapping of potentially lethal flood zones (PLFZs) for humans consists of partitioning the inundation extent into zones of predefined potential lethality classes for humans. The resulting map is an ESRI shapefile of polygon type for each category. The polygons correspond to different levels of potential lethality that are defined based on the maximum depth, D_{max}, and maximum specific discharge, DV_{max}. The PLFZs for different categories of people caught outdoors, cars, mobile homes and typical residential structures are listed in Table 4 (Feinberg, 2017).

Table 4. Definition of potentially lethal flood zones (PLFZs) for different categories (Feinberg, 2017).

Category	Color Code	D_{max} $(ft.)$		DV_{max} (ft^2/s)
Children caught outdoors (tent camping, fishing, hiking, etc.)	Orange	≥2	or	≥5.4
Adults caught outdoors (tent camping, fishing, hiking, etc.)	Red	≥4	or	≥6.5
Motor vehicle (compact car) floating	None	≥1	or	≥4.3
Motor vehicle (compact car) sliding/toppling	None			≥5.4
Mobile homes	None	≥2	or	≥30
Typical residential structures	None	≥4	or	≥75

Results file package of DSS-WISE HCOM contains and ESRI shapefile of polygon type containing two stacked polygons corresponding to the first two categories in Table 4. These two polygons were extracted using the maximum flow depth and maximum specific discharge files provided in the results package of DSS-WISE Lite simulation (see Table 6). For convenience, Map 11 of this report shows the extents of these two PLFZ polygons.

The polygons for the remaining PLFZ zones can also be extracted from the D_{max} and DV_{max} raster files using a suitable GIS software.

6.0 POPULATION AT RISK (PAR) ANALYSIS

The population at risk (PAR) analysis aims to provide an estimate of the number of people that will be potentially affected by the propagation of the dam-break flood. DSS-WISE HCOM provides two different types of PAR analysis based on the two different population data sets that are available (see Section 3.2).

6.1 PAR Analysis Using Census Block Population Data

The results of the PAR analysis using 2010 census block population are given in two different forms:

- The list of the census blocks that are inundated (completely or partially) by the dam-break flood is provided in the "CensusBlock_Analysis" worksheet of the MS Excel file accompanying the present report.
- The polygons of the census blocks that are inundated (completely or partially) by the dam-break flood are provided in a shapefile accompanying the present report. The attributes of the census block polygons are the same as the data columns in the MS Excel file.

The polygons of census blocks included in the inundation extent (completely or partially) are provided as an ESRI shapefile (see Table 6) in the results package of DSS-WISE HCOM. The worksheet "CensusBlock_Analysis" lists all the census blocks and their attributes, which include various data extracted by DSS-WISE HCOM. The attributes of the census-block polygons are the same as the columns in the worksheet "CensusBlock_Analysis" of the MS Excel file accompanying the present report.

These attributes of the census blocks are listed and explained in Table 5. Map 06 in this report shows the census block polygon outlines overlaid on the flood extent.

Table 5. Attributes of the census block polygons in the shapefile and the corresponding columns in the worksheet "CensusBlock_Analysis" of the MS Excel file accompanying the present report.

ExcelFile		Shapefile	Unit	Description
Col	Title	Attributes		
A	State Name	STATE_NAME		Abbreviation of the state name
B	County Name	CNTY_NAME		County Name

C	State FIPS CODE	STATEFP10		2010 Census state FIPS code
D	County FIPS CODE	COUNTYFP10		2010 Census county FIPS code
E	Tract CODE	TRACTCE10		2010 Census tract code
F	Tabulation Block Number	BLOCKCE		2010 Census tabulation block number
G	Block ID Number	BLOCKID10		Census block identifier; A concatenation of 2010 Census state FIPS code, 2010 Census county FIPS code, 2010 Census tract code , and 2010 Census block number
H	Partial Block Indicator	PARTFLG		Y = partial block N = whole block
I	Total Number of Housing	HOUSING10	*Count*	2010 Census Housing Unit Count
J	Total Number of Population	POP10	*Count*	2010 Census Population Count
K	Total Area	AREATOT	*Acres*	Total area of the census block. This information is extracted from the geometry of the census block
L	Inundated Area	AREAINUND	*Acres*	Area of the census block inundated. This information is extracted by intersecting the inundation extent with the census block.
M	Percent Area Inundated	AINUND_PCT	%	This quantity is calculated in the MS Excel spreadsheet by the dividing the AREAINUND (column L) by the AREATOT (column K).

N	Flood Arrival Time (Avg)	FLDAT_AVG	hrs	This quantity is extracted from the arrival time raster. It corresponds to the average value of the arrival times of all computational cells within the extent of the census block.
O	Flood Arrival Time (Min)	FLDAT_MIN	hrs	This quantity is extracted from the arrival time raster. It corresponds to the minimum value of the arrival times of all computational cells within the extent of the census block.
P	Flood Arrival Time (Max)	FLDAT_MAX	hrs	This quantity is extracted from the arrival time raster. It corresponds to the maximum value of the arrival times of all computational cells within the extent of the census block.
Q	Flood Maximum Depth (Avg)	HMAX_AVG	ft	This quantity is extracted from the maximum flood depth raster. It corresponds to the average value of the maximum flood depths of all computational cells within the extent of the census block.
R	Flood Maximum Depth (Min)	HMAX_MIN	ft	This quantity is extracted from the maximum flood depth raster. It corresponds to the minimum value of the maximum flood depths of all computational cells within the extent of the census block.
S	Flood Maximum Depth (Max)	HMAX_MAX	ft	This quantity is extracted from the maximum flood depth raster. It corresponds to the maximum value of the maximum flood depth of all computational cells within the extent of the census block.

T	Flood Maximum DV Arrival Time (Avg)	DVMAXATAVG	hrs	This quantity is extracted from the arrival time of maximum specific discharge raster. It corresponds to the average value of the maximum specific discharge arrival times of all computational cells within the extent of the census block.
U	Flood Maximum DV Arrival Time (Min)	DVMAXATMIN	hrs	This quantity is extracted from the arrival time of maximum specific discharge raster. It corresponds to the minimum value of the maximum specific discharge arrival times of all the computational cells within the extent of the census block.
V	Flood Maximum DV Arrival Time (Max)	DVMAXATMAX	hrs	This quantity is extracted from the arrival time of maximum specific discharge raster. It corresponds to the maximum value of the maximum specific discharge arrival times of all the computational cells within the extent of the census block.
W	Flood Maximum DV (Avg)	DVMAX_AVG	ft^2/s	This quantity is extracted from the maximum specific dishcarge raster. It corresponds to the average value of the maximum specific discharge of all the computational cells within the extent of the census block.
X	Flood Maximum DV (Min)	DVMAX_MIN	ft^2/s	This quantity is extracted from the maximum specific dishcarge raster. It corresponds to the minimum value of the maximum specfic discharge of all the computational cells within the extent of the census block.

Y	Flood Maximum DV (Max)	DVMAX_MAX	ft^2/s	This quantity is extracted from the maximum specific dishcarge raster. It corresponds to the maximum value of the maximum specific discharge of all the computational cells within the extent of the census block.

6.2 PAR Analysis Using LandScan USA Gridded Population Data

The PAR analysis using LandScan USA 3 arc-second gridded population data provides three sets of tabular results classified in up to 17 flood times and 10 flood hazard categories based on DV_{max}:

- Tabular summary of inundation areas as a function of flood time is presented in the worksheet "InundatedArea" of the MS Excel file accompanying the present report. The inundation area values are presented as a stacked column plot in the same worksheet.
- Tabular summary of nighttime PAR counts as a function of flood time is presented in the worksheet "Nighttime_PAR" of the MS Excel fle accompanying the present report. The nighttime PAR counts are plotted as a stacked column plot in the same worksheet.
- Tabular summary of daytime PAR counts as a function of flood time is presented in the worksheet "Daytime_PAR" of the MS Excel fle accompanying the present report. The tabular data is also plotted as a stacked column plot.

The nighttime and daytime PAR counts were obtained from nighttime and daytime population densities, which were extracted from LandScan USA following the methologies described in the technical manual for DSS-WISE HCOM. Map 07 and Map 08 in this report show the nighttime and daytime population densities over the inundation area.

7.0 RESULTS FILES GENERATED BY DSS-WISE HCOM

All the results files generated by DSS-WISE HCOM are listed Table 6.

Table 6. List of results files generated by DSS-WISE HCOM.

No	Name	Type	Description
1	42726_HCOM_Final_Report.pdf	PDF	The present report.
2	42726_HCOM_Analysis.xlsx	Ms Excel	Ms Excel file accompanying this report. It contains four worksheets: 1. InundatedArea 2. Nighttime_PAR 3. Daytime_PAR 4. CensusBlock_Analysis
3	42726_HCOM_Census_Block_polygons.shp	ESRI Shapefile	This ESRI shapefile of polygon type contains the polygons of the census blocks completely or partially included in the inundation extent. The attributes of the polygons are the same as the columns in the worksheet "CensusBlock_Analysis". They are listed in Table 5.
4	42726_HCOM_Outdoor_Hazard_Categories_polygons.shp	ESRI Shapefile	This ESRI shapefile of polygon type contains up to five polygons corresponding to the five potential flood hazard levels for humans caught outdoors by the flood as listed in Table 2 (Section 4.1)
5	42726_HCOM_Indoor_Hazard_Categories_polygons.shp	ESRI Shapefile	This ESRI shapefile of polygon type contains up to five polygons corresponding to the five potential flood hazard levels for humans caught indoors by the flood as listed in Table 3 (Section 4.2)

6	42726_HCOM_PLFZ_polygons.shp	ESRI Shapefile	This ESRI shapefile of polygon type contains up to two stacked polygons corresponding to the PLFZ areas as listed in the first two rows of Table 4.
7	42726_HCOM_NT_PopDensity_persqmi_polygons.shp	ESRI Shapefile	This ESRI shapefile of polygons type contains polygon of nighttime population density per square mile extracted from LandScan USA data. This file should be treated as **FOUO**
8	42726_HCOM_DT_PopDensity_persqmi_polygons.shp	ESRI Shapefile	This ESRI shapefile of polygons type contains polygon of daytime population density per square mile extracted from LandScan USA data. This file should be treated as **FOUO**

8.0 REFERENCES

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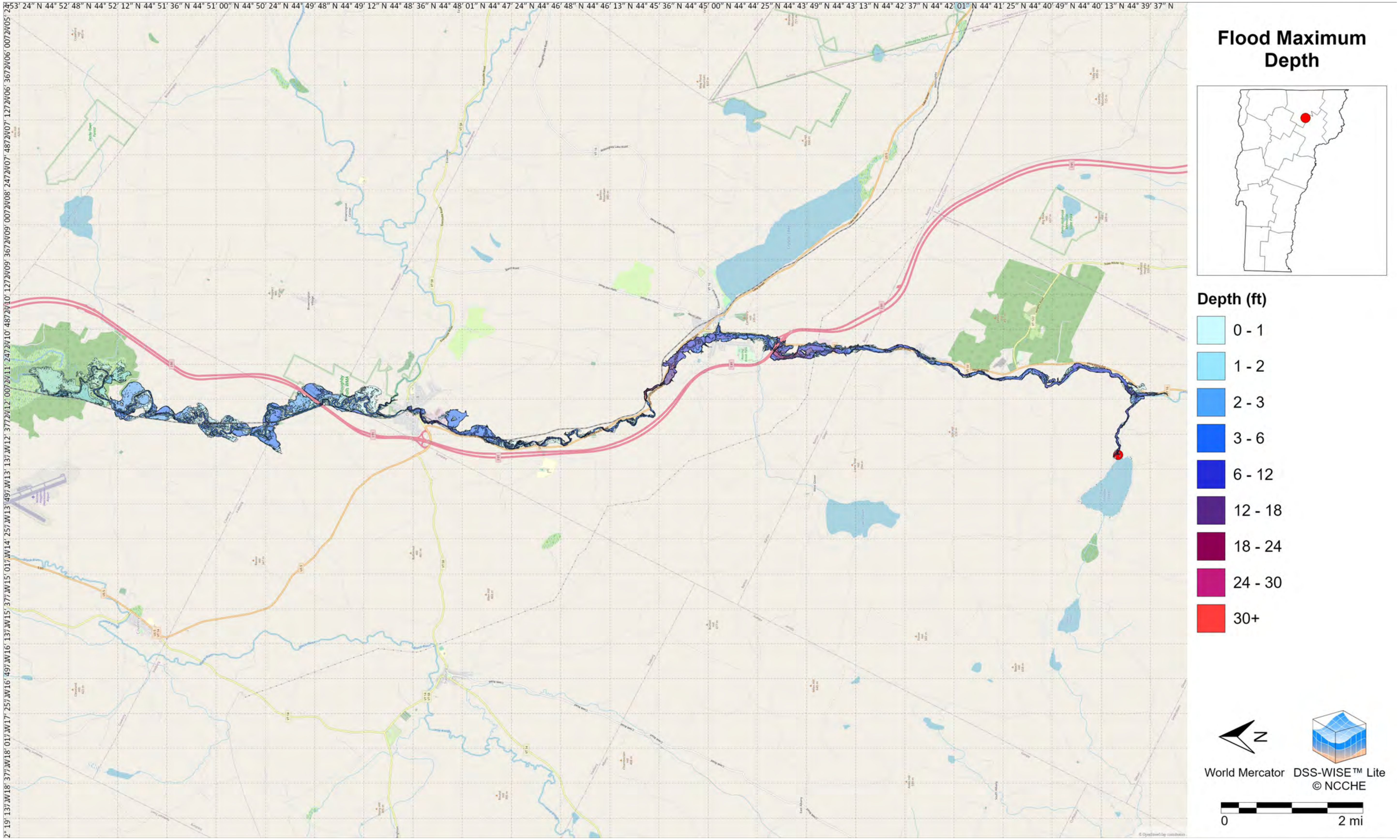
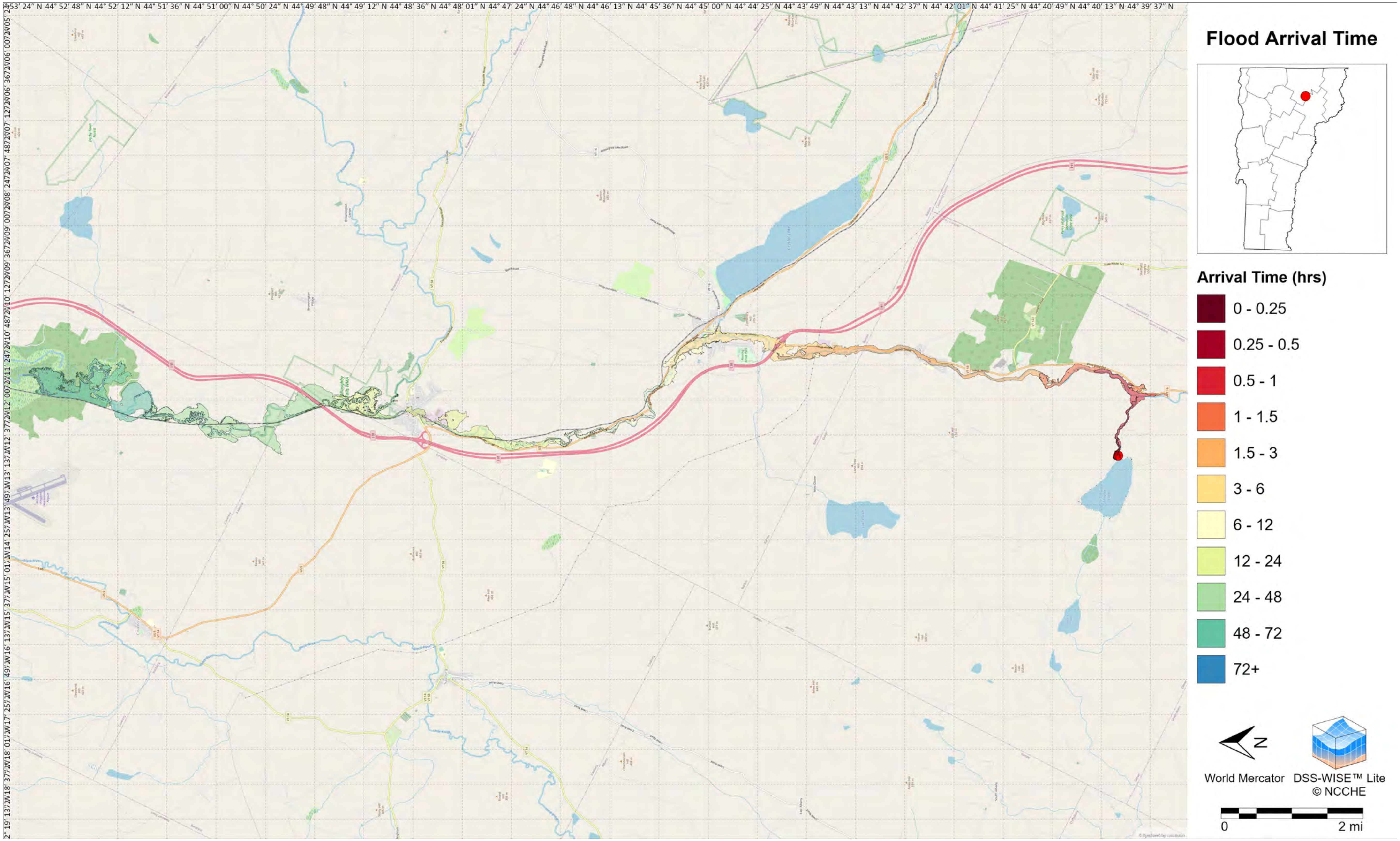
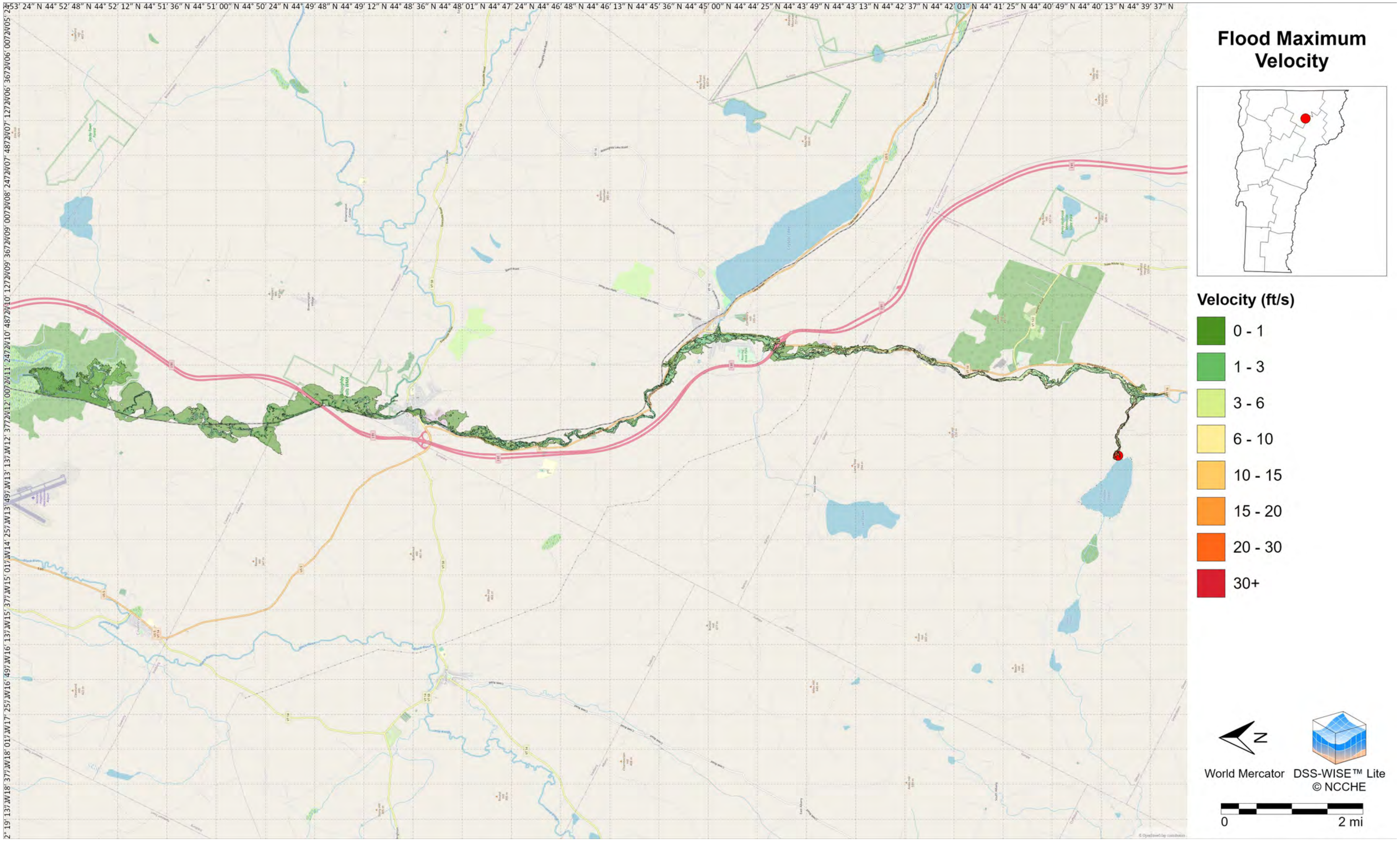
Map 01: Flood Maximum Depth



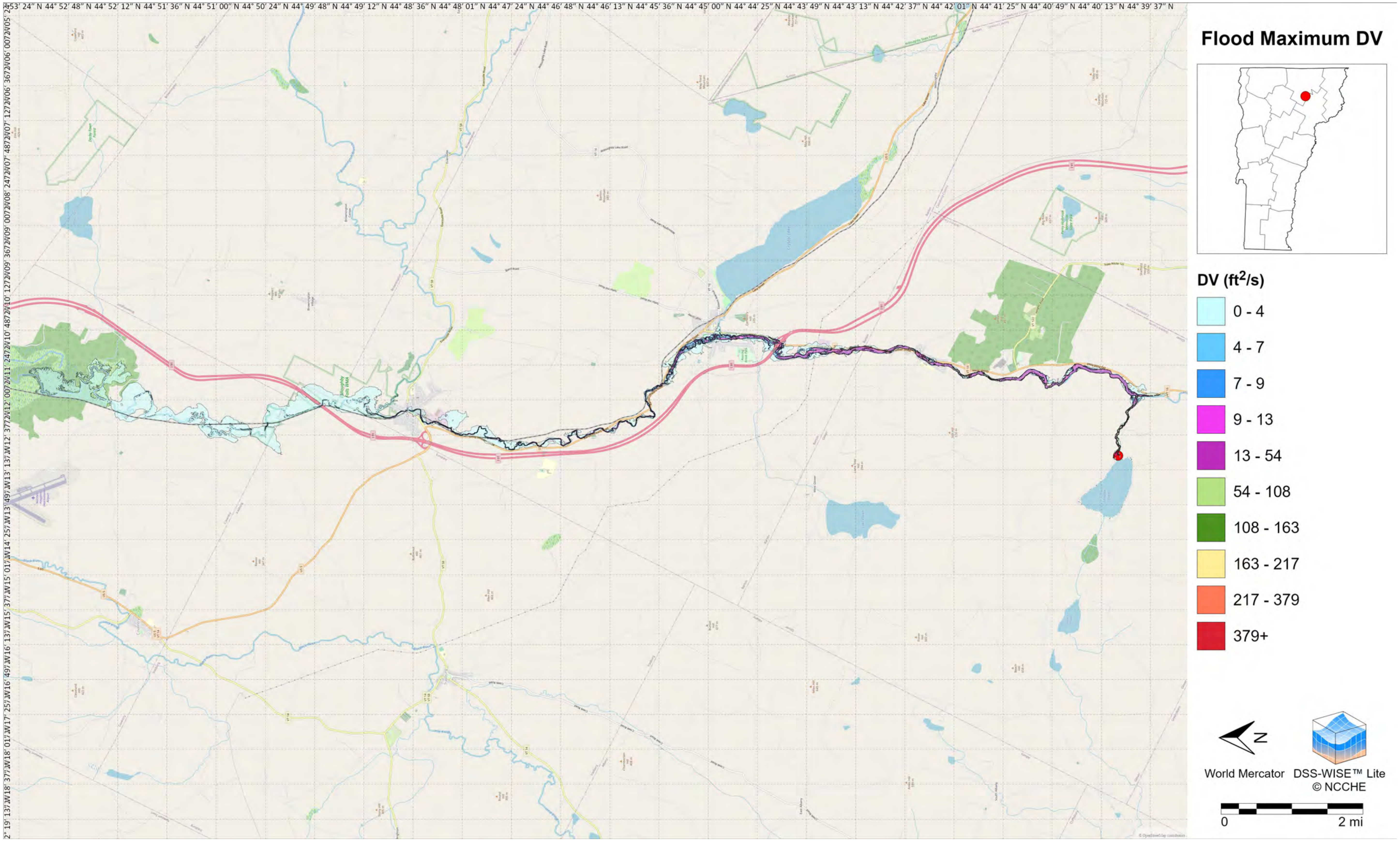
Map 02: Flood Arrival Time



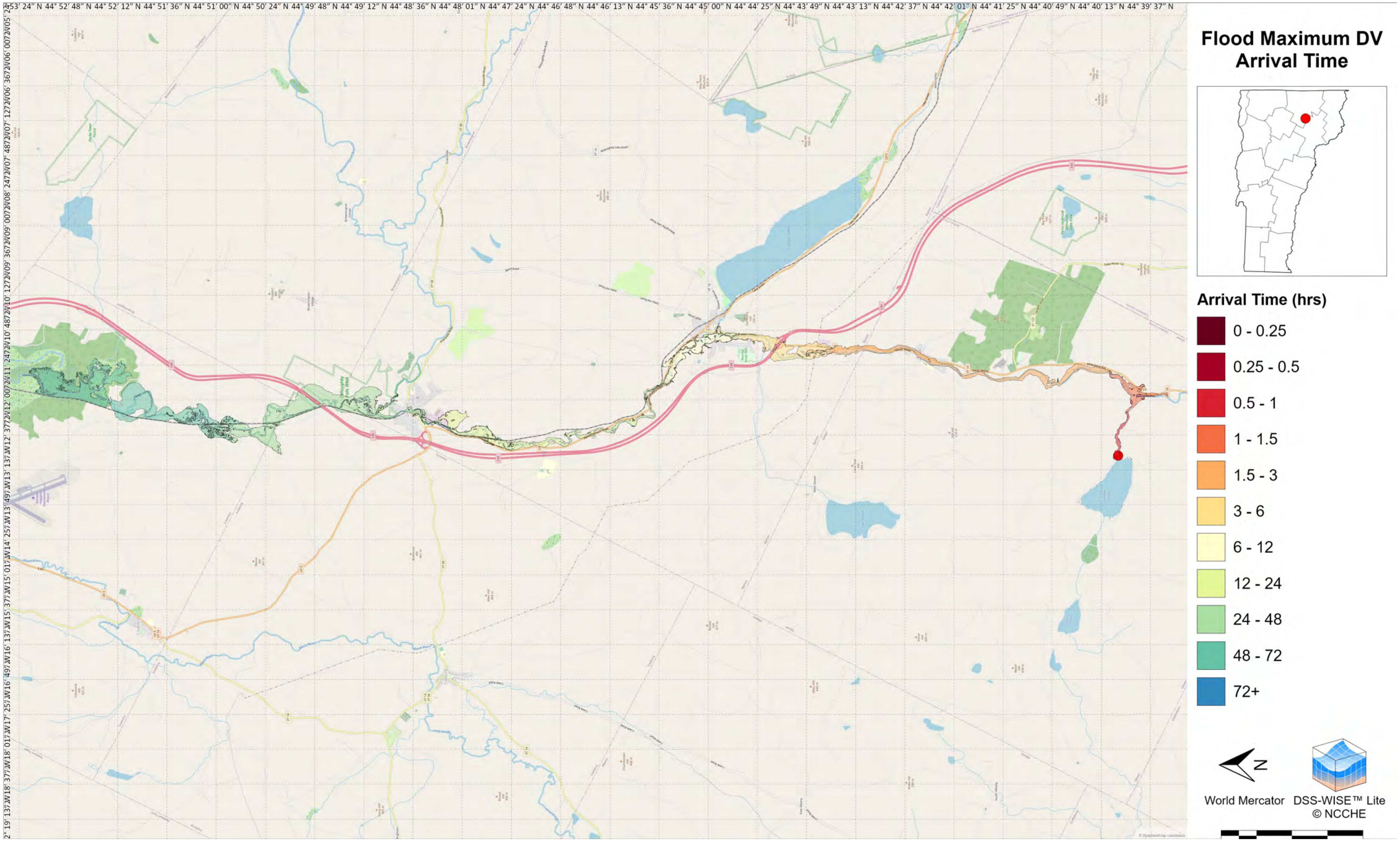
Map 03: Flood Maximum Velocity



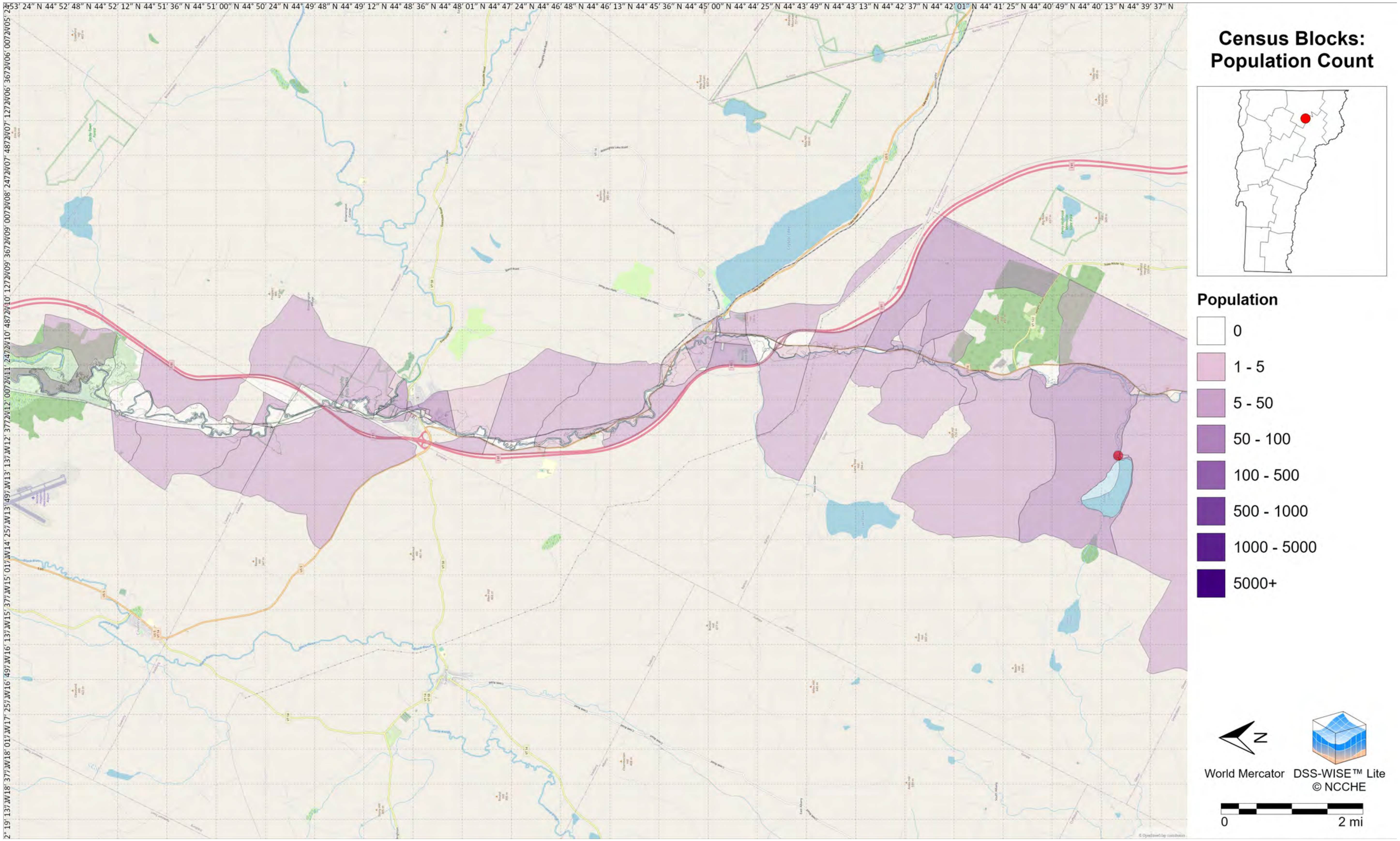
Map 04: Flood Maximum DV



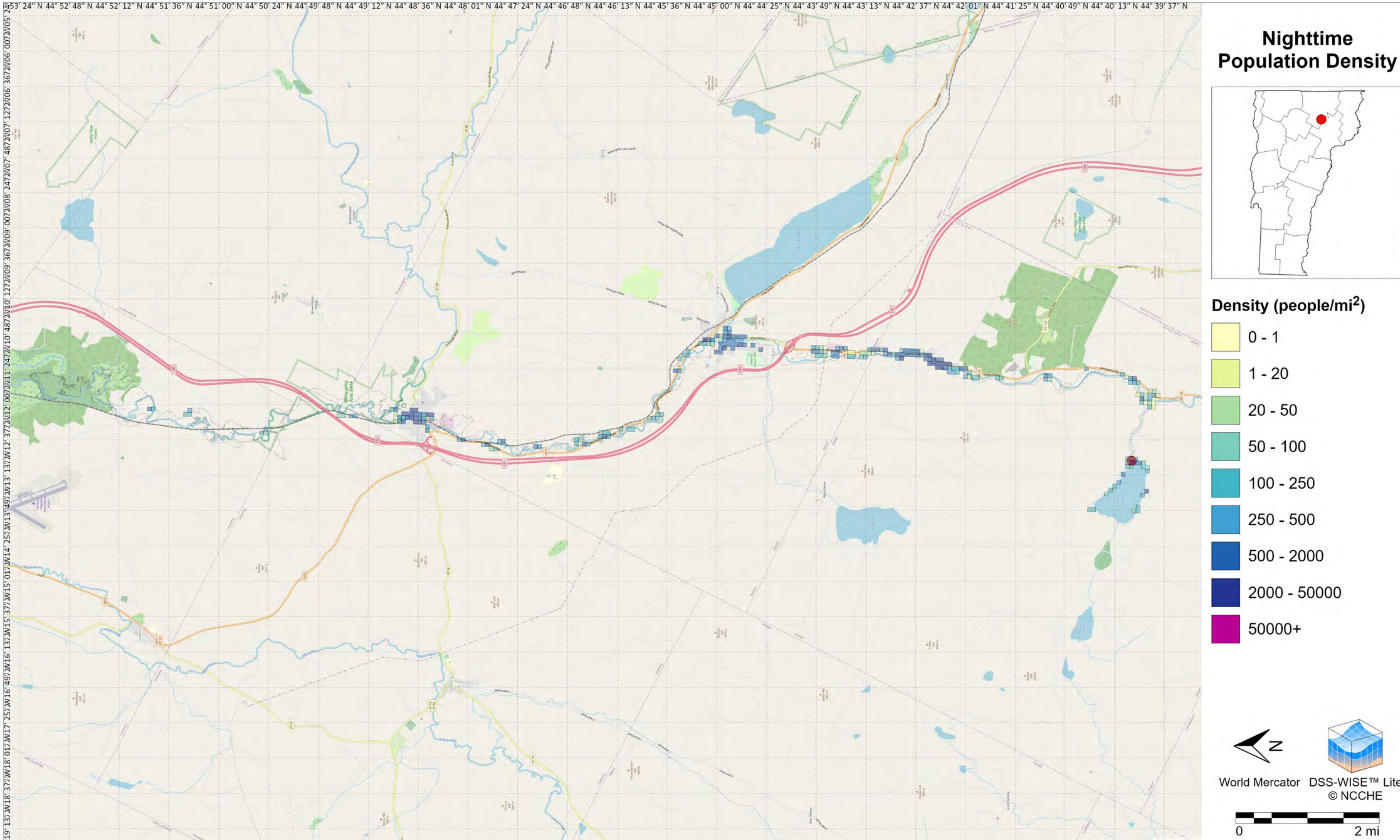
Map 05: Flood Maximum DV Arrival Time



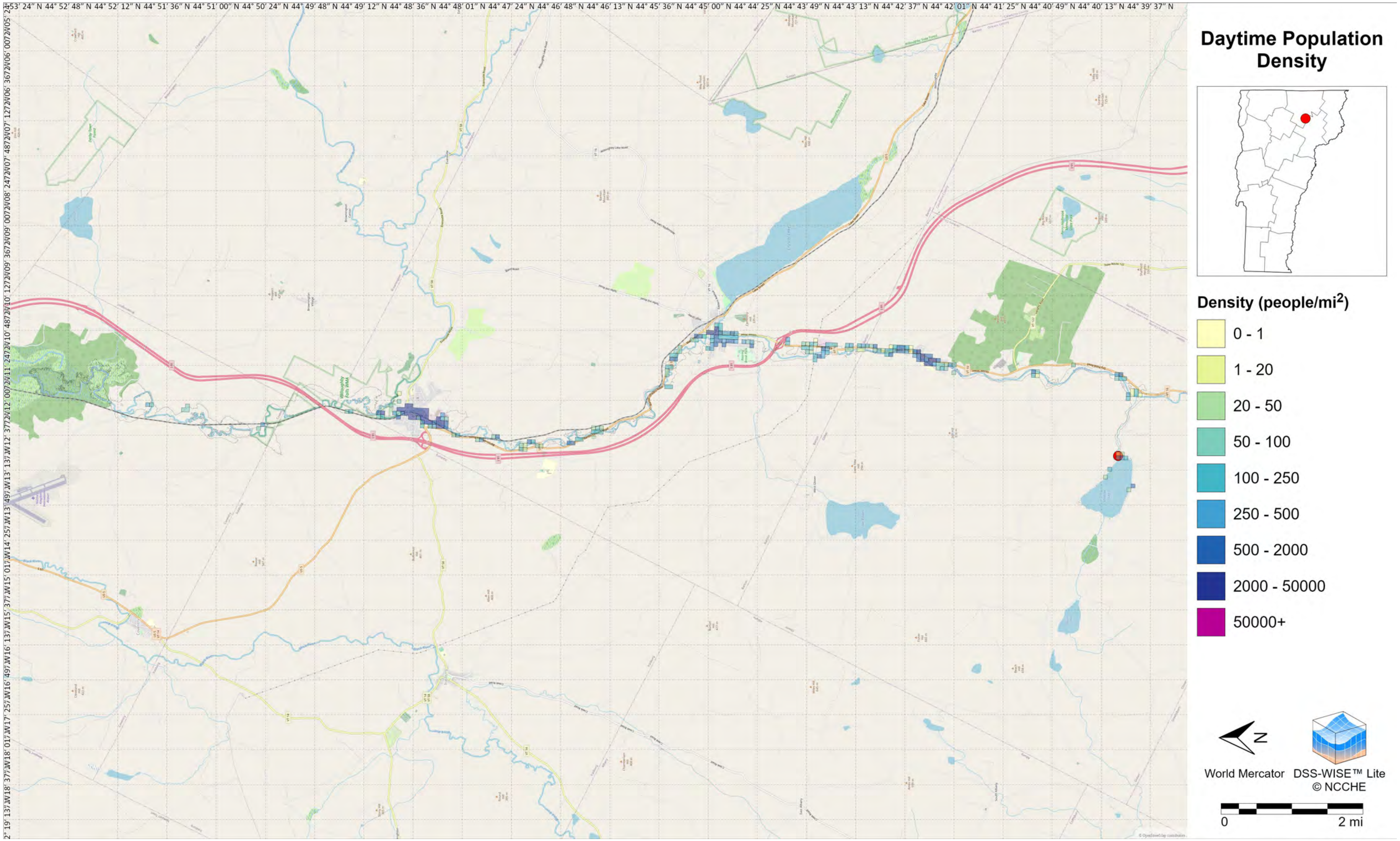
Map 06: Census Blocks: Population Count



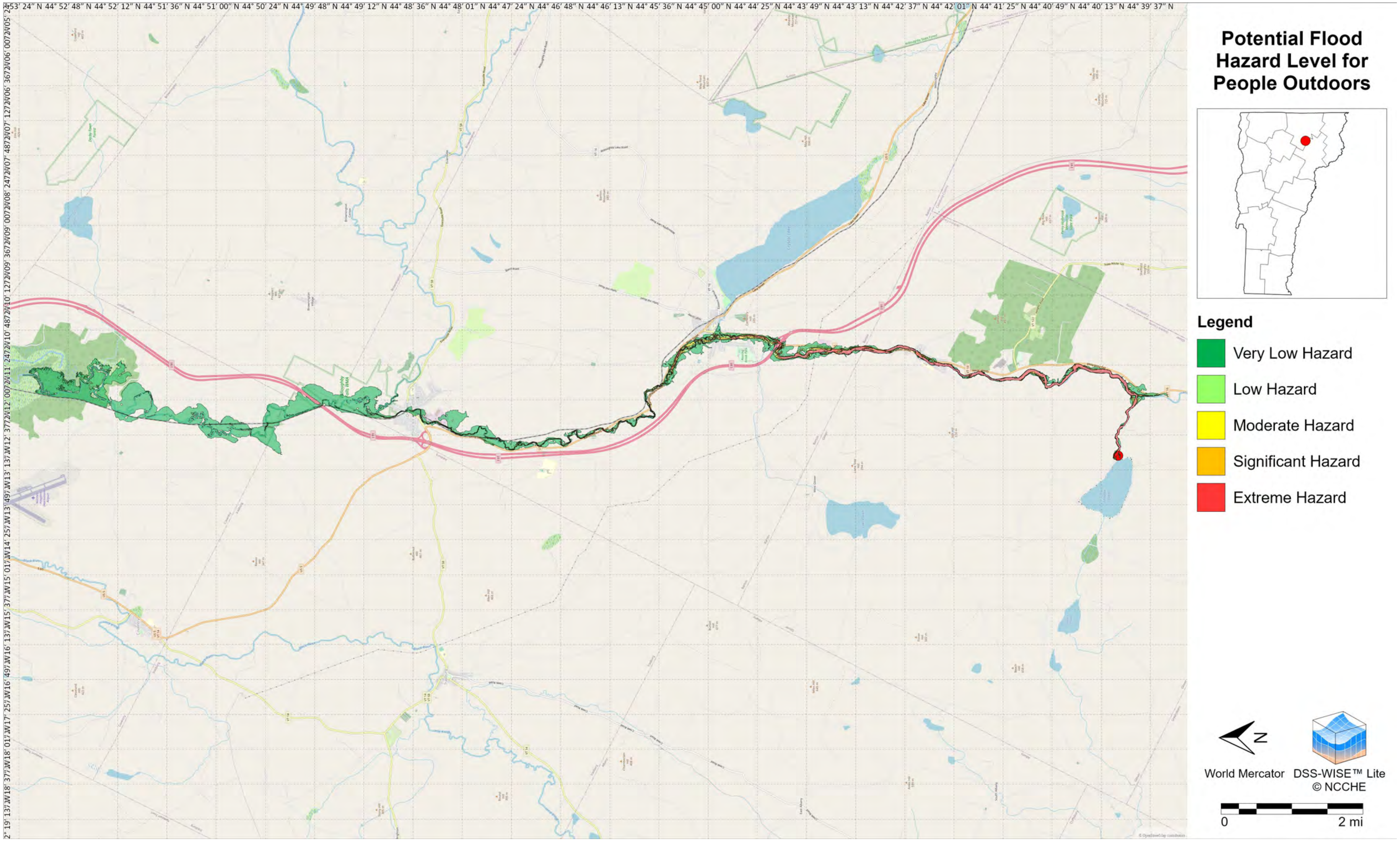
Map 07: Nighttime Population Density



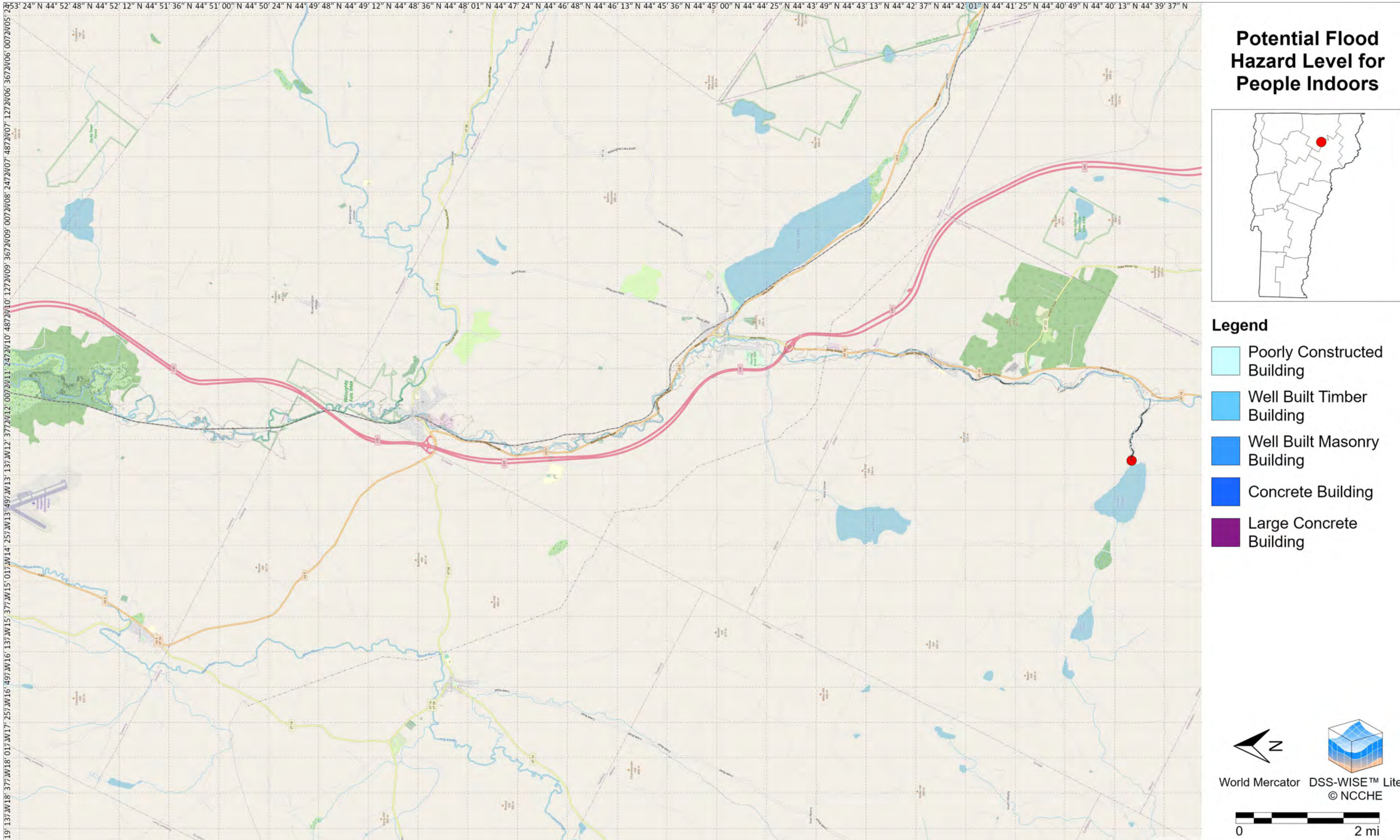
Map 08: Daytime Population Density



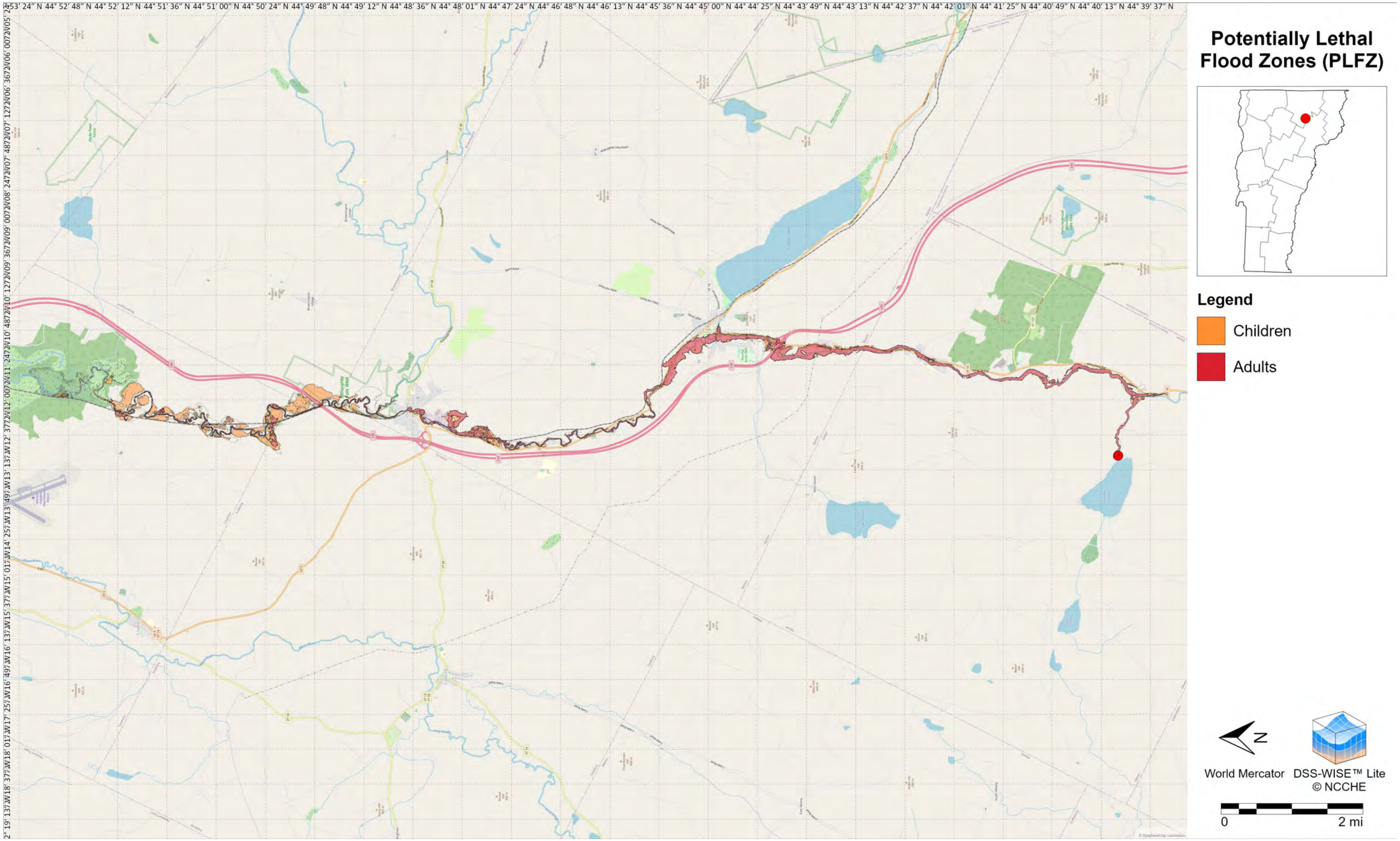
Map 09: Potential Flood Hazard Level for People Outdors



Map 10: Potential Flood Hazard Level for People Indoors



Map 11: Potential Lethal Flood Zones (PLFZ)



Attachment D: ACER Technical Memorandum No. 11 – USBR, Depth-Velocity Flood Danger Relationships

HIGH DANGER ZONE - Occupants of most houses are in danger from floodwater.
JUDGEMENT ZONE - Danger level is based upon engineering judgement.
LOW DANGER ZONE - Occupants of most houses are not seriously in danger from flood water.

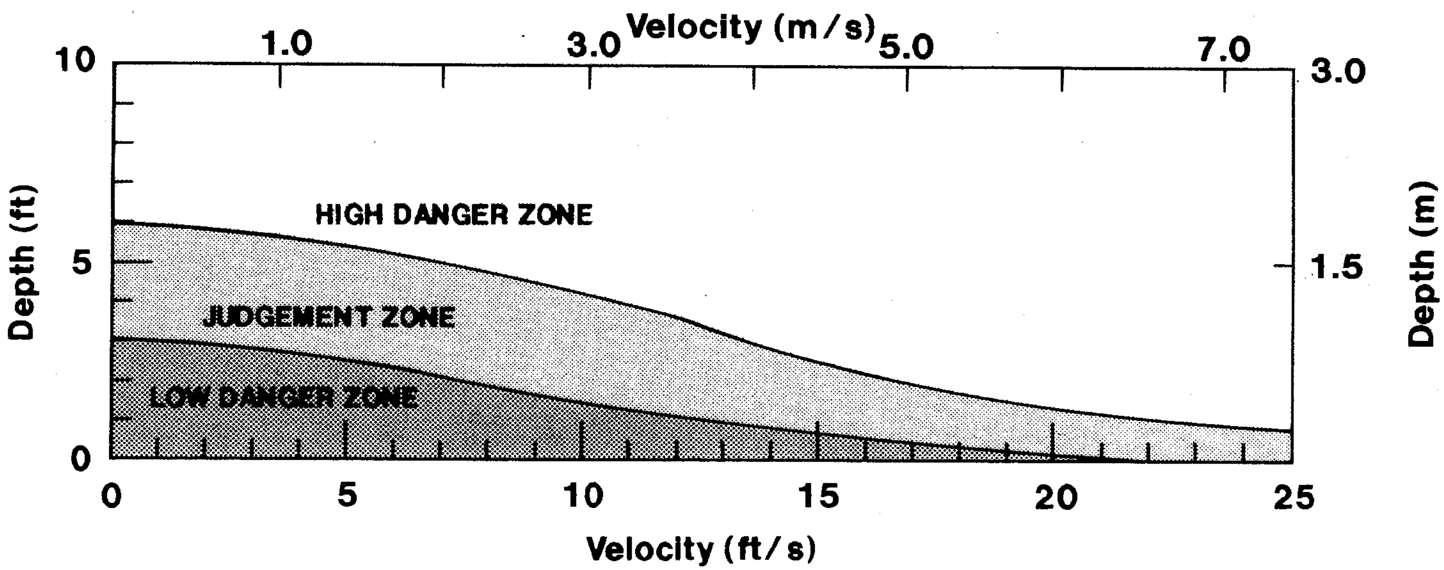


Figure 2. – Depth–velocity flood danger level relationship for houses built on foundations.

HIGH DANGER ZONE – Occupants of almost any size mobile home are in danger from flood water.
JUDGEMENT ZONE – Danger level is based upon engineering judgement.
LOW DANGER ZONE – Occupants of almost any size mobile home are not seriously in danger from flood water.

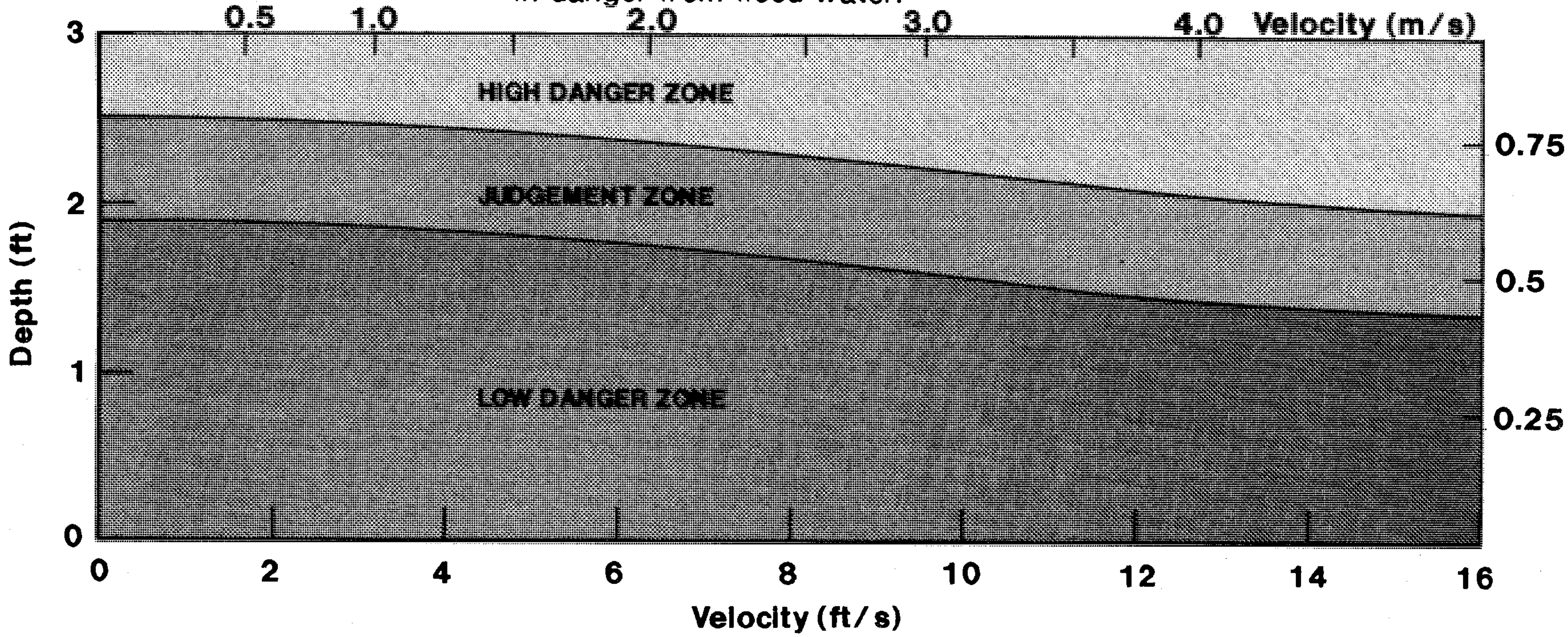


Figure 3. – Depth–velocity flood danger level relationship for mobile homes.