Appendix I

Flood Risk Analysis

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Technical Memorandum

DATE:	February 22, 2024
TO:	Tim Brownell, Deschutes County Director of Solid Waste
FROM:	Seth Sokol, PE
SUBJECT:	Flood Risk Desktop Assessment
CC:	Julie Brandt, PE, Ryan Rudnick, PE
PROJECT NUMBER:	553-2509-011
PROJECT NAME:	Final Solid Waste Management Facility Site Evaluation

Introduction

This technical memorandum documents a desktop flood risk assessment for two proposed solid waste management facility site boundaries (Sites) in Deschutes County, Oregon. The locations are known as the Moon Pit Site and Roth East Site, and they are approximately 16 and 25 miles southeast of Bend, Oregon, respectively. The flood risk assessment evaluates the risk of primary and secondary flood effects on the structures, utilities, and site access; estimates the magnitude of a flood event that could impact operations or present an environmental hazard; projects changes in flooding due to climate change; and recommends risk mitigation measures.

Laws, Plans, Policies, and Regulations

The following federal, state, and local laws, regulations, plans, and policies guide or inform the assessment of floodplains, floodways, and other high-water hazard areas:

Federal

- Clean Water Act, 33 U.S. Code (USC) 1344 et seq., Section 404 – Permits for Dredge or Fill.
- Floodplain Management Presidential Executive Order 11988 of 1977 and its subsequent updates (EO 13690 and 14030).
- National Flood Insurance Act of 1968 and Flood Disaster Protection Act of 1973, 42 USC 4001 et seq.
- Endangered Species Act (ESA) Biological Opinion for the Implementation of the National Flood Insurance Program in the State of Oregon (NMFS 2016).
- Flood Insurance Rate Maps for Deschutes County, Oregon, and Incorporated Areas (FEMA 2007a).
- Flood Insurance Study for Deschutes County, Oregon, and Incorporated Areas (FEMA 2007b)
- 40 Code of Federal Regulations 258.11. Part 258 "Criteria for Municipal Solid Waste Landfills," Subpart B "Location Restrictions," Section 11 "Floodplains."

State

- Oregon Revised Statute Title 45 – Water Resources, Irrigation, Drainage, Flood Control, Reclamation.

- Oregon Department of Transportation (ODOT) Hydraulics Design Manual (ODOT 2014).
- Oregon Natural Hazards Mitigation Plan (DLCD 2020).
- Oregon Administrative Rule 340-094-0030. Division 94 "Solid Waste: Municipal Solid Waste Landfills," Section 0030 "Location Restrictions."

Regional and Local

- Deschutes County Multi-jurisdictional Natural Hazards Mitigation Plan (NHMP; COIC 2021).
- Deschutes County Code. Chapters 18.96 "Flood Plain Zone; FP," "19.72 Flood Plain Combining Zone," and 21.12 "Flood Plain Zone; FP."

Federal and state code require that solid waste management facilities demonstrate that they will not restrict the flow of the 100-year flood, reduce the temporary water storage capacity of the floodplain, or result in solid waste being carried away (washout) such that it poses a hazard to human life, wildlife, or land or water resources.

Methodology

Study Area

The study area for the flood risk assessment (Figure 1) consists of the drainage subbasins where the Sites would be located. The Moon Pit and Roth East sites are in the Smith Canyon-Dry River Basin and Mahogany Butte-Dry River Basin, respectively, according to the U.S. Geological Survey National Hydrography Dataset. They are in an arid region of northeast Oregon, with average annual rainfall of 11.4 and 10.6 inches, respectively (PRISM 2021). The study area is in the Oregon High Desert, and the land cover is classified as shrubland (USGS 2021).

Data Review

The flood risk assessment included investigation and mapping of the following flood hazard areas in the study area.

Floodplains

Land with an annual 1% or greater chance of being inundated by surface waters from any source is referred to as a 100-year floodplain; it is also known as a special flood hazard area. Land with an annual 0.2% (or 1 in 500) or greater chance of being inundated by surface waters from any source is known as a 500-year floodplain.

Floodways

The portion of a main watercourse channel and adjacent lands that represents the area where fill or other encroachment is expected to adversely impact the depth or width of the base flood conveyance beyond allowable standards. Floodways are defined through detailed hydraulic analysis; therefore, many floodplains have not yet had their associated floodways identified.

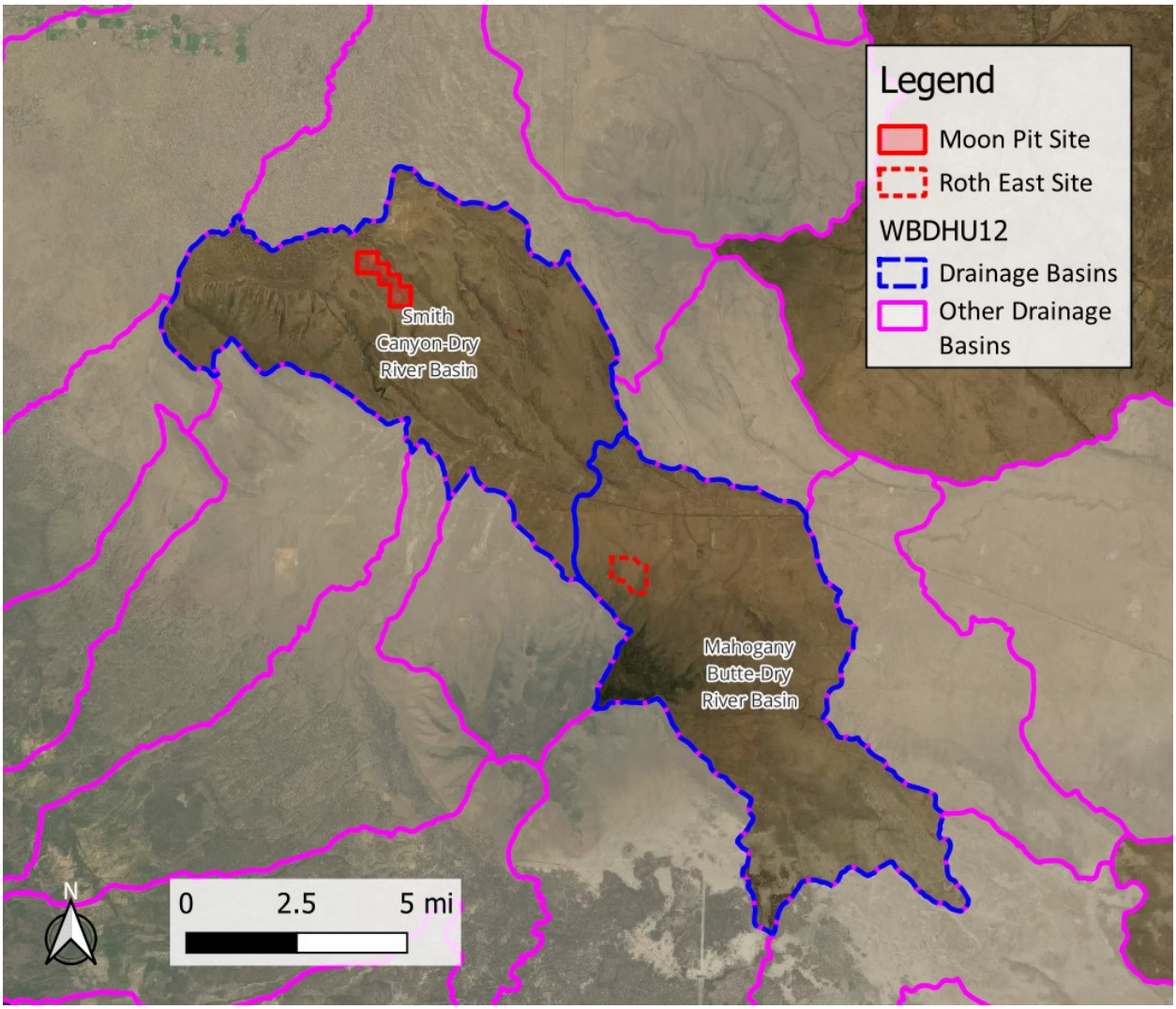

Figure 1. Flood Risk Study Area
Source: U.S. Geological Survey National Hydrography Dataset; MapTiler.com Satellite Map Layer

High Groundwater

High groundwater flood hazard areas occur where high groundwater forms ponds on the ground surface or may overlap with other critical areas such as streams, rivers, lakes, coastal areas, and wetlands.

Federal, state, regional, and local flood studies; mapping data; and records of flood observation were used to identify the flood hazard areas.

Existing Conditions

Mapped Flood Hazard Areas

The extent of the special flood hazard areas is mapped on Federal Emergency Management Agency (FEMA) flood insurance rate maps (FIRMs) for Deschutes County (FEMA 2007a). Mapped flood hazard areas are present in the study area (Figure 2) along the alignment of the Dry River, a tributary of the Crooked River. These are designated flood hazard zone A; they are within the 100-year flood zone, but no base flood elevations or floodway delineations are available. The Moon Pit site is 800 feet from the mapped floodplain, while the Roth East Site is more than 1 mile away.

The mapped flood areas coincide with Central Oregon Highway (U.S. 20) throughout the study area. Climate change is generally expected to make flood risk worse, and areas within existing floodplains are "more likely to be negatively affected sooner" (ODOT 2022). ODOT has prepared projections for its transportation infrastructure risk to climate change (ODOT 2022). Segments of roadway are ranked from 1 to 5, with 1 being the lowest exposure. Risk scores for highway infrastructure near the Sites were obtained from the ODOT TransGIS web application "Inland Flooding Risk" layer and are shown in Table 1.

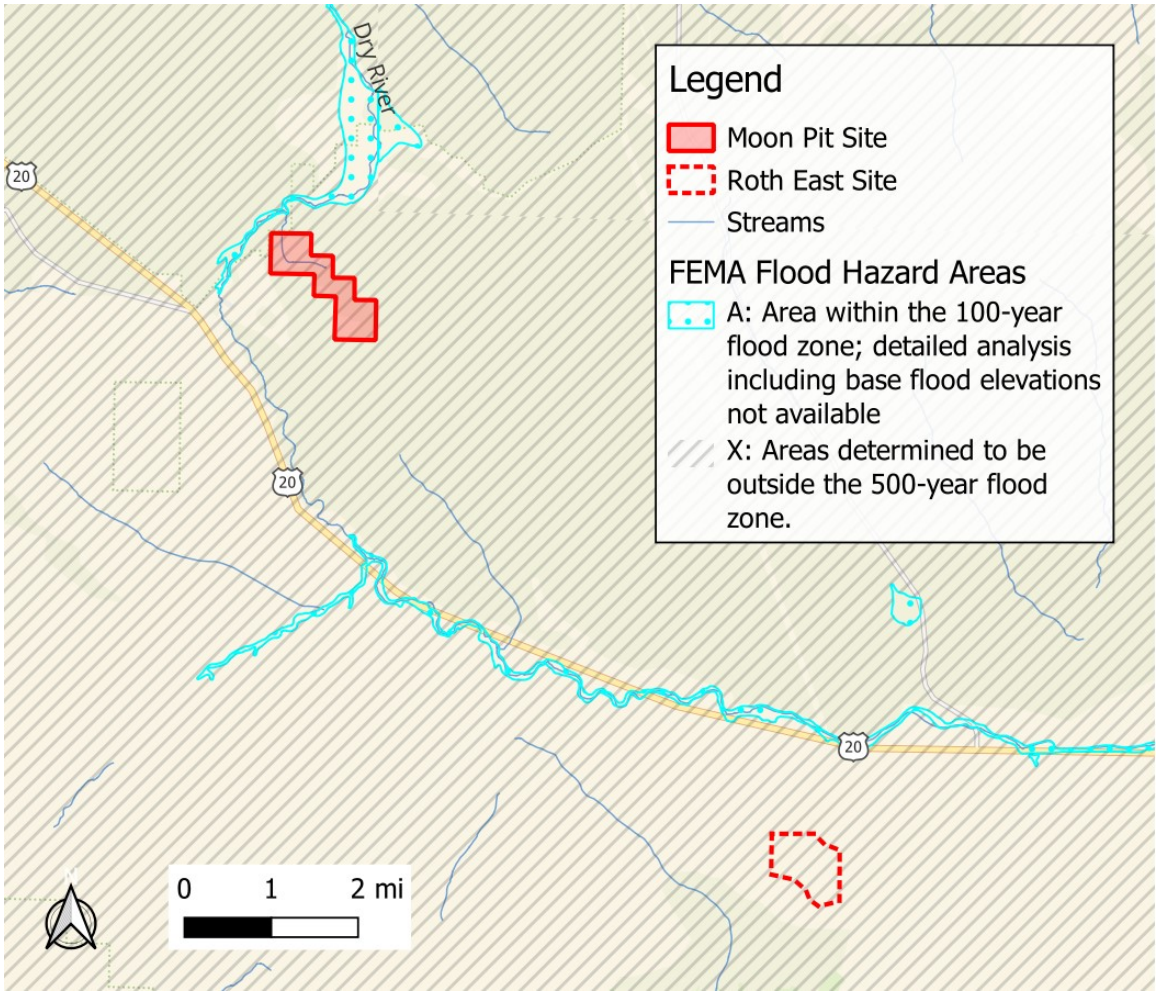

Figure 2. 100-Year Floodplain

Source: Oregon Statewide Flood Hazard Database – 2015 (Oregon Department of Land Conservation and Development)

Table 1. Future Inland Risk on Highways near Arlington, Oregon

Segment	Score [1]	Risk Score Explanation
Central Oregon (U.S. 20)	4.83	In historical 100-year and 500-year floodplain. Assets located in present-day flood zones are more likely to be adversely affected sooner.

ODOT infrastructure risk from climate change (ODOT 2022) on a scale of 1 to 5, with 1 being the lowest risk.

Hazard Studies

The Deschutes County NHMP identifies the principal riverine flood sources in Deschutes County as the "Deschutes River, Little Deschutes River, Paulina Creek, Whychus Creek, and Spring River" (COIC 2021). These rivers and streams are not within the study and are not considered risks at either of the Sites.

The Deschutes County NHMP identifies the five principal types of floods that occur in Deschutes County as "rain on snow (warm winter) flooding, spring/snowmelt flooding, ice jams and frazil ice, flash flood, and dam failure." The assessed risk of each of the mechanisms in the study area are described below:

- Rain-on-snow is the most common flooding event in Deschutes County (COIC 2021); therefore this is a possible flood risk. It may be combined with spring snowmelt as described below.
- Spring snowmelt occurs in the spring and early summer when temperatures rise quickly. This can combine with snowmelt to produce flooding. Climate change may cause mid- to low-elevation areas such as where the Sites are "to experience an increase in winter flood risk due to warmer winter temperatures causing precipitation to fall more as rain and less as snow" (OCCRI 2020).
- Ice jams and frazil ice are not considered a significant risk because Dry River is intermittent. Ice jams are common on the Deschutes River, which is not within the study area.
- Flash floods are caused by intense storms with heavy rainfall in a short period of time. These events "are most common in arid and semi-arid areas of Oregon like Deschutes County where there is often steep topography, little vegetation and intense but short-duration rainfall" (COIC 2021). The dry canyon and riverbed of Dry River are typical of locations where flash flooding is most severe; therefore flash floods are an expected risk. Climate change is expected to increase the intensity of storm events, thus increasing the risk of flash flooding.
- Dam failure is not considered a significant risk. According to the Deschutes County NHMP, "The Oregon Water Resources Department has inventoried all dams located in Oregon and Deschutes County. There are five dams categorized as high hazard; North Canal Diversion, Crescent Lake, Crane Prairie Dam, Wickiup Dam, and the Sunriver Effluent Lagoon." None of these dams are within or nearby the study area. Natural dams, such as the moraine-dammed Carver Lake on the eastern side of South Sister, are not near the study area.

The primary source of county-level climate projects and risk assessment are from the Oregon Climate Change Research Institute. They are "supporting the Oregon Department of Land Conservation and Development in its development of county-level natural hazard mitigation plans"(OCCRI 2023). To

date, 27 of Oregon's 36 counties have completed reports. Deschutes County and nearby Crook County do not have completed reports, therefore assessments of climate change risk at the county scale are unavailable.

Site Topography

The Moon Pit site (Figure 3) is located at an elevation of between 3,580 to 3,840 feet (North American Vertical Datum of 1988 [NAVD 88]). The southern part of the site has an average resultant slope of 4.0%, while the northern part of the site is relatively flat. Several channels collect runoff from the southwest slope of the West Butte of Bear Creek Buttes. These drain northwest though the site and discharge to Dry River. The Oregon Badlands Wilderness is on the opposite side of Dry River to the north and is characterized by low slope and uneven terrain.

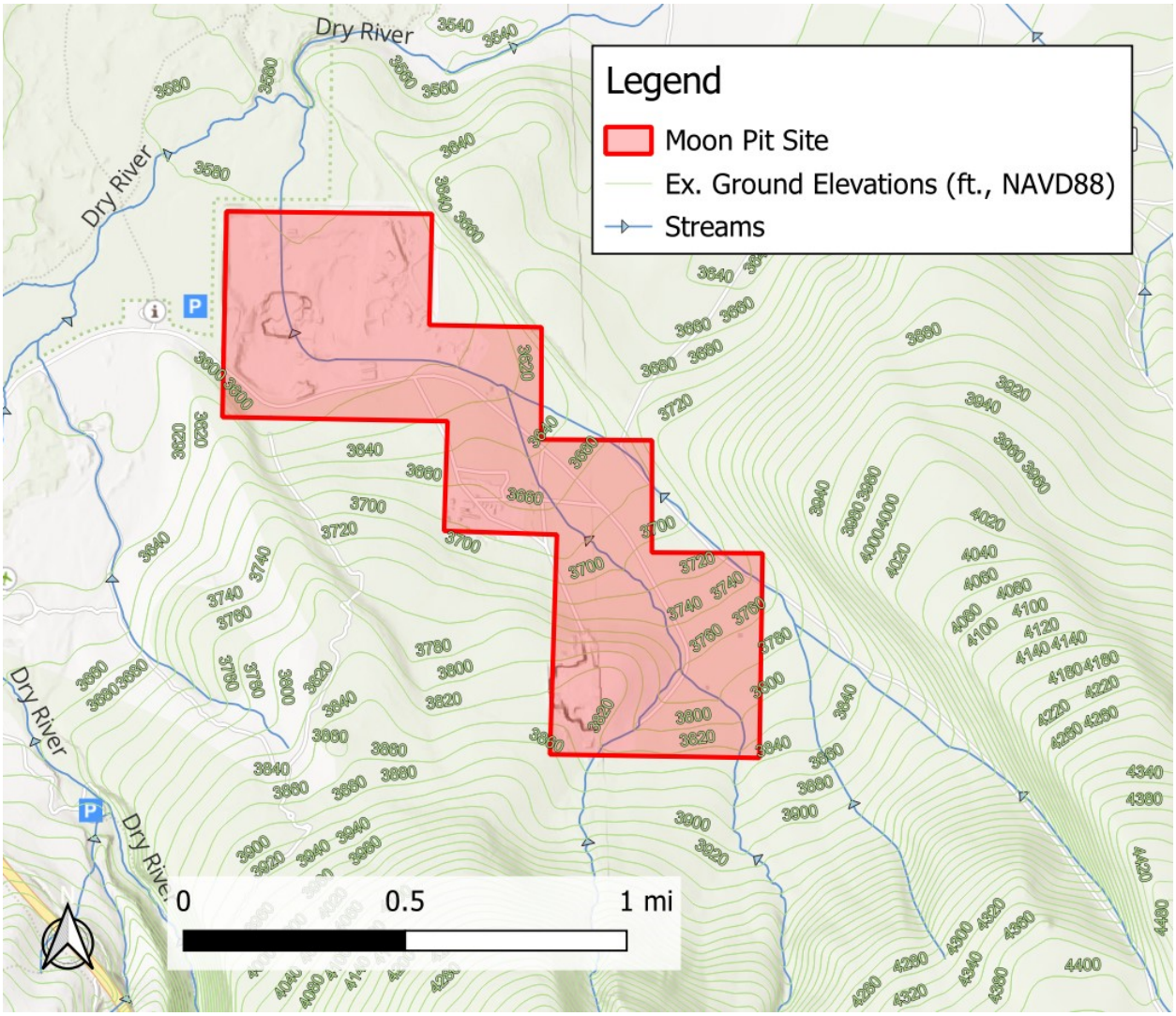

Figure 3. Moon Pit Site Topography and Stream Channels
Source: National Flood Hazard Layer; USGS National Hydrography Dataset; MapTiler.com Streets Layer; ESRI World Hillshade

The Roth East site (Figure 4) is located at an elevation of between 4,480 to 4,600 feet (NAVD88). The site has an average resultant slope of 3.7%. Several channels collect runoff from the northeast slope of Pine Mountain in the Deschutes National Forest. These drain north though the site and discharge to Dry River near U.S. 20.

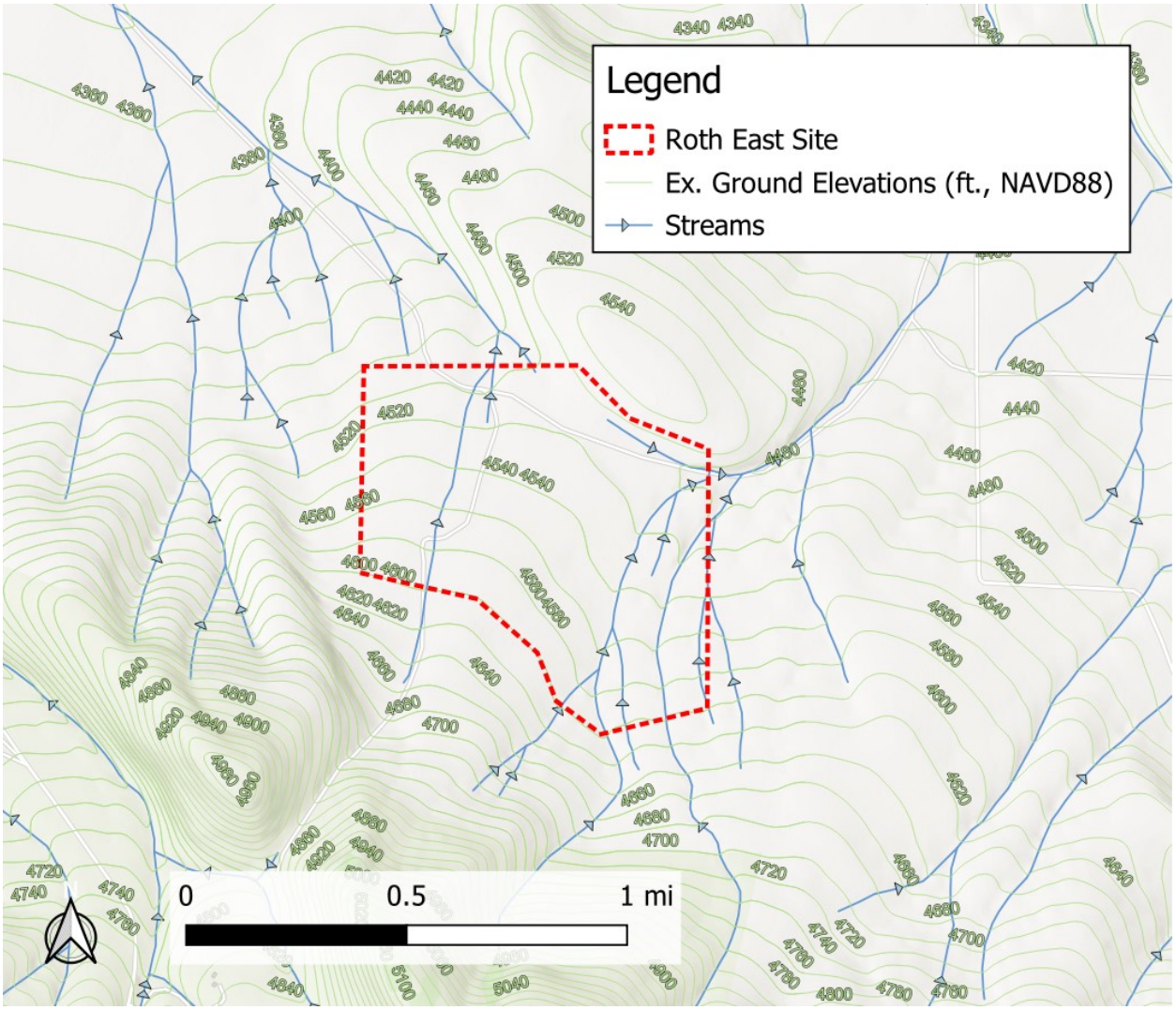

Figure 4. Roth East Site Topography and Stream Channels
Source: National Flood Hazard Layer; USGS National Hydrography Dataset; MapTiler.com Streets Layer; ESRI World Hillshade

Groundwater Flooding Hazards

The Oregon Water Resources Department (OWRD) groundwater well logs for the area (Figure 5) show groundwater to be at depths of several hundred feet or more below the ground surface (OWRD 2023). Groundwater expression or ponding, therefore, is not considered a significant source of flood risk.

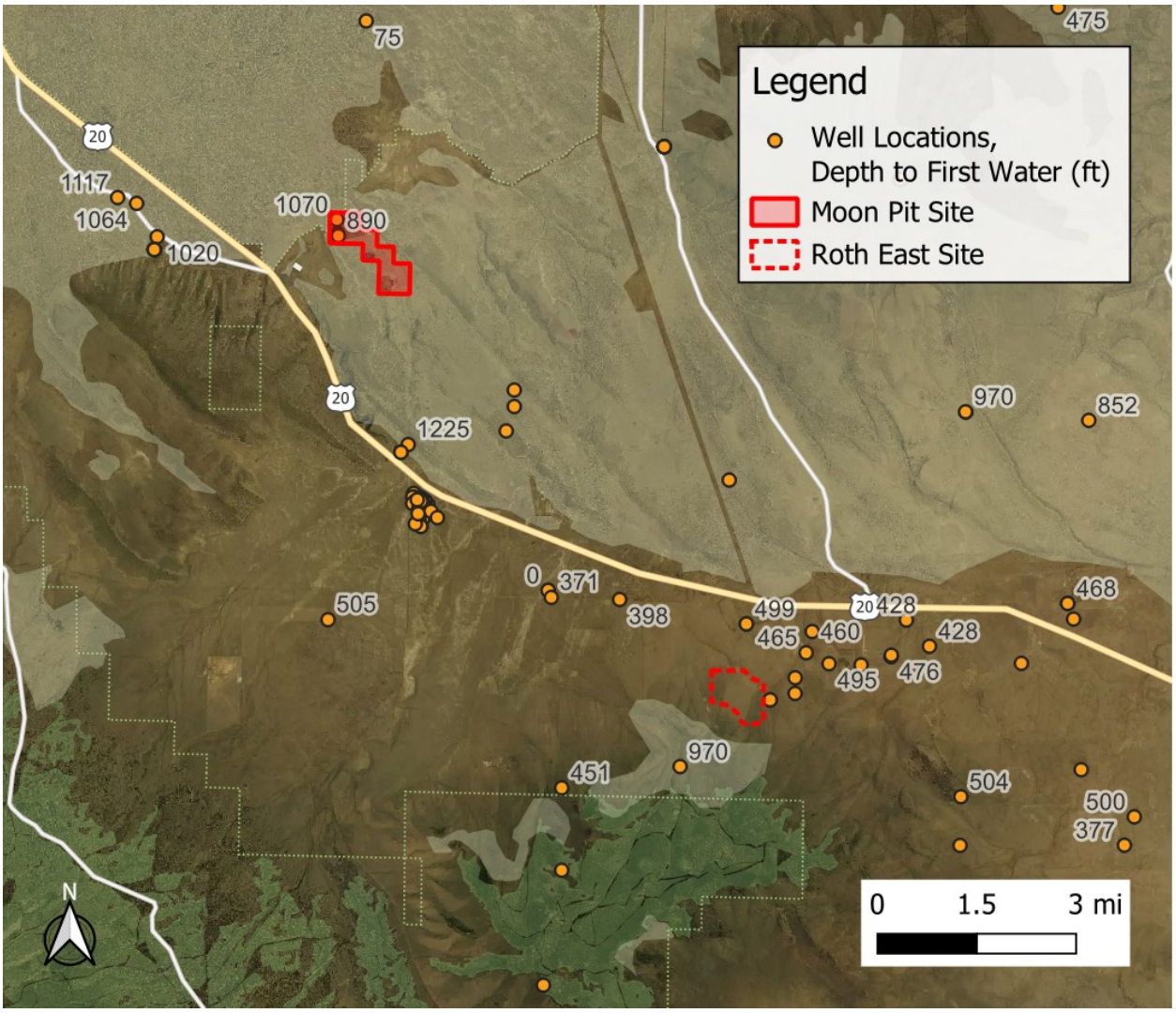

Figure 5. Groundwater Well Locations
Source: OWRD Well Report Geodatabase; Maptiler.com Satellite Map Layer

Recorded Flood Observations

The historical record provides minimal evidence of past flood events at or near the Sites. The lack of evidence could either be attributed to hydrologic conditions that make flooding unlikely or could reflect the remote, sparsely inhabited location of the study area where data have not been collected.

The Deschutes County NHMP identifies past flood events on Whychus Creek in 1964 and 1980, the Deschutes River in 1956, and the Little Deschutes River in 1909 and 1964. However, it concludes that "[g]enerally, river flooding has not historically been a serious problem in Deschutes County. This is mostly due to the porous nature of the underlying volcanic rock" (COIC 2021). It contains no mention of flood events at Dry Creek or near the study area.

The Oregon NHMP reported significant floods in Deschutes County in December 1964, February 1986, July 2001, December 2005, and July 2019 (DLCD 2020). However, none of these were specific to locations near the study area.

The Oregon State Flood Hazards Database (DLCD 2015) contains mapped inundation boundaries from four flood events in 1861, 1943, 1964, and 1996. No flooding was noted in near the study area.

Eight disaster events occurring within the last decade were documented by the Oregon Department of Emergency Management as a series of ArcGIS Story Maps (OEM 2023). These were reviewed, but no evidence was found of historical flooding near the study area.

Findings of Risk and Recommended Mitigation

Primary Flood Risks

The Moon Pit site is not directly located within mapped surface water or groundwater flood hazard areas. However, the northern portion of the site contains flat terrain located near the 100-year floodplain. Because no base flood elevation has been established by FEMA, it is difficult to project potential flood risk onto the site topography without detailed hydraulic analysis. In addition, climate change may likely increase flood frequencies and extents. Therefore, river flooding presents flood risk to the northern part of the Moon Pit site, although there is not sufficient data to estimate the extents without further hydraulic analysis.

The Roth East site is not directly located within mapped surface water or groundwater flood hazard areas; therefore, no primary risks to structures and utilities from river flooding are expected.

At both sites, there are intermittent or ephemeral stream channels with relatively high-slope contributing basins. Both sites could be subject to flash floods or spring to early summer rain-on-snow events that could lead to localized flooding. The likelihood of such events is difficult to assess within the scope of this desktop review.

Secondary Flood Risks

While the Sites themselves have uncertain flood risk, there is a significant risk to the transportation network to the Sites. Both Sites are served by the Central Oregon Highway (U.S. 20), which is within the mapped floodplain. This risk is exacerbated by the lack of alternative routes, which could leave the site inaccessible if floods damaged the roadway.

Severe storm and flood events are unpredictable, and disruption to power and other utilities is always a risk. Furthermore, climate change has the potential to result in increased frequency and magnitude of extreme weather events. These changes can result in more frequent and intense precipitation events and flooding, which could have impacts to areas that currently have no mapped flood hazards and no historical record of flooding.

Recommended Mitigation

Further study of the Upper Dry River watershed may be warranted to quantitatively assess flood risk with the study area. Dry River at the Moon Pit site may be studied using methods typical of a FEMA flood insurance study “detailed method” to estimate more accurate extents of river flooding at the Moon Pit site. Further studies at the subwatershed scale could investigate the hydrologic properties of the soil, survey existing channel geometry, estimate basin areas, and quantify the likelihood of flooding at the 100-, 500-, or 1000-year return-period storms.

Potential mitigation strategies for secondary risk include coordinating with state transportation and hazard mitigation agencies. Detours could be developed to identify alternate routes to the Sites if transportation infrastructure is negatively impacted by flooding.

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