Fluvial Redistribution of Contaminated Tephra: Process-Level Modeling and Parameter Estimation

Donald Hooper and Roland Benke
Center for Nuclear Waste Regulatory Analyses (CNWRA)
Southwest Research Institute®
San Antonio, Texas, USA

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Outline

- Overview of the igneous event scenario
- Surface processes and tephra ("ash") redistribution
- Average time between significant flow events
- Fortymile Wash drainage basin area
- Pre-eruption sediment yield
- Post-eruption sediment yield
- Density of proximal ash deposit

Introduction

- Preparation for a regulatory review of a potential DOE license application for Yucca Mountain, Nevada

- Total-system Performance Assessment (TPA) code developed to provide the capability to independently evaluate the effect of uncertainties in risk-significant features, events, and processes

- Abstracted model developed to gain fundamental insights into tephra ("ash") redistribution processes and risk to the Reasonably Maximally Exposed Individual (RMEI)

Objectives

- Derive system-level input parameters from the process-level modeling of fluvial redistribution of contaminated tephra

- A companion presentation describes the abstracted model for fluvial redistribution
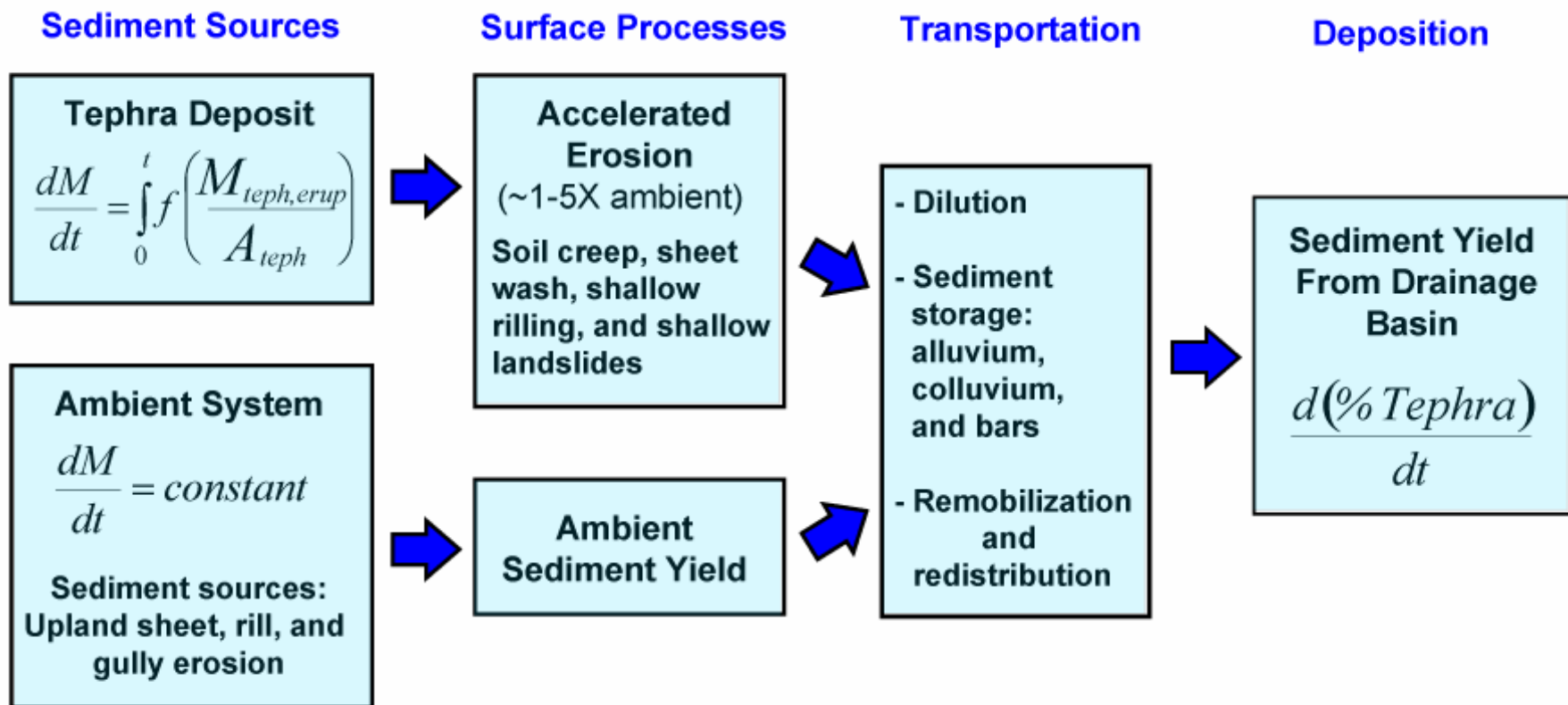
Igneous Event Scenario
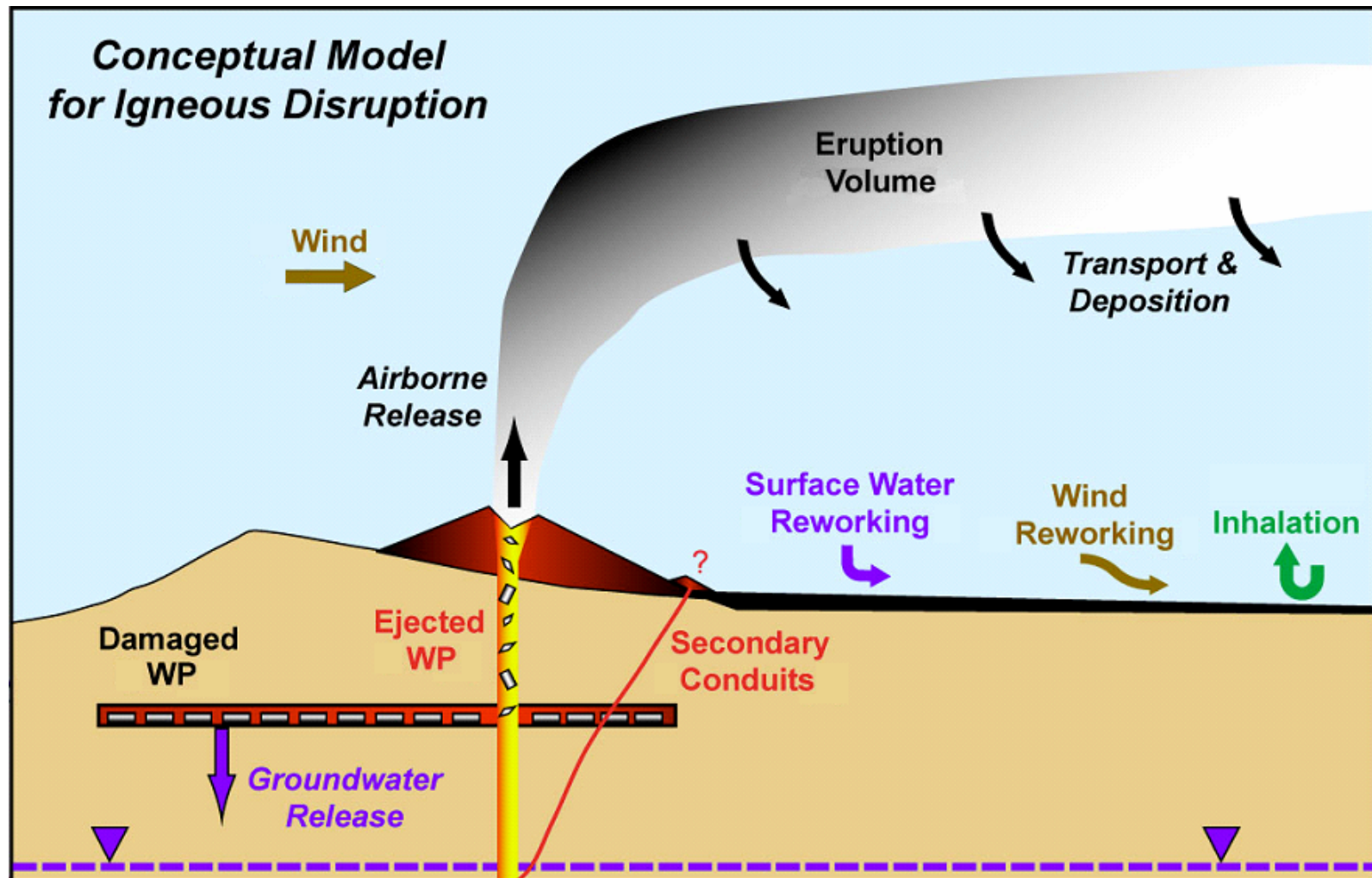
Surface Processes and Tephra Redistribution

- A potential volcanic event within the repository footprint could deposit tephra on hillslopes around Yucca Mountain

- Subsequent surface processes could remobilize contaminated tephra-fall deposits

- Fortymile Wash exhibits episodic (ephemeral) stream flow with an active depositional basin of 24 km^2 (red triangle)
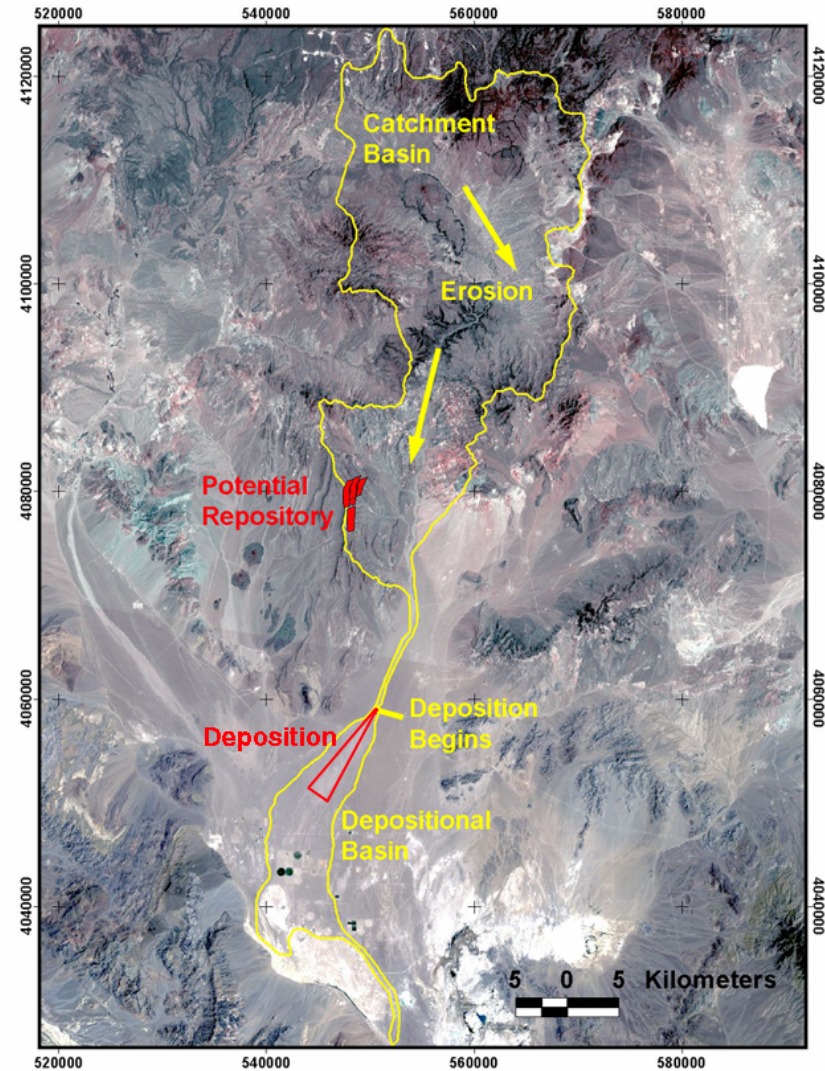
Process-Level Modeling of Long-Term Fluvial Redistribution at Yucca Mountain

Sediment Sources

Tephra Deposit

$$\frac{dM}{dt} = \int_0^t f\left(\frac{M_{teph,erup}}{A_{teph}}\right)$$

Ambient System

$$\frac{dM}{dt} = constant$$

Sediment sources: Upland sheet, rill, and gully erosion

Surface Processes

Accelerated Erosion (~1-5X ambient)

Soil creep, sheet wash, shallow rilling, and shallow landslides

Ambient Sediment Yield

Transportation

- Dilution

- Sediment storage: alluvium, colluvium, and bars

- Remobilization and redistribution

Deposition

Sediment Yield From Drainage Basin

$$\frac{d(\% Tephra)}{dt}$$

Key Parameters

- Average time between significant flow events

- Total area of the drainage basin that discharges through Fortymile Wash

- Pre-eruption sediment volume from the drainage basin that discharges through Fortymile Wash per unit area per discharge event

- Post-eruption volume of fluvial redistributed tephra at the Fortymile Wash depositional region per unit area per discharge event

- Density of proximal ash deposit

Average Time Between Significant Flow Events

- Runoff is infrequent because of high evapotranspiration and low annual precipitation of 150 mm

- Time between flow events: 11 floods between 1969-1998; 7 floods > 0.1 m^3/s

- Recurrence interval: ~ 4 years

Peak Discharge for the Amargosa Valley Gage (Station Number 10251258), Fortymile Wash, Yucca Mountain, Nevada

Date	Peak Discharge (m^3/s)*	Rank
January 25, 1969	42.5	2
February 24–26, 1969	93.5	1
March 3, 1983	11.3	5
July 21–23, 1984	40.5	3
August 18–20, 1984	10.5	6
July 19–20, 1985	0.09	8
February 23, 1987	0.02	9
November 6, 1987	0.02	11
September 23, 1990	0.02	10
March 11–13, 1995	34.0	4
February 23–24, 1998	9.6	7
Estimated 100-yr flood	340	N/A
Estimated 500-yr flood	1,642	N/A

* 1 m^3/s = 35.3 ft^3/s

Sources: Tanko and Glancy, 2001; CRWMS M&O, 2000; Savard, 1998; Squires and Young, 1984

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Drainage Basin Area

- Fortymile Wash has a catchment basin or watershed area of 815 km^2

- Standard spatial attribute derived from geographic information system (GIS) and planimetric methods
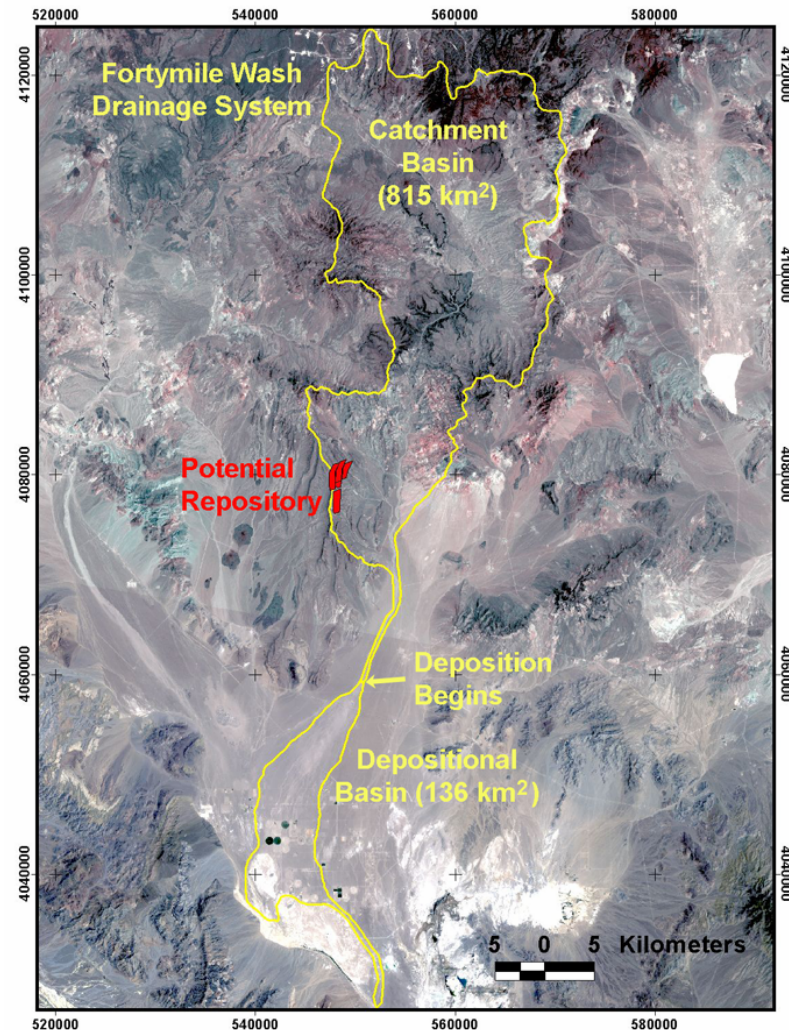
Pre-Eruption Sediment Yield

- Active depositional fan area:
  24±2 km^2 *(from Landsat TM image)*

- Active deposit thickness:
  1-2 m *(direct observation)*

- Sediment age:

  4,000-10,000 yrs *(derived from data in Peterson, et al., 1995)*

- Alluvium density:

  1600 kg/m^3

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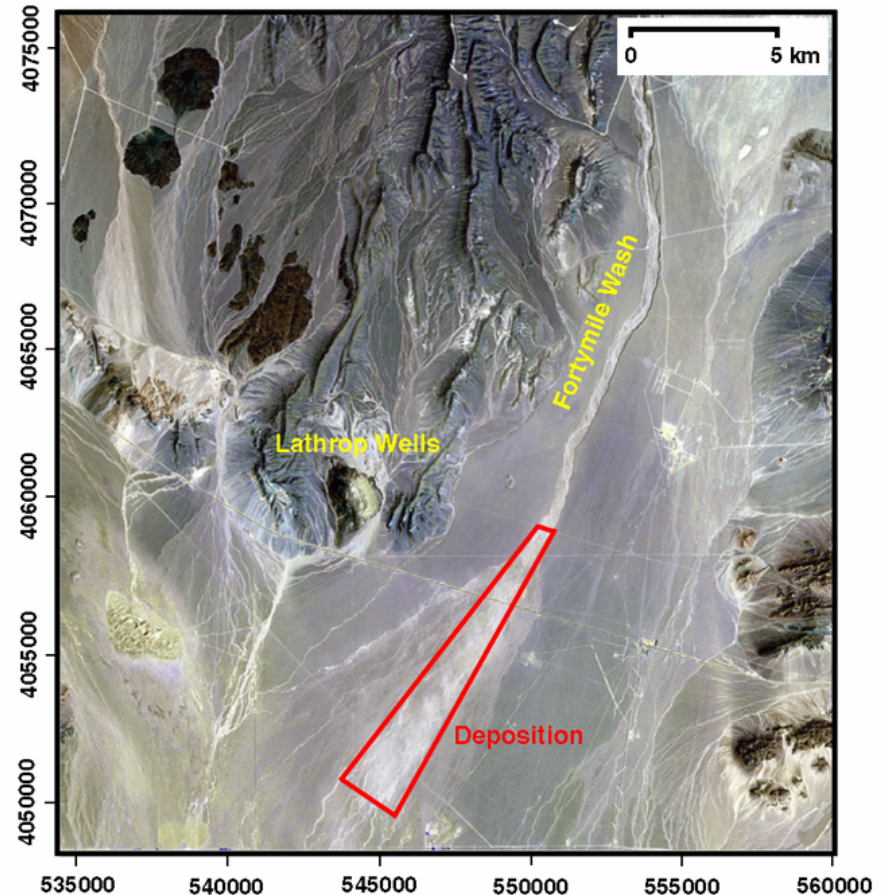
Pre-Eruption Sediment Yield

- Uncertainties propagated using uniform distributions

- Sedimentation rate to depositional basin:

  8.9×10^6 kg/yr

- Pre-eruption ("ambient") sediment yield:

 $7 \text{ m}^3/\text{km}^2\text{-yr}$

Fortymile Wash depositional fan at U.S. Highway 95 crossing

Post-Eruption Sediment Yield

- Following an eruption, the deposition of easily eroded tephra results in accelerated erosion and increased sediment yield in affected drainages.

- Using a diffusion-based model for erosion of basaltic tephra at Yucca Mountain, accelerated erosion elevates the sediment yield to 4.6× the pre-eruption yield after 500 years.

- Mean post-eruption yield is 2× the pre-eruption yield over the lifetime of the potential tephra deposit.

Post-Eruption Sediment Yield

Decline in Erosion of a Modeled Tephra Deposit at Yucca Mtn.

2× pre-eruption yield
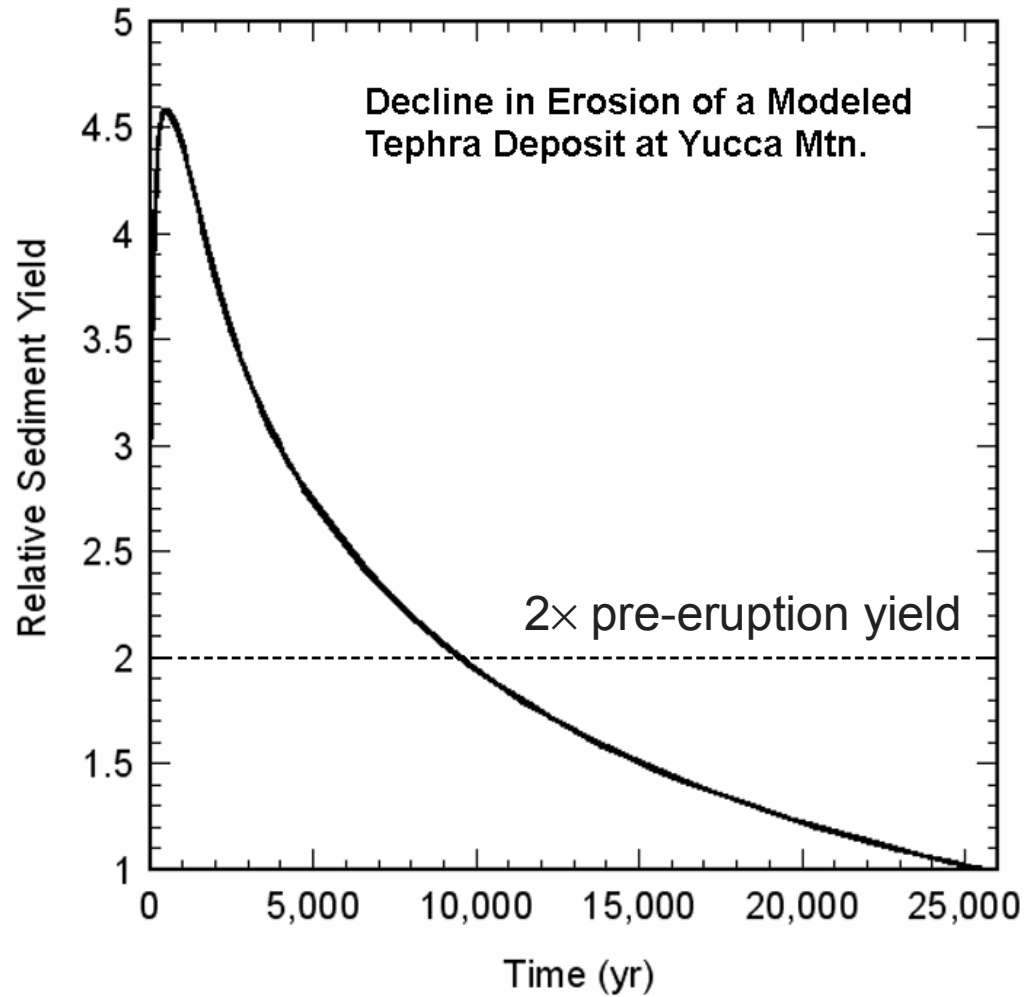
Density of Proximal Ash Deposit

- Density of proximal ash deposit is 1,200 kg/m^3

- Density derived from granulometric analysis of the tephra-fall deposit from the 1995 eruption of Cerro Negro volcano, Nicaragua (Hill, et al., 1998)

Summary and Conclusions

- Process-level modeling supports input for an abstracted model for fluvial redistribution of contaminated tephra ("ash").

- Pre-eruption sediment yield is 7 m^3/km^2-yr and the mean post-eruption yield is $2\times$ the pre-eruption yield over the lifetime of the potential tephra deposit.

- The post-eruption sediment yield affects (i) the time period that fluvial redistribution could contribute contaminated airborne particulates for inhalation dose calculations and (ii) dilution of fluvial deposits due to mixing with clean sediment.

Acknowledgment