ARIZONA DEPARTMENT OF ENVIRONMENTAL QUALITY + US Army Corps of Engineers®

Skeet Fragment Study Kingman, Arizona

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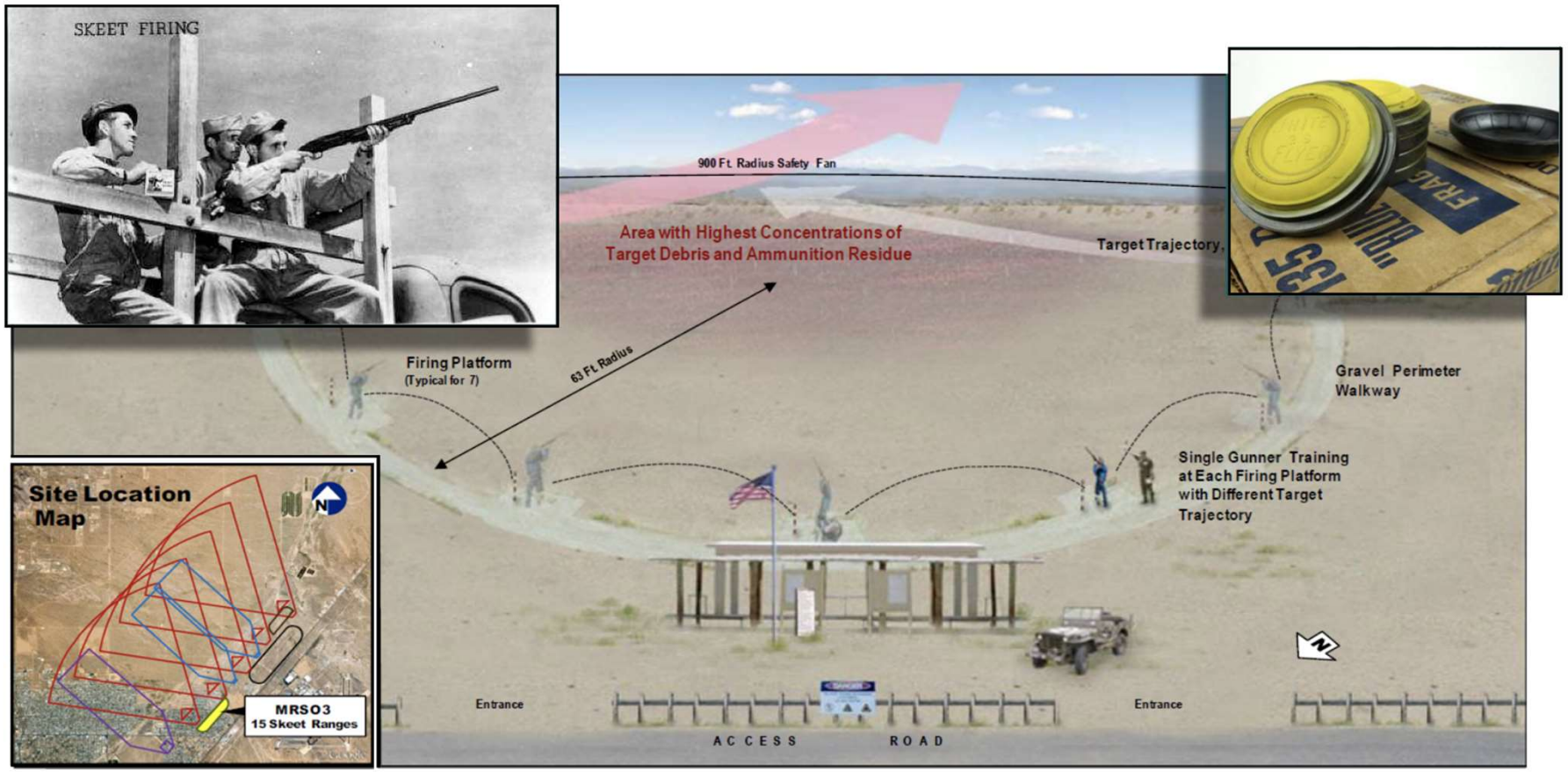
WWII Training at Kingman Gunnery Range

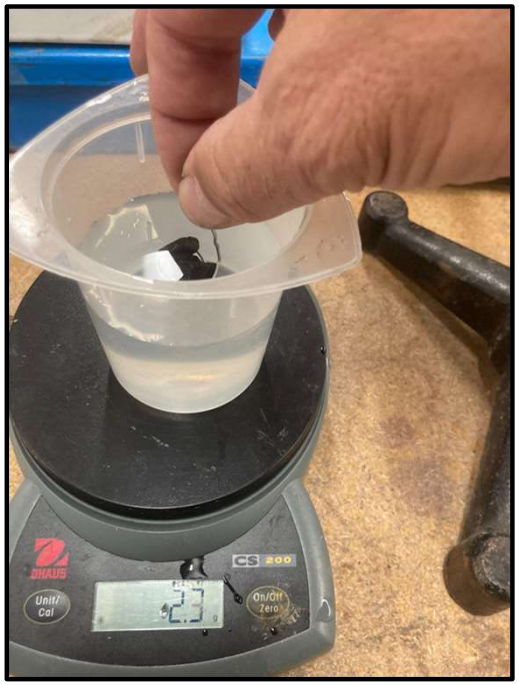
Photo provided by: Kingman Army Airfield Historical Society

WWII Training at 15 Skeet Ranges



1943 Skeet Composition - Limestone & Coal Tar

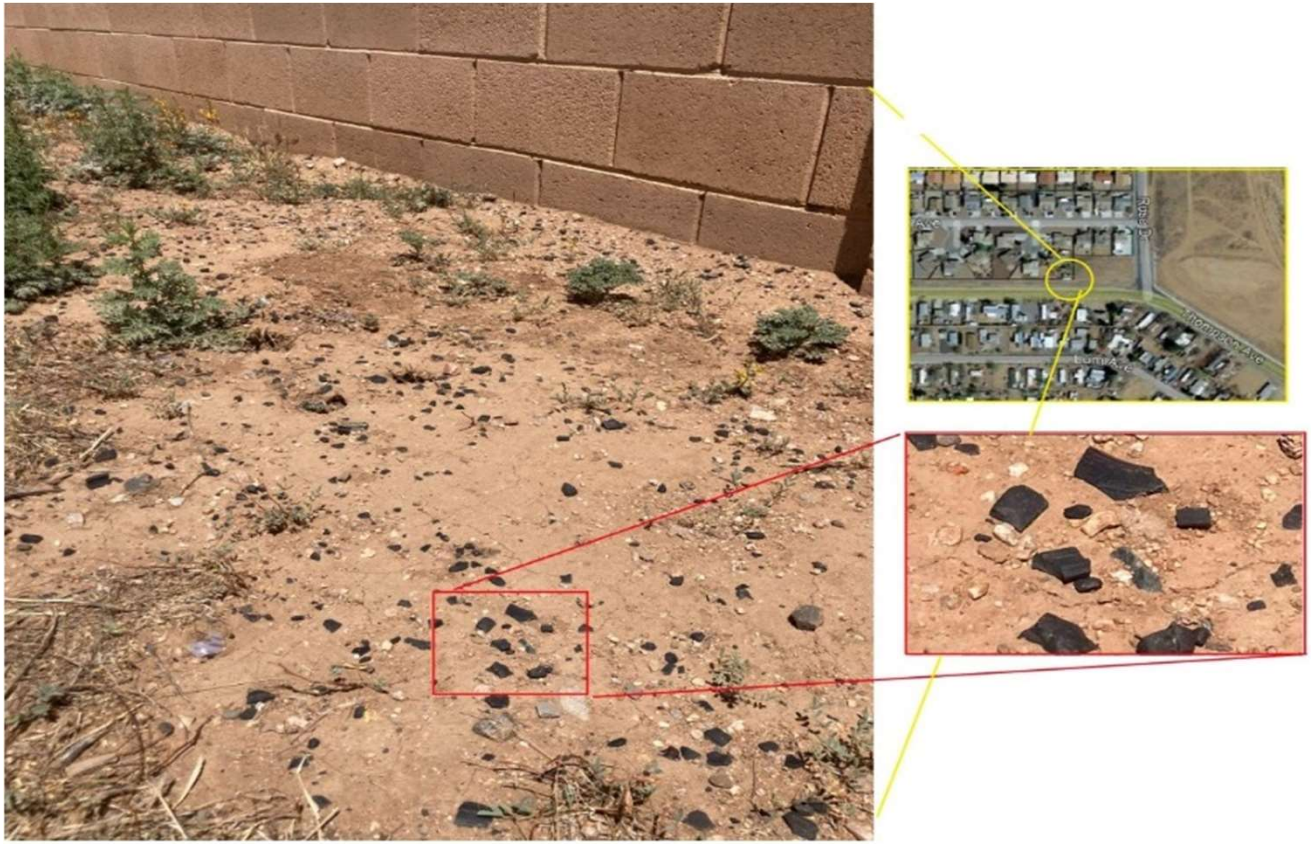
Skeet Properties



ADEQ PAH analysis of skeet estimated 1.2 million ug/Kg B(a)P equivalent compared to risk criterium of 100 ug/Kg

ADEQ measurement of density was 1.8 g/cm^3 compared to soil particles 2.6 g/cm^3

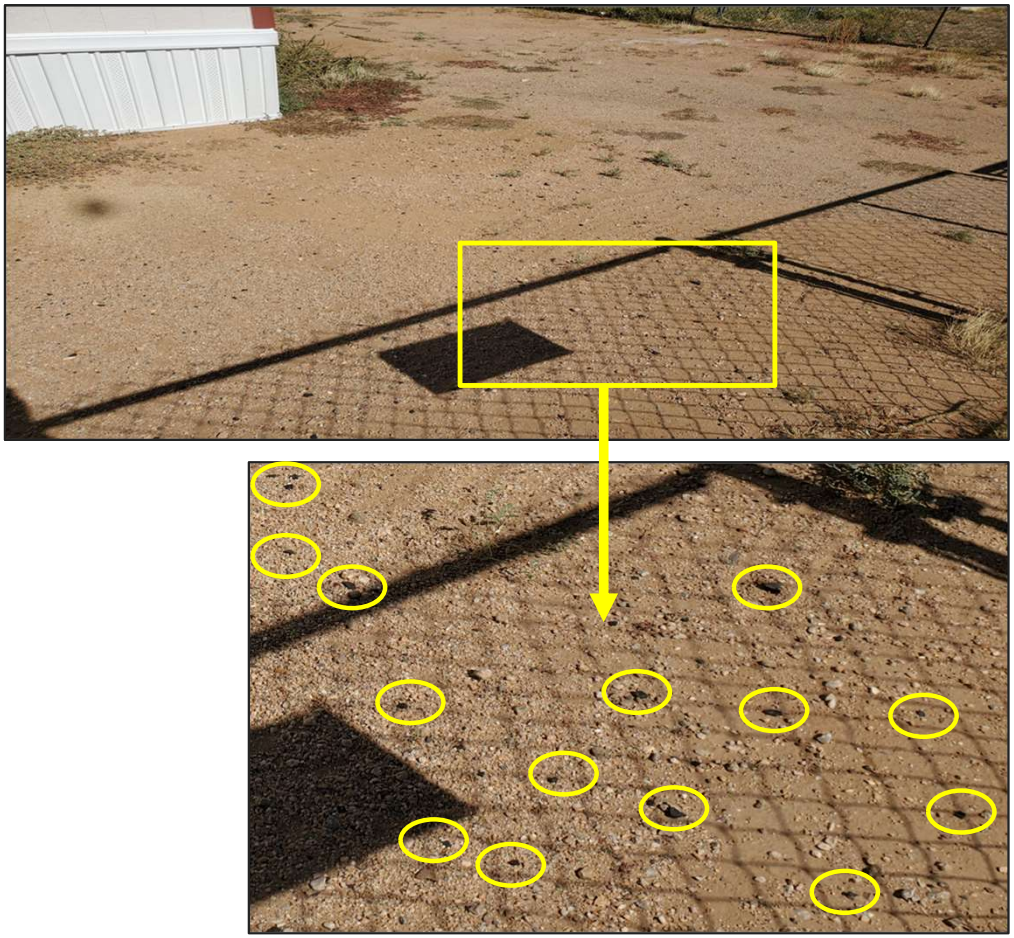
Skeet Fragments 80 Years Later…



Ridges still visible!

Skeet Fragments 80 Years Later…

Child's Bicycle



Cross-Agency Partnership

US Army Corps of Engineers®

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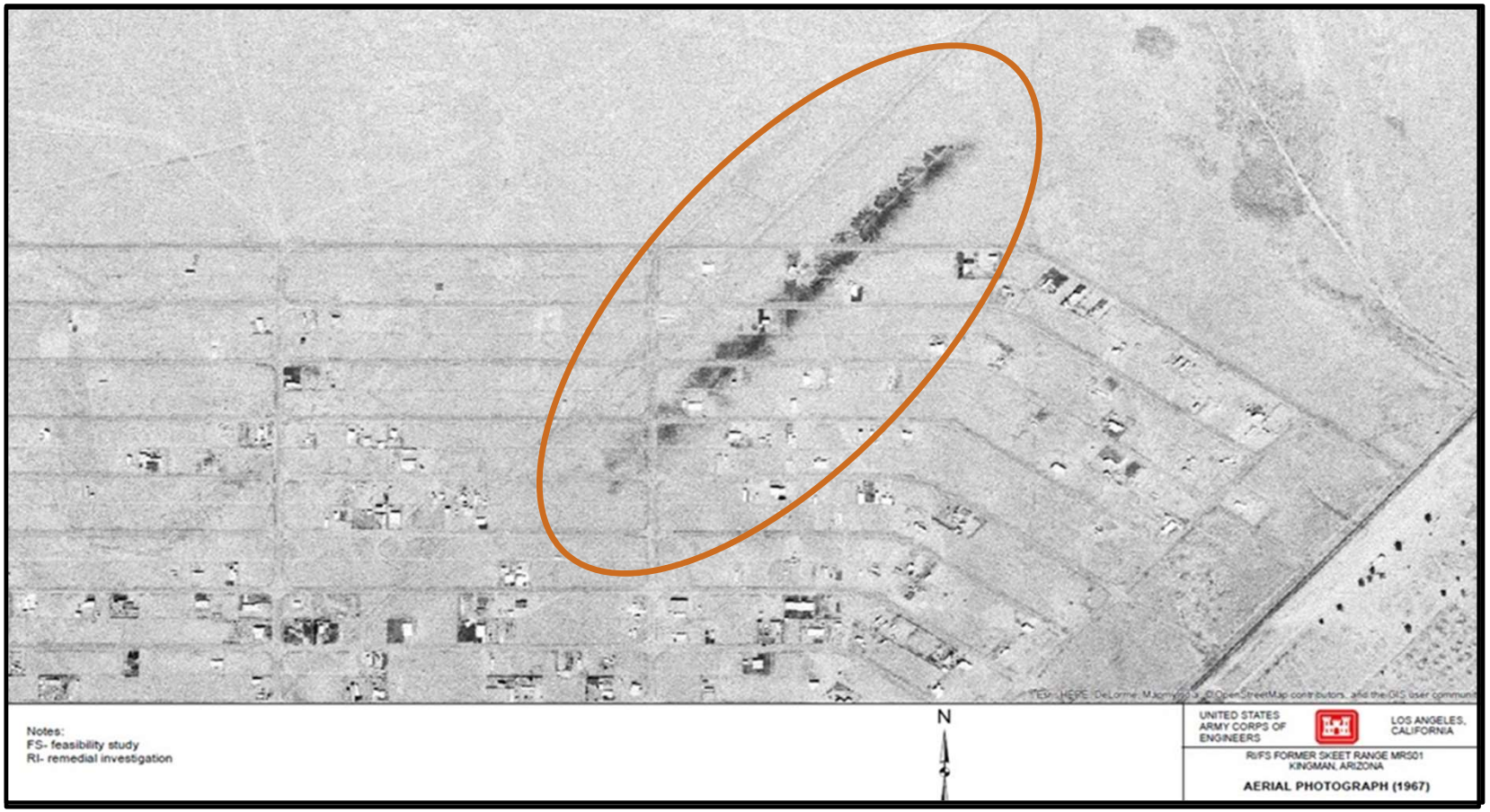
SEAL OF MOHAVE COUNTY ARIZONA · DITAT DEUS · 1864 ·

ROUTE 66 EXPLORE KINGMAN EST. ARIZONA 1882

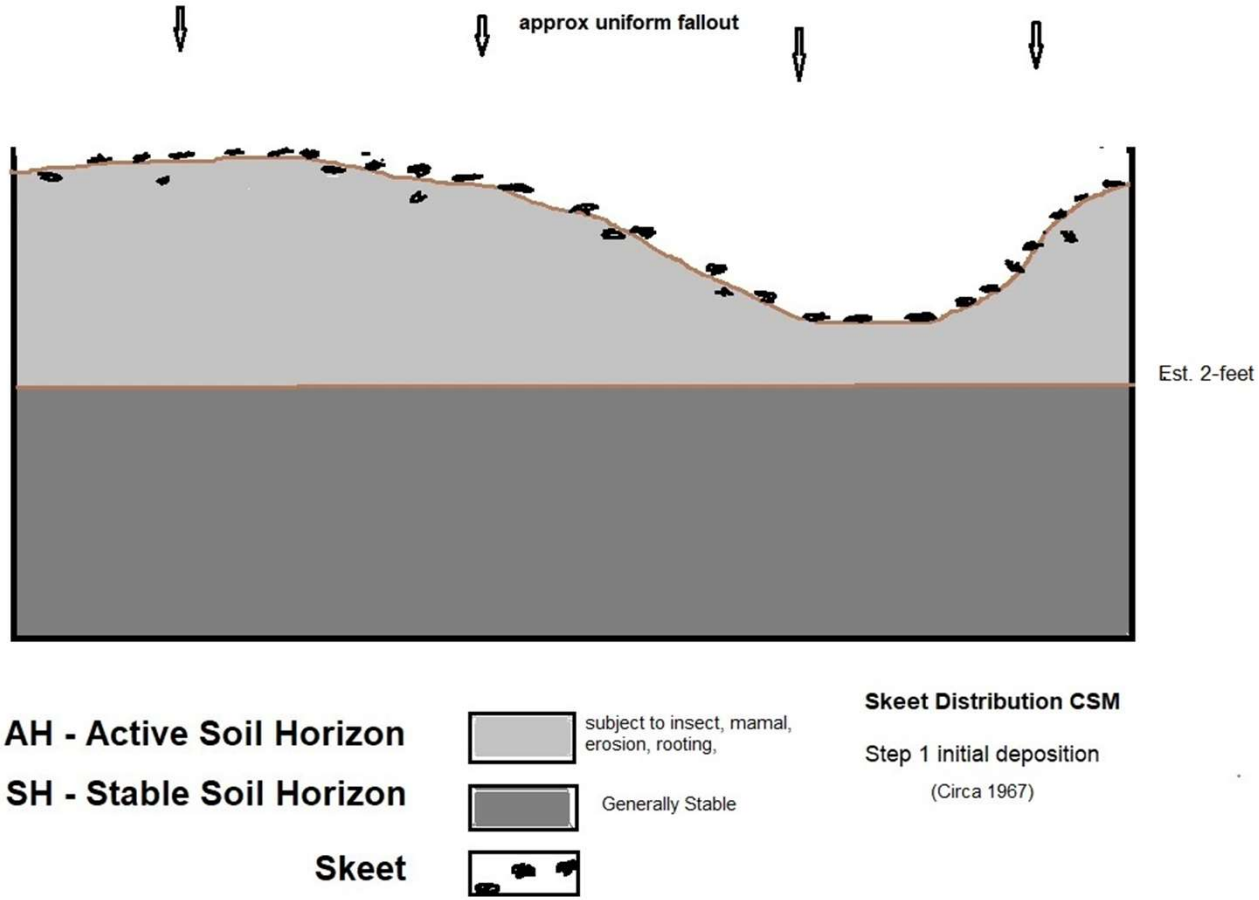
DRAFT: Conceptual Site Model

Mechanisms and the Impact on Study Methods

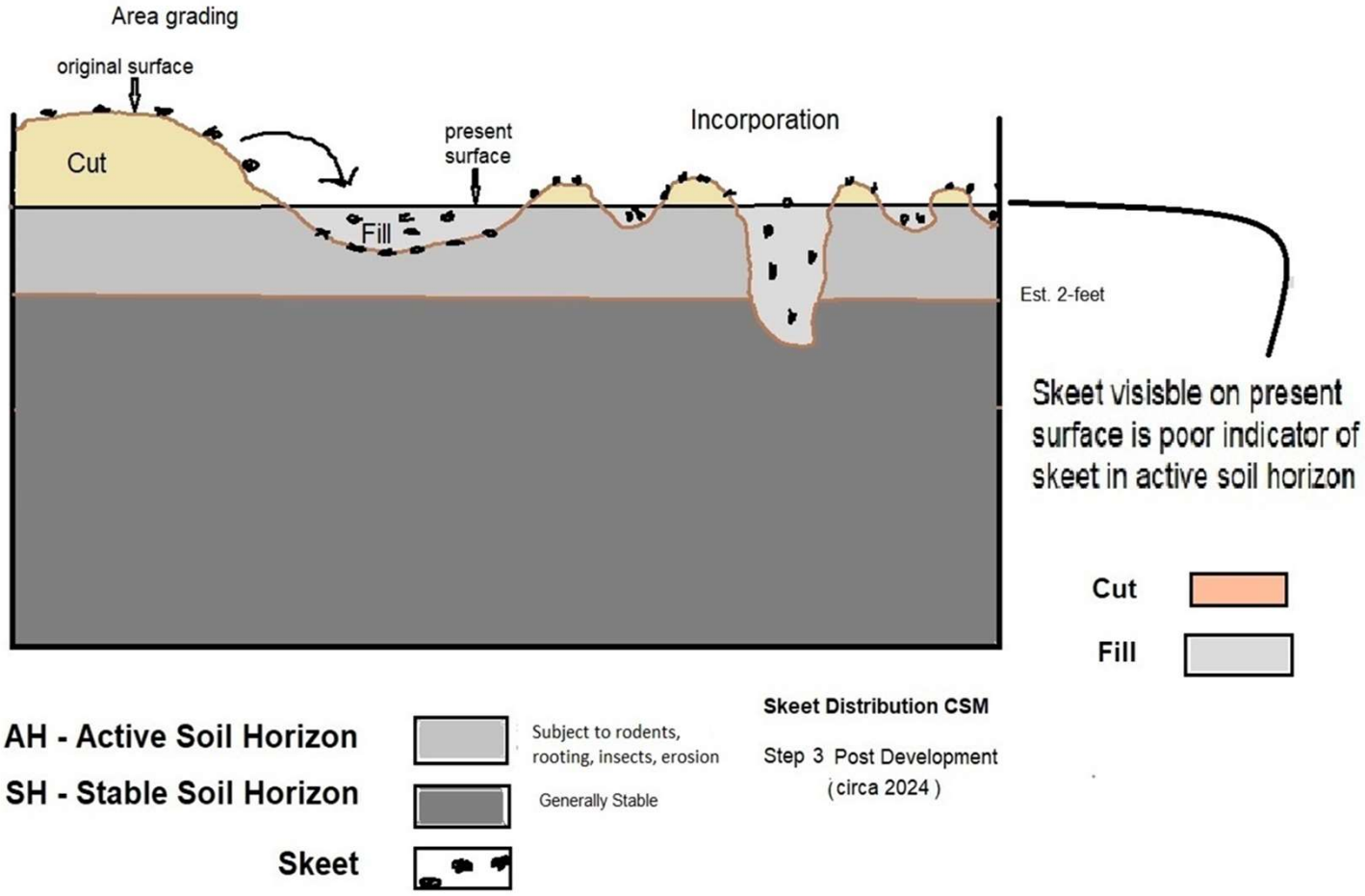
1967 Skeet Visibility



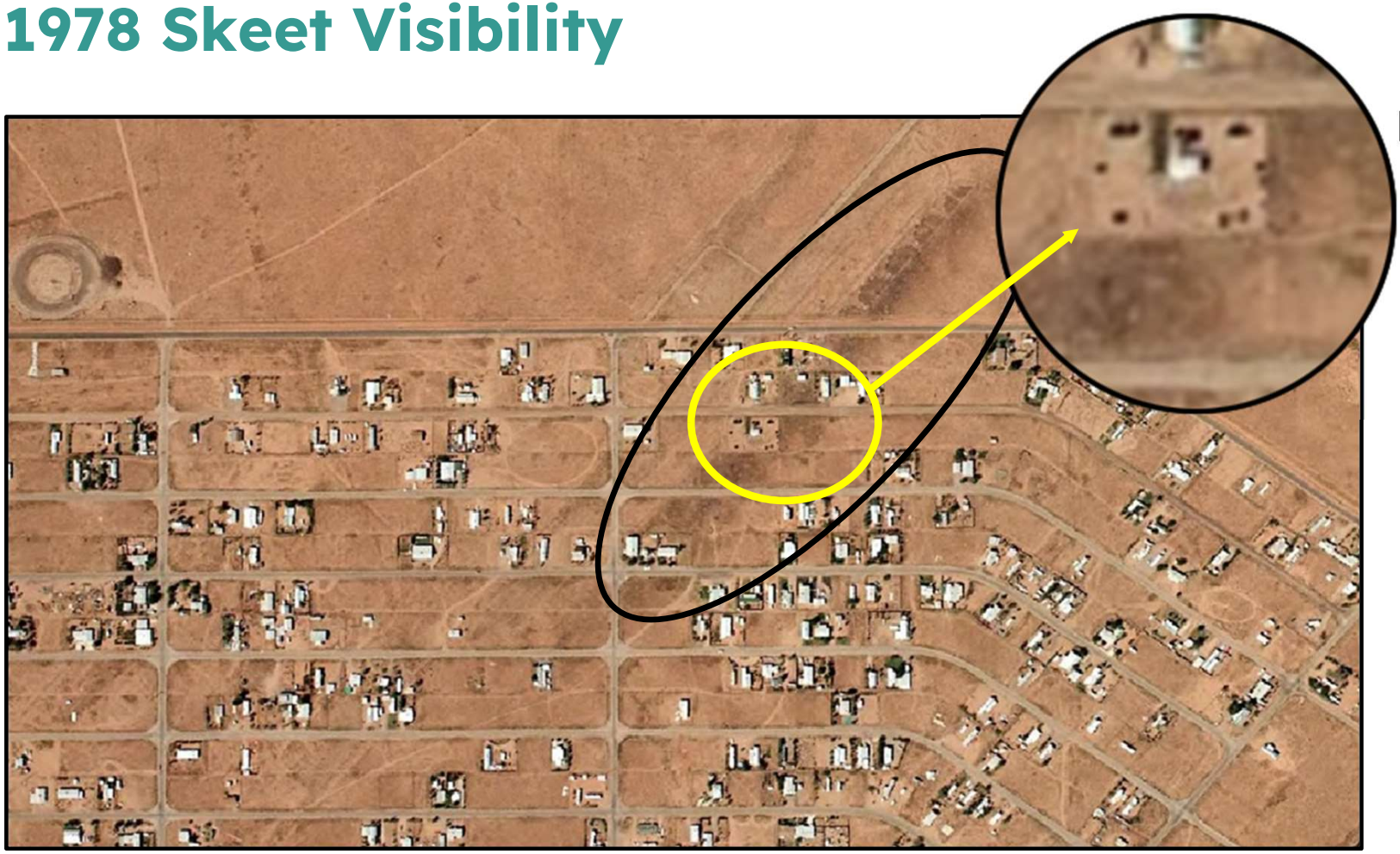
Initial Deposition via Fallout



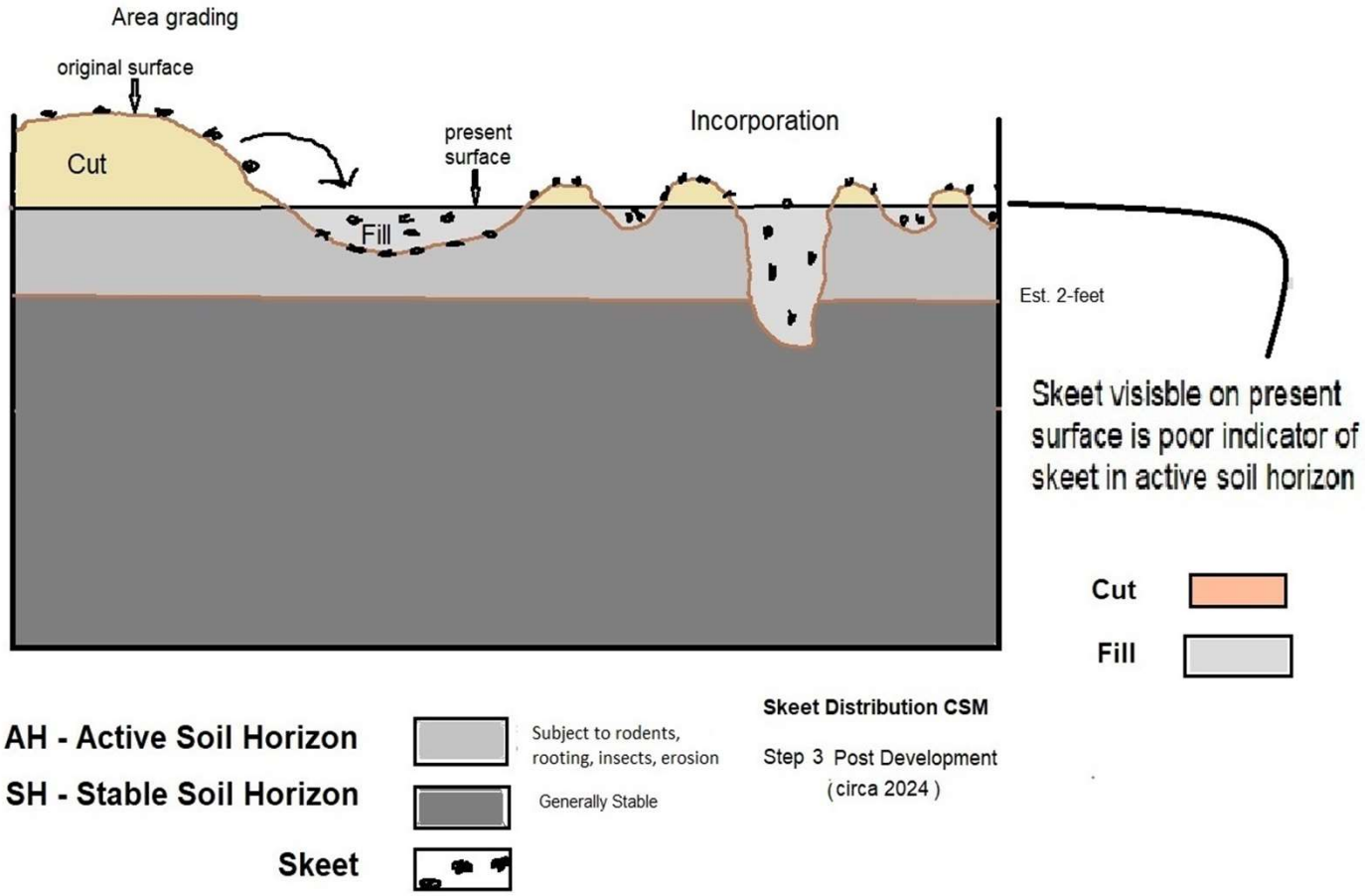
Post Deposition Erosion and Re-Deposition



1978 Skeet Visibility

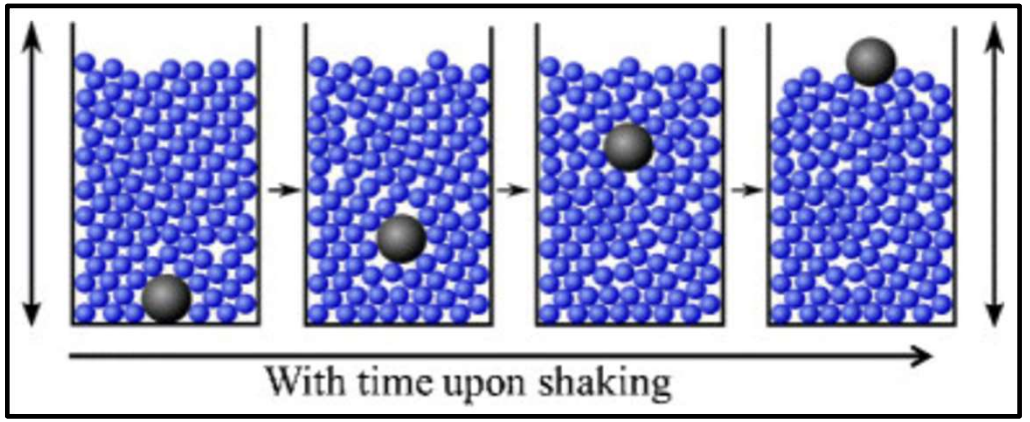


Development Reworking and Redeposition



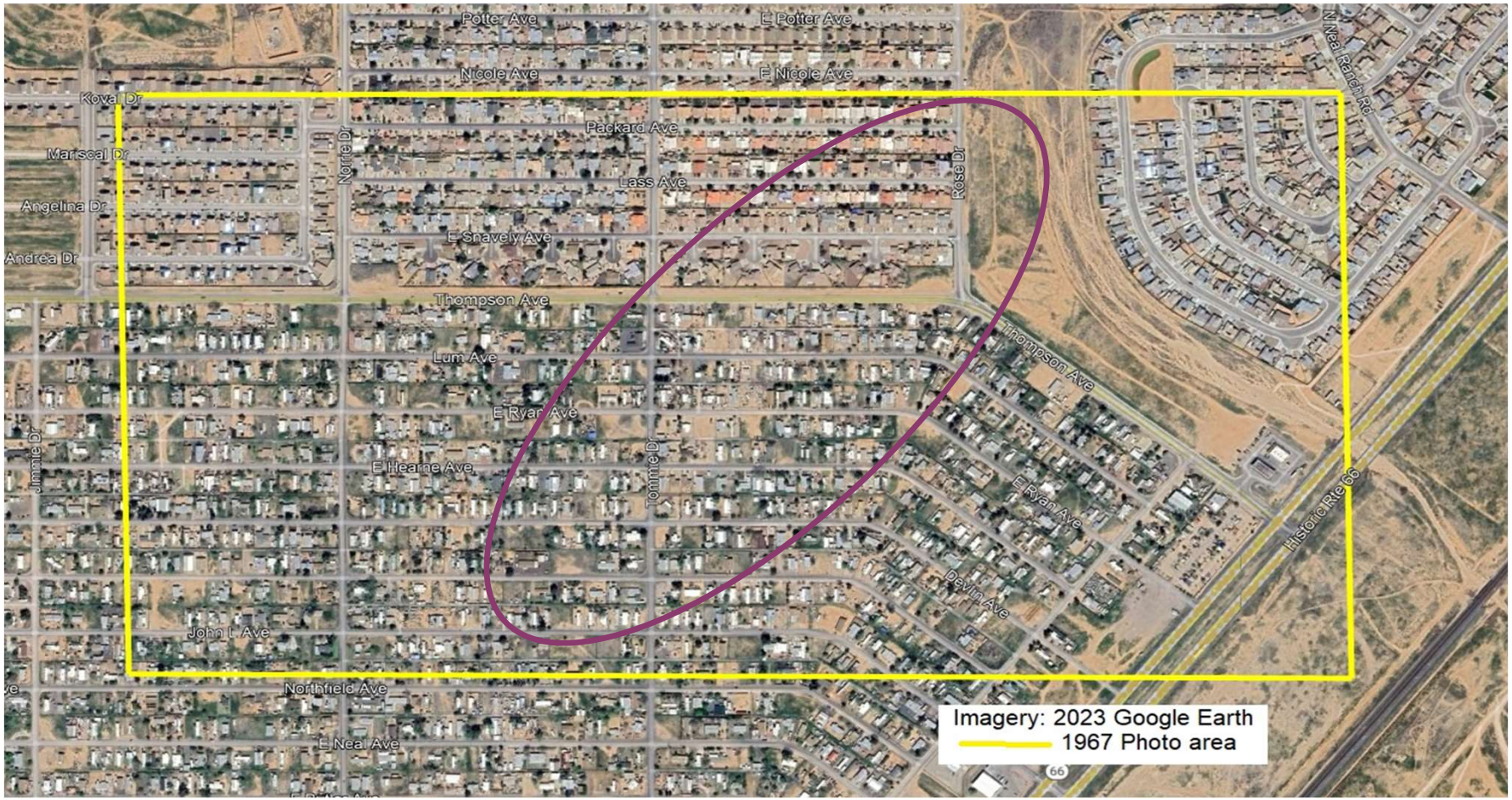
Skeet and the Brazil-Nut Effect

- Large and low density particles in a granular medium tend to migrate to the surface due to **granular convection**. It is often termed the "brazil-nut effect" because in mixed nuts the large Brazils tend to rise to the top.
- Reappearance of skeet at remediated properties is consistent with this effect and can be expected to continue.



References: Size separation of granular particles, Möbius, M., Lauderdale, B., Nagel, S. et al. Size separation of granular particles. Nature 414, 270 (2001). https://doi.org/10.1038/35104697. Why the Brazil nuts are on top: Size segregation of particulate matter by shaking, Anthony Rosato, Katherine J. Strandburg, Friedrich Prinz, and Robert H. Swendsen,Phys. Rev. Lett. 58, 1038 – Published 9 March 1987. More: https://en.wikipedia.org/wiki/Granular_convection.

Present Day


Potter Ave
E Potter Ave
Nicole Ave
E Nicole Ave
Kova Dr
Mariscal Dr
Angelina Dr
Andrea Dr
Norrie Dr
Packard Ave
Lass Ave
E Shavely Ave
Rose Dr
N Nea Ranch Rd
Thompson Ave
Lum Ave
E Ryan Ave
Jimmie Dr
E Hearne Ave
Tommie Dr
Historic Rte 66
Devin Ave
John L Ave
Northfield Ave
E Nea Ave
66
Imagery: 2023 Google Earth
1967 Photo area

CSM Implications for Skeet Definition

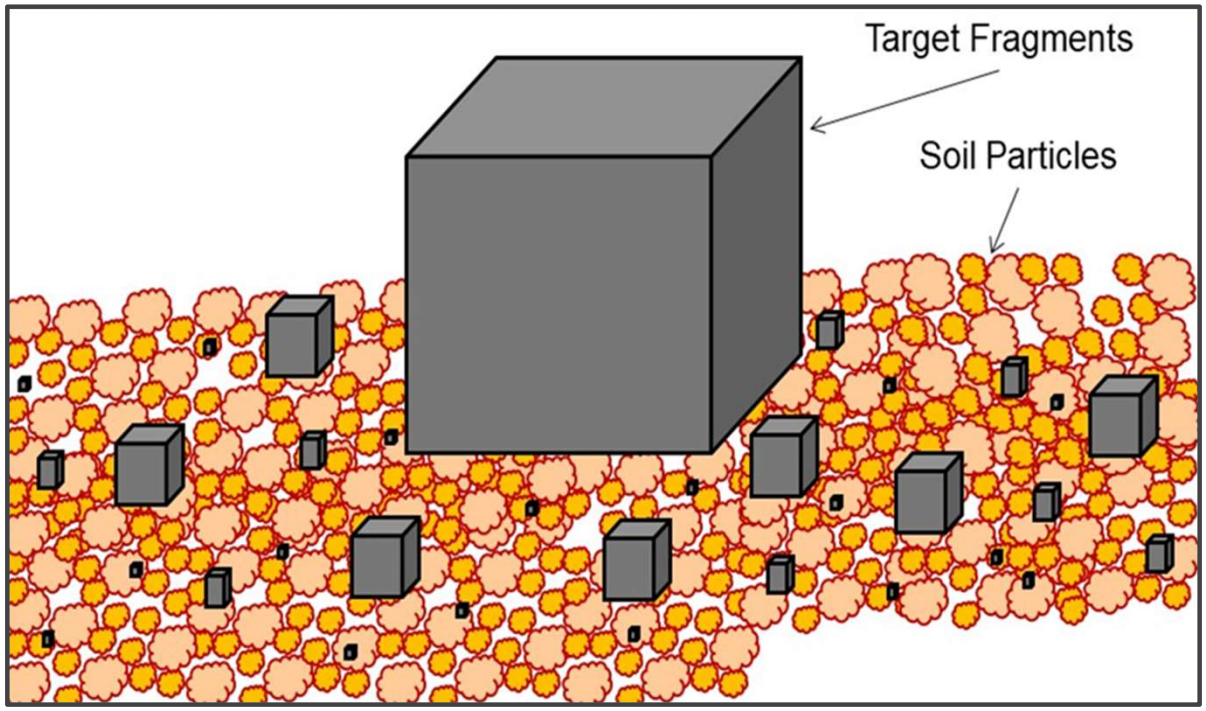
- Given the development and erosion pattern the entire study area is disturbed. There is no evidence of the initial darkened area of skeet deposition remaining in air photos.
- CSM indicates large portion of skeet was redistributed, buried, or covered.
- **Lack** of visible skeet is a poor indicator of skeet in active soil horizon due to complex reworking and regrading of soil. This consistent with historical air photos. It is also consistent with evidence of skeet reappearing in yards as reported by residents and observed by agencies.
- **Presence** of visible skeet is an indicator that skeet is present in the active soil horizon.

DRAFT: Risk Assessment

Risk Assessment on Non-environmental Media - A New Approach

Skeet Range Target Fragments in Soil

- PAHs in target fragments remain in coal tar/limestone matrix
- Mechanical breakdown to soil particle size
- Soil Characteristics affect rate of breakdown:
  - Moisture
  - pH



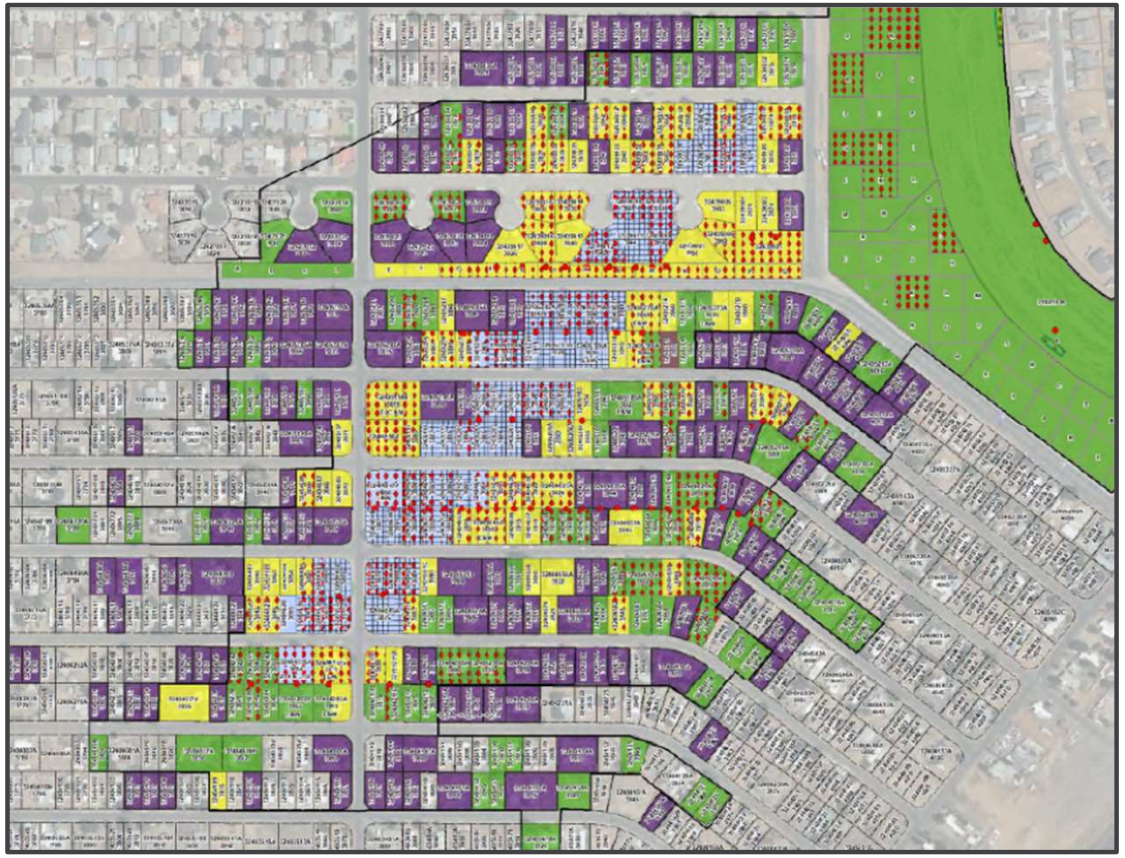
Skeet Fragment Distribution at Kingman

- Typically, Skeet Range Sites having visible fragments in soil have PAH concentrations above risk-based limits
- Limited fragment breakdown in alkaline soil and arid conditions at the Kingman 15 Skeet Range site
- Large numbers of parcels with skeet fragments and PAH concentrations below risk-based limits

PAH > risk-based

PAH < risk-based

Visible Fragments



Risk Assessment and Exposure Scenario

Chronic Environmental Exposure

- Incidental Contact
- Life-time Exposure
- Multiple Exposure Routes
  - Incidental ingestion
  - Dermal absorption
  - Inhalation
- Individual Carcinogenic PAHs
  - Oral slope factor based on benzo(a)pyrene in diet (ppm) converted to daily intake (mg/kg-day)
  - Toxicity Equivalency Factors for other carcinogenic PAHs
- USEPA Exposure Factors
  - Soil ingestion rate
  - Inhalation rate
  - Dermal absorption/adherence
  - Skin surface area
  - Body weight

Acute Dietary Exposure

- Intentional Ingestion
- Childhood Exposure (1-5 yrs)
- Ingestion Exposure Route
- Coal Tar Toxicity Factors
  - Oral slope factor based on coal tar in diet (ppm)
  - Same study (Beland and Culp, 1998) as benzo(a)pyrene oral slope factor
- USEPA Exposure Factors
  - 2011 Exposure Factors Handbook dietary intake in children ages 1 to <3 yrs
  - Body weight
- Relative Bioavailability PAHs in Coal Tar/Limestone Matrix
- Benzo(a)pyrene Age Dependent Adjustment Factor

Risk Model Approach and Assumptions

Fragment Size, Masses, and Coal Tar Oral Slope Factor

Fragment Size	½- square inch	Emergency room literature on objects swallowed by children - pennies
Fragment Mass	2 g	Technical specification on clay pigeon target production
Coal Tar Mass	660 mg	WWII-era targets – 33 percent coal tar and 67 percent limestone
Coal Tar OSL	2.55E-04 $(ppm)^{-1}$	Gaylor et al., 2000 and Beland and Culp, 1998

Kingman Site-specific Ingestion Frequency, Dose, and Risk

Daily	238 ppm in diet	1.2E-03
Weekly	34 ppm in diet	1.7E-04
Monthly	7.9 ppm in diet	4.0E-05
Quarterly	2.6 ppm in diet	1.3E-05

Kingman Site-specific Particle Ingestion Model – USEPA SOP Residential Pesticide Exposure (2012)

Frequency	Target Risk	Fragment Dose	Ft^2/Fragment	Fragments/Parcel	Required Total
Daily	1E-05	0.023 g	880	3	1,850
Weekly	1E-05	0.15 g	130	16	260
Monthly	1E-05	0.66 g	30	67	60
Quarterly	1E-05	2.0 g	10	200	20

Uncertainty Analysis

Excess Lifetime Cancer Risks of Diet and Environmental Exposure Assumptions for Parcels at the Kingman 15 Skeet Range Site

	Coal Tar Diet Analysis	PAH RSL Analysis
Daily	1.2E-03	1.6E-03
Weekly	1.7E-04	2.4E-04
Monthly	4.0E-05	5.5E-05
Quarterly	1.3E-05	1.8E-05

DRAFT: Statistical Sampling Protocol

Statistical Protocol for Non-environmental Media - A New Model

PAH Calculations – B(a)P Equivalent Approach

Input skeet PAH, soil PAH, risk standards, soil thickness

Skeet Conc. ug/kg BaPe	Soil Conc. ug/kg BaPe	Cumulative BaPe standard (ug/kg)	mass soil kg	mass skeet (kg)	mass skeet g/ mass soil kg	skeet size g	pieces per
1,226,590	50	110	1	4.892E-05	0.0489	2	0.024
	subtract from cumulative	allowable skeet BaPe					
		60.0					

	Field Application		
soil density (kg/ft3)	Mixing thickness (ft)	kg soil /ft2	pieces/ft2
55	0.08	4.58	0.11

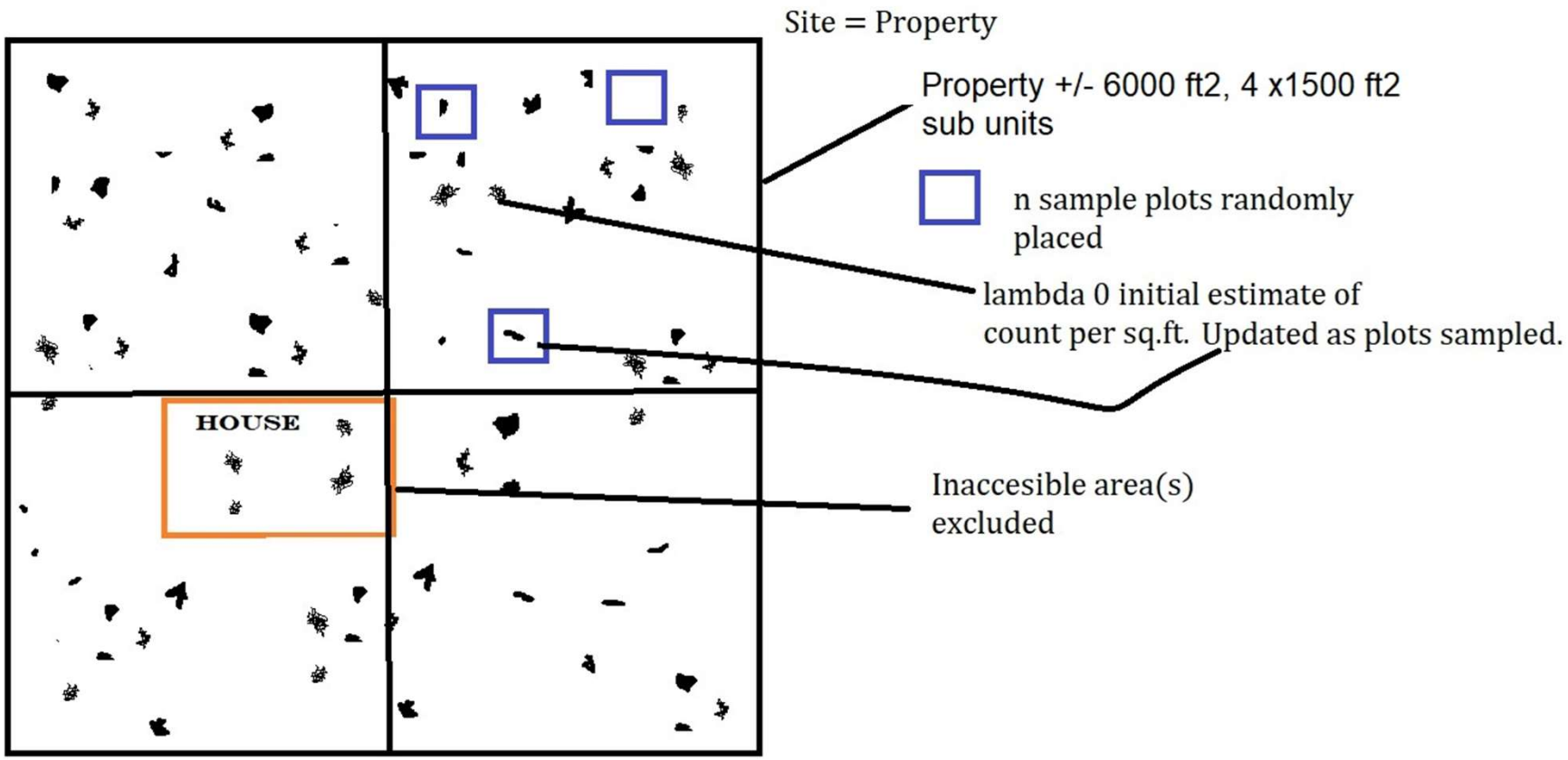
Output allowable skeet (or mass) per square foot

Note: partial spreadsheet shown

Recommended Implementation Approach

- Utilize both acute exposure and a simple mass based approach to determine acceptable skeet/PAH mass allowed to remain in active soil horizon (mass per lot). Assume skeet in active soil horizon will reach surface.
- Develop Bayesian statistical sampling protocol based on relatively large samples and sieving. Gain a 95% confidence interval that enough plots have been sampled (e.g. X 4-ft x 4-ft by 1-ft deep plots randomly placed).

Statistical Challenge: How Many Samples?



Statistical Tool Developed with Neptune and Company, Inc.

	A	B	F	H	J	K
1	**Site data**					
2	risk count/Site	150				
3	Gross Site Area	1500				
4	Building Coverage	0				
5						
6	Effect of varying count for a 10 sample, 10 ft2 plan					
7	1	2	4	6		8
8	number of samples	sample area (ft2)	Initial and updated avg per area count/ft2	Total frags found in all samples	sample estimated Frags per site (k/coverage)	Confidence K is below K*-k
9	n	a	λ 0	k		
10	10	16	0.12	20	188	17.57%
11	10	16	0.091	15	141	64.31%
12	10	16	0.071	12	113	88.67%
13	10	16	0.04	7	66	99.73%
14	10	16	0.01	2	19	100.00%
15						
16						
17						

Count is updated as samples are collected

Proposed Phases or “Buckets”

Bucket 1: Properties identified with soil risk in Current FS. Proceed to remediation with confirmation sampling for skeet and soil at depth

Bucket 2: Property with visible skeet and low soil risk. Proceed to remediation with statistical sampling protocol for confirmation (If skeet exceeds 60 cm may excavate or apply

Bucket 3: Property with acceptable combined soil/skeet risk. Sample with statistical sampling protocol and remediate as necessary

Advantages of Approach

- Approach is relatively simple to explain to the public
- Sampling is simple and efficient
- Utilizes published soil standards as a proxy for chronic risk
- Utilizes simple positive observation of skeet as proxy for acute risk
- Recognize that the CSM suggests most skeet is buried

Next Steps

Finalize Concepts 1-3 months	Pilot Study 6-9 months	Remedial Action 1-2 years
ADEQ & USACE technical team will partner to finalize the skeet fragment risk assessment and sampling protocol	A pilot study will be conducted to verify the new methods are achievable under field conditions If successful, then the methods will be incorporated into the Feasibility Study	New methods will be employed during the full scale cleanup at the Kingman Site, pending the Proposed Plan and Record of Decision

Thank You!

Questions?

ARIZONA DEPARTMENT OF ENVIRONMENTAL QUALITY

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