JE JACOBS ENGINEERING GROUP INC.
ADVANCED SYSTEMS DIVISION, ALBUQUERQUE OPERATIONS

CALCULATION COVER SHEET

CALC NO. BOW-05-89-15-03-00 DISCIPLINE Hydrology NO. OF SHEETS 8

PROJECT: UMTRA Site Characterization

SITE: Bowman, North Dakota

FEATURE: Volumetric Mixing Calculations: to estimate resultant concentrations of hazardous constituents in groundwater in lignite zone at point of compliance beneath Bowman disposal cell.

SOURCES OF DATA:
Source concentrations - from suction lysimeter water quality analyses.
Background water quality - from monitor well water quality analyses.
Cross-sectional area derived from figure E.2.1

SOURCES OF FORMULAE & REFERENCES:
Hem, J. D., 1985. Study and Interpretation of The Chemical Characteristics of Natural Water, USGS ~~Professional Paper~~ Water Supply Paper 2254.

PRELIMINARY CALC. ☐ FINAL CALC. ☒ SUPERSEDES CALC. NO. ______

REV. NO.	REVISION	CALCULATION BY	DATE	CHECKED BY	DATE	APPROVED BY	DATE
		R.J. Heydenkamp	24 Aug 89	D. Metzler	9-15-89		
				[signature]	9/89	Kent Bostick	9/89

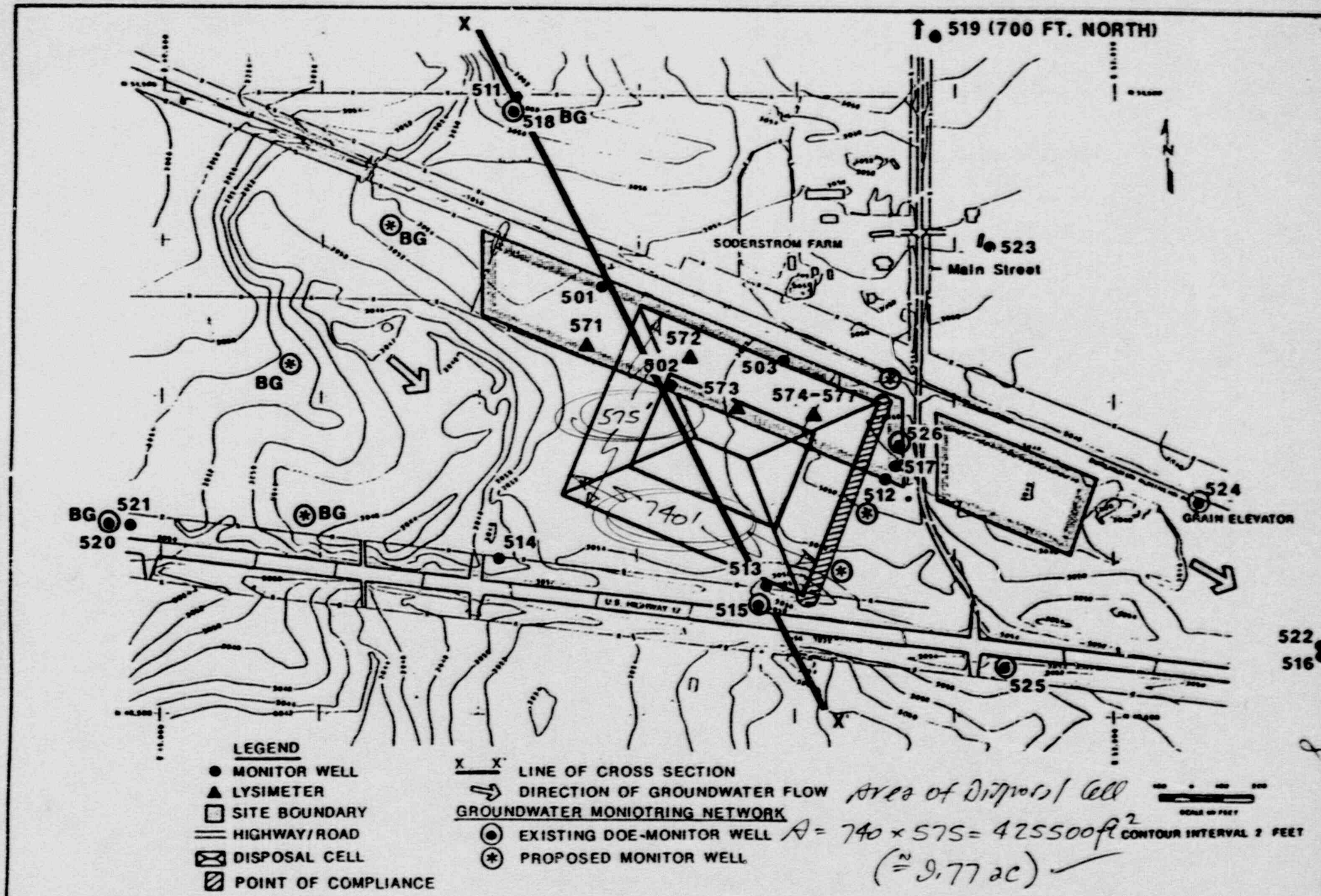

FIGURE E.2.1

PLAN VIEW OF DISPOSAL CELL, POINT OF COMPLIANCE, AND GROUNDWATER MONITORING NETWORK

BOWMAN DISPOSAL SITE – GRIFFIN, NORTH DAKOTA

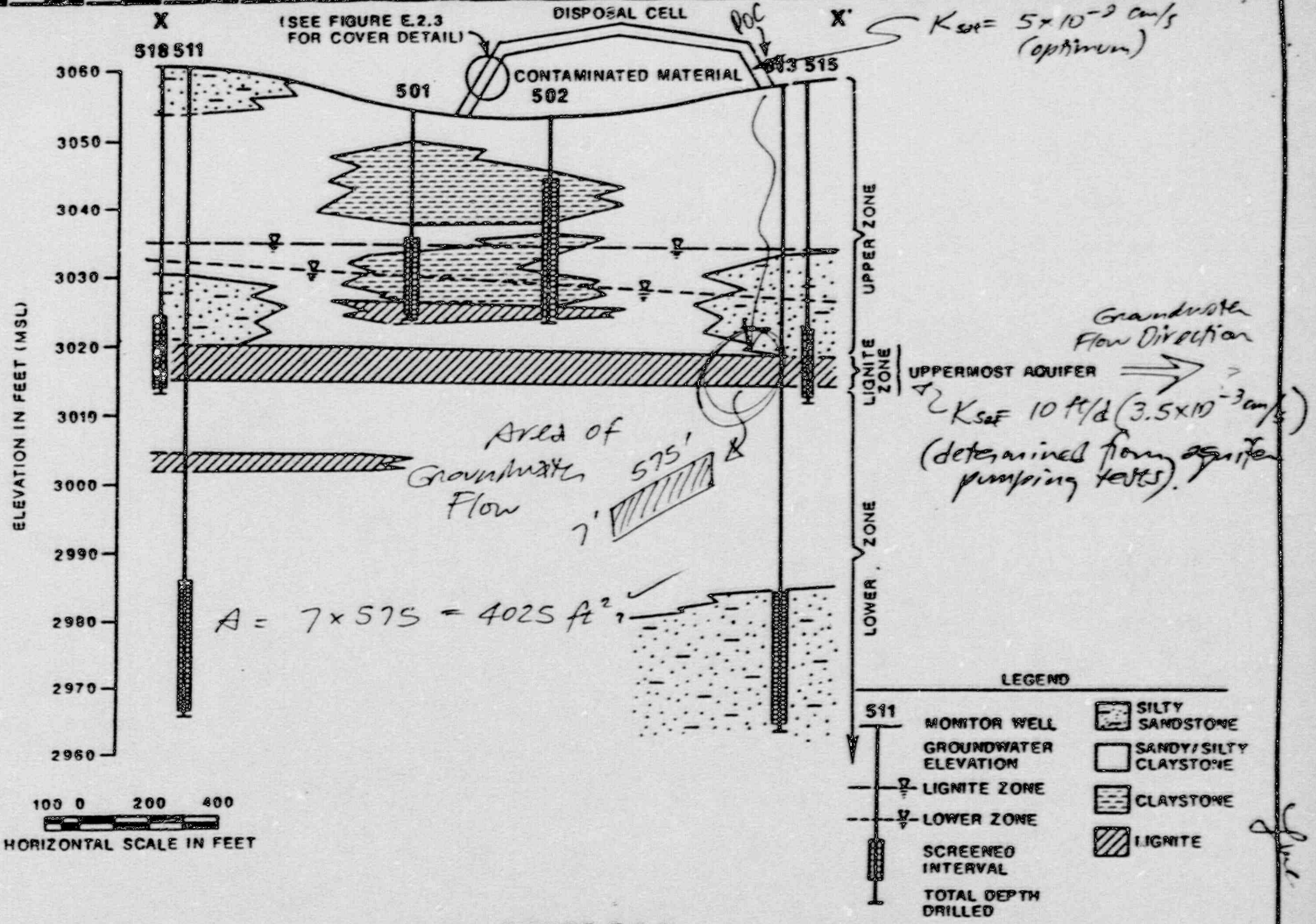

FIGURE E.2.2

DIAGRAMMATIC CROSS SECTION OF PROPOSED DISPOSAL CELL
BOWMAN DISPOSAL SITE - GRIFFIN, NORTH DAKOTA

Table E.3.2 Concentrations of designated hazardous constituents, Bowman disposal site - Griffin, North Dakota

Hazardous constituents[a]	MCL[b] (mg/l)	Proposed concentration limit[a] (mg/l)	C_{GW} Background-lignite zone[c] mean (mg/l)	Background-lignite zone[c] range (mg/l)	C_T Source[d] concentration (mg/l)	C_R Groundwater concentration[e] (mg/l) hydraulic conductivity of cover (cm/s) 5×10^{-9}	1×10^{-8}
Antimony (Sb)	NS	0.02	0.02	0.09	0.09	0.02	0.03
Cadmium (Cd)	0.01	0.01	0.002	0.009	0.011	0.003	0.003
Chromium (Cr)	0.05	0.06	0.06	0.09	0.11	0.06	0.07
Lead (Pb)	0.05	0.05	0.01	0.05	0.05	--	--
Molybdenum (Mo)	0.10	0.10	0.05	0.07	0.20	0.06	0.07
Selenium (Se)	0.01	0.017	0.017	0.029	0.098	0.023	0.027
Uranium (U)	0.044	0.044	0.004	0.007	0.340	0.027	0.047
Vanadium (V)	NS	0.02	0.02	0.04	0.07	0.02	0.03

[a]See Table E.3.1.
[b]MCL: NS = not specified; MCLS from draft final EPA groundwater protection standards for UMTRA sites (40 CFR 192).
[c]Mean concentration from monitor wells 518 and 520.
[d]Mean concentration from lysimeters 572, 573, 575, 576, and 577.
[e]Based on volumetric mixing calculations (Hem, 1985).

JE JACOBS ENGINEERING BOWMAN, ND

DATE 24 Aug 89 SUBJECT SHEET NO

BY RJH CHKD. [illegible] BOW-05-89-15-03-00 JOB NO

A. Purpose of Calculation:

Perform volumetric mixing calculations to estimate resultant concentrations of hazardous constituents in groundwater in lignite zone at point of compliance beneath Bowman processing site.

B. Methods and Procedures:

Resultant concentrations were determined by using a solute-balance equation (Hem, 1985), which considers the volume of water infiltrating through the infiltration/radon barrier under a design saturated hydraulic conductivity of 1×10^{-8} cm/s (and an optimum of 5×10^{-9} cm/s), the source concentrations of hazardous constituents present in the stabilized material, the rate of discharge of groundwater through the lignite zone beneath the disposal cell, and mean background concentrations determined for hazardous constituents in the lignite zone.

C. Data Sources:

Source concentrations (C_T) - from suction lysimeters 572, 573, 575, 576 and 577, Bowman processing site. - water quality analyses.

Background water quality (C_{GW}) - from monitor wells 518 and 520 (lignite zone) - water quality analyses.

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D. Calculations and Analyses:

Solute-balance equation:

$$C_R = \frac{(Q_{GW} \cdot C_{GW}) + (Q_T \cdot C_T)}{Q_{GW} + Q_T}$$

mg/l:
- C_R = resultant concentration in groundwater
- C_{GW} = background concentration in groundwater
- C_T = source concentration in contaminated materials

ft^3/d:
- Q_{GW} = volume of groundwater flow in lignite zone
- Q_T = volume of water flow infiltrating infiltration/radon barrier

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$Q_{GW} = KiA$

K = hydraulic conductivity = 10 ft/d
i = hydraulic gradient = 0.002
A = area = 4025 ft^2

$Q_{GW} = 10\ ft/d \cdot 0.002 \cdot 4025\ ft^2 = 80.5\ ft^3/d$ ✓

$Q_T = KiA$

$K = 1 \times 10^{-8}\ cm/s\ (2.8 \times 10^{-5}\ ft/d)$ ✓, $5 \times 10^{-9}\ cm/s\ (1.4 \times 10^{-5}\ ft/d)$ ✓
i = 1 (unity) (assumption for steady state seepage) [illegible]
$A = 425500\ ft^2$

$Q_T(1 \times 10^{-8}\ cm/s) = 2.8 \times 10^{-5}\ ft/d \cdot 1 \cdot 425500 = 11.9\ ft^3/d$ ✓

$Q_T(5 \times 10^{-9}\ cm/s) = 1.4 \times 10^{-5}\ ft/d \cdot 1 \cdot 425500 = 6.0\ ft^3/d$ ✓

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C_{GW} + C_T + C_R values: See attached Table E.3.2

Calculations:

$$C_R = \frac{(Q_{GW} \cdot C_{GW}) + (Q_T \cdot C_T)}{Q_{GW} + Q_T} \quad \text{(in mg/l)}$$

Cadmium
Cd

1×10^{-8} cm/s $\quad C_R = \frac{(80.5 \cdot 0.002) + (11.9 \cdot 0.011)}{80.5 + 11.9} = 0.003$ ✓

5×10^{-9} cm/s $\quad C_R = \frac{(80.5 \cdot 0.002) + (6.0 \cdot 0.011)}{80.5 + 6.0} = 0.003$ ✓

Chromium
Cr

1×10^{-8} cm/s $\quad C_R = \frac{(80.5 \cdot 0.06) + (11.9 \cdot 0.11)}{80.5 + 11.9} = 0.07$ ✓

5×10^{-9} cm/s $\quad C_R = \frac{(80.5 \cdot 0.06) + (6.0 \cdot 0.11)}{80.5 + 6.0} = 0.06$ ✓

Molybdenum
Mo

1×10^{-8} cm/s $\quad C_R = \frac{(80.5 \cdot 0.05) + (11.9 \cdot 0.20)}{80.5 + 11.9} = 0.07$ ✓

5×10^{-9} cm/s $\quad C_R = \frac{(80.5 \cdot 0.05) + (6.0 \cdot 0.20)}{80.5 + 6.0} = 0.06$ ✓

Selenium
Se

1×10^{-8} cm/s $\quad C_R = \frac{(80.5 \cdot 0.017) + (11.9 \cdot 0.098)}{80.5 + 11.9} = 0.027$ ✓

5×10^{-9} cm/s $\quad C_R = \frac{(80.5 \cdot 0.017) + (6.0 \cdot 0.098)}{80.5 + 6.0} = 0.023$ ✓

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U (uranium)

1×10^{-8} cm/s $CR = \frac{(80.5 \cdot 0.004) + (11.9 \cdot 0.340)}{80.5 + 11.9} = 0.047$ ✓

5×10^{-9} cm/s $CR = \frac{(80.5 \cdot 0.004) + (6.0 \cdot 0.340)}{80.5 + 6.0} = 0.027$ ✓

Sb (antimony)

1×10^{-8} cm/s $CR = \frac{(80.5 \cdot 0.02) + (11.9 \cdot 0.09)}{80.5 + 11.9} = 0.03$ ✓

5×10^{-9} cm/s $CR = \frac{(80.5 \cdot 0.02) + (6.0 \cdot 0.09)}{80.5 + 6.0} = 0.02$ ✓

V (vanadium)

1×10^{-8} cm/s $CR = \frac{(80.5 \cdot 0.02) + (11.9 \cdot 0.07)}{80.5 + 11.9} = 0.03$ ✓

5×10^{-9} cm/s $CR = \frac{(80.5 \cdot 0.02) + (6.0 \cdot 0.07)}{80.5 + 6.0} = 0.02$ ✓

E. Results:

Results of the calculations are summarized in Table E.3.2 (attached).