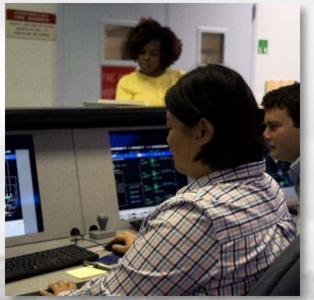
Savannah River Remediation

AECOM | BECHTEL | CH2M | BWXT

July 2018

SRR-CWDA-2018-00034



BRIEFING TO NRC: FEPS AND CONCEPTUAL MODEL FOR THE 2019 SDF PA

Steve Hommel

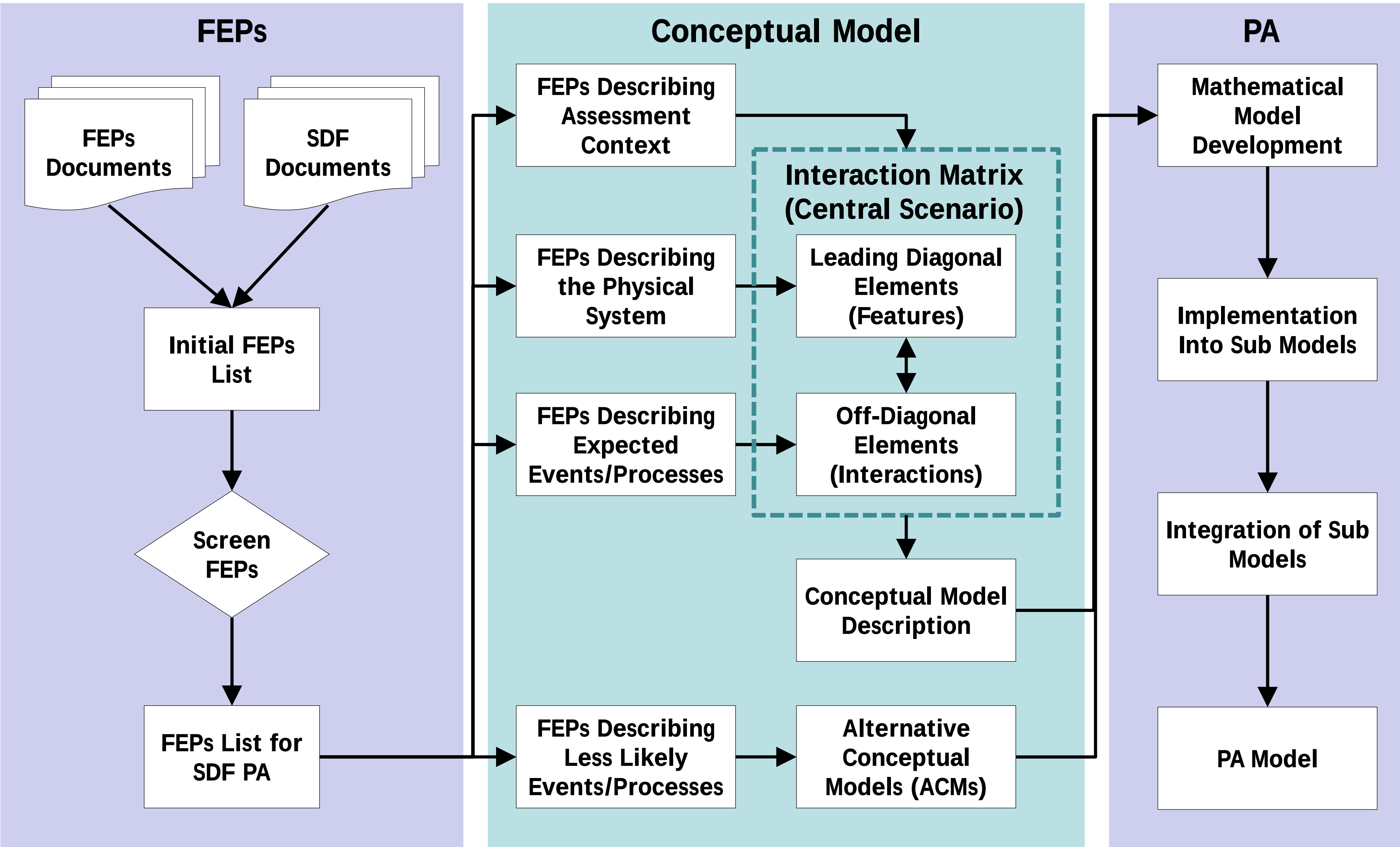
Performance Assessments, Waste Disposal Authority

Overview

- **Using FEPs and Conceptual Modeling to Inform PA Development**
- **FEPs Report (SRR-CWDA-2017-00057)**
  - What Are FEPs?
  - Development of Initial FEPs List
  - FEPs Screening Process
  - FEPs Screening Team
  - Results of FEPs Screening
- **Conceptual Model Report (SRR-CWDA-2018-00006)**
  - Assessment Context and System Description
  - Conceptualization of the System
  - Interaction Matrix and Scenario Development
  - FEPs Auditing
  - Alternative Scenario Development and Alternative Conceptual Models and Sensitivity Modeling

SRR Savannah River Remediation
AECOM | BECHTEL | CH2M | BWXT

Using FEPs and Conceptual Modeling to Inform PA Development



What are FEPs?

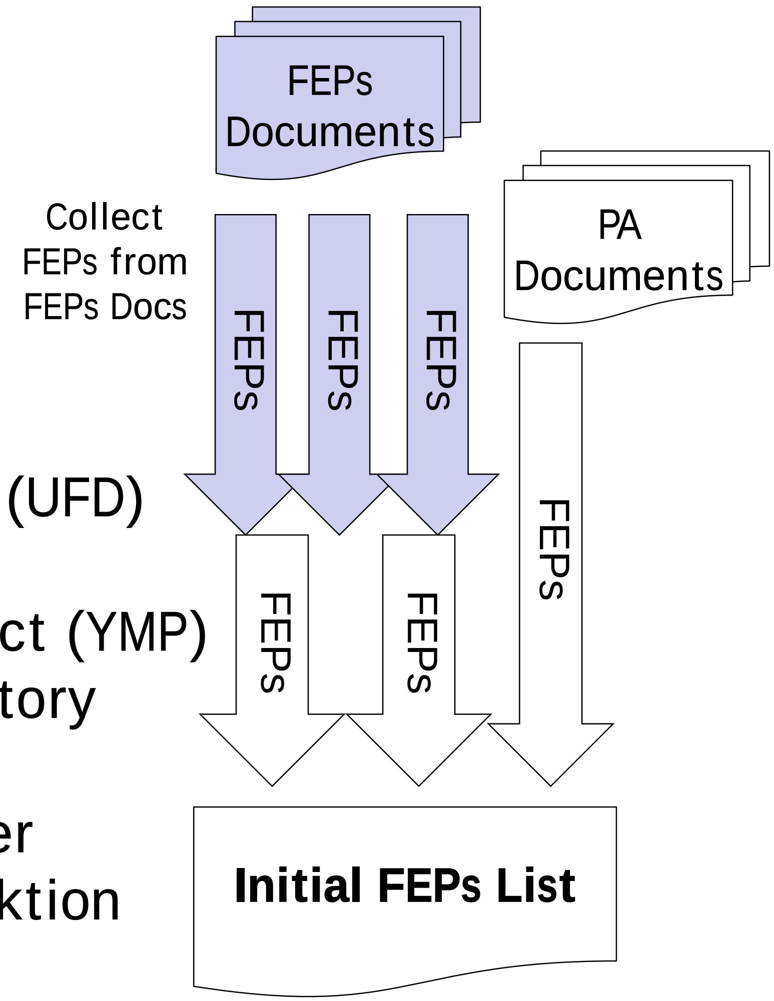
- **Features, Events, and Processes (FEPs)**
  - A **feature** is an object, structure, or condition that has a potential to affect disposal system performance;
  - An **event** is a natural or human-caused phenomenon that has a potential to affect disposal system performance and that occurs during an interval that is short relative to the period of performance; and
  - A **process** is a natural or human-caused phenomenon that has a potential to affect disposal system performance and that operates during all or a significant part of the period of performance.

What are FEPs?

- **Performance Assessments (PAs) should consider all relevant FEPs**
  - Potential FEPs should be identified and screened as relevant or relevant for the PA
  - Justification must be documented for any FEPs that are screened as not relevant for the PA
- **FEPs are used throughout the DOE Complex and by the international radioactive waste disposal community**
- **While FEPs analyses are considered a best practice, they are not explicitly required by regulation for SRS waste disposal**

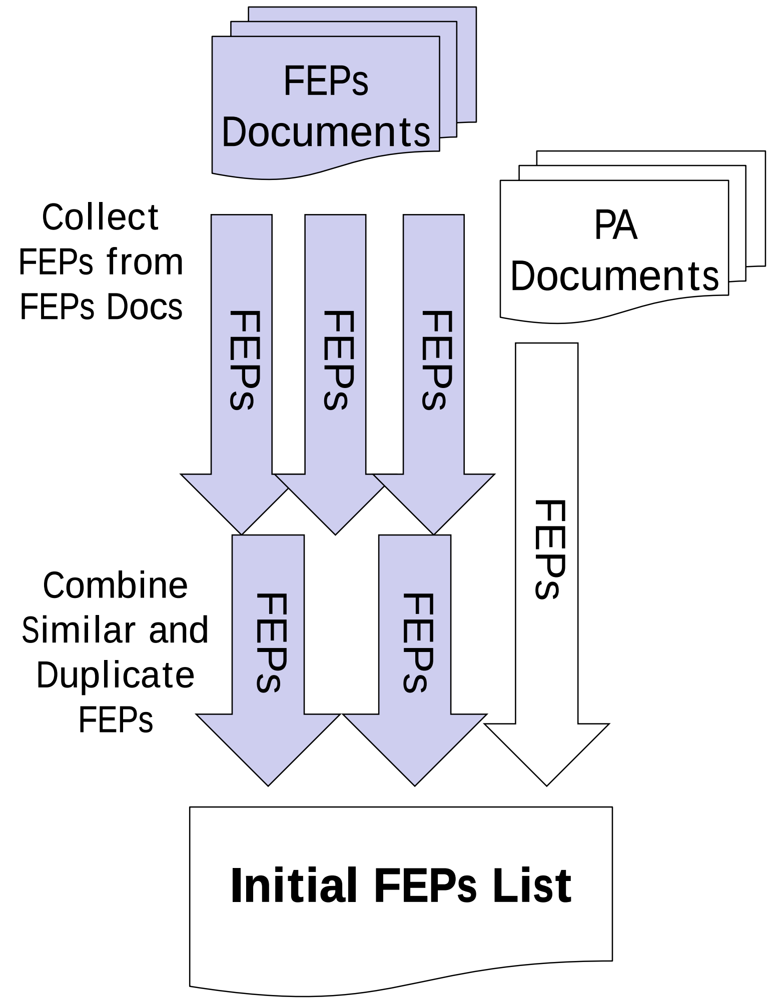
Development of the Initial FEPs List

- **1,383 FEPs collected from domestic and international FEPs Lists**
  - **141** FEPs from Improvement of Safety Assessment Methodologies for Near Surface Disposal Facilities (ISAM)
  - **449** FEPs from Used Fuel Disposition (UFD) Campaign Low Level Waste (LLW)
  - **374** FEPs from Yucca Mountain Project (YMP)
  - **299** FEPs from Deep Geologic Repository (DGR)
  - **120** FEPs from Swedish Nuclear Power Inspectorate (Statens Kärnkraftinspektion [SKI])



Development of the Initial FEPs List

- **The draft FEPs list was dispositioned to identify duplicate or very similar FEPs, resulting in a preliminary list of 245 unique FEPs**

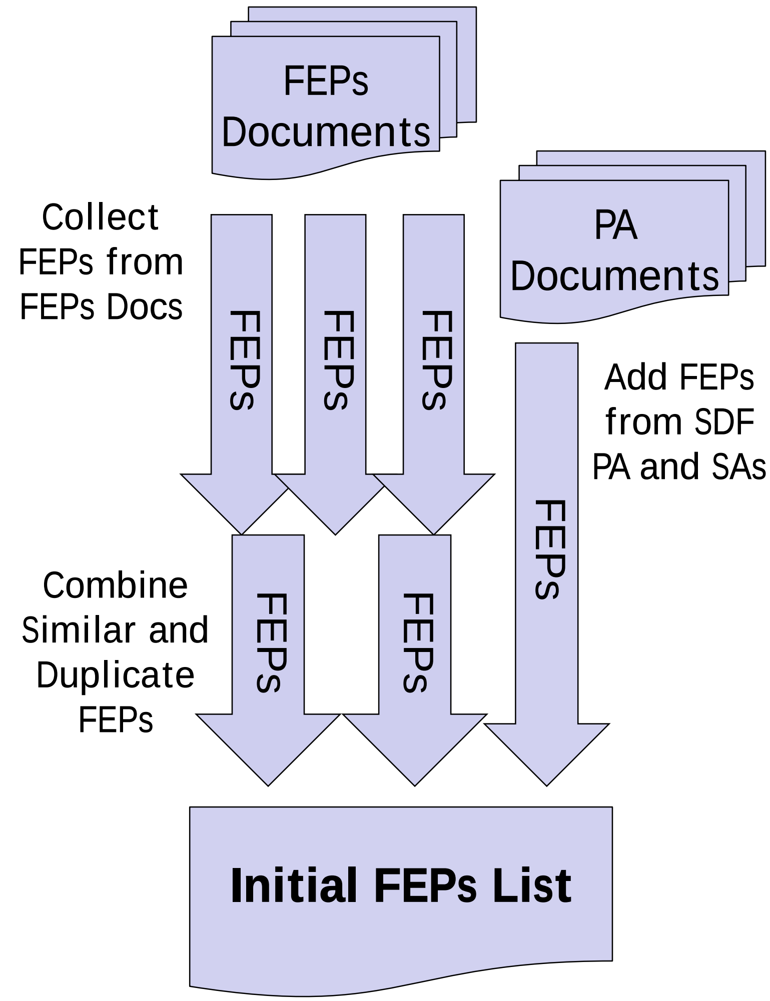


Development of the Initial FEPs List

- **The 2009 SDF PA and SDF SAs were reviewed and used to identify 100 additional FEPs**

- **245+100=345 Initial FEPs**

See SRR-CWDA-2017-00057, Attachment 2



FEPs Screening Process

- **Screening criteria**
  - Two criteria
    - Perceived frequency (probability of occurrence)
    - Perceived impact (consequence)
  - Evaluate qualitatively based on the professional judgment and perception of each team member
  - Two screening phases
    - Phase I: Team survey screening
      - Team members unanimously agree (prior to discussion) that FEPs should be screened in or out
    - Phase II: Team discussion screening
      - Team members discuss and disposition FEPs as screened in or screened out

FEPs Screening Team

- **The FEPs Screening Team had nine members with varying science and engineering backgrounds**
  - Expertise includes geology, hydrology, chemical and nuclear engineering, and material sciences

- **Dr. Andrew Garrabrants**
  - Associate Research Professor of Civil and Environmental Engineering
  - Vanderbilt University and CRESP
  - B.S., M.S., and PhD in Chemical and Biochemical Engineering
- **Steve Hommel**
  - Saltstone Disposal Facility PA SME
  - Savannah River Remediation, Waste Disposal Authority
  - B.S. in Earth Science, M.S. in Information Systems

FEPs Screening Team

- **Terry Killeen**
  - Certified Professional Geologist and Groundwater Monitoring SME
  - Savannah River Nuclear Solutions
  - B.S. in Geology and Geophysics, M.S. in Marine Science
- **Mark Layton**
  - SRS Tank Farm PA SME
  - Savannah River Remediation, Waste Disposal Authority
  - B.S. in Nuclear Engineering
- **Barry Lester**
  - PA Modeler and Hydrology
  - Savannah River Remediation, Waste Disposal Authority
  - B.S. in Earth Science, M.S. in Geology
- **Dr. Jeremiah Mangold**
  - PA Modeler and Geochemist
  - Savannah River Remediation, Waste Disposal Authority
  - B.S., M.S., and PhD in Environmental Engineering

FEPs Screening Team

- **Paul Rutland**
  - Manager of Closure and Interim Measures at Hanford
  - Washington River Protection Solutions
  - B.S. in Chemical Engineering
- **Roger Seitz**
  - Senior Advisory Scientist, PA Technical Consulting
  - Savannah River National Laboratory
  - B.S. in Mathematics
- **Dr. Steve Simner**
  - Cementitious Waste Forms (Saltstone) SME
  - Savannah River Remediation, Waste Disposal Authority
  - B.Eng. and PhD in Materials Engineering

Results of FEPs Screening

Programmatic Screening Prior to Phase I

- 3 FEPs were screened out as non-applicable:
  - FEP 1.3.11: Prospective Evaluation Assessment Approach
  - FEP 1.4.06: Retrievability
  - FEP 3.1.02: Site Development

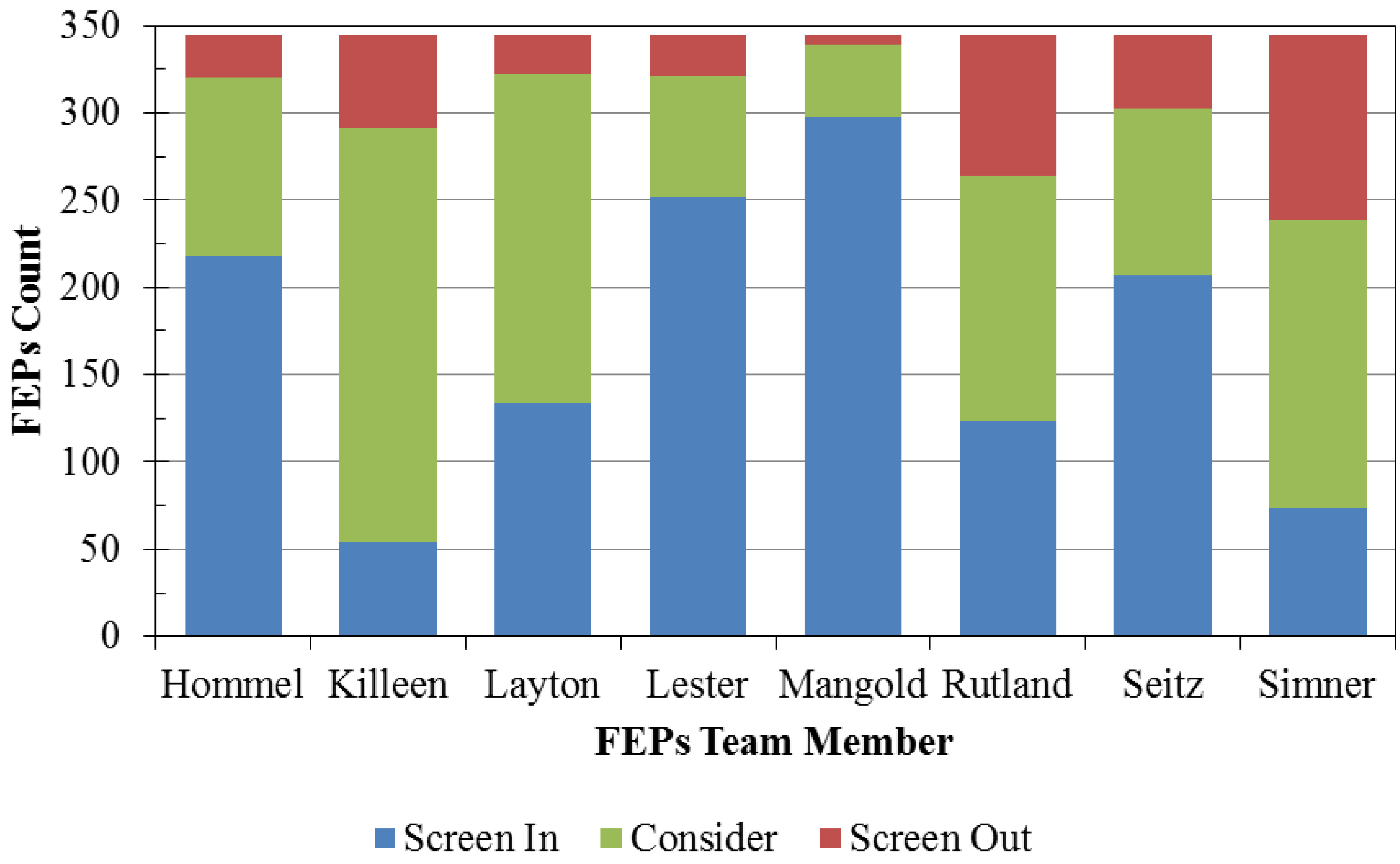
  345 – 3 = 342 FEPs left to screen

- 50 FEPs were screened in by the SDF PA SME prior to the Screening Process as required

  342 – 50 = 292 FEPs left to screen

Results of FEPs Screening

- **Phase I Screening: Screening by Consensus**



Results of FEPs Screening

- **Given the variety of backgrounds and expertise, there was limited agreement among the FEPs Screening Team during Phase I**

- **Only two FEPs were screened out based on group consensus**

  - FEP 6.4.10: Changes to Earth's Tidal Processes
  - FEP 6.4.11: Changes in the Earth's Magnetic Field

292 – 2 = 290 FEPs left to screen

Results of FEPs Screening

Phase II Screening: Screening by Discussion

- In addition to perceived probability and perceived impact, FEPs discussions considered available knowledge and potential synergisms with other FEPs

- 234 FEPs were screened in

  290 – 234 = 56 FEPs left to screen

- 56 FEPs were screened out

  56 – 56 = 0 FEPs left to screen

Results of FEPs Screening

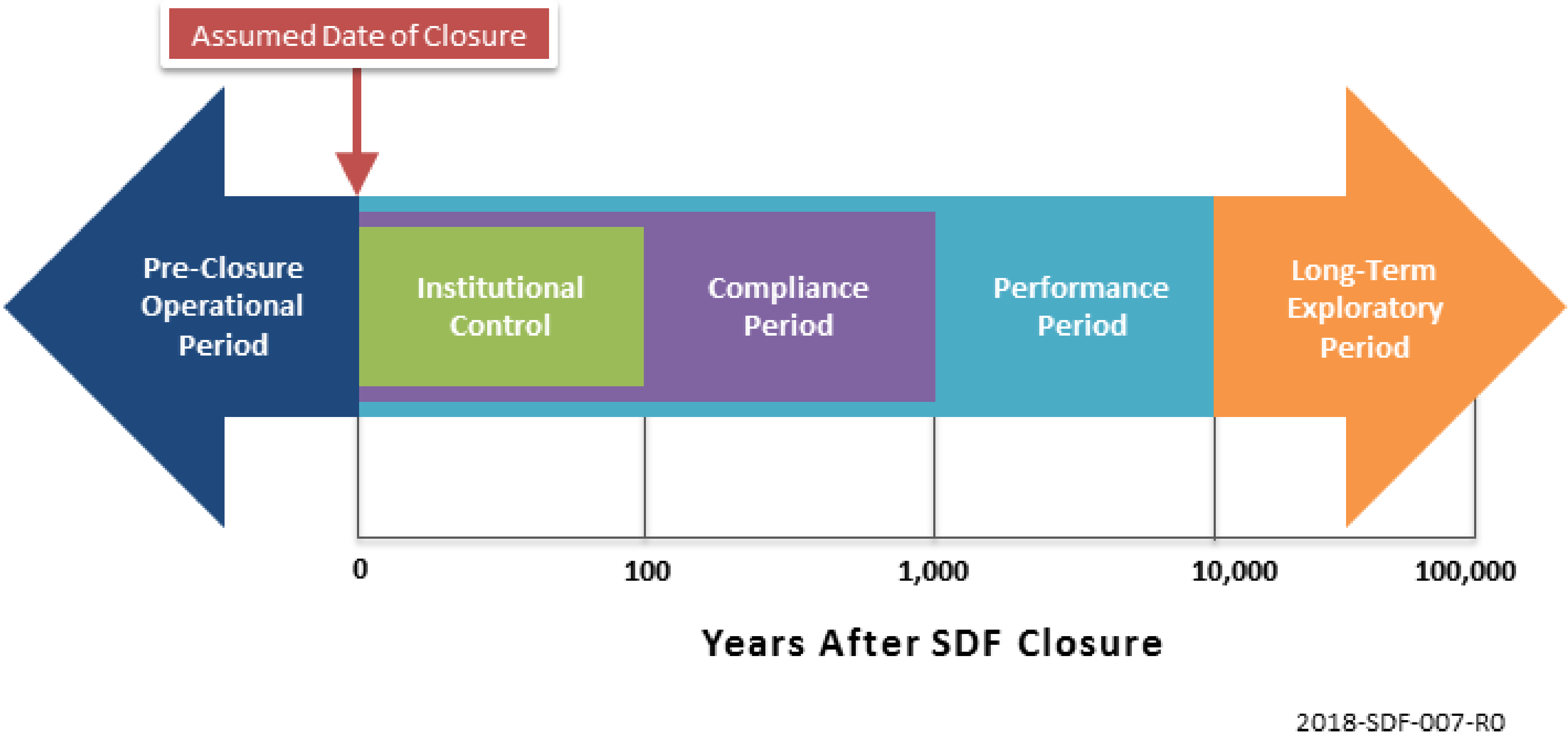
- **Summary of FEPs Screening**

Screening Phase	In	Out
Prior to Phase I (WDA)	50	3
Phase I	0	2
Phase II	234	56
Total	**284**	**61**

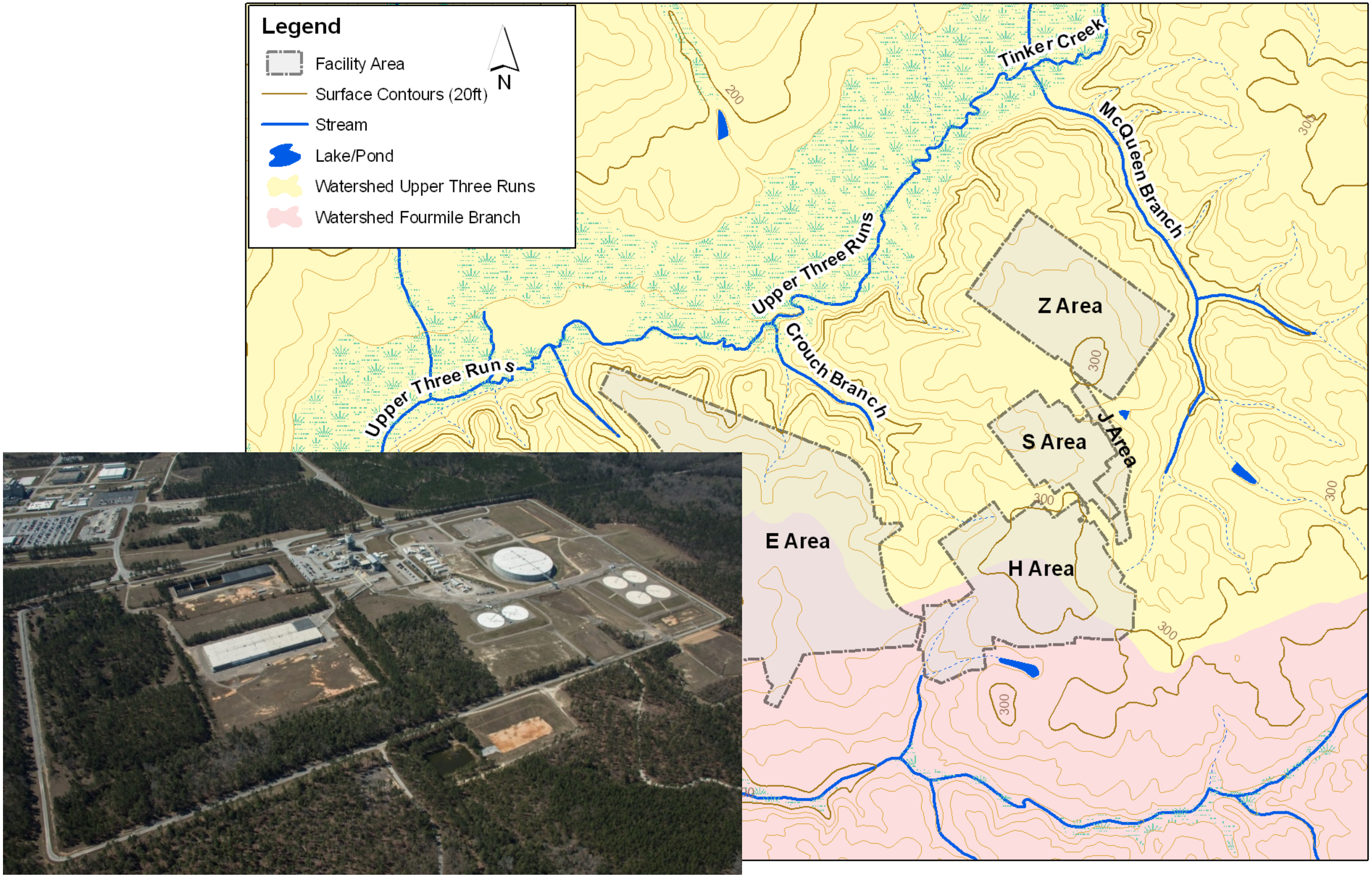
Assessment Context: Performance Objectives

Exposure Pathway	Objective or Measure, within the Compliance Period	Point of Assessment
All Pathways, Member of the Public	25 mrem/yr	Point of highest concentration, at least 100 meters from disposal units
Air Pathway	10 mrem/yr	Point of highest concentration, at least 100 meters from disposal units
Radon	20 pCi/m^2/s	Point of highest concentration at the surface of the disposal facility
All Pathways, Chronic Intruder	100 mrem/yr	Point of highest concentration, within 100 meters of disposal units
All Pathways, Acute Intruder	500 mrem	Point of highest concentration, within 100 meters of disposal units

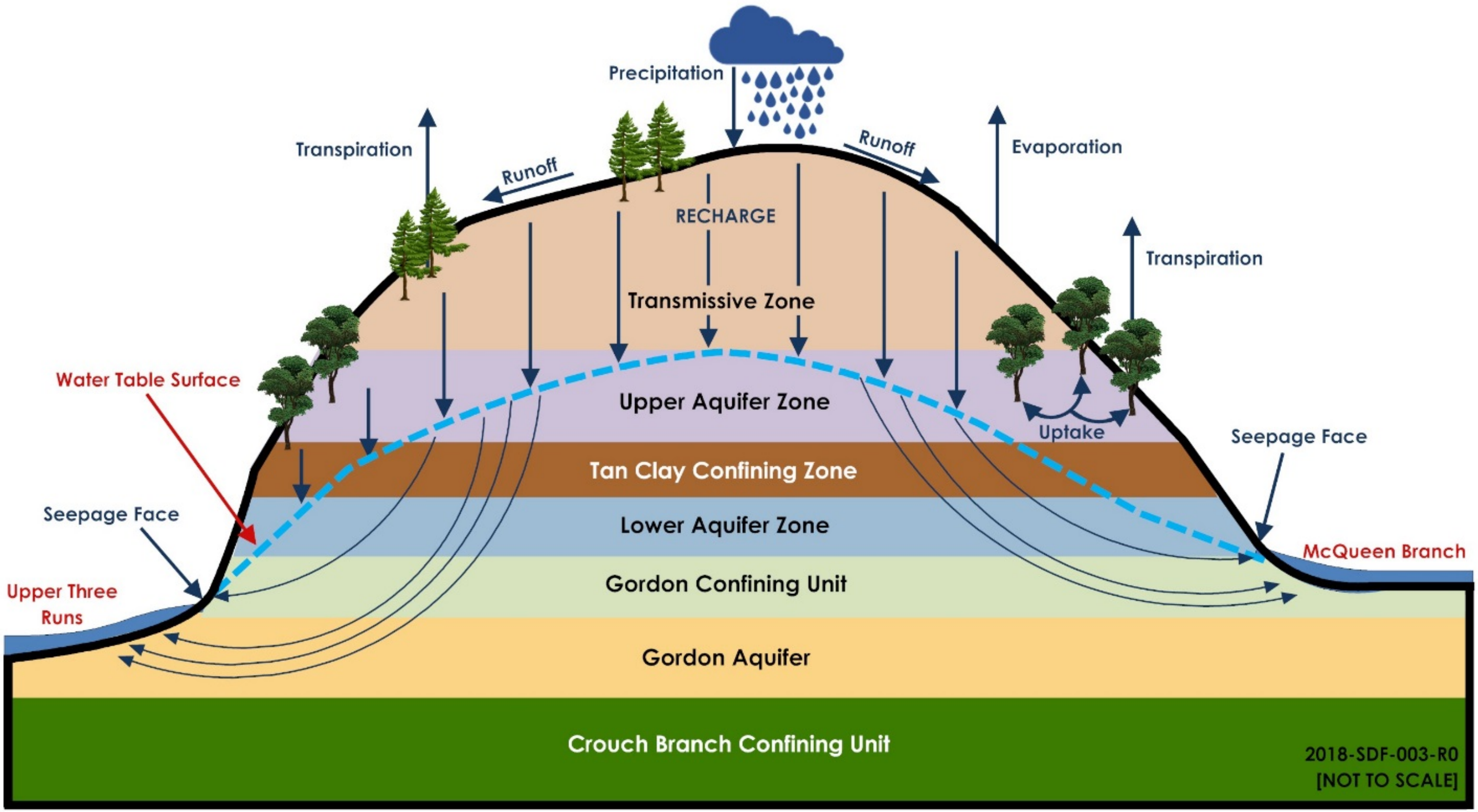
Assessment Context: Timeline



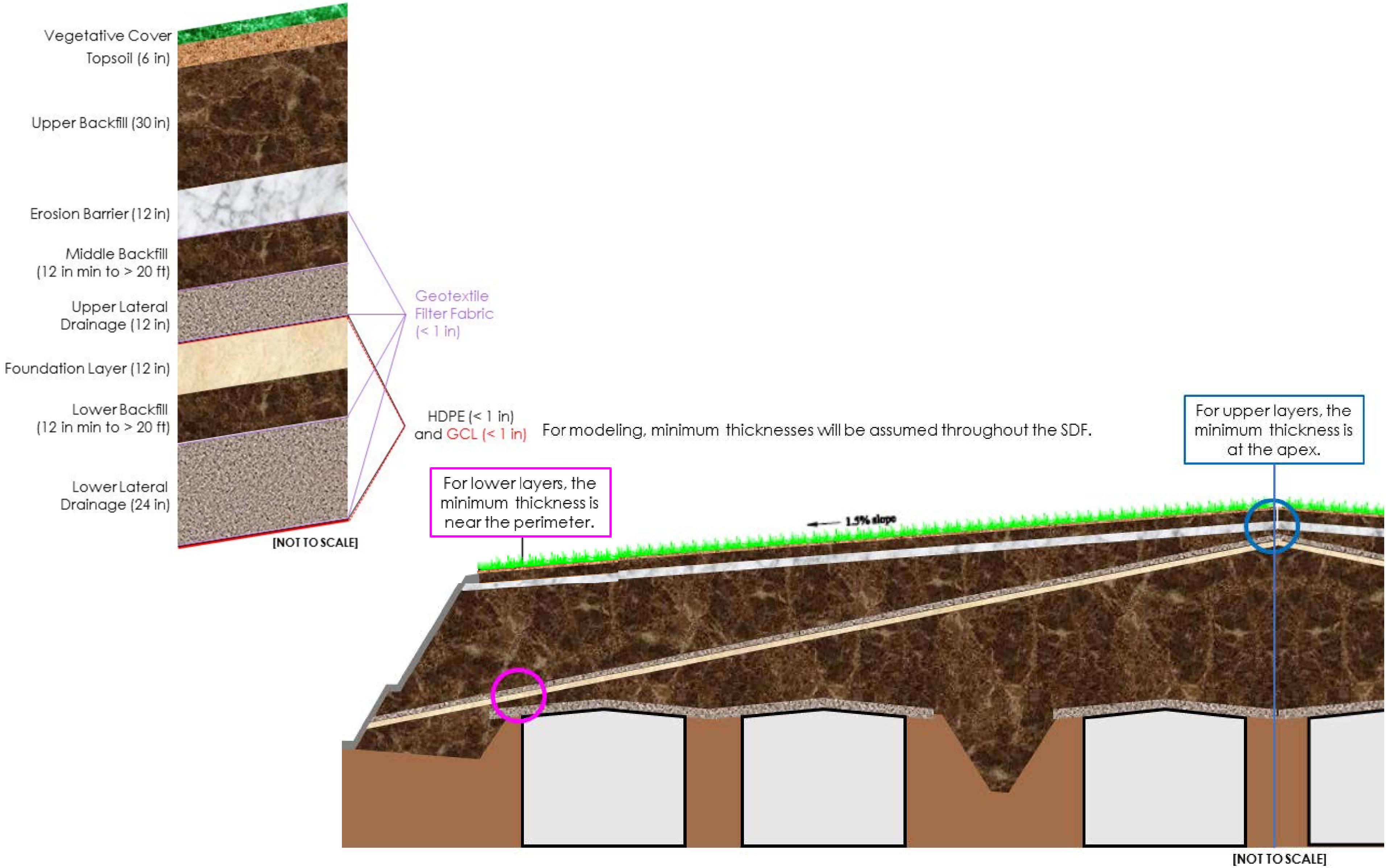
System Description: Natural Setting



System Description: Water Cycle

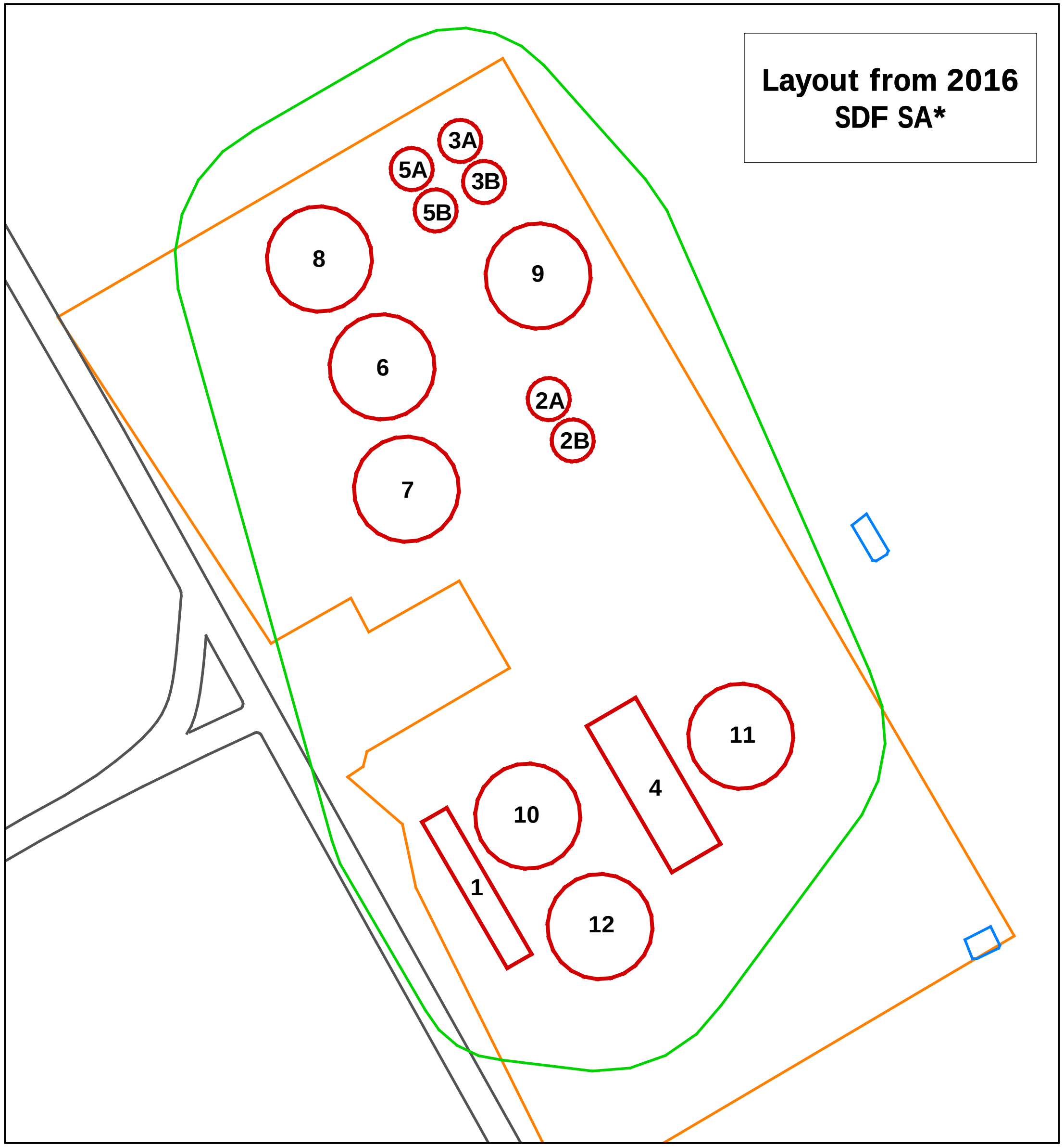


System Description: Closure Cap

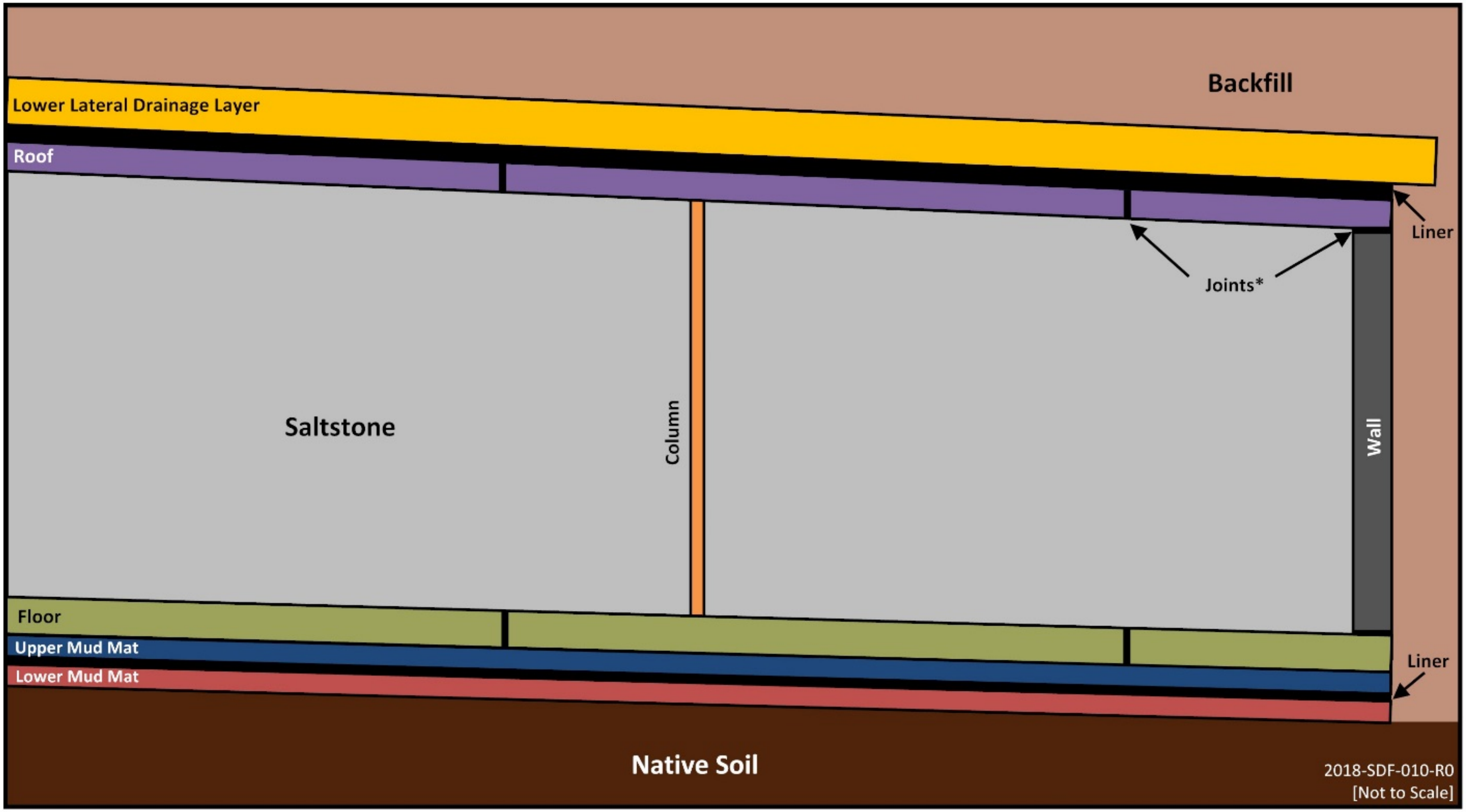


System Description: SDF Layout

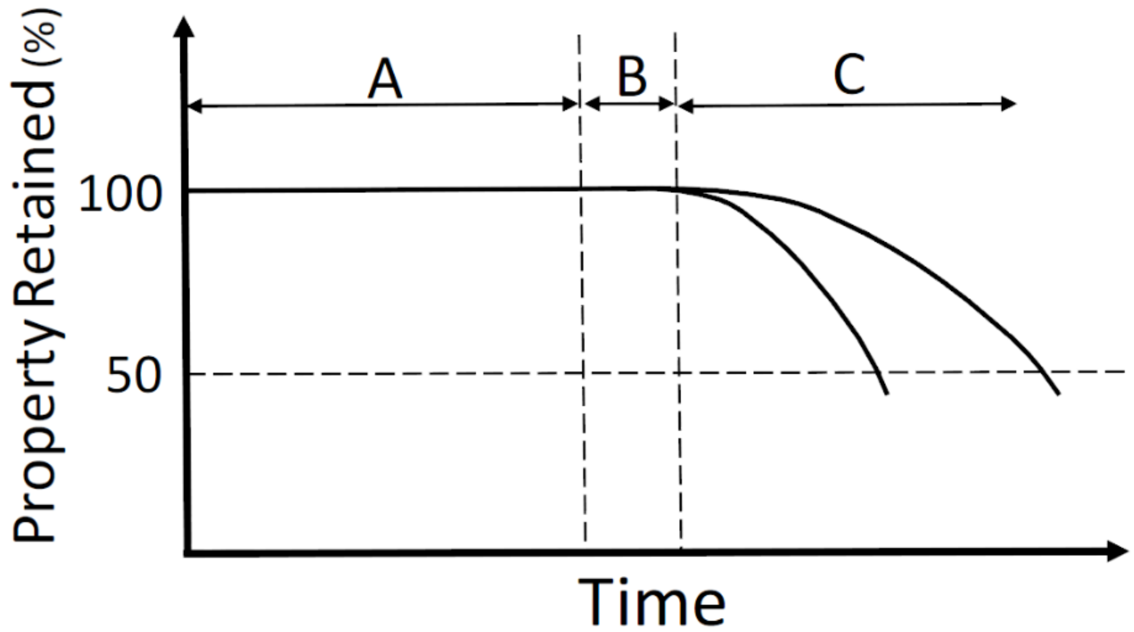
- **The SDF disposal layout has been revised to reduce risk of workers being exposed to contaminants from SDU 4**



System Description: SDUs



Conceptualization: Anti-oxidant Depletion of HDPE



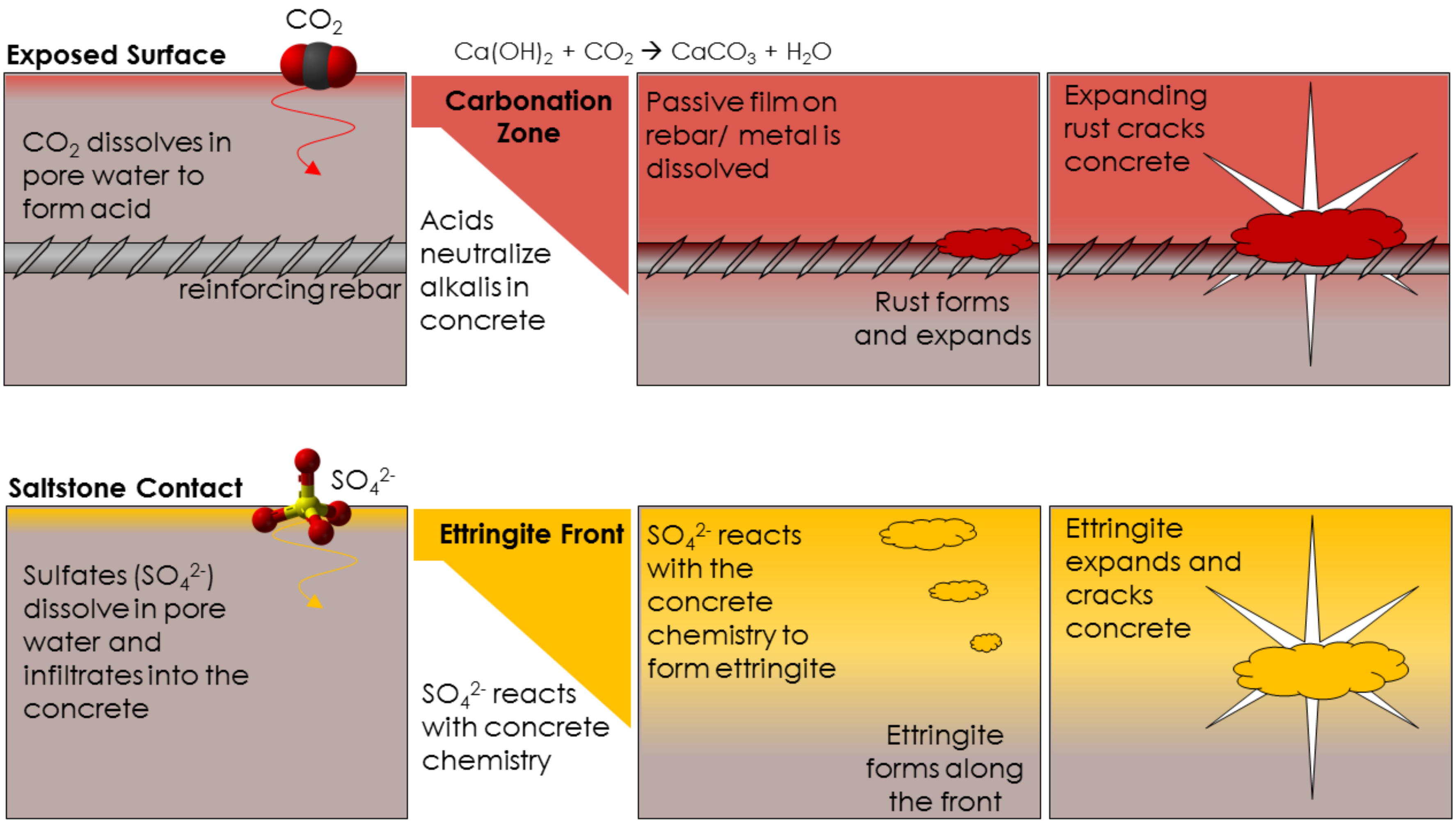
A = Antioxidant Depletion

B = Induction Time

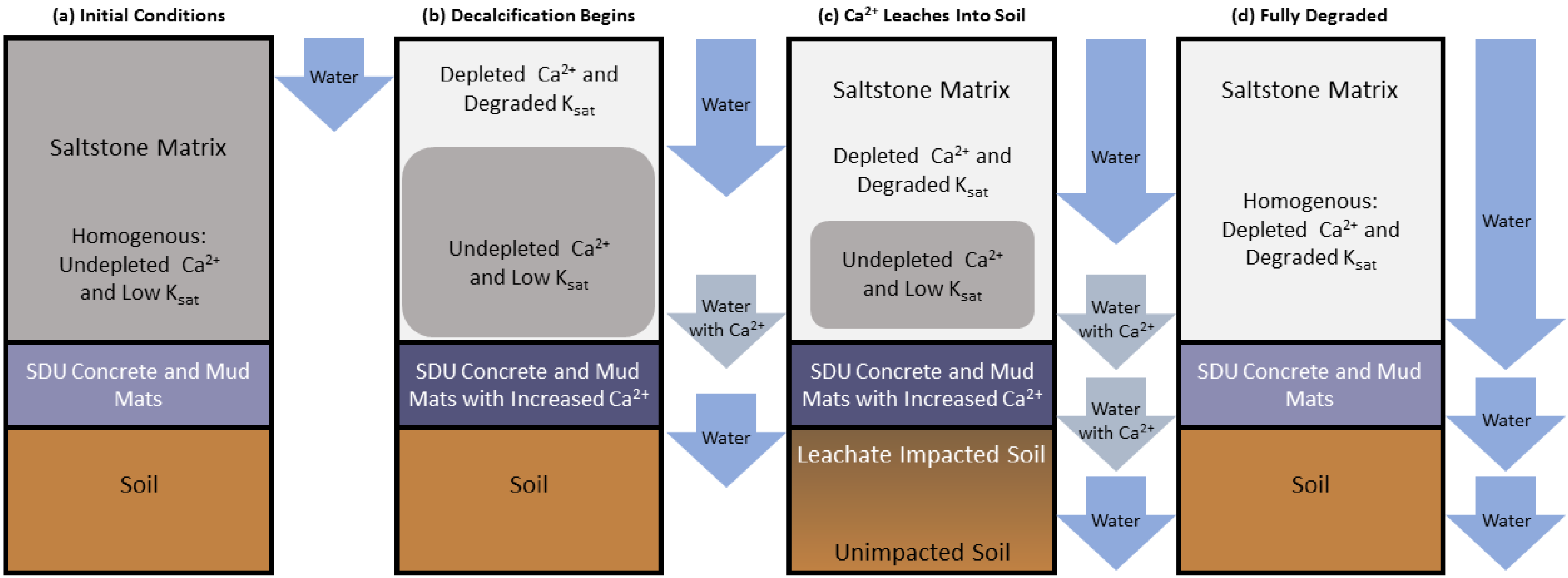
C = 50% property degradation time

$$\text{Service Life } T = T_A + T_B + T_C$$

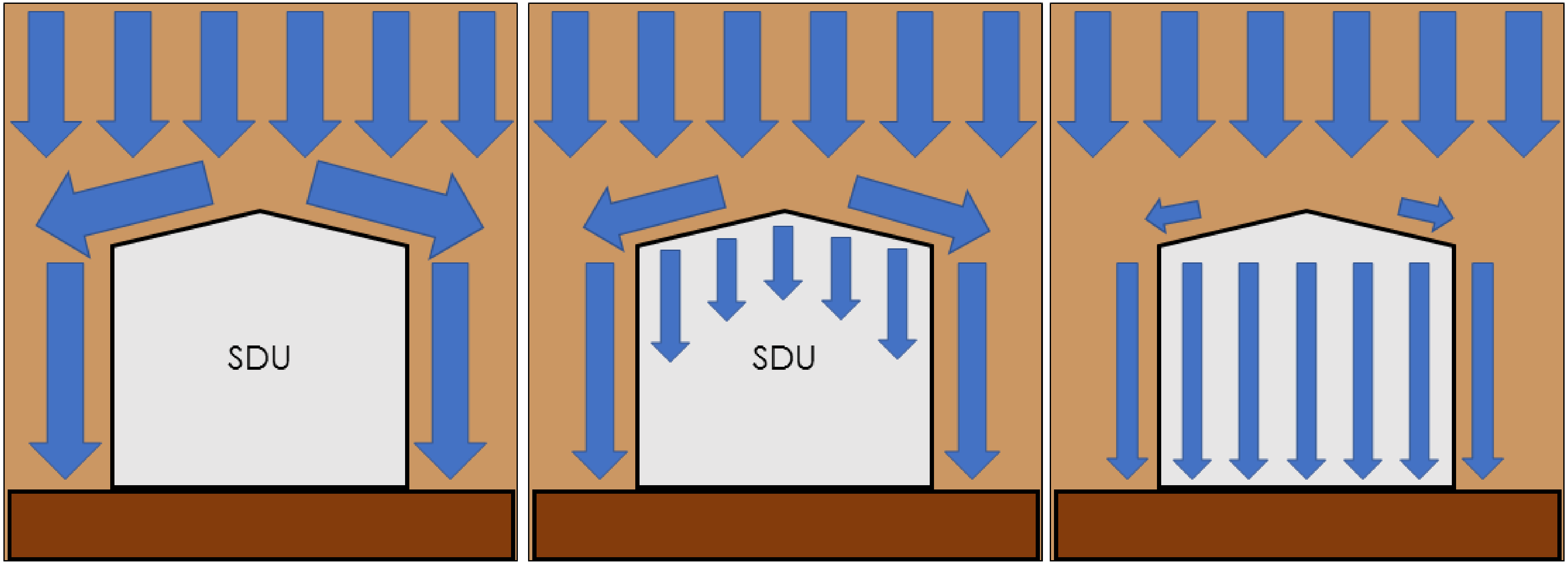
Conceptualization: Chemical Degradation of Concrete



Conceptualization: Decalcification of Saltstone



Conceptualization: SDU Flow Evolution

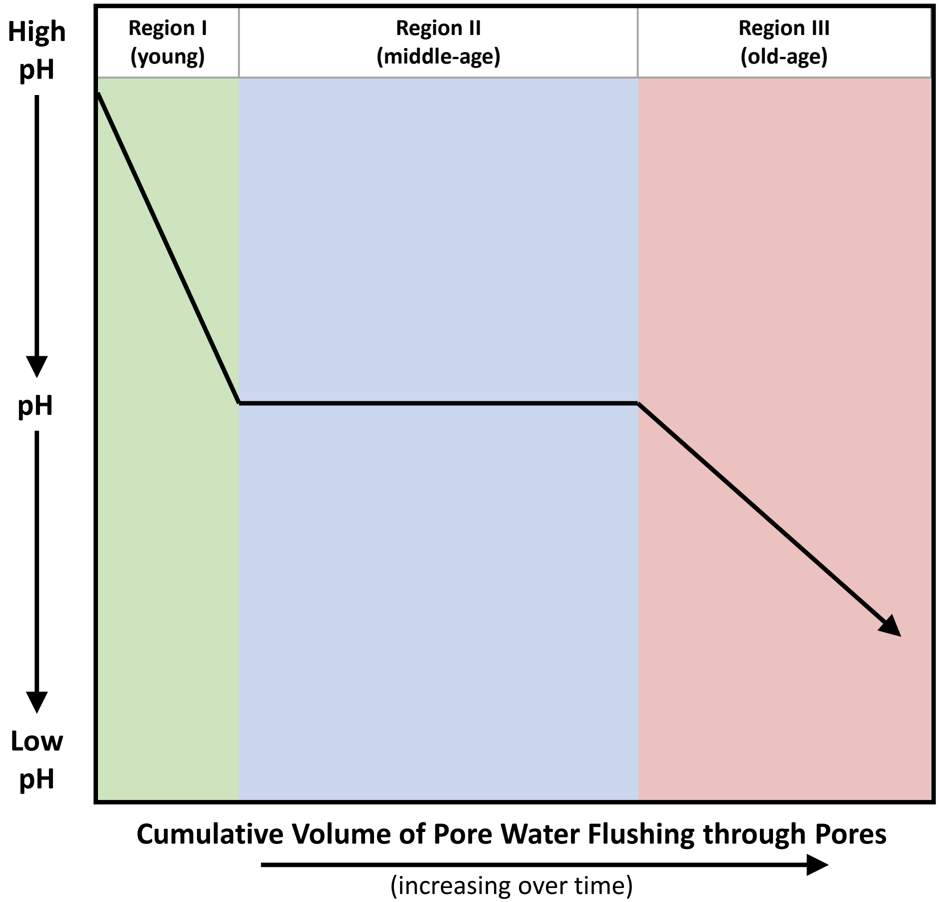


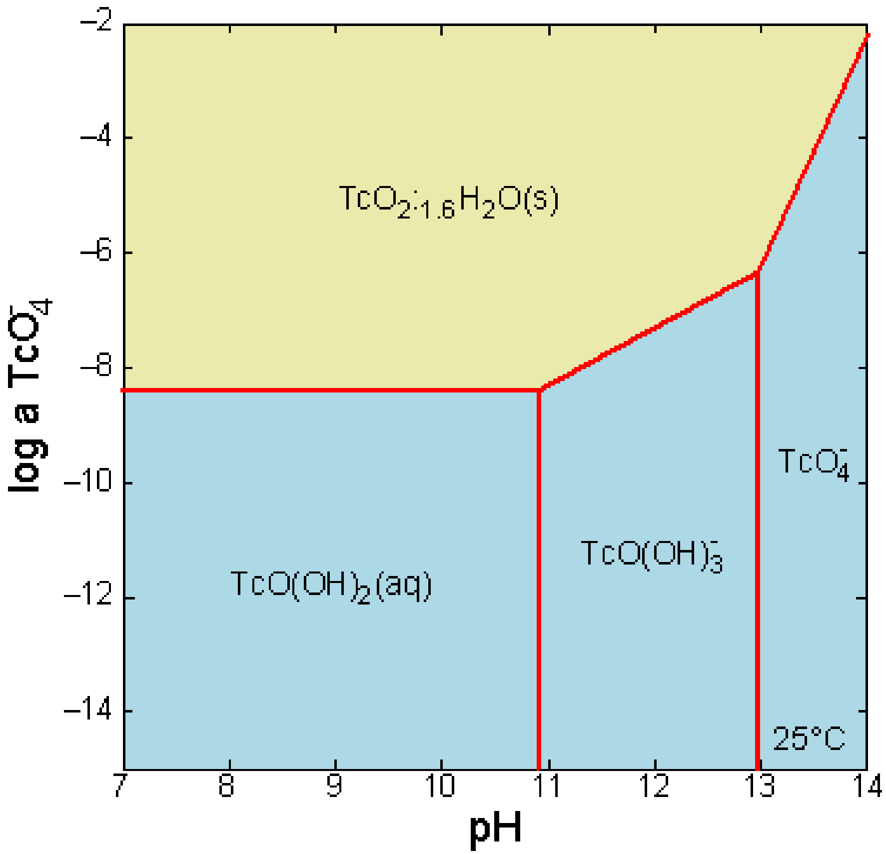
(a) Initially almost all flow will shed from the SDU roof.

(b) As concrete degrades, less flow will shed and more flow will enter into the SDU.

(c) Trend continues until flow through the SDU is similar to flow through backfill.

Conceptualization: Chemical Evolution

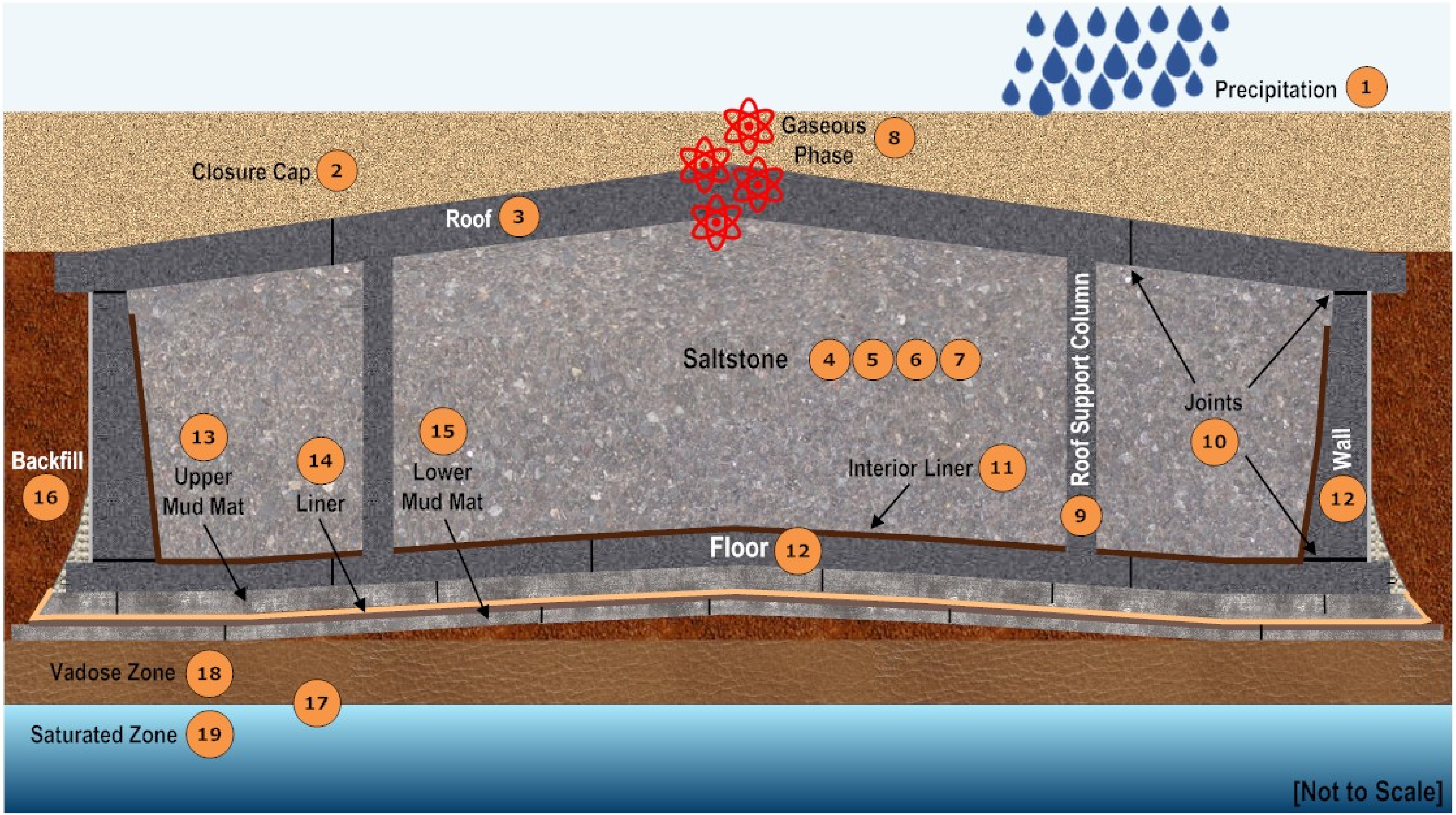




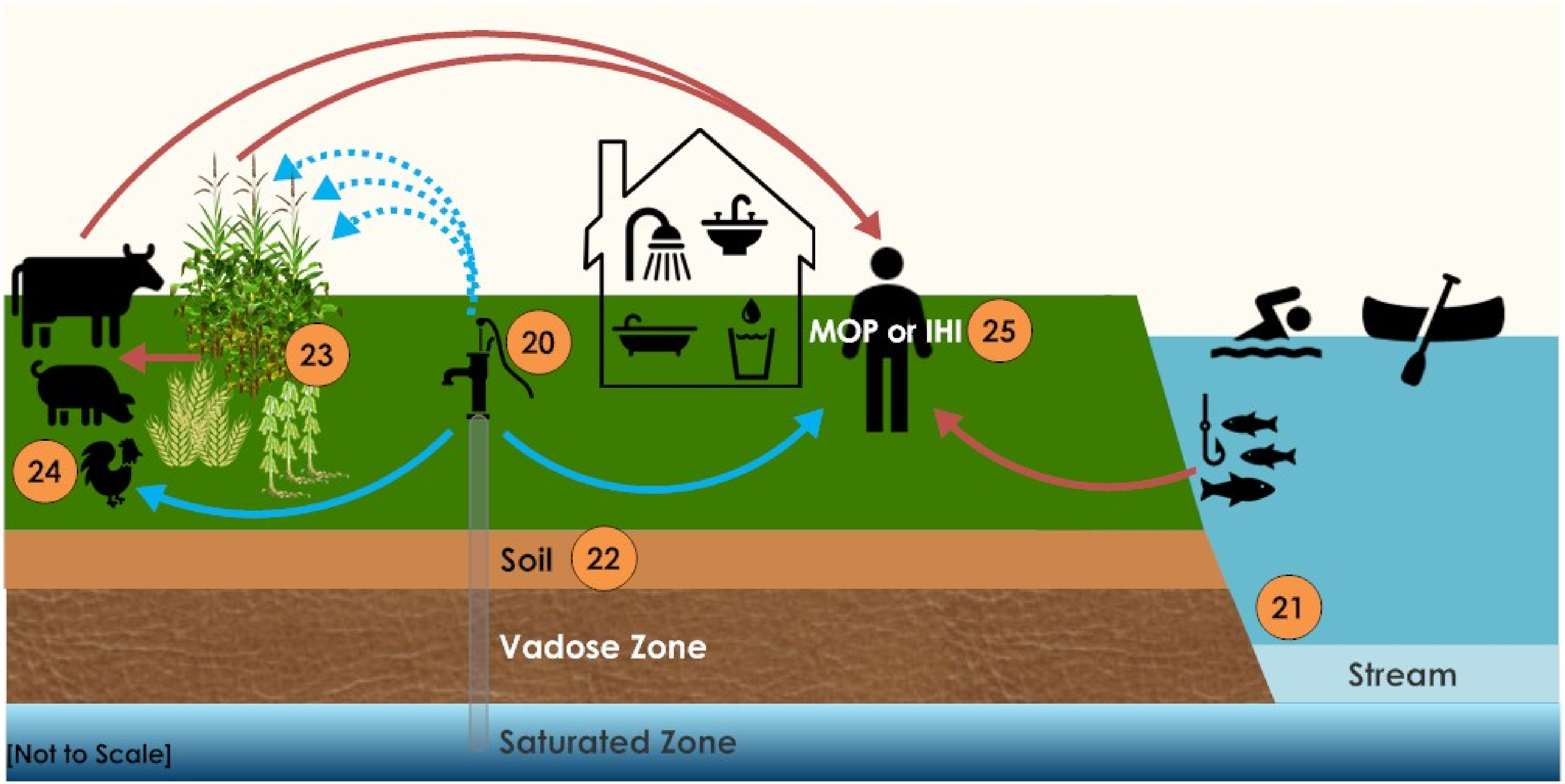
Conceptual Model for the Central Scenario

IM ID	Leading Diagonal Element
IM 01.01	Precipitation
IM 02.02	Closure Cap
IM 03.03	SDU Roof
IM 04.04	Waste (Decontaminated Salt Solution)
IM 05.05	Saltstone Hydraulic Conductivity
IM 06.06	Saltstone Reducing Capacity
IM 07.07	Pore Water Chemistry
IM 08.08	Gaseous Phases
IM 09.09	SDU Columns
IM 10.10	SDU Joints/ Waterstops
IM 11.11	SDU Interior Liner
IM 12.12	SDU Walls and Floor
IM 13.13	Upper Mud Mat
IM 14.14	Liner Between Mud Mats
IM 15.15	Lower Mud Mat
IM 16.16	Backfill
IM 17.17	Groundwater Chemistry
IM 18.18	Vadose Zone
IM 19.19	Saturated Zone
IM 20.20	1-Meter or 100-Meter Well
IM 21.21	Surface Streams
IM 22.22	Soil
IM 23.23	Vegetation
IM 24.24	Livestock
IM 25.25	Human
IM 26.26	Exposure/ Risk

Conceptual Model for the Central Scenario



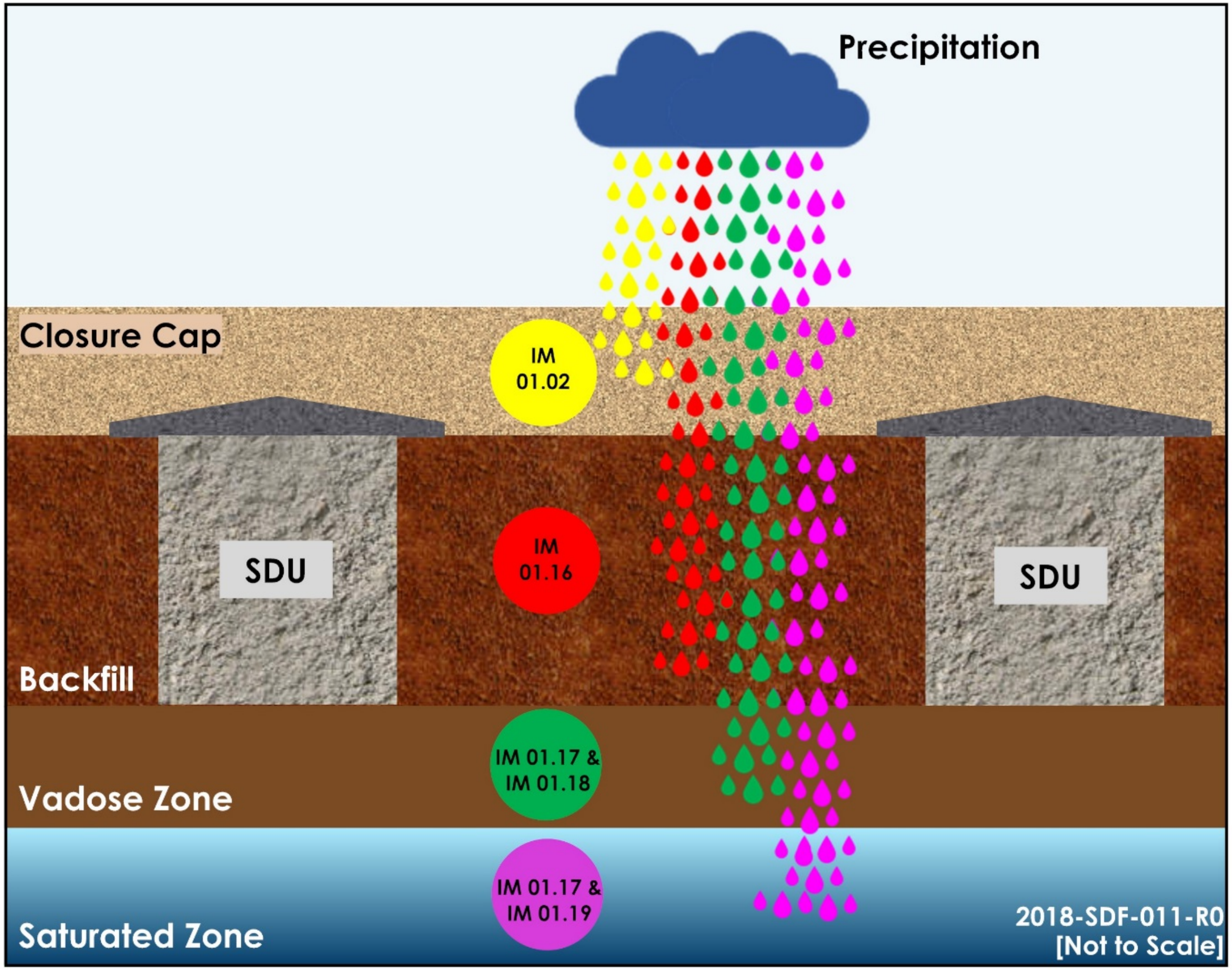
Conceptual Model for the Central Scenario



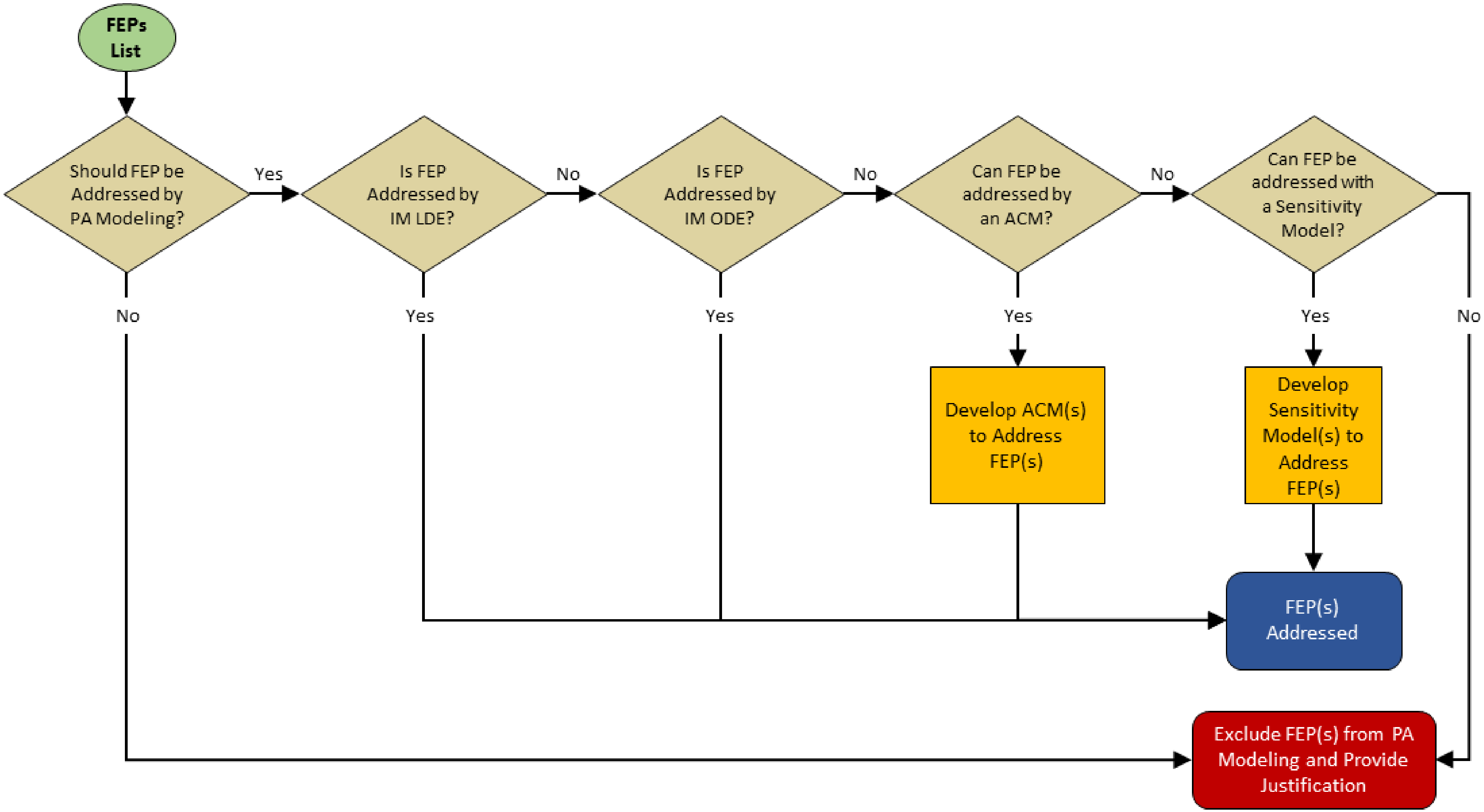
Interaction Matrix and Scenario Development

	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
01	Precipitation	01.02 Infiltration (Water Cycle)	01.03	01.04	01.05	01.06	01.07	01.08	01.09	01.10	01.11	01.12	01.13	01.14	01.15	01.16 Flow Rates, Chemistry	01.17 Chemistry	01.18 Flow Rates	01.19 Flow Rates	01.20	01.21	01.22	01.23	01.24	01.25	01.26
02	02.01	Closure Cap	02.03 Flow Rates, Degradation	02.04	02.05	02.06	02.07 Chemistry, Oxidation	02.08	02.09	02.10	02.11	02.12	02.13	02.14	02.15	02.16 Flow Rates	02.17	02.18	02.19	02.20	02.21	02.22	02.23	02.24	02.25	02.26
03	03.01	03.02 Flow Rates, Degradation	SDU Roof	03.04	03.05 Flow Rates, Degradation	03.06 Flow Rates, Oxidation	03.07	03.08	03.09	03.10 Flow Rates	03.11	03.12	03.13	03.14	03.15	03.16 Flow Rates	03.17	03.18	03.19	03.20	03.21	03.22	03.23	03.24	03.25	03.26
04	04.01	04.02	04.03	Waste (DSS)	04.05 Chemistry	04.06 Chemistry	04.07 Chemistry	04.08 Waste Release, Volatility	04.09	04.10	04.11	04.12 Waste Release	04.13	04.14	04.15	04.16 Waste Release	04.17 Waste Release, Chemistry	04.18	04.19	04.20	04.21	04.22	04.23	04.24	04.25	04.26
05	05.01	05.02	05.03	05.04	Saltstone Hydraulic Conductivity	05.06 Flow Rates, Oxidation	05.07 Flow Rates, Waste Release	05.08 Waste Release, Volatility	05.09 Flow Rates, Degradation	05.10 Flow Rates	05.11	05.12 Flow Rates, Degradation	05.13	05.14	05.15	05.16	05.17	05.18	05.19	05.20	05.21	05.22	05.23	05.24	05.25	05.26
06	06.01	06.02	06.03	06.04	06.05	Saltstone Reducing Capacity	06.07 Waste Release, Chemistry	06.08	06.09 Oxidation, Waste Release	06.10	06.11	06.12 Oxidation, Waste Release	06.13 Oxidation, Waste Release	06.14	06.15 Oxidation, Waste Release	06.16 Waste Release, Chemistry	06.17	06.18	06.19	06.20	06.21	06.22	06.23	06.24	06.25	06.26
07	07.01	07.02	07.03 Degradation, Chemistry	07.04	07.05	07.06	Pore Water Chemistry	07.08 Waste Release, Volatility	07.09 Degradation, Chemistry	07.10	07.11	07.12 Degradation, Chemistry	07.13 Waste Release, Chemistry	07.14	07.15 Waste Release, Chemistry	07.16 Waste Release, Chemistry	07.17 Waste Release, Chemistry	07.18 Chemistry	07.19	07.20	07.21	07.22	07.23	07.24	07.25	07.26
08	08.01	08.02	08.03 Degradation, Oxidation,	08.04	08.05	08.06 Oxidation, Waste Release,	08.07 Degradation, Chemistry	Gaseous Phases	08.09	08.10	08.11	08.12 Degradation, Waste Release,	08.13	08.14	08.15	08.16	08.17	08.18	08.19	08.20	08.21	08.22	08.23	08.24	08.25 Exposure	08.26 Dose
09	09.01	09.02	09.03	09.04 Geometry	09.05	09.06	09.07	09.08	SDU Columns	09.10	09.11	09.12 Flow Rates	09.13	09.14	09.15	09.16	09.17	09.18	09.19	09.20	09.21	09.22	09.23	09.24	09.25	09.26
10	10.01	10.02	10.03 Flow Rates	10.04	10.05	10.06	10.07	10.08	10.09	SDU Joints/ Waterstops	10.11	10.12 Flow Rates	10.13 Flow Rates	10.14	10.15	10.16 Flow Rates	10.17	10.18	10.19	10.20	10.21	10.22	10.23	10.24	10.25	10.26
11	11.01	11.02	11.03	11.04	11.05	11.06	11.07	11.08	11.09	11.10	SDU Interior Liner	11.12	11.13	11.14	11.15	11.16	11.17	11.18	11.19	11.20	11.21	11.22	11.23	11.24	11.25	11.26
12	12.01	12.02	12.03 Flow Rates	12.04	12.05 Flow Rates, Degradation	12.06 Oxidation	12.07	12.08	12.09	12.10 Flow Rates	12.11	SDU Walls and Floor	12.13 Flow Rates	12.14	12.15	12.16 Flow Rates, Waste Release	12.17	12.18	12.19	12.20	12.21	12.22	12.23	12.24	12.25	12.26
13	13.01	13.02	13.03	13.04	13.05	13.06	13.07	13.08	13.09	13.10	13.11	13.12 Flow Rates	Upper Mud Mat	13.14 Flow Rates	13.15 Flow Rates	13.16 Flow Rates	13.17	13.18	13.19	13.20	13.21	13.22	13.23	13.24	13.25	13.26
14	14.01	14.02	14.03	14.04	14.05	14.06	14.07	14.08	14.09	14.10	14.11	14.12	14.13 Flow Rates	Liner Between Mud Mats	14.15 Flow Rates	14.16	14.17		14.19	14.20	14.21	14.22	14.23	14.24	14.25	14.26
15	15.01	15.02	15.03	15.04	15.05	15.06	15.07	15.08	15.09	15.10	15.11	15.12	15.13	15.14 Flow Rates	Lower Mud Mat	15.16 Flow Rates, Chemistry,	15.17 Flow Rates, Chemistry,	15.18 Flow Rates, Chemistry,	15.19	15.20	15.21	15.22	15.23	15.24	15.25	15.26
16	16.01	16.02	16.03	16.04	16.05	16.06	16.07 Chemistry	16.08	16.09	16.10 Flow Rates	16.11	16.12 Flow Rates, Oxidation	16.13 Flow Rates	16.14	16.15 Flow Rates	Backfill	16.17 Chemistry	16.18 Chemistry, Transport	16.19	16.20	16.21	16.22	16.23	16.24	16.25	16.26
17	17.01	17.02	17.03	17.04	17.05	17.06	17.07	17.08	17.09	17.10	17.11	17.12	17.13	17.14	17.15	17.16 Chemistry	Groundwater Chemistry	17.18 Chemistry, Transport	17.19 Chemistry, Transport	17.20 Chemistry, Transport	17.21 Chemistry, Transport	17.22	17.23	17.24	17.25	17.26
18	18.01	18.02	18.03	18.04	18.05	18.06	18.07	18.08	18.09	18.10	18.11	18.12	18.13	18.14	18.15 Flow Rates	18.16 Flow Rates	18.17 Chemistry, Transport	Vadose Zone	18.19 Flow Rates, Geometry	18.20	18.21	18.22	18.23	18.24	18.25	18.26
19	19.01	19.02	19.03	19.04	19.05	19.06	19.07	19.08	19.09	19.10	19.11	19.12	19.13	19.14	19.15	19.16	19.17	19.18 Geometry	Saturated Zone	19.20 Transport	19.21 Transport	19.22	19.23	19.24	19.25	19.26
20	20.01	20.02	20.03	20.04	20.05	20.06	20.07	20.08	20.09	20.10	20.11	20.12	20.13	20.14	20.15	20.16	20.17	20.18	20.19	1-Meter or 100-Meter Well	20.21	20.22 Contamination	20.23 Contamination	20.24 Contamination	20.25 Exposure	20.26 Dose
21	21.01	21.02	21.03	21.04	21.05	21.06	21.07	21.08	21.09	21.10	21.11	21.12	21.13	21.14	21.15	21.16	21.17	21.18	21.19	21.20	Surface Streams	21.22	21.23	21.24	21.25 Exposure	21.26 Dose
22	22.01	22.02	22.03	22.04	22.05	22.06	22.07	22.08	22.09	22.10	22.11	22.12	22.13	22.14	22.15	22.16	22.17	22.18 Contamination	22.19	22.20	22.21	Soil	22.23 Contamination	22.24 Contamination	22.25 Exposure	22.26
23	23.01	23.02	23.03	23.04	23.05	23.06	23.07	23.08	23.09	23.10	23.11	23.12	23.13	23.14	23.15	23.16	23.17	23.18	23.19	23.20	23.21	23.22	Vegetation	23.24 Contamination	23.25 Exposure	23.26
24	24.01	24.02	24.03	24.04	24.05	24.06	24.07	24.08	24.09	24.10	24.11	24.12	24.13	24.14	24.15	24.16	24.17	24.18	24.19	24.20	24.21	24.22	24.23	Livestock	24.25 Exposure	24.26
25	25.01	25.02	25.03	25.04	25.05	25.06	25.07	25.08	25.09	25.10	25.11	25.12	25.13	25.14	25.15	25.16	25.17	25.18	25.19	25.20 Human Behavior, Exposure	25.21	25.22	25.23	25.24	Human	25.26 Human Behavior
26	26.01	26.02	26.03	26.04	26.05	26.06	26.07	26.08	26.09	26.10	26.11	26.12	26.13	26.14	26.15	26.16	26.17	26.18	26.19	26.20	26.21	26.22	26.23	26.24	26.25 Dose	Exposure/ Risk

Interaction Matrix and Scenario Development



FEPs Auditing



FEP = Features, Events, and Processes
IM = Interaction Matrix
PA = Performance Assessment
ACM = Alternative Conceptual Model
LDE = Leading Diagonal Element
ODE = Off-Diagonal Element

FEPs Auditing

- **51 FEPs were excluded from consideration during Conceptual Model Development**
  - FEPs that will be addressed later as part of PA model development/implementation

    Example: FEP 1.3.01: Model and Data Issues
  - FEPs that are outside the assessment context

    Example: FEP 3.2.11: Operation
  - FEPs that are explicitly addressed in other documents

    Example: FEP 4.1.08: SDF Waste Acceptance Criteria

  - 284 – 51 = 233 FEPs left to address

FEPs Auditing

- **108 FEPs were mapped to the Leading Diagonal Elements**
  - 233 – 108 = 125 FEPs left to address
- **55 additional FEPs were mapped to the Off-Diagonal Elements**
  - 125 – 55 = 70 FEPs left to address
- **Alternative Conceptual Models (ACMs) and sensitivity models were then developed to address the remaining 70 FEPs**

Alternative Scenario Development and Alternative Conceptual Models (ACMs)

- **Nine scenarios were developed to address 56 of the 70 remaining FEPs**
  - Early Release Scenario (22 FEPs)
  - Infiltration Variability Scenario (11 FEPs)
  - Fast Flow Paths through SDUs Scenario (20 FEPs)
  - Fast Flow Paths through Groundwater Scenario (12 FEPs)
  - No Closure Cap Scenario (8 FEPs)
  - Stratified Saltstone Scenario (9 FEPs)
  - Perched Water Scenario (4 FEPs)
  - Colloid Transport Scenario (7 FEPs)
  - Inadvertent Human Intruder Scenario (3 FEPs)

Note: The total count of FEPs exceeds 56 because many FEPs of these FEPs are addressed in multiple scenarios

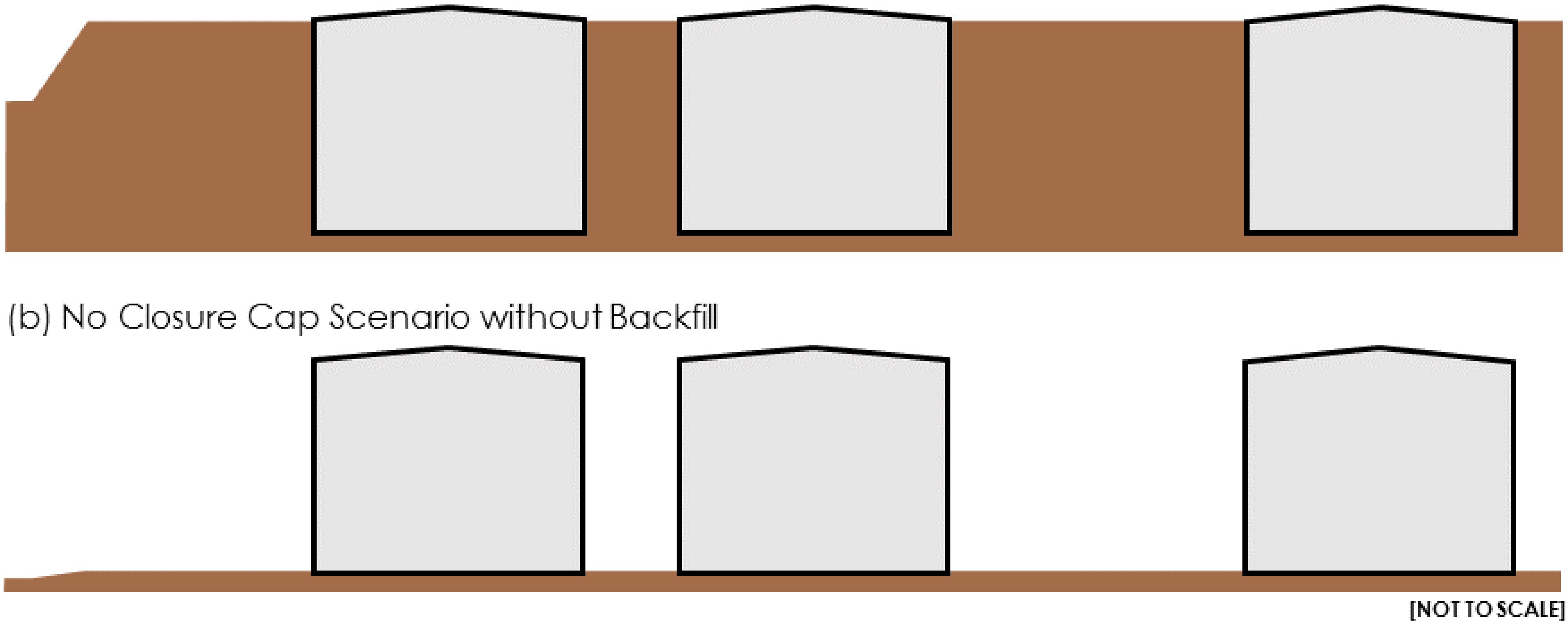
Alternative Scenario Development and Alternative Conceptual Models (ACMs)

- **From these scenarios, Alternative Conceptual Models (ACMs) were prepared, describing how the associated FEPs are addressed**
  - These ACMs do not explicitly simulate the occurrence of specific FEPs, rather they simulate the assumed consequence of the FEPs to provide insights related to risk
  - So FEPs were organized by the assumed consequences, and those consequences were used to determine which ACMs to develop

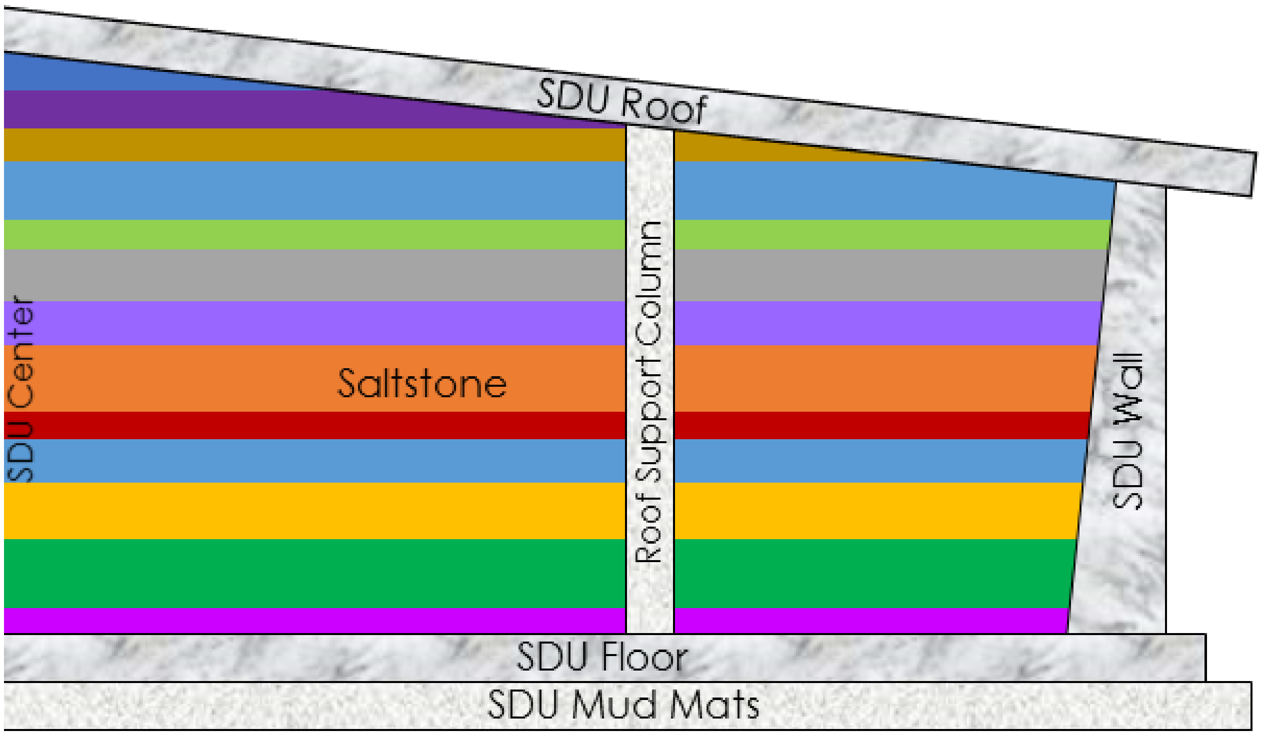
ACM Example: No Closure Cap

(a) No Closure Cap Scenario with Backfill

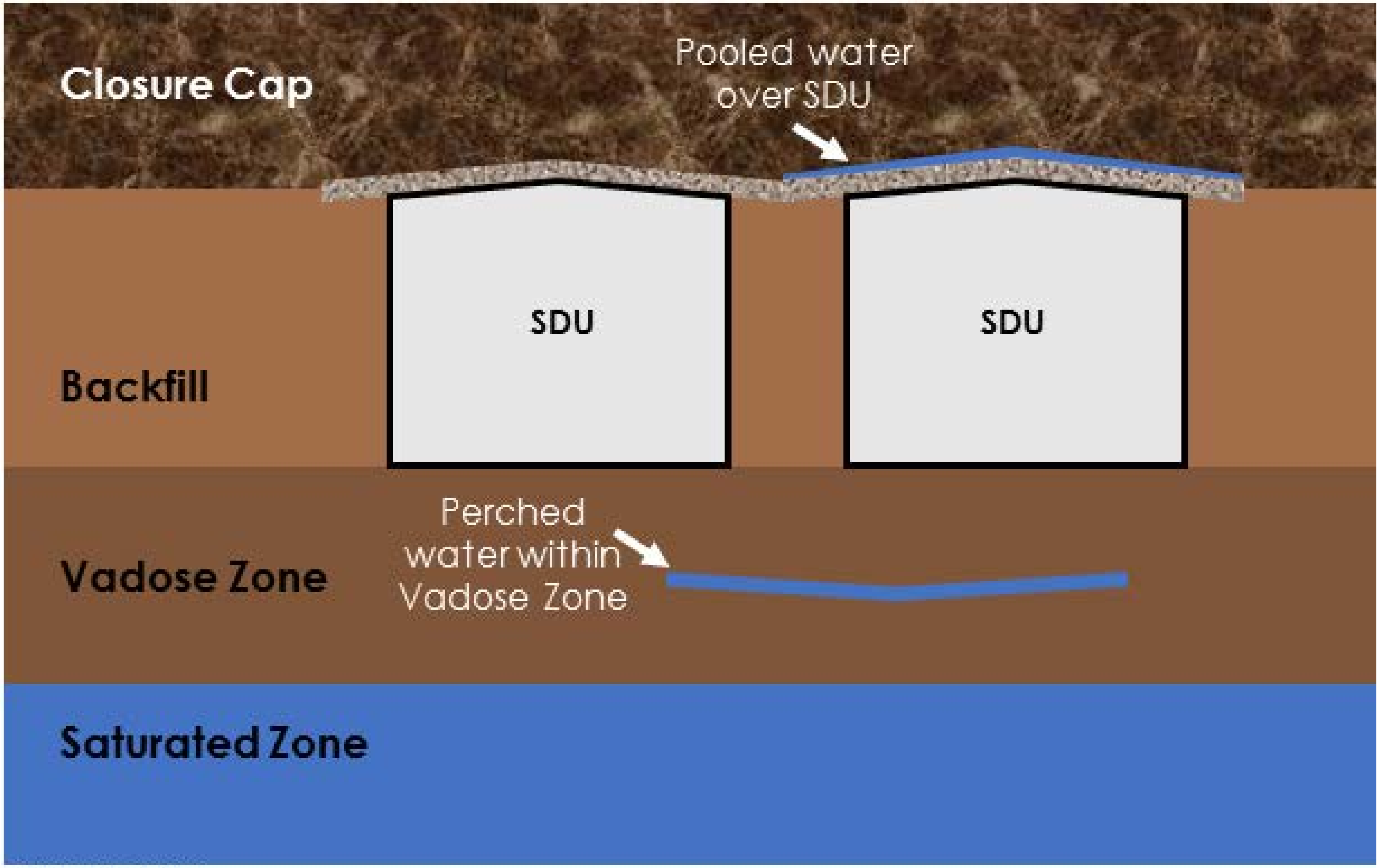
(b) No Closure Cap Scenario without Backfill



ACM Example: Stratified Saltstone

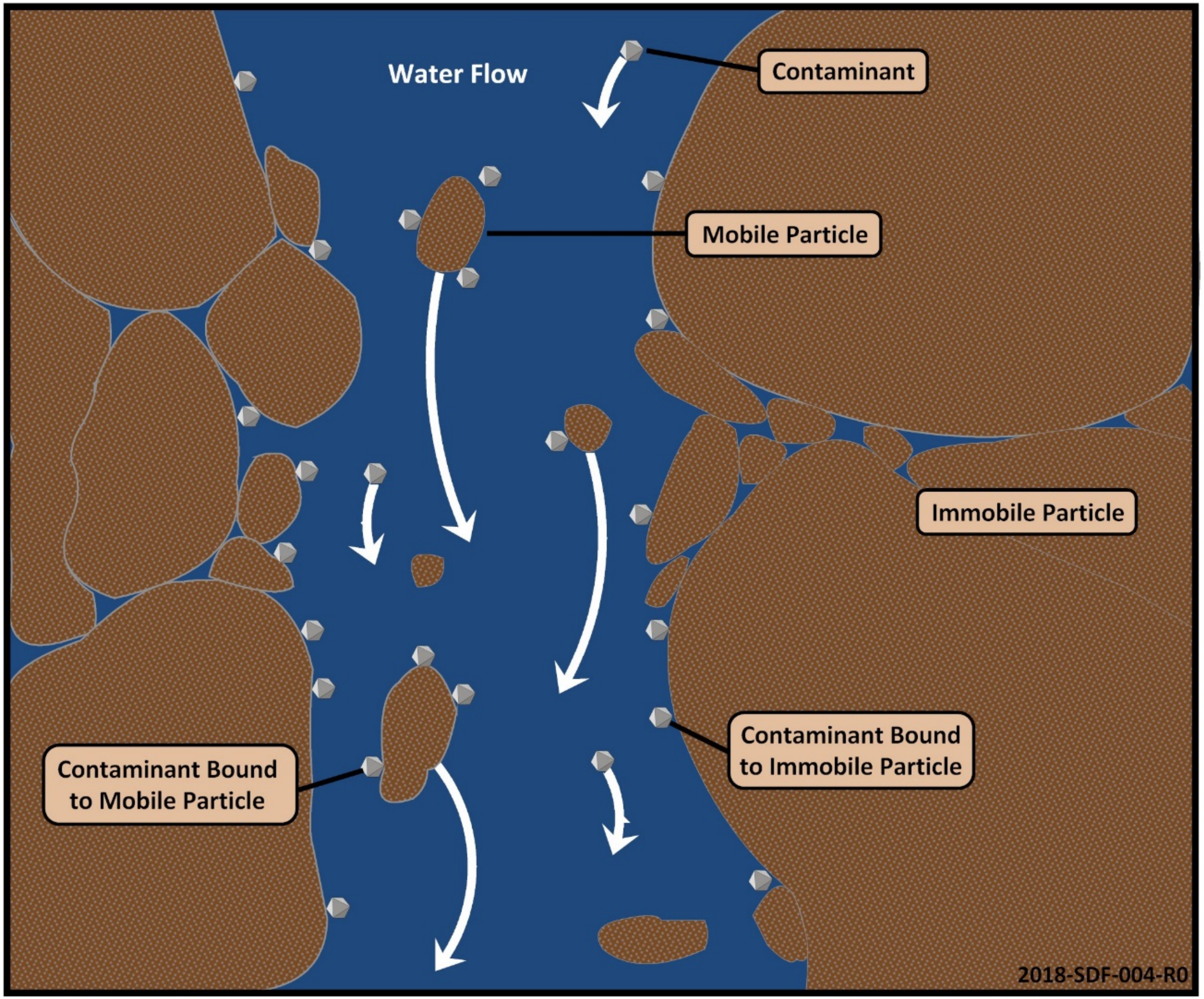


ACM Example: Perched Water



[NOT TO SCALE]

ACM Example: Colloid Transport



Remaining FEPs

- **For the 14 remaining FEPs were identified and organized into one of two groups**
  - FEPs that should be addressed through sensitivity modeling or
  - FEPs that require no further action
- **For the first group, 3 FEPs will be addressed via specific sensitivity models**
  - FEP 2.7.06: Acid Rain
  - FEP 3.2.07: Alternative Container Design and Construction
  - FEP 3.3.07: Ancillary Equipment and Piping/Transfer Lines
- **For the remaining 11 FEPs, no further action will be taken**
  - Discussion within the Conceptual Model Report provides justification

Summary

- **A systematic approach was developed and used to inform decisions related to *what* should be modeled in the SDF PA**
  - WDA prepared an initial list of FEPs
  - A team of experts screened the FEPs for the SDF PA
  - The assessment context was defined
  - The physical system was described and conceptualized
  - An Interaction Matrix was developed
    - The conceptualization of the physical system informed the selection of the LDEs
    - Interactions between each of the LDEs were identified as ODEs
  - The LDEs and ODEs were mapped to the FEPs List
  - The remaining FEPs were used to inform the development of ACMs and sensitivity models