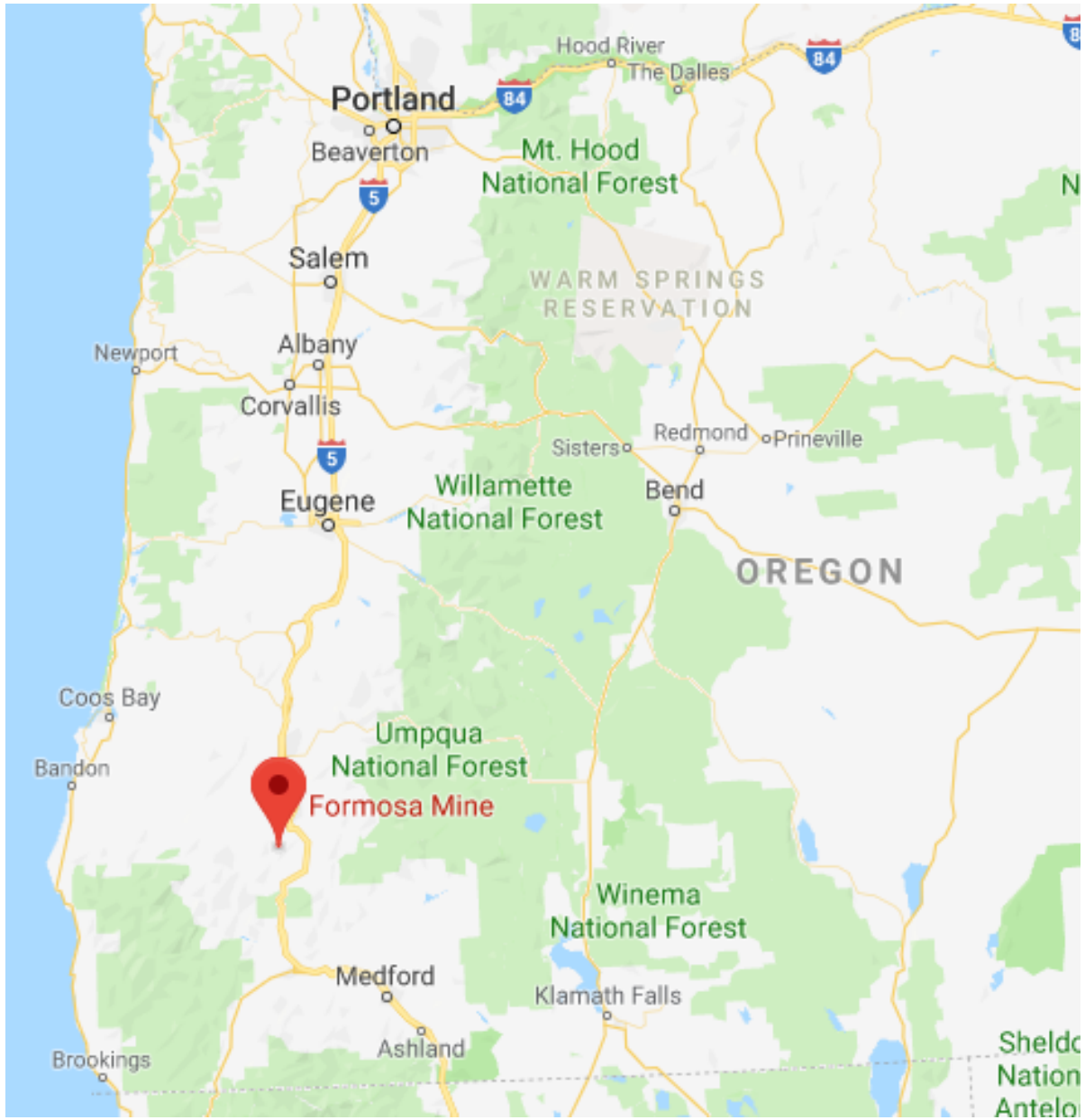
Formosa Mine Groundwater Flow in Fractured Rock



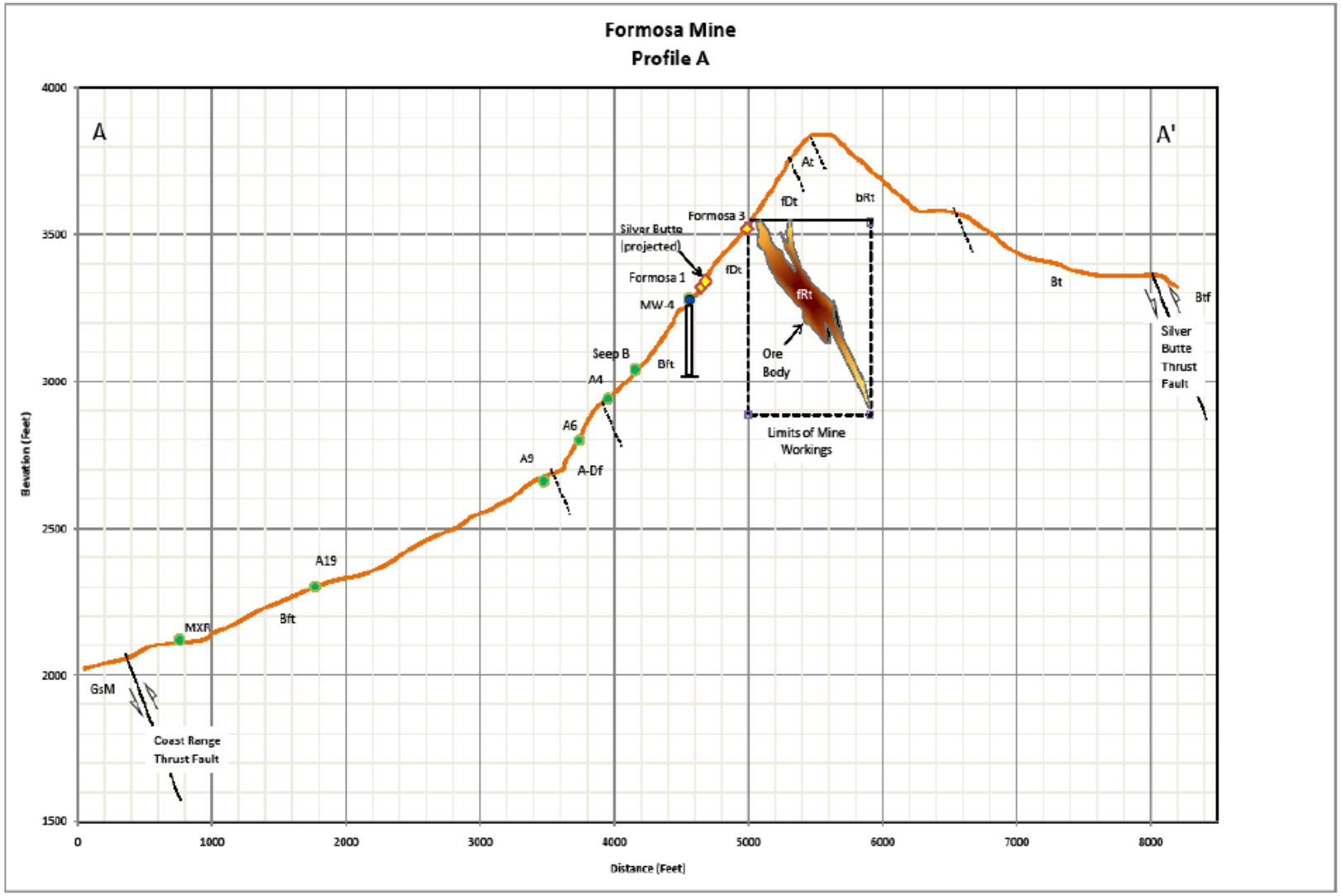
Formosa Mine Superfund Site

The 76-acre Formosa Mine site is located on Silver Butte in Douglas County, Oregon.

Streams

This abandoned mine discharges millions of gallons of acid rock drainage with elevated metals concentrations into the upper reaches of Upper Middle Creek and South Fork Middle Creek every year. These discharges have contaminated surface water and soil with heavy metals. Surface water Ambient Water Quality standards for zinc, copper and cadmium are exceeded.

Silver Butte Deposit



Geology

A massive sulfide deposit that contained valuable metals (copper, zinc, silver and gold) was mined through Adits into a Tunnel Complex. The crystalline igneous rocks have fractures, faults and shears.

Site History

Copper and silver mined from about 1910 to 1937.

Reopened in 1990. Operations ended in 1993.

Reclamation efforts by the Formosa Mine company between 1994 to 1996 reclamation efforts included:

- filling the mine adit with mill tailings, crushed ore, concentrates;
- placing tailings and low-grade ore in a lined cell and capping; and,
- Diverting adit water to a drain field.

Reclamation History

Further reclamation was conducted as a cooperative effort between DOGAMI, ODEQ, and BLM and included removal of tailings from Upper Middle Creek.

Reclamation History

Crusher was removed.

Stockpiled ore moved into the mine.

Low-grade ore was excavated and backfilled into the water and tailings storage pond.

Underlying surfaces were regraded, amended with straw and lime, and seeded

Adits were backfilled with tailings.

Adit portals were sealed with a wooden and burlap bulkhead, crushed limestone backfill, an 8-inch concrete cap, and an outer rock cover.

Adit drainpipes were then installed.

In February 1995 drainpipes were plugged by iron precipitate scale and flow eventually ceased.

Superfund Site:

Superfund Home
This Site's Home Page
Site Contacts
Cleanup Activities
Health & Environment
Redevelopment
Site Documents & Data
Photos, Videos & Audio
View Site on Map

FORMOSA MINE RIDDLE, OR

Background

The 76-acre Formosa Mine site is located on Silver Butte in Douglas County, Oregon. This abandoned mine discharges millions of gallons of acid rock drainage (ARD) and toxic metals into the upper reaches of Middle Creek and South Fork Middle Creek every year. These discharges have contaminated surface water, groundwater, soil and sediment with heavy metals. EPA is currently designing the remedy for Operable Unit 1, which addresses all mine impacted material on the surface at the Mine. OU-2 will address risks to surface and groundwater by the site. The OU 1 remedy consists of excavating or capping various areas ...

Continue reading background »

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(541) 618-2291
selee@blm.gov

Operable Unit 1 – Solid Waste

Adit Bulkhead Installation

2018/2019

2018 bulkhead installation at Formosa 1 adit

2019 Monitoring WQ post bulkhead installation

2019 Replacing mine drainage diversion system

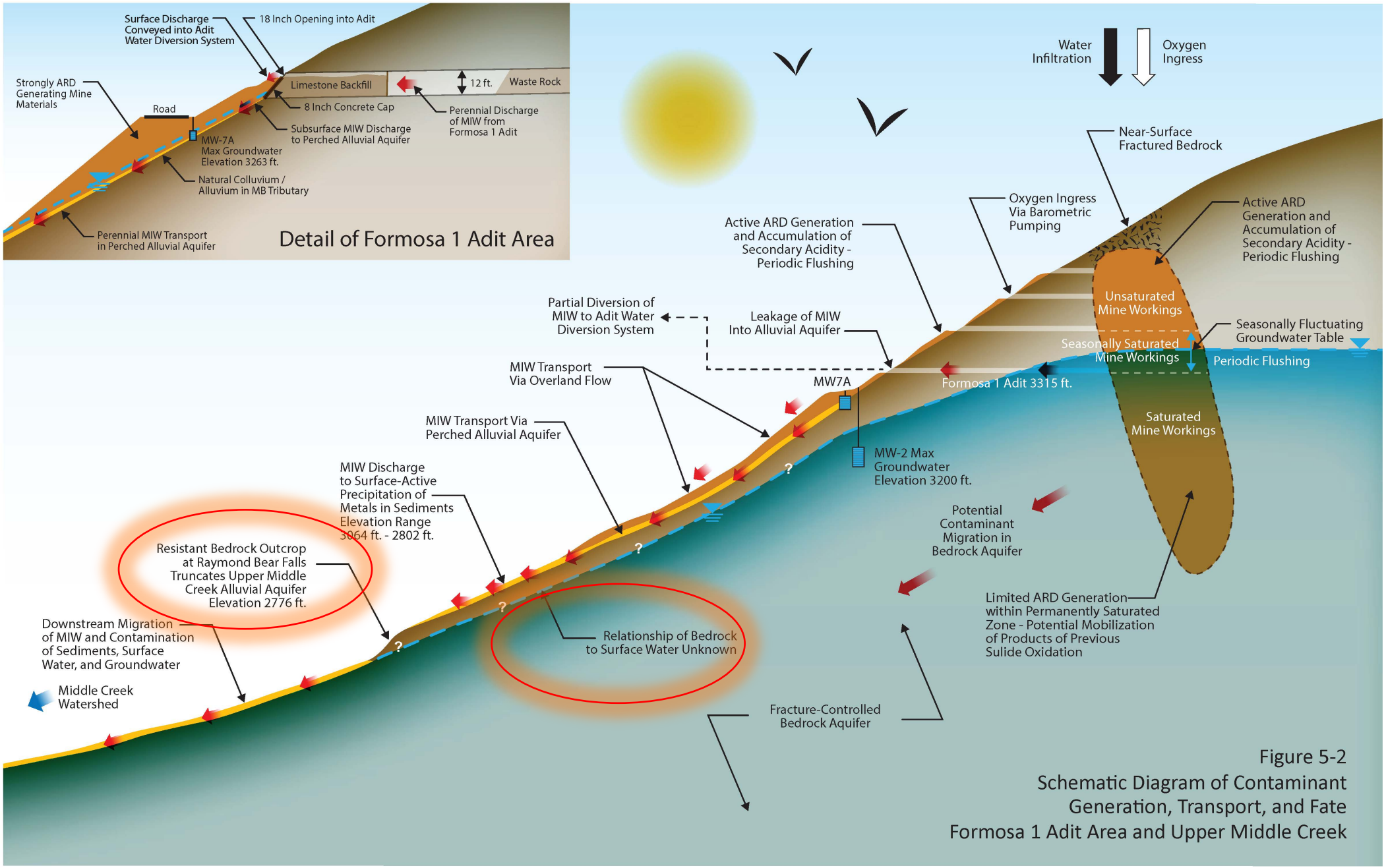
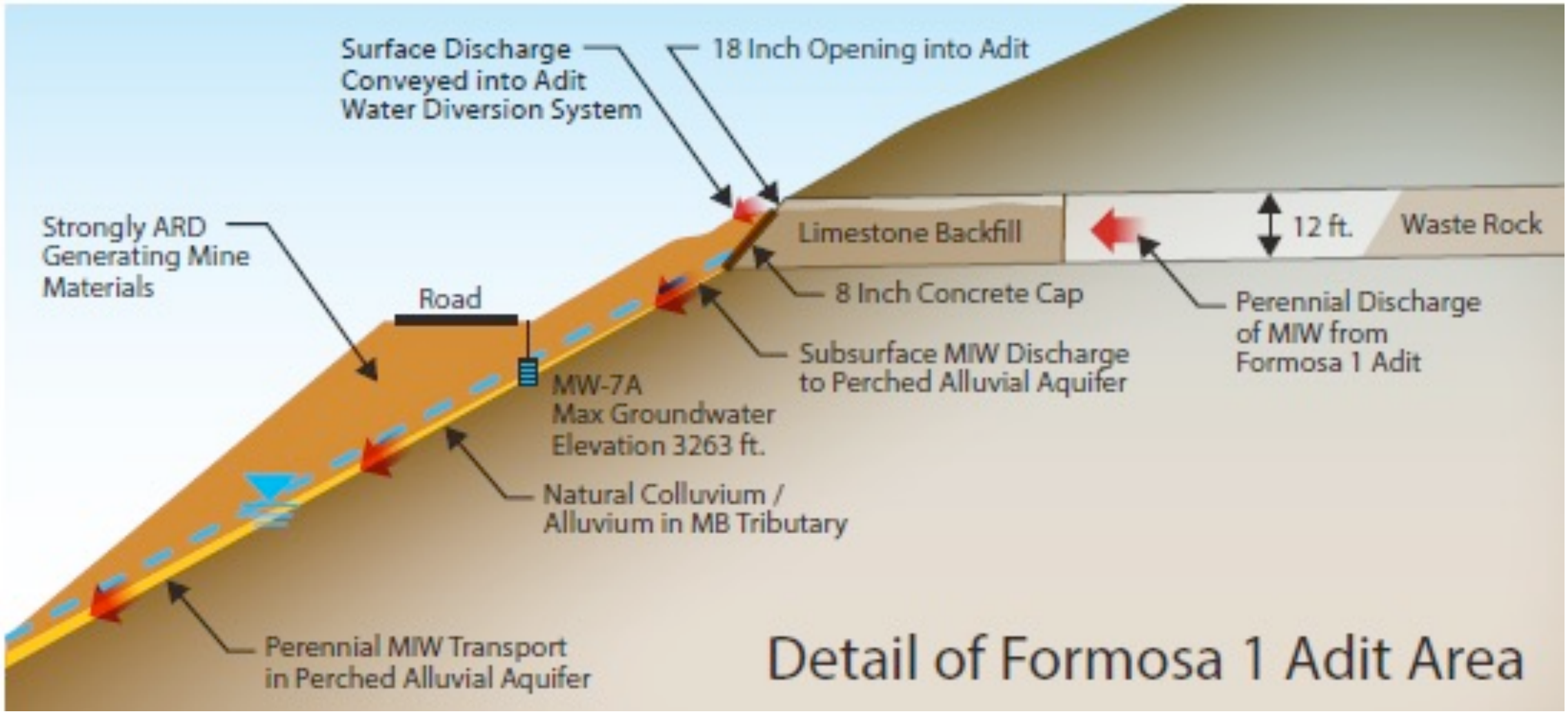


Figure 5-2
Schematic Diagram of Contaminant Generation, Transport, and Fate
Formosa 1 Adit Area and Upper Middle Creek


Surface Discharge
Conveyed into Adit
Water Diversion System
18 Inch Opening into Adit
Strongly ARD
Generating Mine
Materials
Road
Limestone Backfill
12 ft.
Waste Rock
8 Inch Concrete Cap
Perennial Discharge
of MIW from
Formosa 1 Adit
Subsurface MIW Discharge
to Perched Alluvial Aquifer
MW-7A
Max Groundwater
Elevation 3263 ft.
Natural Colluvium /
Alluvium in MB Tributary
Perennial MIW Transport
in Perched Alluvial Aquifer
Detail of Formosa 1 Adit Area

Mining Influenced Water

The underground mine workings act as a conduit system conveying groundwater from upper portions of the mine through fractures to surface seeps or to discharge points located in Upper Middle Creek.

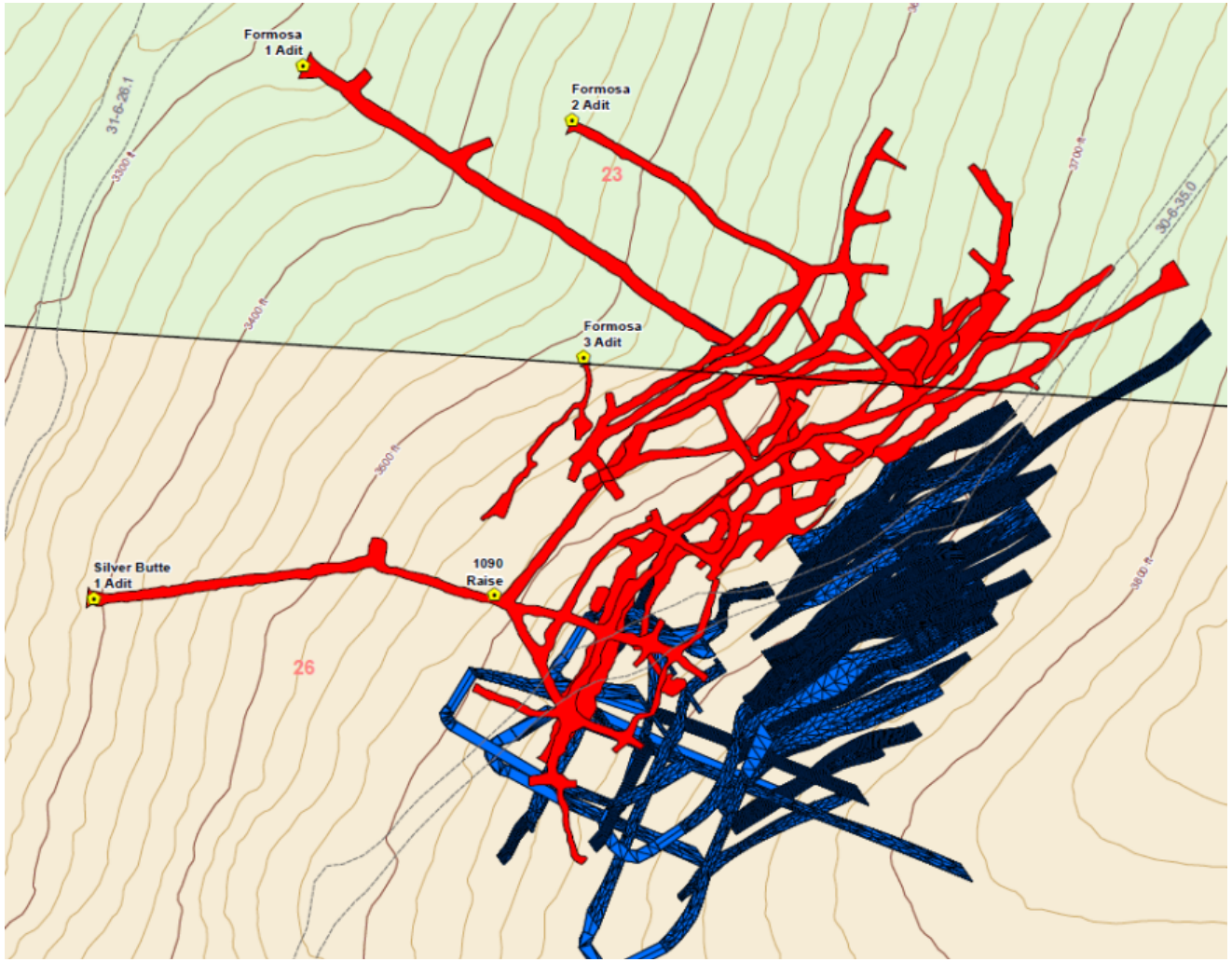
Bedrock Groundwater System

The bedrock aquifer is a source of water flowing into the underground workings where the water (mine pool water) interacts with backfilled mine materials, generates MIW, and discharges at mine adits.

The mine pool gradient, causing MIW to flow towards the Formosa 1 Adit and Upper Middle Creek, may be influenced by the orientation of a major fracture set trending west-northwest.

Mine Tunnels and Adits

The portal of the Formosa 1 Adit is the lowest point of ingress/egress for the mine. The underground workings extend downwards approximately 420 feet and upwards approximately 290 feet from the portal of the Formosa 1 Adit. Much of the underground mine is backfilled with various mine materials placed during mine restoration.



Bedrock Groundwater System

- Near the Formosa 1 Adit there is a fracture zone that has been observed conveying several gpm during the wet (Spring) season.

Bedrock Groundwater System

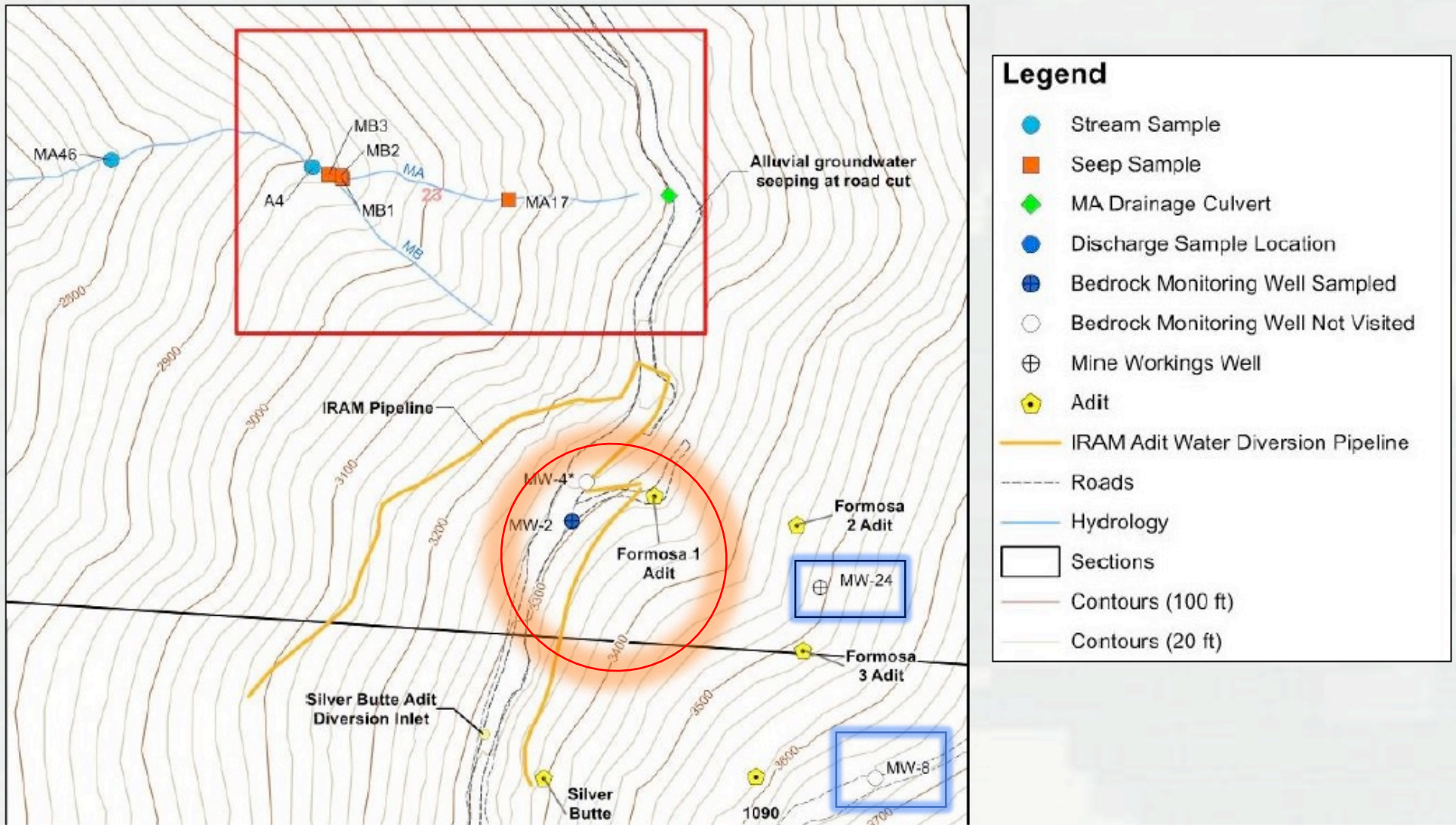
- Three dominant fracture trends denoted S1, S2, and S3:
- S1 strikes north-south and dips 69 degrees towards the east.
- S2 strikes towards the west-northwest and dips 63 degrees towards the northeast.
- S3 strikes north-northeast and dips 76 degrees towards the southeast.

Figure 3-17
Statistical Analysis of Fracture Orientations in Formosa 1 Adit Area

Bedrock Groundwater System

- The S2 fracture trend is of particular interest because contaminant transport along the west northwest trend could convey MIW from mine pool towards Upper Middle Creek.

Monitoring Locations

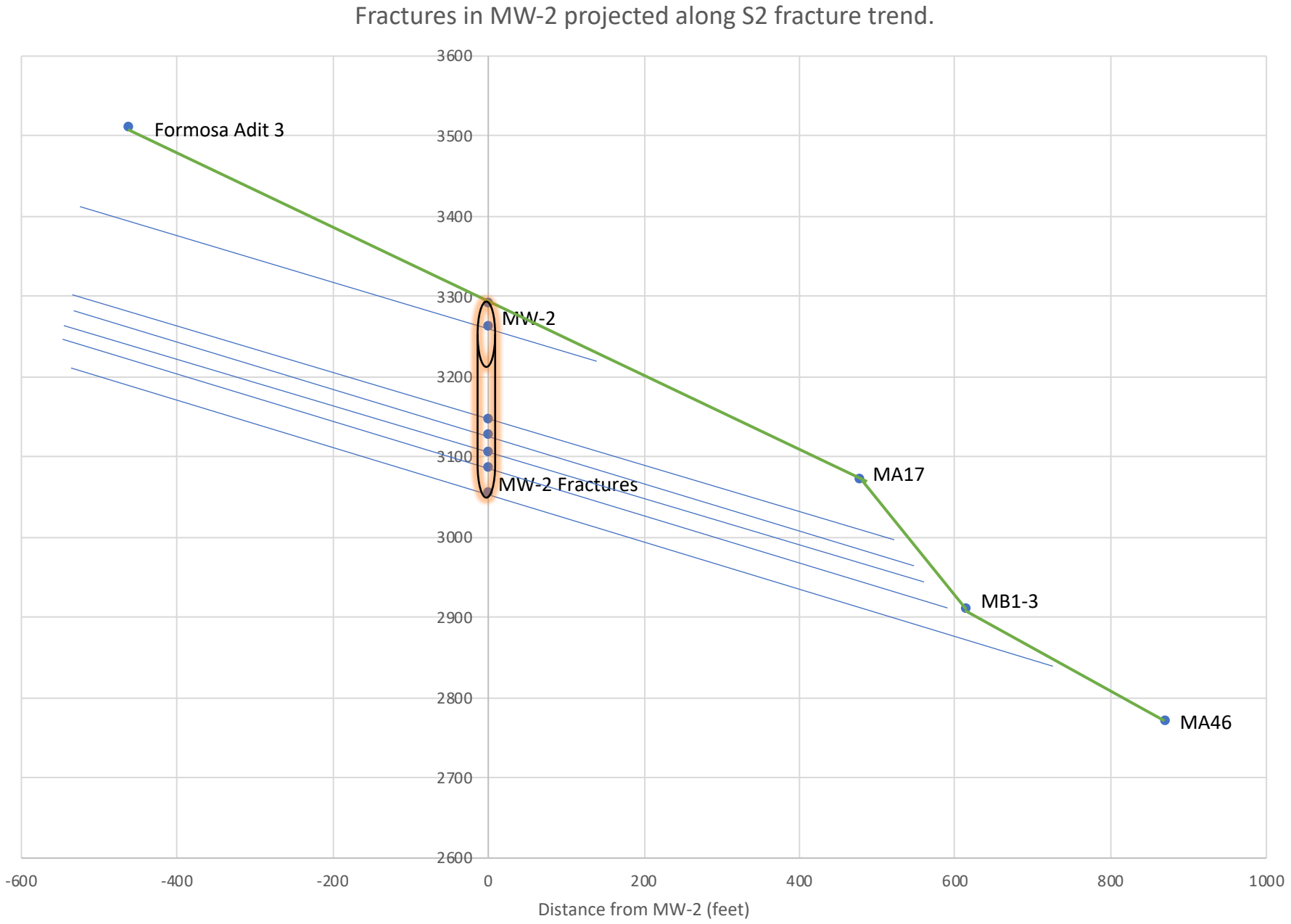


MW-2

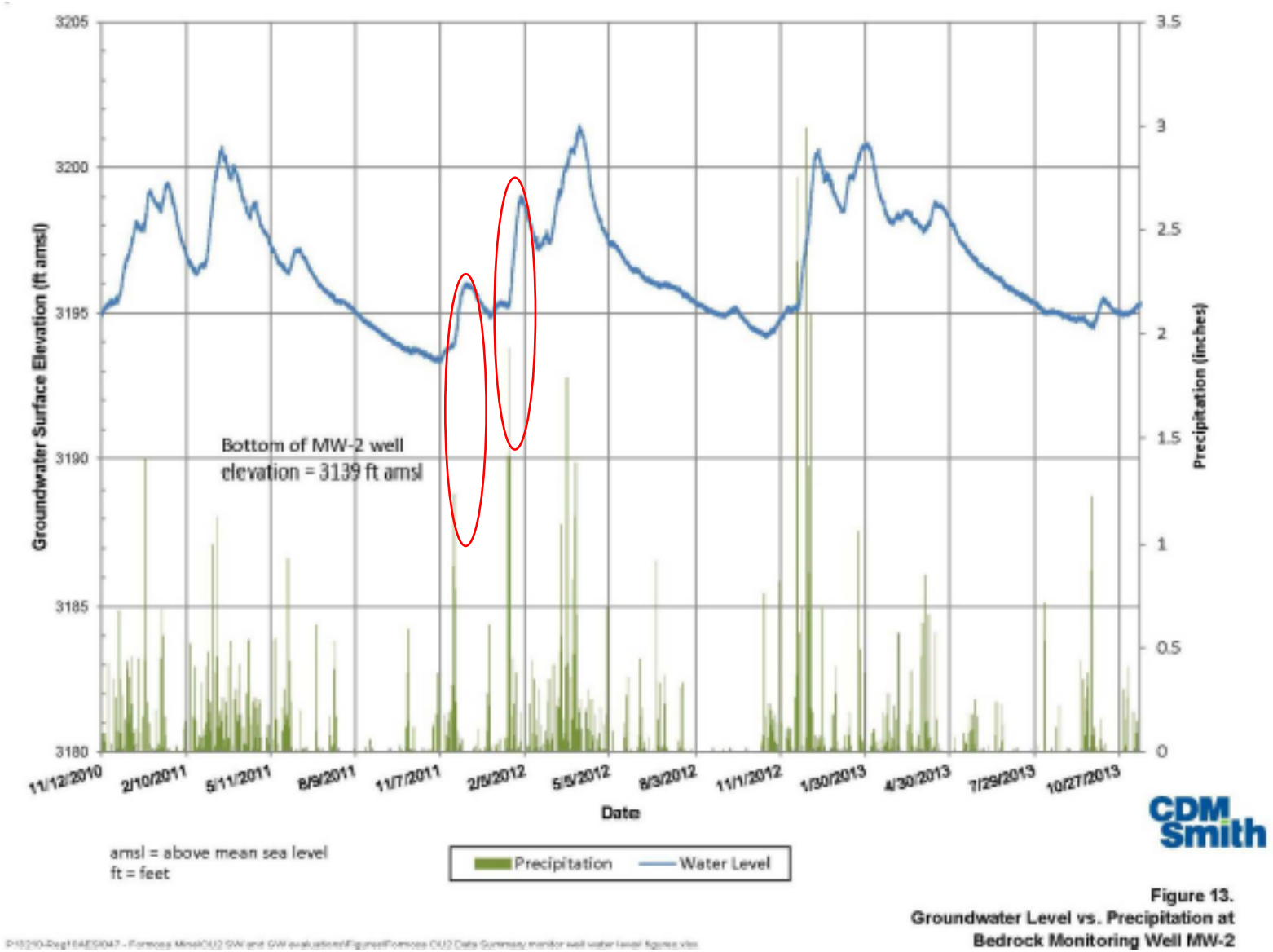
Depth (ft)	Lithology	Notes
0	Tan very fine grained Basalt. Inclusion of chlorite	
10		Competent Bedrock
20		
30	Green and tan fine grained basalt. Inclusion of quartz and chlorite	Intensely Fractured
40		Competent Bedrock
50	Tan very tine grained Basalt with chlorite inclusion with orange and brown staining at 55 fbg.	Fracture zone starting at 48 fbg. Water at 50 fbg
60		Competent Bedrock
70		Fracture zone starting at 71 fbg; producing lots of water at 75 fbg.
80		Competent Bedrock
90		Large fracture zone; possible fault; producing water (3200 ft amsl).
100	Green and tan fine grained basalt. Inclusion of quartz and chlorite	Competent Bedrock
110		Fracture zone between 113 and 115 fbg; 1 gpm flow (3175 ft amsl).
120		Some calcite infilling in fractures.
130		Competent Bedrock at 135 fbg
140	same, some inclusions of pyrite/chalcopyrite	Fracture zone at 145 fbg (3145 ft amsl).
150	BOH at 149.6 fbg	Static water level at completion 70 fbg.

fbg - feet below grade

BOH - bottom of open hole


Fractures in MW-2 projected along S2 fracture trend.
3600
3500
3400
3300
3200
3100
3000
2900
2800
2700
2600
-600
-400
-200
0
200
400
600
800
1000
Distance from MW-2 (feet)
Formosa Adit 3
MW-2
MW-2 Fractures
MA17
MB1-3
MA46

Fractured Bedrock Well Response to Precipitation Events



CDM Smith

Figure 13.
Groundwater Level vs. Precipitation at Bedrock Monitoring Well MW-2

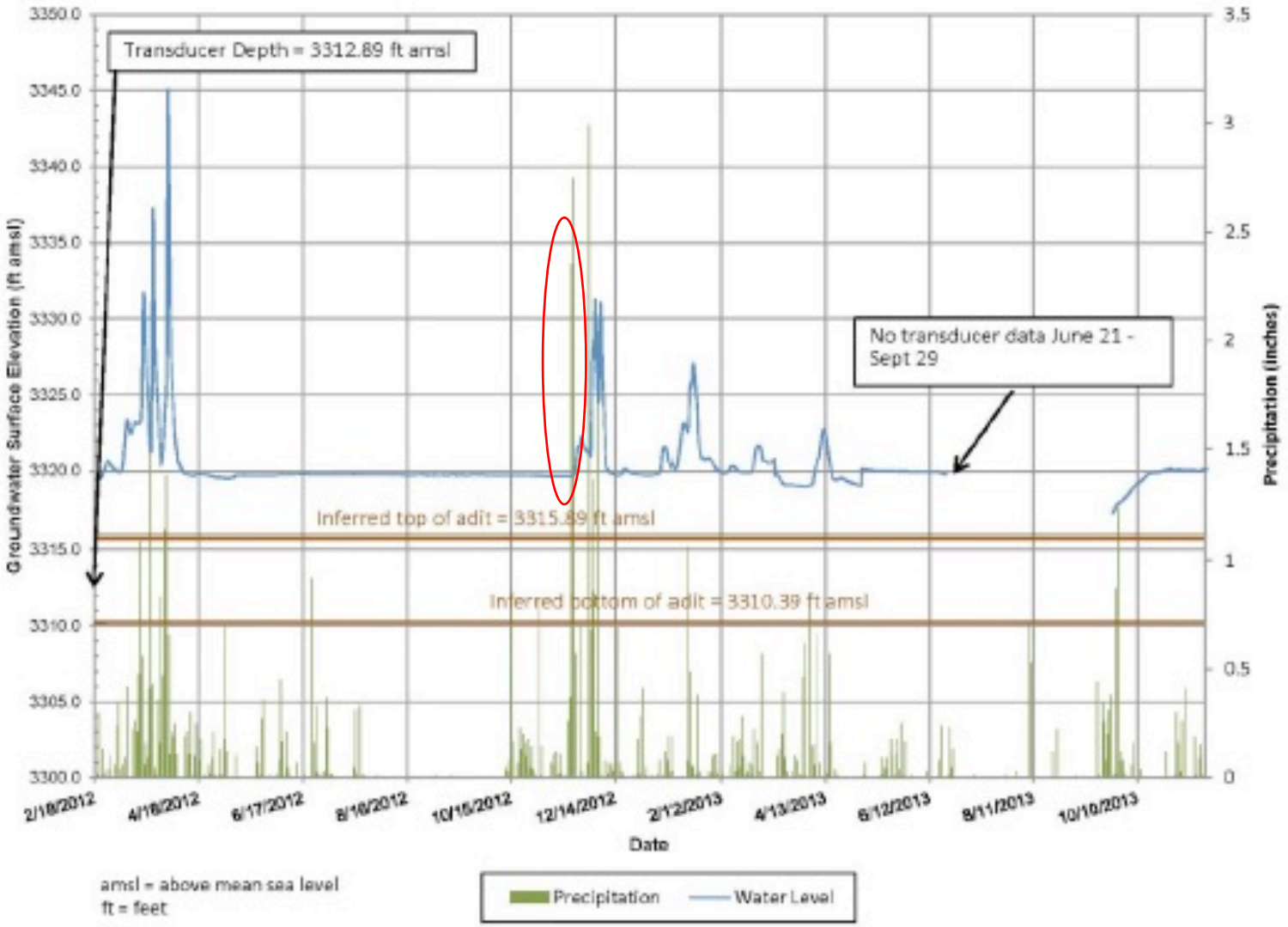


Figure 12.
Groundwater Level vs. Precipitation at Bedrock Monitoring Well MW-24

MW-24 screened behind bulkhead in Formosa Adit 1

MW-8 screened in fractured bedrock.

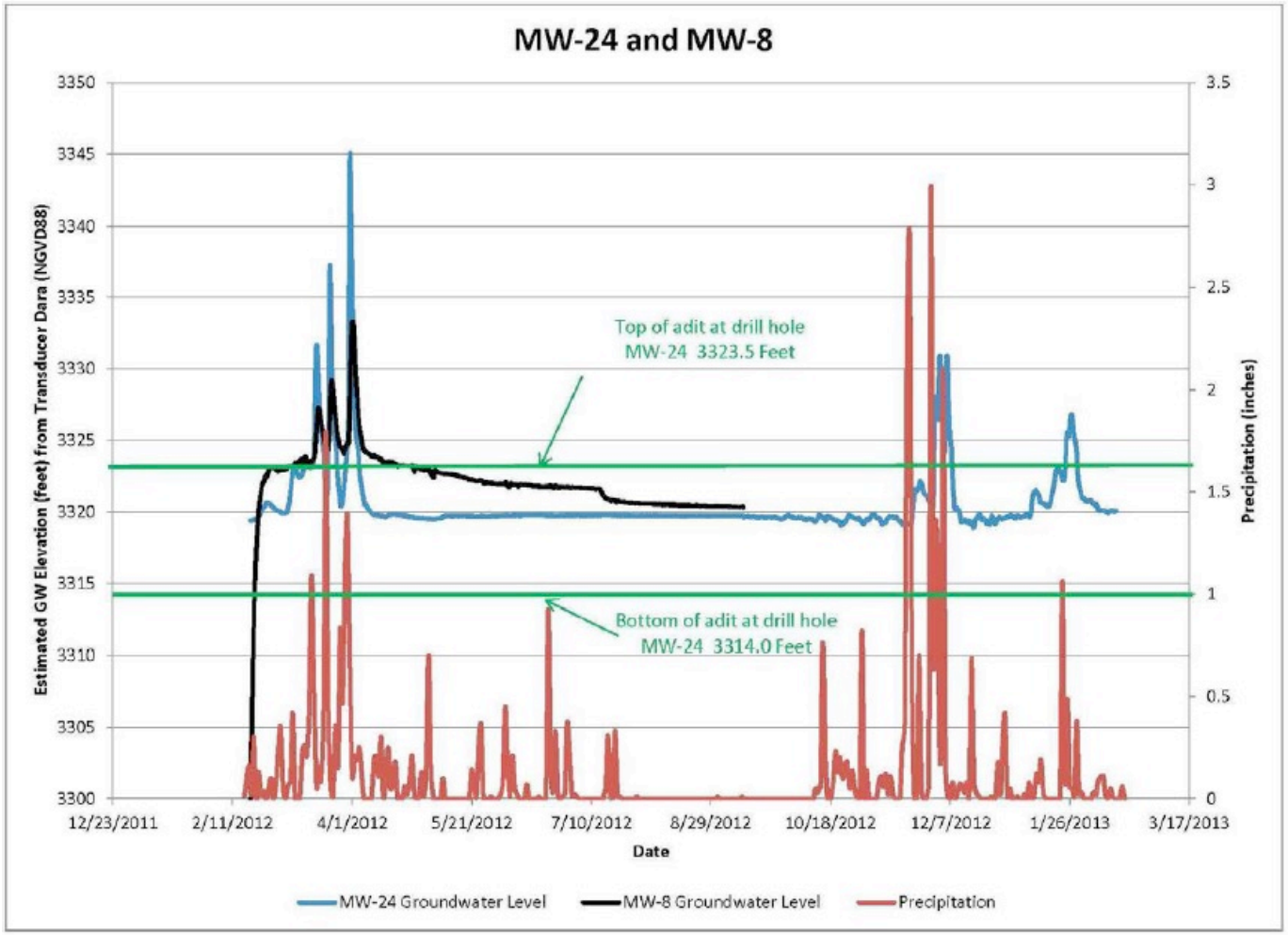
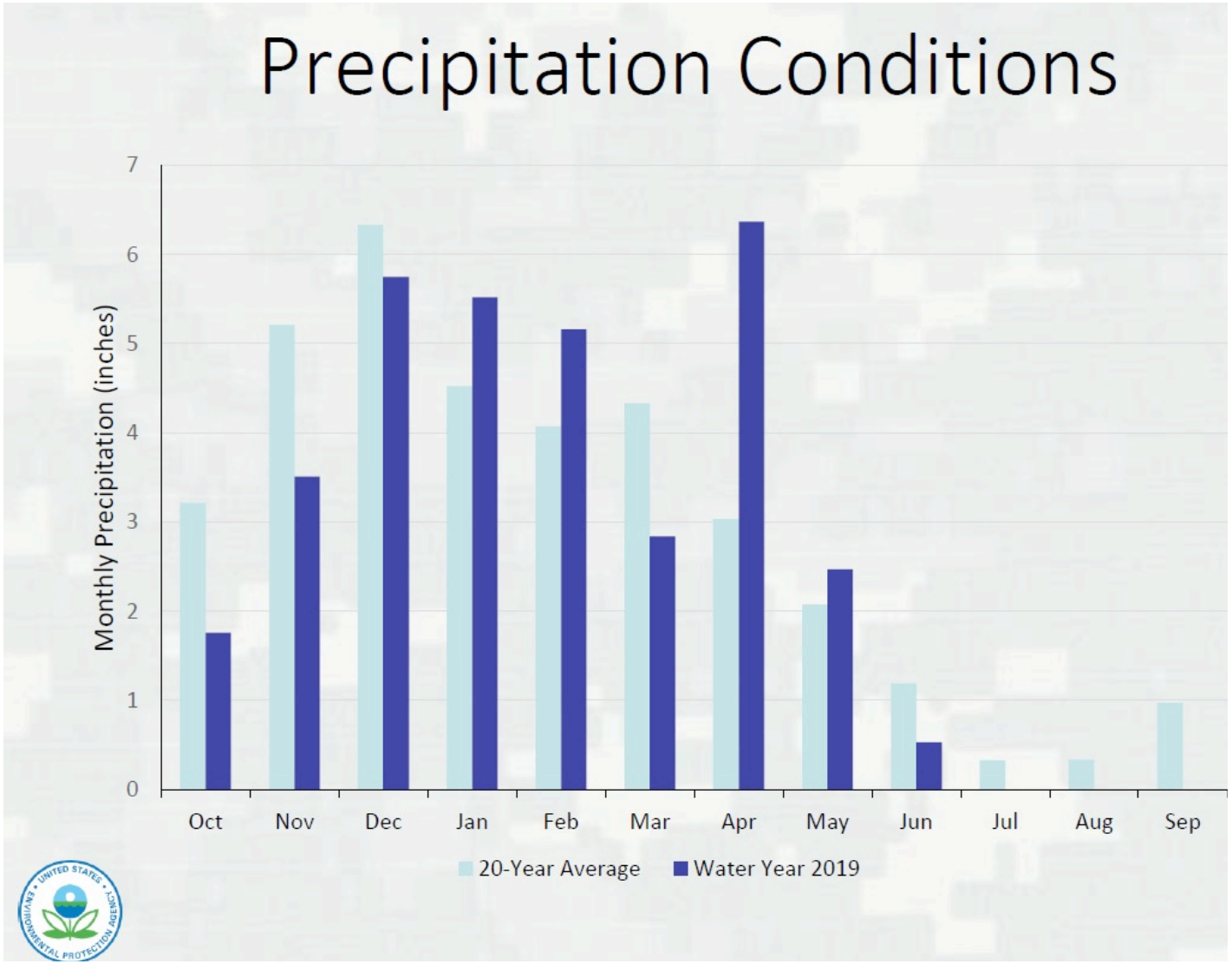
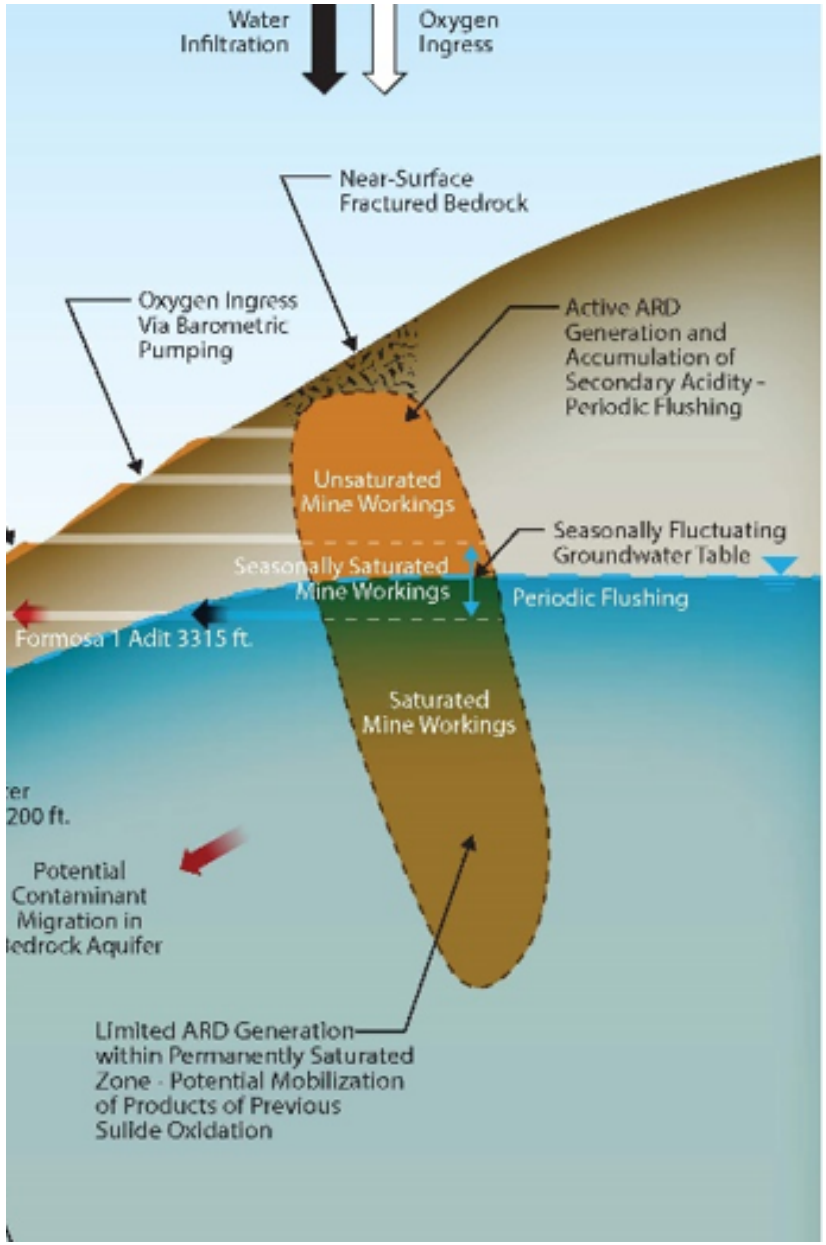


Figure 25. Graph of Monitor Well Transducer and Precipitation Data

April 3, 2019 Site Visit

Precipitation Conditions





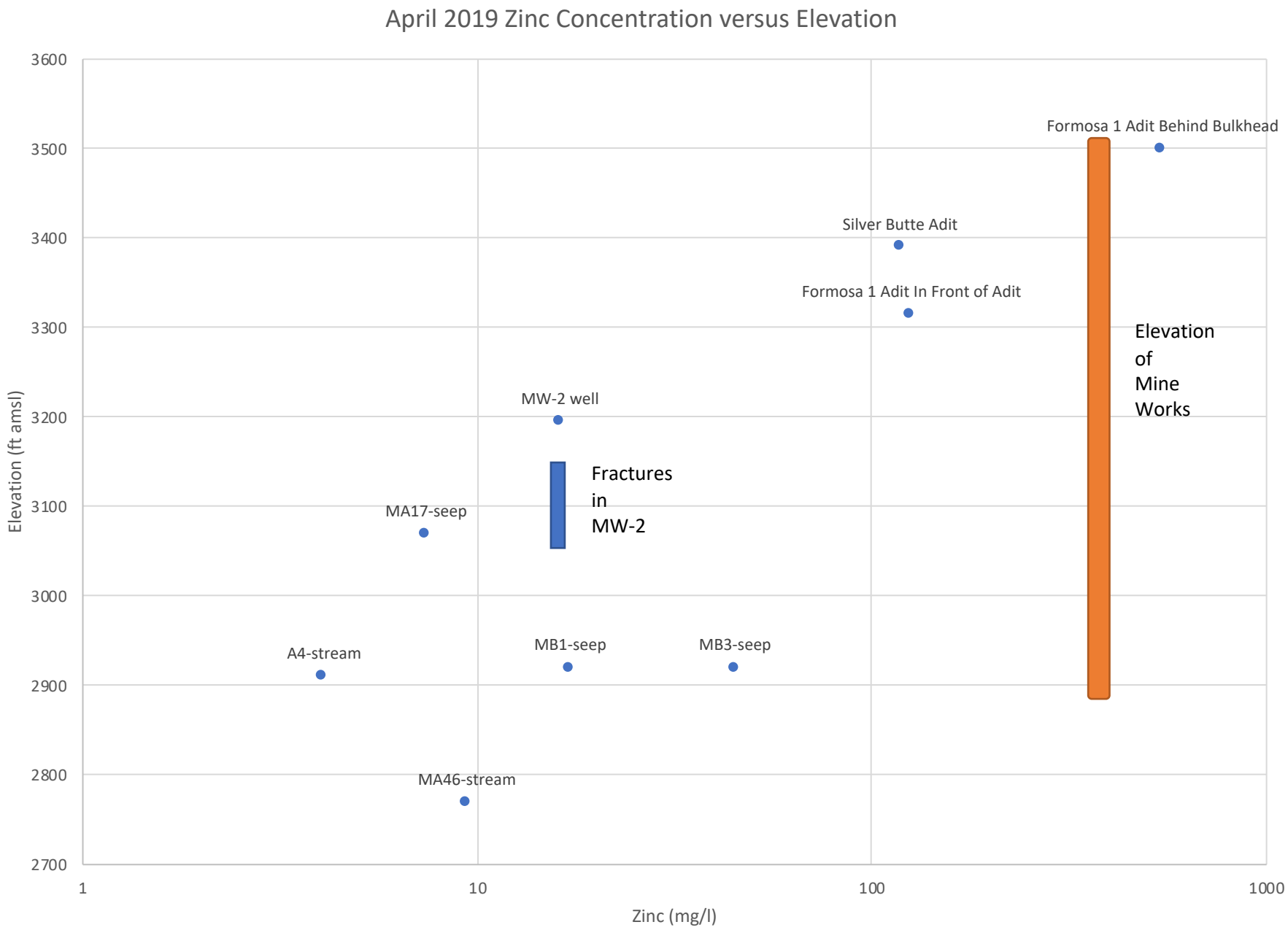
April 2019 Water Sampling Results

		Formosa 1 Adit Behind Bulkhead	MW-2 Brx Well	MA17 Seep Sample	MB1 Seep Sample	MB3 Seep Sample	A4 Stream Sample	MA46 Stream Sample
April 2019 Cadmium	µg/l	948	46	23	55	121	13	31
Historic Cadmium Average	µg/l	263	1	23	9	NA	46	48
Historic Cadmium Maximum	µg/l	666	4	29	12	157	63	78
April 2019 Copper	µg/l	46,300	1,900	3,020	4,830	11,400	865	2,660
Historic Copper Average	µg/l	15,142	29	2,580	615	NA	3,697	4,900
Historic Copper Maximum	µg/l	42,800	64	3,990	1,020	16,600	5,420	7,710
April 2019 Iron	µg/l	1,590,000	9,300	<100	971	3,610	<100	314
Historic Iron Average	µg/l	166,800	127	20	1,171	NA	1,425	1,216
Historic Iron Maximum	µg/l	265,000	239	23	2,310	14,100	2,540	2,620
April 2019 Manganese	µg/l	7,050	1,690	598	2,060	5,740	425	1,310
Historic Manganese Average	µg/l	2,107	171	522	51	NA	1,180	1,171
Historic Manganese Maximum	µg/l	2,310	1,120	886	82	2,450	816	1,740
April 2019 Zinc	µg/l	546,000	16,200	7,420	17,200	45,000	4,090	9,410
Historic Zinc Average	µg/l	80,884	142	6,650	2,155	NA	10,703	13,000
Historic Zinc Maximum	µg/l	146,000	832	10,100	3,030	29,400	14,400	22,000

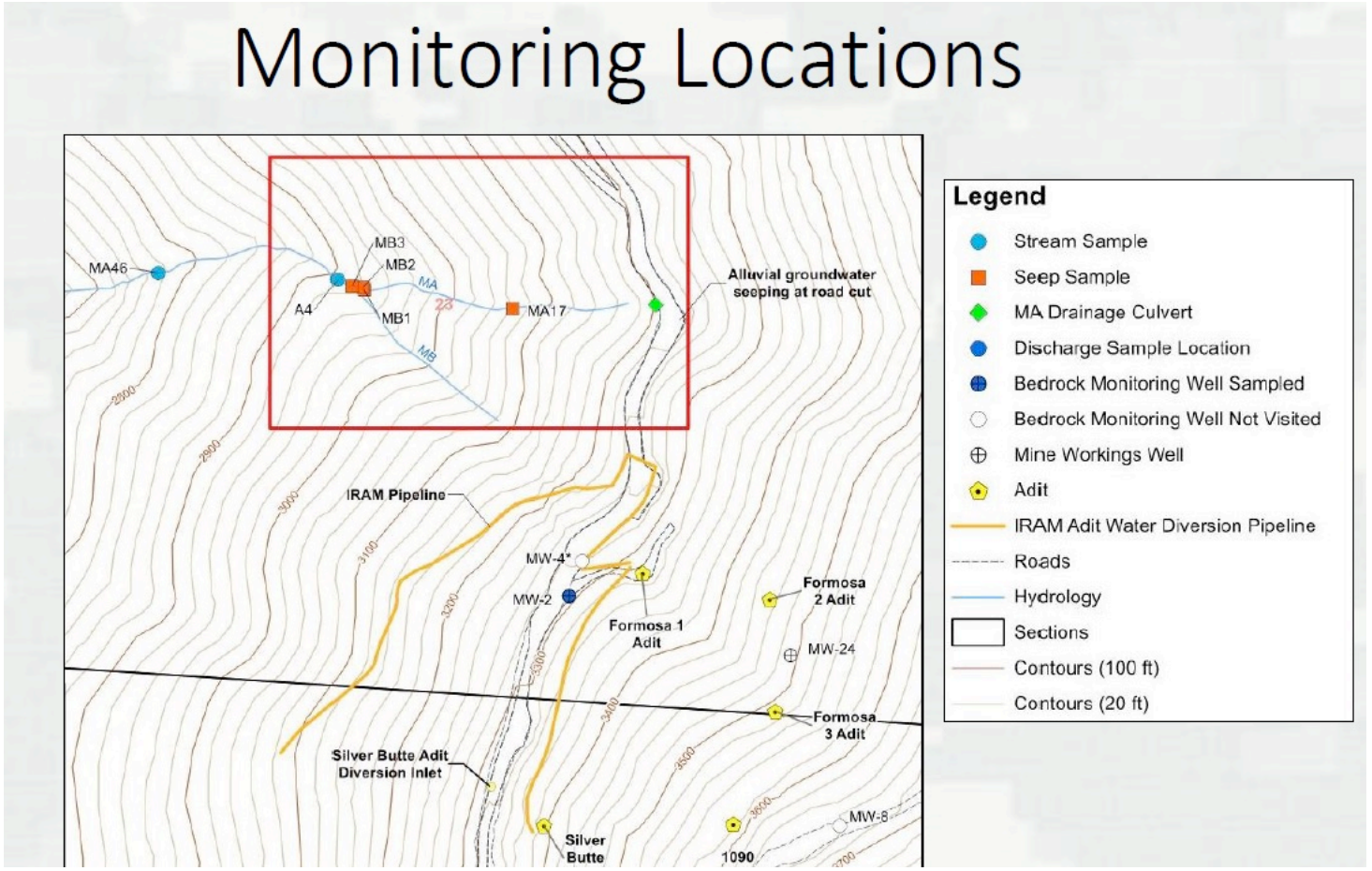
- April 2019 concentration greater than historical range by less than an order of magnitude
- April 2019 concentration greater than historical range by more than an order of magnitude
- April 2019 concentration less than historical range.

NA - only one previous sample result for MB3 was available so average is not calculated.

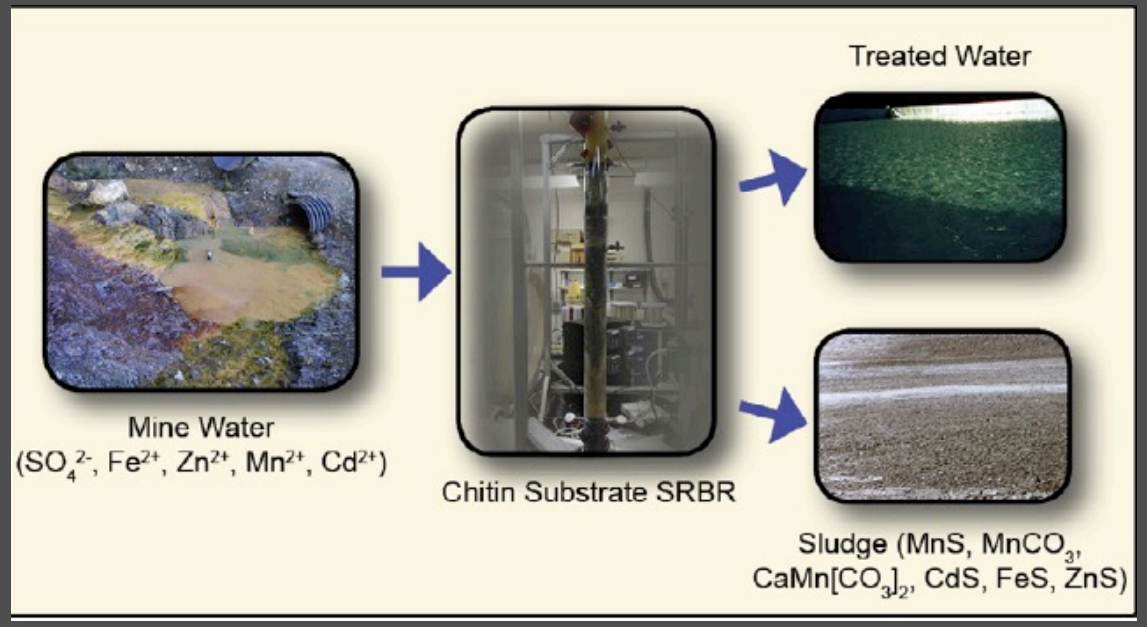
µg/l - micrograms per liter

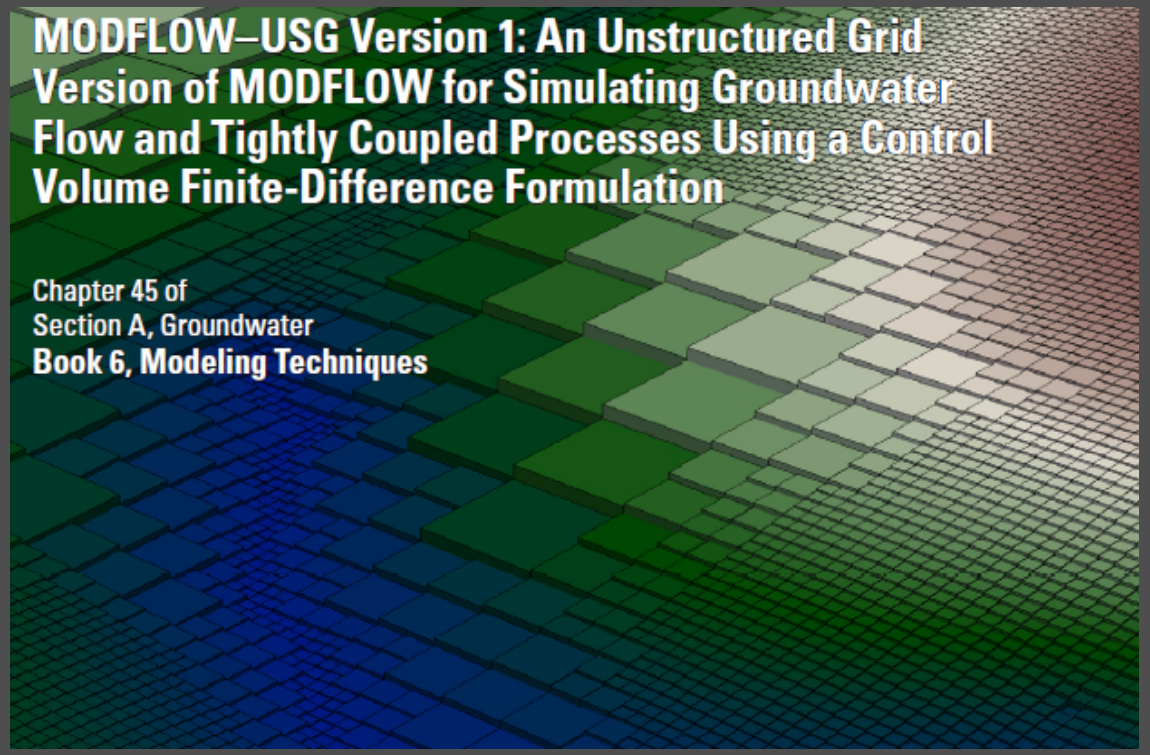

April 2019 Zinc Concentration versus Elevation
Elevation (ft amsl)
3600
3500
3400
3300
3200
3100
3000
2900
2800
2700
1
10
100
1000
Zinc (mg/l)
Formosa 1 Adit Behind Bulkhead
Silver Butte Adit
Formosa 1 Adit In Front of Adit
Elevation of Mine Works
MW-2 well
Fractures in MW-2
MA17-seep
A4-stream
MB1-seep
MB3-seep
MA46-stream

September 2019 Water Sampling Results




Formosa 1 Adit


Treated Water
Mine Water
(SO_4^{2-}, Fe^{2+}, Zn^{2+}, Mn^{2+}, Cd^{2+})
Chitin Substrate SRBR
Sludge (MnS, $MnCO_3$, $CaMn[CO_3]_2$, CdS, FeS, ZnS)



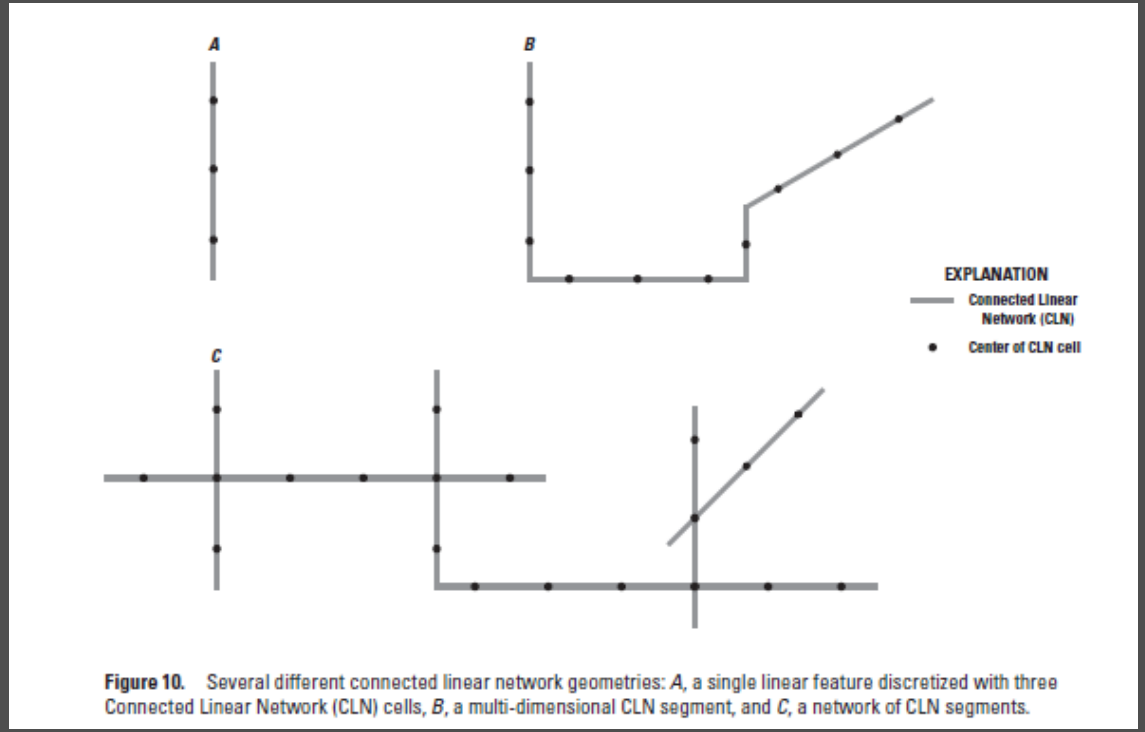


Figure 10. Several different connected linear network geometries: *A*, a single linear feature discretized with three Connected Linear Network (CLN) cells, *B*, a multi-dimensional CLN segment, and *C*, a network of CLN segments.

Questions?

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Image from

Description	Homestead coho salmon
Date	12 July 2014, 10:12
Source	Homestead coho salmon
Author	Oregon Department of Forestry