Appendix 4-MM

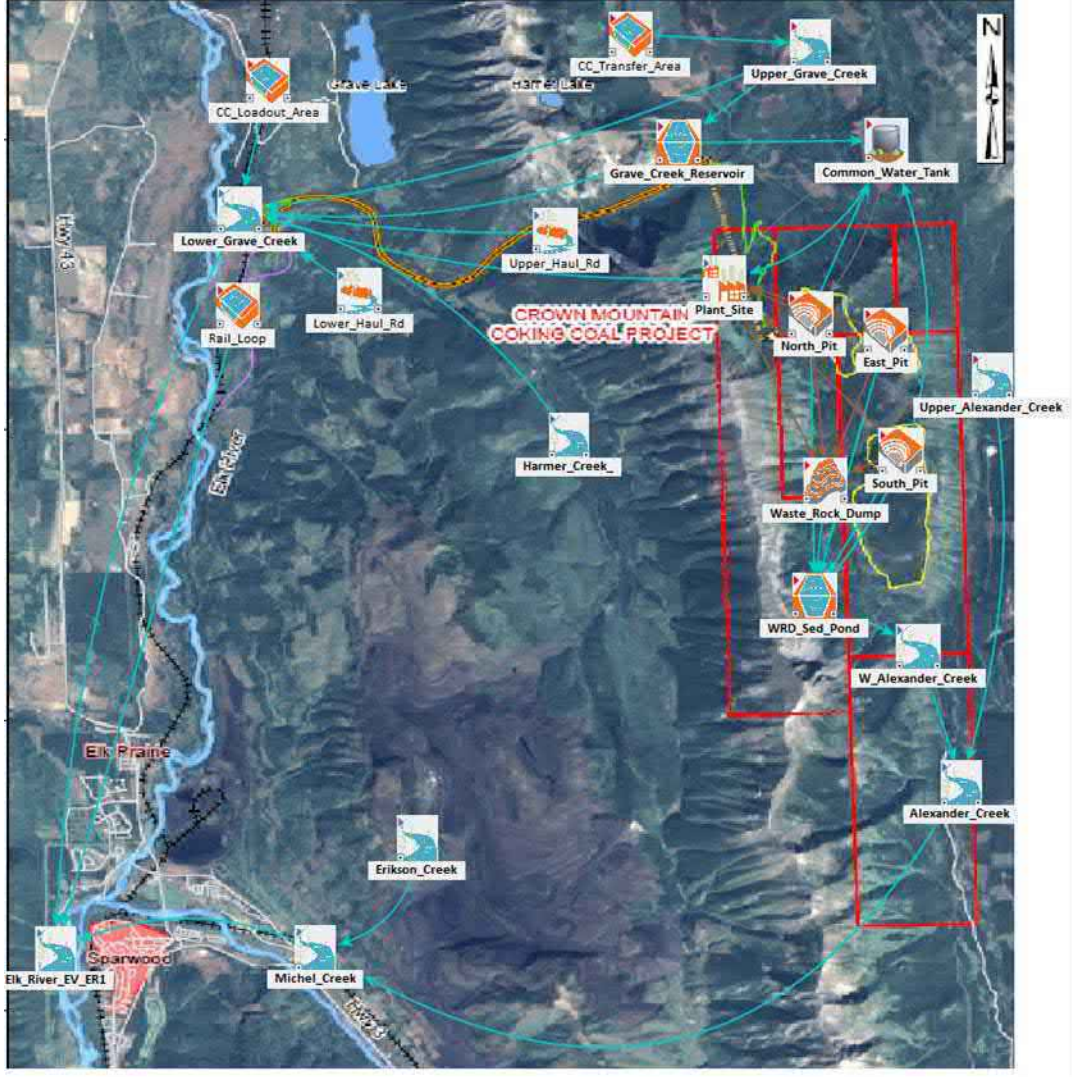
Water Quality Modelling Meeting - June 2020

Crown Mountain

Water Quality Working Group Meeting

June 29, 2020

By Google Meet Videoconference



Outline

Agenda

- Opening Remarks and Introductions
- Presentation
  - Crown Mountain Geochemistry Update
    - Summary of water quality analysis and results for the project: Stephen *Day, SRK*
  - Spoil Pile Design and Modelling of the Layered Approach
    - Purpose and Goals of the Layered Approach: *Mike Allen, NWP*
    - Design approach, material properties, and materials balance : *Mike Allen, NWP*
    - Conceptual Model: *Stephen Day, SRK*
    - Hydrology and Hydraulics of the Layered Approach: *Brent Thiele, SRK*
    - Source Terms, development of P_{50}/P_{95}, Fail/Succeed scenarios: Stephen *Day, SRK*
    - Selection of Reporting Nodes and Results: *Dave Hoekstra, SRK*
  - Water Quality Results: *Dave Hoekstra, SRK*
- Questions and Group Discussion
- Follow-up Action Items
- Closing

Project Team

SRK

Steve Day – Geochemistry

Dan Mackie – Ground Water

Dave Hoekstra – Surface Water Modelling

Brent Thiele – Water/Load Balance Modelling

Michel Noel – Unsaturated Flow Modelling

Dillon / Nupqu – Baseline Data Collection

Stantec

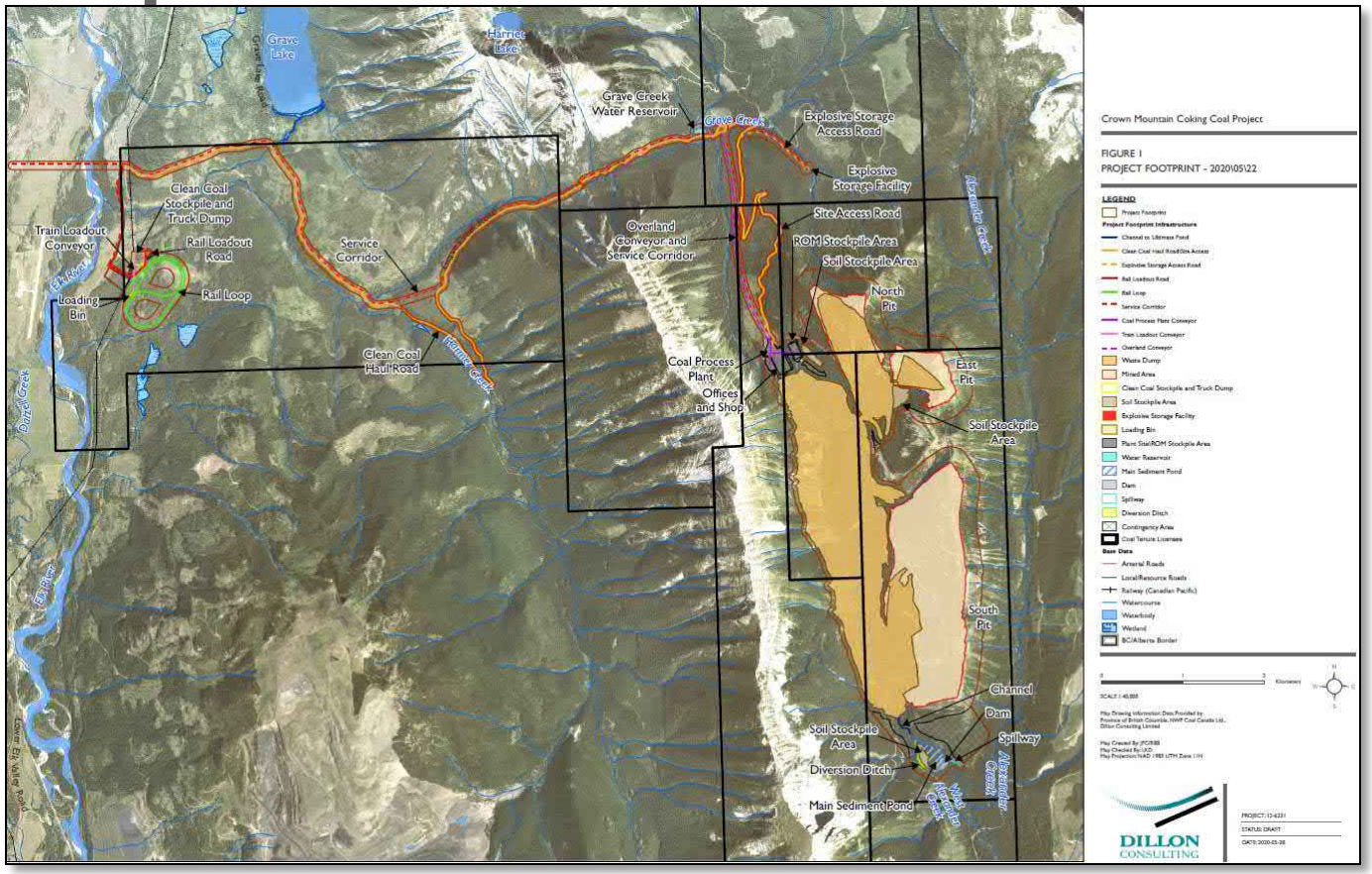
Sean Ennis - Mine Plan / Geotech / Water Management

Project Description

Key project components include:

- Surface extraction areas (three pits - north pit, east pit, and south pit)
- Mine rock management areas
- Plant area (includes raw coal stockpile, processing plant, site support facilities)
- Clean coal transportation route (overland conveyor and haul road)
- Rail load out facility and rail siding
- Power and natural gas supply
- Explosives and fuel storage
- Sewage treatment
- Water supply

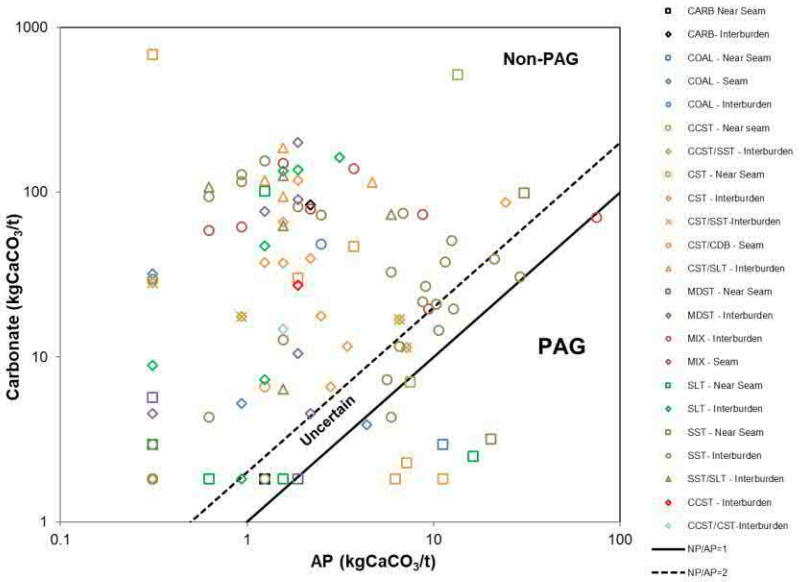
Project Footprint



Crown Mountain Geochemistry Update

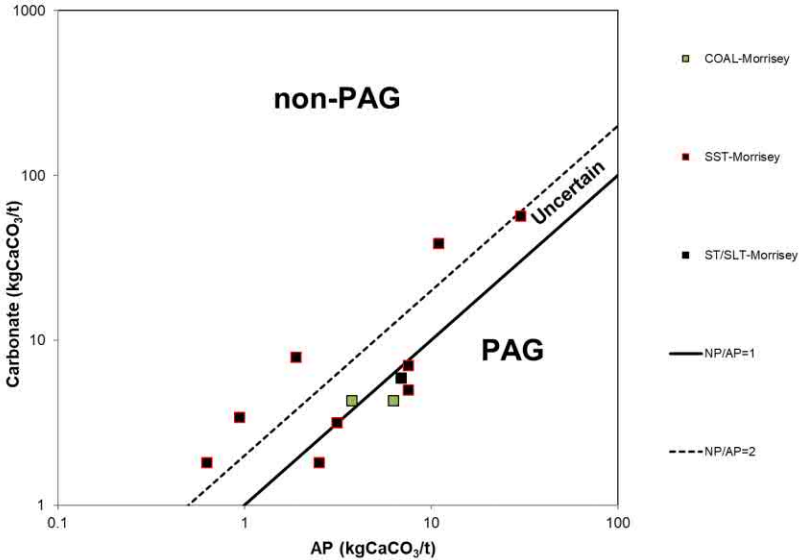
Stephen Day, SRK

Geochemical Characterization - Results



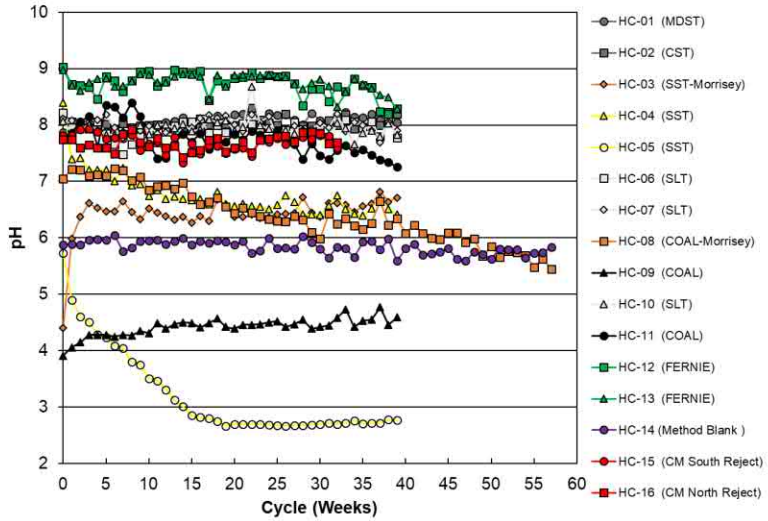
- Mist Mountain Formation is similar to elsewhere in the Elk Valley
  - Dominant formation is bulk of waste rock.
  - Mostly non-PAG except locally very near seams.
  - Selenium concentrations less than 5 mg/kg (one exception).

Geochemical Characterization - Results

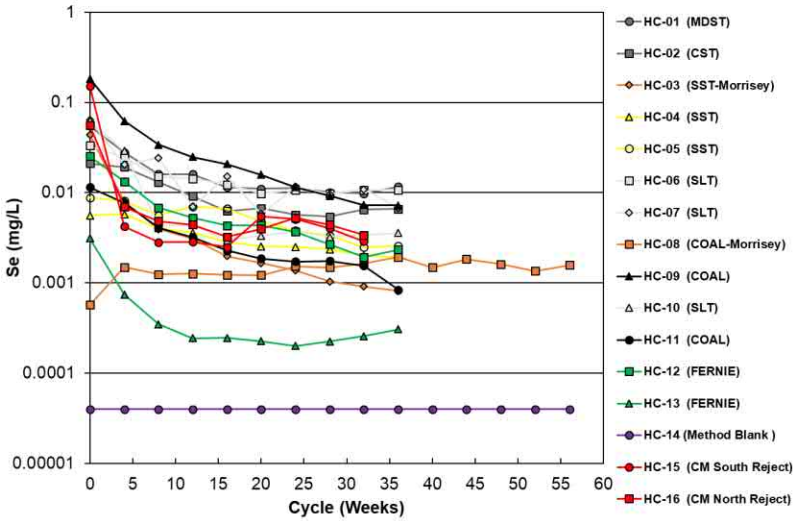


- Morrissey Formation
  - Footwall of MMF mined locally at Crown Mountain for pit wall stability
  - Non-PAG to weakly PAG.

Humidity Cells



P:\01_SITES\Crown Mountain\1CN028.003_Geochemistry\300_Laboratory_Kinetic_Testing\Calculations+Charts\[Crown_Mt_ HCT_WR_conc charts_1CN028.003_rtc_rev01.xlsx



P:\01_SITES\Crown Mountain\1CN028.003_Geochemistry\300_Laboratory_Kinetic_Testing\Calculations+Charts\[Crown_Mt_ HCT_WR_conc charts_1CN028.003_rtc_rev01.xlsx

Current Observations

- Geochemical characteristics are very similar to elsewhere in the Elk Valley.
- Bulk of waste rock is non-PAG and is expected to show similar leaching to waste rock elsewhere in the Elk Valley.
- Controlled management by blending of Morrissey Formation for localized PAG characteristics.

Spoil Pile Design and Modeling of the Layered Approach

Purpose and Goals of the Layered Approach

Mike Allen, NWP

Purpose and Goals of the Layered Approach

- Sustainable approach to selenium treatment
- In-situ treatment of selenium and nitrate
- Incorporation of the process plant rejects into the waste rock dump design

Design Approach, Material Properties, and Materials Balance

Mike Allen, NWP

Design Approach

- Use the process plant coarse and fine tailings as a carbon source and to reduce oxygen levels waste rock
- Incorporate layers of coarse and fine tailings in the spoil pile design
- Geotechnical considerations included in the design
  - 50m maximum height of waste rock dumps
  - Multiple dump locations with sufficient offset for run-out/roll out protection

Material Properties

- Waste Rock – standard blasted rock consistent with other Elk Valley coal mines in size and consistency
- Plant Rejects – a combined coarse coal reject and fine coal rejects (tailings) material
- Soil – salvaged soil from site

Material Quantities Release Schedule

	Y0	Y1	Y2	Y3	Y4	Y5	Y6	Y7
ROMt Coal	0.5	3.5	3.8	3.7	3.8	3.7	3.7	3.9
Waste Rock (Placed Mm^3*)	2.7	15.5	21.2	19	22.8	23.4	23.5	23.1
Rejects (Placed Mm^3**)	0.15	0.97	1.20	1.24	1.3	1.09	1.03	1.14
Ratio WR:Rejects	18.3	16.0	17.6	15.3	17.6	21.5	22.8	20.3
	Y8	**Y9**	**Y10**	**Y11**	**Y12**	**Y13**	**Y14**	**Y15**
ROMt Coal	3.8	3.8	3.8	3.8	3.7	3.7	3.8	2.2
Waste Rock (Placed Mm^3*)	23.3	23.1	30.7	31.3	31	23.8	23.8	12.8
Rejects (Placed Mm^3**)	1.03	1.02	1.08	1.05	1.04	1.02	1.21	0.41
Ratio WR:Rejects	22.6	22.7	28.5	29.7	30.0	23.2	19.6	31.1

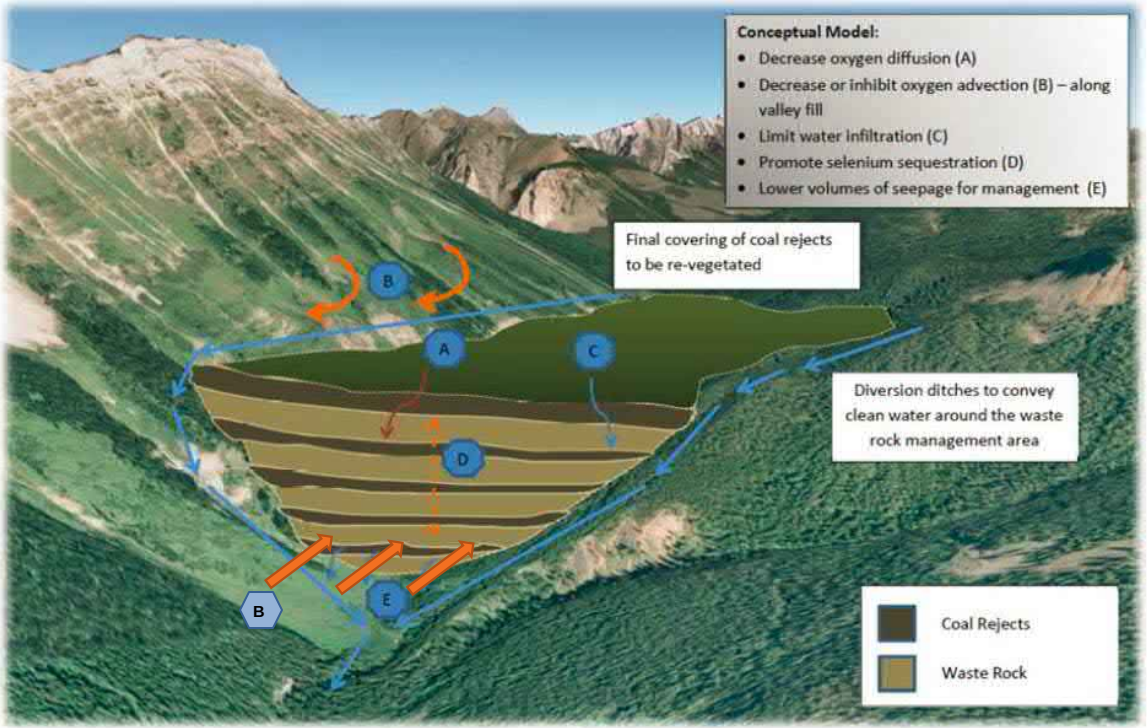
* estimated 30% swell factor

** estimated placed density of 1.4t/m3

Conceptual Model

Stephen Day, SRK

Waste Rock Management: Layered Approach



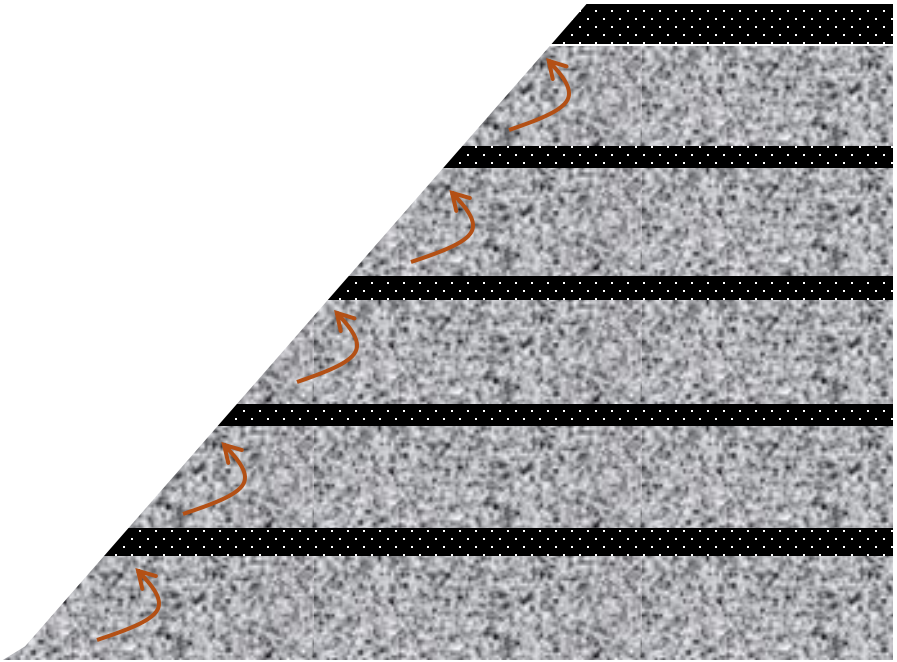
Conceptual Model For Se and NO_3 Attenuation in the Layered Spoil

Expected role of plant refuse layers:

- Retain moisture retarding oxygen transport.
- Generate dissolved organic carbon.
- Provide sub-oxic zones where reductive processes could occur.

Oxygen movement internally by diffusion not advection.

Convection in exposed faces.



Conceptual Model For Se and NO3 Attenuation in the Layered Spoil

- The layers are conceptualized to force O_2 to move slowly by diffusion with convection limited to side slopes.
- Native organic carbon and sulphide in the plant reject and waste rock consumes O_2 by oxidation
- When sufficient O_2 is consumed, Se and NO_3 can be converted to less mobile selenite and elemental selenium, and nitrogen gas by oxidation of organic carbon.
- All processes are microbially-mediated.

Numerical Implementation of the Conceptual Model

- Layering of compacted refuse with waste rock is expected to create sub-oxic conditions in the spoil under unsaturated conditions.
- Sub-oxic conditions provide an environment under which selenium and nitrate can be removed from existing and arriving pore water.
- Removal of oxygen also decreases the volume of spoil contributing to loadings of other parameters leached from waste rock (e.g. SO_4, Cd, Co, Zn).
- The effects of sub-oxic conditions are expected to be observed internally a year after waste rock is placed.

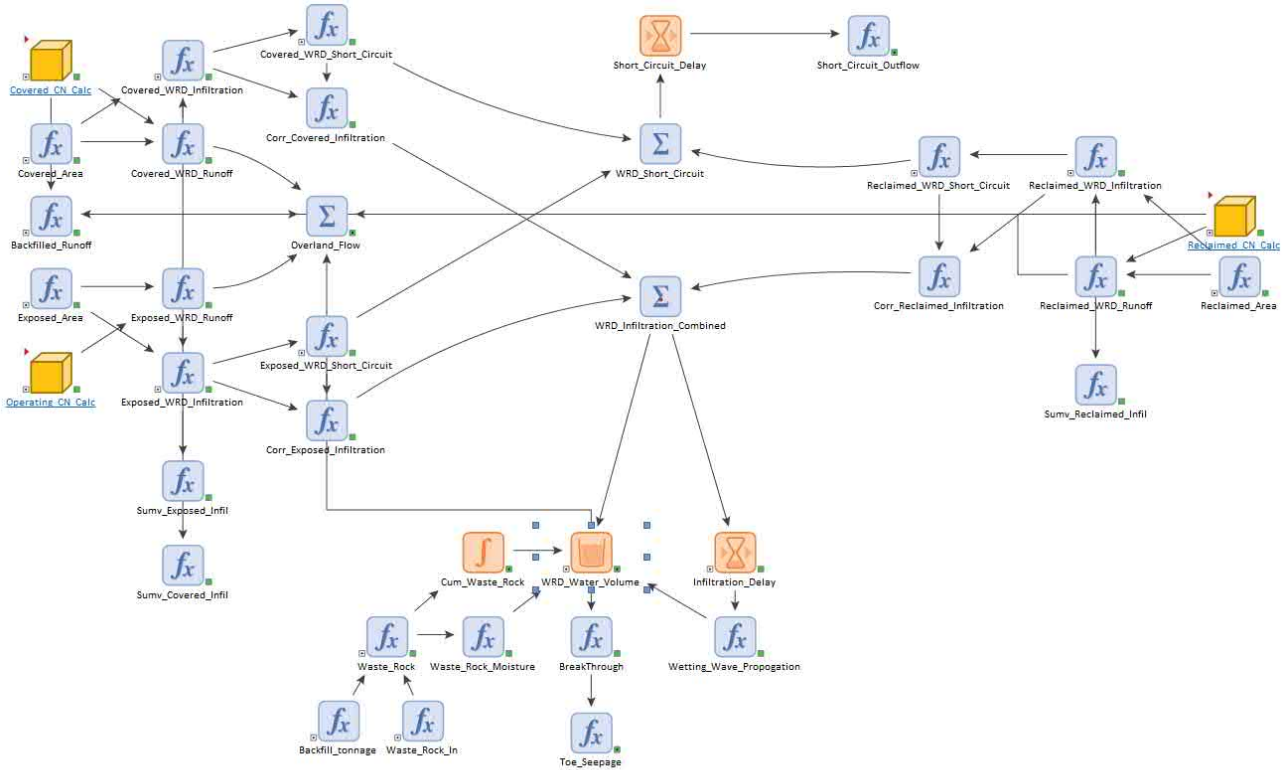
Hydrology and Hydraulics of the Modeled Approach

Brent Thiele, SRK

GoldSim WRD Water Balance Calculations

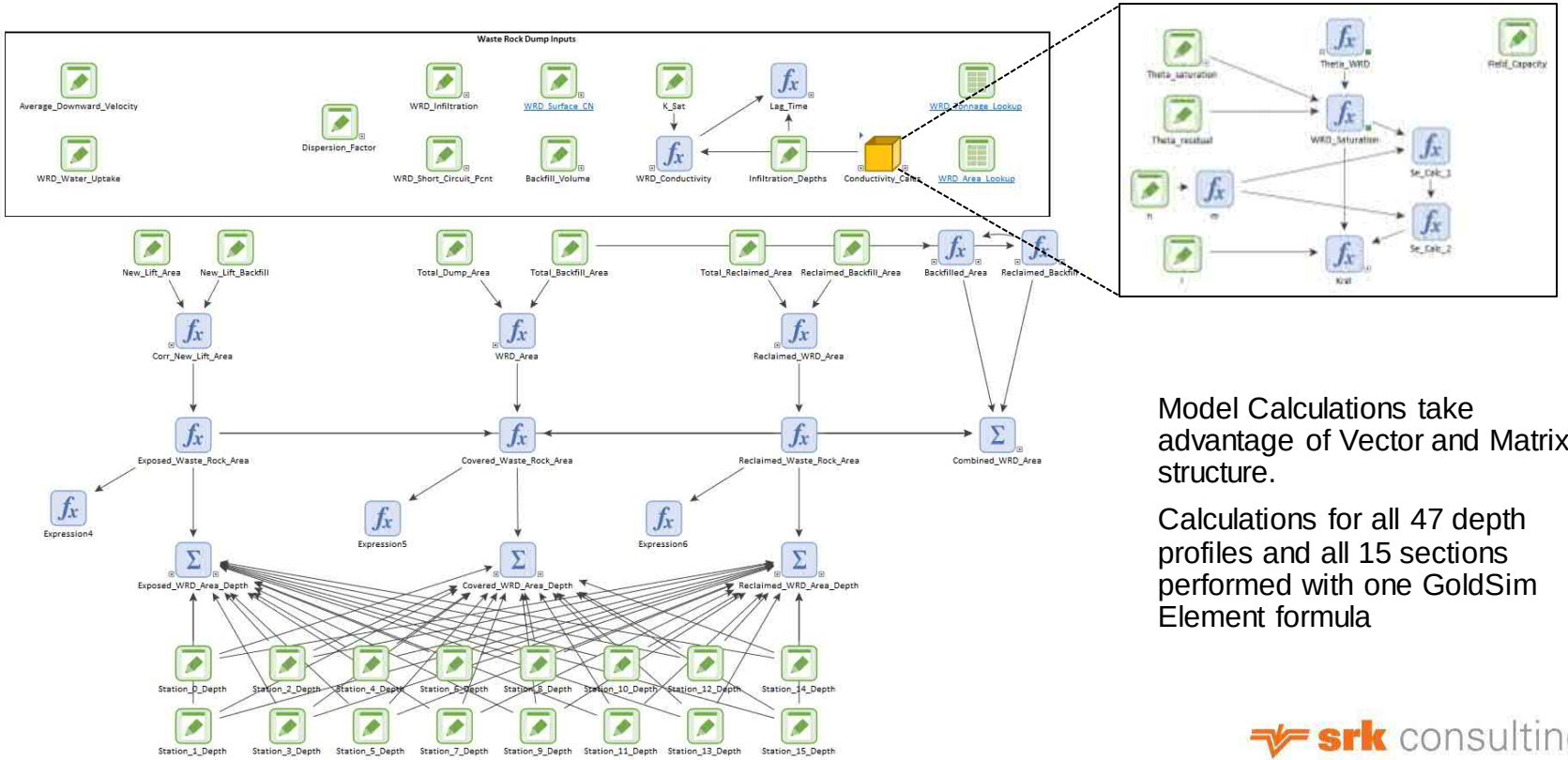
- Differentiate between hydrologic performance of different surfaces
  - Exposed Waste Rock: Low Runoff, High Infiltration
  - Covered Waste Rock: Moderate Runoff, Moderate Infiltration
  - Reclaimed Waste Rock: High Runoff, Low Infiltration
- Some infiltration into the waste rock assumed to short circuit majority of waste rock and will report to toe essentially immediately
- Remainder of Infiltration into the waste rock will be lagged and attenuated before it reports to the toe as seepage
  - Velocity based on unsaturated flow equations, using calculated average moisture content in waste rock profile
  - Travel time based on average velocity and waste rock thickness
- Calibrated to Hydrus 1D unsaturated flow modeling

GoldSim WRD Water Balance Calculations



srk consulting

GoldSim Model
WRD Inputs Container



Model Calculations take advantage of Vector and Matrix structure.

Calculations for all 47 depth profiles and all 15 sections performed with one GoldSim Element formula

srk consulting

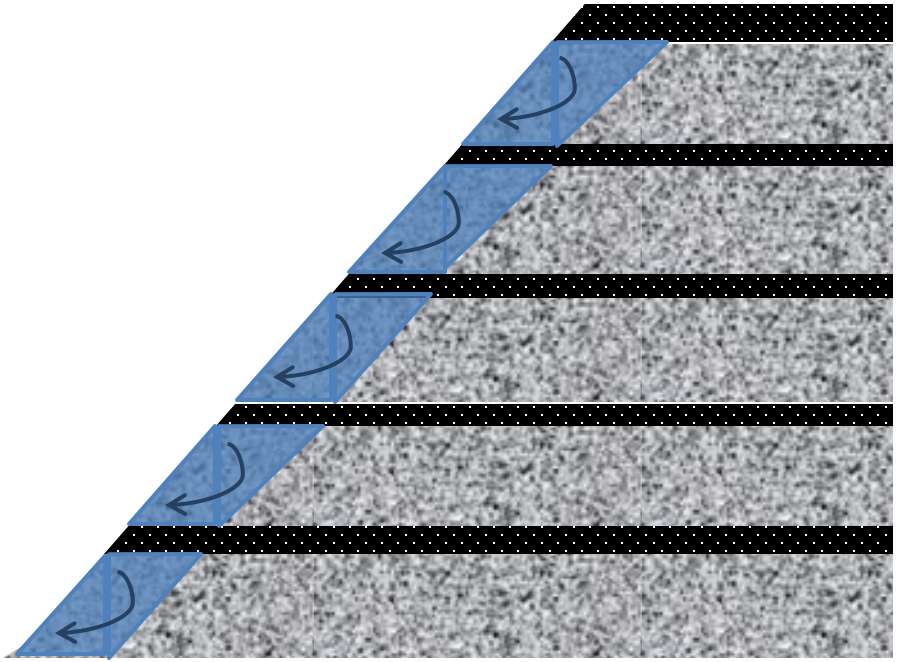
Representing the WRD Geometry (Thickness and Area)

- WRD split into three Surfaces:
  - Exposed Waste Rock
  - Covered Waste Rock
    - Covered with Process Rejects
  - Reclaimed Waste Rock
    - Resloped and vegetated cover

Parameter	Exposed Waste Rock	Covered Waste Rock	Reclaimed Waste Rock
Runoff Curve Number	77	86	91
Infiltration (% of precipitation)	50	15	5
Edge Seepage (% of Infiltration)	5	3	1

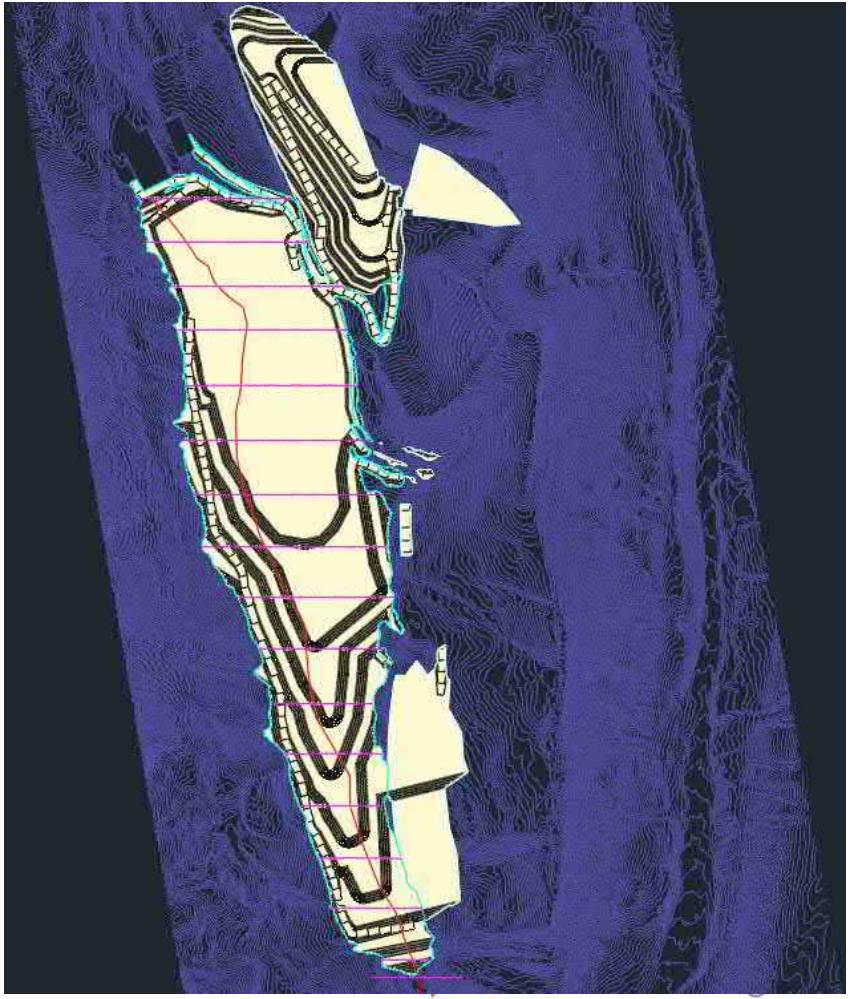
Edge Seepage

- Seepage through the exposed edges of the WRD
  - Produces worse WQ due to unlimited O_2 availability
- Travel time nearly instantaneous vs. percolation through WRD



Dynamic WRD Geometry along Stations

- Magenta lines identifies stations
- Red line follows valley centerline
- Each station line represents a location where a cross section was created for each Mine Year
- Each cross section was then tabulated in Excel



Dynamic WRD Geometry
Annual Layering Progression

Station	0	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000	3100	3200	3300	3400	3500	3600	3700	3800	3900	4000	4100	4200	4300	4400	4500	4600
Year	Layer Thickness																																														
0	18.5	10.0	7.2	16.1	17.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	3.1	45.5	45.3	19.1	0.0	5.1	27.7	45.1	60.2	69.8	77.3	73.8	63.1	56.1	60.6	67.2	68.0	39.2	25.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	1.7	27.7	54.5	75.6	58.8	55.4	38.2	38.0	36.3	25.1	41.0	50.3	39.7	19.4	2.7	17.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	1.4	0.0	0.0	2.0	4.5	6.3	20.9	23.3	29.1	39.3	40.3	19.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	7.3	13.1	13.3	14.5	23.0	41.1	44.6	60.0	60.0	60.1	60.1	60.4	50.2	18.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	2.1	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	10.0	5.2	13.1	20.0	28.6	35.0	40.4	48.2	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	52.0	58.3	60.0	64.1	68.6	69.9	76.8	80.0	82.7	88.3	52.6	57.0	60.0	63.1	65.1	70.1	70.9	38.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.6	40.0	40.0	40.0	40.0	40.0	40.0	40.0	2.0	0.0	0.0	1.6	40.0	39.9	39.9	39.9	40.0	6.5	2.8	41.6	80.0	80.0	35.1	37.0	40.0	40.0	28.2	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	38.0	40.0	40.0	40.0	40.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.6	39.9	39.9	39.9	39.9	39.9	39.9	39.9	39.9	40.0	40.0	34.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.3	38.9	39.1	39.1	39.4	39.6	39.8	39.9	40.1	13.9	0.0	0.0	5.7	40.0	5.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.9	30.9	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.3	40.7	41.1	41.0	41.0	40.7	18.6	0.0	0.0	0.0	26.3	40.0	0.0	0.0	0.0	0.0	32.0	40.0	40.0	40.0	73.5	80.0	80.0	80.0	47.2	72.4	14.1	0.0	0.0	11.8	40.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.9	40.0	20.6	13.4	0.0	0.0	40.0	40.0	40.0	61.4	40.0	40.0	40.0	40.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9	40.0	40.0	8.9	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.7	40.0	40.0	40.0	27.8	19.9	16.5	0.0	0.0	0.0	3.0	26.2	37.9	33.5	1.0	0.0	13.2	11.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.6	40.0	23.1	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

srk consulting

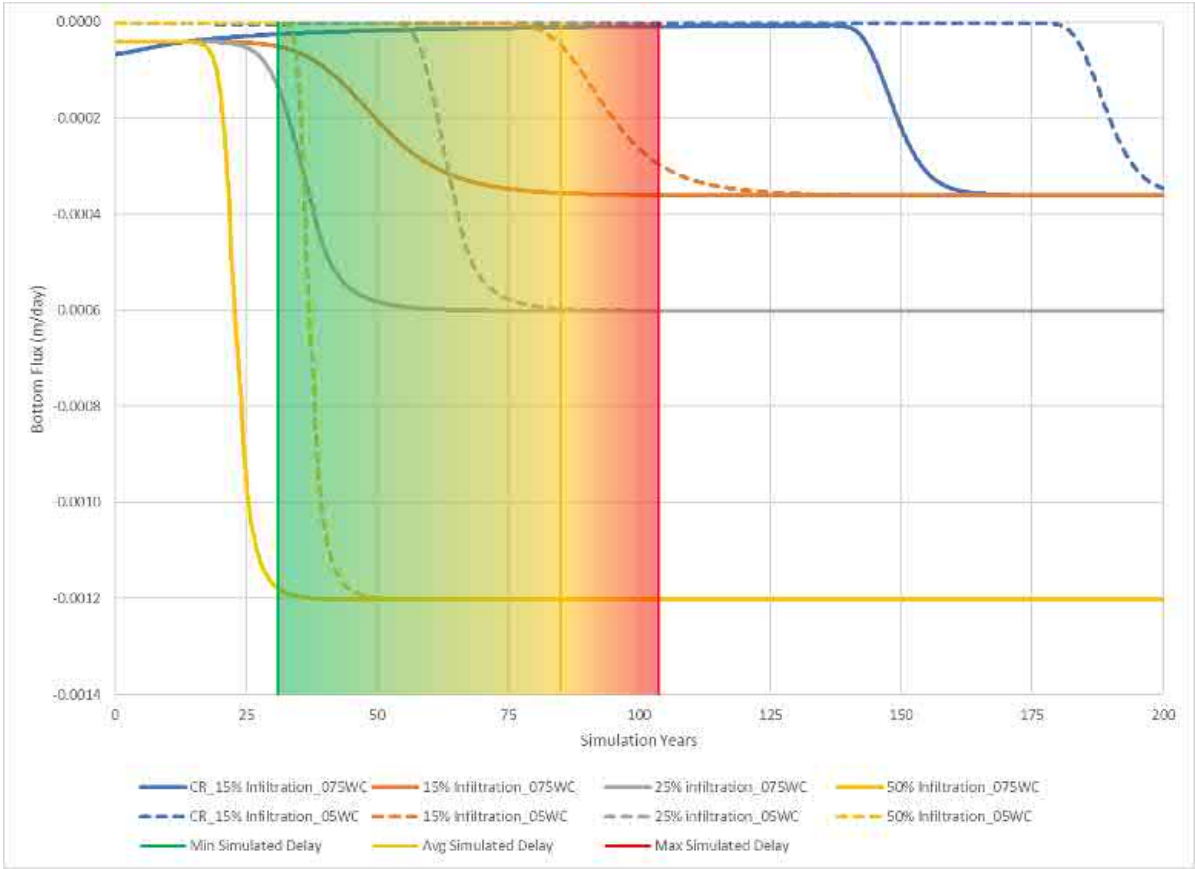
Dynamic WRD Geometry
Total Layer Thickness

Station	0	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000	3100	3200	3300	3400	3500	3600	3700	3800	3900	4000	4100	4200	4300	4400	4500	4600
Year	WRD Depth																																														
0	18.5	10.0	7.2	16.1	17.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	21.6	55.5	52.5	35.2	17.9	0.0	20.5	43.6	60.0	67.5	74.4	71.1	55.6	49.0	57.9	60.0	65.0	30.9	21.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	21.6	56.4	54.2	63.0	72.4	76.0	79.2	99.0	98.2	105.5	110.7	96.2	96.6	99.3	97.6	79.4	67.8	47.9	21.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	21.6	56.4	54.2	63.0	72.4	77.4	79.4	99.0	100.2	110.0	117.0	117.1	119.9	128.5	136.9	119.7	87.4	47.9	21.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	21.6	63.7	67.3	76.3	87.0	100.4	120.5	143.7	160.3	170.1	177.1	177.3	180.2	178.7	155.1	119.7	87.4	47.9	21.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	21.6	65.8	87.3	96.3	107.0	120.4	140.5	163.7	180.3	190.1	197.1	197.3	200.2	178.7	155.1	119.7	87.4	47.9	21.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.9	6.4	13.1	20.2	24.6	30.4	39.8	41.5	0.0
6	21.6	65.8	87.3	96.3	107.0	120.4	140.5	163.7	180.3	190.1	197.1	197.3	200.2	178.7	155.1	119.7	87.4	47.9	41.0	50.1	57.1	60.1	60.4	65.2	70.0	71.0	80.1	79.9	79.8	50.2	50.6	60.0	60.1	60.3	61.1	67.2	38.0	0.0	10.0	6.4	13.1	20.3	24.7	30.5	40.0	41.5	0.0
7	21.6	65.8	87.3	96.3	107.0	120.4	140.5	163.7	180.3	190.1	197.1	197.3	200.2	178.7	155.1	119.7	87.4	47.9	41.0	50.1	57.1	60.1	60.4	65.2	70.0	71.0	80.1	79.9	79.8	50.2	50.6	60.0	60.1	60.3	61.1	67.2	38.0	0.0	10.0	6.4	13.1	20.3	24.7	30.5	40.0	41.5	0.0
8	21.6	65.8	87.3	96.3	107.0	120.4	140.5	163.7	180.3	190.1	197.1	197.3	200.2	178.7	155.1	119.7	87.4	70.5	81.0	90.1	97.1	100.1	100.4	105.2	110.0	72.9	80.1	79.9	81.4	90.1	90.5	100.0	100.0	100.2	67.6	70.0	79.6	80.1	90.0	41.6	50.1	60.3	64.7	58.6	40.0	41.5	0.0
9	21.6	65.8	87.3	96.3	107.0	120.4	140.5	163.7	180.3	190.1	197.1	197.3	200.2	178.7	155.1	119.7	87.4	70.5	81.0	90.1	97.1	100.0	100.3	105.1	109.9	110.9	120.1	119.9	121.4	130.2	98.5	100.0	100.1	100.3	67.6	70.0	79.6	80.1	90.0	41.6	50.1	60.3	64.7	58.6	40.0	41.5	0.0
10	21.6	65.8	87.3	96.3	107.0	120.4	140.5	163.7	180.3	190.1	197.1	197.3	200.2	178.7	155.1	119.7	110.0	110.4	120.9	130.0	137.0	139.9	140.2	145.0	149.8	150.9	160.0	154.2	121.4	130.2	98.5	100.0	100.1	100.3	67.6	70.0	79.6	80.1	90.0	41.6	50.1	60.3	64.7	58.6	40.0	41.5	0.0
11	21.6	65.8	87.3	96.3	107.0	120.4	140.5	163.7	180.3	190.1	197.1	197.3	200.2	178.7	155.1	142.0	148.9	149.5	160.0	169.4	176.6	179.7	180.2	185.1	163.7	151.0	160.1	159.9	161.4	135.5	98.5	100.0	100.1	100.3	67.6	70.0	79.6	80.1	90.0	41.6	71.1	91.1	64.7	58.6	40.0	41.5	0.0
12	21.6	65.8	87.3	96.3	107.0	120.4	140.5	163.7	180.3	190.1	197.1	197.3	200.2	178.7	180.3	182.8	190.0	190.5	201.0	210.1	195.2	180.1	180.4	185.2	190.0	191.0	160.1	159.9	161.4	135.5	130.6	140.0	140.1	140.3	141.1	150.0	159.6	160.1	137.1	114.0	85.2	60.3	64.7	70.5	80.0	41.5	0.0
13	21.6	65.8	87.3	96.3	107.0	120.4	140.5	163.7	180.3	190.1	197.1	197.3	200.2	178.7	180.3	182.8	190.0	190.5	201.0	210.1	217.1	220.1	200.9	198.6	190.0	191.0	200.1	199.9	201.4	197.0	170.6	180.0	180.1	180.3	141.1	150.0	159.6	160.1	137.1	114.0	90.1	100.3	104.7	79.4	80.0	41.5	0.0
14	21.6	65.8	87.3	96.3	107.0	120.4	140.5	163.7	180.3	190.1	197.1	197.3	200.2	210.4	220.3	222.8	230.0	218.3	220.9	226.6	217.1	220.1	200.9	201.6	216.2	228.9	233.6	200.9	201.4	210.2	181.8	180.8	180.1	180.3	141.1	150.0	159.6	160.1	137.1	121.6	130.1	123.4	104.7	79.4	80.0	41.5	0.0
15	21.6	65.8	87.3	96.3	107.0	120.4	140.5	163.7	180.3	190.1	197.1	197.3	200.2	210.4	220.3	222.8	230.0	218.3	220.9	226.6	217.1	220.1	200.9	201.6	216.2	228.9	233.6	200.9	201.4	210.2	181.8	180.8	180.1	180.3	141.1	150.0	159.6	160.1	137.1	121.5	130.1	123.4	104.7	79.4	80.0	41.5	0.0

srk consulting

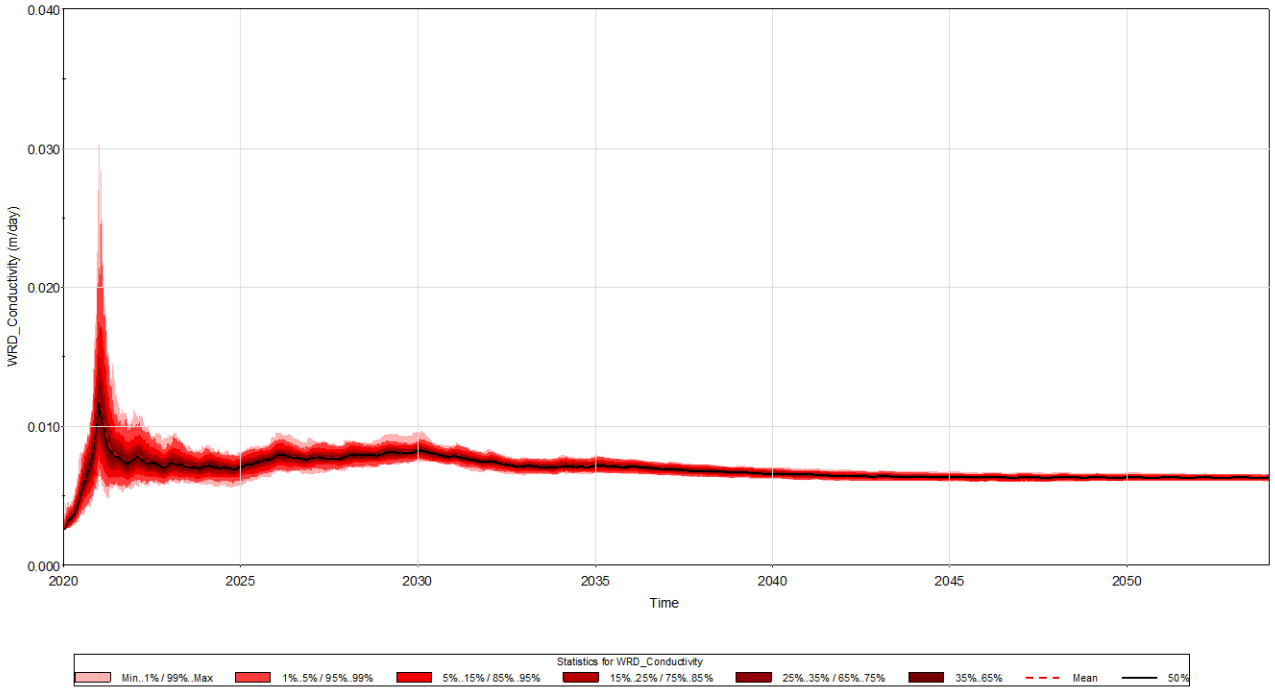
Validation of Goldsim Model

- Simulated Travel times for percolation of water through the WRD falls in line with HYDRUS 1D modeling results
  - Dashed line shows Waste at 5% moisture content
  - Solid Line shows Waste at 7.5% moisture content

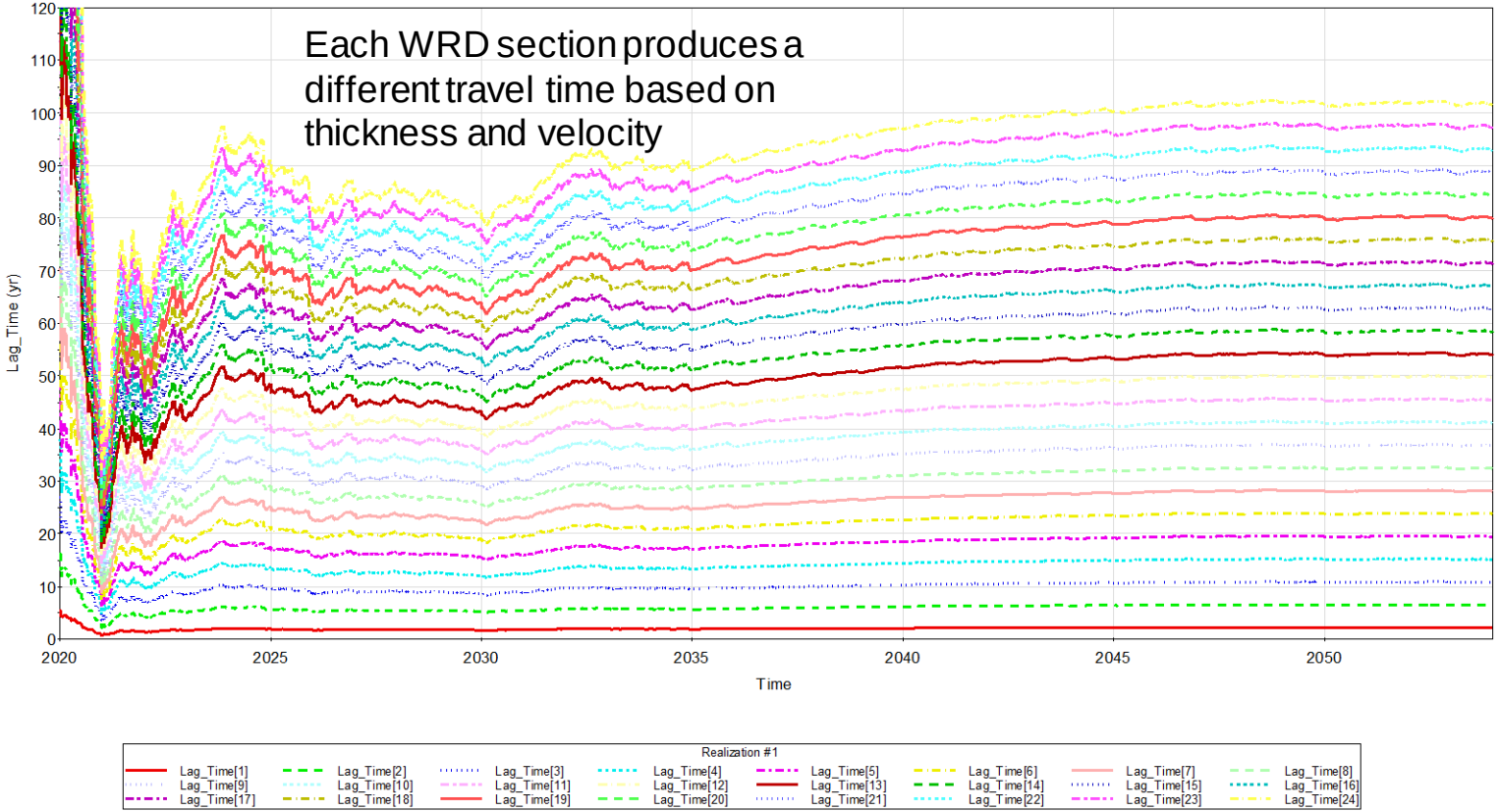


Unsaturated Hydraulic Conductivity

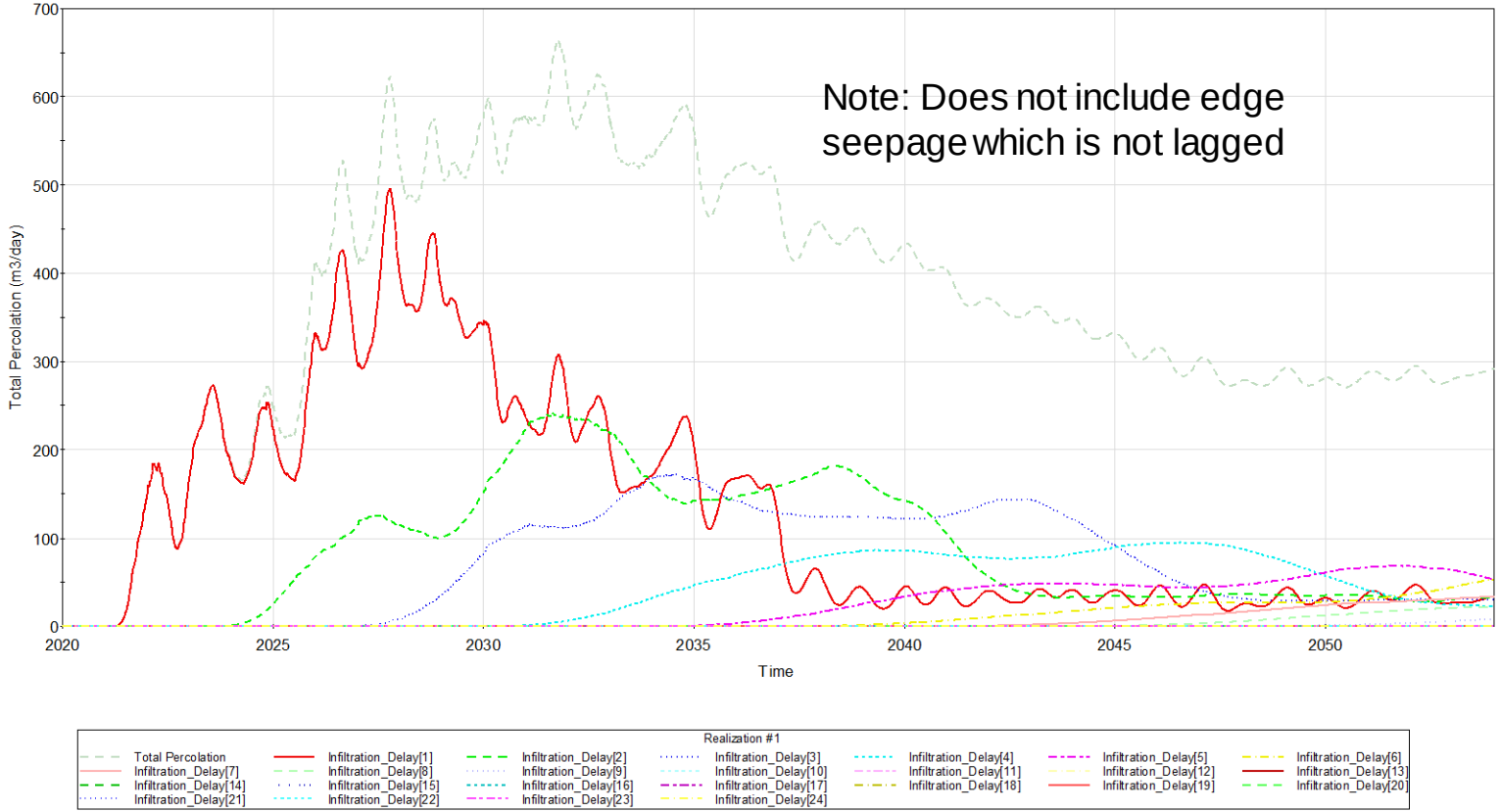
- Spike in Unsaturated Conductivity early in LOM
  - Linked to the average moisture content of the waste rock
  - Highest ratio of surface area to depth/volume
  - Mostly exposed waste rock



Calculated Travel Time through WRD



Seepage Reporting to Toe of WRD



Source Terms

Stephen Day, SRK

Source Terms

- Prediction of contact water chemistry.
- Delivered as an input to water and load balance which is used to predict downstream water quality.

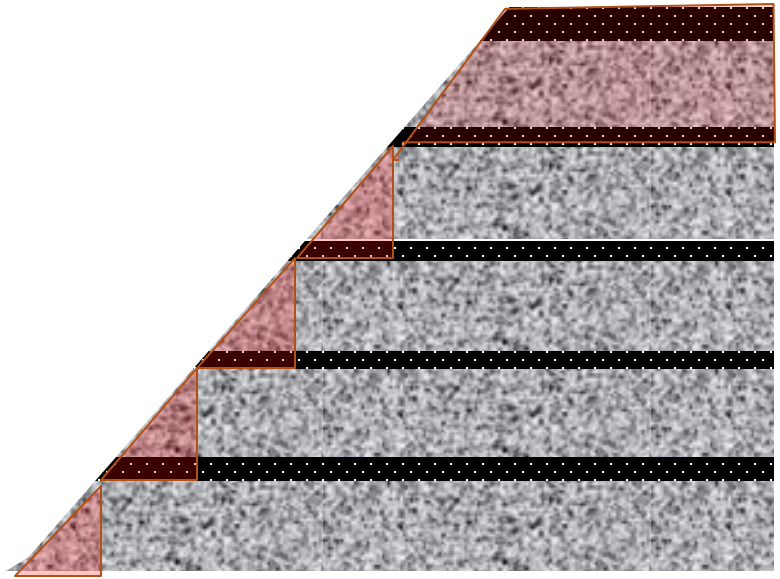
Source Terms

- Waste Rock
- Pit walls
- Overburden stockpiles

Source Term Cases - Waste Rock

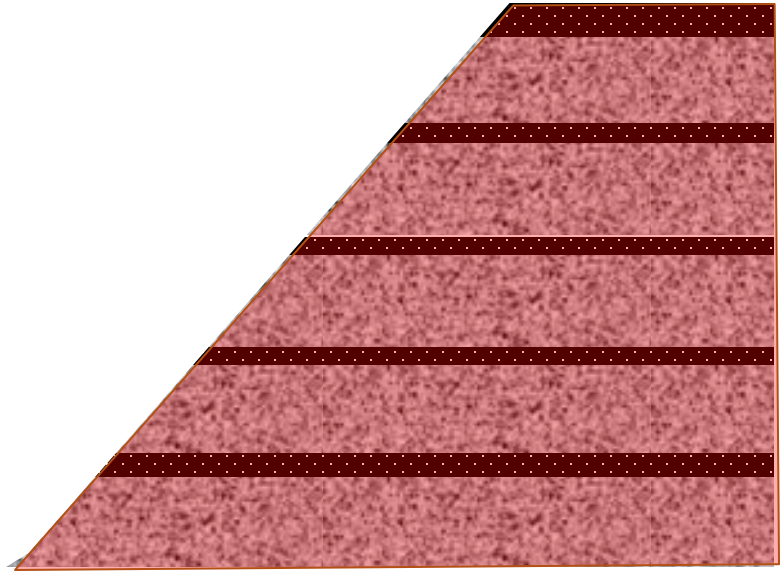
Successful Development of Low O_2 Conditions.

O_2 is unlimited oxidant on the exposed slopes and top lift



Layering System Fails to Develop Low O_2 Conditions.

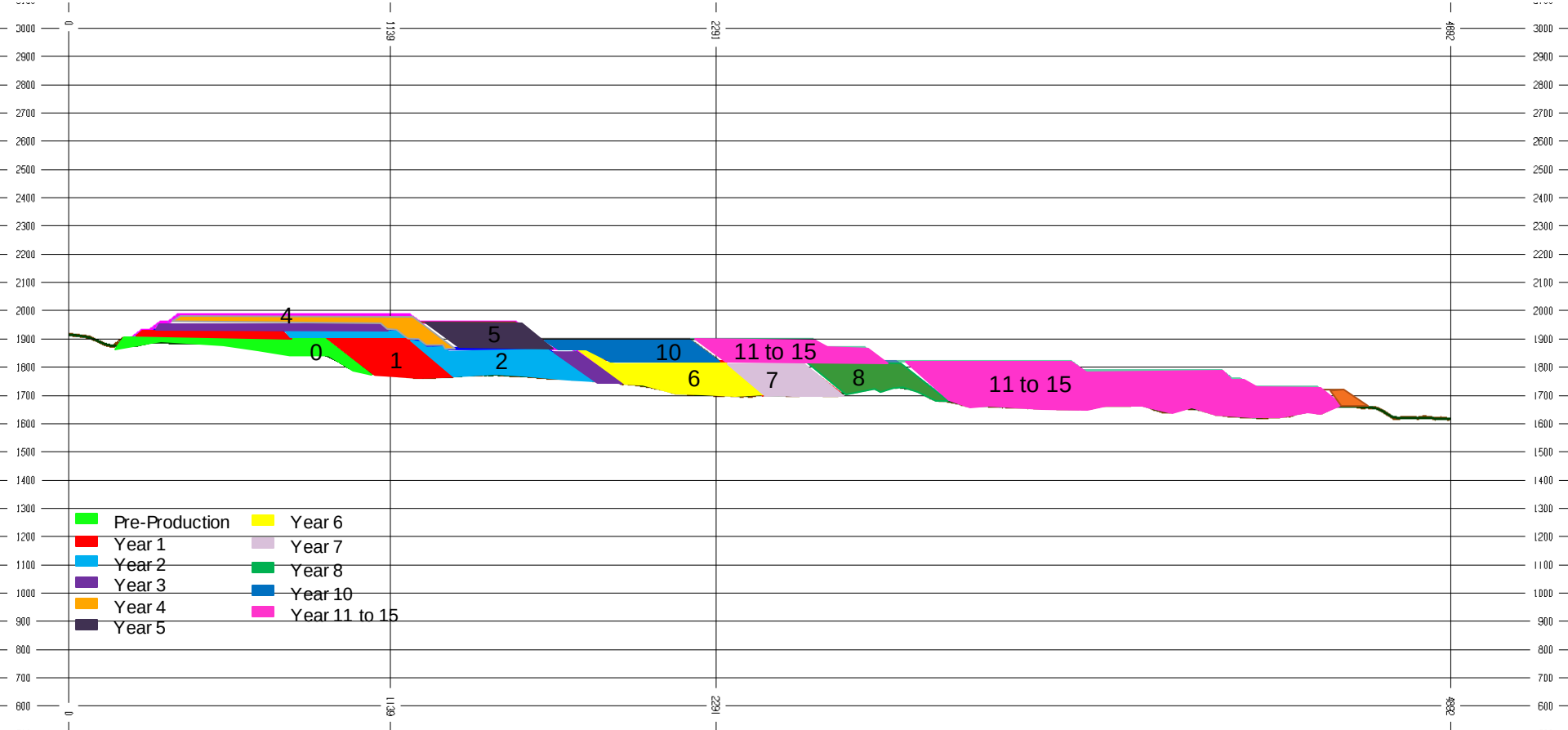
O_2 is unlimited oxidant in the entire spoil



Numerical Implementation

- 2-dimensional model which is used to predict performance in 3-dimensions

Section 1 Year to 15 Year



Numerical Implementation

- Case: Successful Development of Low O_2 Conditions
- Waste rock interior
  - No oxidation.
  - Nitrate is denitrified to nitrogen gas.
- Top layer and slopes are fully oxygenated due to diffusion of O_2 and convection, respectively.
  - Rates of weathering are based on the humidity cells scaled to site conditions using Elk Valley experience.
  - Leached selenium and nitrate from top layer are attenuated.
  - Other parameters are not affected by the low O_2 conditions.

Numerical Implementation

- Case: Layering System Fails to Develop Low O_2 Conditions.
- Entire spoil is fully oxygenated.
- Rates of weathering are based on the humidity cells scaled to site conditions using Elk Valley experience.

Representation of Variability

- Central case: P_{50} of humidity cell rates.
- Upper case: P_{95} of humidity cell rates.

Selected Average Source Terms - Spoils

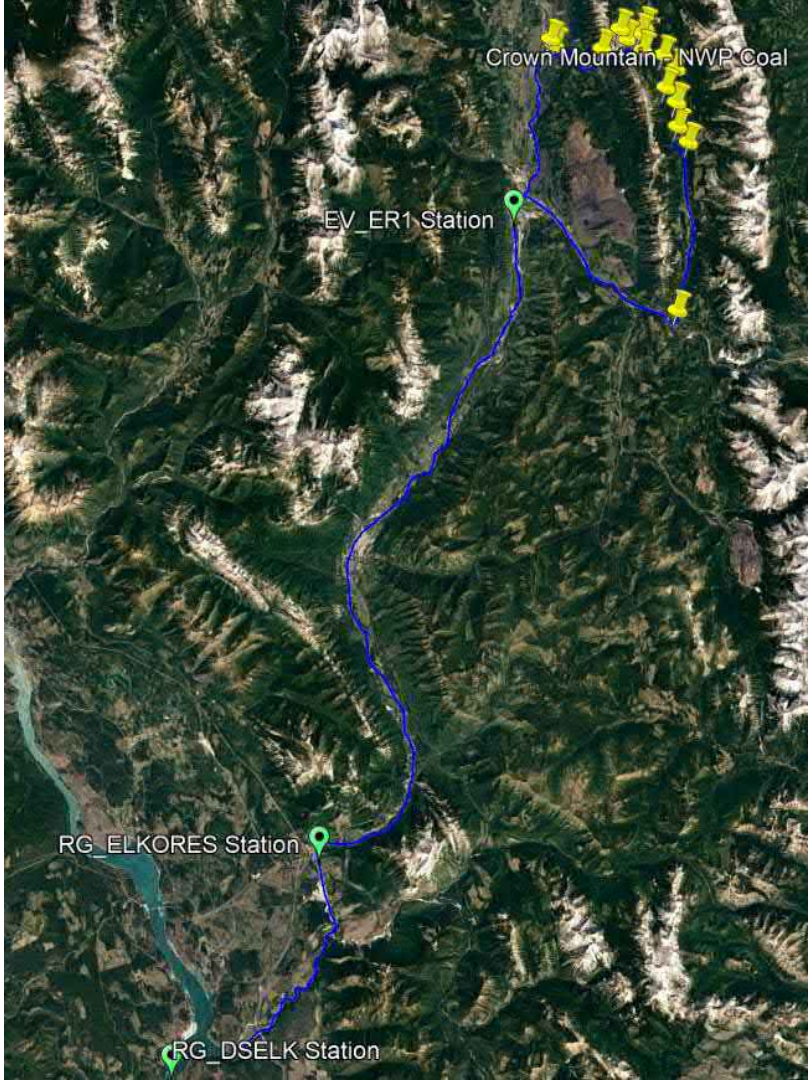
Parameter	Succeeds		Fails	
	P_{50}	P_{95}	P_{50}	P_{95}
SO_4 (mg/L)	530	640	1200	1800
Cd (mg/L)	0.0019	0.0027	0.0027	0.0027
Se (mg/L)	0.045	0.093	0.28	0.58
NO_3 (mg-N/L)	0.5	0.5	22	22

Selection of Reporting Nodes

Dave Hoekstra, SRK

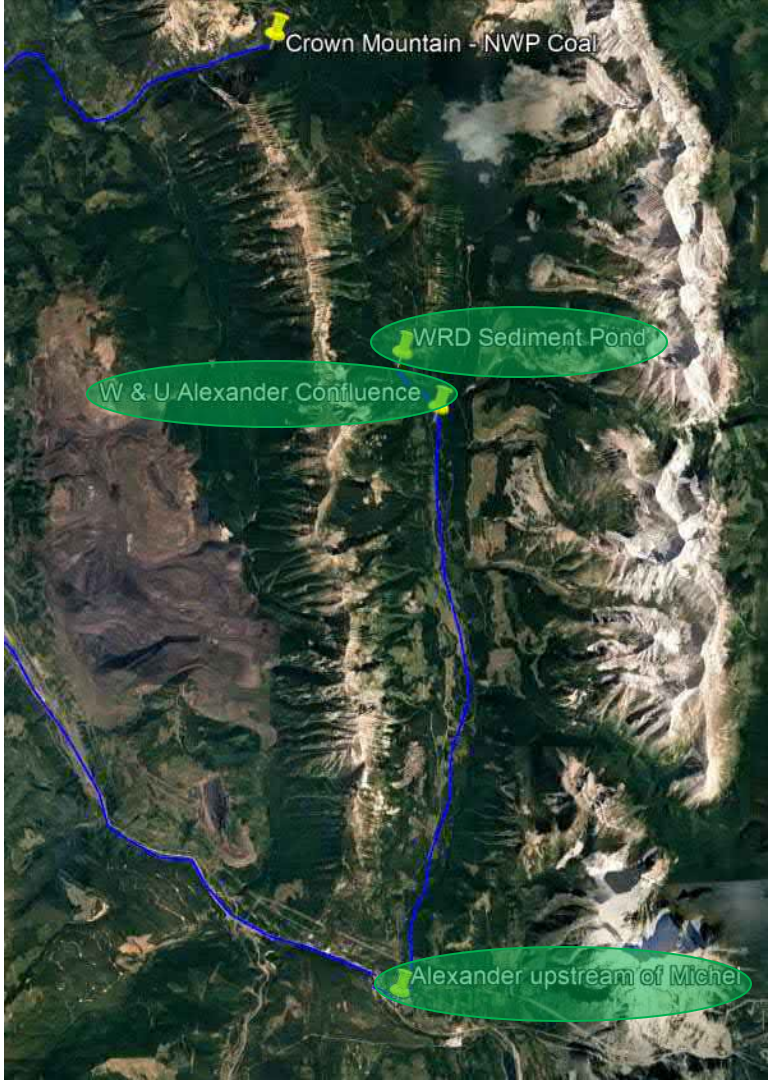
Selection of WQ Results

- The GoldSim model calculates water quality projections at 17 locations within the model, including Pits, WRD, ponds, and confluences
- Chemistry for all 43 chemical constituents (“species” in GoldSim) tracked by the model at each node is available
- Model was run for 4 Scenarios
  - Average (P_{50}) and Upper case (P_{95}) Source Terms
  - Successful and Failed WRD layered system



Selection of WQ Reporting Nodes

- 3 key nodes were selected to represent the performance of the system:
  - WRD Pond Discharge
  - Alexander Creek Below Confluence with West Alexander Creek
  - Alexander Creek above Confluence with Michel Creek



Regional Reporting Stations

- Regional nodes downstream
  - Elk River at Sparwood
    - EV_ER1 Station
  - Elko reservoir
    - RG_ELKORES Station
  - Lake Koocanusa
    - RG_DSELK Station

Selection of WQ Performance Standards

- 3 key species were selected to indicate performance against standards:
  - Selenium
  - Nitrate
  - Sulphate

Species / Deleterious Substance (Chronic Standard)	Proposed Coal Mining Effluent Regulations (CMER) New Mines	Proposed Coal Mining Effluent Regulations (CMER) Existing Mines	British Columbia Water Quality Guidelines For Aquatic Life (BCWQG FAL)
Selenium (Se)	.005 mg/L	.01 mg/L	0.002 mg/L
Nitrate (NO_3)	5 mg/L (as N)	10mg/L (as N)	3 mg/L
Sulphate (SO_4)	-	-	309 mg/L (assuming hardness between 75 mg/L and 180 mg/L)

Selection of Simulation Scenarios

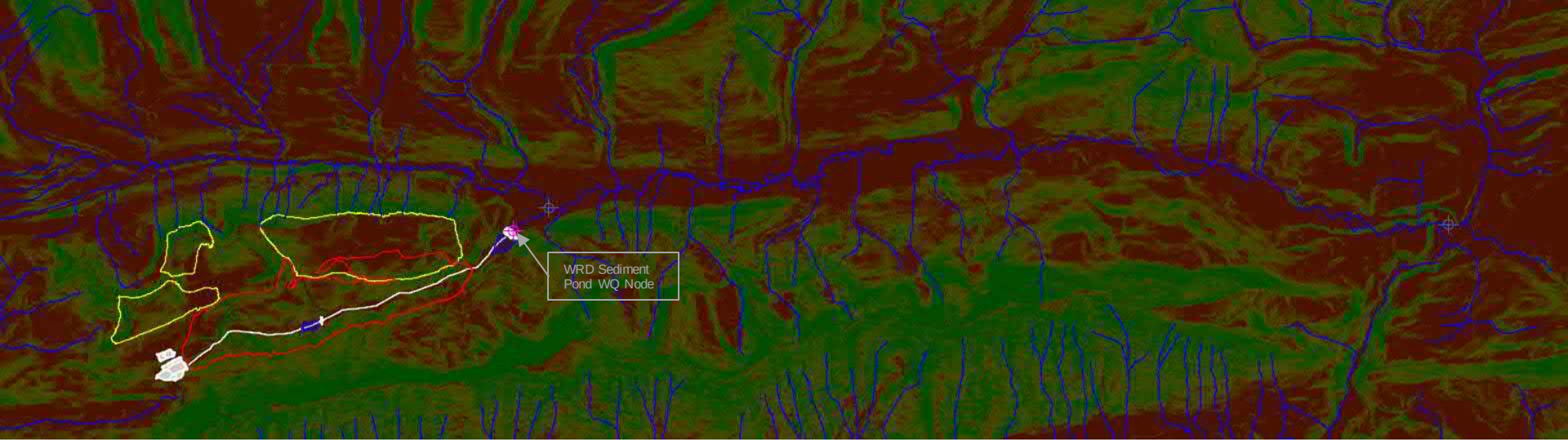
- All four scenario combinations are believed relevant and results are presented for discussion
  - Upper Case Source Terms (P_{95}) and Failed WRD Layer System
  - Upper Case Source Terms (P_{95}) and Successful WRD Layer System
  - Average Source Terms (P_{50}) and Failed WRD Layer System
  - Average Source Terms (P_{50}) and Successful WRD Layer System

Water Quality Results

Dave Hoekstra, SRK

Summary of Results

- Under successful layer cake concept as modelled achieves better water quality than operational water treatment plant design.
  - Water quality guidelines met prior to Michel Creek
- If layer cake method failures, chronic water quality guidelines are not met.
  - Consumptive losses from the Interim Pond delay downstream exceedances for Five Years



WQ Results - Selenium

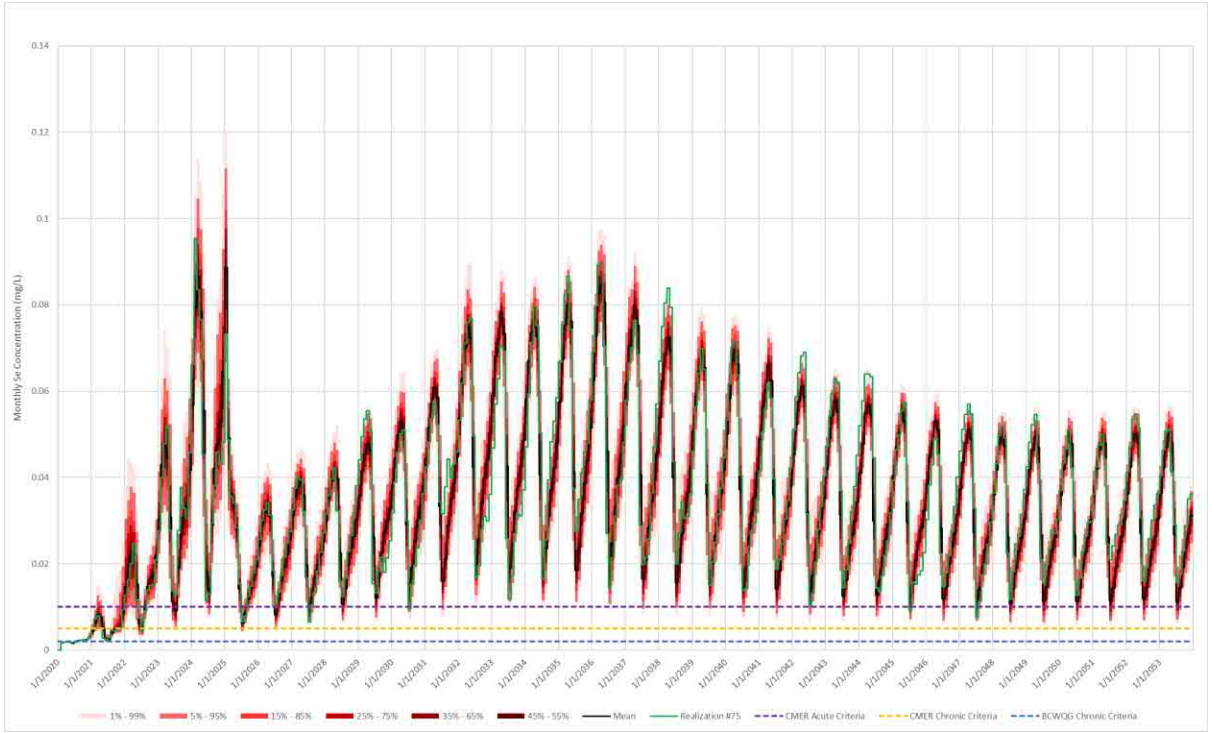
WRD Sedimentation Pond (Interim and Ultimate)

srk consulting

Upper Case (P_{95}) and Layer Approach Fails Selenium

WQ Criteria Legend

- CMER Acute (0.01 mg/L)
- CMER Chronic (0.005 mg/L)
- BCWQGL Chronic (0.002 mg/L)



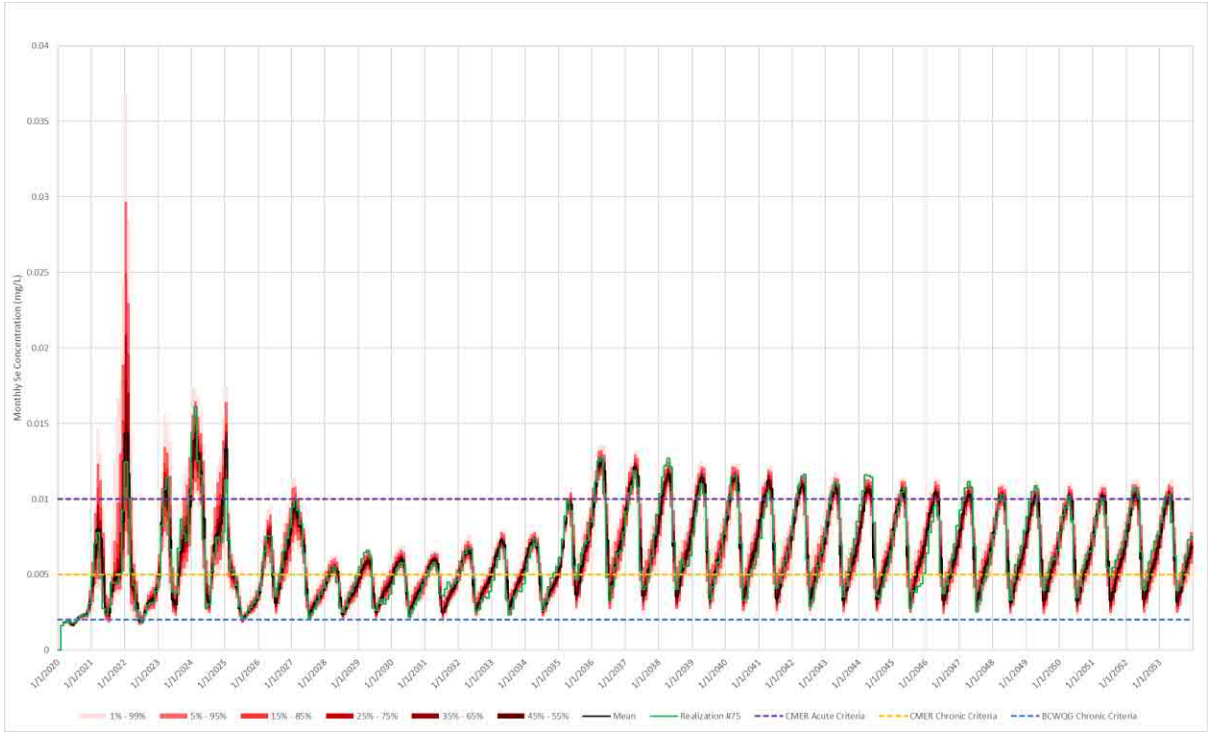
srk consulting

Location: WRD Sedimentation Pond

Upper Case (P_{95}) and Layer Approach Succeeds Selenium

WQ Criteria Legend

- CMER Acute (0.01 mg/L)
- CMER Chronic (0.005 mg/L)
- BCWQGL Chronic (0.002 mg/L)



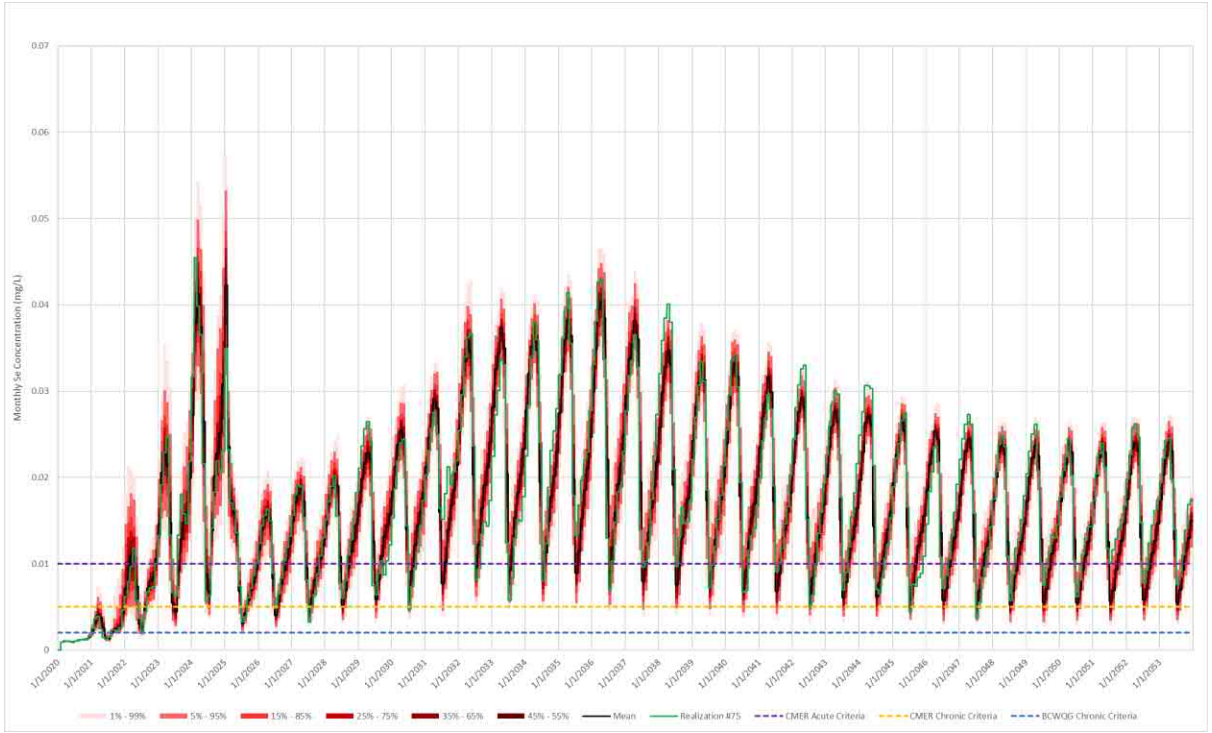
srk consulting

Location: WRD Sedimentation Pond

Average Case (P_{50}) and Layer Approach Fails Selenium

WQ Criteria Legend

- CMER Acute (0.01 mg/L)
- CMER Chronic (0.005 mg/L)
- BCWQGL Chronic (0.002 mg/L)



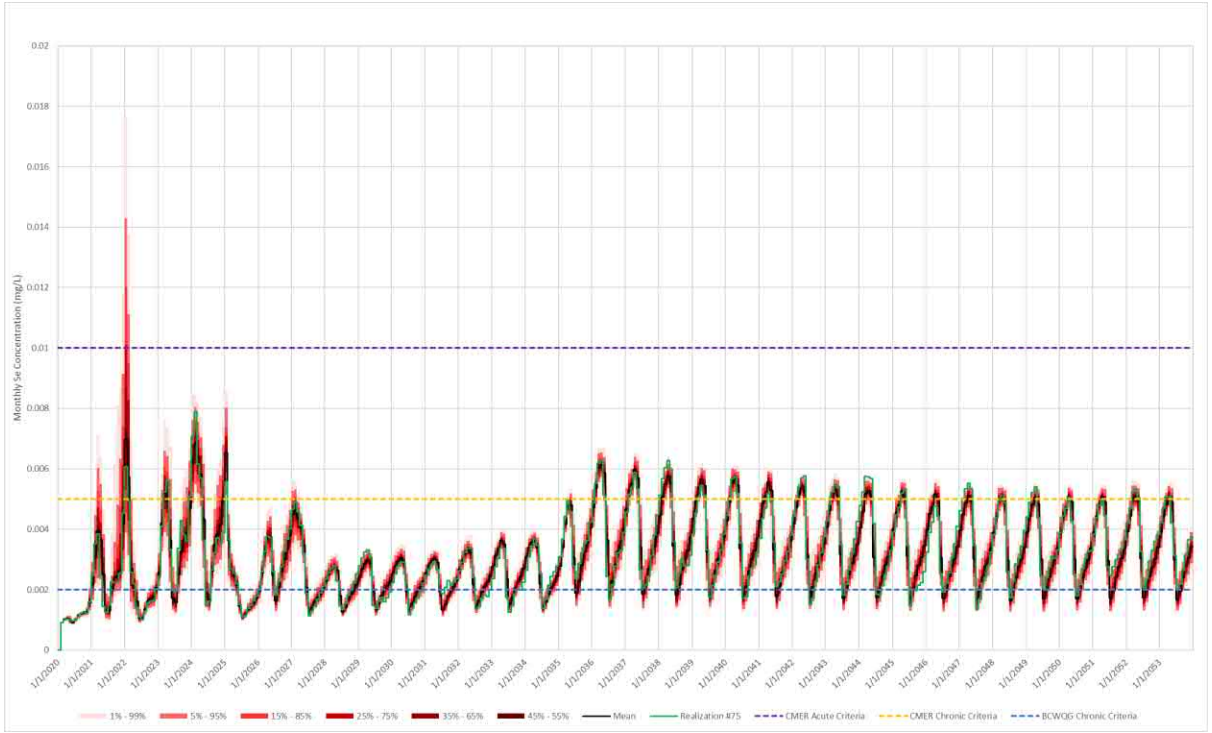
srk consulting

Location: WRD Sedimentation Pond

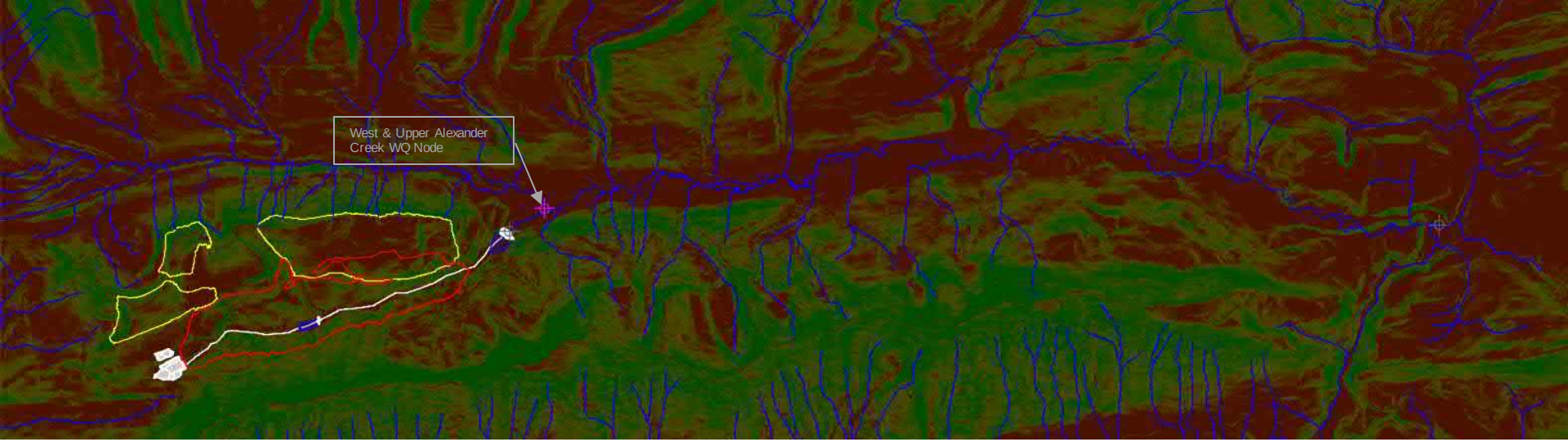
Average Case (P_{50}) and Layer Approach Succeeds Selenium

WQ Criteria Legend

- CMER Acute (0.01 mg/L)
- CMER Chronic (0.005 mg/L)
- BCWQGL Chronic (0.002 mg/L)



Location: WRD Sedimentation Pond



WQ Results - Selenium

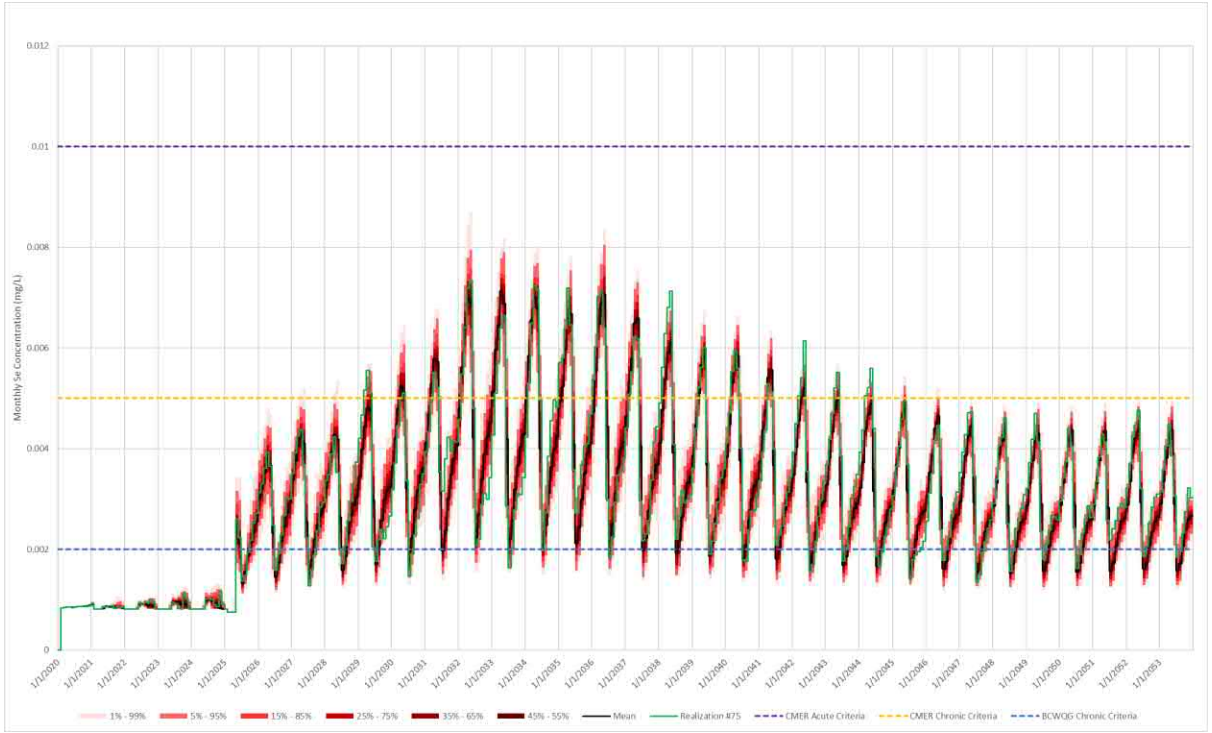
Confluence of West Alexander Creek and Upper Alexander Creek

srk consulting

Upper Case (P_{95}) and Layer Approach Fails Selenium

WQ Criteria Legend

- CMER Acute (0.01 mg/L)
- CMER Chronic (0.005 mg/L)
- BCWQGL Chronic (0.002 mg/L)



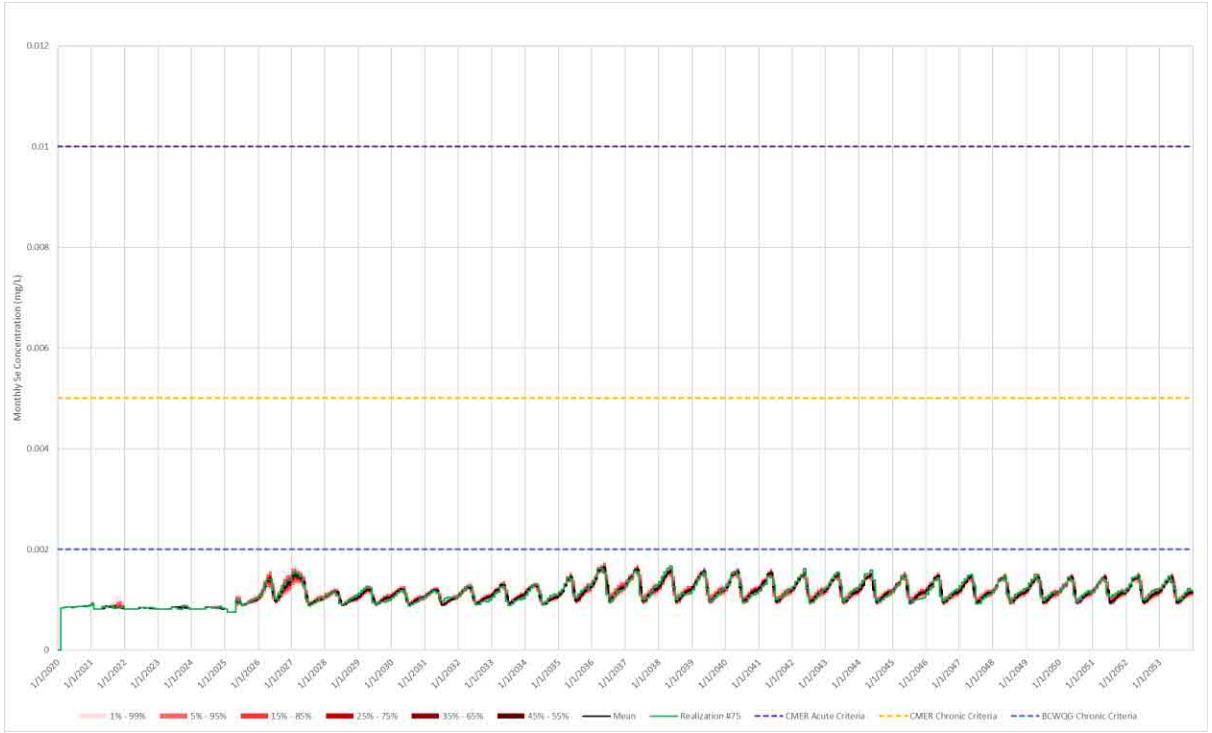
srk consulting

Location: Confluence of W. Alexander and U. Alexander Creek

Upper Case (P_{95}) and Layer Approach Succeeds Selenium

WQ Criteria Legend

- CMER Acute (0.01 mg/L)
- CMER Chronic (0.005 mg/L)
- BCWQGL Chronic (0.002 mg/L)



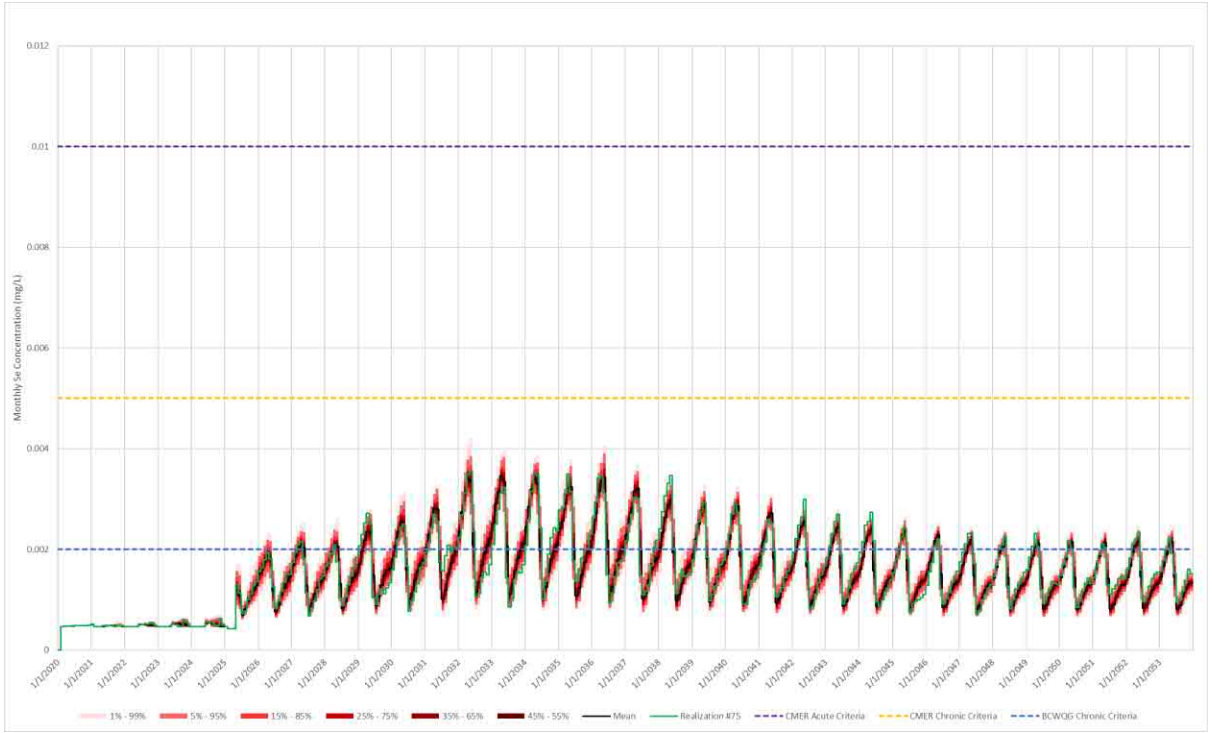
srk consulting

Location: Confluence of W. Alexander and U. Alexander Creek

Average Case (P_{50}) and Layer Approach Fails Selenium

WQ Criteria Legend

- CMER Acute (0.01 mg/L)
- CMER Chronic (0.005 mg/L)
- BCWQGL Chronic (0.002 mg/L)



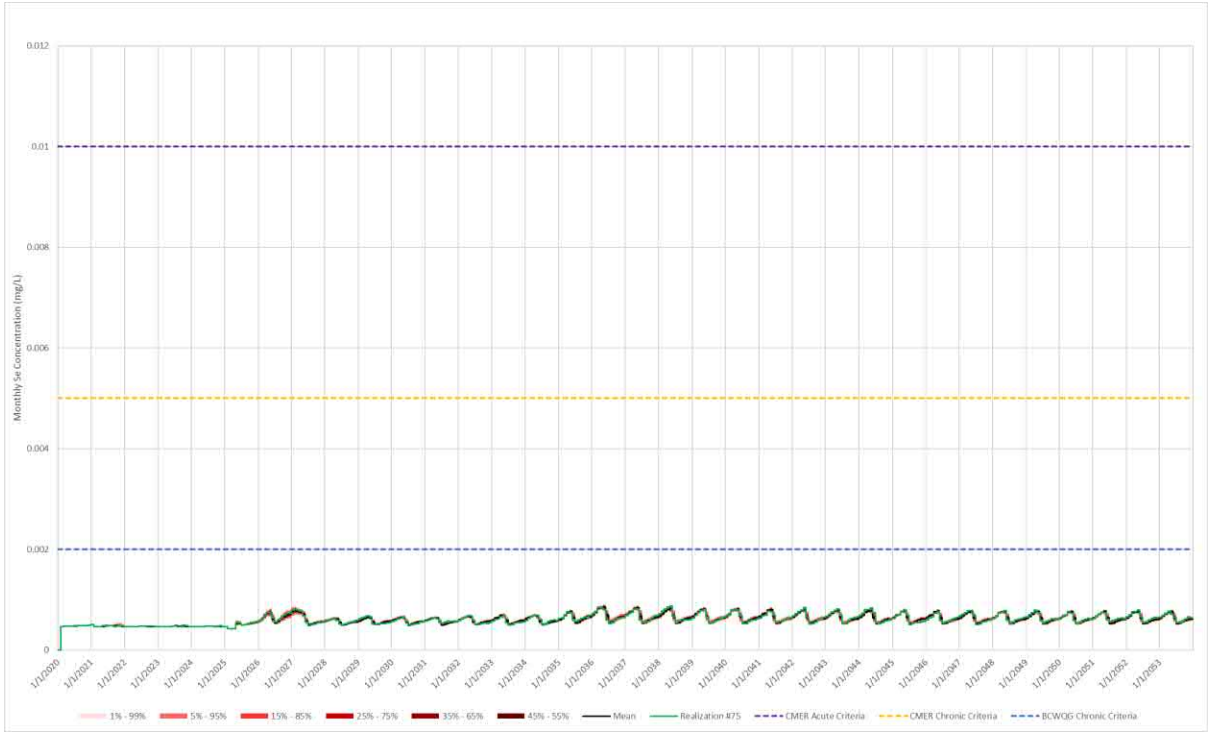
srk consulting

Location: Confluence of W. Alexander and U. Alexander Creek

Average Case (P_{50}) and Layer Approach Succeeds Selenium

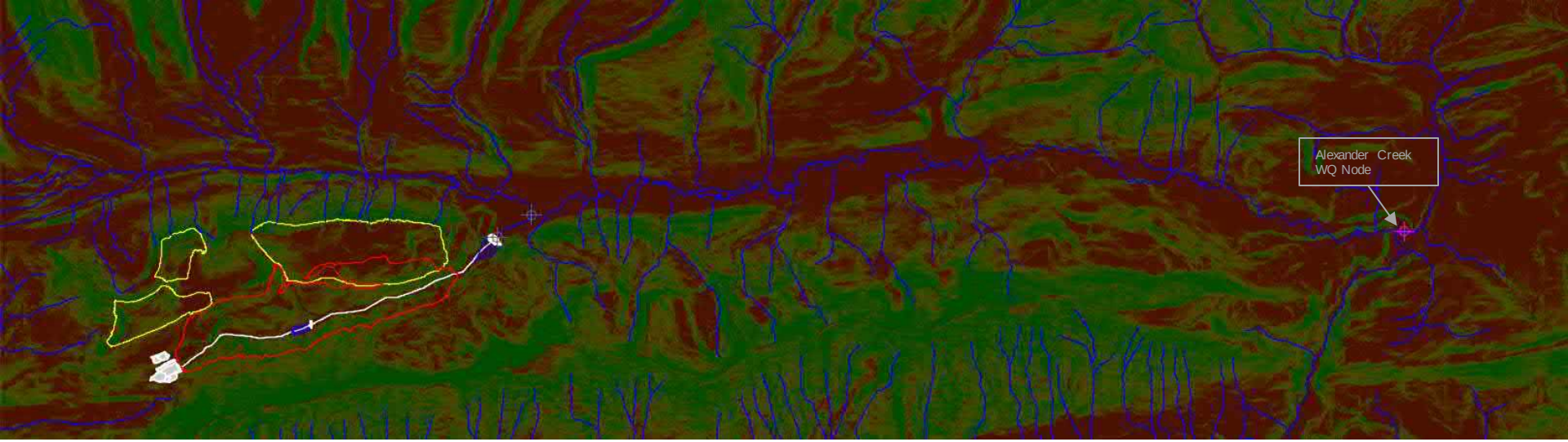
WQ Criteria Legend

- CMER Acute (0.01 mg/L)
- CMER Chronic (0.005 mg/L)
- BCWQGL Chronic (0.002 mg/L)



srk consulting

Location: Confluence of W. Alexander and U. Alexander Creek



WQ Results - Selenium

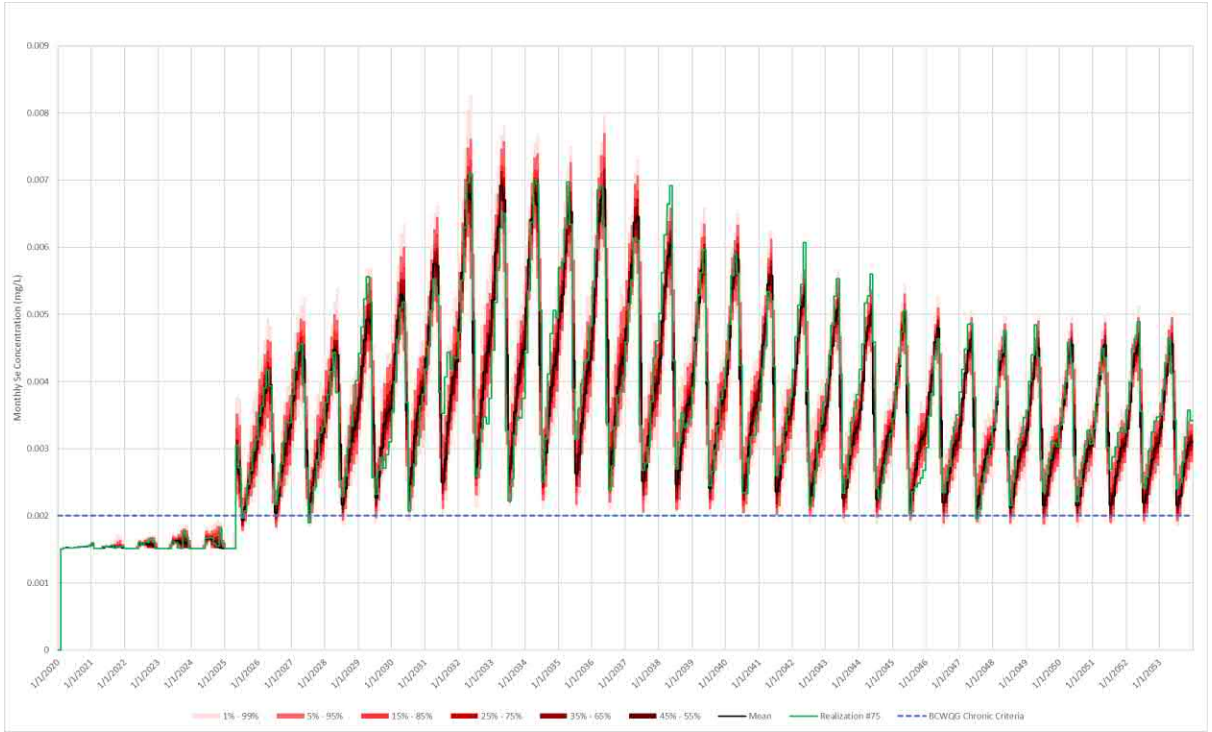
Upstream of Alexander Creek and Michel Creek Confluence

srk consulting

Upper Case (P_{95}) and Layer Approach Fails Selenium

WQ Criteria Legend

--- BCWQGL Chronic (0.002 mg/L)



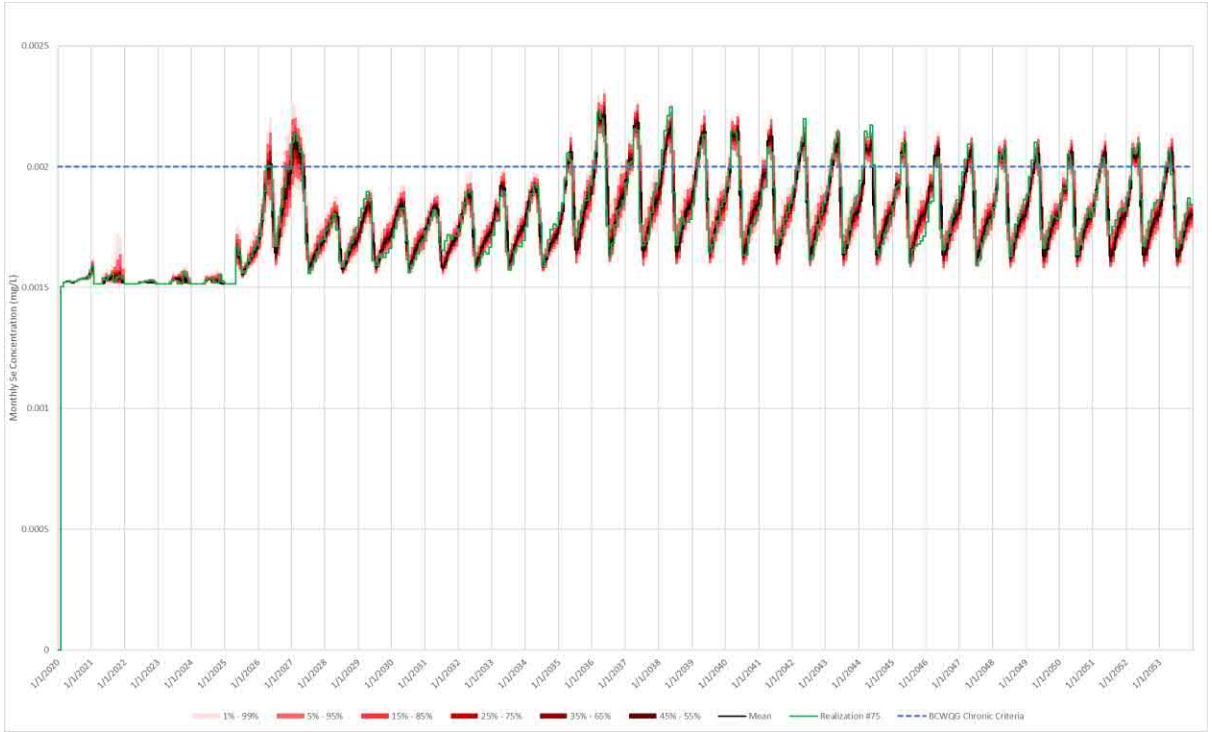
srk consulting

Location: Upstream of Alexander Creek and Michel Creek Confluence

Upper Case (P_{95}) and Layer Approach Succeeds Selenium

WQ Criteria Legend

--- BCWQGL Chronic (0.002 mg/L)

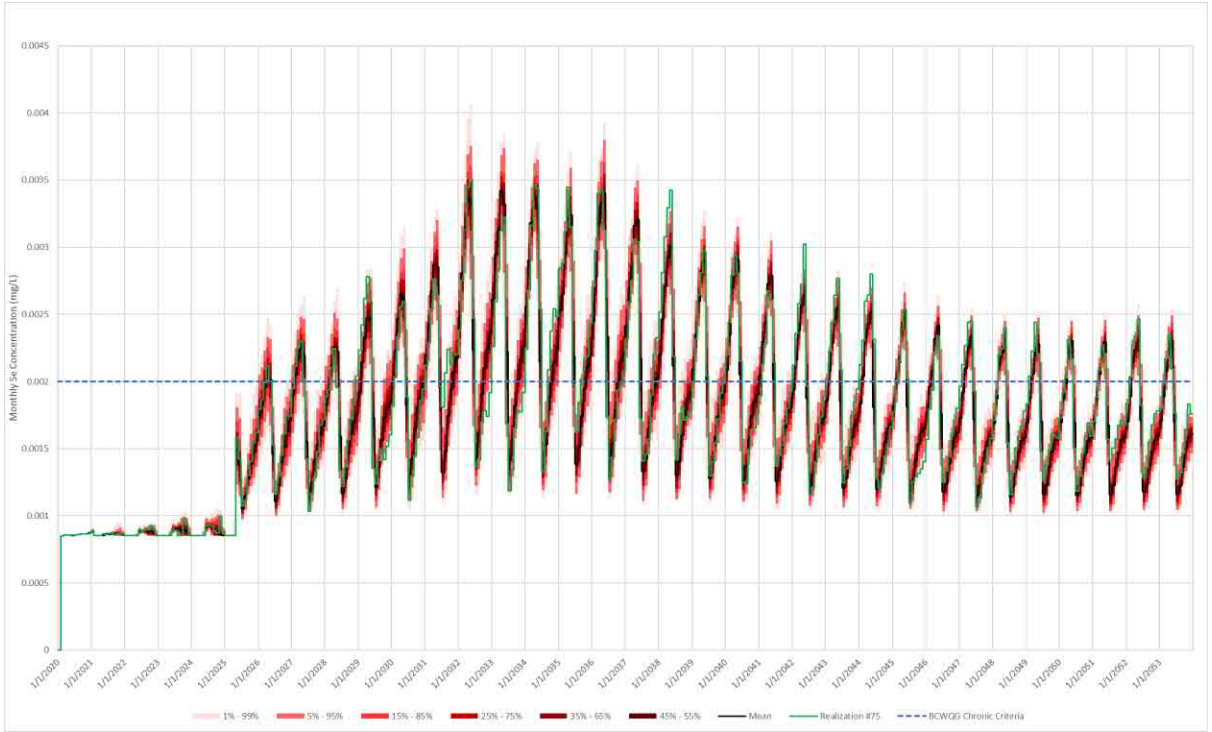


Location: Upstream of Alexander Creek and Michel Creek Confluence

Average Case (P_{50}) and Layer Approach Fails Selenium

WQ Criteria Legend

--- BCWQGL Chronic (0.002 mg/L)



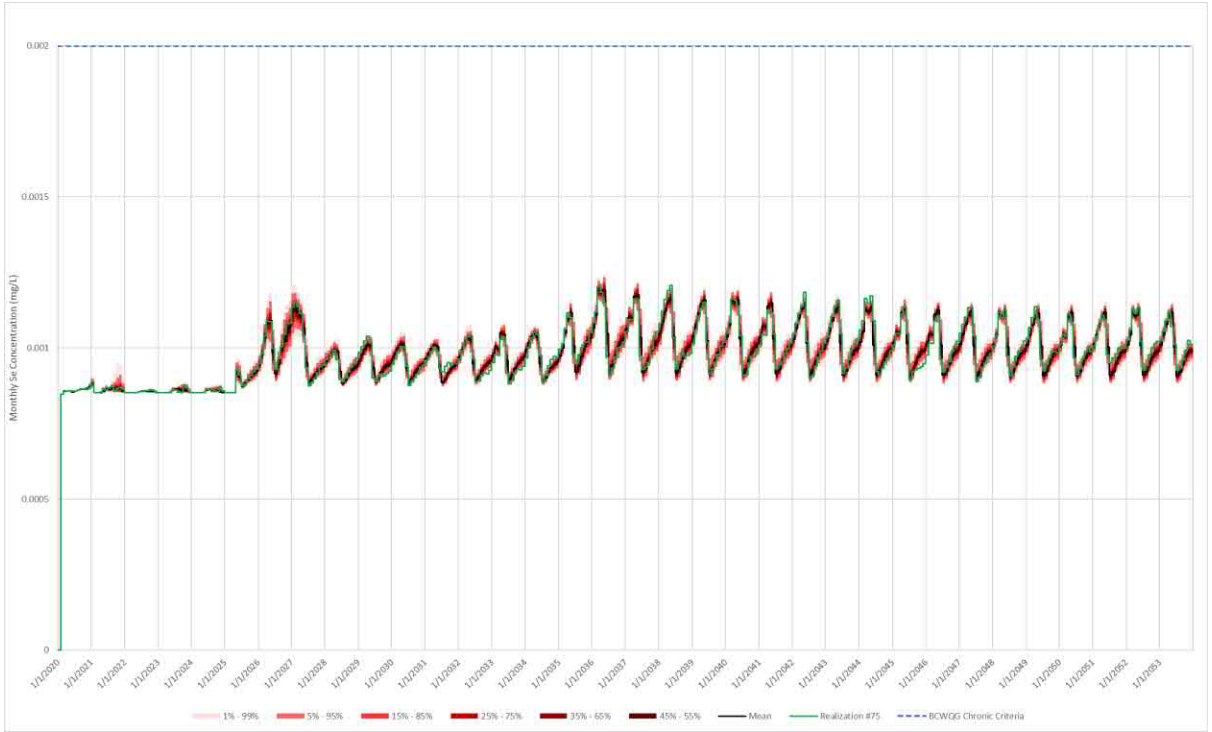
srk consulting

Location: Upstream of Alexander Creek and Michel Creek Confluence

Average Case (P_{50}) and Layer Approach Succeeds Selenium

WQ Criteria Legend

--- BCWQGL Chronic (0.002 mg/L)



Location: Upstream of Alexander Creek and Michel Creek Confluence

WQ Results - Selenium

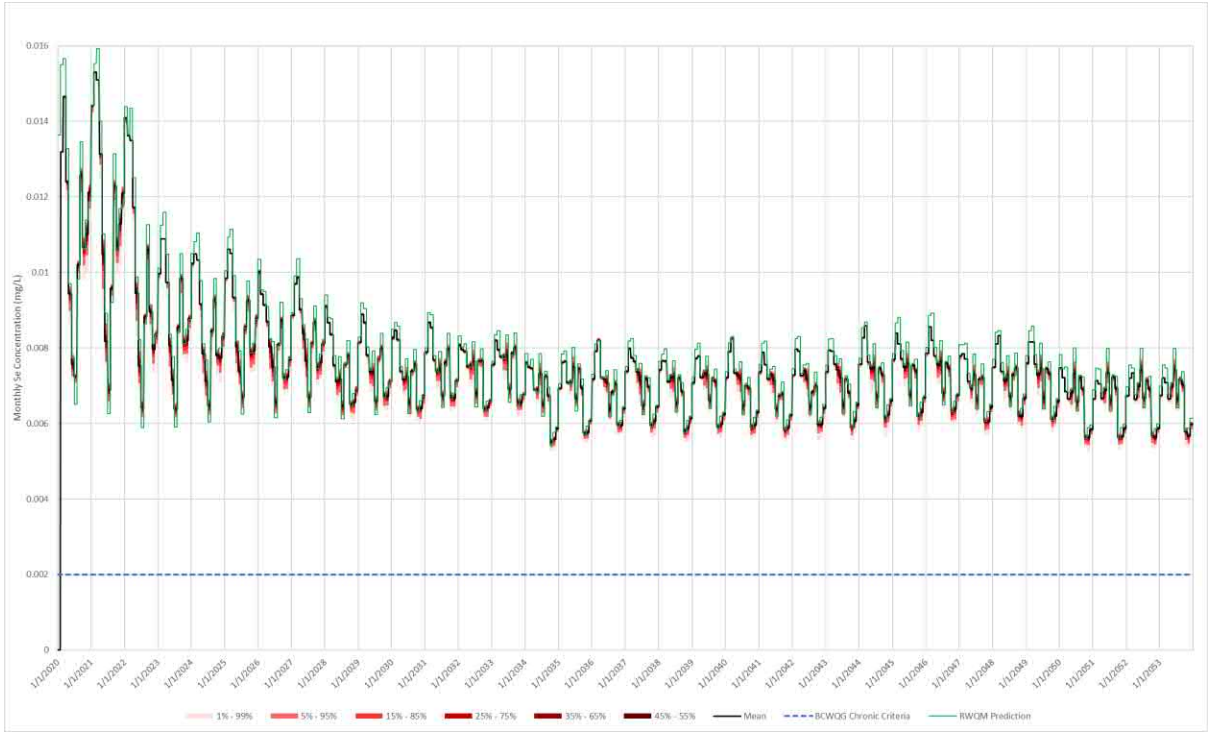
EV_ER1 Station at Sparwood

srk consulting

Upper Case (P_{95}) and Layer Approach Fails Selenium

WQ Criteria Legend

--- BCWQGL Chronic (0.002 mg/L)



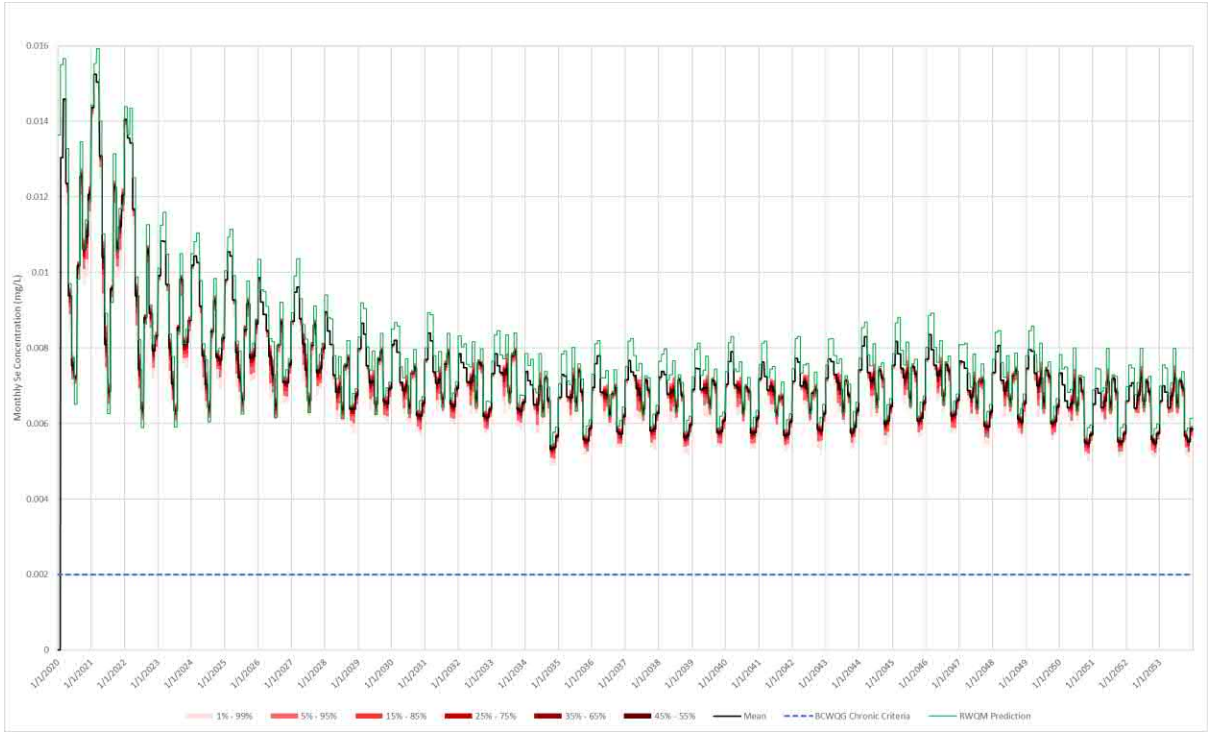
srk consulting

Location: EV_ER1 Station at Sparwood

Average Case (P_{50}) and Layer Approach Succeeds Selenium

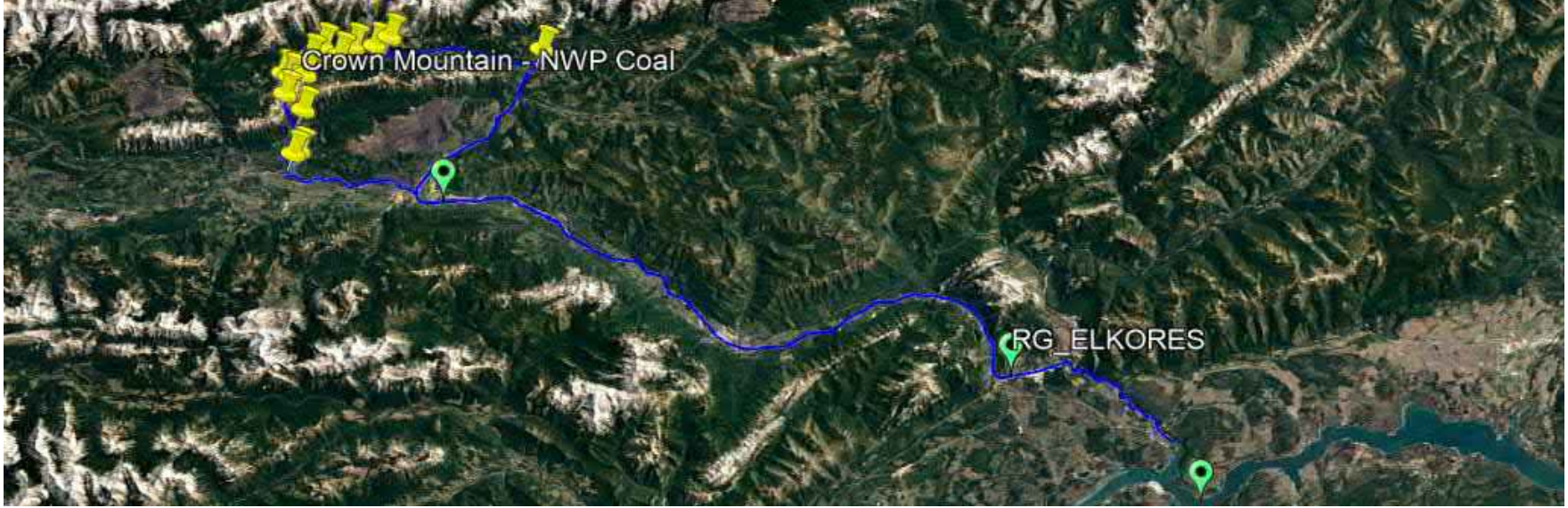
WQ Criteria Legend

--- BCWQGL Chronic (0.002 mg/L)



srk consulting

Location: EV_ER1 Station at Sparwood



WQ Results - Selenium

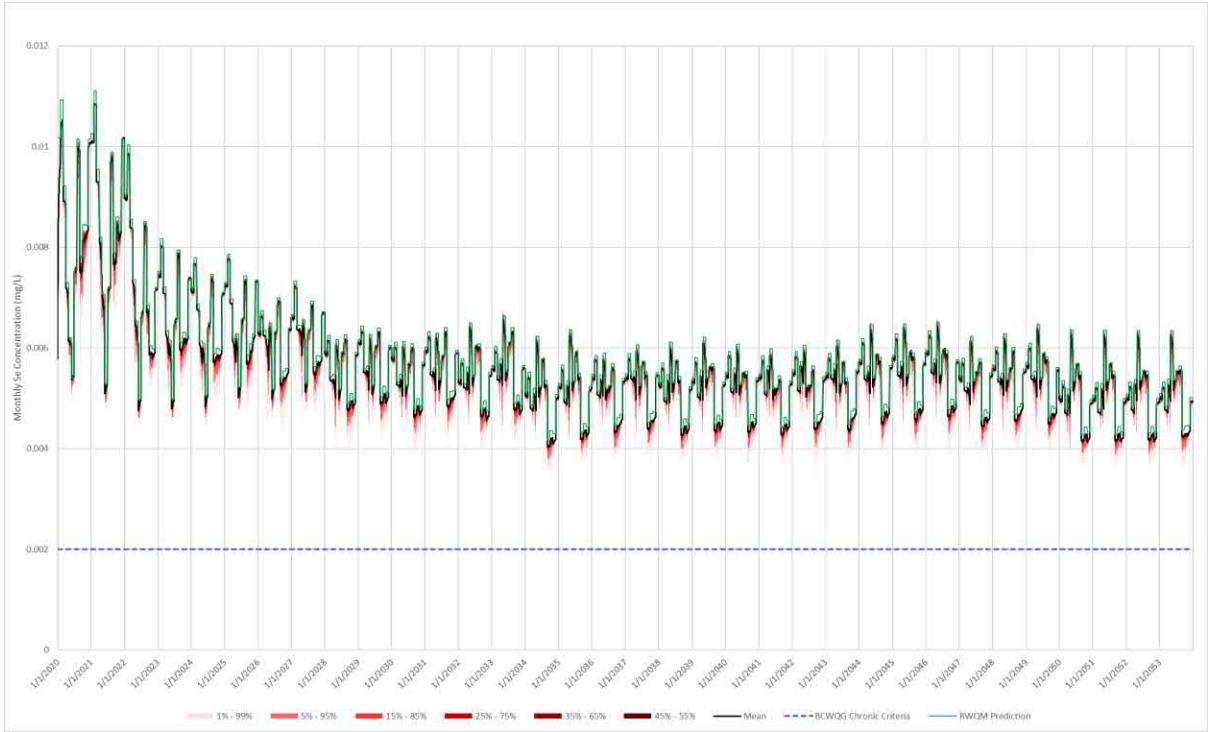
RG_ELKORES Station at Elko Reservoir

srk consulting

Upper Case (P_{95}) and Layer Approach Fails Selenium

WQ Criteria Legend

--- BCWQGL Chronic (0.002 mg/L)

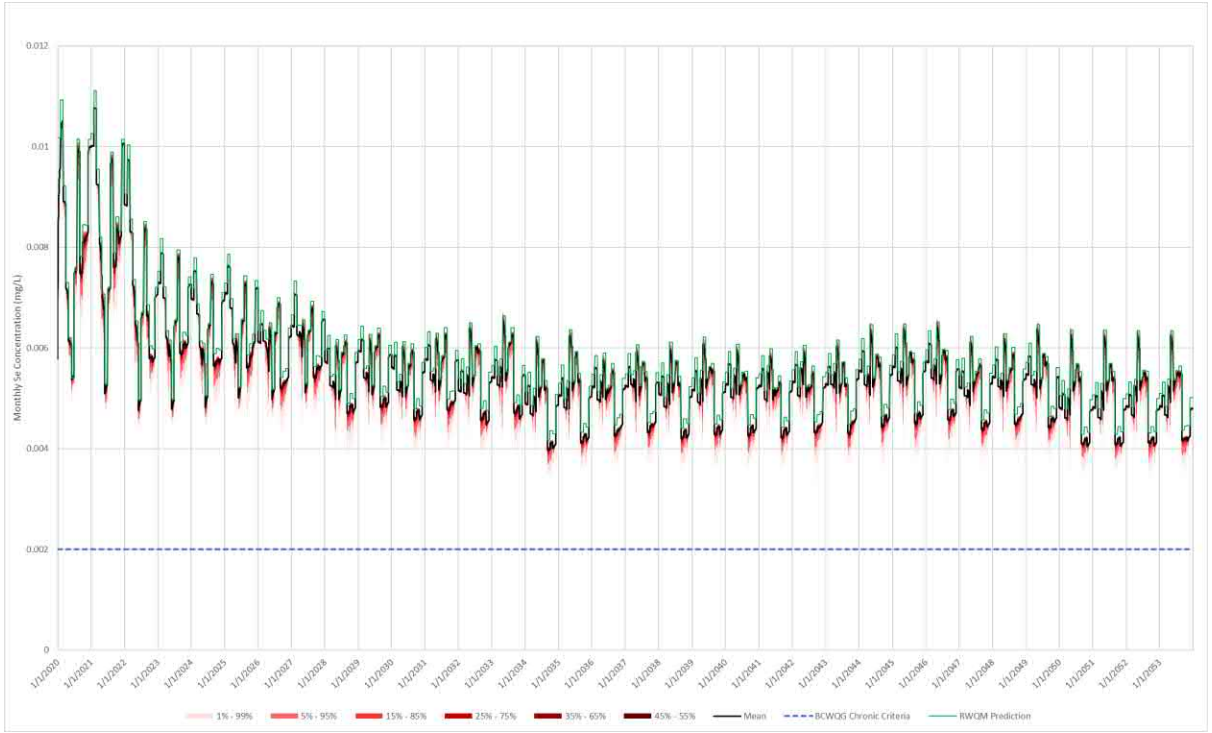


Location: RG_ELKORES Station at Elko Reservoir

Average Case (P_{50}) and Layer Approach Succeeds Selenium

WQ Criteria Legend

--- BCWQGL Chronic (0.002 mg/L)



Location: RG_ELKORES Station at Elko Reservoir

WQ Results - Selenium

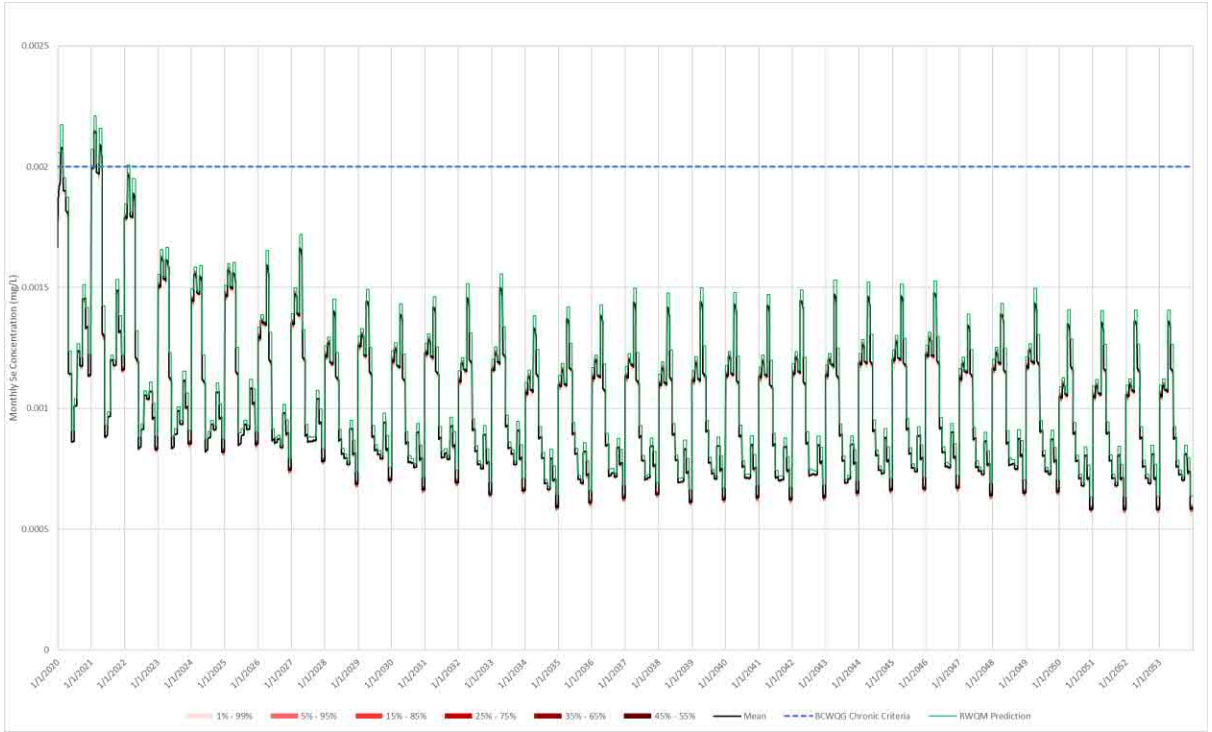
RG_DSELK Station at Lake Koocanusa

srk consulting

Upper Case (P_{95}) and Layer Approach Fails Selenium

WQ Criteria Legend

--- BCWQGL Chronic (0.002 mg/L)

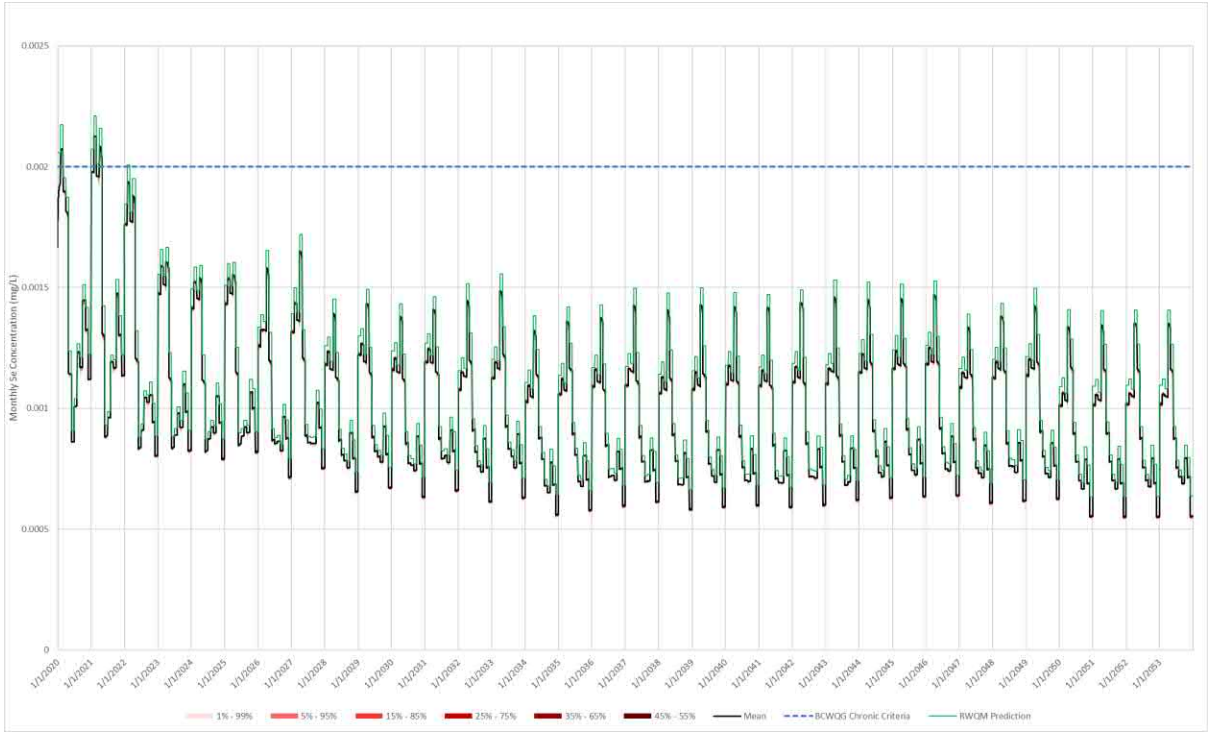


Location: RG_DSELK Station at Lake Koocanusa

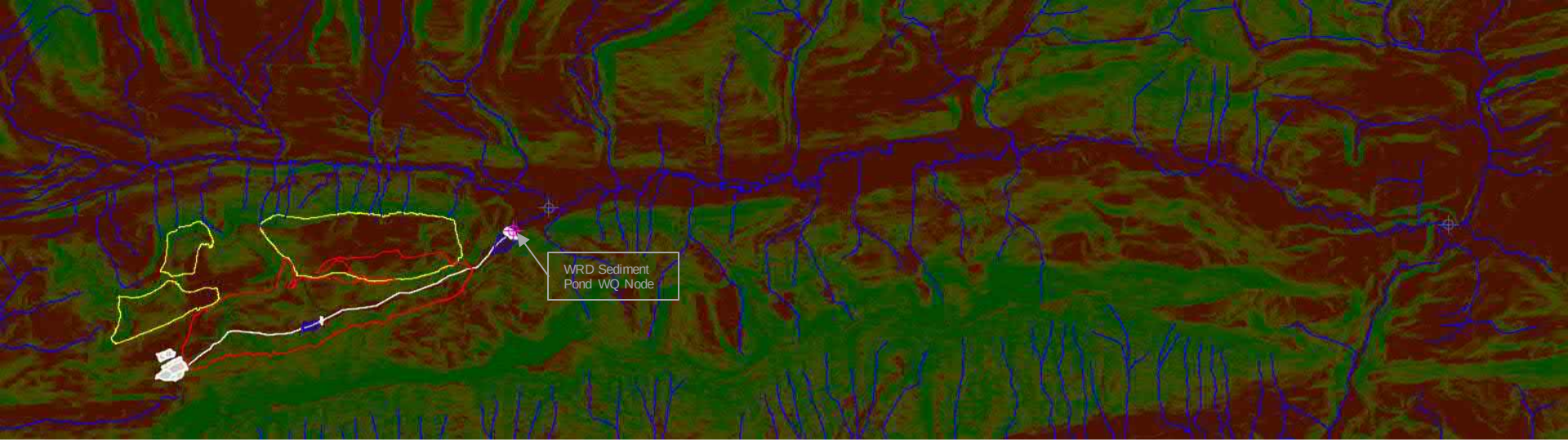
Average Case (P_{50}) and Layer Approach Succeeds Selenium

WQ Criteria Legend

--- BCWQGL Chronic (0.002 mg/L)



Location: RG_DSELK Station at Lake Koocanusa



WQ Results - Nitrate

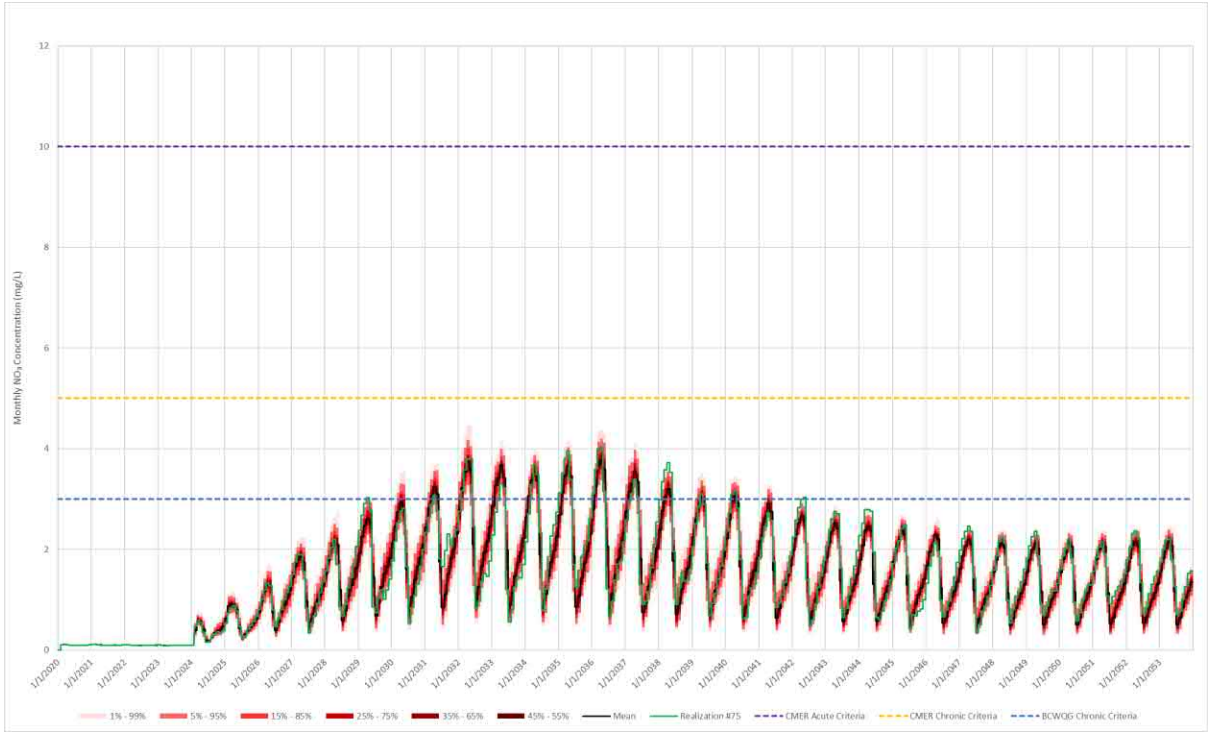
WRD Sedimentation Pond (Interim and Ultimate)

srk consulting

Upper Case (P_{95}) and Layer Approach Fails Nitrate

WQ Criteria Legend

- CMER Acute (10 mg/L)
- CMER Chronic (5 mg/L)
- BCWQGL Chronic (3 mg/L)



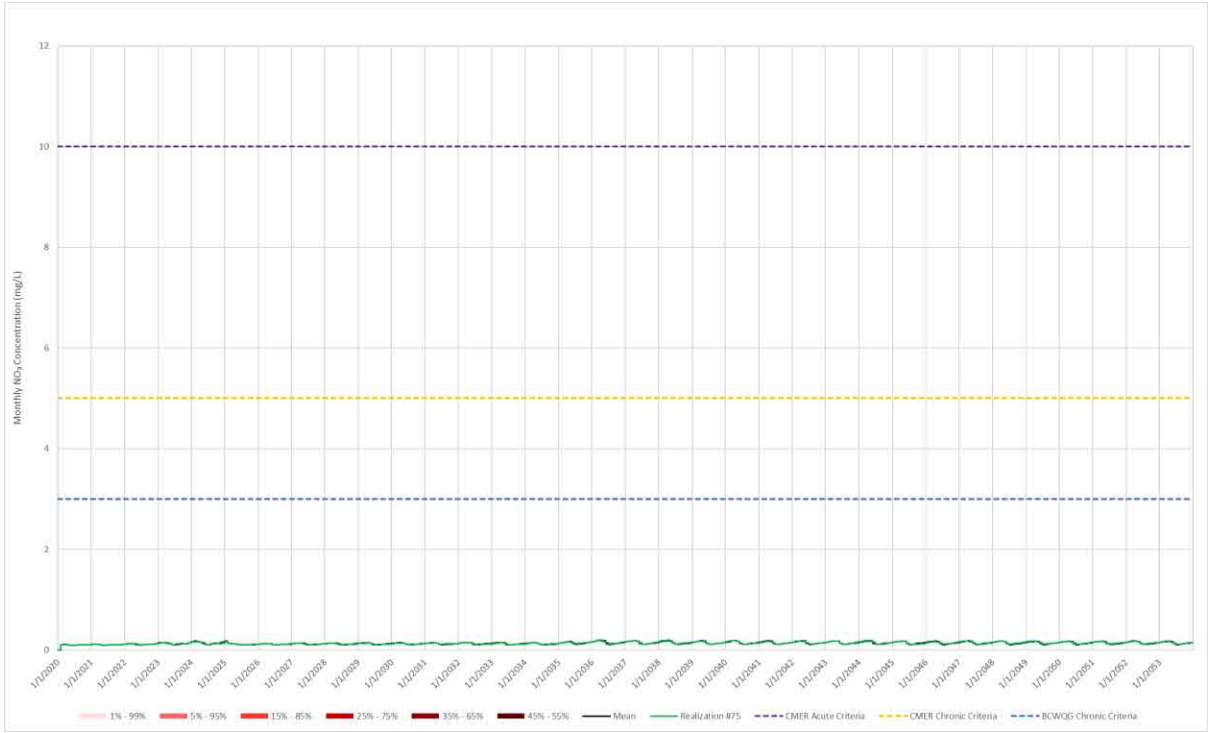
srk consulting

Location: WRD Sedimentation Pond

Upper Case (P_{95}) and Layer Approach Succeeds Nitrate

WQ Criteria Legend

- CMER Acute (10 mg/L)
- CMER Chronic (5 mg/L)
- BCWQGL Chronic (3 mg/L)



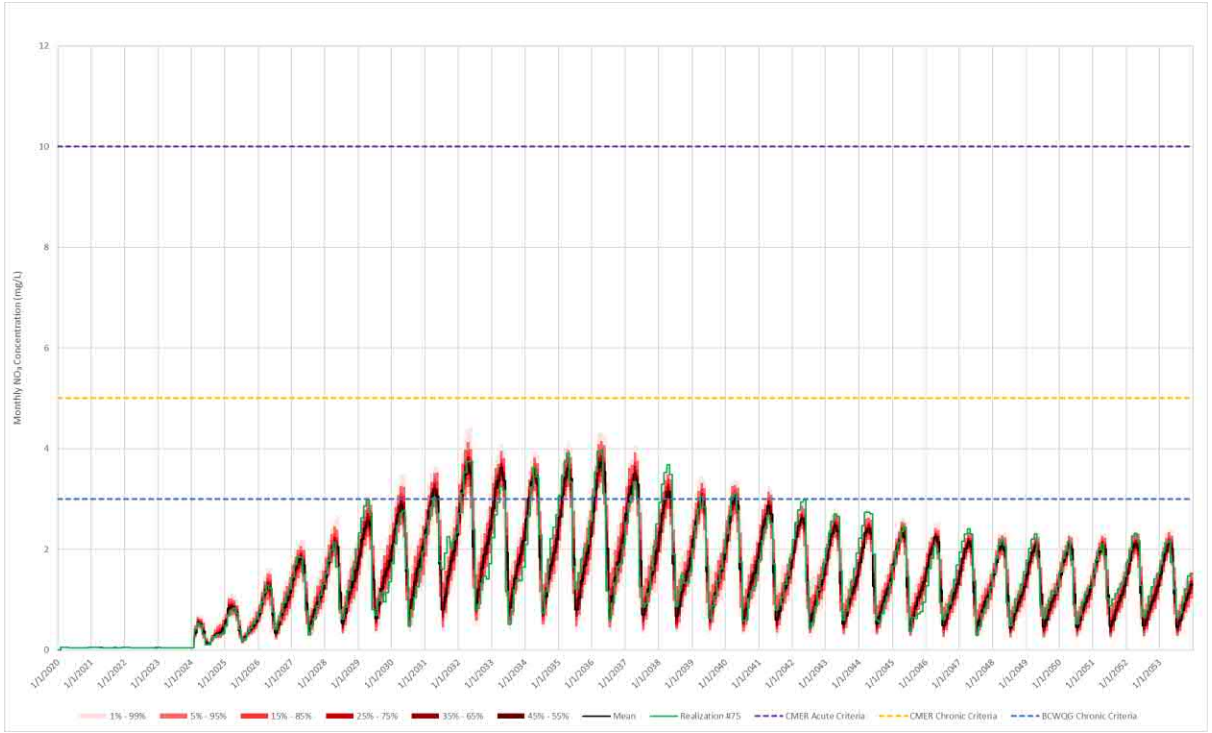
srk consulting

Location: WRD Sedimentation Pond

Average Case (P_{50}) and Layer Approach Fails Nitrate

WQ Criteria Legend

- CMER Acute (10 mg/L)
- CMER Chronic (5 mg/L)
- BCWQGL Chronic (3 mg/L)



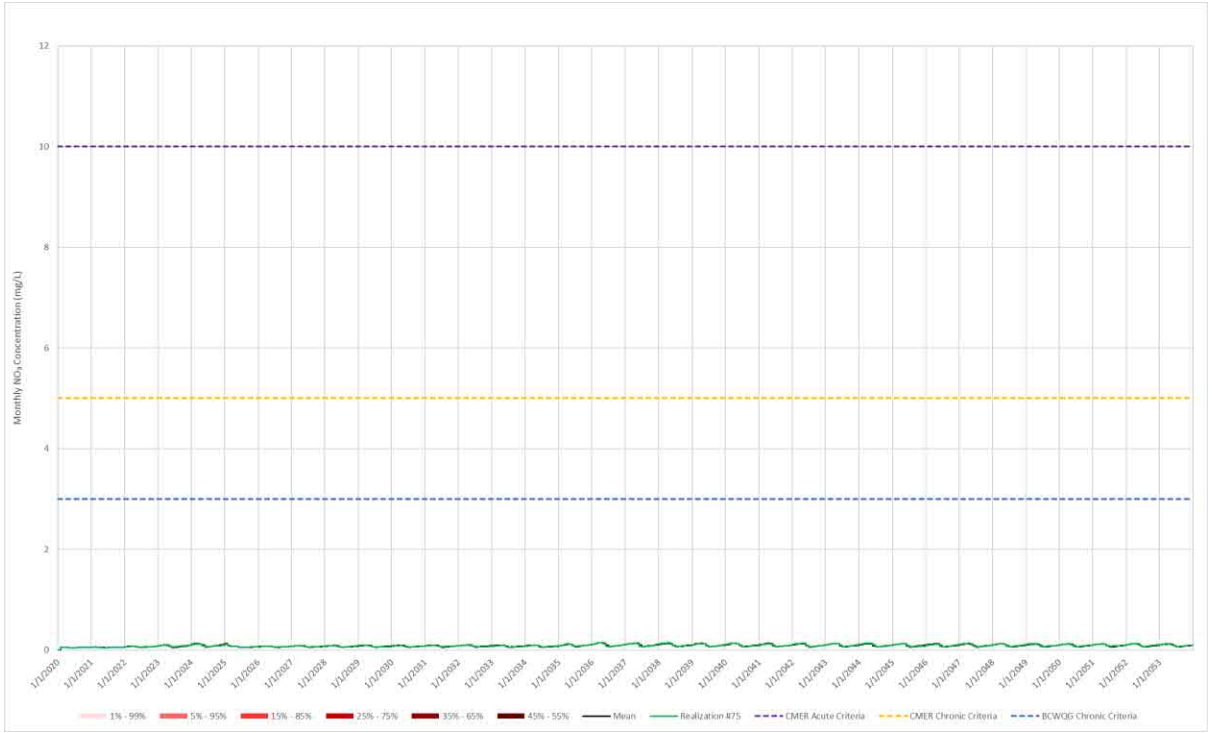
srk consulting

Location: WRD Sedimentation Pond

Average Case (P_{50}) and Layer Approach Succeeds Nitrate

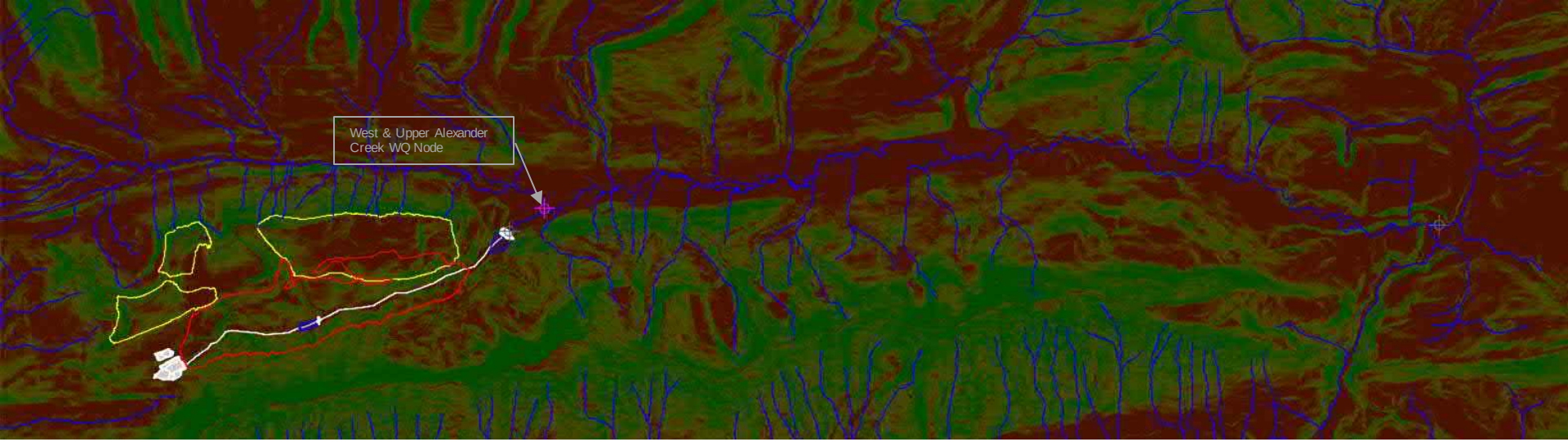
WQ Criteria Legend

- CMER Acute (10 mg/L)
- CMER Chronic (5 mg/L)
- BCWQGL Chronic (3 mg/L)



srk consulting

Location: WRD Sedimentation Pond



WQ Results - Nitrate

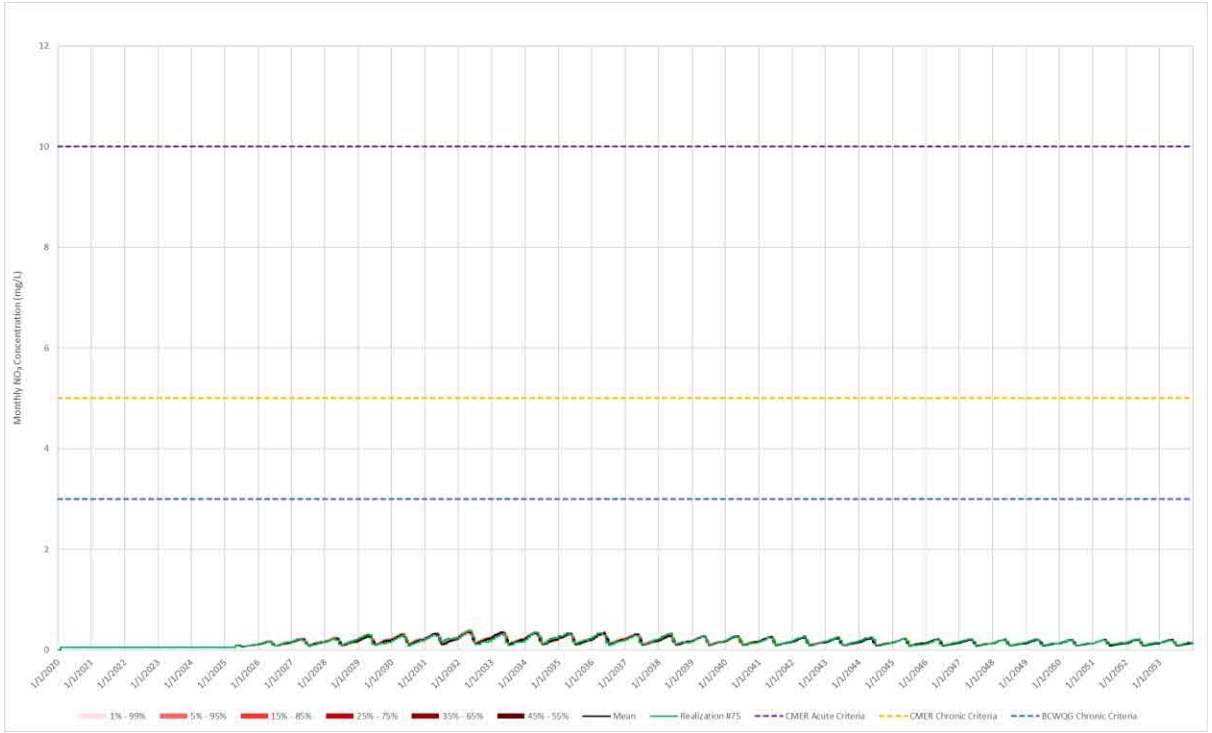
Confluence of West Alexander Creek and Upper Alexander Creek

srk consulting

Upper Case (P_{95}) and Layer Approach Fails Nitrate

WQ Criteria Legend

- CMER Acute (10 mg/L)
- CMER Chronic (5 mg/L)
- BCWQGL Chronic (3 mg/L)



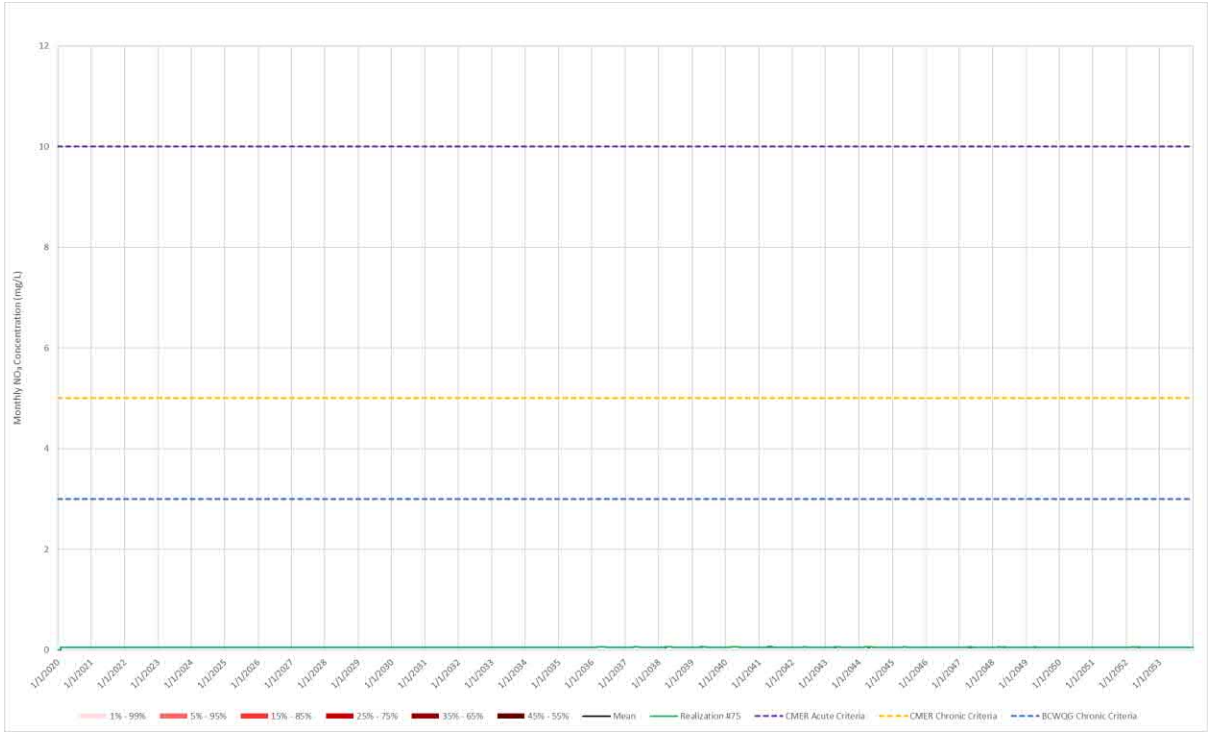
srk consulting

Location: Confluence of W. Alexander and U. Alexander Creek

Upper Case (P_{95}) and Layer Approach Succeeds Nitrate

WQ Criteria Legend

- CMER Acute (10 mg/L)
- CMER Chronic (5 mg/L)
- BCWQGL Chronic (3 mg/L)

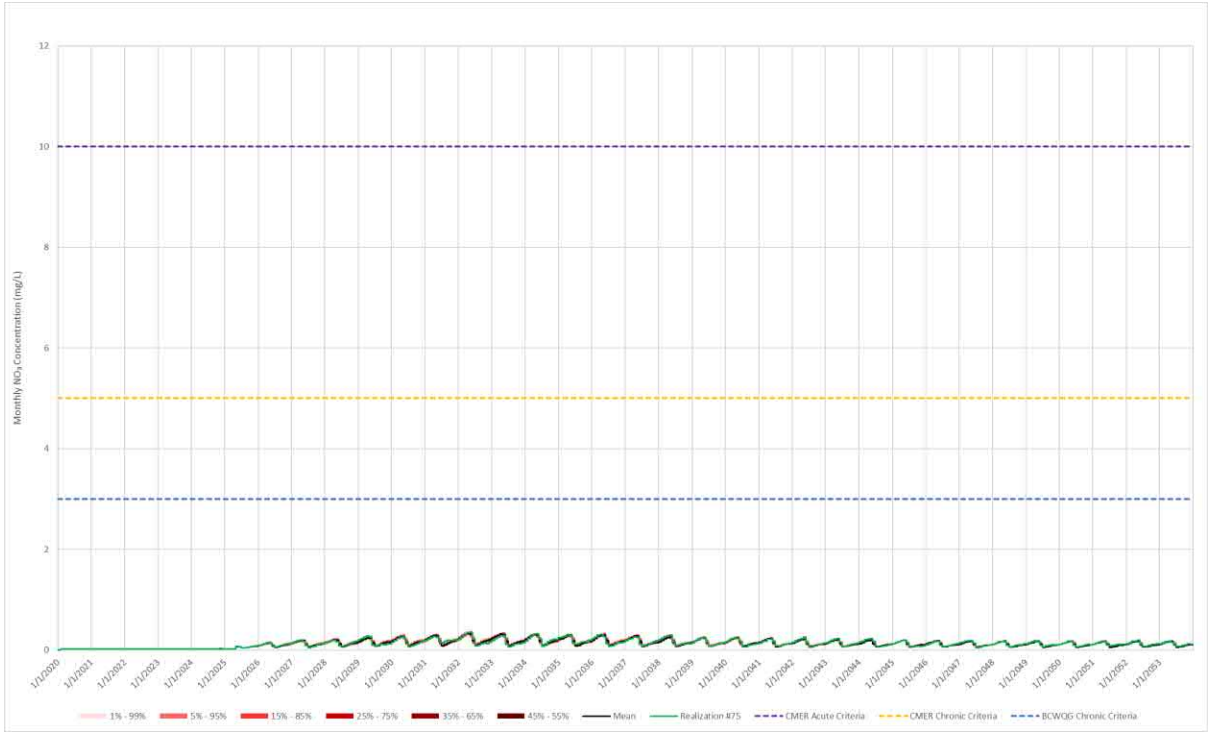


Location: Confluence of W. Alexander and U. Alexander Creek

Average Case (P_{50}) and Layer Approach Fails Nitrate

WQ Criteria Legend

- CMER Acute (10 mg/L)
- CMER Chronic (5 mg/L)
- BCWQGL Chronic (3 mg/L)

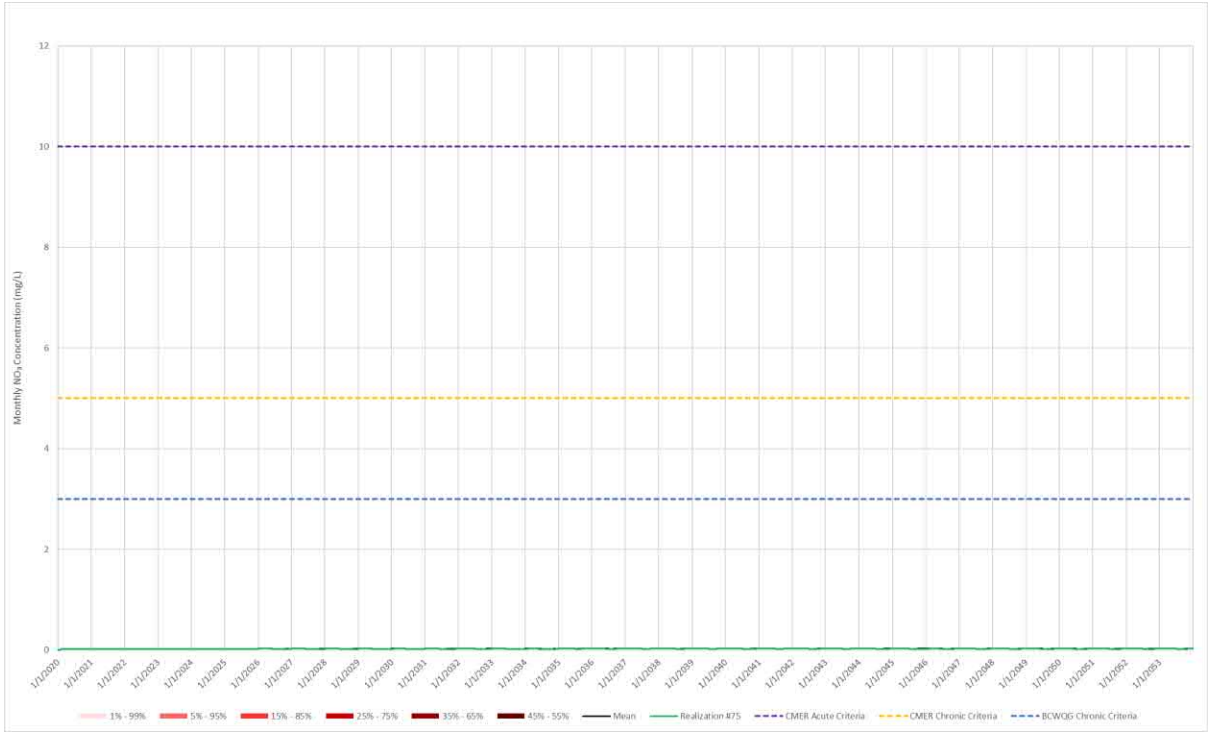


Location: Confluence of W. Alexander and U. Alexander Creek

Average Case (P_{50}) and Layer Approach Succeeds Nitrate

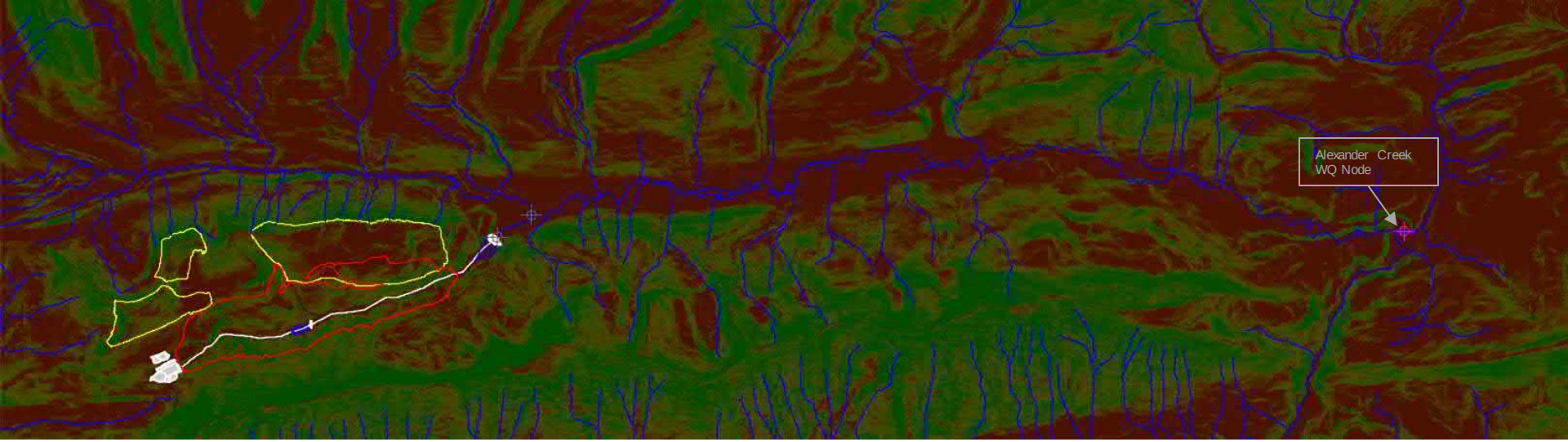
WQ Criteria Legend

- CMER Acute (10 mg/L)
- CMER Chronic (5 mg/L)
- BCWQGL Chronic (3 mg/L)



srk consulting

Location: Confluence of W. Alexander and U. Alexander Creek



WQ Results - Nitrate

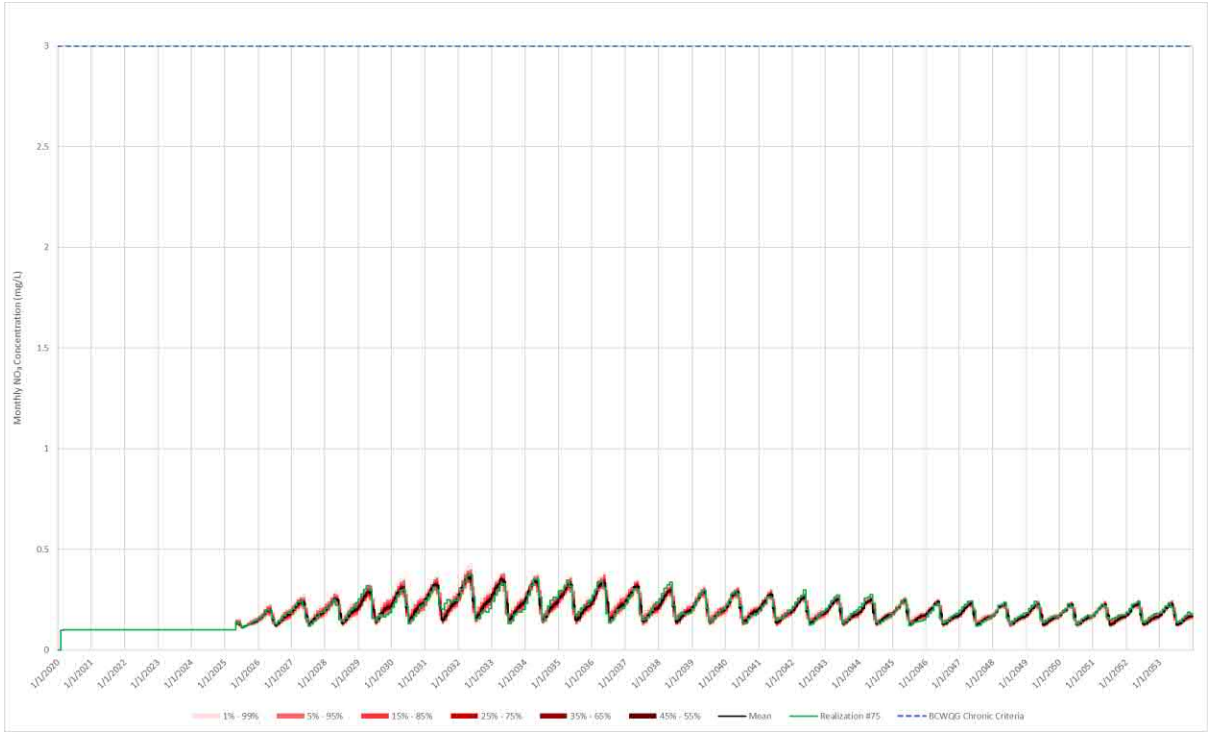
Upstream of Alexander Creek and Michel Creek Confluence

srk consulting

Upper Case (P_{95}) and Layer Approach Fails Nitrate

WQ Criteria Legend

--- BCWQGL Chronic (3 mg/L)



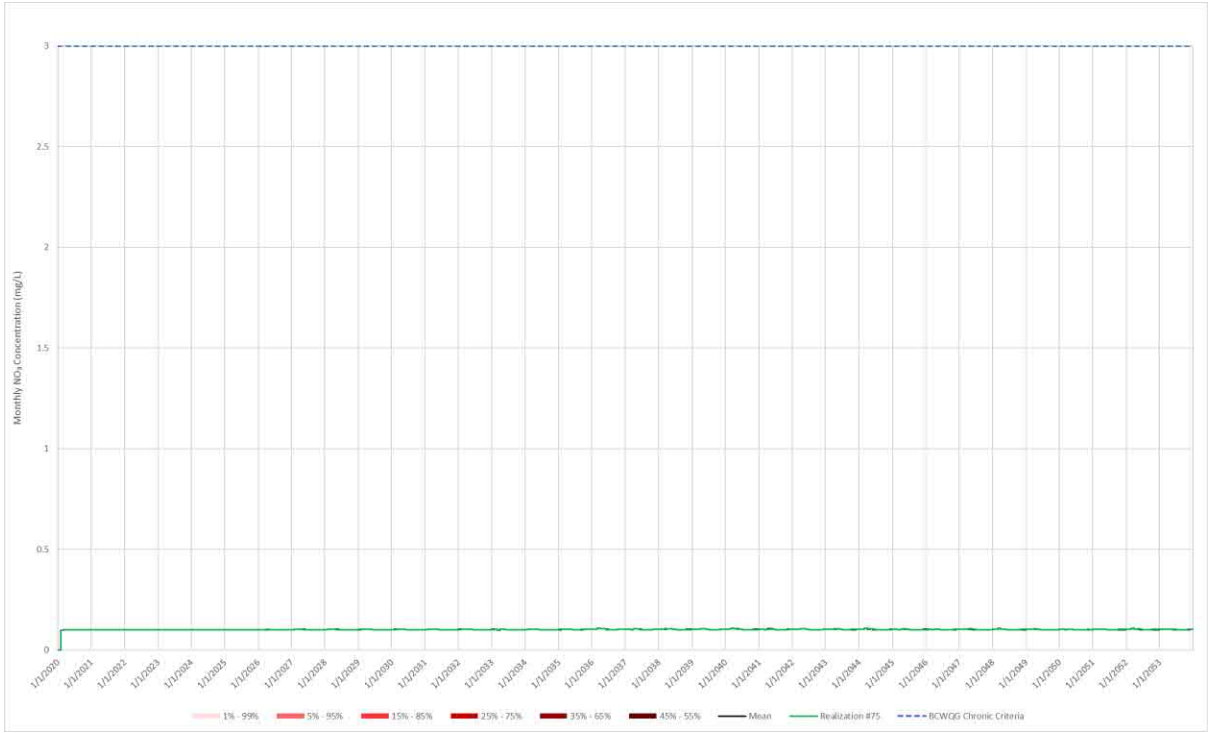
srk consulting

Location: Upstream of Alexander Creek and Michel Creek Confluence

Upper Case (P_{95}) and Layer Approach Succeeds Nitrate

WQ Criteria Legend

--- BCWQGL Chronic (3 mg/L)



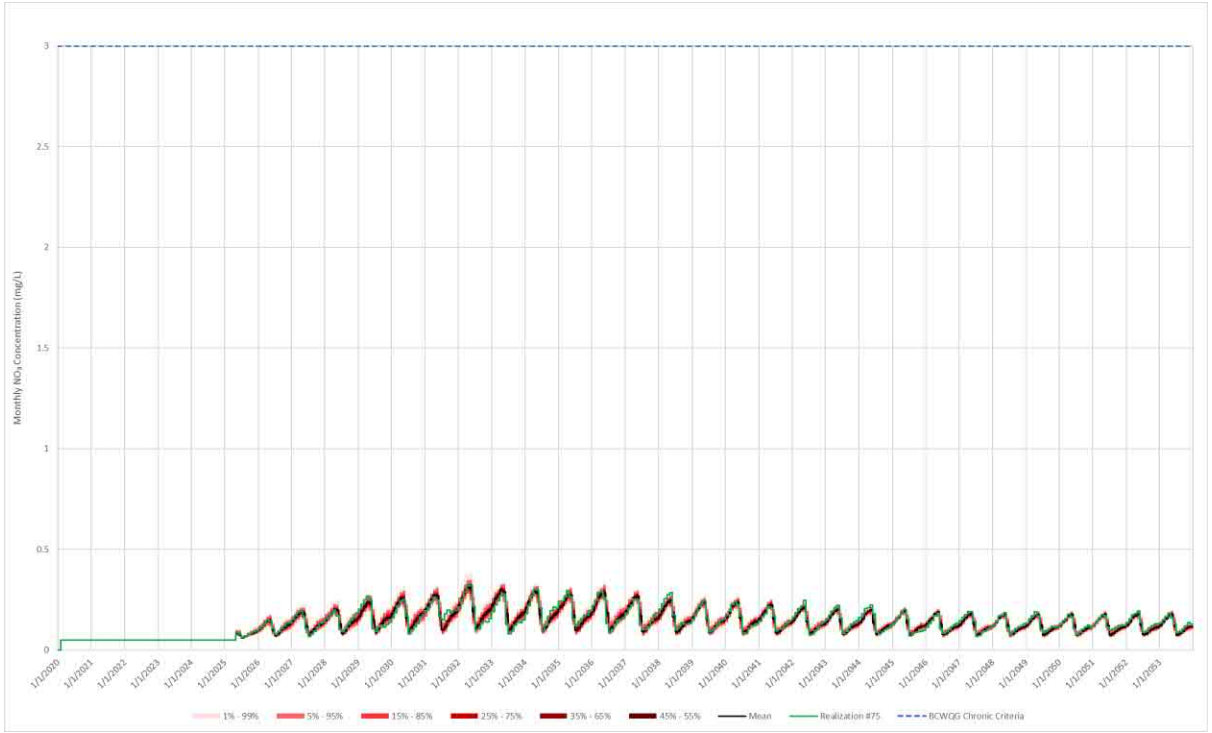
srk consulting

Location: Upstream of Alexander Creek and Michel Creek Confluence

Average Case (P_{50}) and Layer Approach Fails Nitrate

WQ Criteria Legend

--- BCWQGL Chronic (3 mg/L)



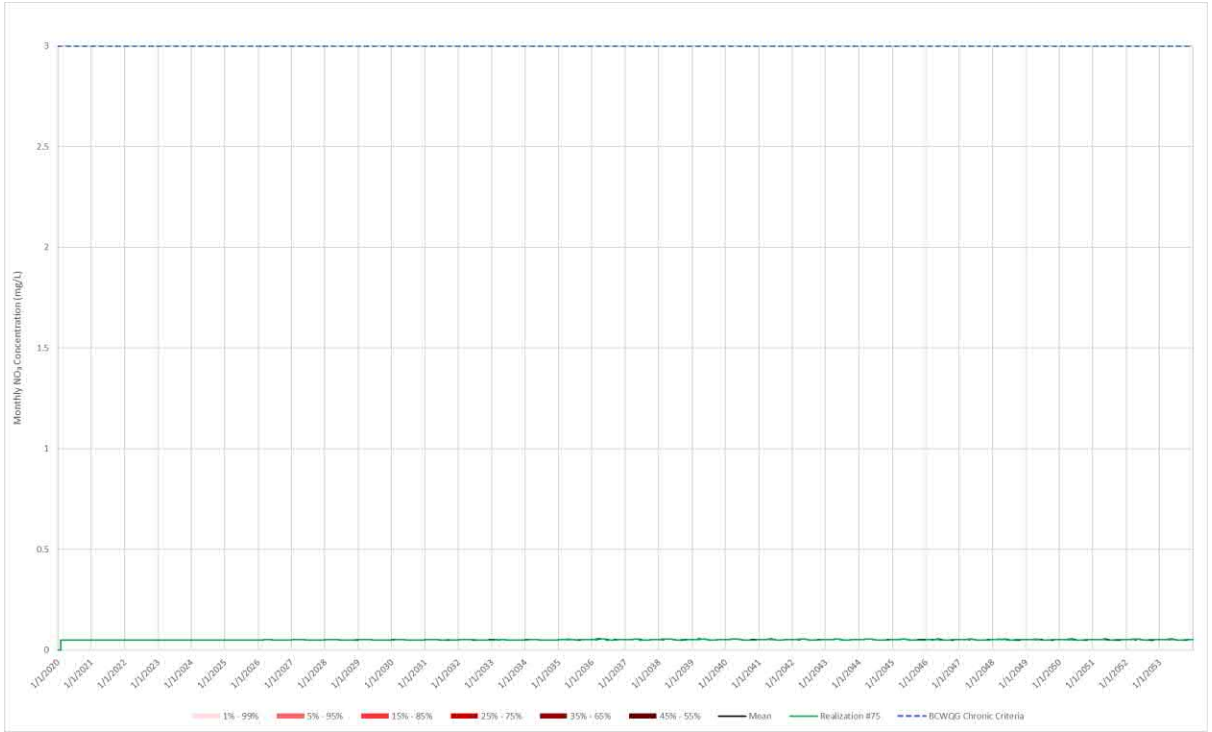
srk consulting

Location: Upstream of Alexander Creek and Michel Creek Confluence

Average Case (P_{50}) and Layer Approach Succeeds Nitrate

WQ Criteria Legend

--- BCWQGL Chronic (3 mg/L)



srk consulting

Location: Upstream of Alexander Creek and Michel Creek Confluence

WQ Results - Nitrate

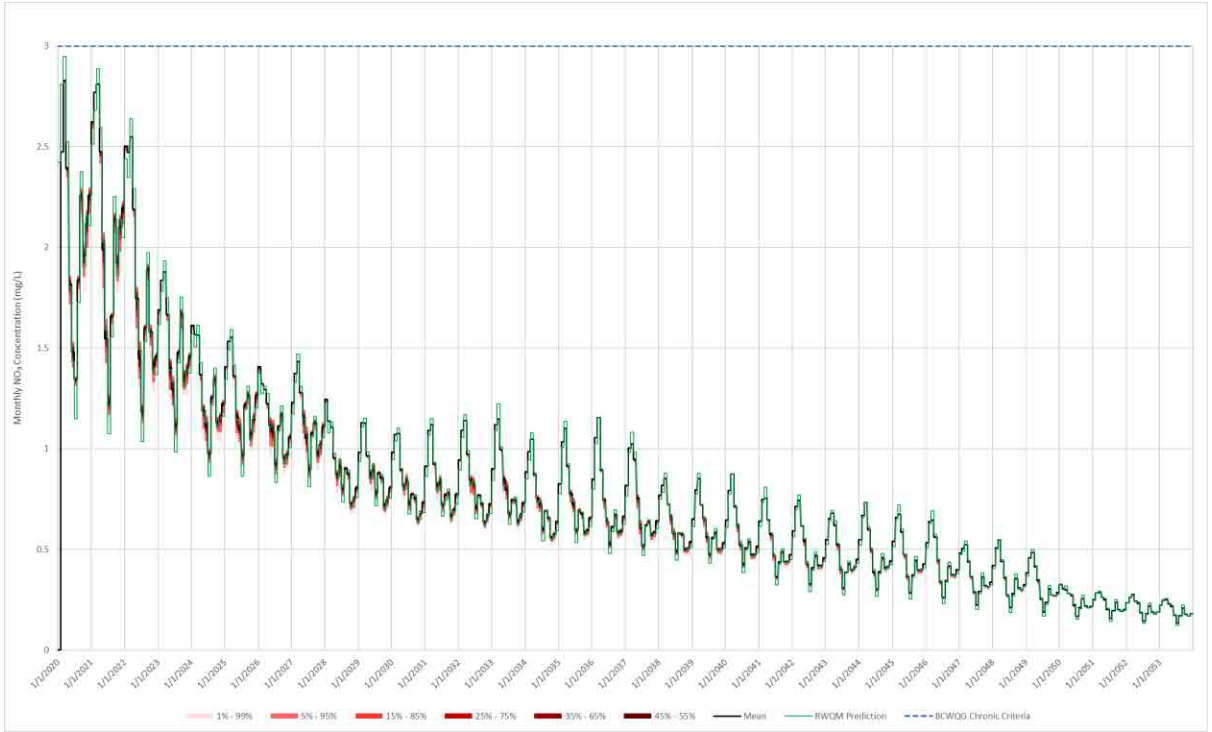
EV_ER1 Station at Sparwood

srk consulting

Upper Case (P_{95}) and Layer Approach Fails Nitrate

WQ Criteria Legend

--- BCWQGL Chronic (3 mg/L)



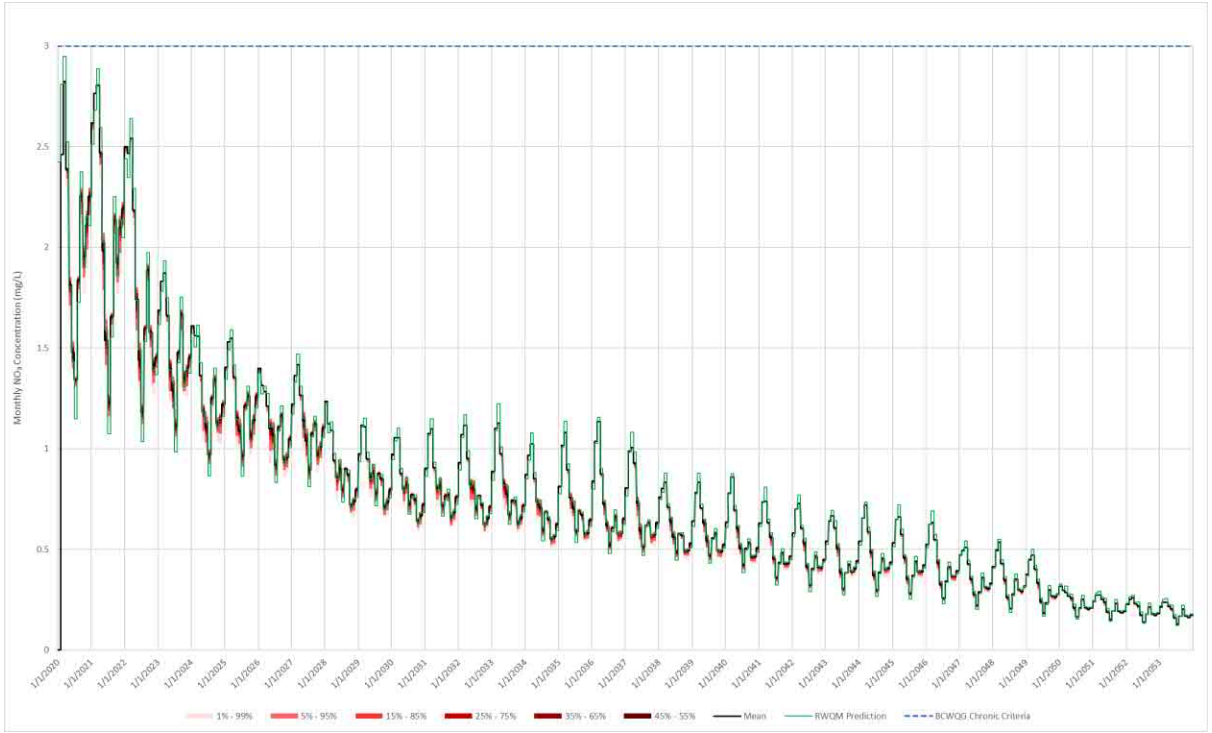
srk consulting

Location: EV_ER1 Station at Sparwood

Average Case (P_{50}) and Layer Approach Succeeds Nitrate

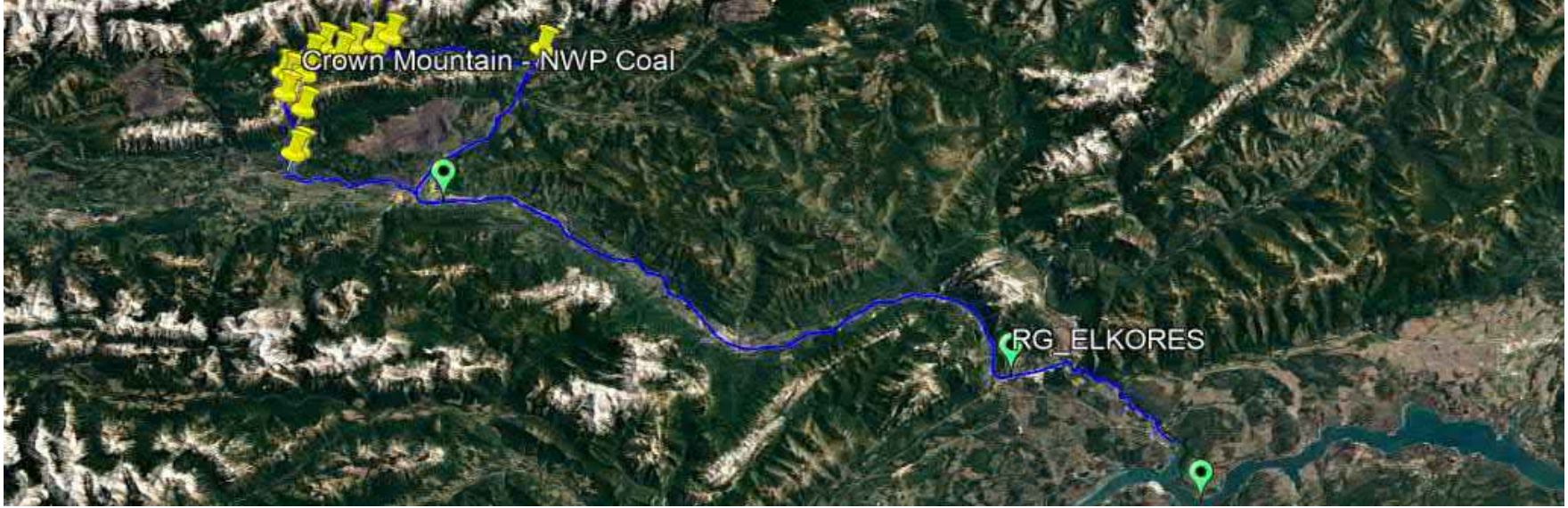
WQ Criteria Legend

--- BCWQGL Chronic (3 mg/L)



srk consulting

Location: EV_ER1 Station at Sparwood



WQ Results - Nitrate

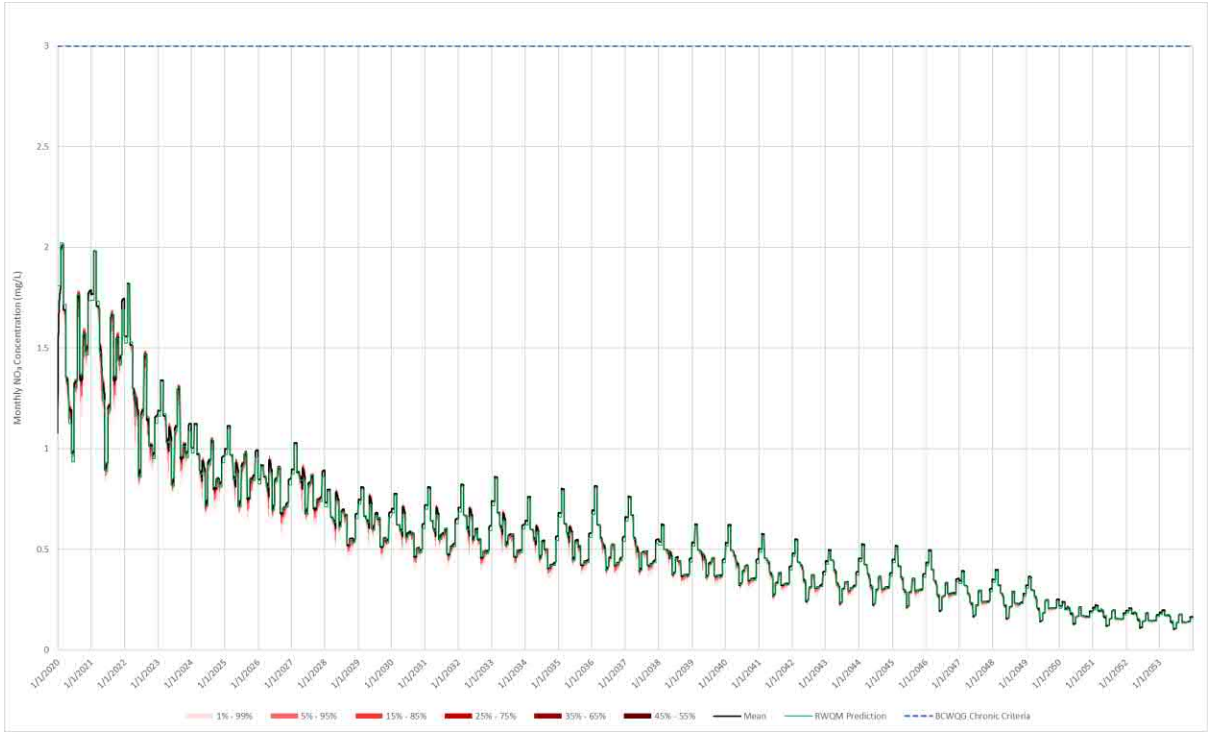
RG_ELKORES Station at Elko Reservoir

srk consulting

Upper Case (P_{95}) and Layer Approach Fails Nitrate

WQ Criteria Legend

--- BCWQGL Chronic (3 mg/L)



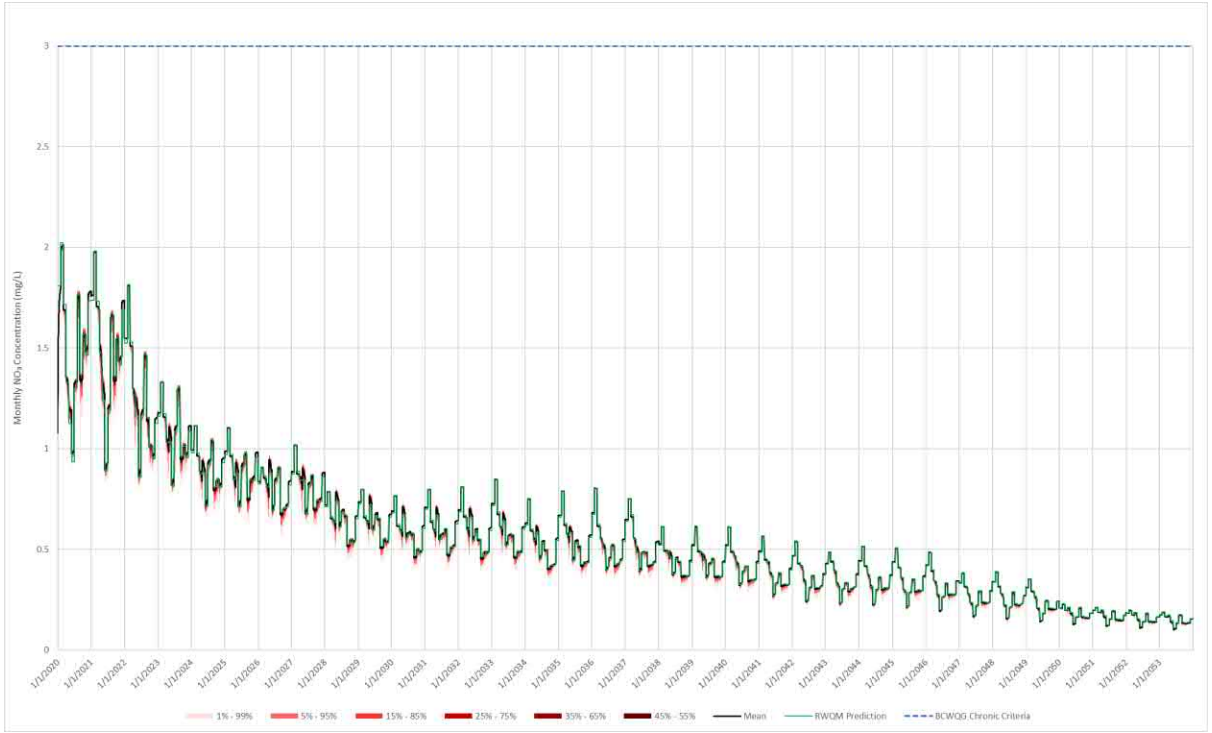
srk consulting

Location: RG_ELKORES Station at Elko Reservoir

Average Case (P_{50}) and Layer Approach Succeeds Nitrate

WQ Criteria Legend

--- BCWQGL Chronic (3 mg/L)



Location: RG_ELKORES Station at Elko Reservoir

WQ Results - Nitrate

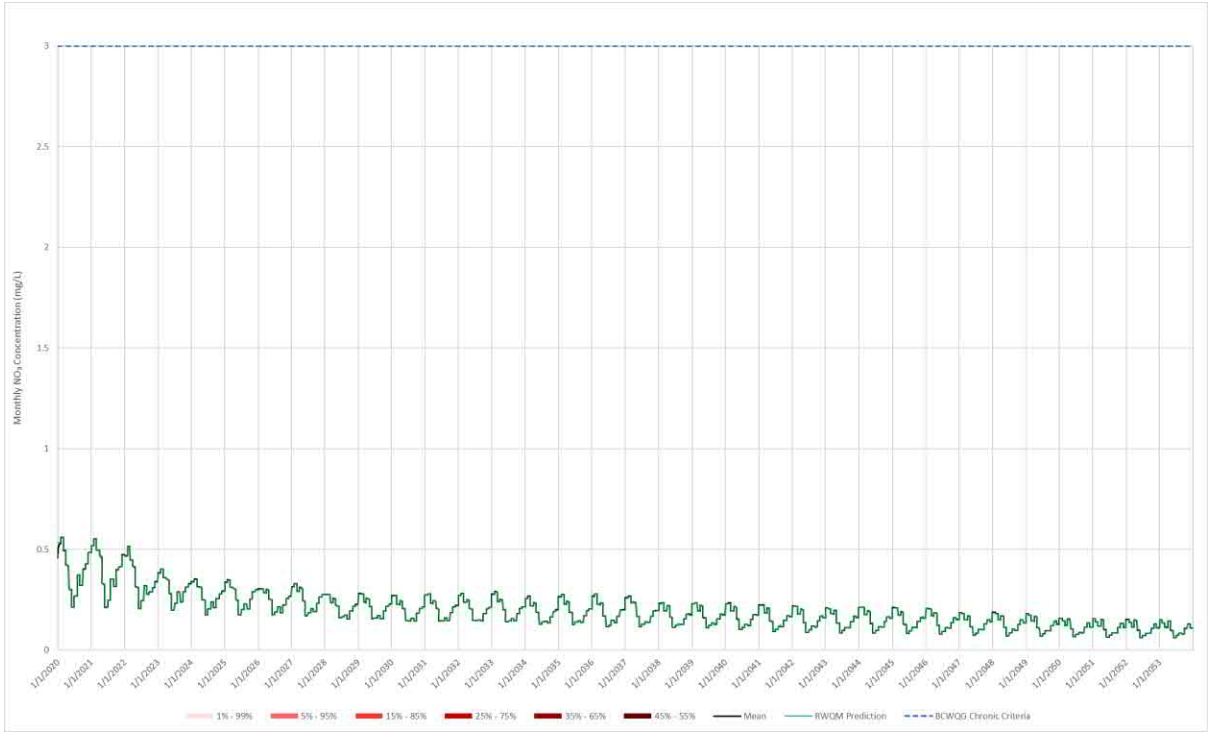
RG_DSELK Station at Lake Koocanusa

srk consulting

Upper Case (P_{95}) and Layer Approach Fails Nitrate

WQ Criteria Legend

--- BCWQGL Chronic (3 mg/L)



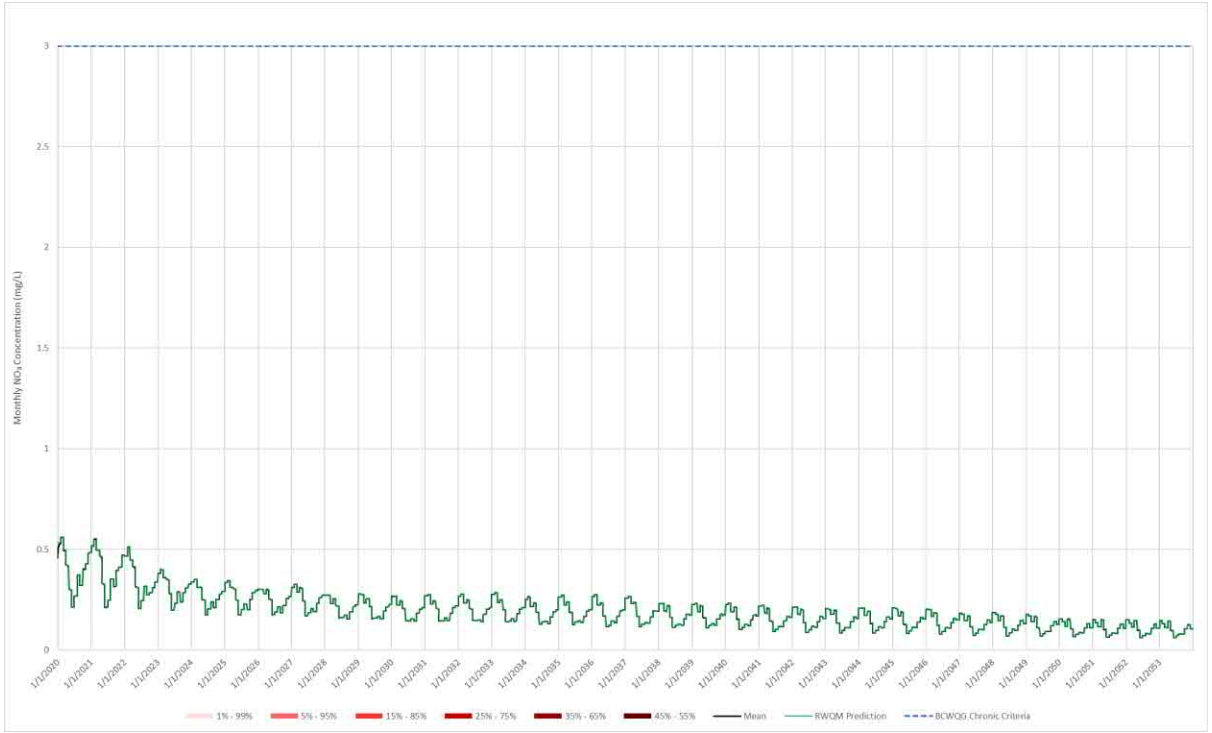
srk consulting

Location: RG_DSELK Station at Lake Koocanusa

Average Case (P_{50}) and Layer Approach Succeeds Nitrate

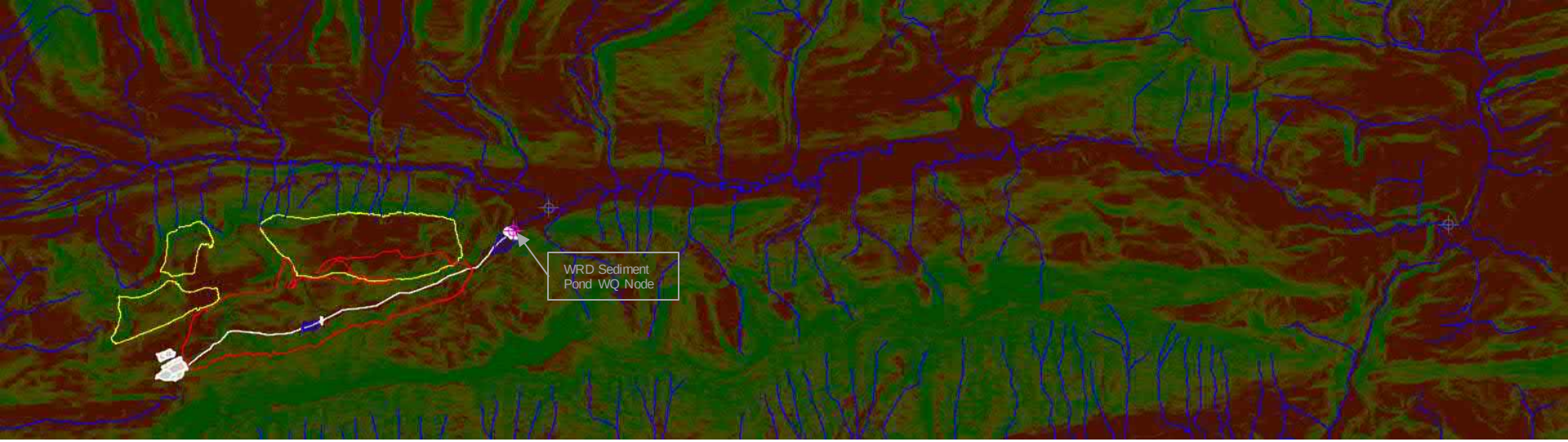
WQ Criteria Legend

--- BCWQGL Chronic (3 mg/L)



srk consulting

Location: RG_DSELK Station at Lake Koocanusa



Water Quality Results - Sulphate

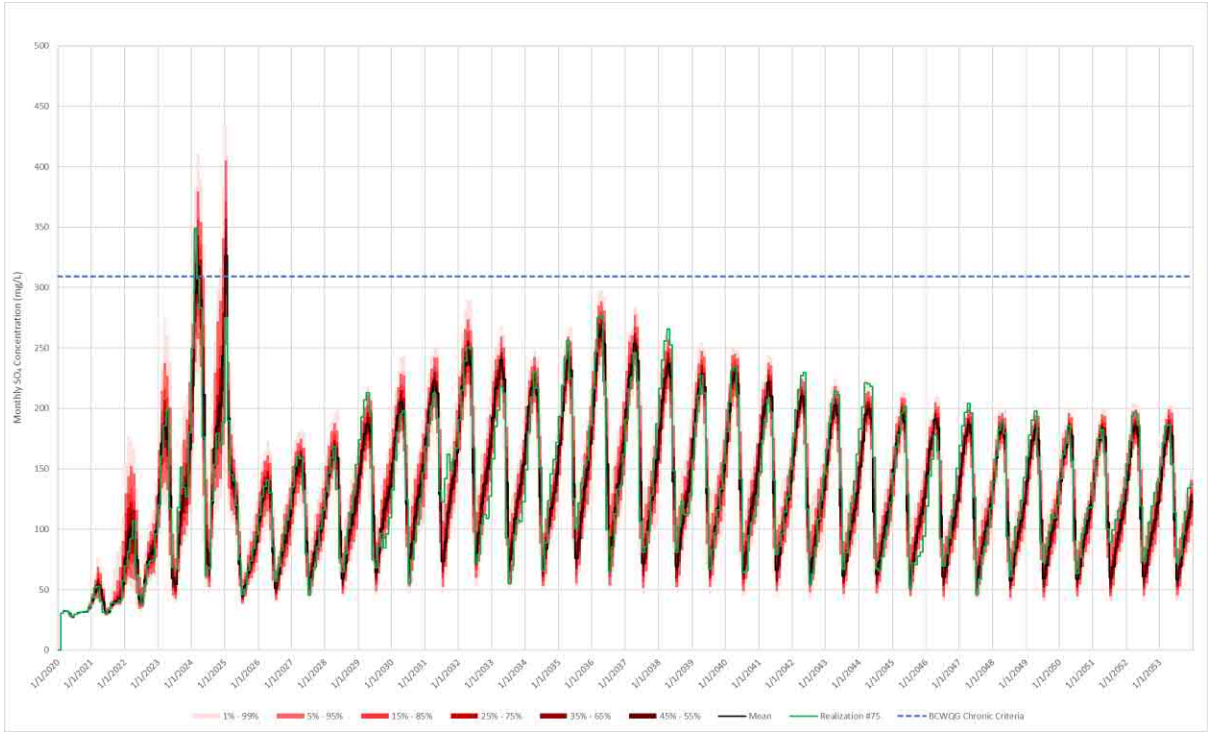
WRD Sedimentation Pond (Interim and Ultimate)

srk consulting

Upper Case (P_{95}) and Layer Approach Fails Sulphate

WQ Criteria Legend

--- BCWQGL Chronic (309 mg/L)



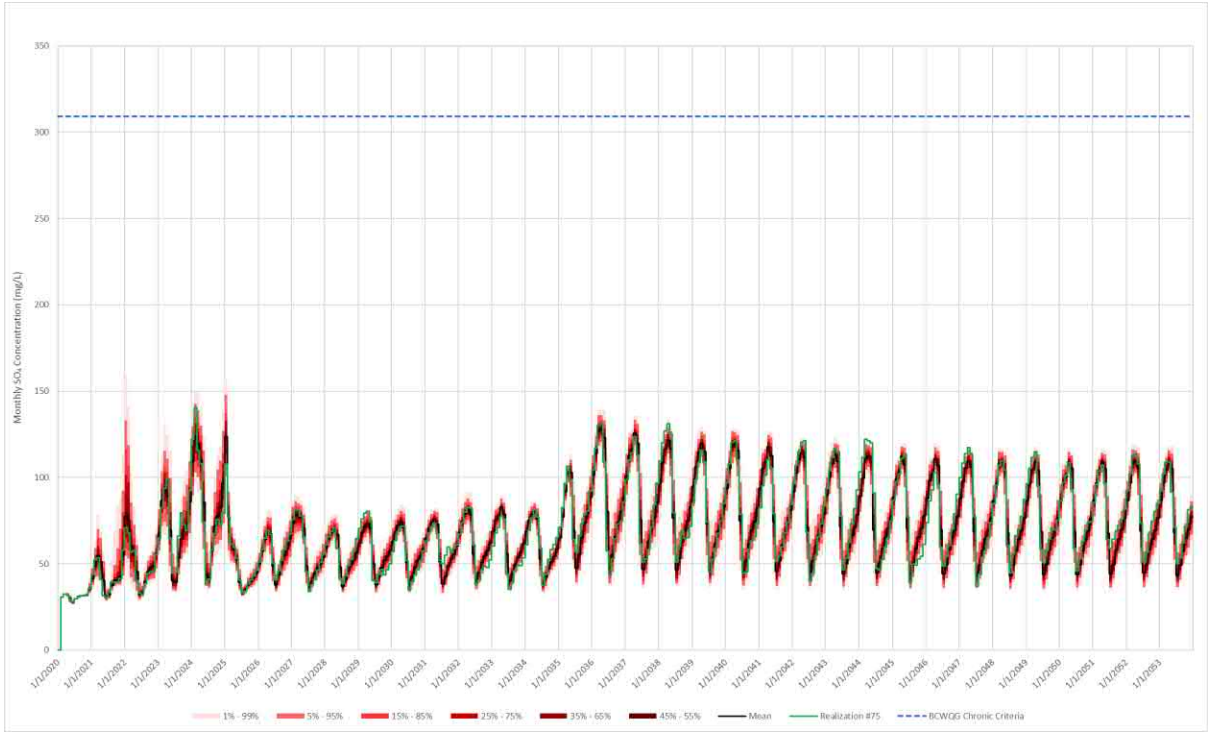
srk consulting

Location: WRD Sedimentation Pond

Upper Case (P_{95}) and Layer Approach Succeeds Sulphate

WQ Criteria Legend

--- BCWQGL Chronic (309 mg/L)



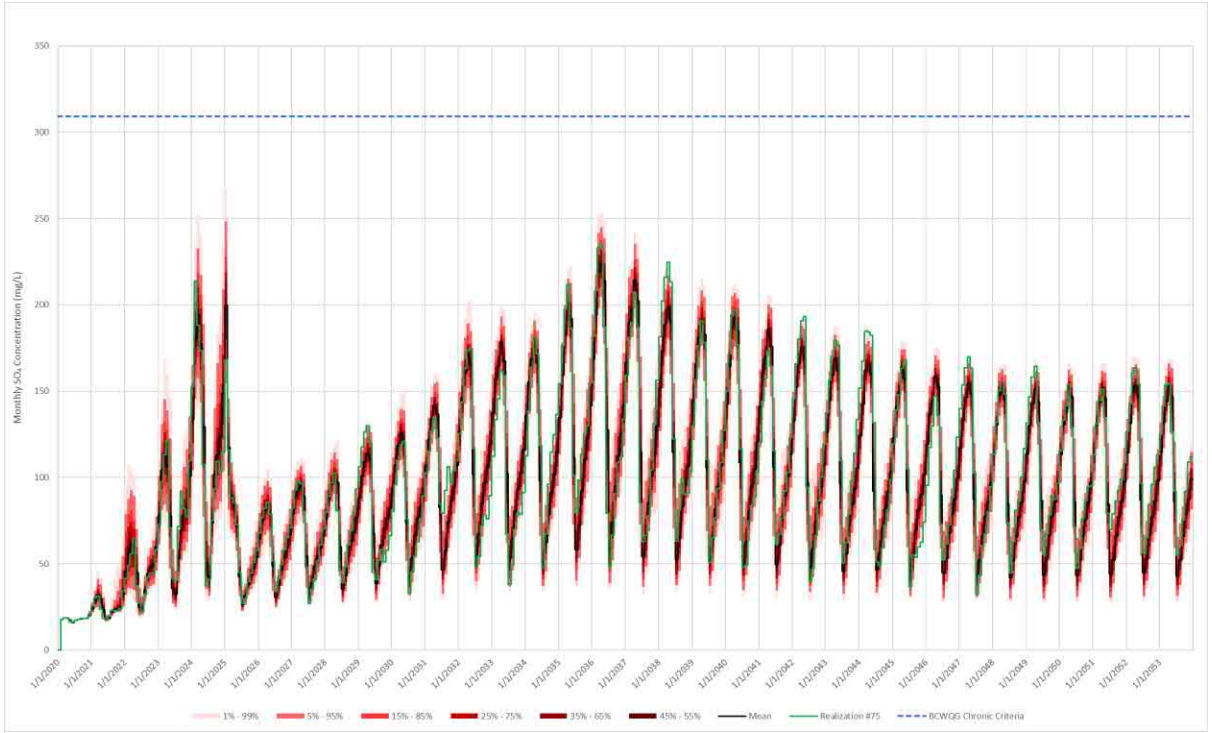
srk consulting

Location: WRD Sedimentation Pond

Average Case (P_{50}) and Layer Approach Fails Sulphate

WQ Criteria Legend

--- BCWQGL Chronic (309 mg/L)



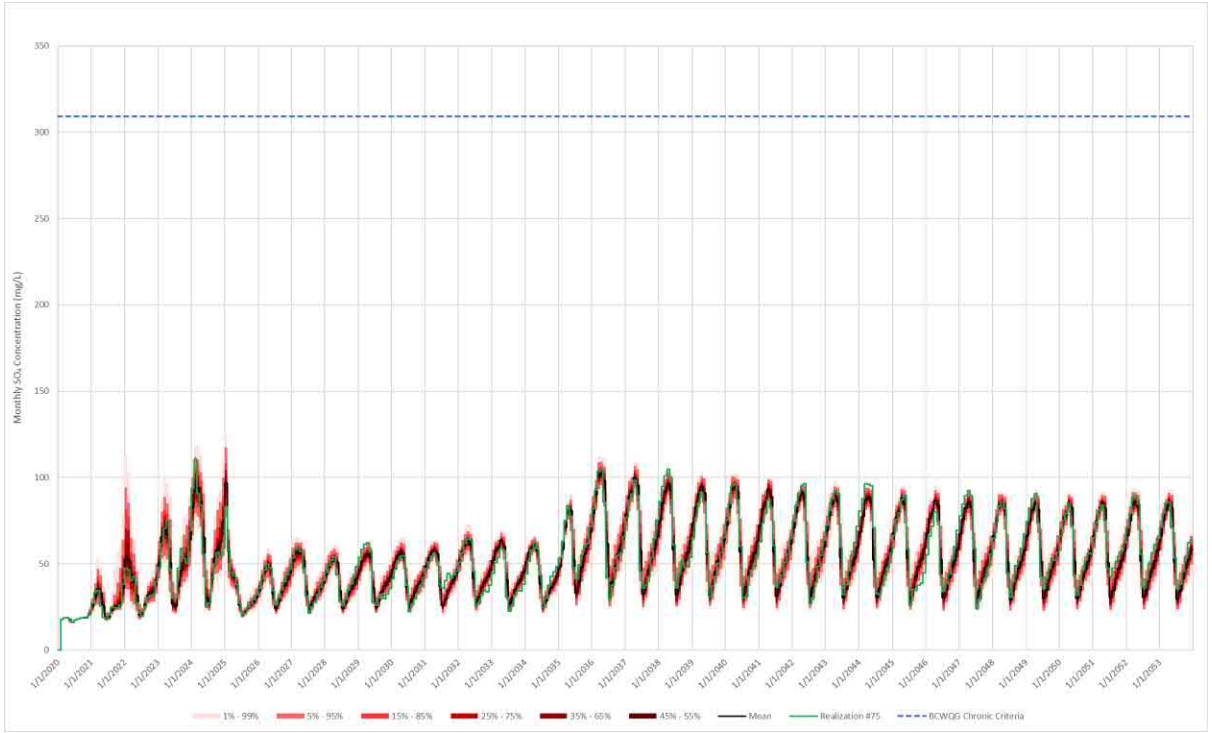
srk consulting

Location: WRD Sedimentation Pond

Average Case (P_{50}) and Layer Approach Succeeds Sulphate

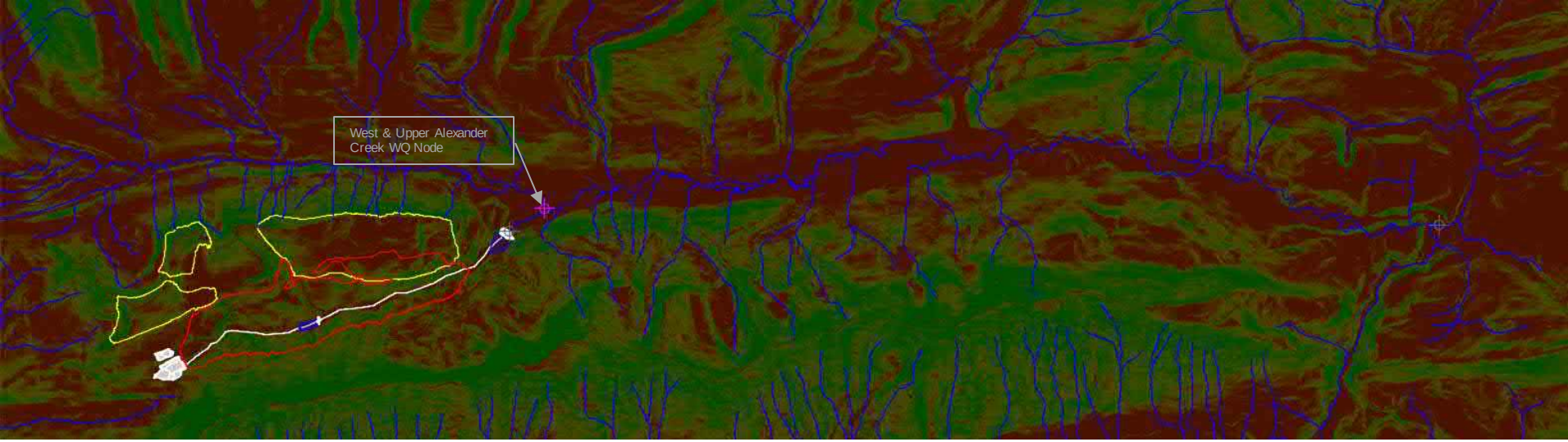
WQ Criteria Legend

--- BCWQGL Chronic (309 mg/L)



srk consulting

Location: WRD Sedimentation Pond



WQ Results - Sulphate

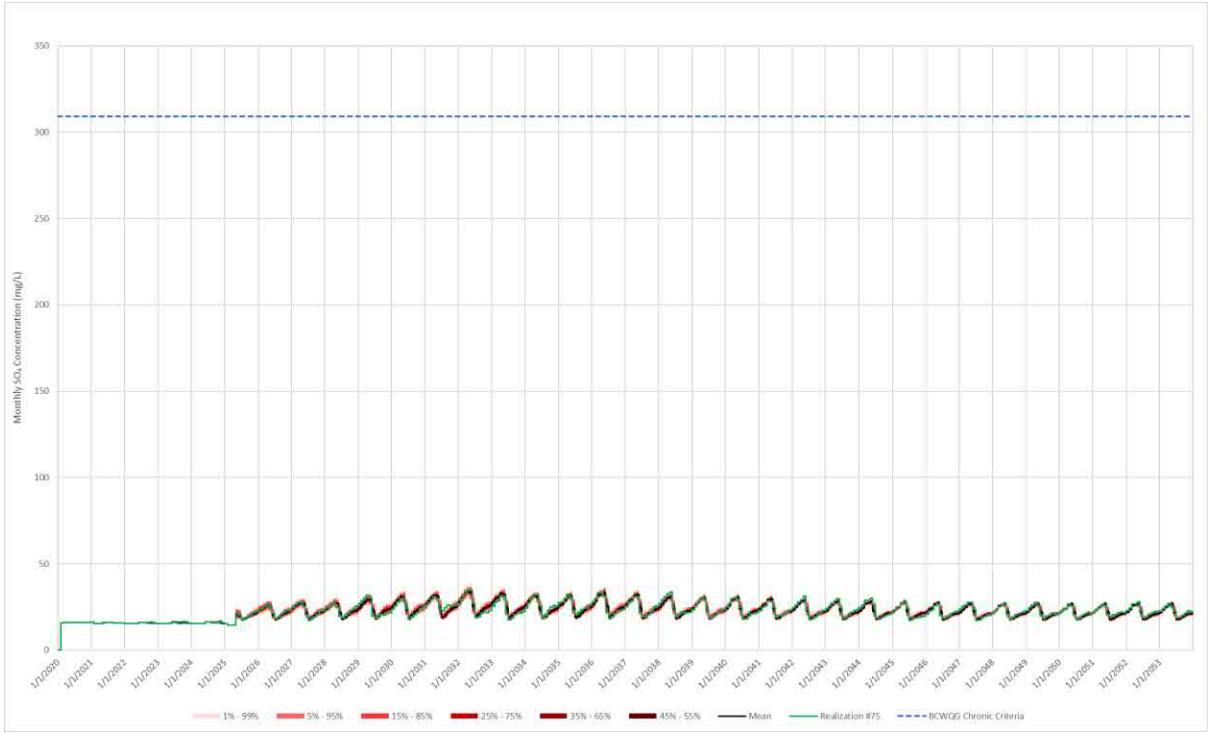
Confluence of West Alexander Creek and Upper Alexander Creek

srk consulting

Upper Case (P_{95}) and Layer Approach Fails Sulphate

WQ Criteria Legend

--- BCWQGL Chronic (309 mg/L)

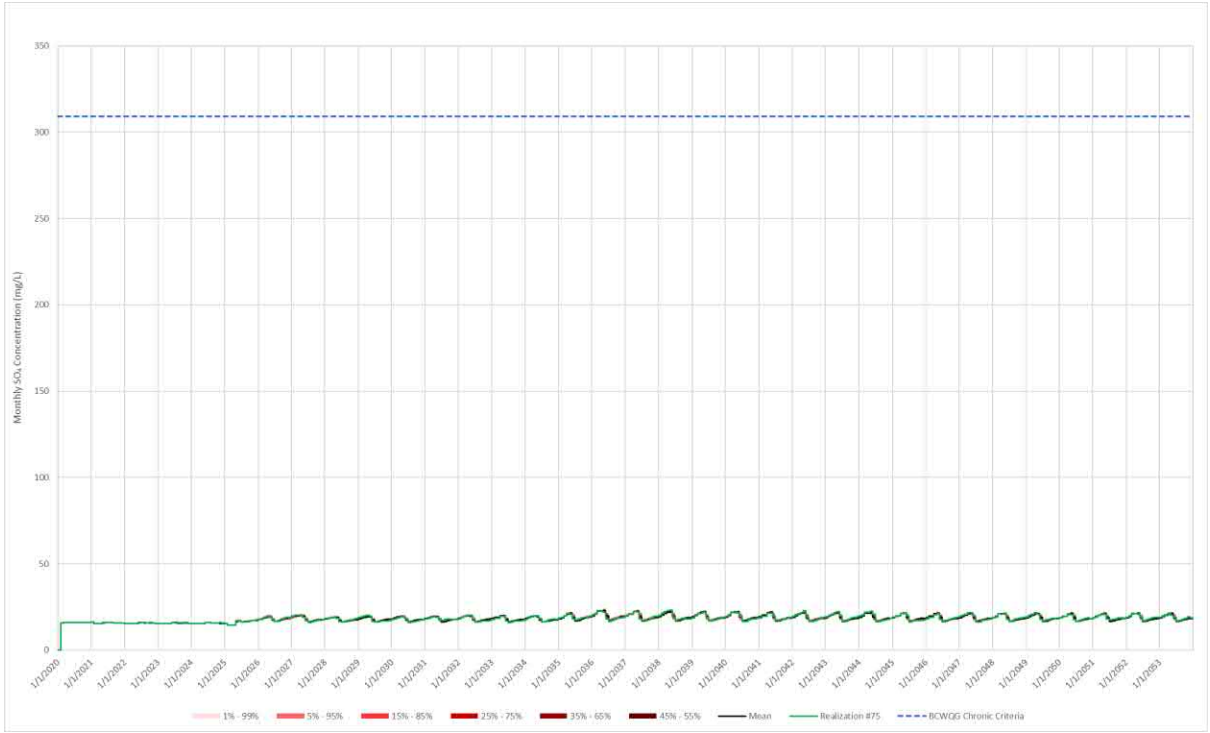


Location: Confluence of W. Alexander and U. Alexander Creek

Upper Case (P_{95}) and Layer Approach Succeeds Sulphate

WQ Criteria Legend

--- BCWQGL Chronic (309 mg/L)

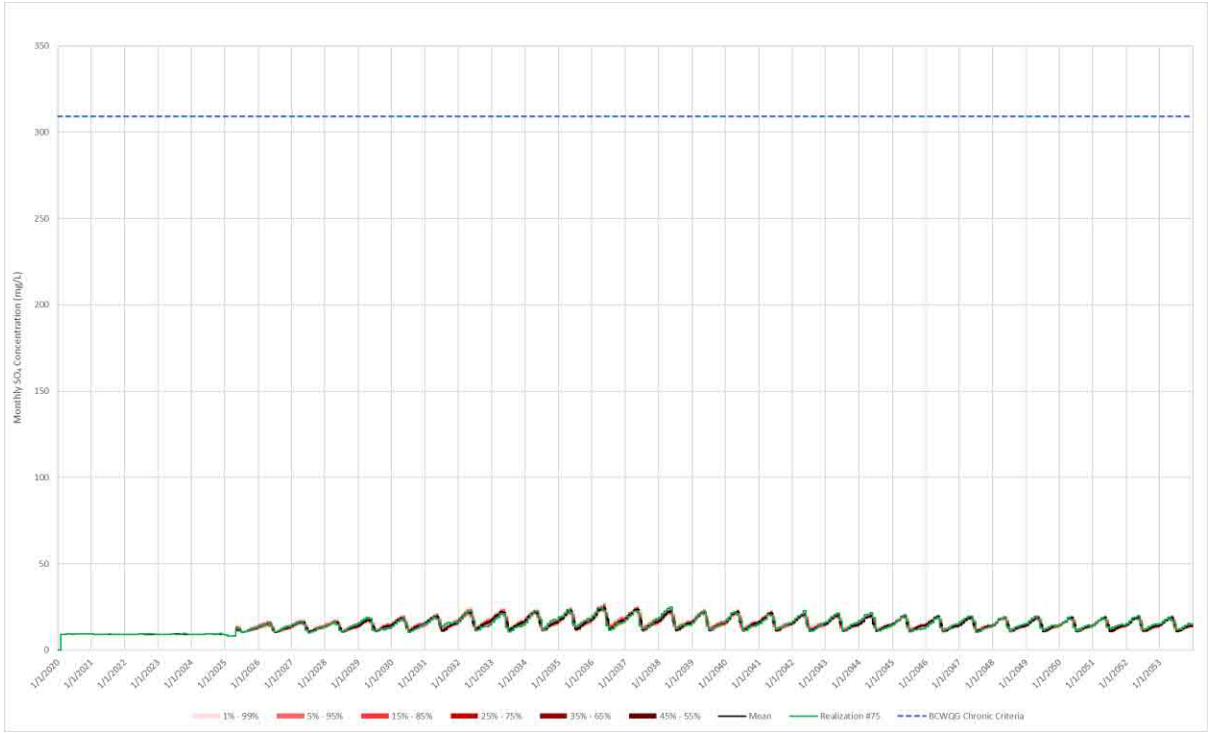


Location: Confluence of W. Alexander and U. Alexander Creek

Average Case (P_{50}) and Layer Approach Fails Sulphate

WQ Criteria Legend

--- BCWQGL Chronic (309 mg/L)



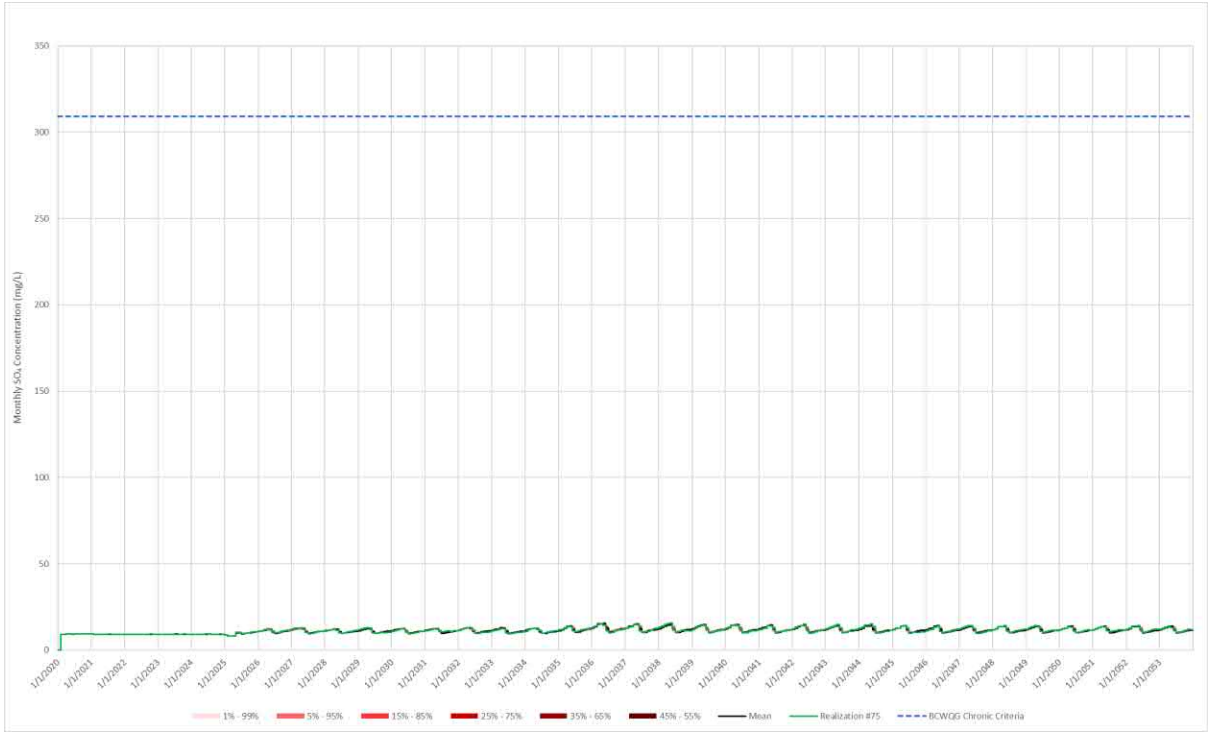
srk consulting

Location: Confluence of W. Alexander and U. Alexander Creek

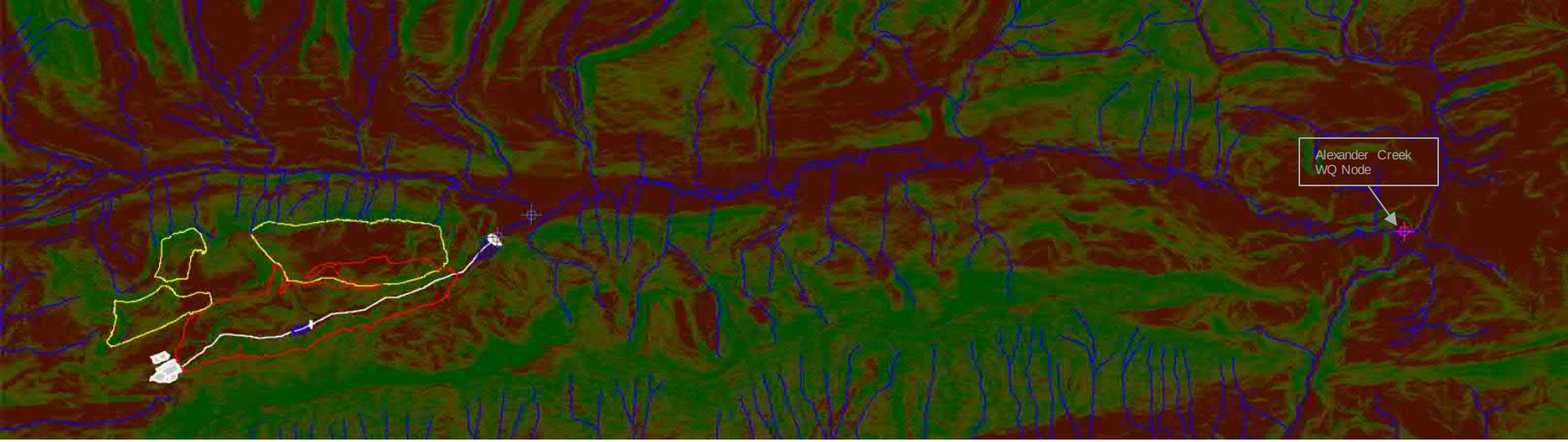
Average Case (P_{50}) and Layer Approach Succeeds Sulphate

WQ Criteria Legend

--- BCWQGL Chronic (309 mg/L)



Location: Confluence of W. Alexander and U. Alexander Creek



WQ Results - Sulphate

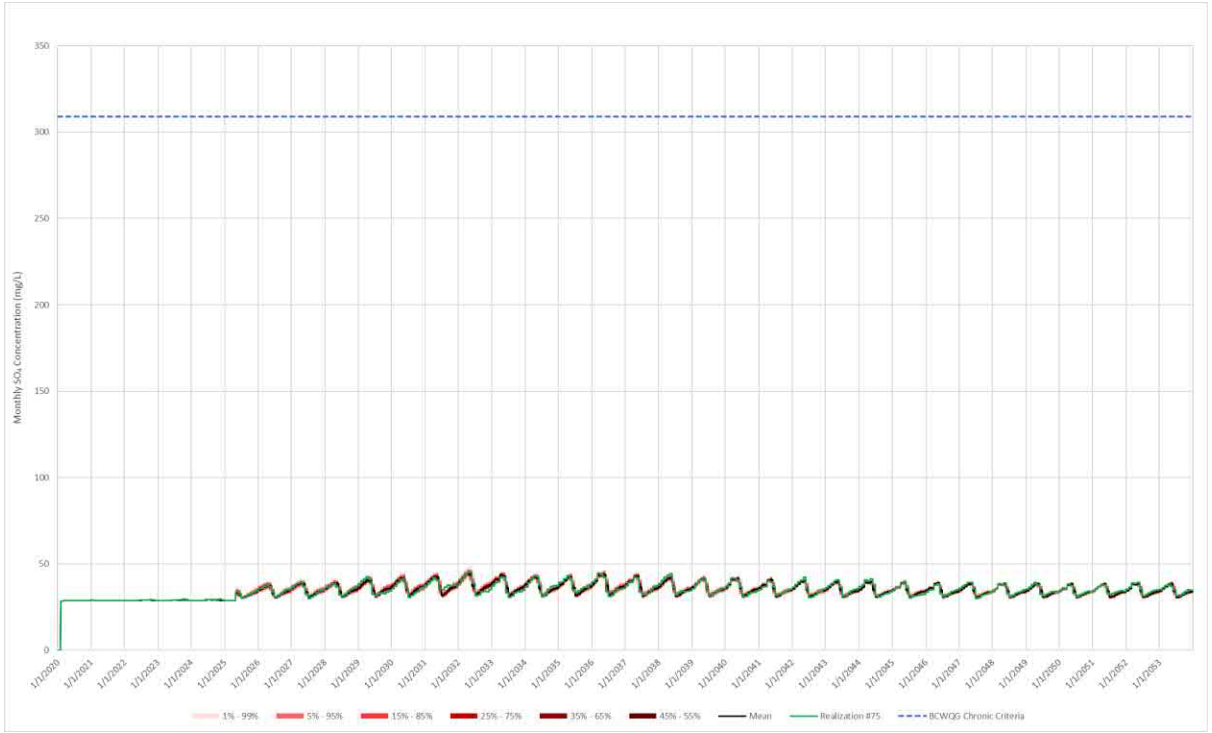
Upstream of Alexander Creek and Michel Creek Confluence

srk consulting

Upper Case (P_{95}) and Layer Approach Fails Sulphate

WQ Criteria Legend

--- BCWQGL Chronic (309 mg/L)



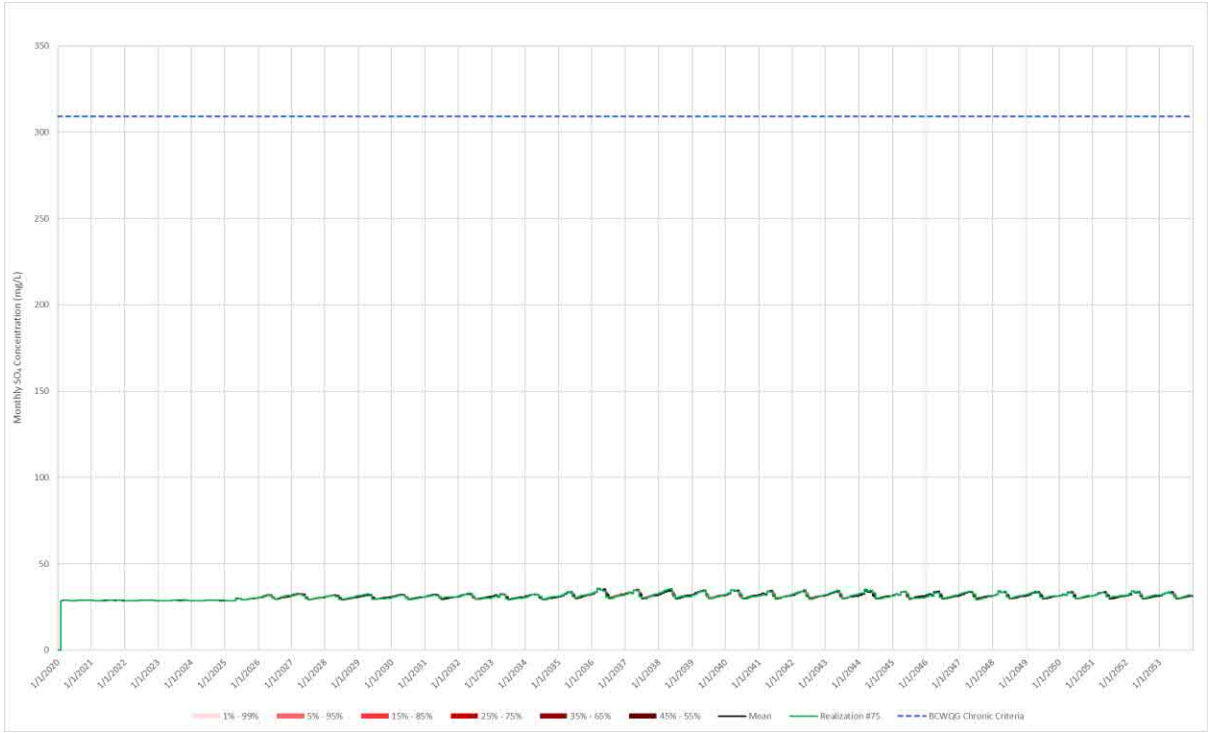
srk consulting

Location: Upstream of Alexander Creek and Michel Creek Confluence

Upper Case (P_{95}) and Layer Approach Succeeds Sulphate

WQ Criteria Legend

--- BCWQGL Chronic (309 mg/L)



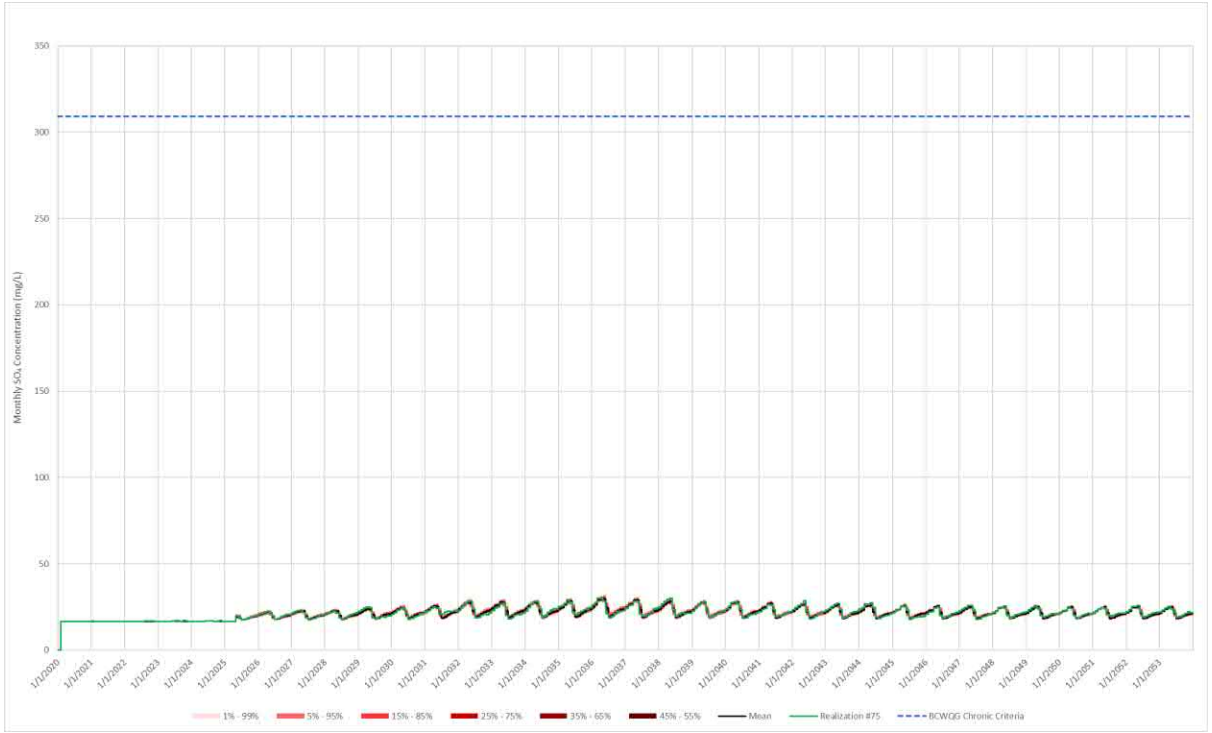
srk consulting

Location: Upstream of Alexander Creek and Michel Creek Confluence

Average Case (P_{50}) and Layer Approach Fails Sulphate

WQ Criteria Legend

--- BCWQGL Chronic (309 mg/L)



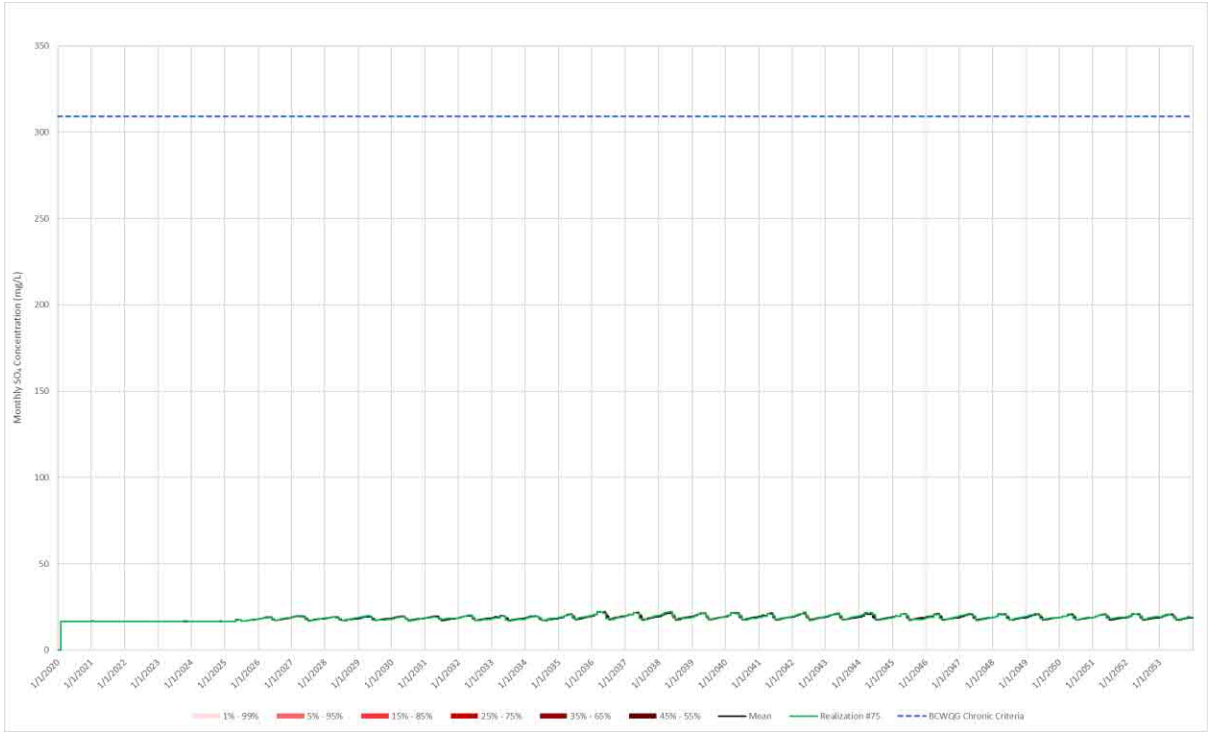
srk consulting

Location: Upstream of Alexander Creek and Michel Creek Confluence

Average Case (P_{50}) and Layer Approach Succeeds Sulphate

WQ Criteria Legend

--- BCWQGL Chronic (309 mg/L)



srk consulting

Location: Upstream of Alexander Creek and Michel Creek Confluence

WQ Results - Sulphate

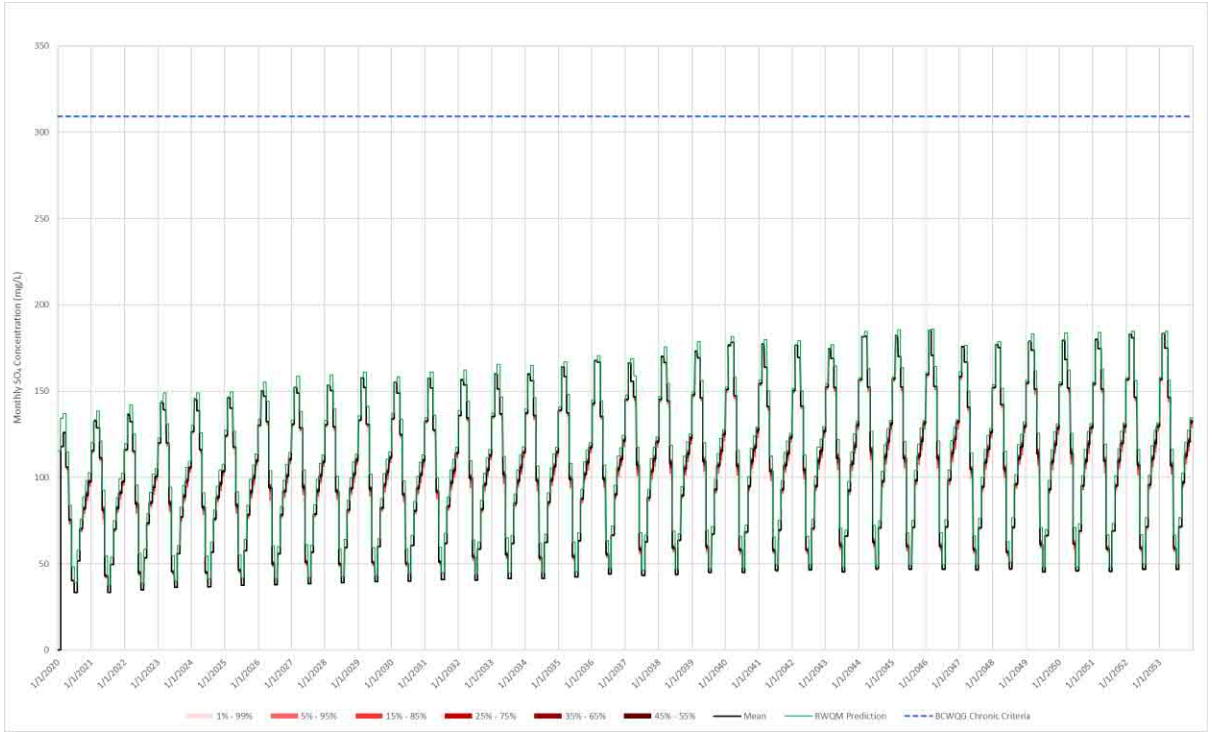
EV_ER1 Station at Sparwood

srk consulting

Upper Case (P_{95}) and Layer Approach Fails Sulphate

WQ Criteria Legend

BCWQGL Chronic (309 mg/L)



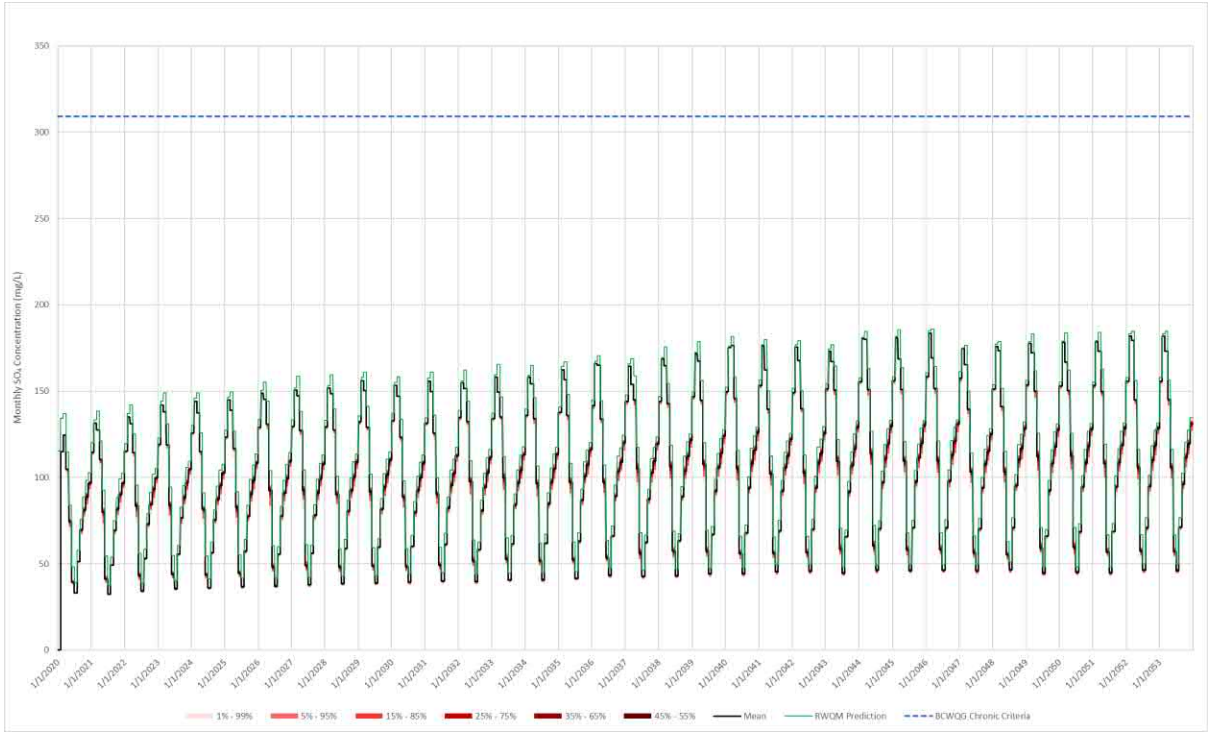
srk consulting

Location: EV_ER1 Station at Sparwood

Average Case (P_{50}) and Layer Approach Succeeds Sulphate

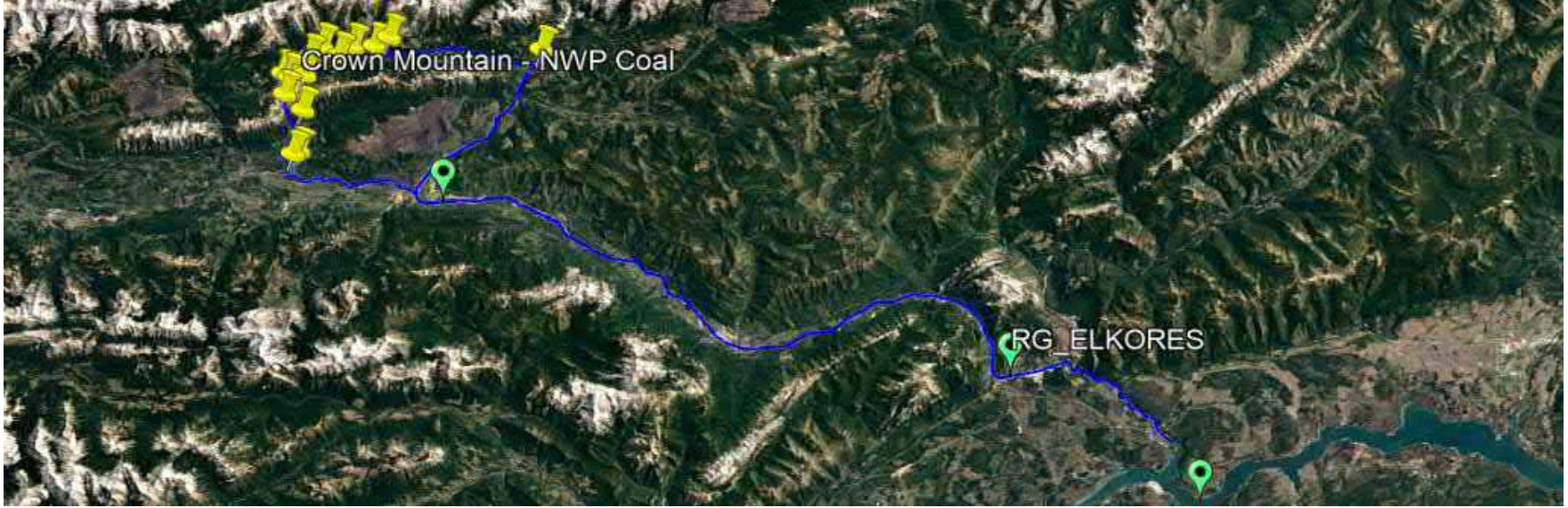
WQ Criteria Legend

--- BCWQGL Chronic (309 mg/L)



srk consulting

Location: EV_ER1 Station at Sparwood



WQ Results - Sulphate

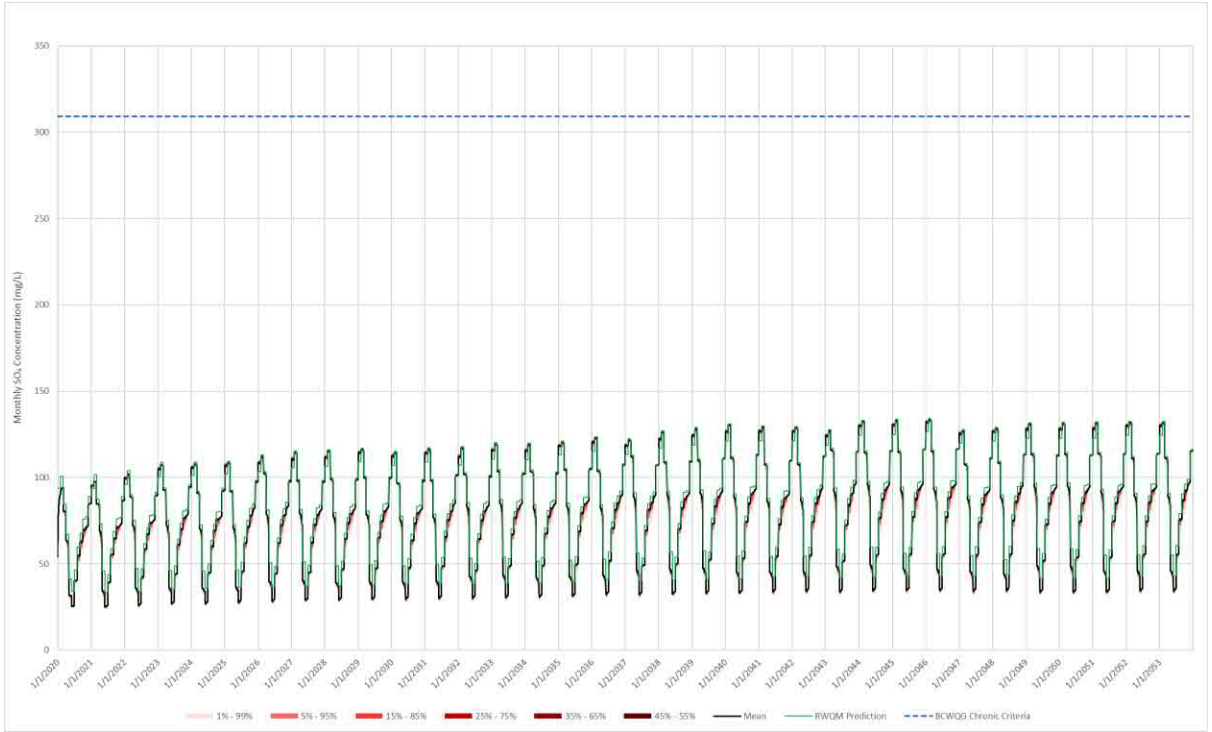
RG_ELKORES Station at Elko Reservoir

srk consulting

Upper Case (P_{95}) and Layer Approach Fails Sulphate

WQ Criteria Legend

--- BCWQGL Chronic (309 mg/L)



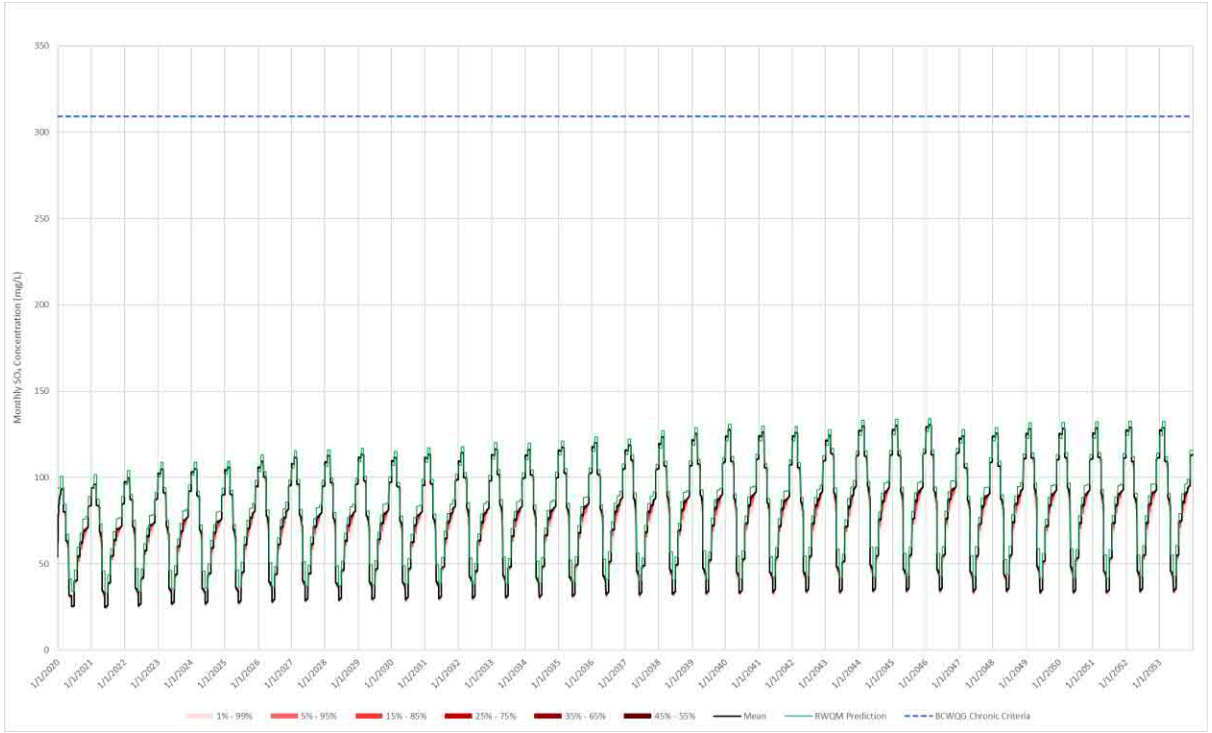
srk consulting

Location: RG_ELKORES Station at Elko Reservoir

Average Case (P_{50}) and Layer Approach Succeeds Sulphate

WQ Criteria Legend

--- BCWQGL Chronic (309 mg/L)



srk consulting

Location: RG_ELKORES Station at Elko Reservoir

WQ Results - Sulphate

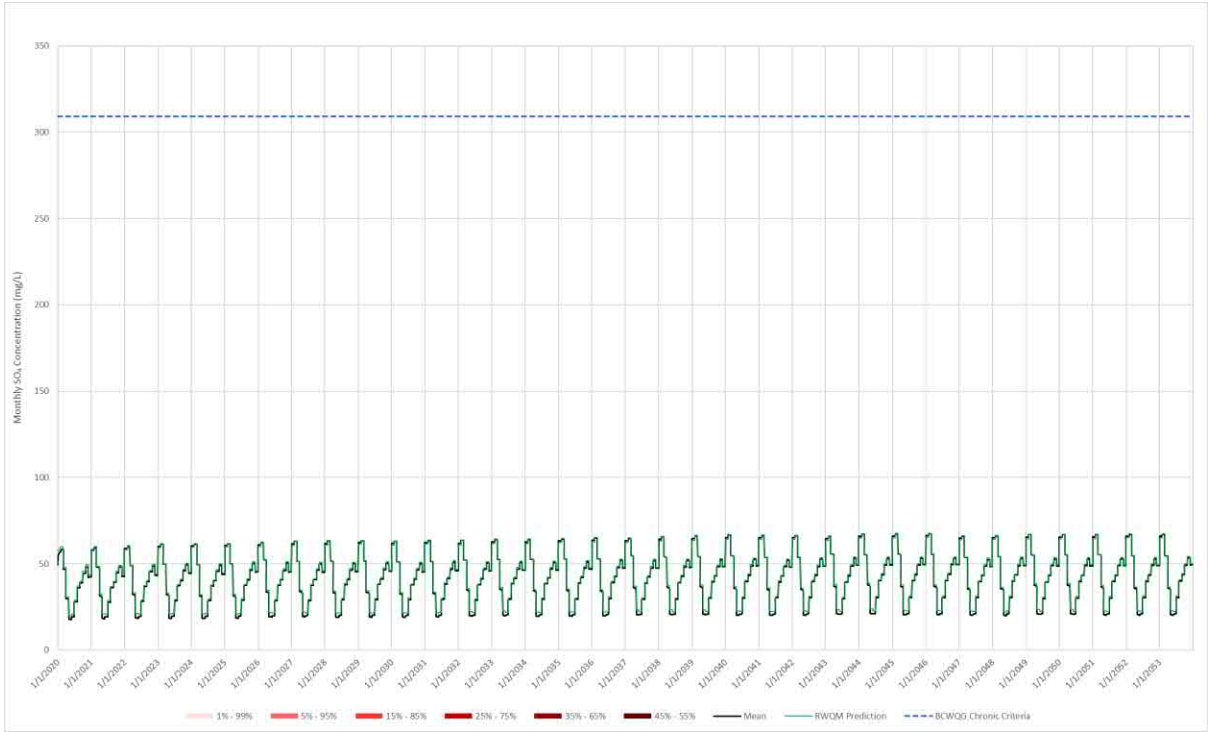
RG_DSELK Station at Lake Koocanusa

srk consulting

Upper Case (P_{95}) and Layer Approach Fails Sulphate

WQ Criteria Legend

--- BCWQGL Chronic (309 mg/L)



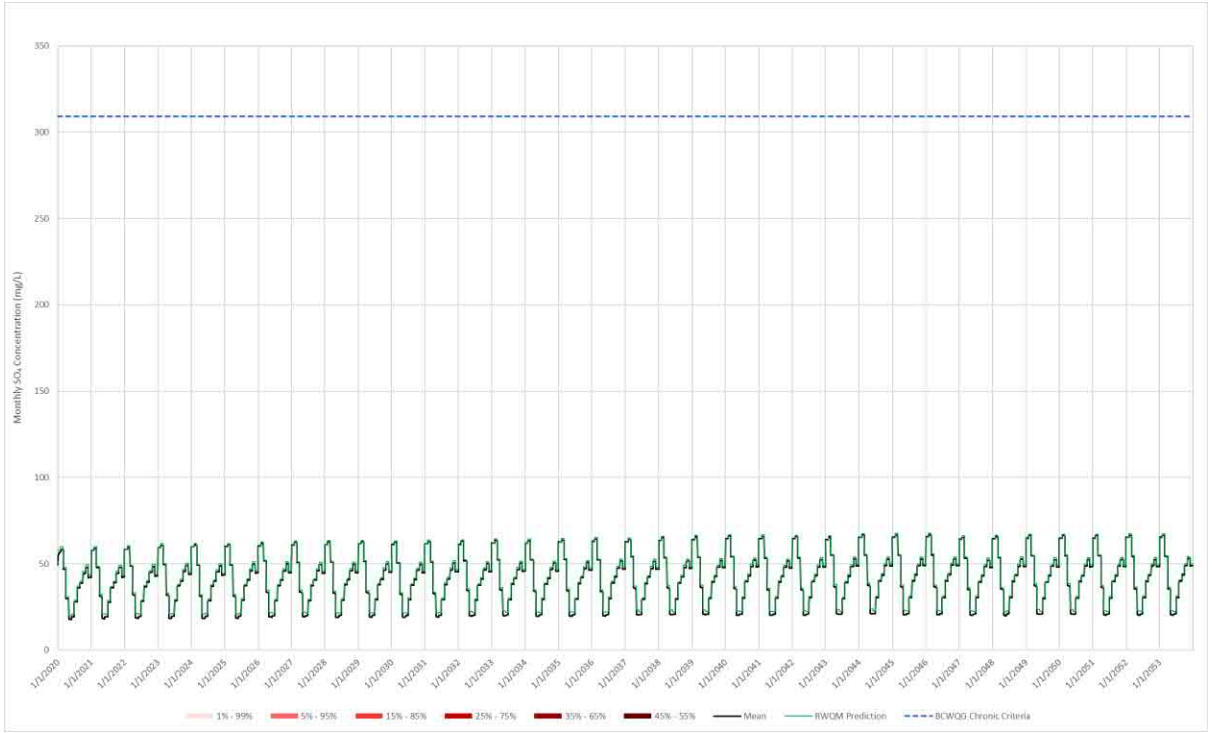
srk consulting

Location: RG_DSELK Station at Lake Koocanusa

Average Case (P_{50}) and Layer Approach Succeeds Sulphate

WQ Criteria Legend

--- BCWQGL Chronic (309 mg/L)



srk consulting

Location: RG_DSELK Station at Lake Koocanusa

Questions and Group Discussion

Follow-up Action Items

Closing