Wellsite Groundwater Metals – Best Management Practices

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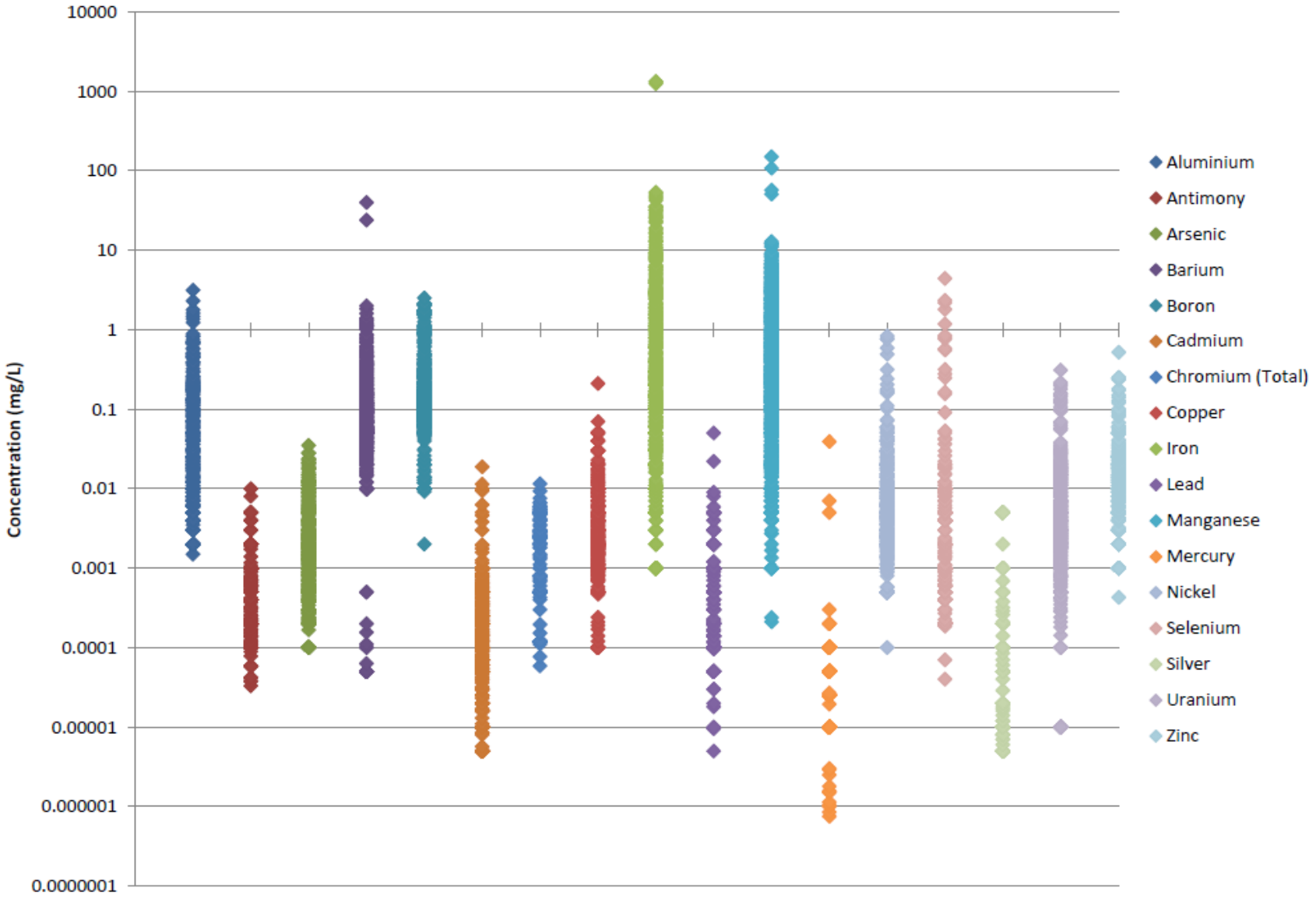
Dissolved Metals															
Aluminium	Antimony	Arsenic	Barium	Boron	Cadmium	Chromium	Copper	Lead	Molybdenum	Nickel	Selenium	Silver	Thallium	Uranium	Zinc
mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
0.05	0.006	0.005	1	0.5	0.00037	0.0049	0.007	0.007		0.13	0.001	0.0001		0.01	0.03
0.01	<0.001	0.004	0.23	0.13	0.00028	0.005	0.008	<0.001	0.003	0.1	0.002	<0.00005	<0.0005	0.017	0.014
0.157	<0.001	0.005	0.05	0.14	0.000134	0.003	0.009	<0.001	0.003	0.11	0.001	<0.00005	<0.0005	0.018	0.01
0.006	<0.001	0.004	0.13	0.1	0.000211	<0.001	0.01	<0.001	0.003	0.1	<0.001	<0.00005	<0.0005	0.017	0.01
0.01	<0.001	0.005	0.06	0.14	0.000102	<0.001	<0.002	<0.001	0.003	0.1	0.002	<0.00005	<0.0005	0.014	<0.01
0.017	<0.001	0.005	0.07	0.11	<0.0001	<0.001	0.002	<0.0005	0.003	0.089	<0.0005	<0.0001	0.0002	-	<0.01
0.029	<0.001	0.029	0.11	0.12	0.00005	0.005	0.008	<0.001	0.021	0.09	<0.001	<0.00005	<0.0005	0.002	0.008
0.036	<0.001	0.027	0.15	0.13	0.000029	0.003	0.005	<0.001	0.02	0.09	<0.001	<0.00005	<0.0005	0.002	0.017
0.007	<0.001	0.022	0.14	0.13	0.00005	0.002	<0.002	<0.001	0.027	0.08	<0.001	<0.00005	<0.0005	0.002	0.02
<0.004	<0.001	0.01	0.11	0.18	0.000044	0.001	<0.002	<0.001	0.023	0.07	0.002	<0.00005	<0.0005	0.004	<0.01
<0.004	<0.001	0.008	0.05	0.03	<0.0001	<0.001	0.002	<0.0005	0.009	0.074	<0.0005	<0.0001	<0.0001	-	<0.01
0.003	<0.001	0.001	<0.05	0.49	0.000164	0.006	0.011	<0.001	<0.003	0.07	0.003	<0.00005	<0.0005	0.097	0.013
0.005	<0.001	0.002	<0.05	0.38	0.000153	0.002	0.011	<0.001	<0.003	0.08	0.002	<0.00005	<0.0005	0.141	0.025
0.008	<0.001	<0.001	<0.05	0.3	0.000156	<0.001	0.006	<0.001	<0.003	0.06	<0.001	<0.00005	<0.0005	0.11	0.01
<0.004	<0.001	<0.001	<0.05	0.4	0.000124	<0.001	0.007	<0.001	<0.003	0.07	0.001	<0.00005	<0.0005	0.13	<0.01
0.006	<0.001	<0.001	<0.05	0.22	0.0001	<0.001	0.005	<0.0005	0.002	0.061	<0.0005	<0.0001	<0.0001	-	<0.01
0.008	<0.001	<0.001	<0.05	0.27	0.0001	<0.001	0.006	<0.0005	0.002	0.06	<0.0005	<0.0001	<0.0001	-	<0.01
0.005	<0.001	0.038	0.05	0.06	0.000049	0.005	0.009	<0.001	0.02	0.1	<0.001	<0.00005	<0.0005	0.005	0.007
0.008	0.003	0.039	0.06	0.09	0.000018	<0.001	0.007	<0.001	0.023	0.11	<0.001	<0.00005	<0.0005	0.004	0.009
0.006	<0.001	0.04	0.07	0.05	0.000024	0.002	<0.002	<0.001	0.02	0.1	<0.001	<0.00005	<0.0005	0.004	<0.01
<0.004	<0.001	0.042	0.07	0.08	0.000022	0.001	<0.002	<0.001	0.022	0.09	0.001	<0.00005	<0.0005	0.003	<0.01
<0.004	<0.001	0.039	0.07	0.07	0.00003	0.001	<0.002	<0.001	0.021	0.09	0.002	<0.00005	<0.0005	0.003	<0.01
0.005	<0.001	0.036	0.1	0.05	<0.0001	0.002	0.001	0.0007	0.018	0.091	0.0006	<0.0001	<0.0001	-	0.01
0.212	<0.001	0.002	<0.05	0.24	0.000096	0.003	0.007	0.001	0.006	0.02	0.004	<0.00005	<0.0005	0.075	0.011
0.758	<0.001	0.003	0.06	0.26	0.000202	0.004	0.009	0.004	0.006	0.02	0.003	<0.00005	<0.0005	0.054	0.013
0.006	<0.001	0.002	0.05	0.4	0.000034	0.002	0.004	<0.001	0.005	<0.01	0.012	<0.00005	<0.0005	0.06	<0.01
0.084	<0.001	0.001	0.05	0.5	0.000056	0.001	0.003	<0.001	0.007	<0.01	0.002	<0.00005	<0.0005	0.04	<0.01
0.075	<0.001	0.001	0.06	0.2	<0.0001	0.003	0.003	<0.0005	0.007	0.004	0.0034	<0.0001	<0.0001	-	<0.01

Background Groundwater Metals Concentrations

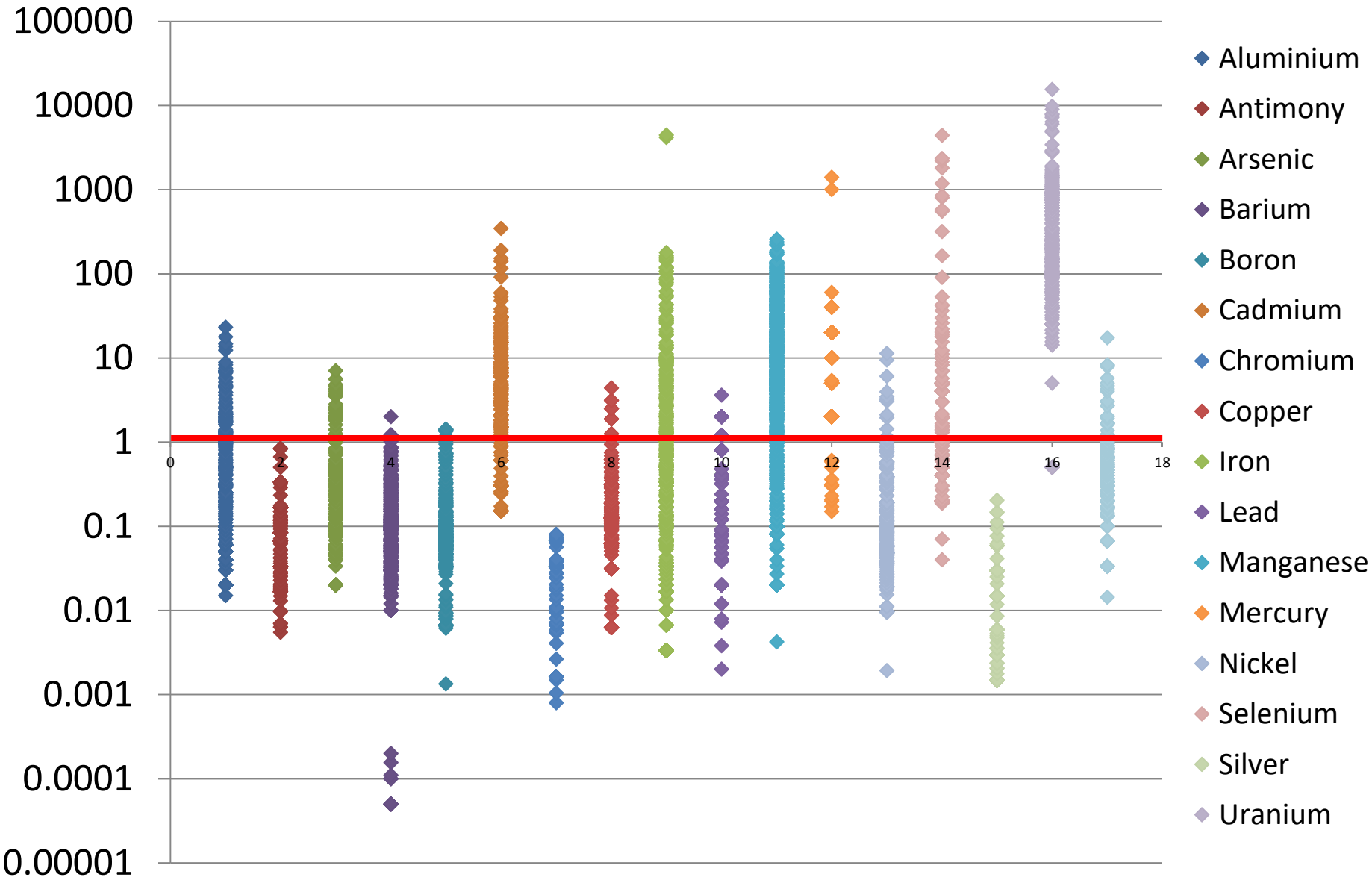


Tier 1 Groundwater Guidelines

Metal	Guideline (mg/L)	Metal	Guideline (mg/L)
Aluminium	0.1	Lead	0.0025
Antimony	0.006	Manganese	0.05
Arsenic	0.005	Mercury	0.000005
Barium	1	Nickel	0.052
Boron	1.5	Selenium	0.001
Cadmium	0.000033	Silver	0.0034
Chromium	0.074	Uranium	0.02
Copper	0.016	Zinc	0.03
Iron	0.3		

Guideline values for Agricultural land use shown, for a water hardness of 100 mg/L

Background Groundwater Metals Relative to Tier 1



Considerations

- Drilling mud components
- Formation waters/produced water
- Anaerobic biodegradation

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Drilling Mud Components

- Methodology:
  - Metals analysis for 314 mud components
- Compare:
  - Highest metal concentration with
  - Tier 1 soil remediation guideline
- Screen based on ratio:
  - <1 – no concern
  - 1-10 – investigate more closely
  - >10 – should be included

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Drilling Mud Tier 1 Ratios

Metal	Ratio	Metal	Ratio
Zinc	2,800	Antimony	3.2
Boron	970	Lead	1.5
Nickel	930	Silver	0.6
Copper	240	Uranium	0.4
Barium	26	Mercury	0.3
Chromium	21	Aluminium	No data
Selenium	16	Iron	No data
Cadmium	6.7	Manganese	No data
Arsenic	5.7		

"Ratio" is the maximum concentration in any drill mud component / Tier 1 soil remediation guideline

Mud Products With Highest Metals Concentrations

Metal	Product Type	Metal	Product Type
Zinc	Sulphide scavenger	Antimony	Lost circulation additive
Boron	Deflocculant	Lead	Drilling System
Nickel	Deflocculant	Silver	-
Copper	Deflocculant	Uranium	-
Barium	Weighting agent	Mercury	-
Chromium	Mica	Aluminium	No data
Selenium	Impurity in KCl	Iron	No data
Cadmium	Deflocculant	Manganese	No data
Arsenic	Lost circulation additive		

Drilling Mud - Conclusions

- Ag, U, Hg: not present in significant concs
- Cd, As, Sb, Pb: not a concern:
  - Highest concentration in a drill product <10x Tier 1
  - That product would only be used <10% of mud
- Zn, B, Ni, Cu, Ba, Cr, Se: potentially present in drill mud at significant concentrations
  - >10x Tier 1 soil concentration

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Produced Water

- Formation water analysis?
- Groundwater data-mining approach:
  - Semi-quantitative approach on large database
  - Data with other contamination excluded
  - Using chloride as tracer of produced water
  - Correlation between chloride and metal

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Groundwater Impact from Produced Water?

Metal	Impact from PW?	Metal	Impact from PW?
Aluminium	No	Lead	No
Antimony	No	Manganese	No
Arsenic	**Possible**	Mercury	No
Barium	No	Nickel	No
Boron	**Possible**	Selenium	**Possible**
Cadmium	No	Silver	No
Chromium	No	Uranium	No
Copper	No	Zinc	No
Iron	No		

Anaerobic Biodegradation

- Iron and Manganese
  - Released during anaerobic biodegradation
  - Should be included

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Criteria for Associating Metals with Oilfield Wellsites

Metal	Drilling Fluid?	Produced Water?	Hydrocarbon Degradation?
Arsenic		✓	
Barium	✓		
Boron	✓	✓	
Chromium	✓		
Copper	✓		
Iron			✓
Manganese			✓
Nickel	✓		
Selenium	✓	✓	
Zinc	✓		

Summary – Tier 1 Groundwater Metals Potentially Associated with Wellsites

Metal	
Arsenic	Lead
Barium	Manganese
Boron	Nickel
Chromium	Selenium
Copper	Zinc
Iron	

Summary – Tier 1 Groundwater Metals Likely Not Associated with Wellsites

Metal	
Aluminium	Mercury
Antimony	Silver
Cadmium	Uranium

Best Management Practices Document

- Intended to apply to “typical” oilfield wellsites
- Additional consideration may be required at other sites including:
  - Thermal facilities
  - Gas plants
  - Facilities with specific metals concerns
- Professional judgement still required to ensure all chemicals are assessed appropriately

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How Do I Use This Document?

- "Regulatory encouragement without formal endorsement"
- Document available on PTAC website:
  - https://auprf.ptac.org/2016-groundwater-metals-associated-with-oilfield-wellsites/
- Or Google "PTAC Groundwater Metals Wellsites"
- Use the document to support your rationale that all relevant chemicals have been assessed
- Important! Does not supersede any other regulatory requirements

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