Final
Soil, Groundwater, Surface Water, and Kuskokwim River Sediment Characterization

Supplement to Remedial Investigation Red Devil Mine, Alaska

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Table of Contents

Chapter **Page**

1 Introduction 1-1
1.1 Definition of the Site 1-2
1.2 Purpose and Objectives 1-3
1.3 RI Supplement and BLM Kuskokwim River Investigation Activities 1-3
1.4 Document Organization 1-5

2 Soil Investigation 2-1
2.1 Soil Investigation Activities 2-1
2.1.1 Soil Boring Installation and Soil Sampling 2-2
2.1.2 XRF Field Screening and Lithological Characterization 2-2
2.1.3 Soil Sampling for Laboratory Analysis 2-3
2.1.4 Deviations from the Field Sampling Plan 2-3
2.2 Soil Investigation Results 2-4
2.2.1 Field Lithological and Mineralogical Characterization 2-4
2.2.2 XRF Field Screening 2-4
2.2.3 Laboratory Soil Sample Results 2-5
2.2.4 Identification and Characterization of Tailings/Waste Rock and Native Soil 2-7
2.2.5 Characterization of Bedrock 2-9
2.2.6 Occurrence of Groundwater 2-14
2.3 Soil Characterization Conclusions 2-15

3 Groundwater Investigation 3-1
3.1 Groundwater Investigations 3-1
3.1.1 Monitoring Well Installation 3-1
3.1.2 Well Survey 3-2
3.1.3 Water Level Measurement 3-2
3.1.4 Groundwater Sampling 3-2
3.1.5 Deviations from the Field Sampling Plan 3-3
3.2 Groundwater Investigation Results 3-4
3.2.1 Monitoring Well Installation 3-4
3.2.2 Groundwater Levels and Gradients 3-7
3.2.3 Groundwater Sample Results 3-10
3.3 Groundwater Investigation Conclusions 3-15
3.3.1 Surface Mined Area 3-15
3.3.2 Area of NTCRA Regrading 3-16

Table of Contents (cont.)

Chapter **Page**

3.3.3 Area Downgradient of Monofill #2 ... 3-17
3.3.4 Organic Compounds in the Main Processing Area ... 3-17
3.3.5 Baseline Monitoring ... 3-17

4 Surface Water Investigation ... 4-1
4.1 Surface Water Investigations ... 4-1
4.1.1 Stream Gaging ... 4-1
4.1.2 Surface Water Sampling ... 4-1
4.1.3 Deviations from the Field Sampling Plan ... 4-2
4.2 Surface Water Investigation Results ... 4-2
4.2.1 Stream Discharge ... 4-2
4.2.2 Surface Water Sample Results ... 4-2
4.3 Surface Water Investigation Conclusions ... 4-4
4.3.1 Stream Discharge ... 4-4
4.3.2 Surface Water Sample Results ... 4-4
4.3.3 Surface Water Contaminant Transport ... 4-4

5 Kuskokwim River Investigations ... 5-1
5.1 Kuskokwim River Sediment RI Supplement Investigations ... 5-1
5.1.1 RI Supplement Sediment Sampling ... 5-3
5.1.2 River Turbidity Measurement ... 5-4
5.1.3 Deviations from the Field Sampling Plan ... 5-4
5.2 BLM Kuskokwim River Investigations ... 5-4
5.2.1 Fish Movement and Tissue Sampling ... 5-5
5.2.2 Periphyton Sampling ... 5-6
5.2.3 Benthic Macroinvertebrate Sampling ... 5-7
5.3 Kuskokwim River Investigation Results ... 5-8
5.3.1 Total Inorganic Elements in Sediment ... 5-8
5.3.2 Methylmercury in Sediment ... 5-10
5.3.3 Mercury Selective Sequential Extraction in Sediment ... 5-11
5.3.4 Grain Size and Total Organic Carbon in Sediment ... 5-12
5.3.5 Sediment Toxicity Testing ... 5-12
5.3.6 River Turbidity Measurement ... 5-12
5.3.7 BLM 2014 Periphyton Tissue Sampling ... 5-12
5.3.8 BLM Fish Movement and Tissue Sampling ... 5-16
5.3.9 Kuskokwim River Surface Water ... 5-17
5.4 Kuskokwim River Investigation Summary ... 5-18
5.4.1 Cross-River and Downriver Extent of Sediment Contamination ... 5-18
5.4.2 Mineral Occurrences near Red Devil Mine ... 5-19
5.4.3 Methylmercury in Sediment ... 5-20
5.4.4 Sediment Toxicity ... 5-20
5.4.5 Kuskokwim River Periphyton ... 5-20
5.4.6 Kuskokwim River Fish ... 5-21

Table of Contents (cont.)

Chapter **Page**

6 Kuskokwim River Human Health Risk Assessment 6-1
6.1 Introduction 6-1
6.1.1 Baseline Human Health Risk Assessment 6-2
6.1.2 Middle Kuskokwim River Investigations 6-2
6.1.3 Human Health Risk Assessment Supplement Approach 6-5
6.1.4 Area of Kuskokwim River HHRA Supplement 6-6
6.2 Exposure Assessment 6-6
6.2.1 Human Health Conceptual Site Model 6-7
6.2.2 Estimation of Exposure Point Concentration 6-7
6.2.3 Estimation of Intake 6-11
6.2.4 Exposure Factors 6-12
6.3 Toxicity Assessment 6-18
6.3.1 Quantitative Indices of Toxicity 6-19
6.3.2 Assessment of Non-carcinogens 6-19
6.3.3 Assessment of Carcinogens 6-20
6.3.4 Assessment of Arsenic 6-20
6.3.5 Assessment of Mercury 6-22
6.3.6 Assessment of Chromium 6-22
6.4 Risk Characterization 6-23
6.4.1 Characterization of Carcinogens 6-23
6.4.2 Characterization of Noncarcinogens 6-25
6.4.3 Assessment of Background Contribution to Risk 6-27
6.4.4 Risk Characterization Conclusions 6-27
6.5 Uncertainty Analysis 6-28
6.5.1 Environmental Sampling and Analysis Uncertainty 6-28
6.5.2 Exposure Point Concentration Uncertainty 6-30
6.5.3 Exposure Assessment Uncertainty 6-31
6.5.4 Toxicity Assessment Uncertainty 6-33
6.5.5 Risk Characterization Uncertainty 6-35

7 Kuskokwim River Ecological Risk Assessment 7-1
7.1 Introduction 7-1
7.2 Problem Formulation 7-1
7.2.1 Contaminant Sources, Migration Pathways, and Principal Site-Related Contaminants 7-2
7.2.2 Potential Ecological Receptors 7-2
7.2.3 Ecological Conceptual Site Model 7-2
7.2.4 Assessment Endpoints, Model Species, Risk Questions, and Measures 7-2
7.3 Exposure Assessment 7-3
7.3.1 Sediment Contaminant Concentrations 7-3
7.3.2 Tissue Contaminant Concentrations 7-5
7.3.3 Wildlife Exposure Estimation 7-7
7.3.4 Benthic Macroinvertebrate Exposure 7-9
7.3.5 Forage Fish Exposure 7-9

Table of Contents (cont.)

Chapter **Page**

7.4 Ecological Effects Assessment 7-9
7.4.1 Wildlife Toxicity Reference Values 7-9
7.4.2 Benthic Macroinvertebrates 7-9
7.4.3 Tissue Screening Concentrations for Effects on Fish 7-13
7.5 Risk Characterization 7-13
7.5.1 Wildlife 7-13
7.5.2 Benthic Macroinvertebrates 7-14
7.5.3 Forage Fish 7-15
7.5.4 Contribution of Background to Potential Risks 7-16
7.6 Uncertainties 7-16
7.7 Summary of Potential Risks 7-18

8 Summary and Conclusions 8-1
8.1 Soil Investigation 8-1
8.2 Groundwater Investigation 8-3
8.2.1 Surface Mined Area 8-3
8.2.2 Area of NTCRA Regrading 8-4
8.2.3 Area Downgradient of Monofill #2 8-5
8.2.4 Organic Compounds in the Main Processing 8-5
8.2.5 Baseline Monitoring 8-5
8.3 Surface Water Investigation 8-6
8.3.1 Stream Discharge 8-6
8.3.2 Stream Water Quality 8-6
8.3.3 Stream Water Contaminant Transport 8-7
8.4 Kuskokwim River Investigations 8-8
8.4.1 Cross-River and Downriver Extent of Sediment Contamination 8-9
8.4.2 Mineral Occurrences near Red Devil Mine 8-9
8.4.3 Methylmercury in Sediment 8-9
8.4.4 Sediment Toxicity 8-10
8.4.5 Kuskokwim River Periphyton 8-10
8.4.6 Kuskokwim River Fish 8-10
8.5 Kuskokwim River Human Health Risk Assessment 8-11
8.6 Kuskokwim River Ecological Risk Assessment 8-13

9 Weight of Evidence Discussion for Potential Risks Associated with Kuskokwim River Fish and Sediments 9-1
9.1 Basis for Using a WOE Approach in Risk Characterization 9-2
9.2 Brief Summary of Risk Results from BERA and HHRA Supplements 9-3
9.2.1 BERA Supplement Risk Summary 9-3
9.2.2 HHRA Supplement Risk Summary 9-3
9.3 Primary Questions Regarding Influence of RDM on Potential Risks Associated with Kuskokwim River Fish Consumption 9-4
9.4 LOE Relevant to Answering the Primary Questions Associated with Kuskokwim River Fish Consumption 9-4
9.4.1 RDM and Kuskokwim River Characteristics 9-5

Table of Contents (cont.)

Chapter **Page**

9.4.2 Contaminant Bioavailability 9-6
9.4.3 Fish Movement and Local Fishing Practices 9-7
9.4.4 Recent and Planned Removal Actions 9-8
9.5 Answers to Primary Questions Regarding Fish Consumption Risks Based on WOE 9-8
9.6 Discussion and WOE for Human Health Risks Associated with Exposure to Sediments in the Kuskokwim River 9-9

10 References 10-1

A Data Review Memoranda

B Summary of Soil Boring Data

C Sediment Toxicity Testing Report

D HHRA ProUCL Input and Output Files

E Sediment Exposure Point Concentrations

F Sediment and Benthic Macroinvertebrate Metals Data for Red Devil Creek and Reference Creeks and Biota Sediment Accumulation Factors

G Slimy Sculpin Metals Data for Red Devil Creek Used to Develop Benthos-to-Sculpin Trophic Transfer Factors

H Red Devil Creek Benthic Macroinvertebrate Metals Data Used to Develop Trophic Transfer Factors

I Development of Benthos-to-Sculpin Trophic Transfer Factors

J Pond Plant (Horsetail) and Pond Sediment Metals Data for Site and Background Ponds and Sediment to Plant Uptake Factors

K Periphyton Metals Data and EPCs for Kuskokwim River Assessment Area

L Reference Creek Benthic Macroinvertebrate Metals Data Used to Develop Background Trophic Transfer Factors

Table of Contents (cont.)

Chapter **Page**

M **Slimy Sculpin Metals Data for Reference Creeks Used to Develop Background Benthos-to-Sculpin Trophic Transfer Factors**

N **Development of Background Benthos-to-Sculpin Trophic Transfer Factors**

O **Site-Specific Fish Tissue Screening Concentrations**

P **Site-Specific Tissue Screening Concentrations for Benthic Macroinvertebrates**

List of Tables

Table | **Page**

Table 2-1 Soil Boring Installation and Soil Sample Collection 2-17

Table 2-2 Field Soil Characterization Summary 2-19

Table 2-3 Subsurface Soil Sample Laboratory Results 2-41

Table 3-1 Monitoring Well Installation Summary 3-19

Table 3-2 Groundwater Sample Collection, Spring 2015 3-21

Table 3-3 Groundwater Sample Collection, Fall 2015 3-23

Table 3-4 Well Construction and Groundwater Depth Information 3-25

Table 3-5 Groundwater Sample Results, Spring 2015 3-29

Table 3-6 Groundwater Sample Results, Fall 2015 3-30

Table 4-1 Surface Water Sample Collection, Spring 2015 4-7

Table 4-2 Surface Water Sample Collection, Fall 2015 4-8

Table 4-3 Red Devil Creek and Seep Discharge 4-9

Table 4-4 Surface Water Sample Results, Spring 2015 4-11

Table 4-5 Surface Water Sample Results, Fall 2015 4-13

Table 5-1 Kuskokwim River Sediment Sample Collection 5-23

Table 5-2 Watershed Characteristics and Number of Fish Sampled per Watershed in the Middle Kuskokwim River Region, Alaska, by Matz et al. (2017) 5-25

Table 5-3a Kuskokwim River Sediment Sample Results, Fall 2015 5-27

Table 5-3b Background Kuskokwim River Sediment Results (2010, 2011, and 2015) 5-29

List of Tables (cont.)

Table		Page
Table 5-3c	Updated Background Statistics for Kuskokwim River Sediments (2010, 2011, and 2015)	5-31
Table 5-4	Periphyton Sample Results, BLM 2014	5-33
Table 5-5	Comparison of Metals Concentrations in Periphyton from the Kuskokwim River Upstream and Downstream from the Red Devil Creek Delta	5-37
Table 5-6	Summary of Mercury Selective Sequential Extraction (SSE) Results for 2015 Kuskokwim River Sediment Samples	5-38
Table 5-7	Mineral Occurrences near Red Devil Mine	5-39
Table 6-1a	Final Compounds of Potential Concern, Red Devil Mine Site	6-37
Table 6-1b	Near-Shore Sediment Samples Used to Determine Exposure Point Concentration	6-38
Table 6-2	Near-Shore Down River Sediment Exposure Point Concentration Summary	6-39
Table 6-3	Near-Shore Near-Red Devil Mine Sediment Exposure Point Concentration Summary	6-40
Table 6-4	Weighted Near-Shore Sediment Exposure Point Concentration Summary	6-41
Table 6-5	Fish Tissue Exposure Point Concentration Summary – Northern Pike	6-42
Table 6-6	Fish Tissue Exposure Point Concentration Summary – Burbot	6-43
Table 6-7	Fish Tissue Exposure Point Concentration Summary – Sheefish	6-44
Table 6-8	Fish Tissue Exposure Point Concentration Summary – Arctic Grayling	6-45
Table 6-9	Calculation of COPC Intake from Incidental Ingestion of Sediment	6-46
Table 6-10	Calculation of COPC Intake from Dermal Sediment Contact	6-47
Table 6-11	Calculation of COPC Intake from Fish Consumption	6-48
Table 6-12	Dermal Absorption Fractions	6-49
Table 6-13	Harvest and 95th Percentile Use Estimates for Fish Ingestion Rates, Red Devil Village	6-50
Table 6-14	Noncancer Toxicity Data - Oral/Dermal	6-51
Table 6-15	Cancer Toxicity Data - Oral/Dermal	6-52
Table 6-16	Percent Inorganic Arsenic in Fish Tissue	6-53

List of Tables (cont.)

Table **Page**

Table 6-17a Calculation of Cancer Risks – Resident and Recreational/Subsistence User 6-54

Table 6-17b Calculation of Cancer Risks with Outliers Removed – Resident and Recreational/Subsistence User 6-55

Table 6-18 Calculation of Cancer Risks – Mine Worker 6-56

Table 6-19 Summary of Excess Lifetime Cancer Risks for Red Devil Mine Region.......... 6-57

Table 6-20a Calculation of Noncancer Hazards – Resident and Recreational/Subsistence User6-58

Table 6-20b Calculation of Noncancer Hazards with Outliers Removed – Resident and Recreational/Subsistence User 6-61

Table 6-21 Calculation of Noncancer Hazards – Mine Worker 6-62

Table 6-22 Summary of Hazard Indices for Red Devil Mine Region 6-65

Table 6-23 Inorganic Arsenic and Methylmercury Hazards 6-66

Table 6-24 Background Exposure Point Concentration for Kuskokwim River Sediments. 6-67

Table 6-25a Calculation of Cancer Risks at Background Levels - Residential and Recreational/Subsistence User 6-68

Table 6-25b Calculation of Noncancer Hazards at Background Levels - Residential and Recreational/Subsistence User 6-69

Table 6-26a Total, Background, and Site Cancer Risks for Future Residents and Recreational/Subsistence Users 6-70

Table 6-26b Total, Background, and Site Hazards for Future Residents and Recreational/Subsistence Users 6-70

Table 6-27a Comparison of Modeled and Actual Subsistence Fish Concentrations Based on Site BSAFs and TTFs 6-71

Table 6-27b Comparison of Modeled and Actual Subsistence Fish Concentrations Based on Background BSAFs and TTFs 6-72

Table 7-1 Assessment Endpoints, Model Species, Risk Questions, and Measures for the Red Devil Mine Site BERA Supplement for the Kuskokwim River Assessment Area 7-20

Table 7-2 Sediment Exposure Point Concentrations for Kuskokwim River Assessment Area Used in Red Devil Mine Site BERA Supplement to Assess Risks to Piscivorous Wildlife (Belted Kingfisher and Mink) 7-21

List of Tables (cont.)

Table **Page**

Table 7-3 Sediment Exposure Point Concentrations for Kuskokwim River Assessment Area Used in BERA Supplement to Assess Risks for Wildlife that may Forage in Shoreline and Nearshore Habitats (Green-Winged Teal and Common Snipe) . 7-22

Table 7-4 Exposure Parameters for Wildlife Receptors, Red Devil Mine Site BERA Supplement for Kuskokwim River Assessment Area....................................... 7-23

Table 7-5a Green-Winged Teal Exposure Point Concentrations, Red Devil Mine Site BERA Supplement for Kuskokwim River Assessment Area: Site Uptake Factors Used.. 7-24

Table 7-5b Green-Winged Teal EPCs, Red Devil Mine Site BERA Supplement for Kuskokwim River Assessment Area: Background Uptake Factors Used 7-25

Table 7-5c Green-Winged Teal EPCs, Red Devil Mine Site BERA Supplement for Kuskokwim River Assessment Area: Downriver Periphyton Results Used 7-26

Table 7-6a Common Snipe Exposure Point Concentrations for Red Devil Mine Site BERA Supplement for Kuskokwim River Assessment Area: Site BSAFs Used to Estimate Dietary Exposure 7-27

Table 7-6b Common Snipe Exposure Point Concentrations for Red Devil Mine Site BERA Supplement for Kuskokwim River Assessment Area: Background BSAFs Used to Estimate Dietary Exposure 7-28

Table 7-7a Belted Kingfisher and Mink Exposure Point Concentrations, Red Devil Mine Site BERA Supplement for Kuskokwim River Assessment Area: Site BSAFs and TTFs used to Model Dietary Exposure... 7-29

Table 7-7b Belted Kingfisher and Mink Exposure Point Concentrations, Red Devil Mine Site BERA Supplement for Kuskokwim River Assessment Area: Background BSAFs and TTFs Used to Model Dietary Exposure 7-30

Table 7-8a Green-Winged Teal Exposure Estimates and HQs, Red Devil Mine Site BERA Supplement for Kuskokwim River Assessment Area: Sediment-to-Aquatic Plant Uptake Factors for Settling Ponds (Appendix J) Used to Estimate Dietary Exposure 7-31

Table 7-8b Green-Winged Teal Exposure Estimates and HQs, Red Devil Mine Site BERA Supplement for Kuskokwim River Assessment Area: Background Sediment-to-Aquatic Plant Uptake Factors (Appendix J) Used to Estimate Dietary Exposure 7-32

Table 7-8c Green-Winged Teal Exposure Estimates and HQs, Red Devil Mine Site BERA Supplement for Kuskokwim River Assessment Area: Downriver Periphyton Results (Appendix K) Used to Estimate Dietary Exposure............................... 7-33

List of Tables (cont.)

Table **Page**

Table 7-9a Common Snipe Exposure Estimates and Hazard Quotients, Red Devil Mine Site BERA Supplement for Kuskokwim River Exposure Area: Site BSAFs (Appendix F) Used to Estimate Dietary Exposure 7-34

Table 7-9b Common Snipe Exposure Estimates and Hazard Quotients, Red Devil Mine Site BERA Supplement for Kuskokwim River Exposure Area: Background BSAFs (Appendix F) Used to Estimate Dietary Exposure 7-35

Table 7-10a Belted Kingfisher Exposure Estimates and Hazard Quotients, Red Devil Mine Site BERA Supplement for Kuskokwim River Assessment Area: Site BSAFs and TTFs Used to Estimate Dietary Exposure 7-36

Table 7-10b Belted Kingfisher Exposure Estimates and Hazard Quotients, Red Devil Mine Site BERA Supplement for Kuskokwim River Assessment Area: Background BSAFs and TTFs Used to Estimate Dietary Exposure 7-37

Table 7-11a Mink Exposure Estimates and Hazard Quotients, Red Devil Mine Site BERA Supplement for Kuskokwim River Assessment Area: Site BSAFs and TTFs Used to Estimate Dietary Exposure 7-38

Table 7-11b Mink Exposure Estimates and Hazard Quotients, Red Devil Mine Site BERA Supplement for Kuskokwim River Assessment Area: Background BSAFs and TTFs Used to Estimate Dietary Exposure 7-39

Table 7-12 Toxicity Reference Values for Birds and Mammals 7-41

Table 7-13 Survival and Growth Results for *Hyalella azteca* 28-day Sediment Toxicity Tests7-43

Table 7-14 Pearson Correlations and Significance Levels between *Hyalella* Survival and Constituents in Kuskokwim River Sediment Samples Collected in Fall 2015.. 7-44

Table 7-15 Spearman Correlations and Significance Levels between *Hyalella* Survival and Constituents in Kuskokwim River Sediment Samples Collected in Fall 2015.. 7-45

Table 7-16 Comparison of Metals Concentrations in 2015 Kuskokwim River Sediment Samples Showing Reduced Growth of *Hyalella* with Sediment Screening Levels and Reference Concentrations 7-46

Table 7-17 Mean SQG Quotients for Kuskokwim River Sediment Samples Used in 28-day *Hyalella* Toxicity Test, Red Devil Mine Site BERA Supplement..... 7-47

Table 7-18 Risk Characterization for Benthic Macroinvertebrates in Kuskokwim River Assessment Area Based on Comparing Modeled Metals Concentrations in Benthic Macroinvertebrates with Tissue Screening Concentrations 7-49

List of Tables (cont.)

Table **Page**

Table 7-19 Risk Characterization for Forage Fish Based on Comparing Modeled Whole-Body Concentrations with Tissue Screening Concentrations for Effects on Fish, Red Devil Mine Site BERA Supplement for Kuskokwim River Assessment Area 7-50

Table 7-20 Calculation of Weighted Benthic Macroinvertebrate (Benthos) Tissue Concentration for Mercury and Calculation of Mercury Exposure and Risk for Common Snipe with Weighted Benthos Tissue Concentration 7-51

Table 7-21 Calculation of Weighted Benthic Macroinvertebrate (Benthos) Tissue Concentration for Mercury and Calculation of Mercury Exposure and Risk for Benthic Macroinvertebrates 7-52

Table 7-22 Calculation of Weighted Forage Fish Tissue Concentration for Mercury and Calculation of Mercury Risk to Forage Fish with Weighted Forage Fish Tissue Concentration 7-53

Table 7-23 Comparison of Mercury Hazard Quotients for Three Receptors Calculated with Tissue Concentrations Modeled with BSAFs and TTFs Developed from Red Devil Creek Data, Reference Creek Data, and Both Red Devil Creek and Reference Creek Data 7-54

Table 7-24 Summary of Potential Risks by Assessment Endpoint, Red Devil Mine Site BERA Supplement for Kuskokwim River Assessment Area 7-55

List of Figures

Figure **Page**

Figure 1-1 Site Location Map 1-7

Figure 1-2 Upland Area Encompassed by Remedial Investigation 1-9

Figure 2-1 2015 Soil Boring and Monitoring Well Locations 2-43

Figure 2-2 2015 Soil Boring and Monitoring Well Locations and Underground Mine Workings 2-45

Figure 2-3 Mercury SSE Percent Fractions F0 - F4 vs. Total F0 - F5 Concentration Subsurface Soil in Main Processing Area 2-47

Figure 2-4 Geologic Cross Section G-G’ 2-49

Figure 2-5 Geologic Cross Section H-H’ 2-51

Figure 2-6 Geologic Cross Section I-I’ and Underground Mine Workings 2-53

Figure 3-1 2015 Groundwater and Surface Water Monitoring Locations 3-31

Figure 3-2 Groundwater Potentiometric Surface, Spring 2015 3-33

Figure 3-3 Groundwater Potentiometric Surface, Fall 2015 3-35

Figure 3-4 Groundwater and Surface Water Sample Results, Spring 2015, Total and Dissolved Antimony 3-37

Figure 3-5 Groundwater and Surface Water Sample Results, Spring 2015, Total and Dissolved Arsenic 3-39

Figure 3-6 Groundwater and Surface Water Sample Results, Spring 2015, Total and Dissolved Mercury 3-41

Figure 3-7 Groundwater and Surface Water Sample Results, Fall 2015, Total and Dissolved Antimony 3-43

Figure 3-8 Groundwater and Surface Water Sample Results, Fall 2015, Total and Dissolved Arsenic 3-45

List of Figures (cont.)

Table **Page**

Figure 3-9 Groundwater and Surface Water Sample Results, Fall 2015, Total and Dissolved Mercury 3-47

Figure 3-10 Groundwater Concentrations and Elevations Over Time for Selected Wells.... 3-49

Figure 4-1 Concentration Versus Distance, Red Devil Creek and Seep Surface Water 4-15

Figure 5-1 Kuskokwim River Sediment and Periphyton Sample Locations – Near Red Devil Mine Site 5-41

Figure 5-2 Kuskokwim River Sediment and Periphyton Sample Locations – Near Red Devil Mine Site and Downriver 5-43

Figure 5-3 2014 Kuskokwim River Periphyton Sample Locations 5-45

Figure 5-4 Watersheds in the Middle Kuskokwim River Region 5-47

Figure 5-5 Total Antimony in Sediment, RI (2010-2012) and RI Supplement (2015) – Near Red Devil Mine Site 5-49

Figure 5-6 Total Antimony in Sediment, RI (2010-2012) and RI Supplement (2015) – Near Red Devil Mine Site and Downriver 5-51

Figure 5-7 Total Arsenic in Sediment, RI (2010-2012) and RI Supplement (2015) – Near Red Devil Mine Site 5-53

Figure 5-8 Total Arsenic in Sediment, RI (2010-2012) and RI Supplement (2015) – Near Red Devil Mine Site and Downriver 5-55

Figure 5-9 Total Mercury in Sediment, RI (2010-2012) and RI Supplement (2015) – Near Red Devil Mine Site 5-57

Figure 5-10 Total Mercury in Sediment, RI (2010-2012) and RI Supplement (2015) – Near Red Devil Mine Site and Downriver 5-59

Figure 5-11 Methylmercury in Sediment, RI (2010-2012) and RI Supplement (2015) – Near Red Devil Mine Site 5-61

Figure 5-12 Methylmercury in Sediment, RI (2010-2012) and RI Supplement (2015) – Near Red Devil Mine Site and Downriver 5-63

Figure 5-13a Total Antimony in Sediment, RI 2010-2012 5-65

Figure 5-13b Total Arsenic in Sediment, RI 2010-2012 5-65

Figure 5-13c Total Mercury in Sediment, RI 2010-2012 5-66

List of Figures (cont.)

Table **Page**

Figure 5-13d Methylmercury in Sediment, RI 2010-2012 5-66

Figure 5-14a Total Antimony in Sediment 2015 5-67

Figure 5-14b Total Arsenic in Sediment 2015 5-67

Figure 5-14c Total Mercury in Sediment 2015 5-68

Figure 5-14d Methylmercury in Sediment 2015 5-68

Figure 5-14e Total Cadmium in Sediment 2015 5-69

Figure 5-14f Total Cobalt in Sediment 2015 5-69

Figure 5-14g Total Copper in Sediment 2015 5-70

Figure 5-14h Total Iron in Sediment 2015 5-70

Figure 5-14i Total Manganese in Sediment 2015 5-71

Figure 5-14j Total Nickel in Sediment 2015 5-71

Figure 5-14k Total Selenium in Sediment 2015 5-72

Figure 5-14l Total Silver in Sediment 2015 5-72

Figure 5-14m Total Vanadium in Sediment 2015 5-73

Figure 5-14n Total Zinc in Sediment 2015 5-73

Figure 5-15a Total Antimony in Periphyton, BLM 2014 5-74

Figure 5-15b Total Antimony in Periphyton, BLM 2014 (log scale) 5-74

Figure 5-15c Total Arsenic in Periphyton, BLM 2014 5-75

Figure 5-15d Total Arsenic in Periphyton, BLM 2014 (log scale) 5-75

Figure 5-15e Inorganic Arsenic in Periphyton, BLM 2014 5-76

Figure 5-15f Percent Inorganic Arsenic in Periphyton, BLM 2014 5-76

Figure 5-15g Total Mercury in Periphyton, BLM 2014 5-77

Figure 5-15h Total Mercury in Periphyton, BLM 2014 (log scale) 5-77

Figure 5-15i Total Cadmium in Periphyton, BLM 2014 5-78

List of Figures (cont.)

Table **Page**

Figure 5-15j Total Copper in Periphyton, BLM 2014 5-78

Figure 5-15k Total Iron in Periphyton, BLM 2014 5-79

Figure 5-15l Total Manganese in Periphyton, BLM 2014.. 5-79

Figure 5-15m Total Nickel in Periphyton, BLM 2014 5-80

Figure 5-15n Total Selenium in Periphyton, BLM 2014... 5-80

Figure 5-15o Total Vanadium in Periphyton, BLM 2014 5-81

Figure 5-15p Total Zinc in Periphyton, BLM 2014 5-82

Figure 5-16 Mean (+ Standard Error) Total Mercury Concentrations in Muscle Biopsies of Radio-Tagged Northern Pike and Burbot Across Capture Watersheds in the Middle Kuskokwim Region, 2011-2013... 5-83

Figure 5-17a Total Antimony in Sediment 2015 (log scale)... 5-84

Figure 5-17b Total Arsenic in Sediment 2015 (log scale)... 5-84

Figure 5-17c Total Mercury in Sediment 2015 (log scale) 5-84

Figure 5-18 Mines, Prospects, and Other Mineral Occurrences in the Red Devil Area, Alaska5-85

Figure 6-1 Kuskokwim River Sediment Exposure Area 6-74

Figure 6-2 Area of Kuskokwim River Risk Assessment Supplement and Watersheds in the Middle Kuskokwim Region.. 6-76

Figure 6-3 Human Health Conceptual Site Model for the Kuskokwim River Risk Evaluation6-78

Figure 7-1 Ecological Conceptual Site Model for Kuskokwim River Risk Evaluation...... 7-56

Figure 9-1 Lines of Evidence Relevant to Kuskokwim River Risk Characterization......... 9-12

List of Abbreviations and Acronyms

µg/L	micrograms per liter
AAC	Alaska Administrative Code
ABSd	dermal absorption fraction
ADEC	Alaska Department of Environmental Conservation
ADF&G	Alaska Department of Fish and Game
ATSDR	Agency for Toxic Substances and Disease Registry
ATV	all-terrain vehicle
AVS:SEM	acid volatile sulfides: simultaneously extracted metals
BERA	Baseline Ecological Risk Assessment
bgs	below ground surface
BLM	Bureau of Land Management
BSAF	Biota-Sediment Accumulation Factor
BTEX	benzene, toluene, ethylbenzene, xylenes
Cal/EPA	California Environmental Protection Agency
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	contaminant of concern
COPC	contaminant of potential concern
CSM	conceptual site model
DRO	diesel range organics
E & E	Ecology and Environment, Inc.
EERs	estimated energy requirements
ELCR	excess lifetime cancer risks
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
ERA	Ecological Risk Assessment

List of Acronyms and Abbreviations (cont.)

FCM	food chain multiplier
FI	fraction ingested
Field Operations Plan	Field Operations Plan – 2014, Quantification of fish and aquatic insect tissue contaminants in the middle Kuskokwim River, Alaska
Field Sampling Plan	Final Field Sampling Plan for 2015 Soil, Groundwater, Surface Water, and Kuskokwim River Sediment Characterization, Supplement to Remedial Investigation, Red Devil Mine, Alaska
FS	Feasibility Study
GRO	gasoline range organics
ha	hectare
HEAST	Health Effects Assessment Summary Table
HHRA	Human Health Risk Assessment
HI	hazard index
HQ	hazard quotient
IRIS	Integrated Risk Information System
ITRC	Interstate Technology and Regulatory Council
LADI	lifetime average daily intake
L/kg	liters per kilogram
LOAEL	Lowest Observed Adverse Effect Level
LOE	lines of evidence
MCL	maximum contaminant level
mg/day	milligrams per day
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MRL	Minimal Risk Level
ng/g	nanograms/gram
ng/L	nanograms per liter
NOAEL	No Observed Adverse Effect Level
NTCRA	non-time-critical removal action
NTU	nephelometric turbidity unit
ppm	parts per million
PPRTV	Provisional Peer Reviewed Toxicity Value
RBA	relative bioavailability factor
RDM	Red Devil Mine

List of Acronyms and Abbreviations (cont.)

RfD	reference dose
RI	Remedial Investigation
RI Supplement Work Plan	Final Work Plan for 2015 Soil, Groundwater, Surface Water, and Kuskokwim River Sediment Characterization, Supplement to Remedial Investigation, Red Devil Mine, Alaska
RME	reasonable maximum exposure
SF	slope factor
SOP	standard operating procedure
SQG	sediment quality guideline
SSE	selective sequential extraction
SUF	site use factor
SVOC	semivolatile organic compound
TAL	target analyte list
TOC	total organic carbon
TSC	tissue screening concentration
TTF	trophic transfer factor
UCL	upper confident limit
UF	uptake factor
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WOE	weight of evidence
XRF	X-ray fluorescence (spectroscopy)

List of Acronyms and Abbreviations (cont.)

1 Introduction

This document presents results of supplemental studies conducted to support the Remedial Investigation (RI) being performed at the Red Devil Mine (RDM), located in Red Devil, Alaska (see Figure 1-1). The RDM consists of an abandoned mercury mine and ore processing facility located on public lands managed by the U.S. Department of the Interior Bureau of Land Management (BLM) in southwest Alaska. The BLM initiated an RI/Feasibility Study (FS) at the RDM in 2009 pursuant to its delegated Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) lead agency authority. An RI was performed by Ecology and Environment, Inc. (E & E) on behalf of the BLM under Delivery Order Number L09PD02160 and General Services Administration Contract Number GS-10F-0160J. Results of the RI are presented in the Final Remedial Investigation Report, Red Devil Mine, Alaska (E & E 2014). Results of the FS are presented in the Final Feasibility Study, Red Devil Mine, Alaska (E & E 2016).

Data collected during the RI were used to define the site physical setting, the nature and extent of contamination, and the fate and transport of contaminants. The RI results were used to assess risk to human health and the environment due to exposure to site contaminants. The FS addresses contaminated tailings/waste rock, soil, and Red Devil Creek sediments. Neither the RI nor FS fully evaluated possible site impacts to the adjacent Kuskokwim River. The FS did not address remedies for groundwater or Kuskokwim River sediments because the need for, and extent of, cleanup of these media have not yet been completely assessed. The RI Supplement is being performed to address data gaps associated with soil, groundwater, and Kuskokwim River sediments that were identified as part of the development of site-wide remedial alternatives during the preparation of the FS. The RI Supplement also addresses changes in the groundwater and surface water monitoring network and possible changes to the groundwater and surface water conditions at the RDM stemming from implementation of a non-time-critical removal action (NTCRA) performed by the BLM at the RDM during the summer of 2014. Lastly, data were collected and evaluated specifically to address questions regarding methylmercury bioaccumulation in the Kuskokwim River food chain, particularly in upper trophic level fish that may be consumed by local residents.

E & E is performing the RI Supplement on behalf of the BLM under BLM National Environmental Services Blanket Purchase Agreement Number L14PA00149, Delivery Order Numbers L14PB00938 and L17PB00236. The RI Supplement is being performed per applicable CERCLA statutes, regulations, and guidance following the Final Work Plan for 2015 Soil, Groundwater, Surface Water, and Kuskokwim River Sediment Characterization, Supplement to Remedial Investigation, Red Devil Mine, Alaska (RI Supplement Work Plan; E & E 2015) and the final Proposed Technical Approach for Kuskokwim River Risk Assessment Supplement, Red Devil Mine, Alaska (BLM 2017).

Historical mining activities at the RDM included underground and surface mining. Ore processing included crushing, retorting/furnacing, milling, and flotation. Historical mining operations left tailings and other remnants that have affected local soil, surface water, sediment, and groundwater. The final RI report provides detailed background information on the RDM and information on the regulatory framework for the RI/FS and supplemental RI work addressed in this document. That information is not repeated in this RI Supplement report. Existing data and information regarding the RDM pertinent to the RI Supplement activities are presented in the final RI report, RI Supplement Work Plan, and other documents.

1.1 Definition of the Site

The RDM encompasses the areal extent of contamination and all suitable areas in very close proximity to the contamination necessary for implementation of a response action. Historical mining operations left tailings and other remnants that have affected local soil, surface water, sediment, and groundwater. Based on the location of tailings and other features, the RI Supplement's objectives and associated data collection pertain to each of the following areas:

- The Main Processing Area.
- Red Devil Creek, extending from a reservoir upstream of the Main Processing Area to the creek's delta at its confluence with the Kuskokwim River.
- The area west of the Main Processing Area where historical surface exploration and mining occurred, referred to as the Surface Mined Area. The Surface Mined Area is underlain by the area of underground mine workings. The "Dolly Sluice" and "Rice Sluice" and their respective deltas on the bank of the Kuskokwim River are associated with the Surface Mined Area.
- Sediments in the Kuskokwim River. The river bed sediments are located within submerged lands of the Kuskokwim River owned by the State of Alaska and managed by the Alaska Department of Natural Resources.

Figure 1-2 illustrates the upland area encompassed by the RI and RI Supplement and the major features identified above based on aerial photographs taken in 2010 (Aero-Metric, Inc. 2010a) and 2001 (Aero-Metric, Inc. 2010b).

The Main Processing Area contains most of the former site structures and is where ore beneficiation and mineral processing were conducted. The area is split by Red Devil Creek. Underground mine openings (shafts, adits, and stopes to the surface) and ore processing and mine support facilities (housing, warehousing, and so forth) were located on the west side of Red Devil Creek until 1955. After 1955, all ore processing was conducted at structures and facilities on the east side of Red Devil Creek. The Main Processing Area includes three monofills. The monofills contain demolished mine structure debris and other material. Two monofills are unlined (Monofills #1 and #3). Monofill #2, on the east side of Red Devil Creek, is an engineered and lined containment structure for building debris and materials from the demolished Post-1955 Retort structure.

1.2 Purpose and Objectives

The purpose of this report is to describe the RI Supplement activities, procedures, and methods that were used to augment existing data for soil, groundwater, surface water, and Kuskokwim River sediment and biota. The objectives of the supplemental RI activities are generally to address data gaps identified during the development of the FS, identify possible changes to site conditions resulting from the NTCRA, and support the development of site-wide remedial alternatives at the RDM. Additionally, sediment toxicity testing was conducted on Kuskokwim River sediment to evaluate potential impacts to benthos near the RDM, and data on total mercury and methylmercury measured in Kuskokwim River periphyton and fish were used to evaluate methylmercury bioaccumulation in the Kuskokwim River food chain near the RDM. A summary of the RI and other pertinent studies is presented in Chapter 2 of the RI Supplement Work Plan. A detailed discussion of the data gaps and data quality objectives of the RI Supplement is presented in Chapter 3 of the RI Supplement Work Plan. Objectives of the supplemental RI activities also are briefly summarized in this report.

This report also presents the results of the Risk Assessment Supplement for the Kuskokwim River in the area of the RDM. The results of the Risk Assessment Supplement will be used along with other lines of evidence to support risk-management decisions for site-related contaminants in the Kuskokwim River near the RDM.

1.3 RI Supplement and BLM Kuskokwim River Investigation Activities

The RI Supplement field investigations were conducted over the course of three field events in 2015:

- June 17 to June 24, 2015 – Spring groundwater and surface water monitoring event.
- July 7 to August 12, 2015 – Soil boring installation and associated subsurface soil sampling and monitoring well installation.
- September 1 to September 11, 2015 – Fall groundwater and surface water monitoring event, well survey, and Kuskokwim River sediment sampling.

The RI Supplement field work was originally planned for two mobilizations, with the soil boring and well installation activities to be performed during the first mobilization immediately after the spring groundwater and surface water monitoring. E & E’s subcontracted driller mobilized to the RDM on June 23, 2015, and the driller and E & E staff began preparing for the planned drilling activities. However, on June 25, an unplanned demobilization was necessary due to a wildfire encroaching upon the village of Red Devil and the RDM. The wildfire apparently started due to a lightning strike on June 24 and was first observed on the morning of June 25, as it was encroaching upon the village of Red Devil. For health and safety reasons, E & E staff, E & E's drilling subcontractor, and BLM staff demobilized from Red Devil early in the afternoon of June 25. On July 7, 2015, after the fire was suppressed, the E & E staff, E & E's drilling subcontractor, and BLM staff remobilized to the site and resumed drilling-related field activities.

The RI Supplement field activities were performed in accordance with the Final Field Sampling Plan for 2015 Soil, Groundwater, Surface Water, and Kuskokwim River Sediment Characterization, Supplement to Remedial Investigation, Red Devil Mine, Alaska (Field Sampling Plan; E & E 2015), included as Appendix A of the RI Supplement Work Plan, except as noted in the sections below.

RI Supplement results are integrated with RI results presented in the final RI report (E & E 2014) in this section as applicable. Consistent with the final RI report, the analytes aluminum, calcium, iron, magnesium, potassium, and sodium are common earth crust elements. Based on U.S. Environmental Protection Agency (EPA) Region 10 policy, these common earth crust elements are not discussed in this report; however, the sample results are presented in the Sections 2 through 5 data tables for reference. For organic analytes, all positive detections are considered to represent site-related "contamination" because there are no nearby offsite sources of organic contaminants that are expected to contribute to onsite contamination.

Analytical data generated from the RI Supplement samples were validated by an E & E chemist in accordance with following:

- Contract Laboratory Program National Functional Guidelines for Inorganic Data Review (EPA 2010).
- Contract Laboratory Program National Functional Guidelines for Organic Data Review (EPA 2008b).
- Quality assurance guidelines in Standard Operating Procedure (SOP) BR-0013 for mercury selective sequential extraction analyses (Brooks Rand Laboratory 2010).

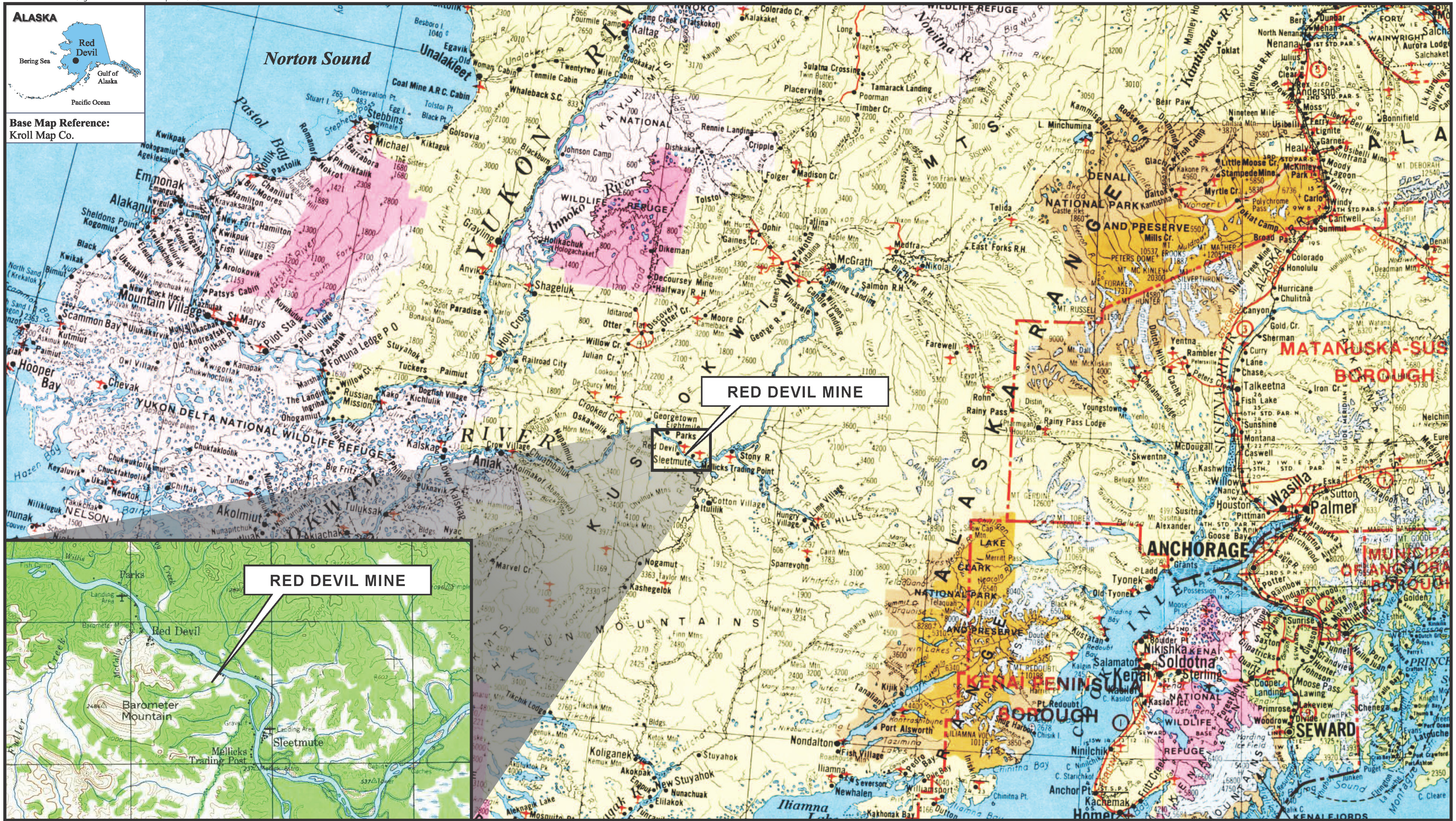
The results of laboratory analytical data validation are summarized in Data Review Memoranda for each laboratory data deliverable and are presented in Appendix A. In general, all data generated for the RI Supplement are considered usable, with qualifications, for evaluation of the nature and extent of contamination assessment of potential risk to human health and ecological receptors. Qualifications of data are described in the Data Review Memoranda. Beginning in 2010, the BLM began a study to examine mercury, methylmercury, and other metals in the Kuskokwim River basin. Those studies pertinent to the present evaluation of Kuskokwim River sediment near the RDM are summarized in Chapter 5.

1.4 Document Organization

As noted above, the RI Supplement and BLM Kuskokwim River investigations collectively are being performed to augment existing data to characterize soil, groundwater, surface water, and Kuskokwim River sediment. The RI Supplement Report is organized by each of these media. For each of these media, the RI Supplement report presents the objectives of the supplemental RI activities; descriptions of the numbers, types, locations, and analytical requirements of laboratory samples collected; the locations and methods used for field data and sample collection; deviations from the RI Supplement Work Plan; results of the RI Supplement and other pertinent investigations; and discussion and conclusions.

The RI Supplement Report is organized as follows:

- **Chapter 1, Introduction**
- **Chapter 2, Soil Investigation**
- **Chapter 3, Groundwater Investigation**
- **Chapter 4, Surface Water Investigation**
- **Chapter 5, Kuskokwim River Sediment Investigations**
- **Chapter 6, Kuskokwim River Human Health Risk Assessment**
- **Chapter 7, Kuskokwim River Ecological Risk Assessment**
- **Chapter 8, Summary and Conclusions**
- **Chapter 9, Weight of Evidence Discussion for Potential Risks Associated with Kuskokwim River Fish and Sediments**
- **Chapter 10, References**
- **Appendices**



ecology and environment, inc.
International Specialists in the Environment
Seattle, Washington

0 40 80
Approximate Scale in Miles

RED DEVIL MINE
Red Devil, Alaska

Figure 1-1
SITE LOCATION MAP

Date: 04/18/13	JSS	02:EE-001096-0070-08

2 Soil Investigation

2.1 Soil Investigation Activities

The RI Supplement soil characterization activities were performed from July 7 to August 12, 2015, and were designed to address data gaps associated with subsurface soil and bedrock. The soil characterization was performed to gather the types of additional information identified in Section 3.3 of the RI Supplement Work Plan. The supplemental RI soil characterization was designed to meet the following objectives:

- Assess lithological and mineralogical characteristics of subsurface soils and bedrock.
- Identify mine waste types and soil types.
- Determine thickness and inorganic element concentrations of tailings/waste rock where present.
- Determine concentrations of inorganic elements in tailings/waste rock where present.
- Identify and determine the thickness of types of native soil/alluvium.
- Determine concentrations of inorganic elements in soil/alluvium below tailings/waste rock from the base of tailings/waste rock to the top of bedrock to assess impacts on native soil/alluvium from deposition of inorganic elements leached from tailings/waste rock.
- Determine depth of bedrock.
- Visually assess whether the bedrock is naturally mineralized.
- Determine the presence, depth, and thickness of saturated interval(s).

Soil characterization included installing additional soil borings at the site, consisting of:

- Seven soil borings in the Main Processing Area;
- Three soil borings in the Red Devil Creek Area; and
- Four soil borings in the Surface Mined Area that were converted to monitoring wells.

The 2015 soil borings and a description of the locations of the soil borings relative to pertinent site features are presented in Table 2-1. The locations of the 2015 soil borings and monitoring wells are shown in Figure 2-1.

Actual drilling locations were refined from the locations proposed in the RI Supplement Work Plan during the investigation based on actual conditions encountered in the field. Sampling and other field procedures were performed in accordance with the Field Sampling Plan, except as noted below. A brief description of field sampling and other procedures is provided below.

2.1.1 Soil Boring Installation and Soil Sampling

Soil boring and monitoring well installation were performed using a drill rig operated by a subcontracted, Alaska-licensed driller. The driller used a track-mounted CME 850 drill rig outfitted to use direct push and hollow-stem auger equipment/method for drilling in unconsolidated material and some weathered bedrock, and air rotary/down-the-hole hammer equipment/method for drilling in bedrock. Soil borings were advanced to the total depths presented in Table 2-1.

A 2-foot-long split spoon sampler was used for subsurface soil sampling using direct-push and hollow-stem auger drilling methods. Soil cores were collected continuously with the split spoon samplers from the ground surface to the base of the unconsolidated materials. While drilling with air rotary/down-the-hole hammer in bedrock, drill cuttings were generally collected at a minimum frequency of every 5 feet, and typically every foot. At most drilling locations, occurrence of groundwater and saturated conditions was readily identifiable based on moisture content of the recovered soil in the split spoon samplers. While drilling in bedrock using air rotary/down-the-hole hammer method, saturated conditions were locally more difficult to identify because groundwater occurs primarily in fractures, and location, density, and orientations of the fractures are not well understood at the site. In comparatively less productive saturated zones, the drilling returns may not provide a clear indication of saturated conditions. If the fractures are not productive and/or if the clay-rich nature of the rock/cuttings (mixed with water) results in coating of the borehole wall and any fractures, any possible flow of water into the borehole would be impeded. Care was taken to observe and record drilling-related information, including rate of penetration, first occurrence of groundwater, water returns (presence and estimated flow rate based on airlift pumping rates), and borehole caving or sloughing, to aid in the identification of saturated intervals in bedrock.

After boreholes were successfully advanced, unless they were converted to monitoring wells, they were abandoned at the completion of sampling or the end of the day in accordance with State of Alaska regulations (18 Alaska Administrative Code [AAC] 75 and 18 AAC 78). Drill cuttings and other investigation-derived waste were managed in accordance with the Field Sampling Plan.

2.1.2 XRF Field Screening and Lithological Characterization

The soil material recovered was visually characterized and logged by the field geologist and field screened for total inorganic elements using X-ray fluorescence spectroscopy (XRF) following the procedures specified in the Field Sampling Plan. Logging and XRF field screening were typically performed at 1-foot intervals in both unconsolidated materials and in bedrock.

The following types of field observations of sampled soil and bedrock materials were made by the E & E field geologist if feasible:

- Soil type (consistent with soil type designations presented in the final RI report);
- Soil group classification (using United Soil Classification System);
- Color;
- Odor;
- Lithology and mineralogical characteristics and grain shape and size of clasts;
- Grain size range and distribution;
- Gradation;
- Soil particle lithology;
- Hardness;
- Plasticity;
- Bedding or sedimentary structures;
- Moisture content;
- Observations of gross contamination, including sheen and elemental mercury;
- Qualitative description of matrix porosity;
- Mineralization, including sulfides and iron staining;
- Weathering;
- Lithological and mineralogical characteristics of bedrock; and
- Bedrock fracture characteristics.

2.1.3 Soil Sampling for Laboratory Analysis

Selected samples of tailings/waste rock and native soil/alluvium were submitted to TestAmerica, Seattle, Washington, under subcontract to E & E, for laboratory analysis. TestAmerica performed analysis for total target analyte list (TAL) inorganics. Under sub-subcontract to TestAmerica, Brooks Rand Labs, Seattle, Washington, performed mercury selective sequential extraction (SSE) analysis on selected samples. Samples were selected for laboratory analyses using XRF field screening results and lithological observations following the criteria specified in the Field Sampling Plan. Soil sampling for laboratory analysis was performed following procedures described in the Field Sampling Plan. Subsurface soil samples submitted to the laboratory for these analyses are summarized in Table 2-1.

2.1.4 Deviations from the Field Sampling Plan

Two of the soil borings/monitoring wells that were originally planned for installation in the Main Processing Area (MP092/MW37 and MP093/MW38) were not installed. These two planned soil borings/monitoring wells were intended to replace RI monitoring wells MW16 and MW17. At the time of the development of the RI Supplement Work Plan, it was thought that wells MW16 and MW17 had been decommissioned as part of the NTCRA performed by BLM in 2014 (described in Section 2.3 of the RI Supplement Work Plan). The wells are located in the Main Processing Area near the edge of the area of tailings/waste rock regrading. During the spring 2015 groundwater and surface water monitoring event, it was determined that these two wells had not been decommissioned and they appeared to be in good condition. Therefore, soil borings/monitoring wells MP092/MW37 and MP093/MW38 were not installed.

Collection of soil samples and rock cuttings generally was performed at a frequency of one sample per foot. However, for several soil borings, the frequency was less over some intervals. Similarly, the frequency of XRF field screening was less than the planned frequency across some intervals in several boreholes. The actual frequency of soil and rock cuttings collection is shown in Appendix B.

A total of five new soil borings/monitoring wells were originally planned for installation in the Surface Mined Area. A total of eight boreholes were installed, including four boreholes that were abandoned and four boreholes in which monitoring wells were installed. Locations of the boreholes and monitoring wells are illustrated in Figure 2-1. Descriptions of the boreholes and monitoring wells are presented in Tables 2-1 and 3-1. Monitoring well installation is discussed in Section 3.1.1.

2.2 Soil Investigation Results

The supplemental RI soil characterization entailed installation of new soil borings at selected locations in the Main Processing Area, Red Devil Creek Area, and Surface Mined Area. Locations of RI Supplement soil borings are illustrated in Figure 2-1. The objectives of the soil investigation are listed in Section 2.1. Soil and bedrock characterization were performed using a combination of field observations, results of XRF field screening for total inorganic elements, and laboratory analysis for TAL inorganic elements and mercury SSE. Results of field characterization and laboratory sample analysis are summarized below.

2.2.1 Field Lithological and Mineralogical Characterization

Field observations of key soil and bedrock lithological and mineralogical characteristics, United Soil Classification System soil group classification, color, mineralization (including sulfide minerals, veins, and iron staining), and weathering, and moisture content are summarized in Table 2-2 and Appendix B.

2.2.2 XRF Field Screening

Field screening of soil samples for total metals using a field portable XRF was performed on soil and bedrock materials samples from boreholes. XRF results for the primary contaminants of concern (COCs) at the site—antimony, arsenic, and mercury—are presented in Table 2-2. The XRF results for all metals analyzed are presented in Appendix B.

2.2.3 Laboratory Soil Sample Results

2.2.3.1 Total Inorganic Elements

Laboratory analytical results for total inorganic elements are presented in Table 2-3. Results are used to support characterization of mine waste and soils, which are discussed in Sections 2.2.4 and 2.2.5.

2.2.3.2 Mercury Selective Sequential Extraction

As discussed in Chapter 5 of the final RI report, multiple interrelated factors affect the fate and transport of mercury in the environment. Chemical processes (redox, precipitation-dissolution, aqueous complexation, adsorption and desorption reactions, and formation and mobilization of colloids), and biogeochemical processes (methylation and demethylation) impact the mobility and toxicity of mercury. In addition, the various forms of mercury that these chemical and biogeochemical processes act upon also affect the fate and transport of mercury. For example, mercury in cinnabar—the mercury (II) sulfide that makes up the primary ore mineral at the RDM—is only minimally soluble under a broad range of conditions, whereas other forms of mercury (II) or elemental mercury [Hg(0)] are relatively more soluble and susceptible to methylation or volatilization. The form of mercury also controls how much mercury is bioavailable.

Historical information on operations at the RDM indicates that cinnabar is the dominant mercury ore mineral at the RDM. Cinnabar ore was subjected to thermal processing, either in retorts or furnaces at the mine, breaking down the cinnabar and allowing recovery of the resulting elemental mercury in a condenser system. No historical information on the specific chemical forms of mercury in RDM ore processing wastes (e.g., calcines) is available. However, at other mercury mine sites, extended X-ray adsorption fine structure spectroscopy studies indicate that the mercury species metacinnabar (m-HgS), corderoite ($Hg_3S_2Cl_2$), schuetteite ($HgSO_4$ -H_20), and mercury chlorides are likely to form during the roasting of mercury ores. Each of these species is more soluble than cinnabar (Rytuba 2002).

To better understand what forms of mercury are present in RDM site soils (including native soils and mine wastes) and sediment, a mercury SSE method was employed. Although the SSE technique does not identify specific minerals, chemical species, or oxidation states, it does differentiate between and quantify groups of mercury-containing solid materials based upon their solubility behavior. The results may be useful for inferring the mineralogical or chemical species present. The mercury SSE method distinguishes between water soluble, synthetic “stomach acid” (weak acid) soluble, organo-complexed, strong complexed, and mineral bound forms of mercury. Each sequential extraction step dissolves a less soluble fraction of mercury-containing material in the sample. A summary of available information regarding the SSE steps, including the extractant types and strengths, extraction procedures, and typical mercury species identified by each extraction step is provided below.

SSE Step	Extractant	Fraction Description	Typical Mercury Compounds
F0	De-ionized Water	Volatile	Hg_0 (vapor phase elemental mercury)
F1	De-ionized Water (shaken)	Water soluble	$HgCl_2$, $HgSO_4$ (salts)
F2	pH 2 HCl/HOAc (shaken)	Synthetic "stomach acid" soluble (weak acid)	HgO
F3	1 M KOH (shaken)	Organo-complexed	Hg-humics, Hg_2Cl_2
F4	12 M HNO_3 (shaken)	Strong complexed	Mineral lattice, Hg_2Cl_2, Hg_0 (liquid phase elemental mercury)
F5	Aqua Regia (concentrated HCl and HNO_3)	Mineral bound	HgS, m-HgS, HgSe, HgAu

Key:
HCl = hydrogen chloride
Hg_0 = elemental mercury
Hg_2Cl_2 = mercurous chloride
HgAu = mercury-gold amalgam
$HgCl_2$ = mercuric chloride
Hg-humics = mercury humics
HgO = mercuric oxide
HgS = cinnabar
HgSe = mercuric selenide
$HgSO_4$ = mercuric sulfate
HNO_3 = nitric acid
HOAc = acetic acid
KOH = potassium hydroxide
m-HgS = metacinnabar
SSE = selective sequential extraction

Mercury SSE results for RDM soil and sediment samples collected during the RI are presented and discussed in Chapters 4 and 5 of the final RI report.

As part of the RI Supplement, additional sampling of subsurface soil for mercury SSE analysis was performed. Selected samples were analyzed using a mercury SSE procedure following Brooks Rand Labs' SOP BR-0013. The soil sample aliquots analyzed for mercury SSE analysis consisted of mixtures predominantly of silt and or clay, with some gravel. Laboratory results for mercury SSE are presented in Table 2-3. Results are used to support characterization of mine waste and soils, which are discussed in Sections 2.2.4 and 2.2.5.

2.2.4 Identification and Characterization of Tailings/Waste Rock and Native Soil

As discussed in Chapter 3 of the final RI report, the distribution and arrangement of soils and mine and ore processing wastes at the site play a significant role in determining the nature and extent of contamination, as well as the fate and transport of contaminants at the RDM. This and other factors and processes that affect the nature and extent and fate and transport of inorganic elements at the RDM are discussed in Chapter 5 of the final RI.

Native soils at the RDM consist of loess, soils derived from Kuskokwim Group bedrock and alluvial deposits associated with the Kuskokwim River and Red Devil Creek. Non-native materials at the site are comprised of various types of mining and ore processing wastes and fill. Mining-related waste consists of waste rock, dozed and sluiced overburden, flotation tailings, and tailings (thermally processed ore, also known as calcines, burnt ore, and retorted ore). Tailings and waste rock are typically mixed and are referred to as tailings/waste rock in the final RI report and this document. Native materials have been removed, disturbed, relocated, covered, and/or mixed with other native soils and/or mine waste and tailings and fill locally across the site. Some of the native soils are naturally mineralized. The presence and nature of naturally mineralized soils at the RDM is discussed in Section 4.1.7 of the final RI report and summarized in Section 2.2.5 below.

During the RI, multiple lines of evidence were used to identify the various mine wastes and soil types and to define their distribution. These lines of evidence are discussed below. In conjunction with other information, visual observations of the presence of red porous rock and rock fragments with a distinctive rust-colored rind are shown to be useful to identify the presence of tailings. Visual observations of the presence of primary ore minerals cinnabar (mercury sulfide) and stibnite (antimony sulfide), and related gangue minerals realgar and orpiment (arsenic sulfides), and calcite and quartz veins, combined with other information, are useful to identify waste rock and naturally mineralized bedrock and rock fragments within native soils. Combined with other information, results of mercury SSE analysis were used to identify the presence of cinnabar and other forms of mercury in soils. Results of the efforts to delineate the lateral and vertical extents of tailings/waste rock, other mine wastes, and site-specific soil types during the RI are presented in Chapter 3 of the final RI report.

The RI Supplement soil characterization built upon the results of the RI, and employed a similar approach to identify types of mine wastes and native soils, and to attempt to identify naturally-mineralized soils and soils impacted by contamination. Field lithological and mineralogical observations were used, in conjunction with XRF field screening data (see Section 2.2.2) and laboratory results for total inorganics and mercury SSE analyses (see Section 2.2.3), to identify mine waste and soil types.

As in the RI, each subsurface soil sample collected as part of the RI Supplement was assigned a site-specific soil type. The interpreted mine waste and soil types identified in the soil borings are presented in Table 2-2. Mine waste types observed in the soil borings include mixed tailings/waste rock and waste rock. Table 2-2 summarizes the thickness of these mine wastes at each borehole location where they were observed. The XRF field screening results for total antimony, arsenic, and mercury for the materials are presented in Table 2-2. The results of the total TAL inorganic analyses and mercury SSE analyses for selected samples are presented in Table 2-3.

For the RI Supplement, selected samples of subsurface soil, including tailings/waste rock and a variety of disturbed and undisturbed native soils and weathered bedrock were analyzed by mercury SSE. Mercury SSE results were evaluated by calculating the proportion of mercury represented by each SSE fraction as a percentage of the total mercury in the SSE samples. The total concentration of mercury in the sample aliquots analyzed for mercury SSE was calculated by adding the concentration values for all the SSE fractions analyzed for a given sample (F0 through F5). The relative solubility of mercury under various conditions in tailings/waste rock and various soil types was evaluated by comparing the calculated percentages to total mercury by soil type. Key results are briefly discussed below. It should be noted that separate aliquots of soil samples analyzed for mercury SSE were analyzed for total mercury via EPA Method 1631 and SW846 7471A. Any significant differences between the sum of SSE fractions F0-F5 and the results for total mercury are most likely attributable to differences in total mercury between the separate aliquots, reflecting heterogeneity of the sample material.

The comparably less soluble SSE fraction F5, which includes cinnabar, generally comprised most of the mercury in samples with relatively higher concentrations of total mercury, including tailings/waste rock, mineralized native soil, and some weathered bedrock. This is consistent with visual observations in those samples with visible cinnabar. Where cinnabar is not visible in the samples, the mercury SSE results provide information on the likely presence of cinnabar as well as other forms of mercury. The more soluble SSE fractions F0 through F4 were detected in comparatively higher proportions relative to total mercury only in those samples that had relatively low total mercury concentrations.

The general tendency of various soil types at the RDM with higher total mercury (i.e., sum of SSE fractions F0 through F5) concentrations to have lower proportions of the more soluble fractions F0 through F4 is illustrated in Figure 2-3.

Geologic cross sections illustrating the generalized distribution of mine wastes, soil types, bedrock, and other pertinent features are presented in Figures 2-4 through 2-6. A cross section reference map is presented in Figures 2-1 and 2-2.

2.2.5 Characterization of Bedrock

In parts of the RDM, including the Main Processing Area, Red Devil Creek Area, and Surface Mined Area, the depth to bedrock is not known. An objective of the RI Supplement soil characterization effort was to determine the depth to bedrock at the borehole locations. Depths to weathered bedrock and competent bedrock, where encountered, are presented in Table2-2.

Another objective of the RI Supplement soil characterization was to identify naturally occurring mineralization in bedrock. Such information may be used to evaluate the nature and extent and fate and transport of COCs at the RDM. Such information also was used to inform the decisions on drilling locations and well depths for new monitoring wells installed in the Surface Mined Area (see Section 3.2.1). Natural mineralization at the RDM comprises not only the discrete high grade mercury ore bodies targeted during mining, but also sub-ore grade zones peripheral to the ore bodies. This peripheral mineralization includes not only mercury and antimony sulfide minerals (primarily cinnabar and stibnite, respectively), but also arsenic sulfides (realgar and orpiment). Weathering of these natural sulfides, and possibly other minerals, results in naturally elevated levels of arsenic, mercury, and antimony in groundwater. Bedrock and soil in zones hydraulically downgradient of the mineralized zones also likely contain naturally elevated metals concentrations from deposition of the mobilized metals (e.g., oxidation of arsenic sulfide and adsorption of resulting arsenate onto clay particles or iron oxide/hydroxide). Migration of inorganic elements in groundwater at the RDM is complicated and is affected by multiple complex groundwater migration pathways and varied geochemical conditions present at any given time at any given location along those pathways. Available information and conclusions regarding these factors are discussed in Section 5.4 of the final RI report. Available information regarding the ore geology and peripheral mineralization is detailed in Section 4.1.7 in the final RI report and summarized below.

Ore Zone Geology

The Red Devil ore bodies are epithermal hydrothermal deposits (Gray et al. 2000). The ore minerals are cinnabar and stibnite sulfide. Other sulfide minerals locally present are realgar and orpiment (arsenic sulfides) and pyrite (iron sulfide). The mineral-laden hydrothermal solutions were derived from dehydration of hydrous minerals in the argillite/shale and mobilization of formation waters of the Kuskokwim Group host rock by heat from igneous plutons that locally intruded the host rock. The hydrothermal solutions migrated through permeable rocks and along fractures and faults (e.g., Gray et al. 2000). Such faults include the northwest-trending Red Devil fault and associated faults that run through the RDM area. Sulfide minerals and possibly other species, along with quartz, carbonate, and clay gangue, were deposited where the chemical and physical conditions favored their formation.

Concentrations of mercury in the RDM ore were typically 2 to 5% (20,000 to 50,000 parts per million [ppm]) and ranged as high as 30% (300,000 ppm). The richest ore mined at the RDM consisted of numerous discrete elongate bodies (ore shoots) that are mainly localized along and near intersections of several igneous dikes (average strike and dip of North 37° East, 63° Southeast) and numerous right lateral faults associated with the Red Devil fault (average strike and dip of North 40° West, 60° Southwest), which cut the dikes into segments. The intersections of the dikes and faults, and thus the main ore shoots, plunge on average approximately 39° on a bearing of South 10° East (Malone 1962). The main ore shoots that were mined are associated with two dikes: the Dolly dike and the “F” zone dike. The right lateral slip along the numerous faults that cut these dikes results in two arrays of ore shoots that comprise the ore zones that were targeted during mining: the zone associated with the Dolly and Rice ore shoots and the zone associated with the “F” ore zone shoots (Malone 1962). Stopes were driven along these ore shoots, and locally reached the surface or were terminated a short distance below the ground surface.

A map illustrating the configuration of the underground mine workings as of 1962 (based on Malone 1962 and MacKevett and Berg 1963) is presented in Figure 2-2. Information from a 1962 mine workings cross section (Alaska Mines and Minerals, Inc. and Decoursey Mountain Mining Co., Inc. 1962) is projected onto geologic cross section I-I’ (modified from RI Report Figure 3-4, Geologic Cross Section B-B’), presented in Figure 2-6 of this document. Information on estimated elevations of key underground mine features is shown in Figures 2-2 and 2-6.

Stope surface openings and other mine openings generally mark the locations where the ore zones reached the top of the bedrock and illustrate the west-northwest-trending alignments of the two primary ore zones (see Figures 2-2 and 2-6). The surface expression of the “F” ore zone is approximated by the “F” Zone Shaft Collar, 325 Adit and 311 Adit Portals, the Main Shaft Collar, and intervening stope surface openings. The surface expression of the Dolly and Rice ore zone is approximated by the Dolly Shaft Collar, the Rice Shaft Collar, and intervening stope surface openings (MacKevett and Berg 1963; Malone 1962).

The extent of the ore-grade mineralization at the RDM is not clear. At a minimum, the extent of ore-grade mercury mineralization would be defined by the extent of mining; however, high concentrations of cinnabar (and other sulfide minerals as well as elevated concentrations of mercury, antimony, and arsenic that may not be present in the form of sulfides) that were not economically recoverable likely are present beyond the extent of mining. The most recent available maps of underground mine workings were based on the mine development that had taken place as of 1962 (MacKevett and Berg 1963; Malone 1962); these maps were used to develop Figure 2-2. However, underground mining occurred after 1962 (see final RI report Section 1.4.2.1). Therefore, the extent of ore zones illustrated in Figures 2-2 and 2-6 represents the minimum extent of the mercury ore zones.

The “F” ore zone extends to the southeast beyond the Main Shaft Collar at least as far as the center of the Main Processing Area, as evidenced by the stopes that branch off the 200 level and approach the surface beneath Red Devil Creek in the vicinity of the seep (see Figures 2-2 and 2-6). The ore shoots that these stopes followed were hypothesized to extend to the top of bedrock in the final RI report.

The elevation of Red Devil Creek where underground workings approach the surface beneath the creek (near the seep) is approximately 210 feet above mean sea level referenced to the North American Vertical Datum 1988. Results of a geophysical survey conducted by the U.S. Geological Survey at the RDM using surface-based, direct-current resistivity and electromagnetic induction methods support the presence of near-surface stopes. The resistivity results indicated the presence of several anomalies in the subsurface along Red Devil Creek in the Main Processing Area, including two anomalies that appear likely to be associated with underground mine workings. Anomaly D is interpreted to be an elongate conductive anomaly that underlies Red Devil Creek for a distance of at least approximately 200 feet. Anomaly E is interpreted to be a nearly vertical anomaly that extends to within approximately 6 feet of the surface. Anomaly E is in close proximity to the seep on the northwest bank of Red Devil Creek (Burton and Ball 2011). The approximate cross sectional positions of these resistivity anomalies are shown in Figures 2-4 and 2-6.

Mineralization Peripheral to the Ore Zones

Existing information on local geology and mine operations and RI soil data indicate the presence of mineralization associated with, but beyond the extent of, the mercury ore zones targeted by mining. The rich ore shoots exploited during mining grade along the northwest-trending faults and associated fractures into zones characterized by networks of closely spaced cinnabar-bearing veinlets, widely spaced veinlets that form protore containing less than 1% mercury, and more distally into a peripheral zone of “barren veinlets” and clay alteration (MacKevett and Berg 1963; Malone 1962). Sub-ore grade mineralization also extended some distance laterally (i.e., toward the northeast and southwest) from the ore zones. Such sub-ore grade mineralization is discussed further below.

For simplicity, the mercury ore zones and the associated zones of sub-ore grade mercury deposits and deposits of other sulfide minerals are collectively referred to as the “mineralized zone” in this report. The extent of the mineralized zone and the distribution of inorganic element concentrations within the zone are not well understood. Information on the extent and distribution of sub-ore grade mineralization at the RDM is limited. This is likely because during mine exploration and development little information was gathered regarding the extent of mineralization at levels below ore grade. Compounding the lack of historical information, the intensive surface mining and exploration activities that took place within the Surface Mined Area and the disposal of tailings and waste rock throughout the Main Processing Area make it difficult to characterize pre-mining conditions on the surface in these areas at the present time. Nonetheless, some information regarding the mineralized zone is available. Pertinent available information is summarized below.

Surface exploratory work performed by the United States Bureau of Mines in the 1940s includes mapping of target mineral concentrations in trenches arrayed across and roughly perpendicular to the ore zones. Sub-ore grade concentrations of mercury and antimony up to several hundred ppm were reported at locations more than 150 feet laterally away from the “F” ore zone. No information on arsenic sulfide concentrations is provided (Webber et al. 1947).

The presence of mineralization outside of the ore zones also is indicated by RI soil data. Such mineralization is presented in final RI report Sections 4.17 and 4.3 and summarized below.

RI Characterization of the Mineralized Zone

Collectively, the historical mining information and RI data indicate that the natural mineralized zone (including the mercury ore zones and associated sub-ore grade deposits of mercury and deposits of antimony and arsenic sulfides and other minerals) lies within an elongate area that trends approximately west-northwest, perpendicular to the Red Devil Creek valley. This mineralized zone underlies part of the Main Processing Area as well as the Surface Mined Area. Historical site information indicates that naturally mineralized Kuskokwim Group bedrock and soils derived from it occurred locally at the surface prior to mine development. As evidenced by the incised nature of the Red Devil Creek valley, Red Devil Creek has eroded into the bedrock, exposing the ore and mineralized zones in the Main Processing Area and transporting eroded ore and other mineralized rock and soil downstream. This is indicated by reports on the early mine history—the mine was discovered when cinnabar float was found in the creek bed. The cinnabar float was followed upstream to the lode, described as being located approximately 1,000 feet up Red Devil Creek from the Kuskokwim River (Webber et al. 1947). This description corresponds to the location where the “F” ore zone intercepts the creek (see Figures 2-2 and 2-6). Cinnabar float in the Red Devil Creek alluvium and other soils in the area of the discovery, described as “detritus material in the vicinity of the lode” (interpreted here to be slope wash or other soils derived from mineralized Kuskokwim Group bedrock), were the source of cinnabar ore during the initial mining (Webber et al. 1947).

As a result of the exposure and erosion of the ore and mineralized zones, the alluvium adjacent to and downstream of the mineralized zone would contain higher natural concentrations of mineralization-related inorganic elements than alluvium found upstream of the ore and mineralized zones. Similarly, soils derived from mineralized Kuskokwim Group bedrock, including colluvium and slope wash transported downslope into Red Devil Creek valley, would contain higher natural concentrations of inorganic elements than Kuskokwim Group-derived soils from areas outside of the ore and mineralized zones. Naturally mineralized geologic materials, including mineralized Kuskokwim Group bedrock and soils and alluvium derived from it that underlie portions of the Main Processing Area and Surface Mined Area, pre-date mining activities. As such, the natural mineralization of these materials represents pre-mining “background” conditions for those areas that are mineralized. Historical mining and ore processing activities, including disposal of the tailings and waste rock, occurred within the Main Processing Area, coinciding with part of the area where the naturally mineralized zone is expected to be present in the shallow subsurface. The presence of tailings/waste rock throughout most of the Main Processing Area makes characterization of naturally mineralized soil conditions in this part of the site difficult because of elevated concentrations of inorganic elements in these mine waste materials, which may leach from the waste materials and be deposited in the native soils.

Within the Surface Mined Area, varying degrees of disturbance by exploration and mining activities have occurred. This disturbance makes it difficult to positively identify naturally mineralized conditions because potential impacts of mining-related disturbance on underlying soils cannot be ruled out, and available information does not readily facilitate differentiation between the natural mineralization and such mining-related impacts on inorganic element concentrations. Efforts to identify and characterize areas of natural mineralization in the Surface Mined Area during the RI are presented in Section 4.1.7 of the final RI report.

RI Supplement Bedrock Characterization

During the RI Supplement, as with soil, identification of natural mineralization included visual observations of the presence of cinnabar (see Photograph 1 inset), stibnite, realgar, orpiment (see Photograph 2 inset), calcite and quartz veins; XRF field screening results for antimony, arsenic, and mercury; and results for total TAL inorganics and mercury SSE analyses. The presence of these ore-related minerals and/or elevated concentrations of these COCs in bedrock suggest that the bedrock is naturally mineralized. Bedrock intervals in the RI Supplement boreholes that exhibit these features are shown in Table 2-2. Naturally mineralized bedrock was observed in most of the boreholes installed in the Surface Mined Area and, within the Main Processing Area, at borehole MP098. The mineralization observed at borehole MP098 is associated with the ore zones targeted by stopes stemming upward from the 150 Level / 200 Level of the underground mine workings (see discussion of Ore Zone Geology above and Figures 2-2 and 2-6).

Photograph 1
Weathered bedrock in split spoon sampler from depth interval 44 to 45 feet bgs, borehole MP098. Note cinnabar (red grains).

Photograph 2
Drill cuttings from borehole SM70b from depth interval 127 to 128 feet bgs. Note orpiment (bright orange grains).

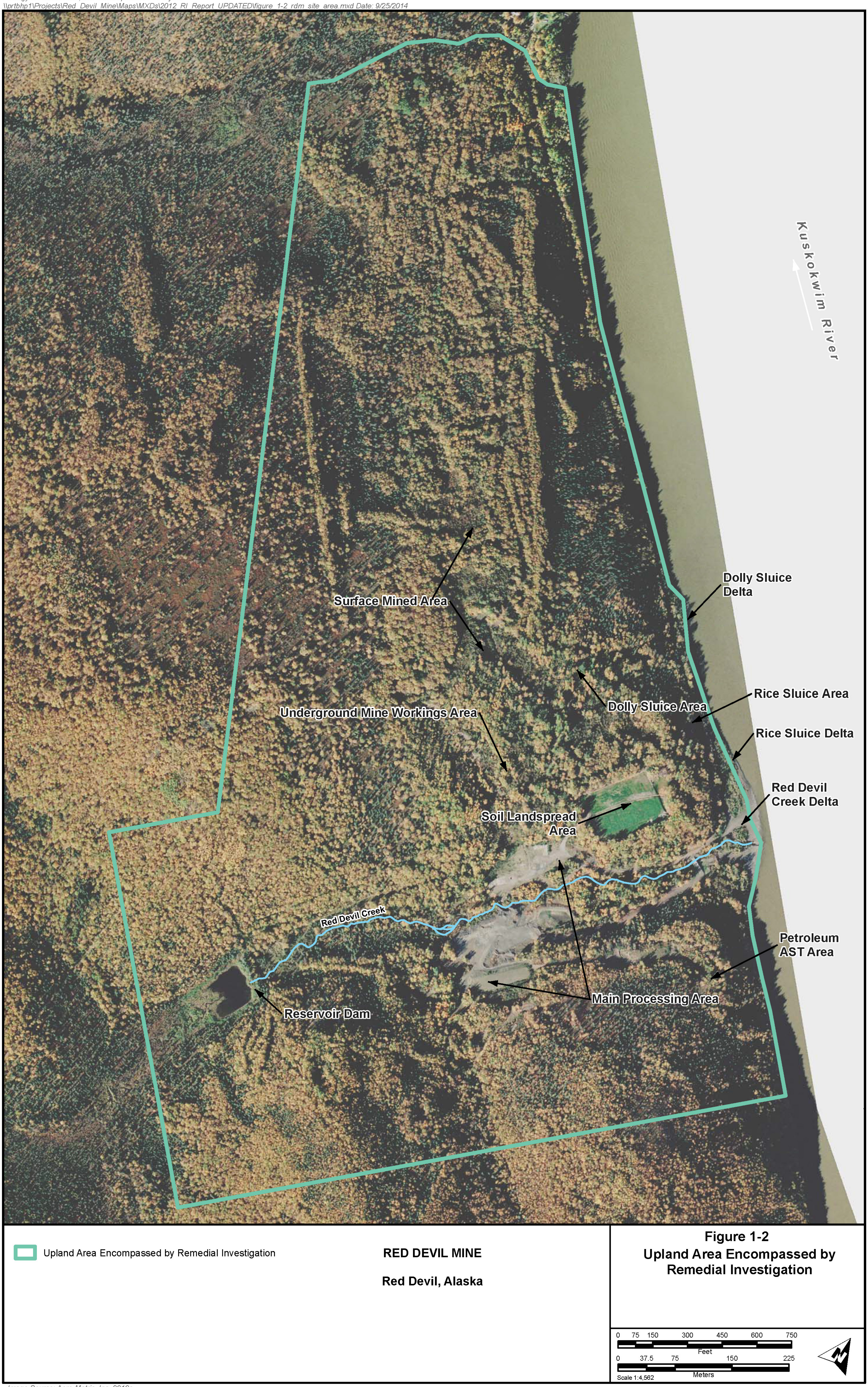
2.2.6 Occurrence of Groundwater

An objective of the RI Supplement soil characterization was to identify saturated zones and depths to groundwater in the new boreholes. This information may be used to evaluate the nature and extent and fate and transport of COCs at the RDM. Such information also was used to inform the decisions on drilling locations and well depths for new monitoring wells installed in the Surface Mined Area (see Section 3.2.1). Observations of soil moisture content and first occurrence of groundwater at each new borehole are summarized in Table 2-2.

2.3 Soil Characterization Conclusions

The RI Supplement soil characterization activities were performed to address data gaps associated with subsurface soil and bedrock. The soil characterization was performed to gather the types of additional information identified in Section 3.3 of the RI Supplement Work Plan and meet the following objectives listed in Section 2.1. It is anticipated that data collected as part of the RI Supplement soil investigation will be used, in conjunction with the RI results, to refine the estimates of depth and volume of material to be remediated through action proposed in the FS.

Results of the soil investigation met the study objectives and are detailed in Section 2.2. The RI Supplement soil characterization built upon the results of the RI, and employed a similar approach to that used in the RI to identify types of mine wastes and native soils, and to attempt to identify naturally-mineralized soils and soils impacted by contamination. Field lithological and mineralogical observations were used, in conjunction with XRF field screening data and laboratory analytical results, to identify mine waste and soil types and their thicknesses. The interpreted mine waste and soil types identified in the soil borings are presented in Table 2-2. Concentrations of inorganic contaminants in mine waste (mixed tailings/waste rock and waste rock), native soils, and bedrock were determined using XRF field screening data and laboratory analytical results. Results are presented in Tables 2-2 and 2-3 and Appendix B. Depth to bedrock and information regarding occurrence of groundwater were gathered during drilling at each borehole. Naturally mineralized bedrock and native soils were identified using visually observable lithological and mineralogical observations and XRF field screening data. Mineralized zones associated with the underground mine workings were targeted during the borehole/monitoring well installation in the Surface Mined Area. Information on depths of bedrock mineralization was used in conjunction with information gathered during drilling regarding occurrence of groundwater to inform well construction decisions of newly installed monitoring wells in the Surface Mined Area. Results are detailed in Table 2-2 and Appendix B.



RED DEVIL MINE

Red Devil, Alaska

Figure 1-2
Upland Area Encompassed by Remedial Investigation

Image Source: Aero-Metric, Inc. 2010a

Table 2-1 Soil Boring Installation and Soil Sample Collection

General Area	Soil Boring ID	Soil Boring Location Description and Notes	Soil Boring Total Depth (feet bgs)	Sample ID	Sample Depth Interval (feet bgs)		Sample Date	Sample Description	Sample Analyses and Methods	
					Top	Bottom			Total TAL Metals - EPA 6010B/6020A /7470A/7471A	Hg SSE (F0 - F5) with Total Hg
Post-1955 Main Processing Area	MP092 (not installed)	Not installed. Originally planned for location near MW16 and MW17.	NA	NA	NA	NA	NA	NA		
	MP093 (not installed)	Not installed. Originally planned for location near MW16 and MW17.	NA	NA	NA	NA	NA	NA		
	MP094	Near RI Soil Borings MP29 and MP30.	24	15MP094SB11	10	11	7/8/2015	Field Sample	X	X
				15MP094SB13	12	13	7/8/2015	Field Sample	X	
				15MP094SB17	16	17	7/8/2015	Field Sample	X	X
				15MP094SB19	18	19	7/8/2015	Field Sample	X	X
				15MP094SB20	19	20	7/8/2015	Field Sample	X	
				15MP200SB01	19	20	7/8/2015	Field Duplicate of 15MP094SB20	X	
	MP095	Near RI Soil Borings MP25 and MP29.	22	15MP095SB04	3	4	7/7/2015	Field Sample	X	X
				15MP095SB05	4	5	7/7/2015	Field Sample	X	X
				15MP095SB10	9	10	7/7/2015	Field Sample	X	X
				15MP095SB11	10	11	7/7/2015	Field Sample	X	
				15MP095SB13	12	13	7/7/2015	Field Sample	X	
				15MP200SB02	12	13	7/7/2015	Field Duplicate of 15MP095SB13	X	
	MP096	Near RI Soil Borings MP27 and MP28.	32	15MP096SB06	5	6	7/8/2015	Field Sample	X	X
				15MP096SB13	12	13	7/8/2015	Field Sample	X	X
				15MP096SB17	16	17	7/8/2015	Field Sample	X	X
				15MP096SB19	18	19	7/8/2015	Field Sample	X	
				15MP096SB26	25	26	7/8/2015	Field Sample	X	
				15MP200SB03	25	26	7/8/2015	Field Duplicate of 15MP096SB26	X	X
	MP097	Near Red Devil Creek Alignment and RI Soil Borings MP29 and MP30.	16	15MP097SB02	1	2	7/8/2015	Field Sample	X	X
				15MP097SB06	5	6	7/8/2015	Field Sample	X	X
				15MP097SB09	8	9	7/8/2015	Field Sample	X	
				15MP097SB11	10	11	7/8/2015	Field Sample	X	X
				15MP200SB04	10	11	7/8/2015	Field Duplicate of 15MP097SB11	X	X
				15MP097SB13	12	13	7/8/2015	Field Sample	X	
Pre-1955 Main Processing Area	MP098	Near RI Soil Borings MP45, MP46, MP47, MP48 and MP60.	46	15MP098SB20	19	20	7/9/2015	Field Sample	X	X
				15MP098SB26	25	26	7/9/2015	Field Sample	X	X
				15MP098SB33	32	33	7/9/2015	Field Sample	X	
				15MP098SB36	35	36	7/9/2015	Field Sample	X	
				15MP098SB38	37	38	7/9/2015	Field Sample	X	X
	MP099	Near RI Soil Boring MP53.	26	15MP099SB11	10	11	7/9/2015	Field Sample	X	X
				15MP099SB12	11	12	7/9/2015	Field Sample	X	
				15MP099SB13	12	13	7/9/2015	Field Sample	X	X
				15MP099SB17	16	17	7/9/2015	Field Sample	X	
				15MP099SB19	18	19	7/9/2015	Field Sample	X	X
				15MP200SB05	18	19	7/9/2015	Field Duplicate of 15MP099SB19	X	X
	MP100	Near RI Soil Borings MP57 and MP58.	37.5	15MP100SB09	8	9	7/10/2015	Field Sample	X	X
				15MP100SB11	10	11	7/10/2015	Field Sample	X	X
				15MP100SB17	16	17	7/10/2015	Field Sample	X	
				15MP100SB19	18	19	7/10/2015	Field Sample	X	X
				15MP100SB21	20	21	7/10/2015	Field Sample	X	
Near Red Devil Creek Alignment in Main Processing Area	MP101	Near Red Devil Creek Alignment and RI Soil Boring MP38.	17.5	15MP101SB11	10	11	7/10/2015	Field Sample	X	X
				15MP101SB13	12	13	7/10/2015	Field Sample	X	X
				15MP101SB14	13	14	7/10/2015	Field Sample	X	

Table 2-1 Soil Boring Installation and Soil Sample Collection

General Area	Soil Boring ID	Soil Boring Location Description and Notes	Soil Boring Total Depth (feet bgs)	Sample ID	Sample Depth Interval (feet bgs)		Sample Date	Sample Description	Sample Analyses and Methods	
					Top	Bottom			Total TAL Metals - EPA 6010B/6020A /7470A/7471A	Hg SSE (F0 - F5) with Total Hg
Near Red Devil Creek in Red Devil Creek Downstream Alluvial Area	RD21	Near Red Devil Creek Alignment and RI Soil Borings MP40 and RD07.	8	15RD21SB05	4	5	7/11/2015	Field Sample	X	X
	RD22	Near Red Devil Creek Alignment and RI Soil Borings RD07 and RD06.	20	15RD22SB01	0	1	7/11/2015	Field Sample	X	
				15RD22SB09	8	9	7/11/2015	Field Sample	X	X
Surface Mined Area	SM67	Northeast of Dolly Shaft and south and assumed downgradient of proposed repository location. Well MW39 installed (see Table 2-2).	90	None	NA	NA	NA	NA		
	SM68a	Near Dolly Shaft and 503 Crosscut and associated stopes. Encountered void at 37 feet bgs. Discontinued drilling and abandoned hole. Relocated to SM68b.	37	15SM68SB11	10	11	7/16/2015	Field Sample	X	
	SM68b	Near Dolly Shaft and 503 Crosscut and associated stopes. Drilled to 135 feet bgs. Hole dry. Hole abandoned. Relocated to SM68c.	135	None	NA	NA	NA	NA		
	SM68c	Near 507 Crosscut and Dolly No. 7 / 1280 Crosscut. Well MW40 installed (see Table 2-2).	155	None	NA	NA	NA	NA		
	SM69 (not installed)	NA. Not installed.	NA	NA	NA	NA	NA	NA		
	SM70a	Near 325 Adit and 150 Level / 200 Level. Hole dry. Hole abandoned. Relocated to SM70b.	96	15SM70SB02	1	2	7/18/2015	Field Sample	X	
	SM70b	Near 325 Adit and 150 Level / 200 Level. Well MW42 installed (see Table 2-2).	140	None	NA	NA	NA	NA		
	SM71a	Near 33 Level. Well installation attempted, but well damaged. Abandoned well. Relocated to SM71b.	99	15SM200SB02	11	12	7/21/2015	Field Duplicate of 15SM71SB12	X	
	SM71b	Near 33 Level. Well installed (see Table 2-2).	120	None	NA	NA	NA	NA		

Key:
bgs = Below ground surface
Hg SSE = Mercury Selective Sequential Extraction
NA = Not applicable
TAL = Target Analyte List

Table 2-2 Field Soil Characterization Summary

Soil Boring ID	Sample Depth Interval (feet bgs)		Mineralogical/Lithological Observations									Soil Color	USCS Symbol	Soil Type (based on Final RI report)	Laboratory Sample ID	XRF Field Screening Results (ppm)						Groundwater Observations		Monitoring Well Insatallation	
	Top	Bottom	Red Porous Rock	Vitreous "Slag"	Red Rind	Elemental Hg	Stibnite	Realgar	Orpiment	Cinnabar	White Vein					Total Antimony	XRF Error Antimony	Total Arsenic	XRF Error Arsenic	Total Mercury	XRF Error Mercury	Moisture observed in Soil Sample or Rock Cuttings	Static Water Level in Completed Well, September 10, 2015 (estimated, feet bgs)	Monitoring Well ID	Monitoring Well Screened Interval (feet bgs)
	0	1											NR	T/WR								Dry			
	1	2	X								X	Dark Gray	SP-SM	T/WR		19127	97	5416	42	135	10	Dry			
	2	3											NR	T/WR											
	3	4	X				X		X			Grayish Brown	SM	T/WR		24765	119	6826	51	112	10	Damp			
	4	5	X				X		X			Gray	SP-SM	T/WR		24560	117	5521	44	98	9	Damp			
	5	6										Brown	OL	DN		557	12	352	8	< LOD	5	Moist			
	6	7										Very Dark Brown	OL	DN		241	11	424	9	< LOD	5	Damp			
	7	8										Very Dark Brown	OL	DN		38	10	111	5	< LOD	5	Moist			
	8	9	X								X	Dark Gray	GM	T/WR		9836	56	2296	24	39	6	Moist			
	9	10										Yellowish Brown	ML	DN (KG)		3144	32	1010	20	20	7	Damp			
	10	11										Dark Grayish Brown	ML	DN (KG)	15MP094SB11	2914	29	1445	19	33	6	Moist			
MP094	11	12										Gray	ML	N		30	11	82	5	< LOD	6	Moist			
	12	13										Gray	GM	N	15MP094SB13	2872	27	734	13	26	5	Wet			
	13	14										Gray	ML	N		< LOD	17	10	3	< LOD	6	Moist			
	14	15										Brown	ML	N		229	12	98	5	< LOD	5	Saturated			
	15	16										Brown	ML	N		< LOD	18	273	9	< LOD	7	Wet			
	16	17									X	Grayish Brown	GM	N (KG)	15MP094SB17	3102	29	918	15	51	6	Moist			
	17	18										Brown	ML	N (KG)		< LOD	16	43	4	< LOD	6	Wet			
	18	19										Grayish Brown	ML	N (KG)	15MP094SB19	1403	20	547	11	12	5	Wet			
	19	20										Brown	ML	N (KG)	15MP094SB20	1028	21	52	5	< LOD	8	Moist			
	20	21										Brown	ML	WB		271	13	168	6	< LOD	5	Moist			
	21	22										Grayish Brown		WB								Wet			
	22	24										Dark Grayish Brown		WB								Wet			
	0	1	X						X		X	Dark Gray	GM	T/WR		13310	142	6284	68	631	18	Damp			
	1	2	X						X		X	Dark Gray	ML	T/WR		9501	97	3274	35	514	14	Damp			
	2	3									X	Dark Gray	SM	T/WR		764	21	283	5	29	4	Damp			
	3	4									X	Dark Gray	SM	T/WR	15MP095SB04	151	19	59	3	<LOD	8	Damp			
	4	5										Dark Gray	ML	N	15MP095SB05	1819	28	485	8	59	5	Moist			
	5	6									X	Dark Gray	ML	N								Moist			
	6	7										Brown	ML	N								Wet			
	7	8										Brown	ML	N		96	19	58	3	16	3	Moist			
	9	10										Brown	ML	N	15MP095SB10	1268	26	584	9	61	5	Moist			
MP095	10	11										Olive Brown	MH	N	15MP095SB11	310	20	108	4	11	3	Moist			
	11	12										Olive Brown	MH	N		905	22	430	7	56	4	Moist			
	12	13									X	Olive Brown	MH	N	15MP095SB13	122	18	59	3	14	3	Moist			
	13	14										Olive Brown	ML	N		<LOD	56	17	2	9	3	Moist			
	14	15										Olive Brown	MH	N		<LOD	50	79	3	<LOD	6	Moist			
	15	16										Dark Brown	ML	N		<LOD	52	24	2	<LOD	7	Damp			
	16	17												WB								Saturated			
	17	18										Dark Gray		WB		<LOD	57	142	4	<LOD	8	Saturated			
	18	19										Dark Grayish Brown		WB		<LOD	51	34	2	10	3	Wet			
	19	20										Dark Grayish Brown		WB		<LOD	56	30	2	<LOD	8	Wet			
	20	22										Dark Grayish Brown		WB								Wet			
	0	1	X		X						X	Brown	GM	T/WR		7034	77	3827	42	287	6	Dry			
	1	2	X		X						X	Grayish Brown	SM	T/WR		3036	37	3568	39	325	7	Dry			
	2	3	X		X				X		X	Grayish Brown	SM	T/WR		6024	70	5782	65	824	13	Damp			
	3	4	X		X				X		X	Grayish Brown	SM	T/WR		4404	57	9157	106	1098	17	Damp			
	4	5	X		X				X		X	Dark Brown	SM	T/WR		5520	63	4396	49	843	13	Damp			
	5	6	X		X				X		X	Dark Grayish Brown	SM	T/WR	15MP096SB06	7976	88	5203	58	580	10	Damp			
	6	7										Yellowish Brown	ML	T/WR		2042	28	2282	26	151	4	Damp			
	7	8										Yellowish Brown	ML	DN		<LOD	33	30	2	4	1				
	8	9										Olive Brown	ML	DN		382	13	203	4	24	1	Moist			
	9	10										Olive Brown	ML	DN		<LOD	32	6	1	<LOD	2	Damp			
	10	11										Olive Brown	ML	DN		341	13	228	5	27	2	Moist			
	11	12										Olive Brown	ML	DN		<LOD	45	7	2	<LOD	3	Moist			
	12	13										Olive Brown	ML	DN	15MP096SB13	453	16	261	6	26	2	Moist			
	13	14										Olive Brown	ML	DN		<LOD	32	10	2	<LOD	2	Moist			
MP096	14	15										Grayish Brown	ML	DN		60	12	20	2	<LOD	2	Moist			
	15	16										Olive Brown	ML	DN		<LOD	34	12	2	<LOD	2	Moist			
	16	17									X	Grayish Brown	ML	DN (KG)	15MP096SB17	1407	21	941	12	122	4	Moist			
	17	18									X	Grayish Brown	GM	DN (KG)		61	12	15	2	<LOD	2	Moist			
	18	19									X	Olive Brown	GM	DN (KG)	15MP096SB19	140	12	418	6	4	1	Wet			
	19	20										Olive Brown	GM	DN (KG)		<LOD	33	30	2	<LOD	2	Wet			
	20	21										Olive Brown	ML	N or DN		39	11	184	4	13	1	Wet			
	21	22										Dark Grayish Brown	ML	N or DN		<LOD	40	14	2	<LOD	3	Moist			
	22	23										Grayish Brown	ML	N		<LOD	35	11	2	<LOD	2	Wet			
	23	24										Olive Brown	ML	N		<LOD	38	15	2	<LOD	3	Moist			
	24	25										Gray	ML	N		<LOD	39	22	2	<LOD	3	Moist			
	25	26										Olive Brown	ML	N	15MP096SB26	133	13	165	4	7	1	Wet			
	26	27										Grayish Brown	GM	N		<LOD	38	23	2	<LOD	3	Moist			
	27	28										Brown	GM	N		<LOD	42	43	3	<LOD	3	Wet			
	28	30										Brown		WB								Wet			
	30	32										Dark Gray		WB								Moist			

Table 2-2 Field Soil Characterization Summary

Soil Boring ID	Sample Depth Interval (feet bgs)		Mineralogical/Lithological Observations									Soil Color	USCS Symbol	Soil Type (based on Final RI report)	Laboratory Sample ID	XRF Field Screening Results (ppm)						Groundwater Observations		Monitoring Well Insatallation	
	Top	Bottom	Red Porous Rock	Vitreous "Slag"	Red Rind	Elemental Hg	Stibnite	Realgar	Orpiment	Cinnabar	White Vein					Total Antimony	XRF Error Antimony	Total Arsenic	XRF Error Arsenic	Total Mercury	XRF Error Mercury	Moisture observed in Soil Sample or Rock Cuttings	Static Water Level in Completed Well, September 10, 2015 (estimated, feet bgs)	Monitoring Well ID	Monitoring Well Screened Interval (feet bgs)
MP097	0	1										Dark Grayish Brown	NR	T/WR								Damp			
	1	2	X		X							Dark Grayish Brown	GM	T/WR	15MP097SB02	2799	27	1064	16	60	6	Damp			
	2	3										Dark Grayish Brown	NR	T/WR								Damp			
	3	4									X	Gray	ML	N or DN		759	17	432	10	15	4	Damp			
	4	5										Gray	ML	N or DN		1040	19	1738	20	36	5	Damp			
	5	6										Tan	ML	N or DN	15MP097SB06	45	12	51	5	< LOD	7	Damp			
	6	7										Gray	ML	N or DN		1475	20	497	11	22	4	Wet			
	7	8										Gray	MH	N or DN		< LOD	16	24	3	< LOD	6	Moist			
	8	9										Brown	ML	N or DN	15MP097SB09	1795	22	464	10	21	4				
	9	10										Grayish Brown	ML	N or DN		54	11	39	4	< LOD	6	Wet			
	10	11										Olive Brown	ML	N or DN	15MP097SB11	856	17	719	13	47	5	Moist			
	11	12										Olive Brown	MH	N or DN		204	12	99	5	< LOD	6	Moist			
	12	13										Olive Brown	GM	N (KG)	15MP097SB13	1431	20	552	11	27	5	Saturated			
	13	14										Olive Brown	ML	N (KG)		374	13	296	8	18	4	Wet			
	14	15										Olive Brown		WB		180	12	175	6	< LOD	6	Saturated			
	15	16										Orange Brown		WB		63	15	42	5	< LOD	9	Damp			
MP098	0	1										Brown	SM	T/WR		1239	18	755	13	85	6	Moist			
	1	2									X	Black	GP	T/WR		647	18	3743	36	92	9	Damp			
	2	3										Brown	GM	T/WR		94	13	761	16	25	6	Moist			
	3	4										Brown	ML	T/WR		290	14	692	14	14	5	Moist			
	4	5										Dark Gray	GM	T/WR		6412	44	1776	22	698	16	Damp			
	5	6								X	X	Gray	GM	T/WR		1393	23	1214	20	230	11	Damp			
	6	7											NR	T/WR											
	7	8										Dark Gray	GM	T/WR								Damp			
	8	9							X			Dark Gray	GP-GM	T/WR								Damp			
	9	10							X			Dark Gray	GP-GM	T/WR								Damp			
	10	11		X						X		Dark Gray	GP	T/WR								Damp			
	11	12								X	X	Dark Gray	GP	T/WR								Dry			
	12	13										Dark Gray	NR	T/WR								Damp			
	13	14										Dark Gray	GP	T/WR								Damp			
	14	15										Dark Gray	GM	T/WR								Damp			
	15	16						X		X	X	Light Gray	GP-GM	T/WR		281	14	1951	23	41	6	Damp			
	16	18											NR	T/WR		188	12	282	8	< LOD	6				
	18	20										Dark Grayish Brown	SM	T/WR	15MP098SB20	339	15	1686	22	90	7	Moist			
	20	21											NR	WR		53	13	917	17	1213	21				
	21	22	X							X		Dark Grayish Brown	ML	WR		44	11	526	11	15	5	Damp			
	22	23								X		Brown	GM	WR		200	15	833	17	219	11	Damp			
	23	24										Brown	SM	DN (KG, MZ)		135	16	90	8	756	21	Damp			
	24	25								X		Brown	ML	DN (KG, MZ)		303	15	270	10	23	6	Damp			
	25	26								X	X	Gray	ML	N or DN (KG, MZ)	15MP098SB26	413	15	1083	17	241	10	Moist			
	26	27								X		Orange Brown	ML	N or DN (KG, MZ)		81	11	293	8	21	4	Damp			
	27	28								X		Orange Brown	GM	N or DN (KG, MZ)		101	11	223	7	16	4	Moist			
	28	29											NR	N (KG, MZ)											
	29	30								X		Orange Brown	ML	N (KG, MZ)		442	16	429	12	42	6	Wet			
	30	31										Yellowish Brown	GM	N (KG, MZ)		264	13	286	8	61	6	Saturated			
	31	32										Gray	ML	N (KG, MZ)		361	15	223	9	11	5	Wet			
	32	33										Brown	ML	N (KG, MZ)	15MP098SB33	418	15	433	11	135	7	Saturated			
	33	34									X	Dark Grayish Brown	ML	N (KG, MZ)		523	16	170	7	13	5	Moist			
	34	35										Gray	GP	N (KG, MZ)								Wet			
	35	36							X		X	Light Gray	GP-GM	WB	15MP098SB36	638	15	1729	20	60	6	Wet			
	36	37											NR	WB											
	37	38										Orange Brown	GM	WB	15MP098SB38	1747	24	2782	28	160	9	Saturated			
	38	39											NR	WB											
	39	40										Orange Brown	GW-GM	WB		1351	21	1857	22	68	6	Saturated			
	40	41											NR	WB											
	41	42								X		Orange Brown	GP-GM	WB		1279	21	2610	27	290	11	Saturated			
	42	44							X	X	X	Light Gray		WB								Wet			
	44	45							X	X	X	Light Gray		WB		1314	26	6243	53	949	24	Wet			
MP099	0	2										Dark Grayish Brown	SM	T/WR								Dry			
	2	4	X							X	X	Grayish Brown	SM	T/WR		6587	47	6264	44	606	16	Dry			
	4	6	X							X		Dark Grayish Brown	SM	T/WR		3139	31	2607	27	142	9	Damp			
	6	7	X								X			T/WR		10017	60	4569	38	133	9				
	7	8	X								X	Olive Brown	ML	DN		558	15	274	8	30	5	Damp			
	8	9	X		X						X			T/WR		2525	26	1601	21	185	9				
	9	10	X		X						X	Brown	ML	DN		63	12	76	5	< LOD	6	Moist			
	10	11			X						X			T/WR	15MP099SB11	11982	67	2450	28	659	17				
	11	12										Olive Brown	ML	DN	15MP099SB12	52	12	379	10	< LOD	7	Damp			
	12	13									X			DN	15MP099SB13	5805	41	4050	36	304	12				
	13	14										Gray	SM	DN		54	11	19	3	< LOD	6	Damp			
	14	15												DN (loess)		< LOD	17	20	3	< LOD	6				
	15	16										Gray	SM	DN		< LOD	16	16	3	< LOD	5	Moist			
	16	17												DN	15MP099SB17	828	16	431	10	25	5				
	17	18	X									Olive Brown	ML	T/WR		< LOD	17	14	3	< LOD	6	Moist			
	18	19												DN	15MP099SB19	258	14	286	9	33	6				
	19	20										Gray	ML	N or DN		< LOD	20	59	6	< LOD	8	Damp			
	20	21												N or DN		< LOD	17	129	6	8	5				
	21	22										Brown	SM	N or DN		< LOD	17	136	7	8	5	Damp			
	22	23												N or DN		< LOD	16	77	5	< LOD	6				
	23	24										Brown	ML	WB		< LOD	16	164	7	9	4	Moist			
	24	26										Brown		WB								Dry			

Table 2-2 Field Soil Characterization Summary

Soil Boring ID	Sample Depth Interval (feet bgs)		Mineralogical/Lithological Observations									Soil Color	USCS Symbol	Soil Type (based on Final RI report)	Laboratory Sample ID	XRF Field Screening Results (ppm)						Groundwater Observations		Monitoring Well Insatallation	
	Top	Bottom	Red Porous Rock	Vitreous "Slag"	Red Rind	Elemental Hg	Stibnite	Realgar	Orpiment	Cinnabar	White Vein					Total Antimony	XRF Error Antimony	Total Arsenic	XRF Error Arsenic	Total Mercury	XRF Error Mercury	Moisture observed in Soil Sample or Rock Cuttings	Static Water Level in Completed Well, September 10, 2015 (estimated, feet bgs)	Monitoring Well ID	Monitoring Well Screened Interval (feet bgs)
MP100	0	1	X								X			T/WR		642	16	2050	23	166	9				
	1	2	X								X	Dark Gray	SM	T/WR		809	18	2163	24	102	7	Damp			
	2	3						X	X		X			T/WR		126	13	2070	24	8	5				
	3	4						X	X		X	Dark Gray	SM	T/WR		569	15	2857	26	7	5	Damp			
	4	6								X	X	Dark Gray	SM	T/WR		255	14	1893	22	79	7	Damp			
	6	7									X			T/WR		115	13	1051	17	36	6				
	7	8									X	Dark Gray	GM	T/WR		559	16	1776	22	120	8	Damp			
	8	9									X			T/WR	15MP100SB09	241	14	1236	18	57	7				
	9	10									X	Brown	SM	DN (loess)		331	12	25	3	< LOD	5	Damp			
	10	11												DN (loess)	15MP100SB11	579	14	129	6	7	4				
	11	12										Gray	ML	N		157	12	4	2	< LOD	5	Moist			
	12	13												N		126	11	< LOD	4	< LOD	5				
	13	14										Gray	ML	N		51	11	29	3	< LOD	6	Moist			
	14	16										Grayish Brown	SM	N		< LOD	16	40	4	< LOD	5	Moist			
	16	17												N (loess)	15MP100SB17	30	11	41	4	< LOD	5				
	17	18										Brown	SP	N (loess)		< LOD	15	51	4	< LOD	5	Moist			
	18	19												N (loess)	15MP100SB19	138	12	73	5	< LOD	6				
	19	20								X		Gray	SP	N		< LOD	15	30	3	< LOD	5	Moist			
	20	21												N	15MP100SB21	27	10	56	4	< LOD	5				
	21	22										Gray	SM	N		< LOD	14	20	3	< LOD	5	Saturated			
	22	23												N		< LOD	16	30	3	< LOD	5				
	23	24										Gray	SP-SM	N		< LOD	15	29	3	< LOD	5	Saturated			
	24	25												N		< LOD	15	35	3	< LOD	5				
	25	26										Gray	ML	N		< LOD	15	23	3	< LOD	5	Moist			
	26	27												N		< LOD	15	33	3	< LOD	5				
	27	28									X	Brownish Yellow	ML	N (KG)		< LOD	17	21	3	< LOD	6	Wet			
	28	29									X			N (KG)		< LOD	17	13	3	< LOD	6				
	29	30										Brown	GM	N (KG)		< LOD	16	22	3	< LOD	5	Wet			
	30	31												N (KG)		< LOD	15	25	3	< LOD	5				
	31	32										Brown	SM	N (KG)		< LOD	23	42	6	< LOD	12	Wet			
	32	33												N (KG)		< LOD	15	26	3	< LOD	5				
	33	34										Brown	GM	N (KG)		< LOD	18	48	4	< LOD	7	Moist			
	34	35												WB		< LOD	16	47	4	< LOD	5				
	35	36										Brown	GM	WB		< LOD	18	110	6	< LOD	7	Wet			
	36	37										Brown		WB		< LOD	19	63	5	< LOD	7	Moist			
MP101	0	1	X								X	Dark Gray	GP	T/WR		836	17	2178	24	25	5	Wet			
	1	2										Dark Gray	GP	T/WR								Wet			
	2	4			X				X		X	Dark Gray	GP-GM	T/WR		6696	45	3175	29	1216	20	Wet			
	5	6										Gray	GP	T/WR		2097	22	1317	17	526	12	Saturated			
	6	8									X	Dark Gray	GP	T/WR		2565	26	1409	18	265	9	Saturated			
	8	10	X						X	X	X	Dark Gray	GP-GM	T/WR		630	22	614	18	77	10	Saturated			
	10	11	X						X	X	X			T/WR	15MP101SB11	2357	25	1353	18	329	10				
	11	12										Dark Gray	CH	N		80	12	98	6	< LOD	7	Moist			
	12	13												N	15MP101SB13	1582	21	915	15	162	8				
	13	14										Dark Gray	CH	N (KG)	15MP101SB14	201	13	267	9	12	5	Moist			
	14	15												WB		205	13	359	9	25	5				
	15	16										Dark Gray	GP-GC	WB		86	13	248	9	< LOD	7	Moist			
	16	17												WB		181	14	772	15	12	5				
	17	18										Brown		WB		97	12	415	10	< LOD	7	Damp			
RD21	1	2			X						X	Dark Grayish Brown	GP-GM	T/WR		1260	19	853	10	41	2	Wet			
	2	3			X						X			T/WR		1190	21	1105	14	30	2				
	3	4	X							X		Brown	GP-GC	T/WR		<LOD	44	16	2	<LOD	3	Wet			
	4	5												T/WR	15RD21SB05	1356	21	867	11	35	2				
	5	6	X							X		Brown	GP-GC	T/WR		56	14	19	2	4	1	Wet			
	6	7												WB		1778	25	1774	20	24	2				
	7	8										Gray		WB		<LOD	42	9	2	3	1	Damp			
RD22	0	1										Brown	ML	N	15RD22SB01	47	11	21	3	< LOD	6	Damp			
	2	3												N		92	11	43	4	< LOD	6				
	3	4										Brown	ML	N		< LOD	16	26	3	< LOD	6	Moist			
	4	5												N		< LOD	15	19	3	< LOD	6				
	5	6										Brown	SM	N		< LOD	17	13	3	< LOD	7	Moist			
	6	7												N		< LOD	16	14	3	< LOD	5				
	7	8										Brown	ML	N (KG)		< LOD	16	10	3	< LOD	6	Moist			
	8	9												N (KG)	15RD22SB09	162	12	74	5	6	4				
	9	10										Grayish Brown	ML	N (KG)		< LOD	17	13	3	< LOD	6	Moist			
	10	11												N (KG)											
	11	12										Gray	GM	N (KG)		< LOD	15	21	3	< LOD	5	Wet			
	12	13												N (KG)											
	13	14										Grayish Brown	ML	N (KG)		< LOD	18	21	4	< LOD	7	Moist			
	14	15												N (KG)		< LOD	18	7	3	< LOD	7				
	15	16										Gray	GC	N (KG)		< LOD	17	6	3	< LOD	7	Moist			
	16	17												N (KG)		< LOD	15	27	3	< LOD	5				
	17	18										Gray	GP-GC	WB		< LOD	18	8	3	< LOD	7	Moist			
	18	19												WB		< LOD	16	21	3	< LOD	6				
	19	20										Gray		WB		< LOD	16	10	3	< LOD	6	Moist			

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Soil Boring ID	Sample Depth Interval (feet bgs)		Mineralogical/Lithological Observations									Soil Color	USCS Symbol	Soil Type (based on Final RI report)	Laboratory Sample ID	XRF Field Screening Results (ppm)						Groundwater Observations		Monitoring Well Insatallation	
	Top	Bottom	Red Porous Rock	Vitreous "Slag"	Red Rind	Elemental Hg	Stibnite	Realgar	Orpiment	Cinnabar	White Vein					Total Antimony	XRF Error Antimony	Total Arsenic	XRF Error Arsenic	Total Mercury	XRF Error Mercury	Moisture observed in Soil Sample or Rock Cuttings	Static Water Level in Completed Well, September 10, 2015 (estimated, feet bgs)	Monitoring Well ID	Monitoring Well Screened Interval (feet bgs)
SM67	1	2										Olive Brown	ML	DN (KG and loess)		<LOD	39	61	3	<LOD	3	Damp			
	2	3												N (loess)		<LOD	95	<LOD	37	<LOD	20				
	3	4										Olive Brown	ML	N (loess)		<LOD	35	16	2	<LOD	2	Damp			
	4	5										Olive Brown	ML	N (loess)		<LOD	32	5	1	<LOD	2	Moist			
	6	7												N (loess)		<LOD	35	6	2	<LOD	2				
	7	8										Olive Brown	ML	N (loess)		<LOD	33	8	1	2	1	Moist			
	8	9												N (loess)		<LOD	41	122	4	4	1				
	9	10										Olive Brown	ML	WB		<LOD	38	111	4	4	1	Moist			
	10	11												WB		<LOD	39	116	4	4	1				
	11	12										Grayish Brown	GP	WB		<LOD	42	157	4	5	1	Dry			
	12	13												WB		<LOD	40	196	5	5	1				
	13	14										Grayish Brown		WB		<LOD	38	138	4	3	1	Damp			
	14	15												WB		<LOD	35	90	3	5	1				
	15	16										Gray		WB		<LOD	44	162	5	<LOD	4	Dry			
	16	17												WB		<LOD	40	103	4	5	1				
	17	18										Gray		WB		<LOD	33	13	1	3	1	Damp			
	18	19												WB		<LOD	44	119	4	<LOD	4				
	19	20										Gray		WB		<LOD	42	98	4	6	1	Damp			
	20	21										Gray		B		<LOD	38	55	3	4	1	Dry			
	21	22										Gray		B		<LOD	36	75	3	6	1	Damp			
	22	23										Gray		B		<LOD	38	78	3	4	1	Dry			
	23	24										Grayish Brown		B		<LOD	36	75	3	4	1	Dry			
	24	25										Grayish Brown		B		<LOD	36	44	2	3	1	Dry			
	25	26										Grayish Brown		B		<LOD	38	106	3	<LOD	3	Dry			
	26	27										Grayish Brown		B		<LOD	38	73	3	3	1	Dry			
	27	28										Grayish Brown		B		<LOD	39	93	3	5	1	Dry			
	28	29										Grayish Brown		B		<LOD	38	85	3	<LOD	3	Dry			
	29	30										Dark Gray		B		<LOD	39	79	3	4	1	Dry			
	30	31										Grayish Brown		B		<LOD	39	60	3	<LOD	3	Dry			
	31	32										Gray		B		<LOD	38	79	3	5	1	Dry			
	32	33										Brown		B		<LOD	37	89	3	5	1	Dry			
	33	34										Brown		B		<LOD	37	112	3	3	1	Dry			
	34	35										Grayish Brown		B		<LOD	37	77	3	4	1	Dry			
	35	36										Grayish Brown		B		<LOD	37	78	3	4	1	Dry			
	36	37										Grayish Brown		B		<LOD	36	67	3	<LOD	3	Dry			
	37	38										Dark Gray		B		<LOD	39	62	3	3	1	Dry			
	38	39										Dark Gray		B		<LOD	35	74	3	<LOD	3	Dry			
	39	40										Black		B		<LOD	36	91	3	5	1	Dry			
	40	41										Dark Gray		B		<LOD	38	92	3	4	1	Dry			
	41	42										Gray		B		<LOD	40	86	3	<LOD	3	Damp			
	42	43										Gray		B		<LOD	41	80	3	<LOD	3	Damp			
	43	44										Dark Gray		B		<LOD	38	95	3	3	1	Damp			
	44	45										Gray		B		<LOD	39	86	3	<LOD	3	Damp			
	45	46									X	Grayish Brown		B		<LOD	41	99	4	<LOD	3	Damp			
	46	47										Brown		B		<LOD	40	176	5	<LOD	3	Damp			
	47	48										Gray		B		<LOD	40	67	3	<LOD	3	Damp			
	48	49										Gray		B		<LOD	41	109	4	<LOD	3	Damp			
	49	50									X	Gray		B		<LOD	39	54	3	4	1	Dry			
	50	51										Dark Gray		B		<LOD	37	41	2	4	1	Dry			
	51	52										Dark Gray		B		<LOD	40	68	3	4	1	Dry			
	52	53										Gray		B		<LOD	38	54	3	<LOD	3	Dry			
	53	54										Gray		B		<LOD	40	60	3	3	1	Dry			
	54	55										Light Gray		B		<LOD	42	53	3	<LOD	3	Dry			
	55	56										Gray		B		<LOD	38	70	3	7	1	Damp			
	56	57										Black		B		<LOD	39	65	3	4	1	Dry			
	57	58										Gray		B		<LOD	42	69	3	<LOD	3	Damp			
	58	59										Gray		B		<LOD	40	64	3	4	1	Dry			
	59	60										Gray		B		<LOD	40	65	3	<LOD	3	Dry			
	60	61										Gray		B		<LOD	45	77	3	<LOD	3	Dry			
	61	62										Gray		B		<LOD	43	369	8	<LOD	4	Dry			
	62	63										Dark Gray		B		<LOD	42	97	4	<LOD	3	Damp			
	63	64										Dark Gray		B		<LOD	39	96	3	4	1	Damp	Dry	MW39	63 - 83
	64	65										Gray		B		<LOD	41	92	3	<LOD	3	Damp			
	65	66										Gray		B		<LOD	38	43	2	3	1	Dry			
	66	67										Gray		B		<LOD	39	59	3	<LOD	3	Dry			
	67	68										Gray		B		<LOD	40	67	3	<LOD	3	Dry			
	68	69										Gray		B		<LOD	40	46	3	<LOD	3	Damp			
	69	70										Light Gray		B		<LOD	39	40	2	4	1	Damp			
	70	71										Gray		B		<LOD	40	159	4	<LOD	3	Damp			
	71	72										Dark Gray		B		<LOD	38	77	3	4	1	Damp			
	72	73										Dark Gray		B		<LOD	39	79	3	3	1	Damp			
	73	74										Gray		B		<LOD	44	69	3	<LOD	3	Dry			
	74	75										Dark Gray		B		<LOD	41	54	3	<LOD	3	Damp			
	75	76										Dark Gray		B		<LOD	38	81	3	5	1	Damp			
	76	77										Dark Gray		B		<LOD	38	85	3	4	1	Damp			
	77	78										Dark Gray		B		<LOD	41	87	3	<LOD	3	Damp			
	78	79										Dark Gray		B		<LOD	39	116	4	3	1	Damp			
	79	80										Dark Gray		B		<LOD	38	93	3	<LOD	3	Damp			
	80	81										Gray		B		<LOD	42	52	3	<LOD	3	Damp			
	81	82										Gray		B		<LOD	38	41	2	<LOD	3	Dry			
	82	83										Light Gray		B		<LOD	42	44	3	4	1	Dry			

Table 2-2 Field Soil Characterization Summary

Soil Boring ID	Sample Depth Interval (feet bgs)		Mineralogical/Lithological Observations									Soil Color	USCS Symbol	Soil Type (based on Final RI report)	Laboratory Sample ID	XRF Field Screening Results (ppm)						Groundwater Observations		Monitoring Well Insatallation	
	Top	Bottom	Red Porous Rock	Vitreous "Slag"	Red Rind	Elemental Hg	Stibnite	Realgar	Orpiment	Cinnabar	White Vein					Total Antimony	XRF Error Antimony	Total Arsenic	XRF Error Arsenic	Total Mercury	XRF Error Mercury	Moisture observed in Soil Sample or Rock Cuttings	Static Water Level in Completed Well, September 10, 2015 (estimated, feet bgs)	Monitoring Well ID	Monitoring Well Screened Interval (feet bgs)
SM67	83	84										Dark Gray		B		<LOD	39	93	3	4	1	Damp			
	84	85										Gray		B		<LOD	40	66	3	3	1	Damp			
	85	86										Dark Gray		B		<LOD	38	83	3	5	1	Damp			
	86	87										Dark Gray		B		<LOD	40	50	3	<LOD	3	Damp			
	87	88										Gray		B		<LOD	38	48	2	<LOD	3	Dry			
	88	89										Gray		B		<LOD	41	43	2	<LOD	3	Dry			
	89	90										Gray		B		<LOD	42	35	2	4	1	Dry			
SM68a	0	2											NR	DN (KG)											
	3	4										Brown	GP-GM	DN (KG)		137	18	187	6	7	2	Damp			
	4	5												DN (KG)		<LOD	68	120	6	<LOD	6				
	5	6											GP-GM	DN (KG)		<LOD	38	93	3	<LOD	3				
	6	7												DN (KG)		<LOD	45	122	4	4	1				
	7	8										Black		DN (KG)		<LOD	42	153	4	4	1	Moist			
	8	9												WB		<LOD	37	176	4	5	1				
	9	10							X		X	Dark Brown		WB		<LOD	41	132	4	<LOD	3	Damp			
	10	11												WB	15SM68SB11	147	13	226	5	<LOD	3				
	11	12										Gray		WB		<LOD	55	140	6	<LOD	4	Damp			
	12	13												WB		<LOD	43	94	4	<LOD	3				
	13	14										Grayish Brown		WB		<LOD	35	58	2	4	1	Damp			
	14	15												WB		<LOD	39	111	4	6	1				
	15	16										Grayish Brown		WB		<LOD	39	80	3	4	1	Dry			
	16	17												WB		71	20	104	6	<LOD	5				
	17	18										Dark Gray		WB		<LOD	51	34	3	<LOD	3	Dry			
	18	19												WB		<LOD	38	72	3	3	1				
	19	20										Gray		WB		<LOD	35	116	3	3	1	Dry			
	20	21												WB		<LOD	83	195	10	<LOD	7				
	21	22										Black		WB		327	17	735	12	<LOD	5	Dry			
	22	23												B		1313	29	1882	30	<LOD	7				
	23	24										Grayish Brown		B		188	13	715	10	5	1	Dry			
	24	25										Black		B		85	13	447	7	7	1	Damp			
	25	26									X	Brown		B		506	16	987	13	6	2	Damp			
	26	27										Brown		B		291	15	828	12	<LOD	4	Damp			
	27	28									X	Grayish Brown		B		151	14	472	8	6	1	Damp			
	28	29										Grayish Brown		B		78	13	423	7	6	1	Damp			
	29	30										Grayish Brown		B		47	13	400	7	<LOD	3	Damp			
	30	31										Dark Gray		B		<LOD	38	183	4	7	1	Damp			
	31	32										Dark Gray		B		<LOD	37	235	5	6	1	Damp			
	32	33										Black		B		<LOD	39	163	4	8	1	Damp			
	33	34										Brownish Yellow		B		<LOD	37	271	5	5	1	Damp			
	34	35										Very Dark Gray		B		<LOD	38	226	5	7	1	Damp			
	35	36									X	Grayish Brown		B		<LOD	39	386	7	8	1	Damp			
	36	37										Gray		B		94	13	620	9	7	1	Damp			
SM68b	0	25	See borehole SM68a interval 0-25 ft.																						
	25	26										Dark Gray		B		<LOD	39	82	3	4	1	Damp			
	26	27										Grayish Brown		B		<LOD	40	72	3	<LOD	3	Moist			
	27	28										Brown		B		<LOD	36	41	2	3	1	Damp			
	28	29										Brown		B		<LOD	38	41	2	3	1	Damp			
	29	30										Gray		B		<LOD	36	54	3	<LOD	3	Dry			
	30	31										Gray		B		<LOD	39	73	3	<LOD	3	Dry			
	31	32										Gray		B		<LOD	36	36	2	3	1	Damp			
	32	33										Gray		B		<LOD	37	36	2	<LOD	3	Damp			
	33	34										Gray		B		<LOD	36	47	2	4	1	Damp			
	34	35										Dark Gray		B		<LOD	35	92	3	3	1	Damp			
	35	36										Black		B		<LOD	36	57	3	<LOD	3	Damp			
	36	37										Dark Gray		B		<LOD	37	67	3	<LOD	3	Damp			
	37	38										Dark Gray		B		<LOD	40	33	2	<LOD	3	Damp			
	38	39										Dark Gray		B		<LOD	40	69	3	<LOD	3	Damp			
	39	40										Gray		B		<LOD	37	54	2	4	1	Damp			
	40	41										Dark Gray		B		<LOD	39	47	3	4	1	Moist			
	41	42										Dark Brown		B		<LOD	35	38	2	<LOD	3	Damp			
	42	43										Dark Brown		B		<LOD	37	93	3	4	1	Damp			
	43	44										Black		B		<LOD	39	76	3	3	1	Damp			
	44	45										Black		B		<LOD	39	83	3	4	1	Damp			
	45	46										Black		B		<LOD	40	106	4	<LOD	3	Damp			
	46	47										Black		B		<LOD	38	64	3	<LOD	3	Damp			
	47	48										Black		B		<LOD	37	91	3	4	1	Damp			
	48	49										Black		B		<LOD	40	67	3	<LOD	3	Damp			
	49	50										Black		B		<LOD	38	93	3	<LOD	3	Moist			
	50	51										Dark Gray		B		<LOD	45	81	4	<LOD	4	Damp			
	51	52										Very Dark Gray		B		<LOD	41	85	3	5	1	Damp			
	52	53										Black		B		<LOD	38	123	4	5	1	Damp			
	53	54										Black		B		<LOD	40	116	4	6	1	Moist			
	54	55										Black		B		<LOD	39	135	4	4	1	Moist			
	55	56										Gray		B		<LOD	40	56	3	<LOD	3	Damp			
	56	57										Dark Gray		B		<LOD	38	110	3	4	1	Damp			
	57	58										Dark Gray		B		<LOD	38	86	3	3	1	Damp			
	58	59										Dark Gray		B		<LOD	38	80	3	<LOD	3	Damp			
	59	60							X			Dark Gray		B		<LOD	40	289	6	7	1	Damp			
	60	61										Dark Gray		B		<LOD	38	164	4	5	1	Damp			
	61	62							X			Dark Gray		B		<LOD	37	287	5	4	1	Dry			
	62	63										Very Dark Gray		B		48	13	444	8	13	2	Moist			
	63	64						X	X		X	Black		B		402	14	1788	20	19	2	Moist			
	64	65					X	X		X	X	Light Gray		B		5659	63	10672	110	16	4	Moist			

Table 2-2 Field Soil Characterization Summary

Soil Boring ID	Sample Depth Interval (feet bgs)		Mineralogical/Lithological Observations									Soil Color	USCS Symbol	Soil Type (based on Final RI report)	Laboratory Sample ID	XRF Field Screening Results (ppm)						Groundwater Observations		Monitoring Well Insatallation	
	Top	Bottom	Red Porous Rock	Vitreous "Slag"	Red Rind	Elemental Hg	Stibnite	Realgar	Orpiment	Cinnabar	White Vein					Total Antimony	XRF Error Antimony	Total Arsenic	XRF Error Arsenic	Total Mercury	XRF Error Mercury	Moisture observed in Soil Sample or Rock Cuttings	Static Water Level in Completed Well, September 10, 2015 (estimated, feet bgs)	Monitoring Well ID	Monitoring Well Screened Interval (feet bgs)
	65	66					X	X	X		X	Very Dark Gray		B		2145	26	2975	29	13	2	Damp			
	66	67						X	X		X	Black		B		218	15	12859	141	<LOD	14	Damp			
	67	68						X	X		X	Very Dark Gray		B		234	14	3791	40	36	3	Damp			
	68	69						X	X	X	X	Dark Gray		B		51	13	1633	18	60	3	Damp			
	69	70						X		X		Gray		B		111	13	2013	21	69	3	Damp			
	70	71						X			X	Very Dark Gray		B		83	12	2017	21	52	3	Damp			
	71	72						X	X	X	X	Dark Gray		B		91	13	2678	28	54	3	Damp			
	72	73						X	X			Dark Gray		B		203	15	6658	73	85	5	Damp			
	73	74						X			X	Dark Gray		B		65	13	3662	38	34	3	Damp			
	74	75						X	X					B		42	12	674	9	19	2				
	75	76						X			X	Black		B		45	13	920	12	10	2	Damp			
	76	77						X			X	Very Dark Gray		B		<LOD	37	247	5	4	1	Damp			
	77	78							X		X	Black		B		<LOD	37	156	4	6	1	Moist			
	78	79						X				Very Dark Gray		B		86	13	213	5	5	1	Damp			
	79	80						X			X	Dark Gray		B		<LOD	37	242	5	4	1	Damp			
	80	81									X	Very Dark Gray		B		<LOD	36	73	3	3	1	Moist			
	81	82										Black		B		<LOD	39	260	6	<LOD	3	Damp			
	82	83						X				Black		B		<LOD	36	117	3	4	1	Damp			
	83	84										Dark Gray		B		<LOD	40	190	5	4	1	Moist			
	84	85										Black		B		<LOD	39	120	4	<LOD	3	Moist			
	85	86										Black		B		<LOD	38	132	4	4	1	Moist			
	86	87										Black		B		<LOD	37	99	3	4	1	Damp			
	87	88										Black		B		<LOD	38	126	4	5	1	Damp			
	88	89										Black		B		<LOD	41	106	4	3	1	Dry			
	89	90										Black		B		<LOD	46	164	5	<LOD	3	Moist			
	90	91										Black		B		<LOD	45	84	3	5	1	Damp			
	91	92										Black		B		<LOD	41	265	6	<LOD	3	Damp			
	92	93										Black		B		<LOD	39	140	4	4	1	Dry			
	93	94										Very Dark Gray		B		<LOD	40	137	4	<LOD	3	Dry			
	94	95										Very Dark Gray		B		<LOD	43	89	3	4	1	Dry			
	95	96									X	Dark Gray		B		<LOD	48	75	4	<LOD	3	Moist			
	96	97									X	Dark Gray		B		<LOD	56	82	4	<LOD	4	Moist			
	97	98									X	Dark Gray		B		<LOD	49	99	4	<LOD	4	Wet			
	98	99									X	Dark Gray		B		<LOD	45	219	6	<LOD	4	Wet			
SM68b	99	100										Dark Gray		B		<LOD	46	78	4	4	1	Wet			
	100	101										Dark Gray		B		<LOD	47	120	4	6	1	Wet			
	101	102										Dark Gray		B		<LOD	46	75	4	<LOD	3	Wet			
	102	103										Black		B		<LOD	46	100	4	<LOD	3	Wet			
	103	104										Gray		B		<LOD	47	61	3	<LOD	3	Wet			
	104	105									X	Gray		B		<LOD	47	61	3	<LOD	3	Wet			
	105	106									X	Gray		B		<LOD	45	68	3	4	1	Wet			
	106	107										Gray		B		<LOD	47	79	4	<LOD	4	Wet			
	107	108										Dark Gray		B		<LOD	48	96	4	6	1	Wet			
	108	109									X	Gray		B		<LOD	46	54	3	<LOD	3	Wet			
	109	110										Dark Gray		B		<LOD	49	58	3	<LOD	3	Wet			
	110	111										Dark Gray		B		<LOD	51	48	3	<LOD	4	Wet			
	111	112										Dark Gray		B		<LOD	49	52	3	<LOD	4	Wet			
	112	113										Dark Gray		B		<LOD	52	96	4	<LOD	4	Wet			
	113	114									X	Dark Gray		B		<LOD	47	78	4	<LOD	3	Wet			
	114	115									X	Dark Gray		B		<LOD	42	57	3	<LOD	3	Wet			
	115	116									X	Dark Gray		B		<LOD	45	65	3	<LOD	3	Wet			
	116	117										Black		B		<LOD	47	133	5	5	1	Wet			
	117	118									X	Dark Gray		B		<LOD	52	83	4	6	1	Damp			
	118	119									X	Gray		B		<LOD	48	85	4	<LOD	4	Damp			
	119	120									X	Gray		B		<LOD	50	95	4	<LOD	4	Dry			
	120	121									X	Gray		B		<LOD	48	100	4	4	1	Dry			
	121	122									X	Gray		B		<LOD	51	96	4	4	1	Dry			
	122	123									X	Gray		B		<LOD	53	136	5	<LOD	4	Dry			
	123	124										Gray		B								Dry			
	124	125									X	Gray		B								Damp			
	125	126										Dark Gray		B								Damp			
	126	127										Dark Gray		B								Dry			
	127	128										Gray		B								Dry			
	128	129										Gray		B								Dry			
	129	130										Gray		B								Dry			
	130	131										Gray		B								Dry			
	131	132										Gray		B								Dry			
	132	133												B											
	133	134										Gray		B								Dry			
	134	135										Gray		B								Dry			
	0	50	See borehole SM68a interval 0-25 ft and borehole SM68b interval 25-50 ft.																						
	50	51									X	Dark Brown		B		ND		116		4		Damp			
	51	53.5										Dark Reddish Brown		B		ND		254				Moist			
	53.5	55										Dark Gray		B		ND		136		5		Dry			
	55	57.5									X	Gray		B		ND		166		5		Dry			
	57.5	60										Dark Gray		B		ND		106		ND		Dry			
SM68c	60	62.5										Dark Reddish Gray		B		ND		207		5		Dry			
	62.5	65										Gray		B		ND		98		ND		Dry			
	65	67.5										Gray		B		ND		78		ND		Dry			
	67.5	70										Gray		B		ND		85		ND		Dry			
	70	72.5										Gray		B		ND		92		5		Dry			
	72.5	75										Gray		B		ND		89		ND		Dry			
	75	77.5										Dark Gray		B		ND		75		ND		Dry			

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Soil Boring ID	Sample Depth Interval (feet bgs)		Mineralogical/Lithological Observations									Soil Color	USCS Symbol	Soil Type (based on Final RI report)	Laboratory Sample ID	XRF Field Screening Results (ppm)						Groundwater Observations		Monitoring Well Insatallation	
	Top	Bottom	Red Porous Rock	Vitreous "Slag"	Red Rind	Elemental Hg	Stibnite	Realgar	Orpiment	Cinnabar	White Vein					Total Antimony	XRF Error Antimony	Total Arsenic	XRF Error Arsenic	Total Mercury	XRF Error Mercury	Moisture observed in Soil Sample or Rock Cuttings	Static Water Level in Completed Well, September 10, 2015 (estimated, feet bgs)	Monitoring Well ID	Monitoring Well Screened Interval (feet bgs)
	77.5	80									X	Gray		B		ND		69		ND		Dry			
	80	82.5									X	Gray		B		ND		81		6		Dry			
	82.5	85										Gray		B		ND		121		ND		Dry			
	85	87.5									X	Gray		B		ND		123		6		Dry			
	87.5	90									X	Gray		B		ND		101		5		Dry			
	90	92.5									X	Gray		B		ND		103		5		Dry			
	92.5	95									X	Gray		B		ND		74		6		Dry			
	95	97.5									X	Gray		B		ND		93		4		Dry			
	97.5	100									X	Gray		B		ND		253		10		Dry			
	100	102.5										Gray		B		ND		447		5		Dry			
	102.5	105						X	X		X	Gray		B		ND		4608		33		Dry			
	105	107.5						X	X		X	Gray		B		ND		359		7		Dry			
	107.5	110									X	Gray		B		ND		128		6		Dry			
	110	112.5										Dark Gray		B		ND		84		10		Dry			
	112.5	115										Gray		B		ND		221		5		Dry			
	115	117.5									X	Gray		B		ND		88		ND		Dry			
	117.5	120									X	Gray		B		ND		166		5		Dry			
	120	122										Gray		B		ND		79		ND		Dry			
	122	125									X	Gray		B		ND		71		5		Dry			
	125	127.5										Gray		B		ND		68		4		Dry			
	127.5	130									X	Gray		B		ND		84		4		Dry			
SM68c	130	132.5									X	Gray		B		ND		118		ND		Dry		MW40	119 - 139
	132.5	135									X	Gray		B		ND		94		6		Damp			
	135	136									X	Dark Gray		B		ND		71		ND		Wet	129.2		
	136	137									X	Dark Gray		B		ND		110		5		Wet			
	137	138									X	Dark Gray		B		ND		74		ND		Wet			
	138	139										Dark Gray		B		ND		79		4		Wet			
	139	140									X	Dark Gray		B		ND		81		4		Wet			
	140	141										Dark Gray		B		ND		75		ND		Wet			
	141	142										Dark Gray		B		ND		87		ND		Wet			
	142	143										Dark Gray		B		ND		95		ND		Wet			
	143	144										Dark Gray		B		ND		126		4		Wet			
	144	145										Black		B		ND		179		5		Wet			
	145	146										Black		B		ND		122		ND		Wet			
	146	147									X	Black		B		ND		99		ND		Wet			
	147	148										Dark Gray		B		ND		184		ND		Wet			
	148	149										Dark Gray		B		ND		112		5		Wet			
	149	150									X	Dark Gray		B		ND		83		4		Wet			
	150	151									X	Dark Gray		B		ND		81		ND		Wet			
	151	152									X	Dark Gray		B		ND		80		ND		Wet			
	152	153										Dark Gray		B		ND		79		ND		Wet			
	153	154										Dark Gray		B		ND		42		ND		Wet			
	154	155										Dark Gray		B		ND		58		ND		Wet			
	0	1						X			X			DN (KG, MZ)		50	13	334	6	10	1				
	1	2						X			X	Brown	GM	DN (KG, MZ)	15SM70SB02	<LOD	40	467	8	13	2	Moist			
	2	3						X						DN (KG, MZ)		<LOD	41	15	2	<LOD	3				
	3	4										Grayish Brown	ML	N (loess)		<LOD	35	14	2	<LOD	2	Damp			
	4	5												N (loess)		<LOD	36	35	2	<LOD	2				
	5	6										Yellowish Brown	SM	N		<LOD	38	7	2	<LOD	2	Dry			
	6	7												N (loess)		<LOD	59	<LOD	9	<LOD	5				
	7	8										Grayish Brown	ML	N (loess)		<LOD	36	8	2	<LOD	2	Damp			
	8	9												N (loess)		<LOD	36	7	2	<LOD	3				
	9	10										Grayish Brown	ML	N (loess)		<LOD	42	11	2	<LOD	3	Damp			
	10	11												N (loess)		<LOD	50	<LOD	7	<LOD	3				
	11	12										Gray	SM	N (loess)		<LOD	47	<LOD	7	<LOD	3	Moist			
	12	13												N (KG)		<LOD	36	21	2	3	1				
	13	14						X			X	Brown	GC	N (KG)		<LOD	38	155	4	4	1	Damp			
	14	15						X			X			WB		<LOD	55	313	8	<LOD	5				
	15	16						X			X	Grayish Brown		WB		<LOD	44	437	8	<LOD	4	Dry			
	16	17						X	X		X			WB		<LOD	40	1074	14	<LOD	5				
	17	18						X	X		X	Brown		WB		<LOD	42	234	5	4	1	Dry			
	18	20									X	Dark Gray		WB								Dry			
SM70a	20	22						X	X		X	Dark Gray		WB								Dry			
	22	24						X			X	Dark Grayish Brown		WB								Dry			
	24	26						X		X	X	Grayish Brown		WB								Dry			
	26	27						X				Brown		B		40		397		ND		Dry			
	27	28										Brown		B		48		427		ND		Dry			
	28	29						X				Brown		B		37		529		ND		Dry			
	29	30						X				Brown		B		44		1027		ND		Dry			
	30	31						X			X	Brown		B		ND		473		ND		Dry			
	31	32						X			X	Brown		B		ND		510		ND		Dry			
	32	33						X				Brown		B		<LOD	38	235	5	5	1	Damp			
	33	34						X				Grayish Brown		B		<LOD	36	186	4	4	1	Damp			
	34	35						X				Grayish Brown		B		<LOD	36	105	3	4	1	Dry			
	35	36						X				Reddish Brown		B		<LOD	37	199	4	<LOD	3	Damp			
	36	37						X				Brown		B		<LOD	39	126	4	5	1	Dry			
	37	38									X	Dark Gray		B		<LOD	38	151	4	5	1	Damp			
	38	39						X				Gray		B		51	14	636	10	<LOD	4	Damp			
	39	40						X				Dark Reddish Brown		B		108	15	967	14	<LOD	5	Damp			
	40	41						X				Dark Reddish Brown		B		41	12	444	7	6	1	Damp			
	41	42										Dark Brown		B		<LOD	38	247	5	5	1	Damp			
	42	43						X				Brown		B		41	13	314	6	4	1	Damp			
	43	44						X				Brown		B		<LOD	37	249	5	4	1	Damp			

Table 2-2 Field Soil Characterization Summary

Soil Boring ID	Sample Depth Interval (feet bgs)		Mineralogical/Lithological Observations									Soil Color	USCS Symbol	Soil Type (based on Final RI report)	Laboratory Sample ID	XRF Field Screening Results (ppm)						Groundwater Observations		Monitoring Well Insatallation	
	Top	Bottom	Red Porous Rock	Vitreous "Slag"	Red Rind	Elemental Hg	Stibnite	Realgar	Orpiment	Cinnabar	White Vein					Total Antimony	XRF Error Antimony	Total Arsenic	XRF Error Arsenic	Total Mercury	XRF Error Mercury	Moisture observed in Soil Sample or Rock Cuttings	Static Water Level in Completed Well, September 10, 2015 (estimated, feet bgs)	Monitoring Well ID	Monitoring Well Screened Interval (feet bgs)
SM70a	44	45						X				Brown		B		<LOD	38	299	6	5	1	Damp			
	45	46										Dark Gray		B		<LOD	37	168	4	5	1	Damp			
	46	47						X				Dark Gray		B		<LOD	38	197	5	5	1	Damp			
	47	48						X				Dark Grayish Brown		B		38	12	291	5	<LOD	3	Damp			
	48	49										Grayish Brown		B		41	12	222	5	5	1	Damp			
	49	50										Dark Grayish Brown		B		<LOD	37	225	5	5	1	Damp			
	50	51										Dark Grayish Brown		B		<LOD	37	206	5	5	1	Damp			
	51	52										Dark Grayish Brown		B		<LOD	38	123	4	4	1	Damp			
	52	53										Dark Grayish Brown		B		<LOD	39	145	4	4	1	Damp			
	53	54												B		<LOD	40	188	5	4	1				
	54	55										Grayish Brown		B		<LOD	36	164	4	4	1	Damp			
	55	56										Black		B		<LOD	42	82	3	<LOD	3	Damp			
	56	57										Black		B		<LOD	38	113	4	4	1	Damp			
	57	58										Black		B		<LOD	39	129	4	3	1	Damp			
	58	59										Dark Gray		B		<LOD	37	113	3	4	1	Damp			
	59	60										Black		B		<LOD	38	145	4	4	1	Damp			
	60	61										Very Dark Gray		B		<LOD	42	118	4	<LOD	3	Damp			
	61	62										Black		B		<LOD	39	108	4	4	1	Damp			
	62	63										Very Dark Gray		B		<LOD	36	100	3	4	1	Damp			
	63	64										Black		B		<LOD	39	77	3	5	1	Damp			
	64	65										Dark Gray		B		<LOD	39	79	3	4	1	Damp			
	65	66										Gray		B		<LOD	38	109	3	5	1	Damp			
	66	67										Gray		B		<LOD	37	69	3	<LOD	3	Dry			
	67	68										Gray		B		<LOD	37	70	3	4	1	Damp			
	68	69										Dark Gray		B		<LOD	37	58	3	<LOD	3	Damp			
	69	70										Dark Gray		B		<LOD	39	45	2	4	1	Dry			
	70	71										Gray		B		<LOD	40	67	3	<LOD	3	Damp			
	71	72										Gray		B		<LOD	37	106	3	5	1	Damp			
	72	73										Black		B		65	13	91	3	7	1	Damp			
	73	74										Black		B		<LOD	39	99	3	4	1	Damp			
	74	75										Very Dark Gray		B		<LOD	38	72	3	5	1	Damp			
	75	76										Very Dark Gray		B		<LOD	39	110	4	4	1	Damp			
	76	77										Gray		B		<LOD	38	190	4	4	1	Damp			
	77	78										Gray		B		<LOD	38	108	3	3	1	Dry			
	78	79										Gray		B		<LOD	37	76	3	3	1	Dry			
	79	80										Gray		B		<LOD	38	73	3	3	1	Dry			
	80	81										Gray		B		<LOD	39	80	3	5	1	Dry			
	81	82										Gray		B		<LOD	38	181	4	3	1	Dry			
	82	83										Gray		B		63	13	372	6	4	1	Dry			
	83	84										Gray		B		<LOD	36	117	3	<LOD	3	Dry			
	84	85										Gray		B		82	13	385	7	4	1	Dry			
	85	86						X				Very Dark Gray		B		66	12	399	7	9	1	Damp			
	86	87						X						B		<LOD	38	475	8	8	1				
	87	88										Black		B		<LOD	39	419	7	14	2	Damp			
	88	89						X	X			Dark Gray		B		<LOD	40	2170	25	57	3	Dry			
	89	90						X	X	X	X	Dark Gray		B		51	14	3831	41	1531	19	Damp			
	90	91						X	X	X	X	Black		B		67	13	2351	24	300	6	Damp			
	91	92						X	X		X	Black		B		42	13	645	10	231	5	Damp			
	92	93						X	X		X	Black		B		70	13	279	6	33	2	Damp			
	93	94						X			X	Very Dark Gray		B		<LOD	43	162	5	12	2	Damp			
	94	95						X			X	Dark Gray		B		52	14	195	5	12	1	Damp			
	95	96						X				Black		B		<LOD	40	416	7	12	1	Damp			
SM70b	0	30	See borehole SM70a interval 0-30 ft.																						
	30	31						X				Brown		B		<LOD	41	350	7	4	1	Damp			
	31	32						X				Brown		B		<LOD	38	421	7	5	1	Damp			
	32	33										Black		B		<LOD	36	132	4	9	1	Damp			
	33	34										Very Dark Gray		B		<LOD	37	179	4	6	1	Damp			
	34	35						X				Very Dark Gray		B		<LOD	40	90	3	4	1	Damp			
	35	36										Very Dark Gray		B		<LOD	37	151	4	5	1	Damp			
	36	37						X				Very Dark Gray		B		<LOD	39	132	4	4	1	Damp			
	37	38										Very Dark Gray		B		<LOD	38	208	5	4	1	Damp			
	38	39										Dark Grayish Brown		B		<LOD	37	59	3	6	1	Damp			
	39	40										Dark Grayish Brown		B		<LOD	38	66	3	7	1	Damp			
	40	41										Dark Brown		B		<LOD	37	140	4	5	1	Damp			
	41	42										Dark Brown		B		<LOD	39	162	4	5	1	Damp			
	42	43										Dark Grayish Brown		B		<LOD	35	76	3	4	1	Damp			
	43	44										Dark Grayish Brown		B		<LOD	38	69	3	5	1	Damp			
	44	45										Dark Grayish Brown		B		<LOD	37	138	4	5	1	Damp			
	45	46										Grayish Brown		B		<LOD	39	72	3	<LOD	3	Damp			
	46	47										Dark Grayish Brown		B		<LOD	37	80	3	5	1	Damp			
	47	48										Dark Grayish Brown		B		<LOD	38	71	3	5	1	Damp			
	48	49										Dark Grayish Brown		B		<LOD	35	102	3	3	1	Damp			
	49	50										Dark Grayish Brown		B		<LOD	36	297	5	4	1	Damp			
	50	51										Dark Grayish Brown		B		<LOD	38	149	4	8	1	Damp			
	51	52										Dark Grayish Brown		B		<LOD	36	72	3	5	1	Moist			
	52	53										Black		B		<LOD	38	81	3	5	1	Damp			
	53	54										Black		B		<LOD	37	81	3	4	1	Damp			
	54	55										Black		B		<LOD	41	92	3	5	1	Damp			
	55	56										Dark Grayish Brown		B		<LOD	40	84	3	4	1	Damp			
	56	57									X	Very Dark Gray		B		<LOD	36	139	4	6	1	Damp			
	57	58										Gray		B		<LOD	39	121	4	6	1	Damp			
	58	59										Grayish Brown		B		<LOD	41	414	7	4	1	Damp			
	59	60										Gray		B		<LOD	41	266	6	<LOD	4	Dry			

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Soil Boring ID	Sample Depth Interval (feet bgs)		Mineralogical/Lithological Observations									Soil Color	USCS Symbol	Soil Type (based on Final RI report)	Laboratory Sample ID	XRF Field Screening Results (ppm)						Groundwater Observations		Monitoring Well Insatallation	
	Top	Bottom	Red Porous Rock	Vitreous "Slag"	Red Rind	Elemental Hg	Stibnite	Realgar	Orpiment	Cinnabar	White Vein					Total Antimony	XRF Error Antimony	Total Arsenic	XRF Error Arsenic	Total Mercury	XRF Error Mercury	Moisture observed in Soil Sample or Rock Cuttings	Static Water Level in Completed Well, September 10, 2015 (estimated, feet bgs)	Monitoring Well ID	Monitoring Well Screened Interval (feet bgs)
SM70b	60	61									X	Light Brownish Gray		B		<LOD	42	120	4	4	1	Dry			
	61	62										Gray		B		<LOD	41	128	4	5	1	Dry			
	62	63										Grayish Brown		B		<LOD	39	123	4	5	1	Damp			
	63	64										Gray		B		<LOD	39	43	3	5	1	Dry			
	64	65										Gray		B		<LOD	42	39	2	6	1	Dry			
	65	66					X					Gray		B		<LOD	40	95	3	<LOD	3	Dry			
	66	67										Dark Gray		B		<LOD	37	93	3	5	1	Damp			
	67	68										Black		B		<LOD	45	68	3	4	1	Damp			
	68	69										Black		B		<LOD	38	76	3	4	1	Damp			
	69	70										Black		B		<LOD	40	77	3	5	1	Dry			
	70	71										Black		B		<LOD	42	112	4	4	1	Moist			
	71	72										Black		B		<LOD	39	77	3	5	1	Moist			
	72	73										Black		B		<LOD	38	91	3	<LOD	3	Moist			
	73	74										Black		B		<LOD	40	74	3	3	1	Damp			
	74	75										Black		B		<LOD	41	98	4	5	1	Moist			
	75	76										Black		B		<LOD	41	247	6	4	1	Moist			
	76	77										Black		B		<LOD	43	82	4	<LOD	3	Moist			
	77	78										Black		B		<LOD	40	96	3	4	1	Moist			
	78	79										Black		B		<LOD	39	109	4	5	1	Damp			
	79	80									X	Dark Gray		B		<LOD	39	153	4	<LOD	3	Damp			
	80	81									X	Dark Gray		B		<LOD	48	117	4	5	1	Wet			
	81	82										Black		B		<LOD	44	85	4	<LOD	3	Saturated			
	82	83									X	Black		B		<LOD	47	102	4	5	1	Saturated			
	83	84									X	Black		B		<LOD	45	87	4	6	1	Saturated			
	84	85										Gray		B		<LOD	50	131	5	<LOD	4	Damp			
	85	86									X	Gray		B		<LOD	49	134	5	6	1	Damp			
	86	87									X	Gray		B		<LOD	52	160	5	<LOD	4	Damp			
	87	88									X	Light Gray		B		<LOD	48	167	5	<LOD	4	Dry			
	88	89									X	Light Gray		B		<LOD	48	96	4	<LOD	4	Dry			
	89	90										Light Gray		B		<LOD	47	105	4	5	1	Dry			
	90	91										Yellowish Brown		B		<LOD	47	163	5	6	1	Dry			
	91	92					X				X			B		<LOD	50	64	3	<LOD	3				
	92	93									X	Gray		B		<LOD	46	75	4	7	1	Damp			
	93	94									X	Gray		B		<LOD	50	225	6	6	2	Dry			
	94	95									X	Gray		B		<LOD	46	317	7	6	2	Dry			
	95	96									X	Gray		B		<LOD	52	179	6	<LOD	4	Dry			
	96	97									X	Grayish Brown		B		<LOD	55	139	5	<LOD	4	Dry			
	97	98									X	Dark Reddish Brown		B		<LOD	49	105	4	5	1	Damp			
	98	99									X	Dark Grayish Brown		B		<LOD	44	112	4	<LOD	4	Moist			
	99	100									X	Dark Brown		B		<LOD	49	96	4	<LOD	4	Wet			
	100	101									X	Dark Gray		B		<LOD	47	111	4	<LOD	4	Wet			
	101	102									X	Dark Gray		B		<LOD	50	109	4	<LOD	4	Wet			
	102	103									X	Dark Gray		B		<LOD	47	115	4	6	1	Wet			
	103	104									X	Dark Gray		B		<LOD	49	113	4	5	1	Wet			
	104	105									X	Dark Gray		B		<LOD	50	56	3	<LOD	3	Wet			
	105	106										Black		B		<LOD	51	122	5	6	1	Wet			
	106	107									X	Dark Brownish Gray		B		<LOD	49	110	4	<LOD	4	Wet			
	107	108									X	Dark Brownish Gray		B		<LOD	48	151	5	5	1	Wet			
	108	109									X	Dark Gray		B		<LOD	47	139	5	<LOD	4	Wet			
	109	110									X	Black		B		<LOD	47	98	4	<LOD	4	Wet			
	110	111									X	Dark Gray		B		<LOD	46	124	4	<LOD	4	Moist			
	111	112									X	Dark Gray		B		<LOD	50	90	4	<LOD	4	Wet			
	112	113									X	Dark Gray		B		<LOD	48	112	4	<LOD	3	Wet			
	113	114										Gray		B		<LOD	47	96	4	<LOD	4	Wet			
	114	115										Dark Gray		B		<LOD	47	94	4	<LOD	3	Wet			
	115	116									X	Dark Gray		B		<LOD	47	78	4	<LOD	4	Wet			
	116	117									X	Gray		B		<LOD	46	90	4	5	1	Wet			
	117	118										Black		B		<LOD	50	115	5	<LOD	4	Wet			
	118	119									X	Black		B		<LOD	47	331	7	5	1	Wet			
	119	120									X	Dark Gray		B		<LOD	45	346	7	<LOD	4	Wet		MW42	119 - 139
	120	121									X	Dark Gray		B		<LOD	43	480	9	4	1	Wet			
	121	122									X	Dark Gray		B		<LOD	49	302	7	6	2	Wet			
	122	123									X	Dark Gray		B		84	16	1312	19	8	2	Wet			
	123	124									X	Dark Gray		B		<LOD	43	918	13	9	2	Wet			
	124	125					X				X	Dark Gray		B		<LOD	47	783	13	10	2	Wet			
	125	126									X	Dark Gray		B		<LOD	48	718	12	8	2	Wet			
	126	127									X	Dark Gray		B		<LOD	46	475	9	5	1	Wet	126.5		
	127	128							X		X	Dark Gray		B		<LOD	45	1713	22	8	2	Wet			
	128	129							X		X	Dark Gray		B		<LOD	47	828	13	11	2	Wet			
	129	130									X	Dark Gray		B		<LOD	46	1981	26	10	2	Wet			
	130	131									X	Dark Gray		B		<LOD	48	2223	30	12	3	Wet			
	131	132									X			B		<LOD	48	793	13	12	2				
	132	133										Black		B		<LOD	47	727	12	39	3	Wet			
	133	134									X	Dark Gray		B		<LOD	62	3133	51	<LOD	11	Wet			
	134	135										Dark Gray		B		<LOD	52	3458	48	16	3	Wet			
	135	136									X	Dark Gray		B		<LOD	48	475	9	11	2	Wet			
	136	137									X	Black		B		<LOD	47	370	8	7	2	Wet			
	137	138									X	Dark Gray		B		<LOD	46	371	8	8	2	Wet			
	138	139									X	Dark Gray		B		<LOD	45	555	10	9	2	Wet			
	139	140									X	Dark Gray		B								Wet			

Table 2-2 Field Soil Characterization Summary

Soil Boring ID	Sample Depth Interval (feet bgs)		Mineralogical/Lithological Observations									Soil Color	USCS Symbol	Soil Type (based on Final RI report)	Laboratory Sample ID	XRF Field Screening Results (ppm)						Groundwater Observations		Monitoring Well Insatallation	
	Top	Bottom	Red Porous Rock	Vitreous "Slag"	Red Rind	Elemental Hg	Stibnite	Realgar	Orpiment	Cinnabar	White Vein					Total Antimony	XRF Error Antimony	Total Arsenic	XRF Error Arsenic	Total Mercury	XRF Error Mercury	Moisture observed in Soil Sample or Rock Cuttings	Static Water Level in Completed Well, September 10, 2015 (estimated, feet bgs)	Monitoring Well ID	Monitoring Well Screened Interval (feet bgs)
SM71a	0	1						X						DN (KG and Loess)		<LOD	38	197	4	5	1				
	1	2						X				Brown	GM	DN (KG and Loess)		<LOD	41	253	6	6	1	Moist			
	2	3												DN (KG and Loess)		<LOD	44	208	5	7	1				
	3	4										Brown	GM	DN (KG and Loess)		<LOD	39	11	2	<LOD	3	Moist			
	4	5												DN (loess)		<LOD	35	11	2	<LOD	2				
	5	6										Grayish Brown	SP-SM	DN (loess)		<LOD	34	11	2	<LOD	2	Moist			
	6	7						X						DN (KG and Loess)		<LOD	36	23	2	<LOD	2				
	7	8						X				Brown	GM	DN (KG and Loess)		<LOD	44	62	3	<LOD	3	Moist			
	8	9												DN (KG and Loess)		<LOD	36	49	2	<LOD	3				
	9	10										Grayish Brown	GM	DN (KG and Loess)		<LOD	40	153	4	<LOD	3	Moist			
	11	12						X				Grayish Brown	GP	DN (KG and Loess)	15SM71SB12	93	13	164	4	5	1	Damp			
	12	13												WB		<LOD	36	92	3	10	1				
	13	14										Grayish Brown	GP	WB		<LOD	65	123	7	<LOD	5	Dry			
	14	15						X						WB		<LOD	39	114	3	8	1				
	15	16						X				Dark Grayish Brown		WB		<LOD	45	130	5	6	1	Damp			
	16	17						X						WB		<LOD	49	109	4	5	1				
	17	18						X				Dark Grayish Brown		WB		<LOD	38	95	3	4	1	Dry			
	18	19						X						WB		<LOD	38	137	4	4	1				
	19	20						X				Grayish Brown		WB		<LOD	37	93	3	5	1	Damp			
	20	21												WB		<LOD	37	159	4	7	1				
	21	22						X				Dark Grayish Brown		WB		<LOD	41	236	6	8	1	Dry			
	22	23						X						WB		<LOD	42	112	4	4	1				
	23	24						X				Dark Grayish Brown		WB		<LOD	37	76	3	4	1	Dry			
	24	25						X				Brown		B		<LOD	37	81	3	5	1	Damp			
	25	26						X				Brown		B		<LOD	37	104	3	5	1	Damp			
	26	27						X				Brown		B		<LOD	39	123	4	5	1	Damp			
	27	28						X				Dark Grayish Brown		B		42	13	121	4	5	1	Damp			
	28	29										Dark Grayish Brown		B		<LOD	36	118	3	4	1	Damp			
	29	30										Brown		B		<LOD	36	149	4	5	1	Damp			
	30	31						X				Grayish Brown		B		<LOD	37	212	5	5	1	Damp			
	31	32						X				Brown		B		<LOD	38	189	4	5	1	Damp			
	32	33						X				Dark Grayish Brown		B		<LOD	37	247	5	6	1	Damp			
	33	34						X				Dark Grayish Brown		B		<LOD	39	217	5	4	1	Damp			
	34	35						X				Brown		B		<LOD	38	183	4	3	1	Damp			
	35	36										Grayish Brown		B		<LOD	37	142	4	4	1	Damp			
	36	37										Dark Brown		B		<LOD	35	86	3	5	1	Damp			
	37	38										Very Dark Grayish Brown		B		<LOD	38	117	4	4	1	Damp			
	38	39										Dark Brown		B		<LOD	38	145	4	5	1	Damp			
	39	40						X				Dark Grayish Brown		B		<LOD	40	400	7	<LOD	4	Damp			
	40	41						X				Dark Brown		B		<LOD	35	306	5	4	1	Damp			
	41	42						X				Dark Grayish Brown		B		<LOD	36	170	4	4	1	Damp			
	42	43						X				Dark Grayish Brown		B		<LOD	36	144	4	4	1	Damp			
	43	44										Dark Grayish Brown		B		<LOD	36	99	3	6	1	Damp			
	44	45						X				Very Dark Gray		B		<LOD	37	117	3	5	1	Damp			
	45	46										Dark Grayish Brown		B		<LOD	37	125	4	3	1	Damp			
	46	47										Dark Gray		B		<LOD	37	154	4	3	1	Damp			
	47	48										Dark Grayish Brown		B		<LOD	36	115	3	4	1	Damp			
	48	49										Dark Grayish Brown		B		<LOD	36	135	4	4	1	Damp			
	49	50										Dark Grayish Brown		B		<LOD	38	114	4	7	1	Damp			
	50	51										Very Dark Gray		B		<LOD	36	109	3	5	1	Damp			
	51	52										Very Dark Gray		B		<LOD	36	88	3	5	1	Damp			
	52	53										Black		B		<LOD	38	88	3	5	1	Damp			
	53	54										Very Dark Gray		B		<LOD	35	97	3	5	1	Damp			
	54	55										Black		B		<LOD	36	82	3	5	1	Damp			
	55	56										Black		B		<LOD	36	101	3	6	1	Damp			
	56	57										Dark Grayish Brown		B		<LOD	36	48	2	6	1	Damp			
	57	58										Dark Gray		B		<LOD	35	46	2	4	1	Damp			
	58	59										Very Dark Gray		B		<LOD	38	94	3	6	1	Damp			
	59	60						X				Dark Grayish Brown		B		<LOD	37	72	3	5	1	Damp			
	60	61									X	Dark Gray		B		<LOD	37	62	3	3	1	Damp			
	61	62									X	Dark Gray		B		<LOD	36	52	2	5	1	Damp			
	62	63					X					Very Dark Gray		B		<LOD	36	92	3	7	1	Damp			
	63	64										Black		B		<LOD	38	90	3	4	1	Damp			
	64	65										Black		B		<LOD	40	96	3	<LOD	3	Moist			
	65	66										Black		B		<LOD	39	104	3	5	1	Moist			
	66	67										Dark Gray		B		<LOD	36	117	3	3	1	Damp			
	67	68										Very Dark Gray		B		<LOD	38	71	3	3	1	Damp			
	68	69										Very Dark Gray		B		<LOD	37	82	3	3	1	Damp			
	69	70										Very Dark Gray		B		<LOD	37	63	3	5	1	Damp			
	70	71										Very Dark Gray		B		<LOD	37	53	2	<LOD	3	Damp			
	71	72									X	Dark Gray		B		<LOD	39	54	3	3	1	Damp			
	72	73									X	Dark Gray		B		<LOD	37	69	3	<LOD	3	Damp			
	73	74									X	Dark Gray		B		<LOD	37	68	3	<LOD	3	Damp			
	74	75									X	Black		B		<LOD	38	113	4	6	1	Damp			
	75	76									X	Black		B		<LOD	38	99	3	8	1	Damp			
	76	77									X	Black		B		<LOD	38	133	4	8	1	Damp			
	77	78										Black		B		<LOD	39	129	4	6	1	Damp			
	78	79										Black		B		<LOD	40	94	3	9	1	Damp			
	79	80									X	Very Dark Gray		B		<LOD	38	51	2	<LOD	3	Damp			
	80	81										Very Dark Gray		B		<LOD	38	59	3	5	1	Damp			
	81	82										Very Dark Gray		B		<LOD	39	59	3	<LOD	3	Damp			
	82	83									X	Very Dark Gray		B		<LOD	37	52	2	3	1	Damp			
	83	84										Very Dark Gray		B		<LOD	37	74	3	5	1	Damp			

Table 2-2 Field Soil Characterization Summary

Soil Boring ID	Sample Depth Interval (feet bgs)		Mineralogical/Lithological Observations									Soil Color	USCS Symbol	Soil Type (based on Final RI report)	Laboratory Sample ID	XRF Field Screening Results (ppm)						Groundwater Observations		Monitoring Well Insatallation	
	Top	Bottom	Red Porous Rock	Vitreous "Slag"	Red Rind	Elemental Hg	Stibnite	Realgar	Orpiment	Cinnabar	White Vein					Total Antimony	XRF Error Antimony	Total Arsenic	XRF Error Arsenic	Total Mercury	XRF Error Mercury	Moisture observed in Soil Sample or Rock Cuttings	Static Water Level in Completed Well, September 10, 2015 (estimated, feet bgs)	Monitoring Well ID	Monitoring Well Screened Interval (feet bgs)
SM71a	84	85										Very Dark Gray		B		<LOD	38	78	3	4	1	Damp			
	85	86										Black		B		<LOD	38	80	3	5	1	Damp			
	86	87										Black		B		<LOD	40	84	3	5	1	Damp			
	87	88										Very Dark Gray		B		<LOD	44	62	3	5	1	Damp	87.5		
	88	89										Very Dark Gray		B		<LOD	36	113	3	3	1	Damp			
	89	90											NR	B											
	90	91										Very Dark Gray		B								Moist			
	91	92										Very Dark Gray		B		<LOD	37	87	3	4	1	Moist			
	92	93										Very Dark Gray		B		<LOD	42	106	4	5	1	Moist			
	93	94										Very Dark Gray		B		<LOD	54	100	5	6	2	Moist			
	94	95									X	Very Dark Gray		B		<LOD	39	129	4	5	1	Wet			
	95	96						X			X	Black		B		<LOD	39	180	4	4	1	Wet			
	96	97									X	Very Dark Gray		B		<LOD	39	107	3	8	1	Wet			
	97	98										Very Dark Gray		B		<LOD	32	69	3	<LOD	2	Wet			
	98	99										Black		B		<LOD	35	139	4	7	1	Wet			
SM71b	0	100	See borehole SM71a interval 0-100 ft.																						
	100	101										Black		B		<LOD	46	86	4	<LOD	4	Wet	87.5	MW43	98 - 118
	102	103										Dark Gray		B		<LOD	62	55	4	<LOD	5	Wet			
	103	104										Dark Gray		B		<LOD	45	125	4	4	1	Wet			
	104	105										Dark Gray		B		<LOD	47	182	5	<LOD	4	Wet			
	105	106									X	Dark Gray		B		<LOD	49	185	6	5	1	Wet			
	106	107									X	Dark Gray		B		<LOD	50	225	6	<LOD	4	Wet			
	107	108									X	Dark Gray		B		<LOD	48	248	7	<LOD	4	Wet			
	108	109									X	Dark Gray		B		<LOD	49	475	9	<LOD	5	Wet			
	109	110									X	Dark Gray		B		<LOD	49	1285	19	7	2	Wet			
	110	111									X	Dark Gray and White		B		<LOD	47	803	13	6	2	Wet			
	111	112									X	Dark Gray		B		<LOD	48	4026	51	<LOD	10	Wet			
	112	113									X	Dark Gray		B		<LOD	48	2880	36	11	3	Wet			
	113	114										Black		B		61	16	1150	18	7	2	Moist			
	114	115					X				X	Dark Gray		B		51	16	3397	44	<LOD	9	Wet			
	115	116					X				X	Gray		B		<LOD	52	6954	94	<LOD	13	Wet			
	116	117									X	Gray		B		<LOD	47	916	14	7	2	Wet			
	117	118										Dark Gray		B		<LOD	42	431	8	6	1	Wet			
	118	119										Dark Gray		B		<LOD	48	478	10	<LOD	5	Wet			
	119	120					X					Black		B		<LOD	47	363	8	5	1	Wet			
	120	121										Black		B		<LOD	49	212	6	6	1	Wet			

Key
<LOD = Less than level of detection
bgs = Below ground surface
ND = Not detected
NR = Not reported
ppm = Parts per million
XRF = X-ray fluoresence spectroscopy

RI Soil Type Descriptions
B = Bedrock of the Kuskokwim Group.
DN (KG and Loess) = Disturbed native soil that comprises a mixture of soil derived from Kuskokwim group bedrock and glacially-derived windblown silt and very fine sand.
DN (KG) = Disturbed native soil that is derived from Kuskokwim Group bedrock and contains clasts of the same.
DN (KG, MZ) = Disturbed native soil that is derived from mineralized Kuskokwim group bedrock.
DN (loess) = Glacially derived windblown silt and very fine sand that has been disturbed by anthropogenic activity.
DN = Native unconsolidated soil that do not appear to have been disturbed by anthropogenic activity.
N (KG) = Native soil that is derived from Kuskokwim group bedrock and contains clasts of the same.
N (KG, MZ) = Native soil that is derived from mineralized Kuskokwim group bedrock and contains clasts of the same.
N (loess) = Glacially-derived windblown silt and very fine sand that is undisturbed by anthropogenic activity.
N = Native unconsolidated soils not otherwise specified that are undisturbed by anthropogenic activity.
N or DN (KG, MZ) = Native soil that may or may not have been disturbed that is derived from mineralized Kuskokwim Group bedrock.
N or DN = Native soil not otherwise specified that may or may not have been disturbed.
T/WR = Mine waste that includes tailings (thermally processed or) and/or waste rock. May also contain vitreous material and furnace dusts.
WB = Weathered bedrock of the Kuskokwim Group.
WR = Waste rock.

Table 2-3 Subsurface Soil Sample Laboratory Results

Soil Boring ID	Sample Depth Interval (feet bgs)		Sample ID	Total Inorganic Elements (mg/kg)																							Mercury Selective Sequential Extraction (ng/g)								Total Mercury (ng/g)
				Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Nickel	Potassium	Selenium	Silver	Sodium	Thallium	Vanadium	Zinc	F0	F1	F2	F3	F4	F5	Sum of Fractions F0 - F2	Sum of Fractions F0 - F5	Total Mercury
	Top	Bottom		SW846 6010B	SW846 6020A	SW846 6020A	SW846 6020A	SW846 6020A	SW846 6020A	SW846 6010B	SW846 6020A	SW846 6020A	SW846 6020A	SW846 6010B	SW846 6020A	SW846 6010B	SW846 6020A	SW846 7471A	SW846 6020A	SW846 6010B	SW846 6020A	SW846 6020A	SW846 6010B	SW846 6020A	SW846 6020A	SW846 6020A	Hg SSE (F0 - F5) with Total Hg	Hg SSE (F0 - F5) with Total Hg	Hg SSE (F0 - F5) with Total Hg	Hg SSE (F0 - F5) with Total Hg	Hg SSE (F0 - F5) with Total Hg	Hg SSE (F0 - F5) with Total Hg	Hg SSE (F0 - F5) with Total Hg	Hg SSE (F0 - F5) with Total Hg	EPA 1631 Appendix
MP094	10	11	15MP094SB11	**6900**	**9600**	**2900**	**220**	**0.53**	**0.25**	**3900**	**33**	**12**	**49**	**27000**	**9.4**	**4500**	**360**	**89**	**45**	**870**	**1.4**	**0.14**	**6460 J**	**6460 J**	**32**	**95**	8 U	**611**	**7.39**	**32900**	**9270**	**36500**	**626**	**79296**	**106000**
	12	13	15MP094SB13	**6800**	**3300**	**860**	**130**	**0.39**	**0.45**	**2100**	**25**	**11**	**33**	**20000**	**7.9**	**3300**	**260**	**37**	**34**	**520**	**2.2**	**0.11**	**63 J**	**0.096 J**	**32**	**75**									
	16	17	15MP094SB17	**6500**	**2300**	**1100 J+**	**190 J+**	**0.49**	**0.33**	**1900 J+**	**21 J+**	**14**	**43**	**25000**	**9**	**3400**	**380**	**120**	**44 J+**	**730 J+**	**1.4**	**0.11**	**72 J**	**0.14 J**	**30 J+**	**92**	**24.4**	**1780 J**	**3.07**	**294**	**10900 J**	**24100**	**1807**	**37101**	**45000**
	18	19	15MP094SB19	**7000**	**1500**	**700**	**150**	**0.47**	**0.33**	**1900**	**24**	**14**	**43**	**31000**	**9.1**	**3100**	**450**	**76**	**45**	**570**	**1.7**	**0.12**	**68**	**0.11 J**	**36**	**100**	**20.1**	**374**	**0.86**	**437**	**5820**	**9700**	**395**	**16352**	**25500**
	19	20	15MP094SB20	**7300**	**410 J**	**37**	**110**	**0.55**	**0.66**	**1600**	**22**	**13**	**47**	**26000**	**12**	**2300**	**330**	**1.8**	**44**	**570**	**3.2**	**0.1**	**40 J**	**0.081 J**	**40**	**100**									
MP095	3	4	15MP095SB04	**6400**	**180**	**83**	**71**	**0.39**	**0.13**	**1200**	**21**	**9.3**	**17**	**23000**	**5.5**	**2500**	**180**	**2.5**	**32**	**390**	**1.1**	**0.049 J**	42 U	0.075 U	**31**	**70**	8.07 U	**46.4**	**0.46**	**1090**	**58.4**	**59.8**	**55**	**1263**	**1280**
	4	5	15MP095SB05	**7200**	**630**	**370**	**120**	**0.43**	**0.16**	**1400**	**23**	**10**	**27**	**25000**	**8.1**	**2600**	**230**	**42**	**35**	**540**	**1.3**	**0.083 J**	**53 J**	**0.082 J**	**32**	**140**	7.11 U	**7.52**	0.2 U	**280**	**72.5**	**58.1**	**15**	**425**	**462**
	9	10	15MP095SB10	**6500**	**1200**	**590**	**150**	**0.55**	**0.31**	**3600**	**22**	**14**	**40**	**42000**	**9.9**	**2900**	**1800**	**45**	**41**	**660**	**1.5**	**0.086**	**90**	**0.099 J**	**31**	**120**	**36.7**	**829**	**0.41**	**479**	**6080**	**6870**	**866**	**14295**	**22200**
	10	11	15MP095SB11	**7700**	**380**	**180**	**130**	**0.54**	**0.42**	**2700**	**29**	**13**	**45**	**34000**	**11**	**3000**	**850**	**18**	**43**	**640**	**1.7**	**0.097 J**	**59 J**	**0.085 J**	**37**	**120**									
	12	13	15MP095SB13	**9500**	**140 J**	**80 J**	**160**	**0.58**	**0.41**	**2000**	**26**	**13**	**49**	**19000**	**13**	**3200**	**530**	**29 J**	**45**	**590**	**1.7**	**0.14**	**61 J**	**0.11 J**	**39**	**110**									
MP096	5	6	15MP096SB06	**7100**	**13000**	**6800**	**550**	**0.69**	**0.34**	**4800**	**30**	**15**	**64**	**28000**	**11**	**4800**	**680**	**2100**	**44**	**2000**	**2**	**0.21**	**190**	**0.54**	**28**	**83**	**850**	**45800**	**6910**	**41500**	**63000**	**1310000**	**53560**	**1468060**	**1730000**
	12	13	15MP096SB13	**9800**	**650**	**410**	**170**	**0.4**	**0.26**	**1200**	**24**	**8.2**	**25**	**15000**	**8.6**	**2900**	**290**	**77**	**25**	**510**	**1.7**	**0.088 J**	**77 J**	**0.12 J**	**39**	**66**	**44.1**	**819**	**11.8**	**1420**	**12000**	**29500**	**875**	**43795**	**17100**
	16	17	15MP096SB17	**8000**	**1800**	**1200**	**190**	**0.41**	**0.16**	**2000**	**24**	**7.3**	**36**	**23000**	**12**	**3500**	**310**	**320**	**25**	**950**	**1.4**	**0.12**	**96**	**0.16 J**	**32**	**61**	**86.9**	**4170**	**2000**	**1740**	**12200**	**37300**	**6257**	**57497**	**326000**
	18	19	15MP096SB19	**5800**	**250**	**740**	**100**	**0.46**	**0.37**	**1900**	**19**	**17**	**39**	**19000**	**10**	**2600**	**670**	**4.2**	**32**	**570**	**1.4**	**0.1 J**	41 U	0.073 U	**29**	**84**									
	25	26	15MP096SB26	**7100**	**60 J**	**71 J**	**120**	**0.43**	**0.26**	**1800**	**24**	**13**	**31**	**23000**	**8**	**2800**	**310**	**19 J**	**36**	**510**	**1.6**	**0.093 J**	**78 J**	0.072 U	**38**	**84**									
MP097	1	2	15MP097SB02	**7400**	**4300**	**1700**	**270**	**0.56**	**0.3**	**2100**	**24**	**13**	**45**	**24000**	**11**	**3200**	**410**	**390**	**40**	**960**	**1.8**	**0.14**	**100**	**0.19**	**32**	**89**	**375**	**12000**	**113**	**2410**	**44500**	**474000**	**12488**	**533398**	**568000**
	5	6	15MP097SB06	**8400**	**710**	**770**	**150**	**0.52**	**0.39**	**1900**	**28**	**17**	**42**	**26000**	**11**	**3200**	**380**	**76**	**51**	**670**	**2**	**0.13**	**66 J**	**0.13 J**	**37**	**120**	**36**	**1390**	**5.05**	**1420**	**19000**	**52000**	**1431**	**73851**	**90100**
	8	9	15MP097SB09	**7800**	**1800**	**1100**	**180**	**0.51**	**0.37**	**2200**	**25**	**14**	**38**	**26000**	**9.3**	**3800**	**390**	**92**	**45**	**780**	**1.8**	**0.11**	**83 J**	**0.14 J**	**32**	**110**									
	10	11	15MP097SB11	**6700**	**650 J+**	**800 J+**	**160 J+**	**0.44 J+**	**0.36 J+**	**1800**	**24 J+**	**14 J+**	**36 J+**	**20000**	**9.9 J+**	**2900**	**330**	**110**	**40 J+**	**700 J+**	**1.5 J+**	**0.12 J+**	**87**	**0.13 J+**	**33 J+**	**93 J+**	**12.6**	**1510**	**1.52**	**638**	**11900**	**31200**	**1524**	**45262**	**45300**
	12	13	15MP097SB13	**9000**	**160**	**330**	**140**	**0.51**	**0.44**	**1500**	**26**	**18**	**41**	**23000**	**12**	**3200**	**390**	**22**	**51**	**630**	**1.7**	**0.13**	**61 J**	**0.11 J**	**39**	**110**									
MP098	19	20	15MP098SB20	**5400 J**	**220**	**1200**	**140**	**0.63**	**0.55**	**8000**	**23**	**17**	**57**	**32000**	**15**	**6200**	**1000**	**250**	**59**	**870**	**1.6**	**0.2**	**94**	**0.15 J**	**32**	**120**	**26.2**	**433**	**1.67**	**727**	**9410**	**40900**	**461**	**51498**	**147000**
	25	26	15MP098SB26	**2400**	**120**	**590**	**100**	**0.62**	**0.29**	**1000**	**19**	**9.8**	**56**	**23000**	**11**	**1600**	**270**	**8900**	**42**	**740**	**1.3**	**0.26**	**61 J**	**0.27**	**23**	**90**	**16.2**	**159**	**4420**	**7040**	**8790**	**1200000**	**4595**	**1220425**	**740000**
	32	33	15MP098SB33	**3400**	**200**	**630**	**130**	**0.72**	**0.61**	**1200**	**40**	**19**	**65**	**31000**	**14**	**1600**	**720**	**470**	**63**	**770**	**1.7**	**0.19**	**48 J**	**0.43**	**35**	**130**									
	35	36	15MP098SB36	**2100**	**480**	**4900**	**110**	**0.87**	**0.7**	**3700**	**44**	**26**	**74**	**40000**	**18**	**4800**	**490**	**200**	**110**	**700**	**4.4**	**0.16**	39 U	**0.85**	**35**	**110**									
	37	38	15MP098SB38	**2300**	**1600**	**4600**	**300**	**0.66**	**0.79**	**1500**	**83**	**28**	**61**	**63000**	**16**	**1500**	**700**	**470**	**110**	**410**	**4.7**	**0.21**	40 U	**0.21 J**	**37**	**120**	**102**	**5200**	**15.2**	**4300**	**32400**	**364000**	**5317**	**406017**	**243000**
MP099	10	11	15MP099SB11	**7500**	**10000**	**4000**	**430**	**0.68**	**0.44**	**5700**	**30**	**17**	**65**	**28000**	**14**	**5100**	**710**	**540**	**54**	**2000**	**1.6**	**0.23**	**190**	**0.37**	**30**	**98**	**143**	**4590**	**22.9**	**1330**	**22900**	**428000**	**4756**	**456986**	**656000**
	11	12	15MP099SB12	**5700 J**	**110**	**280**	**120**	**0.62**	**0.75**	**1900**	**23**	**14**	**45**	**38000**	**10**	**2000**	**410**	**35**	**48**	**500**	**1.2**	**0.14**	**63 J**	**0.093 J**	**35**	**120**									
	12	13	15MP099SB13	**6600**	**3400**	**3200**	**300**	**0.58**	**0.43**	**3300**	**22**	**16**	**52**	**28000**	**13**	**4000**	**500**	**640**	**40**	**1500**	**1.4**	**0.18**	**160**	**0.27**	**28**	**89**	**217**	**13900**	**34.2**	**4060**	**31200**	**565000**	**14151**	**614411**	**517000**
	16	17	15MP099SB17	**8900**	**380**	**590**	**140**	**0.57**	**0.29**	**1700**	**25**	**13**	**35**	**15000**	**9.6**	**2700**	**290**	**130**	**32**	**720**	**1.1**	**0.12**	**89 J**	**0.12 J**	**39**	**68**									
	18	19	15MP099SB19	**1400**	**25 J**	**200**	**120**	**0.52**	**1.2**	**890**	**14**	**14**	**53**	**37000**	**9.1**	**240**	**1900 J**	**16**	**46**	**540**	**1.2**	**0.12**	39 U	**0.11 J**	**21**	**150**	**50**	**1160**	**25.2**	**1310**	**7400**	**22500**	**1235**	**32445**	**23000**
MP100	8	9	15MP100SB09	**1300**	**430**	**2100**	**100**	**0.65**	**0.67**	**3600**	**11**	**23**	**63**	**33000**	**13**	**7600**	**880**	**160**	**66**	**720**	**1.5**	**0.24**	35 U	**0.087 J**	**20**	**130**	**16.8**	**347**	0.19 U	**1010**	**14000**	**5680000**	**364**	**5695374**	**260000**
	10	11	15MP100SB11	**7100**	**730**	**140**	**81**	**0.39**	**0.17**	**1300**	**21**	**6.8**	**22**	**14000**	**6.6**	**2300**	**130**	**6.3**	**25**	**370**	**0.85**	**0.074 J**	**49 J**	**0.071 J**	**37**	**59**	7.52 U	**212**	**0.96**	**11200**	**1590**	**67400**	**220**	**80410**	**290000**
	16	17	15MP100SB17	**9900**	**63**	**110**	**86**	**0.32**	**0.16**	**1700**	**21**	**7.1**	**19**	**19000**	**6**	**4100**	**250**	**8.9**	**24**	**490**	**0.8**	**0.053 J**	**81**	**0.076 J**	**31**	**61**									
	18	19	15MP100SB19	**8000**	**220 J+**	**110 J+**	**87 J+**	**0.32 J+**	**0.21 J+**	**1700 J+**	**30 J+**	**8.1 J+**	**21 J+**	**22000**	**6.2 J+**	**3000**	**250**	**28**	**26 J+**	**550 J+**	**1.1 J+**	**0.061 J+**	**97 J**	**0.083 J+**	**37 J+**	**56 J+**	7.9 U	**294**	**1.03**	**418**	**3220 J**	**9960 J**	**303**	**13901**	**17900**
	20	21	15MP100SB21	**7600**	**63**	**96**	**94**	**0.3**	**0.19**	**1700**	**19**	**8.5**	**16**	**10000**	**5.7**	**2500**	**130**	**13**	**21**	**410**	**0.86**	**0.079 J**	**96**	**0.088 J**	**30**	**49**									
MP101	10	11	15MP101SB11	**6100**	**2500**	**1700**	**220**	**0.59**	**0.5**	**1900**	**25**	**21**	**54**	**30000**	**13**	**2600**	**500**	**520**	**69**	**760**	**1.9**	**0.18**	**57 J**	**0.2**	**33**	**100**	**879**	**11800**	**48000**	**8800**	**163000**	**1440000**	**60679**	**1672479**	**616000**
	12	13	15MP101SB13	**3500**	**870**	**840**	**140**	**0.66**	**0.35**	**2100**	**20**	**15**	**72**	**33000**	**14**	**2200**	**450**	**220**	**61**	**840**	**4.4**	**0.29**	**62 J**	**0.13 J**	**31**	**100**	**237**	**6310**	**1640**	**1010**	**31100**	**86300**	**8187**	**126597**	**148000**
	13	14	15MP101SB14	**1000**	**200**	**300**	**53**	**0.48**	**0.54**	**2000**	**17**	**18**	**43**	**39000**	**11**	**4000**	**770**	**21**	**63**	**470**	**4.7**	**0.21**	39 U	0.065 U	**32**	**110**									
RD21	4	5	15RD21SB05	**4900 J**	**740**	**1300**	**180**	**0.6**	**0.52**	**1700**	**23**	**18**	**70**	**36000**	**12**	**5200**	**1000**	**200**	**59**	**1100**	**1.8**	**0.22**	**90**	**0.17 J**	**30**	**110**	**21.3**	**777**	**168**	**1010**	**10200**	**91100**	**966**	**103276**	**106000**
RD22	0	1	15RD22SB01	**9100**	**210**	**270**	**120**	**0.47**	**0.25**	**1400**	**24**	**12**	**32**	**24000**	**8.6**	**2900**	**370**	**20**	**34**	**520**	**1.1**	**0.098 J**	**64 J**	**0.11 J**	**40**	**76**									
	8	9	15RD22SB09	**6800**	**9.9**	**24 J+**	**74 J+**	**0.38**	**0.13**	**1700 J+**	**20 J+**	**9.4 J+**	**26 J+**	**16000**	**8.2 J+**	**2600 J+**	**170 J+**	**3.5**	**29 J+**	**470 J+**	**1**	**0.12 J+**	**59 J**	0.065 U	**30 J+**	**68 J+**	7.66 U	**17.6 J**	0.21 U	**381 J**	**54.6**	**138 J**	**25**	**599**	**3480**
SM68	10	11	15SM68SB11	**2100**	**9.1**	**260**	**190**	**0.87**	**0.95**	**1000**	**17**	**26**	**84**	**64000**	**18**	**310**	**1800**	**11**	**68**	**780**	**1.7**	**0.3**	39 U	**0.18 J**	**31**	**160**									
SM70	1	2	15SM70SB02	**2200**	**35**	**850**	**110**	**1**	**0.62**	**1600**	**13**	**20**	**75**	**38000**	**15**	**490**	**880**	**29**	**69**	**800**	**1.6**	**0.19**	39 U	**0.12 J**	**25**	**130**									
SM71	11	12	15SM71SB12	**1500**	**120**	**510**	**130**	**0.93**	**1.2**	**650**	**25**	**23**	**68**	**49000**	**14**	**180**	**1800**	**18**	**76**	**500**	**1.4**	**0.17**	37 U	**0.15 J**	**43**	**140**									

Key:

Bold = Detected

Hg = Mercury

J = The analyte was detected. The associated result is estimated.

J+ = The analyte was detected. The associated result is estimated with a high bias.

mg/kg = Milligrams per kilogram

ng/g = Nanograms per gram

SSE = Selective Sequential Extraction

U = The analyte was analyzed for but not detected. The value provided is the method detection limit.

- 2015 Soil Boring
- Soil Boring/Monitoring Well Location – Abandoned
- 2015 Soil Boring / Monitoring Well
- Existing RI Monitoring Well Location
- Decommissioned Well
- Existing RI Soil Boring Location
- 2014 5-foot Contour
- 2014 1-foot Contour
- Area of 2014 NTCRA Re-grading
- 2010 5-foot Contour
- Post-NTCRA Stream Alignment
- Red Devil Creek
- Line of Geologic Cross Section
- Settling Pond
- Monofill
- Historical Structure
- Approximate Location of Proposed Repository Footprint
- Seep Location

Digital 2010 5-foot topographic contours based on the aerial orthophotograph taken on September 21, 2010 (AeroMetric 2012)

Digital 2014 5-foot and 1-foot topographic contours based on Marsh Creek (2014)

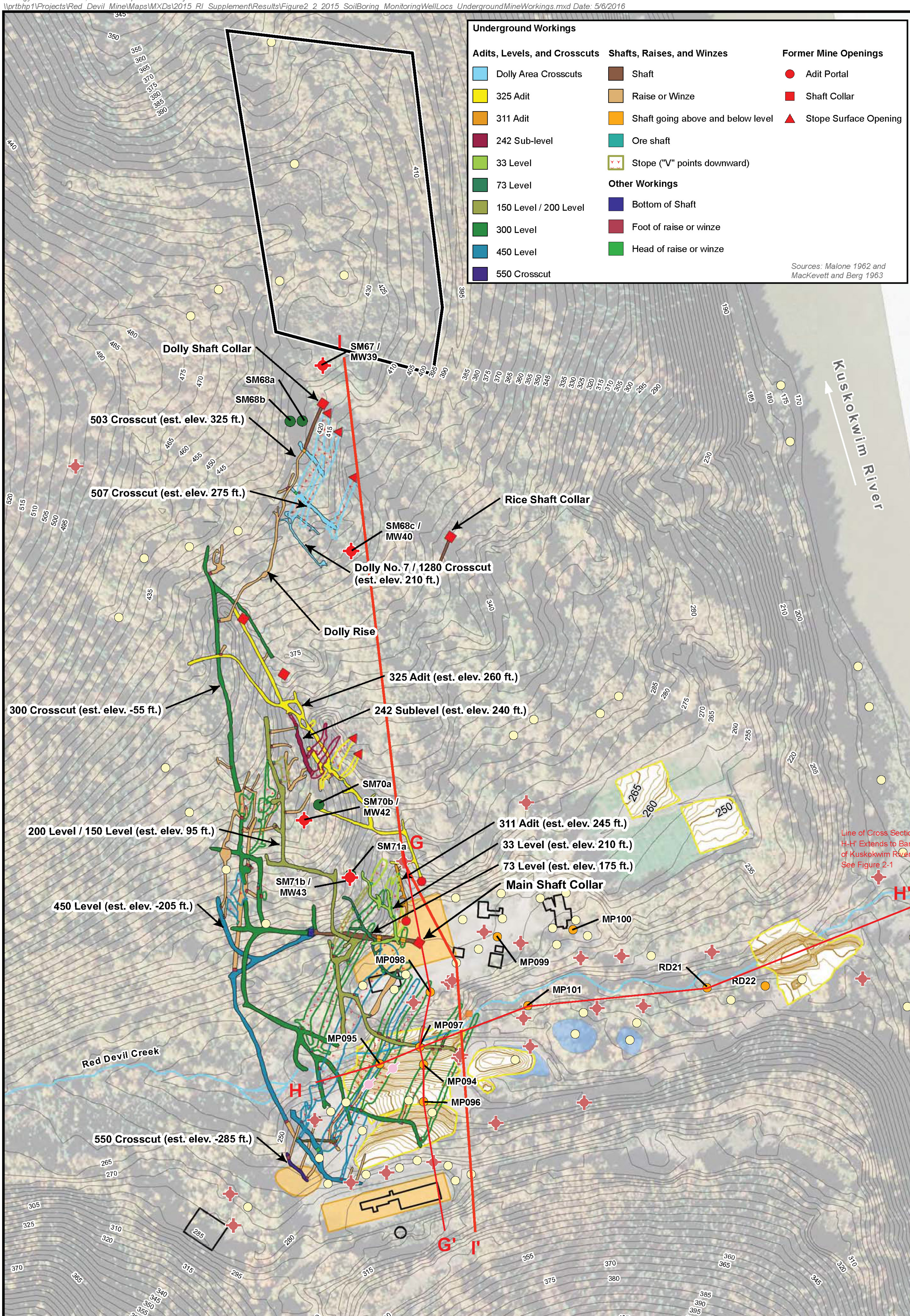
RED DEVIL MINE

Red Devil, Alaska

Figure 2-1
2015 Soil Boring and Monitoring Well Locations

0 37.5 75 150 225 300
Feet
0 10 20 40 60 80 100
Meters
Scale 1:2,500

Ecology & Environment, Inc. GIS Department Project:
\\prtbhp1\Projects\Red_Devil_Mine\Maps\MXDs\2015_RI_Supplement\Results\Figure2_2_2015_SoilBoring_MonitoringWellLocs_UndergroundMineWorkings.mxd Date: 5/6/2016



2015 Soil Boring
Soil Boring/Monitoring Well Location – Abandoned
2015 Soil Boring / Monitoring Well
Existing RI Monitoring Well Location
Decommissioned Well
Existing RI Soil Boring Location

2014 5-foot Contour
2014 1-foot Contour
Area of 2014 NTCRA Re-grading
2010 5-foot Contour
Post-NTCRA Stream Alignment
Red Devil Creek
Line of Geologic Cross Section

Settling Pond
Monofill
Historical Structure
Approximate Location of Proposed Repository Footprint
Seep Location

Digital 2010 5-foot topographic contours based on the aerial orthophotograph taken on September 21, 2010 (AeroMetric 2012)

Digital 2014 5-foot and 1-foot topographic contours based on Marsh Creek (2014)

RED DEVIL MINE

Red Devil, Alaska

Figure 2-2
2015 Soil Boring and Monitoring Well Locations and Underground Mine Workings

0 37.5 75 150 225 300
Feet
0 10 20 40 60 80 100
Meters
Scale 1:2,500

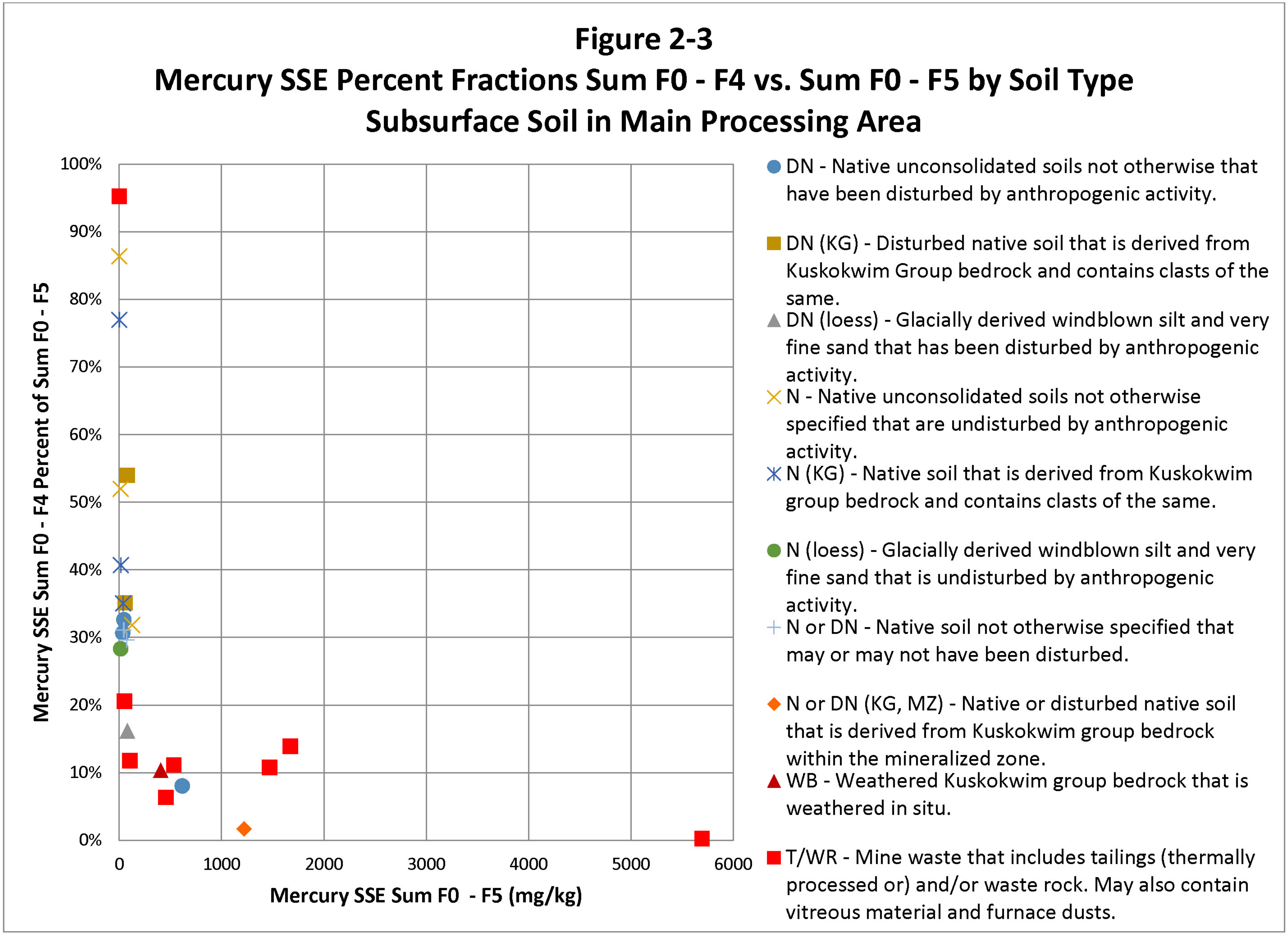
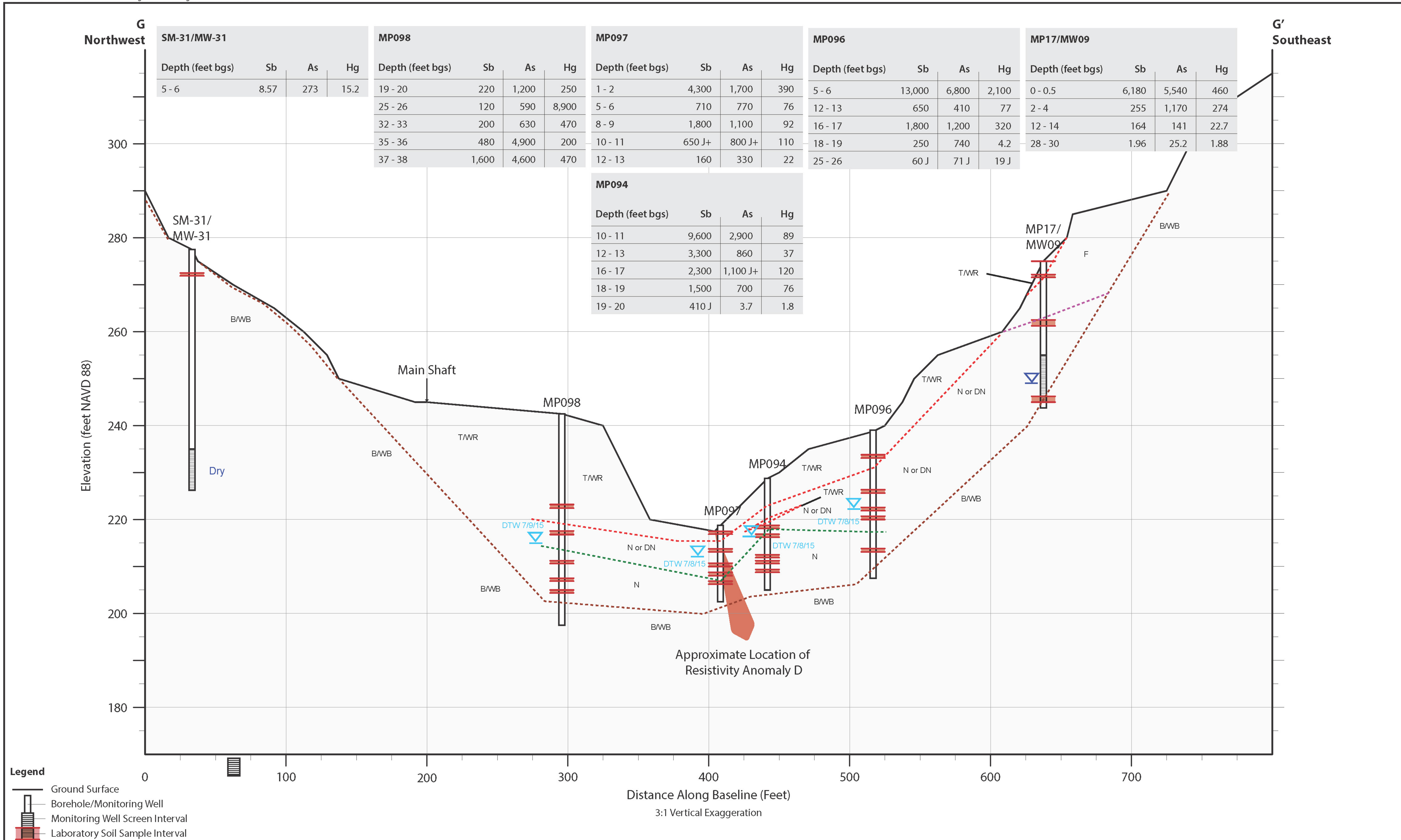


Figure 2-3
Mercury SSE Percent Fractions Sum F0 - F4 vs. Sum F0 - F5 by Soil Type
Subsurface Soil in Main Processing Area
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Mercury SSE Sum F0 - F4 Percent of Sum F0 - F5
0
1000
2000
3000
4000
5000
6000
Mercury SSE Sum F0 - F5 (mg/kg)
DN - Native unconsolidated soils not otherwise that have been disturbed by anthropogenic activity.
DN (KG) - Disturbed native soil that is derived from Kuskokwim Group bedrock and contains clasts of the same.
DN (loess) - Glacially derived windblown silt and very fine sand that has been disturbed by anthropogenic activity.
N - Native unconsolidated soils not otherwise specified that are undisturbed by anthropogenic activity.
N (KG) - Native soil that is derived from Kuskokwim group bedrock and contains clasts of the same.
N (loess) - Glacially derived windblown silt and very fine sand that is undisturbed by anthropogenic activity.
N or DN - Native soil not otherwise specified that may or may not have been disturbed.
N or DN (KG, MZ) - Native or disturbed native soil that is derived from Kuskokwim group bedrock within the mineralized zone.
WB - Weathered Kuskokwim group bedrock that is weathered in situ.
T/WR - Mine waste that includes tailings (thermally processed or) and/or waste rock. May also contain vitreous material and furnace dusts.



SM-31/MW-31

Depth (feet bgs)	Sb	As	Hg
5 - 6	8.57	273	15.2

MP098

Depth (feet bgs)	Sb	As	Hg
19 - 20	220	1,200	250
25 - 26	120	590	8,900
32 - 33	200	630	470
35 - 36	480	4,900	200
37 - 38	1,600	4,600	470

MP097

Depth (feet bgs)	Sb	As	Hg
1 - 2	4,300	1,700	390
5 - 6	710	770	76
8 - 9	1,800	1,100	92
10 - 11	650 J+	800 J+	110
12 - 13	160	330	22

MP094

Depth (feet bgs)	Sb	As	Hg
10 - 11	9,600	2,900	89
12 - 13	3,300	860	37
16 - 17	2,300	1,100 J+	120
18 - 19	1,500	700	76
19 - 20	410 J	3.7	1.8

MP096

Depth (feet bgs)	Sb	As	Hg
5 - 6	13,000	6,800	2,100
12 - 13	650	410	77
16 - 17	1,800	1,200	320
18 - 19	250	740	4.2
25 - 26	60 J	71 J	19 J

MP17/MW09

Depth (feet bgs)	Sb	As	Hg
0 - 0.5	6,180	5,540	460
2 - 4	255	1,170	274
12 - 14	164	141	22.7
28 - 30	1.96	25.2	1.88

Notes:

1. Surface topography is based on: 1) digital 2010 5-foot topographic contours based on the aerial orthograph taken on September 21, 2010 (Aerometric 2012); and 2) digital 2014 5-foot and 1-foot topographic contours based on Marsh Creek (2014).
2. Approximate resistivity anomaly locations based on USGS (2011).
3. Tabulated sample results are for laboratory total antimony (Sb), arsenic (As), and mercury (Hg) in soil in milligrams per kilogram.

Figure 2-4
Geologic Cross Section G-G'
Red Devil Mine
Red Devil, Alaska

1001095.0014.05 - RDM Cross Sections\Figure 2-5 Geologic Cross Section H-H'.ai-08/02/17-GRA

MW095			
Depth (feet bgs)	Sb	As	Hg
3 - 4	180	83	2.5
4 - 5	630	370	42
8 - 9	1,200	590	45
10 - 11	380	180	18
12 - 13	140 J	80 J	29 J

MP097			
Depth (feet bgs)	Sb	As	Hg
1 - 2	4,300	1,700	390
5 - 6	710	770	76
8 - 9	1,800	1,100	92
10 - 11	650 J+	800 J+	110
12 - 13	160	330	22

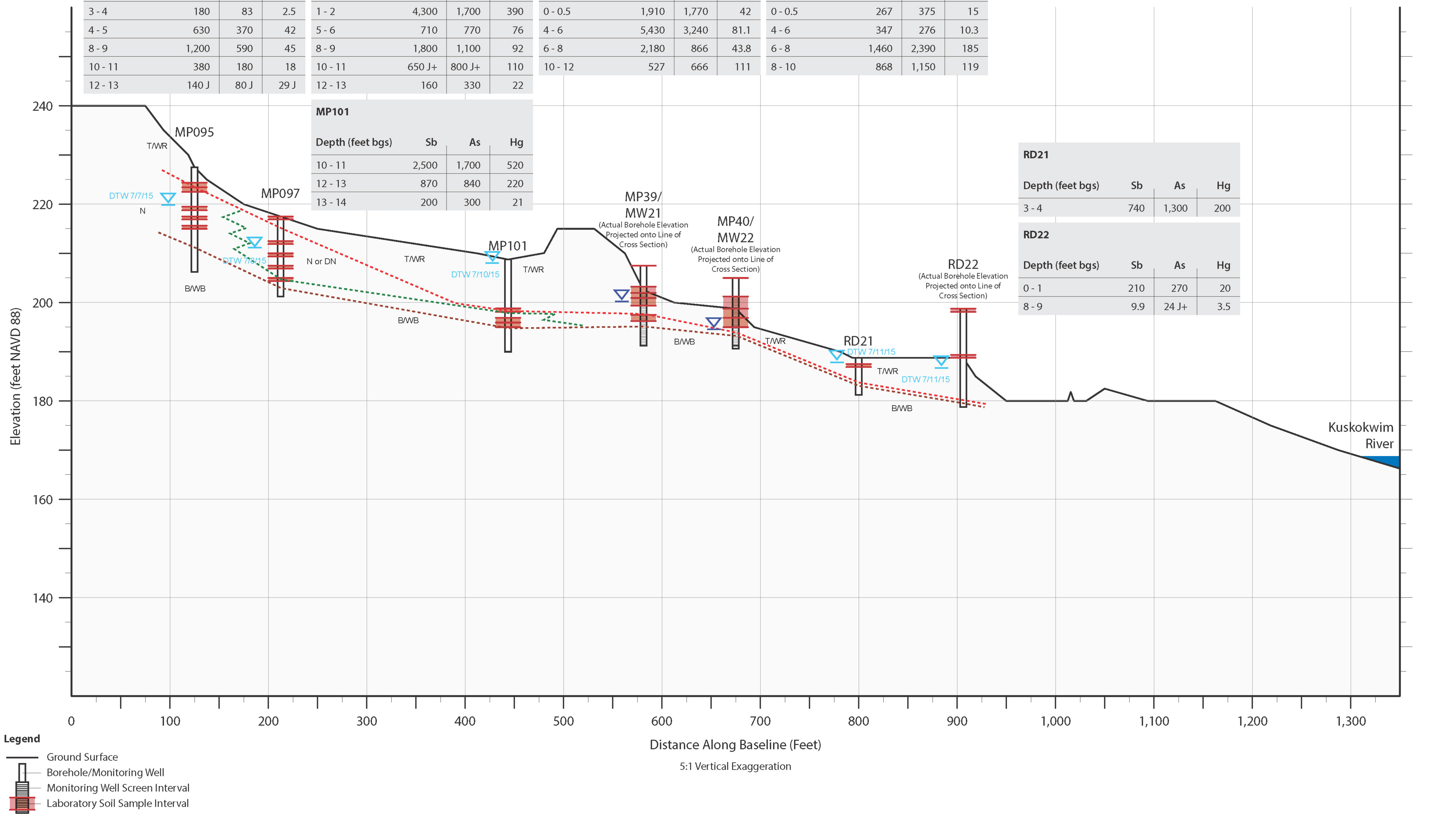
MP39/MW21			
Depth (feet bgs)	Sb	As	Hg
0 - 0.5	1,910	1,770	42
4 - 6	5,430	3,240	81.1
6 - 8	2,180	866	43.8
10 - 12	527	666	111

MP40/MW22			
Depth (feet bgs)	Sb	As	Hg
0 - 0.5	267	375	15
4 - 6	347	276	10.3
6 - 8	1,460	2,390	185
8 - 10	868	1,150	119

MP101			
Depth (feet bgs)	Sb	As	Hg
10 - 11	2,500	1,700	520
12 - 13	870	840	220
13 - 14	200	300	21

RD21			
Depth (feet bgs)	Sb	As	Hg
3 - 4	740	1,300	200

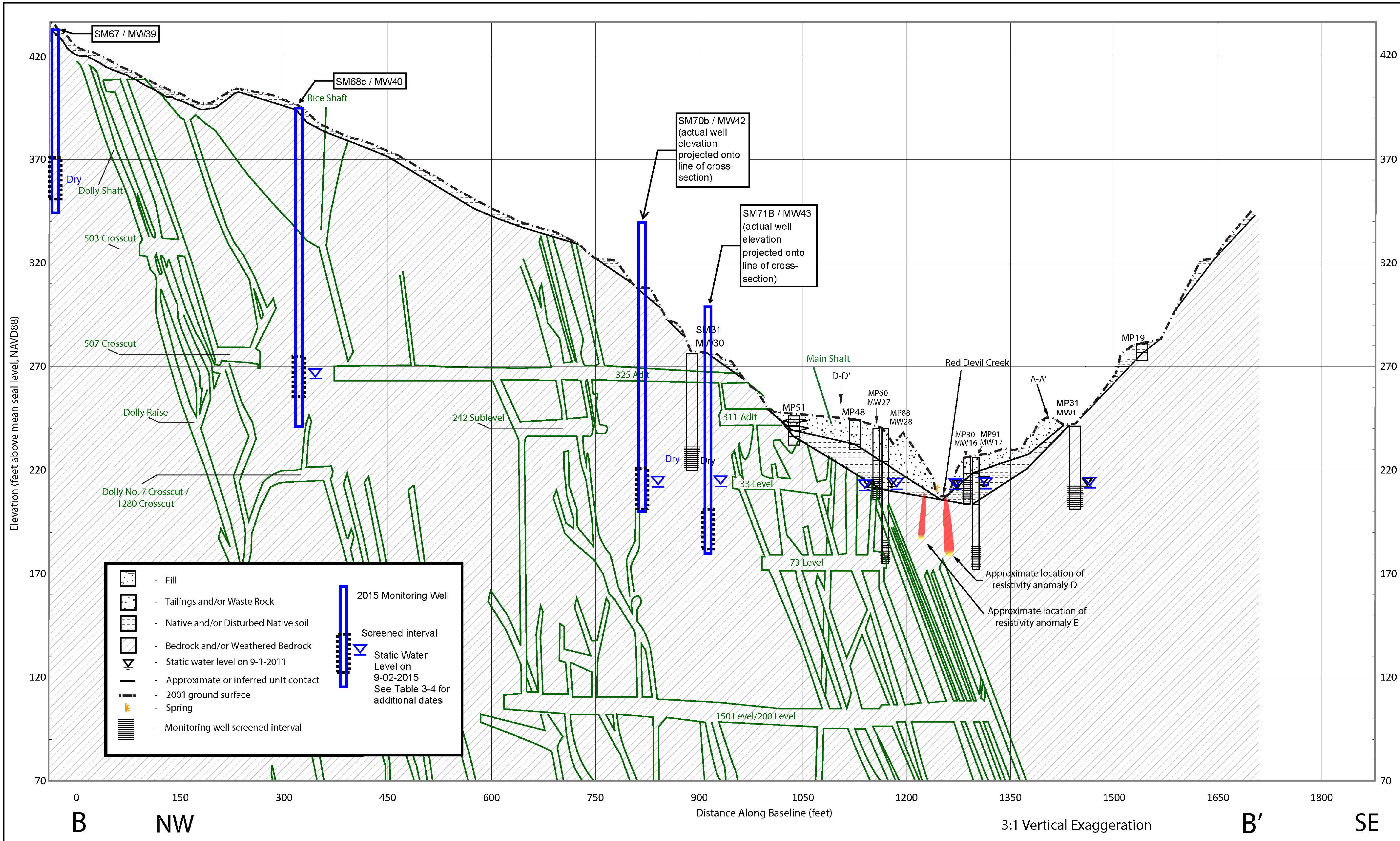
RD22			
Depth (feet bgs)	Sb	As	Hg
0 - 1	210	270	20
8 - 9	9.9	24 J+	3.5



Notes:

1. Surface topography is based on: 1) digital 2010 5-foot topographic contours based on the aerial orthograph taken on September 21, 2010 (Aerometric 2012); and 2) digital 2014 5-foot and 1-foot topographic contours based on Marsh Creek (2014).
2. Tabulated sample results are for laboratory total antimony (Sb), arsenic (As), and mercury (Hg) in soil in milligrams per kilogram.

Figure 2-5
Geologic Cross Section H-H'
Red Devil Mine
Red Devil, Alaska



Notes: 1) Surface topography based on 5/27/2001 aerial photograph and topographic map (Aero-Metric, Inc. 2010)

2) Mine workings projected onto geological cross section based on March 1962 longitudinal projection (Alaska Mines and Minerals, Inc. and Decoursey Mountain Mining Co., Inc., 1962)

3) Approximate resistivity anomaly locations based on USGS (2011)

RED DEVIL MINE

Red Devil, Alaska

Figure 2-6
Geologic Cross Section and Underground Mine Workings

02:001095.0002.01

3 Groundwater Investigation

3.1 Groundwater Investigations

The RI Supplement groundwater characterization activities were designed to address data gaps associated with groundwater in the Main Processing Area, the Red Devil Creek downstream alluvial area, and the Surface Mined Area. Additional groundwater characterization was performed to gather the types of additional information identified in Section 3.3 of the RI Supplement Work Plan. The supplemental RI groundwater characterization was designed to meet the following objectives:

- Assess groundwater occurrence, depth, and quality in the Surface Mined Area to better understand impacts of naturally mineralized bedrock and underground mine workings on groundwater flow paths and inorganic element concentrations.
- Assess groundwater occurrence, depth, and quality in the portions of the RDM affected by the 2014 NTCRA construction.
- Provide additional data on groundwater conditions in the area downgradient of Monofill #2.
- Assess groundwater concentrations of semivolatile organic compounds (SVOCs), diesel-range organics (DRO), gasoline range organics (GRO), and benzene, toluene, ethylbenzene, xylenes (BTEX) in selected wells located within and upgradient of part of the Main Processing Area.
- Provide additional information on baseline groundwater conditions at the site.

Although the wells installed in the Surface Mined Area are intended primarily to assess the potential influence of natural mineralization and mine workings on groundwater conditions upgradient of the Main Processing Area, the resulting data may also be useful for characterizing groundwater conditions downgradient of the proposed on-site repository considered as part of the FS.

Sampling and other field procedures were performed in accordance with the Field Sampling Plan, except as noted below. A brief description of field sampling and other procedures is provided below.

3.1.1 Monitoring Well Installation

Additional groundwater characterization included installation of additional monitoring wells at the site. Four new monitoring wells were installed in the

Surface Mined Area. A description of the new monitoring wells and their locations relative to the underground mine workings features targeted by the well installation is presented in Table 3-1. The locations of the 2015 monitoring wells are shown in Figures 2-1, 2-2, and 3-1. Actual monitoring well locations were refined from the locations proposed in the RI Supplement Work Plan during the investigation based on actual conditions encountered in the field. A description of the monitoring well installation results is presented in Section 3.2.1.

Well installation, completion, and development were performed in accordance with the Field Sampling Plan, except as noted below. Monitoring well installation was performed using a drill rig operated by a subcontracted, Alaska-licensed driller. Soil borings installation and field soil characterization conducted as part of the monitoring well installation were performed as described in Section 2.1. Well construction details are provided in Table 3-1. Those boreholes that were not converted to monitoring wells were abandoned at the completion of drilling in accordance with State of Alaska regulations (18 AAC 75 and 18 AAC 78). Drill cuttings and other investigation-derived waste were managed in accordance with the Field Sampling Plan.

3.1.2 Well Survey

On September 11, 2015, the horizontal and vertical coordinates of new monitoring wells were surveyed by a subcontracted, Alaska-registered land surveyor. Vertical coordinates were surveyed to within the nearest 0.1 foot. Well elevation survey data are presented in Section 3.2.

3.1.3 Water Level Measurement

Water levels were measured in the monitoring wells over the course of three rounds in 2015. The locations of the 2015 and RI monitoring wells are shown in Figure 3-1. The 2015 measurements took place on:

- Spring groundwater and surface water monitoring event – June 17, June 18 (MW16 and MW17) and June 22, 2015 (MW31, MW34, MW35, and MW36).
- Following installation of monitoring wells (all wells except MW34, MW35, and MW36) – August 12, 2015.
- Fall groundwater and surface water monitoring event – September 2 and September 10, 2015.

3.1.4 Groundwater Sampling

Additional groundwater characterization included collecting groundwater data from new and selected existing monitoring wells. Additional groundwater characterization was performed using a combination of field data collection and the results of laboratory analysis for selected analytical parameters. Groundwater samples were collected during two sampling events in 2015—the spring event in June and the fall event in September.

Groundwater samples were collected from selected wells during each monitoring event. Wells sampled as part of the spring and fall 2015 groundwater monitoring events are listed in Tables 3-2 and 3-3, respectively. Locations of monitoring wells sampled are illustrated in Figure 3-1.

All groundwater samples were collected for field water quality parameters (pH, specific conductance, oxidation reduction potential, turbidity, dissolved oxygen, and temperature) and the following laboratory analyses: total TAL inorganic elements and low-level mercury; dissolved low-level mercury; inorganic ions (chloride, fluoride, and sulfate); nitrate-nitrite as N; total suspended solids; and alkalinity (as carbonate/ bicarbonate). In addition, samples from wells MW19 and MW22 were analyzed for SVOCs, DRO, GRO, and BTEX. Well MW19 is located upgradient of the Main Processing Area, and well MW22 is located downgradient of Settling Pond #3. Groundwater samples collected for the various laboratory analyses for the two monitoring events are listed in Tables 3-2 and 3-3. Groundwater samples were submitted to TestAmerica, Seattle, Washington, for laboratory analysis. TestAmerica performed all analyses except total and dissolved low-level mercury analyses, which were performed under sub-subcontract to TestAmerica by Brooks Rand Labs, Seattle, Washington.

3.1.5 Deviations from the Field Sampling Plan

As discussed in Section 2.1.4, two of the soil borings/monitoring wells that were originally planned for installation in the Main Processing Area (MP092/MW37 and MP093/MW38) were not installed. These borings/monitoring wells were intended to replace RI monitoring wells MW16 and MW17, which, at the time of the development of the RI Supplement Work Plan, were thought to have been decommissioned as part of the 2014 NTCRA. During the spring 2015 groundwater monitoring event, it was determined that these two wells had not been decommissioned and they appeared to be in good condition.

As discussed in Section 2.1.4, a total of five new soil borings and associated monitoring wells were originally planned for installation in the Surface Mined Area. However, only four new wells were installed. Over the course of the drilling effort in the Surface Mined Area, a total of eight boreholes were drilled, including the four boreholes in which monitoring wells were installed. Locations of the boreholes and monitoring wells are illustrated in Figures 2-1, 2-2, and 3-1. As described in Tables 2-1 and 3-1, it was necessary to abandon several of the boreholes originally planned for monitoring well installation because groundwater was not encountered at the targeted depths. Further discussion of monitoring well installation is provided in Section 3.2.1.

The initial sampling of the new monitoring wells was originally planned to be performed following their completion at the end of the soil boring/monitoring well installation event. However, because the wildfire demobilization/ remobilization resulted in an overall delay of the well installation activities, the new wells were not completed until mid-August. Since the new wells were planned for sampling in September as part of the planned fall 2015 field event, the initial sampling of the wells would have been performed only a few weeks before the September sampling, rendering the initial sampling essentially redundant. Therefore, the BLM directed E & E to not perform the planned initial sampling of the wells in August. Well MW30 was not sampled in the June or September 2015 sampling events because the water levels were too low at the time of the sampling events.

Well MW09 was not sampled in June 2015 because the water level was too low at the time of the sampling event.

Newly installed well MW39 was not developed or sampled because the well was dry at the times these activities were attempted (see Section 3.2.1 for a description of well installation).

3.2 Groundwater Investigation Results

Additional groundwater characterization included installation of additional monitoring wells at the site and monitoring of the new wells and existing RI wells. The objectives of the groundwater investigation are listed in Section 3.1. Groundwater characterization was performed using a combination of field observations and results of laboratory analysis of groundwater samples. Results of groundwater characterization are summarized below.

3.2.1 Monitoring Well Installation

A primary objective of the new monitoring wells is to assess groundwater occurrence, depth, and quality in the Surface Mined Area to better understand impacts of naturally mineralized bedrock and underground mine workings on groundwater flow paths and inorganic element concentrations. Four new monitoring wells were installed in the Surface Mined Area. The new monitoring wells and a description of their locations relative to pertinent mine workings are presented in Table 3-1. The locations of the 2015 monitoring wells are shown in Figures 2-1, 2-2, and 3-1.

Monitoring well installation in the Surface Mined Area targeted the mineralized zone, if present, and associated network of underground mine workings. The nature of the mineralized zone at the RDM is discussed in Section 2.2.5. As stated in the RI report, the presence of an extensive network of underground mine workings at the site is expected to influence the groundwater flow patterns at the RDM. It was hypothesized that the mine workings provide a highly transmissive groundwater flow network that connects a large portion of the Surface Mined Area and the Main Processing Area and that, assuming the mine workings are not plugged, the mine workings and associated bedrock fractures would exert a draining effect where the mine workings lie below the water table within the host bedrock but above the nearby base level, which is the level of Red Devil Creek. The nature of groundwater flow and migration patterns in this area is presented in Section 2.1.2 of the RI Supplement Work Plan and summarized below.

The planned new monitoring wells were designed to characterize shallow groundwater conditions in the mineralized zone, if present, in the vicinity of the underground mine workings. Therefore, the planned well construction entailed installation of the wells with screen intervals that are within or close to the mineralized zone, if present, and straddle or are near the water table.

The planned monitoring well locations were selected to meet the following criteria: 1) the drilling location can be accessed with the drilling and support equipment; 2) the mineralized zone is expected to be present and at a generally shallow depth; and 3) the depth to groundwater is expected to be fairly close to the depth of the targeted mineralized zone.

As described in Section 2.2.5, the Red Devil ore zones consisted of multiple parallel linear ore shoots that plunge, on average, at an angle of approximately 39° from horizontal on a bearing of South 10° East. The three-dimensional location and configuration of the ore zone can thus be estimated based on the positions of the mapped underground mine workings (see Figures 2-2 and 2-6). The groups of parallel ore shoots thus collectively form several tabular-shaped zones that dip approximately 35° toward the southwest. Peripheral sub-ore grade mineralization was hypothesized to extend to some degree generally along the strike of the tabular bodies defined by the mined ore shoots. Such zones were the zones targeted by the RI Supplement drilling program.

Although the subsurface positions of the mineralized zones can be approximated, the depths to groundwater at the planned well locations were not known prior to drilling. If the mine workings and associated bedrock fractures exert a draining effect where the mine workings locally lie below the water table but above the nearby base level of Red Devil Creek, the depth to the water table would be expected to vary abruptly and significantly in the vicinity of the mine workings. This was found to be the case during the new well installation. As a result, multiple attempts were required to install several monitoring wells with screen intervals that are in close proximity (both laterally and vertically) to the mine workings and associated mineralized bedrock.

A total of eight soil borings were installed in the Surface Mined Area in the attempt to install the planned monitoring wells. A total of four new monitoring wells were installed. A summary of the soil boring and monitoring well installation are presented in Tables 2-1 and 3-1, respectively. Well construction details are provided in Table 3-1. Information regarding bedrock mineralized zones and occurrence of groundwater is presented in Table 2-2.

Each of the new monitoring wells–MW39, MW40, MW42, and MW43–was completed in competent bedrock in close proximity to one or more features of the underground mine workings network. The mine workings features located nearest to each well are identified in Table 3-1. The map locations of the monitoring wells and mine workings features are illustrated in Figure 2-2. The elevations of the generally horizontal features of the mine workings (adits, levels/sublevels, and crosscuts) are indicated on Figure 2-2. The vertical positions of the generally horizontal mine location features and the sub-vertical mine workings features that interconnect the generally horizontal mine workings (shafts, raises, winzes, and stopes), as projected horizontally onto the line of geologic cross section I-I' (see Figure 2-2), are illustrated in Figure 2-6.

Observations regarding bedrock mineralized zones and occurrence of groundwater for completed monitoring wells are described below:

- Well MW39 was installed in borehole SM67 near its originally planned location northwest of the Dolly Shaft and assumed downgradient of the proposed repository location (see Figures 2-2 and 2-6). No visual evidence of mineralization was observed in the borehole (see Table 2-2). During borehole drilling, evidence for groundwater was observed at several intervals as shallow as 63 feet bgs. As noted in Section 2.1.1, while drilling in bedrock using air rotary/down-the-hole hammer method, identification of saturated conditions was locally difficult because groundwater occurs primarily in fractures, and location, density, and orientations of the fractures are not well understood at the site. Further, in comparatively less productive saturated zones, the drilling returns may not provide a clear indication of saturated conditions. Such conditions appear to have been experienced during drilling of borehole SM67. Moisture mixed with the clayey cuttings resulted in a clayey coating of the borehole wall, which was suspected to have obscured and possibly limited flow of water into the borehole. Based on interpretation of available information made during drilling, a well was installed with a screen interval of 63 to 83 feet bgs.
- Well MW40 was installed in borehole SM68c, the third borehole drilled in the attempt to install the well. The well was installed near the 507 Crosscut and Dolly No. 7 / 1280 Crosscut (see Figures 2-2 and 2-6). Abundant visual evidence of mineralization (stibnite, realgar, orpiment, and cinnabar in cuttings) and comparatively high XRF field screening concentrations of antimony (up to 5,659 ppm) and arsenic (12, 859 ppm) were identified in boreholes SM68a and SM68b. In borehole SM68c, comparatively weak mineralization was identified. The well was installed in an area where the water table was relatively well defined with a screen interval of 119 to 139 feet bgs that straddled the water table within a zone of weak mineralization (see Table 2-2).
- Well MW42 was installed in borehole SM70b, the second borehole drilled in the attempt to install the well. The well was installed near the 150 Level / 200 Level and rises/winzes extending upward from the 150 Level / 200 Level (see Figures 2-2 and 2-6). Indications of mineralization were identified in borehole SM70a. In borehole SM70b, some visual evidence of mineralization, consisting of thin intervals with orpiment (see Photograph 2 inset in Section 2.2.5) and stibnite and XRF field screening arsenic concentrations up to 3,458 ppm were identified within a zone ranging from approximately 120 to 140 feet below ground surface (bgs).

The water table was observed at a depth of approximately 127 feet bgs on September 10, 2015. The well was installed with a screen interval of 119 to 139 feet bgs, straddling the water table and coinciding with the mineralized zone (see Table 2-2).

- Well MW43 was installed in borehole SM71b, the second borehole drilled in the attempt to install the well. The well was installed near the 33 Level and 73 Level (see Figures 2-2 and 2-6). Indications of mineralization, including visual observation of stibnite in two thin intervals and XRF field screening arsenic concentrations up to 6,954 ppm, were identified in the boreholes within a zone between approximately 108 and 120 feet bgs, about 20 feet below the water table (approximately 88 feet bgs on September 10, 2015). Installation of a well in borehole SM71a was attempted, but the well was damaged in the process. A well was successfully installed in borehole SM71b a short distance from SM71a, with a screen interval of 98 to 118 feet bgs (see Table 2-2).

3.2.2 Groundwater Levels and Gradients

Depth to groundwater measurements and calculated groundwater elevations for wells monitored during the spring 2015 and fall 2015 monitoring events are presented in Table 3-4. For comparison, water level data collected during previous monitoring events also are included in the table. Based on static water elevations and stream elevations along Red Devil Creek, groundwater potentiometric surface maps for the spring and fall monitoring events were generated and are presented in Figures 3-2 and 3-3, respectively.

During the spring and fall 2015 groundwater monitoring events, as observed during the RI and 2012 baseline monitoring events, groundwater at the site generally flowed toward Red Devil Creek, with groundwater elevations generally mimicking topography over much of the site (see final RI report). Of notable exception is the groundwater in the Surface Mined Area. As noted in Section 3.2.1 and the final RI report, the presence of underground mine workings was hypothesized to exert a draining effect where the mine workings lie below the water table within the host bedrock but above the nearby base level, which is the level of Red Devil Creek. This includes a part of the Surface Mined Area. During the fall 2015 monitoring event, the depths to groundwater in Surface Mined Area wells whose lateral positions and screened intervals are in close proximity to the mine workings—MW39, MW40, MW42, and MW43—were substantially lower than in other nearby wells installed in bedrock further away from the mine workings (e.g., MW31). The positions of these wells relative to the mine workings are illustrated in Figures 2-2, 2-6, and 3-3.

Well MW39, located near the Dolly Shaft and downgradient of the proposed repository, was dry at the time of monitoring in the fall of 2015, indicating a depth to groundwater of greater than 83 feet bgs (the depth of the bottom of the screen interval). This corresponds to a groundwater elevation less than approximately 350 feet. The groundwater elevations in wells MW42 and MW43, located nearest to Red Devil Creek, were approximately 213 feet, nearly the same elevation as Red Devil Creek at its closest point (approximately 210 feet). The groundwater levels in these wells are deeper than would be expected in the bedrock for this area, and appear to be depressed due to the presence of the nearby underground mine workings. These observations support the conclusion that the mine workings network provides a highly transmissive hydraulic connection between the area of the wells and the creek.

As indicated by the groundwater elevation contours in Figures 3-2 and 3-3, the mine workings efficiently drain part of the Surface Mined Area with a groundwater gradient toward the mine workings. Based on comparison of the positions of the well screened intervals to the mine workings, and the groundwater potentiometric surface in the vicinity of the mine workings (see Figure 3-3), it is concluded that the screened interval of each of these wells is positioned hydraulically upgradient of the nearby underground mine workings features.

As further indicated by the groundwater elevation contours in Figures 3-2 and 3-3, much of the groundwater in the Surface Mined Area flows toward the Red Devil Creek valley. Much of this groundwater likely flows via the preferential flow pathways of the interconnected underground mine workings to shallow depths below Red Devil Creek (see Figure 2-6). Based on the groundwater elevations and stream elevations in Red Devil Creek (see Figures 3-2 and 3-3), much of the groundwater within the Red Devil Creek valley, including groundwater in the Main Processing Area and the area downstream of the Main Processing Area, emerges into Red Devil Creek and enters the Kuskokwim River as surface water rather than as groundwater.

Groundwater elevations during both 2015 monitoring events were generally lower than during previous groundwater monitoring events at the RDM at similar times of the year. Groundwater elevations were lower during the fall 2015 event than during the spring 2015 event. Details are presented in Table 3-4, and comparisons of water elevations between the 2015 and previous monitoring events are summarized below:

- During the spring (June) 2015 monitoring event, groundwater elevations were lower than during the spring (May) 2012 monitoring event in all wells by a range of 0.64 to 11.44 feet and by an average of 4.08 feet.
- During the fall (September 10) 2015 monitoring event, groundwater elevations were lower than during the fall (September 10) 2012 monitoring event in all but one well. The water elevations were lower in 2015 than in 2012 by a range of 0.85 to 9.14 feet and by an average of 3.49 feet. The water elevation in MW25 was 1.42 feet higher in 2015 than in 2012.
- During the fall (September 10) 2015 monitoring event, groundwater elevations were lower than during the RI (September 1, 2011) monitoring event in all but one well. The water elevations were lower in 2015 than in 2011 by a range of 0.12 to 6.15 feet and by an average of 1.80 feet. The

water elevation in well MW16 was 0.09 feet higher in September 2015 than in September 2011.
- During the fall (September 10) 2015 monitoring event, groundwater elevations were lower in all wells than during the spring (June) 2015 monitoring event by a range of 0.38 to 6.23 feet and by an average of 1.85 feet.

It is expected that groundwater elevations generally are tied to rates of precipitation, snowmelt, and other meteorological and hydrologic factors. No site-specific meteorological data for the RDM are available to allow detailed evaluation of the correlation between groundwater levels and these factors. To inform a general understanding of precipitation in the region around the RDM, annual precipitation for a given year was compared with that of other years for population centers in the region. The Alaska Climate Research Center (ACRC) has compiled historical meteorological data, including annual precipitation, for McGrath (located approximately 100 miles northeast of RDM) and Bethel (located approximately 160 miles west-southwest of RDM). For these two locations, the following observations of precipitation are made (ACRC 2017):

- In 2015, annual precipitation was very slightly higher than normal (based on the period 1981-2010). Precipitation was 4% higher than normal (18.54 inches) in Bethel and 2% higher than normal (18.00 inches) in McGrath.
- In 2012, annual precipitation was higher than normal (based on the period 1981-2010). Precipitation was 15% higher than normal in Bethel and 28% higher than normal in McGrath.
- In 2011, annual precipitation was 11% lower than normal (based on the period 1981-2010) in Bethel and 6% higher in McGrath.

During the fall 2015 monitoring event, there was an upward gradient in the MW27/MW28 well pair, consistent with the direction observed during the RI and 2012 baseline monitoring events. The upward gradient during the fall 2015 monitoring event was 0.016, slightly lower than the gradients observed during the RI and 2012 baseline monitoring events, which ranged from 0.021 to 0.127. An upward gradient in the vicinity of wells MW27 and MW28 is consistent with the previous interpretation that groundwater in that part of the Main Processing Area emerges into Red Devil Creek (see Section 3.2 of the final RI report).

During the spring and fall 2015 monitoring events, there was a downward gradient in the MW16/MW17 well pair, consistent with the direction observed during the 2012 baseline monitoring events and all except one monitoring event (September 1, 2011) during the RI. The downward gradients observed in 2015 ranged from 0.044 to 0.149. The downward gradients observed during the RI and 2012 baseline monitoring events ranges from 0.020 to 0.048. The downward gradient observed during most of the monitoring events in the MW16/MW17 area may be attributable to losing conditions in that area such as those interpreted along Red Devil Creek in part of the Main Processing Area during the RI and 2012 baseline monitoring events (see Section 3.2.2 of the final RI report). Such losing conditions would result in a localized generally downward flow of surface water into the subsurface.

3.2.3 Groundwater Sample Results

Groundwater sampling was performed at selected RI wells and new wells to meet the RI Supplement objectives listed in Section 3.1 pertaining to groundwater quality. Laboratory results and field water quality measurements of groundwater sampling conducted during the spring and fall 2015 monitoring events are presented in Tables 3-5 and 3-6, respectively. Results for key constituents—total antimony, total arsenic, and total and dissolved mercury—are presented in Figures 3-4 through 3-6 for the spring 2015 event, and Figures 3-7 through 3-9 for the fall 2015 event. Groundwater concentration and elevations over time for selected monitoring wells also are presented graphically in Figure 4-1. Results as they pertain to RI Supplement objectives are discussed below.

3.2.3.1 Surface Mined Area

To assess groundwater quality in the Surface Mined Area, groundwater monitoring was performed at existing (MW29 and MW30) during the spring and fall monitoring events, and at newly installed wells (MW39, MW40, MW42, and MW43) during the fall event.

RI Wells MW29 and MW30

Wells MW29 and MW30 are located in the Surface Mined Area. Well MW29 is not located in close proximity to known locations of underground mine workings. Well MW30 is located within the general vicinity of the underground mine workings (see Figures 2-6 and 3-3). During both monitoring events, as with previous monitoring events, MW30 was suspected to be dry (see Table 3-4). This is likely because the water level in the area of MW30 is locally depressed due to the draining effect of the underground mine workings. Well MW30 has a screened interval of 42 to 52 feet bgs, corresponding to an elevation of approximately 224 to 234 feet, which is above the water level expected for that area (see Figure 3-3). For well MW29, the 2015 results are presented in Tables 3-5 and 3-6 and Figures 3-4 through 3-9. The 2015 sampling results for total antimony, total arsenic, total mercury, and dissolved mercury are compared to previous sampling results below.

Spring

In well MW29, total antimony was detected in the spring 2015 sample at a concentration 0.75 micrograms per liter (µg/L), similar to concentrations observed during previous RI or 2012 baseline monitoring samples. Total arsenic was detected at 75 µg/L in the spring 2015 sample, less than the concentration in the spring 2012 baseline sample (102 µg/L). Total mercury was detected at a concentration of 215 nanograms per liter (ng/L) in the spring 2015 sample, similar to the concentration in the RI sample (247 ng/L), and greater than in the spring 2012 baseline samples (6 ng/L). Dissolved mercury was detected at a concentration of 1.45 ng/L in the spring 2015 sample, similar to the concentration in the RI sample (0.71 ng/L, estimated) and the spring 2012 baseline sample (1 ng/L).

Fall

Total antimony was not detected in the fall 2015 sample from well MW29. Total arsenic was detected at 35 µg/L in the fall 2015 sample, slightly lower than the concentrations in the RI sample (36.9 µg/L) and fall 2012 baseline sample (44 µg/L). Total mercury was not detected in the fall 2015 sample; total mercury was detected at a concentration of 6 ng/L in the fall 2012 baseline sample. Dissolved mercury was detected at a concentration of 5.69 ng/L in the fall 2015 sample, greater than the concentration in the RI sample (0.71 ng/L, estimated) and similar to the fall 2012 baseline concentration (7 ng/L).

New Wells MW39, MW40, MW42, and MW43

New wells MW39, MW40, MW42, and MW43 were installed to better understand impacts of the underground mine workings on groundwater depths, gradient, and flow paths. The wells also were installed to better understand the impacts of naturally mineralized bedrock on inorganic element concentrations in groundwater. As noted in Section 3.2.2, the screened interval of each of these wells is positioned in competent bedrock close to, but hydraulically upgradient of, the nearest underground mine workings. As noted in Section 3.2.1, the wells are screened in bedrock intervals that exhibit natural sub-ore grade mineralization peripheral to the ore zones that were targeted by the mining (see Section 2.2.5). Therefore, groundwater samples from the wells provide information useful for assessing the impacts on groundwater quality of the natural mineralization present in bedrock close to, but hydraulically upgradient of, the mine workings.

Samples were collected from the wells during the fall monitoring event. During the fall event, well MW39 was dry and no sample was collected. Results are presented in Table 3-6 and Figures 3-7 through 3-9 and summarized below.

Total antimony concentrations in the new wells ranged from 6.2 µg/L (MW40) to 250 µg/L (MW42). Total arsenic was detected at concentrations of 38 µg/L (MW38), 85 µg/L (MW40), and 610 µg/L (MW42). Total mercury concentrations were qualified nondetect. Dissolved mercury concentrations ranged from nondetect to 48.2 ng/L in MW42.

3.2.3.2 Area of NTCRA Regrading

Groundwater quality in the vicinity of the 2014 NTCRA regrading was evaluated by sampling wells MW16, MW17, MW27, MW28. Only wells MW27 and MW28 were sampled during the spring event. All four wells were sampled during the fall event. Results are presented in Tables 3-5 and 3-6 and Figures 3-4 through 3-9. Sampling results for total antimony, total arsenic, total mercury, and dissolved mercury were compared to previous sampling results. No obvious trends in concentrations of these analytes for the area as a whole have been noted to date. A comparison of the 2015 sampling results to previous sampling results is described in detail below.

Spring 2015

Well MW27

In the spring 2015 sample from well MW27, total antimony was detected at 11 µg/L, similar to the 2011 RI result (9.16 µg/L, estimated) and the spring 2012 baseline result (12.7 µg/L). Total arsenic was detected at 29 µg/L, similar to the RI result (22.6 µg/L) and the spring 2012 baseline result (37 µg/L). Total mercury was detected at 663 ng/L, greater than the RI result (411 ng/L) and spring 2012 baseline result (140 ng/L). Dissolved mercury was detected at 131 ng/L, less than the RI result (277 ng/L) and spring 2012 baseline result (170 ng/L).

Well MW28

In the spring 2015 sample from well MW28, total antimony was detected at 7 µg/L, less than the 2011 RI result (19.3 µg/L, estimated) and the spring 2012 baseline result (13.2 µg/L). Total arsenic was detected at 75 µg/L, greater than the RI result (32.8 µg/L) and similar to the spring 2012 baseline result (73 µg/L). Total mercury was detected at 1,890 ng/L, less than the RI result (4,000 ng/L) but greater than the spring 2012 baseline result (1,340 ng/L). Dissolved mercury was detected at 27.5 ng/L, greater than the RI result (10.9 ng/L) but less than the spring 2012 baseline result (38 ng/L).

Fall 2015

Well MW16

In the fall 2015 sample from well MW16, total antimony was detected at 570 µg/L, slightly less than the 2011 RI result (678 µg/L) and the fall 2012 baseline result (757 µg/L). Total arsenic was detected at 1,700 µg/L, greater than the RI result (1,020 µg/L) and the fall 2012 baseline result (830 µg/L). Total mercury was detected at 1,540 ng/L, greater than the RI result (1,210 ng/L) and fall 2012 baseline result (664 ng/L). Dissolved mercury was detected at 702 ng/L, greater than the RI result (285 ng/L) and fall 2012 baseline result (285 ng/L).

Well MW17

In the fall 2015 sample from well MW17, total antimony was detected at 9.3 µg/L, less than the 2011 RI result (53.9 µg/L) but greater than the fall 2012 baseline result (6.44 µg/L). Total arsenic was nondetect; the RI result was 28.5 µg/L and the fall 2012 baseline result was 3 µg/L). Total mercury was detected at 361 ng/L (estimated), less than the RI result (6,070 ng/L) and but greater than the fall 2012 baseline result (10 ng/L). Dissolved mercury was detected at 7.98 ng/L, similar to the RI result (9.49 ng/L). The fall 2012 baseline result was nondetect.

Well MW27

In the fall 2015 sample from well MW27, total antimony was detected at 8.3 µg/L, slightly less than the 2011 RI result (9.16 µg/L, estimated) and the fall 2012 baseline result (12.9 µg/L). Total arsenic was detected at 27 µg/L, somewhat greater than the RI result (22.6 µg/L) and less than the fall 2012 baseline result (31 µg/L). Total mercury was detected at 401 ng/L, similar to the RI result (411 ng/L) and several times that of the fall 2012 baseline result (112 ng/L). Dissolved mercury was detected at 253 ng/L, similar to the RI result (277 ng/L) and greater than the fall 2012 baseline result (60 ng/L).

<u>Well MW28</u>
In the fall 2015 sample from well MW28, total antimony was detected at 16 µg/L, similar to the 2011 RI result (19.3 µg/L, estimated) and the fall 2012 baseline result (17.4 µg/L). Total arsenic was detected at 130 µg/L, greater than the RI result (32.8 µg/L) and the fall 2012 baseline result (68 µg/L). Total mercury was detected at 1,320 ng/L (estimated), less than the RI result (4,000 ng/L) but greater than the fall 2012 baseline result (183 ng/L). Dissolved mercury was detected at 294 ng/L, greater than the RI result (10.9 ng/L) and the fall 2012 baseline result (26 ng/L).

3.2.3.3 Area Downgradient of Monofill #2

To provide additional data on groundwater conditions in the area downgradient of Monofill #2, groundwater was sampled from wells MW09 and MW10. During the spring sampling event a sample was collected from MW10; there was insufficient water recharge to collect a sample from MW09. Samples were collected from both wells during the fall sampling event. Results are presented in Tables 3-5 and 3-6 and Figures 3-4 through 3-9 Well MW09 had been sampled previously only during the fall 2012 baseline monitoring event. Sampling results for total antimony, total arsenic, total mercury, and dissolved mercury were compared to previous sampling results. No obvious trends in concentrations of these analytes for the area as a whole have been noted to date. A comparison of the 2015 sampling results to previous sampling results is described in detail below.

Spring
<u>Well MW10</u>
In the spring 2015 sample from well MW10, total antimony was detected at 0.21 µg/L (estimated), less than the 2011 RI result (6.49 µg/L) and the spring 2012 baseline result (1.23 µg/L). Total arsenic was detected at 95 µg/L, similar to the RI result (96.9 µg/L) and less than the spring 2012 baseline result (148 µg/L). Total mercury was detected at 7.95 ng/L, less than the RI result (532 ng/L) and spring 2012 baseline result (32 ng/L). Dissolved mercury was detected at 2.32 ng/L, greater than the RI result (0.62 ng/L, estimated); the spring 2012 baseline result was nondetect.

Fall
<u>Well MW09</u>
In the fall 2015 sample from well MW09, total antimony was detected at 7.8 µg/L, less than the fall 2012 baseline result (11.7 µg/L). Total arsenic was nondetect; the fall 2012 baseline result was 13 µg/L. Total mercury was detected at 1,020 ng/L, greater than the fall 2012 baseline result (172 ng/L). Dissolved mercury was detected at 5.46 ng/L, less than the fall 2012 baseline (11 ng/L).

Well MW10
In the fall 2015 sample from well MW10, the total antimony result was nondetect; the 2011 RI result was 6.49 µg/L) and the fall 2012 baseline result was 2.65 µg/L. Total arsenic was detected at 100 µg/L (estimated), similar to the RI result (96.9 µg/L) and the fall 2012 baseline result (110 µg/L). The total mercury result was nondetect; the RI result was 532 ng/L and the fall 2012 baseline result was nondetect. Dissolved mercury was detected at 32.3 ng/L (estimated), greater than the RI result (0.62 ng/L, estimated); the fall 2012 baseline result was nondetect.

3.2.3.4 Organic Compounds in the Main Processing Area
Groundwater samples collected from wells MW19 and MW22 during the spring and fall 2015 monitoring events were analyzed for SVOCs, DRO, GRO, and BTEX. Well MW19 is located upgradient of the Main Processing Area and well MW22 is located downgradient of Settling Pond #3. Results for the spring and fall event are presented in Tables 3-5 and 3-6, respectively. The tables present only those SVOC analytes that were detected in one or more samples. Results are discussed below.

The following SVOCs were detected in one or more samples: butyl benzyl phthalate; benzoic acid; benzyl alcohol; diethyl phthalate; di-n-butyl phthalate; 2-fluorobiphenyl. All results at concentrations below federal drinking water maximum contaminant level (MCL) and/or Alaska groundwater cleanup levels (18 AAC 75.345 Table C), if applicable.

DRO was not detected in the samples from MW19, but was detected in samples from MW22 collected in the spring (0.063 milligrams per liter [mg/L], estimated) and fall (0.19 mg/L), below the Alaska groundwater cleanup level (1.5 mg/L).

GRO was detected only in the sample collected from MW19 in the fall event at a concentration of 0.055 mg/L, below the Alaska groundwater cleanup level (2.2 mg/L).

The only BTEX compound detected is toluene, which was detected at an estimated concentration of 0.054 µg/L in the sample collected from MW19 in the spring event. This concentration is below the MCL and Alaska groundwater cleanup level (1.0 mg/L).

3.2.3.5 Other Wells Sampled for Baseline Monitoring
In addition to the wells that were sampled to address objectives associated with specific site features and geographic areas (see Sections 3.2.3.1 through 3.2.3.4), other wells distributed across the RDM—MW01, MW26, MW06, MW19, MW22, MW32, and MW33— were sampled in 2015 to gather additional information on baseline groundwater conditions at the RDM. Sample results for these wells are presented in Tables 3-4 and 3-6 and Figures 3-4 through 3-9. The 2015 sampling results for total antimony, total arsenic, total mercury, and dissolved mercury were compared to previous sampling results. No obvious trends in concentrations have been noted to date.

3.3 Groundwater Investigation Conclusions

The RI Supplement groundwater characterization activities were designed to address data gaps associated with groundwater in the Main Processing Area, the Red Devil Creek downstream alluvial area, and the Surface Mined Area. Additional groundwater characterization was performed to gather the types of additional information identified in Section 3.3 of the RI Supplement Work Plan and to meet the objectives listed in Section 3.1. Results of the RI Supplement groundwater investigation activities are detailed in Section 3.2. Key findings of the study are briefly summarized below. It is anticipated that results of the supplemental groundwater characterization will be used to support the development of site-wide remedial alternatives at the RDM.

3.3.1 Surface Mined Area

It was hypothesized in the final RI report (e.g., Section 5.4.2) that the system of underground mine workings at the RDM likely dominates groundwater flow pathways in bedrock within those parts of the Surface Mined Area and Main Processing Area where underground mining took place, and that the presence of the mine workings network in the Surface Mined Area exerts a draining effect where the mine workings lie below the water table within the host bedrock but above the nearby base level, which is the level of Red Devil Creek. The draining effect would serve to establish a hydraulic gradient toward such mine workings. It was further hypothesized that groundwater within the system likely eventually flows to the Red Devil Creek valley and emerges as surface water in Red Devil Creek, and that flow within the mine workings and connected fracture systems likely results in impacts on groundwater chemistry due to the presence of naturally occurring mineralization. Such impacts were stated to be likely to impact local groundwater as well as surface water in Red Devil Creek (see final RI report Section 5.4.3.2).

New monitoring wells MW39, MW40, MW42, and MW43 were installed in the Surface Mined Area to provide additional information on groundwater conditions in the Surface Mined Area in the vicinity (laterally and vertically) of the underground mine workings. Detailed information on the well installation is presented in Section 3.2.1.

RI Supplement groundwater elevation results show that the depths to groundwater in the new Surface Mined Area wells were substantially greater than in other nearby wells installed in bedrock further away from the mine workings. The groundwater elevations in wells MW42 and MW43, located nearest to Red Devil Creek, were nearly the same as the elevation of Red Devil Creek at its closest point to the wells (approximately 210 feet). These results clearly demonstrate that the mine workings provide a highly transmissive hydraulic connection between the area of the wells and the creek that serves to depress the water table in portions of the Surface Mined Area where the mine workings lie below the water table but above the nearby base level of Red Devil Creek. The results support the conclusion that the interconnected mine workings provide a preferential flow pathway of groundwater in areas drained by the mine workings from the Surface Mined Area to shallow depths below Red Devil Creek. Based on the groundwater elevations and stream elevations in Red Devil Creek, much of the groundwater within the Red Devil Creek valley, including groundwater in the Main Processing Area and the area downstream of the Main Processing Area, emerges into Red Devil Creek and enters the Kuskokwim River as surface water rather than via groundwater flow.

It was further hypothesized in the RI (see Section 5.4.3 of the final RI report) that naturally mineralized bedrock, such as the sub-ore grade mineralization associated with the mine workings, is a source of some of the arsenic, antimony, and mercury groundwater impacts at the RDM. New monitoring wells MW39, MW40, MW42, and MW43 were installed with screened intervals in or near zones of natural sub-ore grade mineralization associated with the underground mine workings, and hydraulically upgradient of the underground mine workings. Groundwater samples from the wells therefore provide information useful for assessing the impacts on groundwater quality of the natural mineralization present in bedrock close to, but hydraulically upgradient of, the mine workings. RI Supplement groundwater sample results from the newly installed wells contained concentrations of total antimony and arsenic ranging up to 250 µg/L and 610 µg/L, respectively. Dissolved mercury concentrations in those samples ranged as high as 48.2 ng/L. These concentrations are significantly higher than observed previously in the groundwater samples collected elsewhere in the Surface Mined Area from wells not installed in close proximity to the underground mine workings. These results demonstrate that the groundwater that flows into the underground mine workings network is impacted by the natural sub-ore grade mineralization associated with the Red Devil ore zones. Much of this impacted groundwater is expected to migrate via the underground mine workings network and emerge in Red Devil Creek along gaining reaches within the Main Processing Area where components of the mine workings system approach the surface. The RI and RI Supplement data collectively support this conclusion.

3.3.2 Area of NTCRA Regrading

Groundwater quality in the vicinity of the 2014 NTCRA regrading and stream realignment was evaluated by sampling wells MW16, MW17, MW27, and MW28. Only wells MW27 and MW28 were sampled during the spring event. All four wells were sampled during the fall event. Sampling results for total antimony, total arsenic, total mercury, and dissolved mercury were compared to previous sampling results. No obvious trends in concentrations or changes in concentration of these analytes that could be positively attributed to the NTCRA regrading have been noted to date.

During the fall 2015 monitoring event, there was an upward gradient in the MW27/MW28 well pair consistent with the direction observed during the RI and 2012 baseline monitoring events. An upward gradient in the vicinity of wells MW27 and MW28 is consistent with the previous interpretation that groundwater in that part of the Main Processing Area emerges into Red Devil Creek.

During the spring and fall 2015 monitoring events, there was a downward gradient in the MW16/MW17 well pair, consistent with the direction observed during all except one of the previous monitoring events in the MW16/MW17 well pair. The downward gradient appears to be localized and may be attributable to losing conditions in that area. Localized losing conditions in this area are consistent with the pre-NTCRA conditions interpreted along Red Devil Creek in that part of the Main Processing Area during the RI and 2012 baseline monitoring events.

3.3.3 Area Downgradient of Monofill #2

To provide additional data on groundwater conditions in the area downgradient of Monofill #2, groundwater was sampled from wells MW09 and MW10. During the spring sampling event a sample was collected from MW10; there was insufficient water recharge to collect a sample from MW09. Samples were collected from both wells during the fall sampling event. The 2015 sampling results for total antimony, total arsenic, total mercury, and dissolved mercury were compared to previous sampling results. No obvious trends in concentrations have been noted to date.

3.3.4 Organic Compounds in the Main Processing Area

Groundwater samples collected from wells MW19 and MW22 during the spring and fall 2015 monitoring events were analyzed for SVOCs, DRO, GRO, and BTEX. The following SVOCs were detected in one or more samples: butyl benzyl phthalate; benzoic acid; benzyl alcohol; diethyl phthalate; di-n-butyl phthalate; 2-fluorobiphenyl. All detected SVOCs are at concentrations below federal MCLs and/or Alaska groundwater cleanup levels, if applicable. DRO was not detected in the samples from MW19, but was detected in samples from MW22 collected in the spring and fall at concentrations below the Alaska groundwater cleanup level (1.5 mg/L). GRO was detected only in the sample collected from MW19 in the fall event at a concentration below the Alaska groundwater cleanup level (2.2 mg/L). The only BTEX compound detected is toluene, which was detected at a concentration below the federal MCL and Alaska groundwater cleanup level (1.0 mg/L).

3.3.5 Baseline Monitoring

Groundwater monitoring was performed at selected wells to address specific objectives associated with various site features and geographic areas, discussed in Sections 3.3.1 to 3.3.4 above. In addition to those specific objectives, groundwater monitoring data was collected to from those wells to augment existing information on baseline groundwater conditions at the RDM.

Other wells distributed across the RDM—MW01, MW26, MW06, MW19, MW22, MW32, and MW33— also were monitored in 2015 to gather additional information on baseline groundwater conditions at the RDM. For these wells the 2015 sampling results for total antimony, total arsenic, total mercury, and dissolved mercury were compared to previous sampling results. No obvious trends in concentrations were noted.

In general, groundwater elevations at most of the wells across the RDM during the spring and fall 2015 monitoring events were lower than during previous groundwater monitoring events at the RDM at similar times of the year. During the spring and fall 2015 groundwater monitoring events, as observed during the RI and 2012 baseline monitoring events, groundwater at the site generally flowed toward Red Devil Creek, with groundwater elevations generally mimicking topography over much of the site. An important exception is the groundwater elevations in the surface Mined Area (see Section 3.3.1).

Table 3-1 Monitoring Well Installation Summary

General Area	Soil Boring ID	Monitoring Well ID	Description	Soil Boring Total Depth (feet bgs)	Monitoring Well Total Depth (feet bgs)	Monitoring Well Screened Interval (feet bgs)
Post-1955 Main Processing Area	MP092 (not installed)	MW37 (not installed)	Not installed. Originally planned for location near MW16 and MW17.	NA	NA	NA
	MP093 (not installed)	MW38 (not installed)	Not installed. Originally planned for location near MW16 and MW17.	NA	NA	NA
Surface Mined Area	SM67	MW39	Northeast of Dolly Shaft and south and assumed downgradient of proposed repository location. Well installed.	90	84	63 - 83
	SM68a (abandoned)	NA	Near Dolly Shaft and 503 Crosscut and associated stopes. Encountered void at 37 feet bgs. Discontinued drilling and abandoned hole. Relocated to SM68b.	37	NA	NA
	SM68b (abandoned)	NA	Near Dolly Shaft and 503 Crosscut and associated stopes. Drilled to 135 feet bgs. Hole dry. Hole abandoned. Relocated to SM68c.	135	NA	NA
	SM68c	MW40	Near 507 Crosscut and Dolly No. 7 / 1280 Crosscut. Well installed.	155	140	119 - 139
	SM69 (not installed)	MW41 (not installed)	Not installed. Originally planned for location near Dolly Area crosscuts.	NA	NA	NA
	SM70a (abandoned)	NA	Near 150 Level / 200 Level and raises/winzes extending upward from 150 Level / 200 Level. Hole dry. Hole abandoned. Relocated to SM70b.	96	NA	NA
	SM70b	MW42	Near 150 Level / 200 Level and raises/winzes extending upward from 150 Level / 200 Level. Well installed.	140	140	119 - 139
	SM71a (abandoned)	NA	Near 33 Level and 73 Level. Well installation attempted, but well damaged. Abandoned well. Relocated to SM71b.	99	NA	NA
Surface Mined Area	SM71b	MW43	Near 33 Level and 73 Level. Well installed.	120	118.5	98 - 118

Key:
bgs = below ground surface
NA = Not applicable

Table 3-2 Groundwater Sample Collection - Spring 2015

General Area	Monitoring Well ID	Sample ID	Sample Date	Sample Collection Equipment	Sample Description	Sample Analyses and Methods									
						Total TAL Metals	Total Low-Level Hg	Dissolved Low-Level Hg	Total Suspended Solids	Inorganic Ions	Nitrate Nitrite as N	Carbonate Alkalinity as CaCO3	SVOCs	BTEX/GRO	DRO
						EPA 6010B/6020 A /7470A	EPA 1631E	EPA 1631E	SM 2540D	MCAWW 300.0	MCAWW 353.2	SM 2320B	SW846 8270D	SW846 8260C / AK101	AK102
Post-1955 Main Processing Area	MW01	0615MW01GW	6/19/2015	Submersible pump	Field Sample	X	X	X	X	X	X	X			
	MW09	Not sampled. Insufficient water.	NA	NA	NA										
	MW10	0615MW10GW	6/20/2015	Submersible pump	Field Sample	X	X	X	X	X	X	X			
	MW22	0615MW22GW	6/23/2015	Peristaltic pump	Field Sample	X	X	X	X	X	X	X	X	X	X
		0615MW50GW	6/23/2015	Peristaltic pump	Field Duplicate of 0615MW22GW	X	X	X	X	X	X	X	X	X	X
Pre-1955 Main Processing Area	MW06	0615MW06GW	6/20/2015	Peristaltic pump	Field Sample	X	X	X	X	X	X	X			
	MW26	0615MW26GW	6/22/2015	Submersible pump	Field Sample	X	X	X	X	X	X	X			
	MW27	0615MW27GW	6/21/2015	Submersible pump	Field Sample	X	X	X	X	X	X	X			
	MW28	0615MW28GW	6/22/2015	Submersible pump	Field Sample	X	X	X	X	X	X	X			
Red Devil Creek Delta Area	MW32	0615MW32GW	6/21/2015	Peristaltic pump	Field Sample	X	X	X	X	X	X	X			
	MW33	0615MW33GW	6/21/2015	Peristaltic pump	Field Sample	X	X	X	X	X	X	X			
Surface Mined Area	MW29	0615MW29GW	6/23/2015	Submersible pump	Field Sample	X	X	X	X	X	X	X			
	MW30	Not sampled. Insufficient water.	NA	NA	NA										
Upgradient of Post-1955 Main Processing Area	MW08	0615MW08GW	6/20/2015	Peristaltic pump	Field Sample	X	X	X	X	X	X	X			
	MW19	0615MW19GW	6/23/2015	Peristaltic pump	Field Sample	X	X	X		X	X	X	X	X	X
		0615MW51GW	6/23/2015	Peristaltic pump	Field Duplicate of 0165MW19GW	X	X	X		X	X	X			
Upland Area West of Surface Mined Area	MW31	0615MW31GW	6/22/2015	Submersible pump	Field Sample	X	X	X	X	X	X	X			

Key:
BTEX = Benzene, toluene, ethylbenzene, and xylenes
DRO = Diesel range organics
EPA= Environmental Protection Agency
GRO =Gasoline range organics
Hg = Mercury
MCAWW = Methods for Chemical Analysis of Water and Wastes
NA = Not applicable
SVOCs = Semivolatile organic compounds
TAL = Target Analyte List

Table 3-3 Groundwater Sample Collection - Fall 2015

General Area	Monitoring Well ID	Sample ID	Sample Date	Sample Collection Equipment	Sample Description	Sample Analyses and Methods									
						Total TAL Metals EPA 6010B/6020A /7470A	Total Low-Level Hg EPA 1631E	Dissolved Low-Level Hg EPA 1631E	Total Suspended Solids SM 2540D	Inorganic Ions MCAWW 300.0	Nitrate Nitrite as N MCAWW 353.2	Carbonate Alkalinity as CaCO3 SM 2320B	SVOCs SW846 8270D	BTEX/GRO SW846 8260C / AK101	DRO AK102
Post-1955 Main Processing Area	MW01	0915MW01GW	9/3/2015	Submersible pump	Field Sample	X	X	X	X	X	X	X			
	MW09	0915MW09GW	9/9/2015	Bladder pump	Field Sample	X	X	X	X	X	X	X			
	MW10	0915MW10GW	9/5/2015	Submersible pump	Field Sample	X	X	X	X	X	X	X			
		0915MW50GW	9/5/2015	Submersible pump	Field Duplicate of 0915MW10GW	X	X	X	X	X	X	X			
	MW16	0915MW16GW	9/5/2015	Submersible pump	Field Sample	X	X	X	X	X	X	X			
	MW17	0915MW17GW	9/5/2015	Submersible pump	Field Sample	X	X	X	X	X	X	X			
	MW22	0915MW22GW	9/9/2015	Peristaltic pump	Field Sample	X	X	X	X	X	X	X	X	X	X
		0915MW52GW	9/9/2015	Peristaltic pump	Field Duplicate of 0915MW22GW (organic analyses only)								X	X	X
Pre-1955 Main Processing Area	MW06	0915MW06GW	9/8/2015	Peristaltic pump	Field Sample	X	X	X	X	X	X	X			
	MW26	0915MW26GW	9/4/2015	Submersible pump	Field Sample	X	X	X	X	X	X	X			
	MW27	0915MW27GW	9/4/2015	Submersible pump	Field Sample	X	X	X	X	X	X	X			
	MW28	0915MW28GW	9/4/2015	Submersible pump	Field Sample	X	X	X	X	X	X	X			
Red Devil Creek Delta Area	MW32	0915MW32GW	9/8/2015	Peristaltic pump	Field Sample	X	X	X	X	X	X	X			
	MW33	0915MW33GW	9/8/2015	Peristaltic pump	Field Sample	X	X	X	X	X	X	X			
Surface Mined Area	MW29	0915MW29GW	9/7/2015	Bladder pump	Field Sample	X	X	X	X	X	X	X			
	MW30	Not sampled. Insufficient water.	NA	NA	NA										
	MW39	Not sampled. Dry.	NA	NA	NA										
	MW40	0915MW40GW	9/6/2015	Bladder pump	Field Sample	X	X	X	X	X	X	X			
	MW42	0915MW42GW	9/6/2015	Bladder pump	Field Sample	X	X	X	X	X	X	X			
	MW43	0915MW43GW	9/6/2015	Bladder pump	Field Sample	X	X	X	X	X	X	X			
		0915MW51GW	9/6/2015	Bladder pump	Field Duplicate of 0915MW43GW	X	X	X	X	X	X	X			
Upgradient of Post-1955 Main Processing Area	MW08	0915MW08GW	9/8/2015	Peristaltic pump	Field Sample	X	X	X	X	X	X	X			
Upgradient of Post-1955 Main Processing Area	MW19	0915MW19GW	9/8/2015	Peristaltic pump	Field Sample	X	X	X	X	X	X	X	X	X	X
Upland Area West of Surface Mined Area	MW31	0915MW31GW	9/6/2015	Submersible pump	Field Sample	X	X	X	X	X	X	X			

Key:
BTEX = Benzene, toluene, ethylbenzene, and xylenes
DRO = Diesel range organics
Environmental Protection Agency = EPA
GRO =Gasoline range organics
Hg = Mercury
MCAWW = Methods for Chemical Analysis of Water and Wastes
SVOCs = Semivolatile organic compounds
TAL = Target Analyte List

Table 3-4 Well Construction and Groundwater Depth Information

Monitoring Well ID	Soil Boring ID	Reported Well Total Depth As Constructed (feet bgs)	Reported Screened Interval (feet bgs)	Surveyed Ground Elevation (feet NAVD88)	Surveyed Top of Casing Elevation (feet NAVD88)	GW Encountered During Drilling (feet bgs)	Measured Well Total Depth (feet below TOC)	Static Water Level			Ground Water Elevation (feet NAVD88)
								Depth (feet below TOC)	Date	Time	
MW01	B01	29.5	19.0 - 29.0	254.51	257.51	17.8 - TD		21.72	8/14/2000	NR	235.79
MW01	B01	29.5	19.0 - 29.0	254.51	257.51	17.8 - TD		19.87	9/5/2007	13:15	237.64
MW01	B01	29.5	19.0 - 29.0	254.51	257.51	17.8 - TD		22.16	9/18/2008	13:28	235.35
MW01	B01	29.5	19.0 - 29.0	254.51	257.51	17.8 - TD		19.62	6/19/2009	NR	237.89
MW01	B01	29.5	19.0 - 29.0	254.51	257.51	17.8 - TD		22.27	10/6/2009	17:30	235.24
MW01	B01	29.5	19.0 - 29.0	254.51	257.51	17.8 - TD		20.04	9/20/2010	18:18	237.47
MW01	B01	29.5	19.0 - 29.0	254.51	257.51	17.8 - TD		19.46	8/24/2011	16:38	238.05
MW01	B01	29.5	19.0 - 29.0	254.51	257.51	17.8 - TD		19.55	9/1/2011	16:03	237.96
MW01	B01	29.5	19.0 - 29.0	254.51	257.51	17.8 - TD		17.56	5/26/2012	14:32	239.95
MW01	B01	29.5	19.0 - 29.0	254.51	257.51	17.8 - TD		18.62	9/9/2012	17:05	238.89
MW01	B01	29.5	19.0 - 29.0	254.51	257.51	17.8 - TD		19.43	6/17/2015	13:03	238.08
MW01	B01	29.5	19.0 - 29.0	254.51	257.51	17.8 - TD		20.80	8/12/2015	12:15	236.71
MW01	B01	29.5	19.0 - 29.0	254.51	257.51	17.8 - TD		21.03	9/2/2015	9:50	236.48
MW01	B01	29.5	19.0 - 29.0	254.51	257.51	17.8 - TD	29.82	20.36	9/10/2015	NR	237.15
MW03	B03	25.5	15.0 - 25.0	228.37	230.77	19.0 - TD		22.28	8/14/2000	NR	208.49
MW03	B03	25.5	15.0 - 25.0	228.37	230.77	19.0 - TD		20.68	9/5/2007	14:40	210.09
MW03	B03	25.5	15.0 - 25.0	228.37	230.77	19.0 - TD		22.57	9/18/2008	14:11	208.20
MW03	B03	25.5	15.0 - 25.0	228.37	230.77	19.0 - TD		19.51	6/19/2009	NR	211.26
MW03	B03	25.5	15.0 - 25.0	228.37	230.77	19.0 - TD		23.01	10/7/2009	13:20	207.76
MW03	B03	25.5	15.0 - 25.0	228.37	230.77	19.0 - TD		20.95	9/20/2010	19:50	209.82
MW03	B03	25.5	15.0 - 25.0	228.37	230.77	19.0 - TD		19.44	8/26/2011	10:18	211.33
MW03	B03	25.5	15.0 - 25.0	228.37	230.77	19.0 - TD		19.96	9/1/2011	15:41	210.81
MW03	B03	25.5	15.0 - 25.0	228.37	230.77	19.0 - TD		15.47	5/26/2012	15:17	215.30
MW03	B03	25.5	15.0 - 25.0	228.37	230.77	19.0 - TD		17.24	9/9/2012	17:10	213.53
MW03	B03	25.5	15.0 - 25.0	228.37	230.77	19.0 - TD		19.74	6/17/2015	10:54	211.03
MW03	B03	25.5	15.0 - 25.0	228.37	230.77	19.0 - TD		21.83	8/12/2015	12:33	208.94
MW03	B03	25.5	15.0 - 25.0	228.37	230.77	19.0 - TD		22.20	9/2/2015	9:45	208.57
MW03	B03	25.5	15.0 - 25.0	228.37	230.77	19.0 - TD	27.98	21.92	9/10/2015	NR	208.85
MW04	B04	30.5	20.0 - 30.0	239.92	242.12	25.3 - TD		27.77	8/14/2000	NR	214.35
MW04	B04	30.5	20.0 - 30.0	239.92	242.12	25.3 - TD		26.78	9/5/2007	12:25	215.34
MW04	B04	30.5	20.0 - 30.0	239.92	242.12	25.3 - TD		26.82	9/18/2008	12:32	215.30
MW04	B04	30.5	20.0 - 30.0	239.92	242.12	25.3 - TD		25.43	6/19/2009	NR	216.69
MW04	B04	30.5	20.0 - 30.0	239.92	242.12	25.3 - TD		27.77	10/6/2009	18:55	214.35
MW04	B04	30.5	20.0 - 30.0	239.92	242.12	25.3 - TD		26.79	9/20/2010	16:09	215.33
MW04	B04	30.5	20.0 - 30.0	239.92	242.12	25.3 - TD		25.24	8/22/2011	16:02	216.88
MW04	B04	30.5	20.0 - 30.0	239.92	242.12	25.3 - TD		25.99	9/1/2011	15:00	216.13
MW04	B04	30.5	20.0 - 30.0	239.92	242.12	25.3 - TD		21.72	5/26/2012	16:47	220.40
MW04	B04	30.5	20.0 - 30.0	239.92	242.12	25.3 - TD		23.72	9/10/2012	14:15	218.40
MW04	B04	30.5	20.0 - 30.0	239.92	242.12	25.3 - TD		26.95	6/17/2015	15:13	215.17

Table 3-4 Well Construction and Groundwater Depth Information

Monitoring Well ID	Soil Boring ID	Reported Well Total Depth As Constructed (feet bgs)	Reported Screened Interval (feet bgs)	Surveyed Ground Elevation (feet NAVD88)	Surveyed Top of Casing Elevation (feet NAVD88)	GW Encountered During Drilling (feet bgs)	Measured Well Total Depth (feet below TOC)	Static Water Level			Ground Water Elevation (feet NAVD88)
								Depth (feet below TOC)	Date	Time	
MW04	B04	30.5	20.0 - 30.0	239.92	242.12	25.3 - TD		NR	8/12/2015	NR	NR
MW04	B04	30.5	20.0 - 30.0	239.92	242.12	25.3 - TD		28.61	9/2/2015	11:40	213.51
MW04	B04	30.5	20.0 - 30.0	239.92	242.12	25.3 - TD	33.11	28.32	9/10/2015	NR	213.80
MW06	B06	23.5	13.0 - 23.0	214.99	217.49	20.0 - TD		19.29	8/14/2000	NR	198.20
MW06	B06	23.5	13.0 - 23.0	214.99	217.49	20.0 - TD		18.63	9/5/2007	15:30	198.86
MW06	B06	23.5	13.0 - 23.0	214.99	217.49	20.0 - TD		19.08	9/18/2008	11:35	198.41
MW06	B06	23.5	13.0 - 23.0	214.99	217.49	20.0 - TD		17.90	6/19/2009	NR	199.59
MW06	B06	23.5	13.0 - 23.0	214.99	217.49	20.0 - TD		19.29	10/7/2009	17:25	198.20
MW06	B06	23.5	13.0 - 23.0	214.99	217.49	20.0 - TD		19.03	9/20/2010	13:22	198.46
MW06	B06	23.5	13.0 - 23.0	214.99	217.49	20.0 - TD		18.78	8/24/2011	14:56	198.71
MW06	B06	23.5	13.0 - 23.0	214.99	217.49	20.0 - TD		18.70	9/1/2011	15:09	198.79
MW06	B06	23.5	13.0 - 23.0	214.99	217.49	20.0 - TD		16.25	5/26/2012	16:02	201.24
MW06	B06	23.5	13.0 - 23.0	214.99	217.49	20.0 - TD		18.29	9/9/2012	11:45	199.20
MW06	B06	23.5	13.0 - 23.0	214.99	217.49	20.0 - TD		18.24	6/17/2015	14:25	199.25
MW06	B06	23.5	13.0 - 23.0	214.99	217.49	20.0 - TD		19.17	8/12/2015	11:03	198.32
MW06	B06	23.5	13.0 - 23.0	214.99	217.49	20.0 - TD		19.20	9/2/2015	11:15	198.29
MW06	B06	23.5	13.0 - 23.0	214.99	217.49	20.0 - TD	26.19	19.18	9/10/2015	NR	198.31
MW07	B07	21.5	11.0 - 21.0	278.39	280.89	14.8 - TD		Dry	8/14/2000	NR	Dry (Water Elevation <257.4 ft bgs)
MW07	B07	21.5	11.0 - 21.0	278.39	280.89	14.8 - TD		20.42	9/5/2007	14:00	260.47
MW07	B07	21.5	11.0 - 21.0	278.39	280.89	14.8 - TD		Dry	9/18/2008	NR	Dry (Water Elevation <257.4 ft bgs)
MW07	B07	21.5	11.0 - 21.0	278.39	280.89	14.8 - TD		20.10	6/19/2009	NR	260.79
MW07	B07	21.5	11.0 - 21.0	278.39	280.89	14.8 - TD		Dry	10/7/2009	NR	Dry (Water Elevation <257.4 ft bgs)
MW07	B07	21.5	11.0 - 21.0	278.39	280.89	14.8 - TD		20.40	9/21/2010	10:20	260.49
MW07	B07	21.5	11.0 - 21.0	278.39	280.89	14.8 - TD		19.51	8/26/2011	9:12	261.38
MW07	B07	21.5	11.0 - 21.0	278.39	280.89	14.8 - TD		19.97	9/1/2011	16:14	260.92
MW07	B07	21.5	11.0 - 21.0	278.39	280.89	14.8 - TD		19.68	5/26/2012	13:36	261.21
MW07	B07	21.5	11.0 - 21.0	278.39	280.89	14.8 - TD		20.57	9/9/2012	16:45	260.32
MW07	B07	21.5	11.0 - 21.0	278.39	280.89	14.8 - TD		21.10	6/17/2015	12:25	259.79
MW07	B07	21.5	11.0 - 21.0	278.39	280.89	14.8 - TD		21.97	8/12/2015	11:54	258.92
MW07	B07	21.5	11.0 - 21.0	278.39	280.89	14.8 - TD		22.36	9/2/2015	10:50	258.53
MW07	B07	21.5	11.0 - 21.0	278.39	280.89	14.8 - TD	23.67	22.41	9/10/2015	NR	258.48
MW08	11MP01SB	16.0	5.0 - 15.0	328.92	331.32	2.5 - 4.0, 10.5 - TD		13.70	8/30/2011	9:21	317.62
MW08	11MP01SB	16.0	5.0 - 15.0	328.92	331.32	2.5 - 4.0, 10.5 - TD		13.65	9/1/2011	16:28	317.67
MW08	11MP01SB	16.0	5.0 - 15.0	328.92	331.32	2.5 - 4.0, 10.5 - TD		11.64	5/26/2012	13:23	319.68
MW08	11MP01SB	16.0	5.0 - 15.0	328.92	331.32	2.5 - 4.0, 10.5 - TD		12.74	9/9/2012	16:10	318.58
MW08	11MP01SB	16.0	5.0 - 15.0	328.92	331.32	2.5 - 4.0, 10.5 - TD		13.54	6/17/2015	12:41	317.78
MW08	11MP01SB	16.0	5.0 - 15.0	328.92	331.32	2.5 - 4.0, 10.5 - TD		14.87	8/12/2015	11:58	316.45
MW08	11MP01SB	16.0	5.0 - 15.0	328.92	331.32	2.5 - 4.0, 10.5 - TD		15.04	9/2/2015	10:35	316.28
MW08	11MP01SB	16.0	5.0 - 15.0	328.92	331.32	2.5 - 4.0, 10.5 - TD	17.61	14.89	9/10/2015	NR	316.43

Table 3-4 Well Construction and Groundwater Depth Information

Monitoring Well ID	Soil Boring ID	Reported Well Total Depth As Constructed (feet bgs)	Reported Screened Interval (feet bgs)	Surveyed Ground Elevation (feet NAVD88)	Surveyed Top of Casing Elevation (feet NAVD88)	GW Encountered During Drilling (feet bgs)	Measured Well Total Depth (feet below TOC)	Static Water Level			Ground Water Elevation (feet NAVD88)
								Depth (feet below TOC)	Date	Time	
MW09	11MP17SB	31.0	20.0 - 30.0	274.88	277.28	14.0 - 16.0, 31.0 - TD		>31.56	8/29/2011	18:21	--
MW09	11MP17SB	31.0	20.0 - 30.0	274.88	277.28	14.0 - 16.0, 31.0 - TD		28.11	9/1/2011	16:43	249.17
MW09	11MP17SB	31.0	20.0 - 30.0	274.88	277.28	14.0 - 16.0, 31.0 - TD		26.67	5/26/2012	14:04	250.61
MW09	11MP17SB	31.0	20.0 - 30.0	274.88	277.28	14.0 - 16.0, 31.0 - TD		27.88	9/9/2012	15:30	249.40
MW09	11MP17SB	31.0	20.0 - 30.0	274.88	277.28	14.0 - 16.0, 31.0 - TD		27.81	9/11/2012	11:20	249.47
MW09	11MP17SB	31.0	20.0 - 30.0	274.88	277.28	14.0 - 16.0, 31.0 - TD		27.60	6/17/2015	11:31	249.68
MW09	11MP17SB	31.0	20.0 - 30.0	274.88	277.28	14.0 - 16.0, 31.0 - TD		27.93	8/12/2015	12:04	249.35
MW09	11MP17SB	31.0	20.0 - 30.0	274.88	277.28	14.0 - 16.0, 31.0 - TD		28.30	9/2/2015	10:00	248.98
MW09	11MP17SB	31.0	20.0 - 30.0	274.88	277.28	14.0 - 16.0, 31.0 - TD	34.72	29.38	9/10/2015	NR	247.90
MW10	11MP14SB	61.0	50.0 - 60.0	274.31	276.21	48.0 - TD		30.60	8/29/2011	16:15	245.61
MW10	11MP14SB	61.0	50.0 - 60.0	274.31	276.21	48.0 - TD		29.17	9/1/2011	16:38	247.04
MW10	11MP14SB	61.0	50.0 - 60.0	274.31	276.21	48.0 - TD		25.62	5/26/2012	14:14	250.59
MW10	11MP14SB	61.0	50.0 - 60.0	274.31	276.21	48.0 - TD		26.39	9/9/2012	15:45	249.82
MW10	11MP14SB	61.0	50.0 - 60.0	274.31	276.21	48.0 - TD		26.88	9/10/2012	11:35	249.33
MW10	11MP14SB	61.0	50.0 - 60.0	274.31	276.21	48.0 - TD		28.98	6/17/2015	11:37	247.23
MW10	11MP14SB	61.0	50.0 - 60.0	274.31	276.21	48.0 - TD		32.90	8/12/2015	12:09	243.31
MW10	11MP14SB	61.0	50.0 - 60.0	274.31	276.21	48.0 - TD		33.52	9/2/2015	10:25	242.69
MW10	11MP14SB	61.0	50.0 - 60.0	274.31	276.21	48.0 - TD	63.54	31.02	9/10/2015	NR	245.19
MW11	11MP12SB	23.0	12.0 - 22.0	268.70	271.30	dry		Dry	8/29/2011	12:00	Dry (Water Elevation <246.7 ft bgs)
MW11	11MP12SB	23.0	12.0 - 22.0	268.70	271.30	dry		Dry	9/1/2011	16:34	Dry (Water Elevation <246.7 ft bgs)
MW11	11MP12SB	23.0	12.0 - 22.0	268.70	271.30	dry		22.60	5/26/2012	14:24	248.70
MW11	11MP12SB	23.0	12.0 - 22.0	268.70	271.30	dry		24.24	9/9/2012	16:00	Suspected Dry (Water Elevation <246.7 ft bgs)
MW11	11MP12SB	23.0	12.0 - 22.0	268.70	271.30	dry		23.69	6/17/2015	15:52	Suspected Dry (Water Elevation <246.7 ft bgs)
MW11	11MP12SB	23.0	12.0 - 22.0	268.70	271.30	dry		24.08	8/12/2015	12:11	Suspected Dry (Water Elevation <246.7 ft bgs)
MW11	11MP12SB	23.0	12.0 - 22.0	268.70	271.30	dry		24.36	9/2/2015	10:30	Suspected Dry (Water Elevation <246.7 ft bgs)
MW11	11MP12SB	23.0	12.0 - 22.0	268.70	271.30	dry	25.70	24.16	9/10/2015	NR	Suspected Dry (Water Elevation <246.7 ft bgs)
MW12	11RD13SB	15.0	4.0 - 14.0	263.22	265.62	1.0 - TD		3.72	8/31/2011	13:34	261.90
MW12	11RD13SB	15.0	4.0 - 14.0	263.22	265.62	1.0 - TD		3.70	9/1/2011	16:20	261.92
MW12	11RD13SB	15.0	4.0 - 14.0	263.22	265.62	1.0 - TD		2.46	5/26/2012	11:04	263.16
MW12	11RD13SB	15.0	4.0 - 14.0	263.22	265.62	1.0 - TD		3.30	9/9/2012	16:39	262.32
MW12	11RD13SB	15.0	4.0 - 14.0	263.22	265.62	1.0 - TD		5.02	6/17/2015	13:18	260.60
MW12	11RD13SB	15.0	4.0 - 14.0	263.22	265.62	1.0 - TD		6.80	8/12/2015	11:46	258.82
MW12	11RD13SB	15.0	4.0 - 14.0	263.22	265.62	1.0 - TD		6.98	9/2/2015	11:00	258.64
MW12	11RD13SB	15.0	4.0 - 14.0	263.22	265.62	1.0 - TD	17.68	5.97	9/10/2015	NR	259.65
MW13	11MP20SB	32.0	21.0 - 31.0	274.30	276.70	27.0 - TD		30.05	8/30/2011	18:04	246.65
MW13	11MP20SB	32.0	21.0 - 31.0	274.30	276.70	27.0 - TD		29.70	9/1/2011	16:09	247.00
MW13	11MP20SB	32.0	21.0 - 31.0	274.30	276.70	27.0 - TD		18.41	5/26/2012	13:45	258.29
MW13	11MP20SB	32.0	21.0 - 31.0	274.30	276.70	27.0 - TD		24.06	9/9/2012	16:50	252.64
MW13	11MP20SB	32.0	21.0 - 31.0	274.30	276.70	27.0 - TD		29.85	6/17/2015	12:13	246.85

Table 3-4 Well Construction and Groundwater Depth Information

Monitoring Well ID	Soil Boring ID	Reported Well Total Depth As Constructed (feet bgs)	Reported Screened Interval (feet bgs)	Surveyed Ground Elevation (feet NAVD88)	Surveyed Top of Casing Elevation (feet NAVD88)	GW Encountered During Drilling (feet bgs)	Measured Well Total Depth (feet below TOC)	Static Water Level			Ground Water Elevation (feet NAVD88)
								Depth (feet below TOC)	Date	Time	
MW13	11MP20SB	32.0	21.0 - 31.0	274.30	276.70	27.0 - TD		DRY	8/12/2015	11:51	Dry (Water Elevation <243.3 ft bgs)
MW13	11MP20SB	32.0	21.0 - 31.0	274.30	276.70	27.0 - TD		DRY	9/2/2015	10:45	Dry (Water Elevation <243.3 ft bgs)
MW13	11MP20SB	32.0	21.0 - 31.0	274.30	276.70	27.0 - TD	31.70	DRY	9/10/2015	NR	Dry (Water Elevation <243.3 ft bgs)
MW14	11MP25SB	36.0	25.0 - 35.0	246.71	249.01	25.7 - TD		30.51	8/31/2011	10:05	218.50
MW14	11MP25SB	36.0	25.0 - 35.0	246.71	249.01	25.7 - TD		30.01	9/1/2011	16:00	219.00
MW14	11MP25SB	36.0	25.0 - 35.0	246.71	249.01	25.7 - TD		24.40	5/26/2012	14:45	224.61
MW14	11MP25SB	36.0	25.0 - 35.0	246.71	249.01	25.7 - TD		27.34	9/10/2012	17:35	221.67
MW14	11MP25SB	36.0	25.0 - 35.0	246.71	249.01	25.7 - TD		--	--	--	Decommissioned in 2014 NTCRA
MW14	11MP25SB	36.0	25.0 - 35.0	246.71	249.01	25.7 - TD		--	--	--	Decommissioned in 2014 NTCRA
MW15	11MP29SB	26.0	15.0 - 25.0	242.63	244.93	16.2 - TD		19.64	8/30/2011	10:35	225.29
MW15	11MP29SB	26.0	15.0 - 25.0	242.63	244.93	16.2 - TD		19.59	9/1/2011	15:56	225.34
MW15	11MP29SB	26.0	15.0 - 25.0	242.63	244.93	16.2 - TD		18.33	5/26/2012	14:56	226.60
MW15	11MP29SB	26.0	15.0 - 25.0	242.63	244.93	16.2 - TD		18.3	9/8/2012	13:00	226.63
MW15	11MP29SB	26.0	15.0 - 25.0	242.63	244.93	16.2 - TD		--	--	--	Decommissioned in 2014 NTCRA
MW15	11MP29SB	26.0	15.0 - 25.0	242.63	244.93	16.2 - TD		--	--	--	Decommissioned in 2014 NTCRA
MW16	11MP30SB	22.0	11.0 - 21.0	226.09	228.09	16.0 - TD		13.84	8/30/2011	11:35	214.25
MW16	11MP30SB	22.0	11.0 - 21.0	226.09	228.09	16.0 - TD		14.90	9/1/2011	15:50	213.19
MW16	11MP30SB	22.0	11.0 - 21.0	226.09	228.09	16.0 - TD		6.17	5/26/2012	15:08	221.92
MW16	11MP30SB	22.0	11.0 - 21.0	226.09	228.09	16.0 - TD		8.88	9/8/2012	14:30	219.21
MW16	11MP30SB	22.0	11.0 - 21.0	226.09	228.09	16.0 - TD		13.13	6/18/2015	19:52	214.96
MW16	11MP30SB	22.0	11.0 - 21.0	226.09	228.09	16.0 - TD		14.80	8/12/2015	12:19	213.29
MW16	11MP30SB	22.0	11.0 - 21.0	226.09	228.09	16.0 - TD		15.19	9/2/2015	9:35	212.90
MW16	11MP30SB	22.0	11.0 - 21.0	226.09	228.09	16.0 - TD	24.14	14.81	9/10/2015	NR	213.28
MW17	11MP91SB	52.5	41.5 - 51.5	226.36	228.66	25.0 - 33.0, 33.0 - TD		15.00	8/30/2011	9:20	213.66
MW17	11MP91SB	52.5	41.5 - 51.5	226.36	228.66	25.0 - 33.0, 33.0 - TD		13.78	9/1/2011	15:52	214.88
MW17	11MP91SB	52.5	41.5 - 51.5	226.36	228.66	25.0 - 33.0, 33.0 - TD		8.20	5/26/2012	15:03	220.46
MW17	11MP91SB	52.5	41.5 - 51.5	226.36	228.66	25.0 - 33.0, 33.0 - TD		10.79	9/8/2012	16:20	217.87
MW17	11MP91SB	52.5	41.5 - 51.5	226.36	228.66	25.0 - 33.0, 33.0 - TD		15.03	6/18/2015	19:40	213.63
MW17	11MP91SB	52.5	41.5 - 51.5	226.36	228.66	25.0 - 33.0, 33.0 - TD		17.01	8/12/2015	12:18	211.65
MW17	11MP91SB	52.5	41.5 - 51.5	226.36	228.66	25.0 - 33.0, 33.0 - TD		17.28	9/2/2015	9:36	211.38
MW17	11MP91SB	52.5	41.5 - 51.5	226.36	228.66	25.0 - 33.0, 33.0 - TD	55.02	19.93	9/10/2015	NR	208.73
MW18	11MP31SB	40.0	29.0 - 39.0	241.33	243.83	38.0 - TD		29.66	8/31/2011	15:47	214.17
MW18	11MP31SB	40.0	29.0 - 39.0	241.33	243.83	38.0 - TD		29.87	9/1/2011	15:37	213.96
MW18	11MP31SB	40.0	29.0 - 39.0	241.33	243.83	38.0 - TD		21.82	5/26/2012	13:10	222.01
MW18	11MP31SB	40.0	29.0 - 39.0	241.33	243.83	38.0 - TD		24.83	9/9/2012	17:20	219.00
MW18	11MP31SB	40.0	29.0 - 39.0	241.33	243.83	38.0 - TD		29.17	6/17/2015	10:46	214.66
MW18	11MP31SB	40.0	29.0 - 39.0	241.33	243.83	38.0 - TD		31.43	8/12/2015	12:31	212.40
MW18	11MP31SB	40.0	29.0 - 39.0	241.33	243.83	38.0 - TD		31.65	9/2/2015	9:30	212.18
MW18	11MP31SB	40.0	29.0 - 39.0	241.33	243.83	38.0 - TD	41.57	31.20	9/10/2015	NR	212.63

Table 3-4 Well Construction and Groundwater Depth Information

Monitoring Well ID	Soil Boring ID	Reported Well Total Depth As Constructed (feet bgs)	Reported Screened Interval (feet bgs)	Surveyed Ground Elevation (feet NAVD88)	Surveyed Top of Casing Elevation (feet NAVD88)	GW Encountered During Drilling (feet bgs)	Measured Well Total Depth (feet below TOC)	Static Water Level			Ground Water Elevation (feet NAVD88)
								Depth (feet below TOC)	Date	Time	
MW19	11MP33SB	43.0	32.0 - 42.0	237.70	240.00	39.0 - TD		19.47	9/1/2011	15:32	220.53
MW19	11MP33SB	43.0	32.0 - 42.0	237.70	240.00	39.0 - TD		11.54	5/26/2012	12:59	228.46
MW19	11MP33SB	43.0	32.0 - 42.0	237.70	240.00	39.0 - TD		16.02	9/9/2012	17:25	223.98
MW19	11MP33SB	43.0	32.0 - 42.0	237.70	240.00	39.0 - TD		18.48	6/17/2015	10:31	221.52
MW19	11MP33SB	43.0	32.0 - 42.0	237.70	240.00	39.0 - TD		23.48	8/12/2015	12:33	216.52
MW19	11MP33SB	43.0	32.0 - 42.0	237.70	240.00	39.0 - TD		24.95	9/2/2015	9:20	215.05
MW19	11MP33SB	43.0	32.0 - 42.0	237.70	240.00	39.0 - TD	45.70	23.94	9/10/2015	NR	216.06
MW20	11MP38SB	15.5	4.5 - 14.5	212.90	215.20	6.5 - TD		6.89	8/31/2011	8:53	208.31
MW20	11MP38SB	15.5	4.5 - 14.5	212.90	215.20	6.5 - TD		6.97	9/1/2011	15:43	208.23
MW20	11MP38SB	15.5	4.5 - 14.5	212.90	215.20	6.5 - TD		4.82	5/26/2012	15:26	210.38
MW20	11MP38SB	15.5	4.5 - 14.5	212.90	215.20	6.5 - TD		5.53	9/9/2012	10:10	209.67
MW20	11MP38SB	15.5	4.5 - 14.5	212.90	215.20	6.5 - TD		7.11	6/17/2015	10:18	208.09
MW20	11MP38SB	15.5	4.5 - 14.5	212.90	215.20	6.5 - TD		7.92	8/12/2015	12:39	207.28
MW20	11MP38SB	15.5	4.5 - 14.5	212.90	215.20	6.5 - TD		8.12	9/2/2015	9:10	207.08
MW20	11MP38SB	15.5	4.5 - 14.5	212.90	215.20	6.5 - TD	17.70	7.96	9/10/2015	NR	207.24
MW21	11MP39SB	17.5	6.5 - 16.5	208.23	210.13	7.0 - TD		8.80	8/31/2011	10:16	201.33
MW21	11MP39SB	17.5	6.5 - 16.5	208.23	210.13	7.0 - TD		8.82	9/1/2011	17:10	201.31
MW21	11MP39SB	17.5	6.5 - 16.5	208.23	210.13	7.0 - TD		7.91	5/26/2012	15:36	202.22
MW21	11MP39SB	17.5	6.5 - 16.5	208.23	210.13	7.0 - TD		8.29	9/8/2012	17:35	201.84
MW21	11MP39SB	17.5	6.5 - 16.5	208.23	210.13	7.0 - TD		8.55	6/17/2015	10:08	201.58
MW21	11MP39SB	17.5	6.5 - 16.5	208.23	210.13	7.0 - TD		9.10	8/12/2015	12:39	201.03
MW21	11MP39SB	17.5	6.5 - 16.5	208.23	210.13	7.0 - TD		9.45	9/2/2015	9:00	200.68
MW21	11MP39SB	17.5	6.5 - 16.5	208.23	210.13	7.0 - TD	10.67	9.14	9/10/2015	NR	200.99
MW22	11MP40SB	15.5	4.5 - 14.5	203.10	205.10	7.8 - TD		8.20	8/31/2011	11:08	196.90
MW22	11MP40SB	15.5	4.5 - 14.5	203.10	205.10	7.8 - TD		8.48	9/1/2011	17:04	196.62
MW22	11MP40SB	15.5	4.5 - 14.5	203.10	205.10	7.8 - TD		5.55	5/26/2012	15:44	199.55
MW22	11MP40SB	15.5	4.5 - 14.5	203.10	205.10	7.8 - TD		7.77	9/9/2012	17:35	197.33
MW22	11MP40SB	15.5	4.5 - 14.5	203.10	205.10	7.8 - TD		8.47	6/17/2015	9:46	196.63
MW22	11MP40SB	15.5	4.5 - 14.5	203.10	205.10	7.8 - TD		10.01	8/12/2015	12:43	195.09
MW22	11MP40SB	15.5	4.5 - 14.5	203.10	205.10	7.8 - TD		10.33	9/2/2015	8:50	194.77
MW22	11MP40SB	15.5	4.5 - 14.5	203.10	205.10	7.8 - TD	17.74	10.19	9/10/2015	NR	194.91
MW23	11MP66SB	29.0	18.0 - 28.0	201.96	204.16	20.0 - TD		16.02	8/30/2011	16:31	188.14
MW23	11MP66SB	29.0	18.0 - 28.0	201.96	204.16	20.0 - TD		16.01	9/1/2011	15:14	188.15
MW23	11MP66SB	29.0	18.0 - 28.0	201.96	204.16	20.0 - TD		14.60	5/26/2012	15:56	189.56
MW23	11MP66SB	29.0	18.0 - 28.0	201.96	204.16	20.0 - TD		15.56	9/9/2012	17:47	188.60
MW23	11MP66SB	29.0	18.0 - 28.0	201.96	204.16	20.0 - TD		15.88	6/17/2015	14:15	188.28
MW23	11MP66SB	29.0	18.0 - 28.0	201.96	204.16	20.0 - TD		16.92	8/12/2015	11:06	187.24
MW23	11MP66SB	29.0	18.0 - 28.0	201.96	204.16	20.0 - TD		16.63	9/2/2015	11:10	187.53
MW23	11MP66SB	29.0	18.0 - 28.0	201.96	204.16	20.0 - TD	30.95	16.54	9/10/2015	NR	187.62

Table 3-4 Well Construction and Groundwater Depth Information

Monitoring Well ID	Soil Boring ID	Reported Well Total Depth As Constructed (feet bgs)	Reported Screened Interval (feet bgs)	Surveyed Ground Elevation (feet NAVD88)	Surveyed Top of Casing Elevation (feet NAVD88)	GW Encountered During Drilling (feet bgs)	Measured Well Total Depth (feet below TOC)	Static Water Level			Ground Water Elevation (feet NAVD88)
								Depth (feet below TOC)	Date	Time	
MW24	11MP62SB	30.0	19.0 - 29.0	221.41	223.51	20.0 - TD		17.70	8/30/2011	14:51	205.81
MW24	11MP62SB	30.0	19.0 - 29.0	221.41	223.51	20.0 - TD		17.61	9/1/2011	15:06	205.90
MW24	11MP62SB	30.0	19.0 - 29.0	221.41	223.51	20.0 - TD		14.59	5/26/2012	16:15	208.92
MW24	11MP62SB	30.0	19.0 - 29.0	221.41	223.51	20.0 - TD		16.45	9/9/2012	14:00	207.06
MW24	11MP62SB	30.0	19.0 - 29.0	221.41	223.51	20.0 - TD		16.89	6/17/2015	14:31	206.62
MW24	11MP62SB	30.0	19.0 - 29.0	221.41	223.51	20.0 - TD		17.88	8/12/2015	10:58	205.63
MW24	11MP62SB	30.0	19.0 - 29.0	221.41	223.51	20.0 - TD		19.02	9/2/2015	11:12	204.49
MW24	11MP62SB	30.0	19.0 - 29.0	221.41	223.51	20.0 - TD	32.30	17.88	9/10/2015	NR	205.63
MW25	11MP89SB	42.0	31.0 - 41.0	237.56	239.76	32.0 - TD		31.85	8/30/2011	18:02	207.91
MW25	11MP89SB	42.0	31.0 - 41.0	237.56	239.76	32.0 - TD		31.88	9/1/2011	14:50	207.88
MW25	11MP89SB	42.0	31.0 - 41.0	237.56	239.76	32.0 - TD		29.74	5/26/2012	16:22	210.02
MW25	11MP89SB	42.0	31.0 - 41.0	237.56	239.76	32.0 - TD		33.87	9/9/2012	10:30	205.89
MW25	11MP89SB	42.0	31.0 - 41.0	237.56	239.76	32.0 - TD		31.81	6/17/2015	14:40	207.95
MW25	11MP89SB	42.0	31.0 - 41.0	237.56	239.76	32.0 - TD		32.48	8/12/2015	10:56	207.28
MW25	11MP89SB	42.0	31.0 - 41.0	237.56	239.76	32.0 - TD		32.60	9/2/2015	11:20	207.16
MW25	11MP89SB	42.0	31.0 - 41.0	237.56	239.76	32.0 - TD	44.43	32.45	9/10/2015	NR	207.31
MW26	11MP52SB	43.0	32.0 - 42.0	244.03	245.93	34.0 - TD		36.25	8/30/2011	11:35	209.68
MW26	11MP52SB	43.0	32.0 - 42.0	244.03	245.93	34.0 - TD		36.30	9/1/2011	14:47	209.63
MW26	11MP52SB	43.0	32.0 - 42.0	244.03	245.93	34.0 - TD		32.76	5/26/2012	16:30	213.17
MW26	11MP52SB	43.0	32.0 - 42.0	244.03	245.93	34.0 - TD		34.01	9/9/2012	17:55	211.92
MW26	11MP52SB	43.0	32.0 - 42.0	244.03	245.93	34.0 - TD		36.04	6/17/2015	14:48	209.89
MW26	11MP52SB	43.0	32.0 - 42.0	244.03	245.93	34.0 - TD		36.98	8/12/2015	10:50	208.95
MW26	11MP52SB	43.0	32.0 - 42.0	244.03	245.93	34.0 - TD		37.24	9/2/2015	11:25	208.69
MW26	11MP52SB	43.0	32.0 - 42.0	244.03	245.93	34.0 - TD	45.13	36.42	9/10/2015	NR	209.51
MW27	11MP60SB	34.0	23.0 - 33.0	241.04	242.94	29.0 - TD		30.30	8/30/2011	16:50	212.64
MW27	11MP60SB	34.0	23.0 - 33.0	241.04	242.94	29.0 - TD		30.37	9/1/2011	14:58	212.57
MW27	11MP60SB	34.0	23.0 - 33.0	241.04	242.94	29.0 - TD		26.28	5/26/2012	16:38	216.66
MW27	11MP60SB	34.0	23.0 - 33.0	241.04	242.94	29.0 - TD		28.64	9/9/2012	12:50	214.30
MW27	11MP60SB	34.0	23.0 - 33.0	241.04	242.94	29.0 - TD		34.41	6/17/2015	14:58	Suspected Dry (Water Elevation <208.4 ft)
MW27	11MP60SB	34.0	23.0 - 33.0	241.04	242.94	29.0 - TD		NR	8/12/2015	NR	--
MW27	11MP60SB	34.0	23.0 - 33.0	241.04	242.94	29.0 - TD		31.42	9/2/2015	22:30	211.52
MW27	11MP60SB	34.0	23.0 - 33.0	241.04	242.94	29.0 - TD	35.77	31.24	9/10/2015	NR	211.52
MW28	11MP88SB	64.0	53.0 - 63.0	239.94	241.94	49.0 - TD		25.50	8/30/2011	14:57	216.44
MW28	11MP88SB	64.0	53.0 - 63.0	239.94	241.94	49.0 - TD		28.61	9/1/2011	14:53	213.33
MW28	11MP88SB	64.0	53.0 - 63.0	239.94	241.94	49.0 - TD		24.19	5/26/2012	16:41	217.75
MW28	11MP88SB	64.0	53.0 - 63.0	239.94	241.94	49.0 - TD		27.01	9/10/2012	15:43	214.93
MW28	11MP88SB	64.0	53.0 - 63.0	239.94	241.94	49.0 - TD		28.90	6/17/2015	15:08	213.04
MW28	11MP88SB	64.0	53.0 - 63.0	239.94	241.94	49.0 - TD		29.88	8/12/2015	10:46	212.06
MW28	11MP88SB	64.0	53.0 - 63.0	239.94	241.94	49.0 - TD		30.10	9/2/2015	11:35	211.84

Table 3-4 Well Construction and Groundwater Depth Information

Monitoring Well ID	Soil Boring ID	Reported Well Total Depth As Constructed (feet bgs)	Reported Screened Interval (feet bgs)	Surveyed Ground Elevation (feet NAVD88)	Surveyed Top of Casing Elevation (feet NAVD88)	GW Encountered During Drilling (feet bgs)	Measured Well Total Depth (feet below TOC)	Static Water Level			Ground Water Elevation (feet NAVD88)
								Depth (feet below TOC)	Date	Time	
MW28	11MP88SB	64.0	53.0 - 63.0	239.94	241.94	49.0 - TD	65.87	29.95	9/10/2015	NR	211.99
MW29	11MP41SB	70.0	59.0 - 69.0	280.35	282.25	61.0 - TD		63.21	9/1/2011	13:20	219.04
MW29	11MP41SB	70.0	59.0 - 69.0	280.35	282.25	61.0 - TD		52.65	5/26/2012	17:09	229.60
MW29	11MP41SB	70.0	59.0 - 69.0	280.35	282.25	61.0 - TD		61.20	9/9/2012	16:22	221.05
MW29	11MP41SB	70.0	59.0 - 69.0	280.35	282.25	61.0 - TD		64.08	6/17/2015	15:41	218.17
MW29	11MP41SB	70.0	59.0 - 69.0	280.35	282.25	61.0 - TD		66.60	8/12/2015	11:12	215.65
MW29	11MP41SB	70.0	59.0 - 69.0	280.35	282.25	61.0 - TD		66.89	9/2/2015	12:11	215.36
MW29	11MP41SB	70.0	59.0 - 69.0	280.35	282.25	61.0 - TD	71.75	66.81	9/10/2015	NR	215.44
MW30	11SM31SB	53.0	42.0 - 52.0	275.71	277.41	45.0 - TD		53.53	9/1/2011	14:35	Suspected Dry (Water Elevation <223.7 ft)
MW30	11SM31SB	53.0	42.0 - 52.0	275.71	277.41	45.0 - TD		52.63	5/26/2012	16:58	Suspected Dry (Water Elevation <223.7 ft)
MW30	11SM31SB	53.0	42.0 - 52.0	275.71	277.41	45.0 - TD		NR	9/9/2012	NR	Suspected Dry (Water Elevation <223.7 ft)
MW30	11SM31SB	53.0	42.0 - 52.0	275.71	277.41	45.0 - TD		54.25	6/17/2015	19:33	Suspected Dry (Water Elevation <223.7 ft)
MW30	11SM31SB	53.0	42.0 - 52.0	275.71	277.41	45.0 - TD		54.28	8/12/2015	11:19	Suspected Dry (Water Elevation <223.7 ft)
MW30	11SM31SB	53.0	42.0 - 52.0	275.71	277.41	45.0 - TD		54.32	9/2/2015	12:15	Suspected Dry (Water Elevation <223.7 ft)
MW30	11SM31SB	53.0	42.0 - 52.0	275.71	277.41	45.0 - TD	55.63	54.45	9/10/2015	NR	Suspected Dry (Water Elevation <223.7 ft)
MW31	11UP11SB	44.8	33.8 - 43.8	495.79	497.99	34.0 - TD		37.75	8/29/2011	13:51	460.24
MW31	11UP11SB	44.8	33.8 - 43.8	495.79	497.99	34.0 - TD		37.51	9/1/2011	14:05	460.48
MW31	11UP11SB	44.8	33.8 - 43.8	495.79	497.99	34.0 - TD		34.12	5/26/2012	10:10	463.87
MW31	11UP11SB	44.8	33.8 - 43.8	495.79	497.99	34.0 - TD		36.29	9/9/2012	18:10	461.70
MW31	11UP11SB	44.8	33.8 - 43.8	495.79	497.99	34.0 - TD		39.31	6/22/2015	19:09	458.68
MW31	11UP11SB	44.8	33.8 - 43.8	495.79	497.99	34.0 - TD		42.25	8/12/2015	11:31	455.74
MW31	11UP11SB	44.8	33.8 - 43.8	495.79	497.99	34.0 - TD		43.07	9/2/2015	12:45	454.92
MW31	11UP11SB	44.8	33.8 - 43.8	495.79	497.99	34.0 - TD	47.10	41.75	9/10/2015	NR	456.24
MW32	11RD05SB	25.0	14.0 - 24.0	194.38	196.58	16.5 - TD		18.90	8/31/2011	15:55	177.68
MW32	11RD05SB	25.0	14.0 - 24.0	194.38	196.58	16.5 - TD		18.86	9/1/2011	15:26	177.72
MW32	11RD05SB	25.0	14.0 - 24.0	194.38	196.58	16.5 - TD		16.71	5/26/2012	12:45	179.87
MW32	11RD05SB	25.0	14.0 - 24.0	194.38	196.58	16.5 - TD		17.21	9/8/2012	15:40	179.37
MW32	11RD05SB	25.0	14.0 - 24.0	194.38	196.58	16.5 - TD		19.03	6/17/2015	9:30	177.55
MW32	11RD05SB	25.0	14.0 - 24.0	194.38	196.58	16.5 - TD		19.49	8/12/2015	12:47	177.09
MW32	11RD05SB	25.0	14.0 - 24.0	194.38	196.58	16.5 - TD		20.17	9/2/2015	12:45	176.41
MW32	11RD05SB	25.0	14.0 - 24.0	194.38	196.58	16.5 - TD	26.73	20.05	9/10/2015	NR	176.53
MW33	11RD20SB	23.0	12.0 - 22.0	176.62	178.92	10.5 - TD		8.14	8/31/2011	17:57	170.78
MW33	11RD20SB	23.0	12.0 - 22.0	176.62	178.92	10.5 - TD		8.19	9/1/2011	15:20	170.73
MW33	11RD20SB	23.0	12.0 - 22.0	176.62	178.92	10.5 - TD		3.98	5/26/2012	12:33	174.94
MW33	11RD20SB	23.0	12.0 - 22.0	176.62	178.92	10.5 - TD		5.97	9/8/2012	12:30	172.95
MW33	11RD20SB	23.0	12.0 - 22.0	176.62	178.92	10.5 - TD		8.50	6/17/2015	14:04	170.42
MW33	11RD20SB	23.0	12.0 - 22.0	176.62	178.92	10.5 - TD		9.05	8/12/2015	11:09	169.87
MW33	11RD20SB	23.0	12.0 - 22.0	176.62	178.92	10.5 - TD		9.23	9/2/2015	8:40	169.69
MW33	11RD20SB	23.0	12.0 - 22.0	176.62	178.92	10.5 - TD	24.26	9.12	9/10/2015	NR	169.80

Table 3-4 Well Construction and Groundwater Depth Information

Monitoring Well ID	Soil Boring ID	Reported Well Total Depth As Constructed (feet bgs)	Reported Screened Interval (feet bgs)	Surveyed Ground Elevation (feet NAVD88)	Surveyed Top of Casing Elevation (feet NAVD88)	GW Encountered During Drilling (feet bgs)	Measured Well Total Depth (feet below TOC)	Static Water Level			Ground Water Elevation (feet NAVD88)
								Depth (feet below TOC)	Date	Time	
MW34	AST5 MW1	NR	NR	290.95	294.25			15.57	9/1/2011	16:49	278.68
MW34	AST5 MW1	NR	NR	290.95	294.25			15.82	6/22/2015	11:54	278.43
MW34	AST5 MW1	NR	NR	290.95	294.25			17.11	9/2/2015	10:20	277.14
MW34	AST5 MW1	NR	NR	290.95	294.25		22.80	16.38	9/10/2015	NE	277.87
MW35	AST5 MW2	NR	NR	285.76	289.26			41.97	9/1/2011	16:55	247.29
MW35	AST5 MW2	NR	NR	285.76	289.26			40.01	6/22/2015	11:58	249.25
MW35	AST5 MW2	NR	NR	285.76	289.26			44.94	9/2/2015	10:15	244.32
MW35	AST5 MW2	NR	NR	285.76	289.26		55.30	44.42	9/10/2015	NR	244.84
MW36	AST5 MW3	NR	NR	286.33	290.03			35.81	9/1/2011	16:57	254.22
MW36	AST5 MW3	NR	NR	286.33	290.03			33.16	6/22/2015	12:08	256.87
MW36	AST5 MW3	NR	NR	286.33	290.03			40.89	9/2/2015	10:10	249.14
MW36	AST5 MW3	NR	NR	286.33	290.03		65.38	39.39	9/10/2015	NR	250.64
MW39	SM67	84.0	63 - 83	432.83	435.26			85.11	8/3/2015	9:00	Suspected Dry (Water Elevation <349.8 ft)
MW39	SM67	84.0	63 - 83	432.83	435.26			Dry (>84)	8/12/2015	11:25	Dry (Water Elevation <349.8 ft)
MW39	SM67	84.0	63 - 83	432.83	435.26			Dry (>84)	9/2/2015	12:35	Dry (Water Elevation <349.8 ft)
MW39	SM67	84.0	63 - 83	432.83	435.26		86.02	Dry (>84)	9/10/2015	NR	Dry (Water Elevation <349.8 ft)
MW40	SM68c	140.0	119 - 139	392.86	395.18	135		131.11	8/12/2015	11:37	264.07
MW40	SM68c	140.0	119 - 139	392.86	395.18	135		131.49	9/2/2015	12:25	263.69
MW40	SM68c	140.0	119 - 139	392.86	395.18	135	142.45	131.60	9/10/2015	NR	263.58
MW42	SM70b	140.0	119 - 139	339.85	342.34	99		NR	8/12/2015	NR	
MW42	SM70b	140.0	119 - 139	339.85	342.34	99		129.10	9/2/2015	11:50	213.24
MW42	SM70b	140.0	119 - 139	339.85	342.34	99	142.97	129.01	9/10/2015	NR	213.33
MW43	SM71b	118.5	98 - 118	300.87	303.69	94		90.25	8/12/2015	10:33	213.44
MW43	SM71b	118.5	98 - 118	300.87	303.69	94		90.42	9/2/2015	12:00	213.27
MW43	SM71b	118.5	98 - 118	300.87	303.69	94	121.13	90.34	9/10/2015	NR	213.35

Notes

Elevation datum: NAVD88 calculated using GEOID09.

Top of casing (TOC) refers to the top of PVC inner casing.

Key

NR	Not Recorded
TD	Total depth
TOC	Top of Casing
bgs	Below ground surface

Table 3-5 Groundwater Sample Results, Spring 2015

Analyte	Station ID		Units	MW08	MW19	MW10	MW01	MW22	MW26	MW27	MW28	MW06	MW32	MW33	MW29	MW31
	Geographic Area			Post-1955 MPA					Pre-1955 MPA				Red Devil Creek Downstream Alluvial Area and Delta		Surface Mined Area	Upland Area West of Surface Mined Area
	Sample ID			0615MW08GW	0615MW19GW	0615MW10GW	0615MW01GW	0615MW22GW	0615MW26GW	0615MW27GW	0615MW28GW	0615MW06GW	0615MW32GW	0615MW33GW	0615MW29GW	0615MW31GW
	Method															
Total Inorganic Elements																
Aluminum	Metals (ICP)	SW846 6010B	µg/L	190 U	190 U	190 U	**1300 J**	190 U	190 U	190 U	**350 J**	190 U	190 U	**840 J**	**720 J**	**3900**
Antimony	Metals (ICP/MS)	SW846 6020A	µg/L	**0.24 J**	**0.21 J**	**0.21 J**	**11**	**340**	**37**	**11**	**7**	**6.1**	**1.2**	**430**	**0.75 J**	**0.36 J**
Arsenic	Metals (ICP/MS)	SW846 6020A	µg/L	**0.27 J**	**0.55 J**	**95**	**130**	**59**	**1300**	**29**	**75**	**34**	**0.65 J**	**23**	**75**	**4.1**
Barium	Metals (ICP/MS)	SW846 6020A	µg/L	**38**	**46**	**88**	**200**	**46**	**610**	**40**	**54**	**80**	**14**	**39**	**250**	**94**
Beryllium	Metals (ICP/MS)	SW846 6020A	µg/L	0.1 U	0.1 U	0.1 U	**0.21 J**	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	**0.19 J**
Cadmium	Metals (ICP/MS)	SW846 6020A	µg/L	0.028 U	0.028 U	0.028 U	**0.19 J**	0.028 U	0.028 U	**0.091 J**	0.028 U	0.028 U	0.028 U	0.028 U	0.028 U	**0.036 J**
Calcium	Metals (ICP)	SW846 6010B	µg/L	**11000**	**18000**	**21000**	**18000**	**14000**	**66000**	**86000**	**40000**	**31000**	**11000**	**15000**	**53000**	**7800**
Chromium	Metals (ICP/MS)	SW846 6020A	µg/L	**0.33 J**	**0.2 J**	**1.5**	**30**	**0.31 J**	1.9 U	**16**	**8.6**	0.14 U	**0.43**	**2**	**20**	**56**
Cobalt	Metals (ICP/MS)	SW846 6020A	µg/L	0.032 U	**0.045 J**	**0.98**	**1.5**	**0.032 J**	**12**	**2.7 J**	**4.7**	**1.1**	**0.13 J**	**0.44**	**1.9**	**5.1**
Copper	Metals (ICP/MS)	SW846 6020A	µg/L	0.6 U	0.6 U	0.6 U	7.2 U	**0.7 J**	**1.1 J**	4 U	**1.6 J**	0.6 U	**0.79 J**	**2.4**	2.9 U	11 U
Iron	Metals (ICP)	SW846 6010B	µg/L	180 U	180 U	**930**	**56000**	180 U	**56000**	**740**	**1400**	**2100**	180 U	**1100**	**3900**	**6800**
Lead	Metals (ICP/MS)	SW846 6020A	µg/L	0.034 U	0.034 U	0.034 U	**2.8**	0.034 U	**0.065 J**	**0.1 J**	**0.38 J**	0.034 U	**0.041 J**	**1.3**	**0.71**	**3.9**
Magnesium	Metals (ICP)	SW846 6010B	µg/L	**8400**	**13000**	**32000**	**12000**	**11000**	**40000**	**53000**	**30000**	**30000**	**9100**	**11000**	**52000**	**5800**
Manganese	Metals (ICP/MS)	SW846 6020A	µg/L	0.35 U	**6.7 J**	**110**	**220**	**2 J**	**6300**	**750**	**890**	**550**	**12**	**37**	**450**	**220**
Mercury	Mercury (CVAA)	SW846 7470A	µg/L	0.041 U	0.041 U	0.041 U	**0.76**	**0.057 J**	**0.4**	**0.14 J**	**0.92**	0.041 U	0.041 U	**0.42**	**0.19 J**	**0.34**
Nickel	Metals (ICP/MS)	SW846 6020A	µg/L	**0.73 J**	0.4 U	**1.7 J**	**23**	**1.2 J**	**8.3 J**	**41**	**14 J**	**1.8 J**	**5**	**2.2 J**	**18**	**44**
Potassium	Metals (ICP)	SW846 6010B	µg/L	**410 J**	**290 J**	**1000 J**	**760 J**	**360 J**	**3400**	**1400 J**	**990 J**	**760 J**	**360 J**	**840 J**	**1100 J**	**1700 J**
Selenium	Metals (ICP/MS)	SW846 6020A	µg/L	**0.58 J**	**0.91 J**	0.3 U	**2**	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U	**0.92 J**	**0.47 J**	0.3 U	**0.67 J**
Silver	Metals (ICP/MS)	SW846 6020A	µg/L	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	**0.23 J**
Sodium	Metals (ICP)	SW846 6010B	µg/L	**1300 J**	**2400**	**3500**	**2500**	**2600**	**6300**	**16000**	**11000**	**4300**	**1600 J**	**4100**	**2400**	**1500 J**
Thallium	Metals (ICP/MS)	SW846 6020A	µg/L	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U
Vanadium	Metals (ICP/MS)	SW846 6020A	µg/L	0.98 U	0.98 U	0.98 U	**16**	0.98 U	0.98 U	0.98 U	**1.2 J**	0.98 U	0.98 U	**3.3 J**	**2.9 J**	**11**
Zinc	Metals (ICP/MS)	SW846 6020A	µg/L	1.9 U	**1.9 J**	1.9 U	**15**	1.9 U	**4.9 J**	**16 J**	**2.8 J**	1.9 U	**11**	**6.9 J**	**5.6 J**	**21 J**
Total Low Level Mercury																
Mercury	Total Mercury by EPA 1631	EPA 1631	ng/L	**2.35**	2.01 U	**7.95**	**532**	**246**	**483**	**663**	**1890**	**4**	**47.9**	**745**	**215**	**376**
Dissolved Low Level Mercury																
Mercury	Dissolved Mercury by EPA 1631	EPA 1631	ng/L	**1.48**	**0.91**	**2.32**	**4.52**	**108**	**32.4**	**131**	**27.5**	**0.51**	**18.5**	**5.84**	**1.45**	**14.5**
Semivolatile Organic Compounds																
Benzoic acid	Semivolatile Organic Compounds (GC/MS)	SW846 8270D	µg/L		**0.82 J**			**0.75 J**								
Benzyl alcohol	Semivolatile Organic Compounds (GC/MS)	SW846 8270D	µg/L		0.095 U			**0.1 J**								
Butyl benzyl phthalate	Semivolatile Organic Compounds (GC/MS)	SW846 8270D	µg/L		0.19 U			**0.19 J**								
Diethyl phthalate	Semivolatile Organic Compounds (GC/MS)	SW846 8270D	µg/L		**0.2 J**			**0.2 J**								
2-Fluorobiphenyl	Semivolatile Organic Compounds (GC/MS)	SW846 8270D	µg/L		**86**			**80**								
Benzene, Toluene, Ethylbenzene, and Xylenes																
Benzene	Volatile Organic Compounds (GC/MS)	SW846 8260C	µg/L		0.025 U			0.025 U								
Toluene	Volatile Organic Compounds (GC/MS)	SW846 8260C	µg/L		0.025 U			**0.054 J**								
Ethylbenzene	Volatile Organic Compounds (GC/MS)	SW846 8260C	µg/L		0.03 U			0.03 U								
m-Xylene & p-Xylene	Volatile Organic Compounds (GC/MS)	SW846 8260C	µg/L		0.05 U			0.05 U								
o-Xylene	Volatile Organic Compounds (GC/MS)	SW846 8260C	µg/L		0.06 U			0.06 U								
Gasoline Range Organics and Diesel Range Organics																
Gasoline Range Organics (GRO)-C6-C10	Alaska - Gasoline Range Organics (GC)	ADEC AK101	mg/L		0.015 U			0.015 U								
DRO (nC10-<nC25)	Alaska - Diesel Range Organics & Residual Range Organics (GC)	ADEC AK102 & 103	mg/L		0.022 UJ-			**0.063 J**								
General Chemistry																
Total Suspended Solids	Solids, Total Suspended (TSS)	SM 2540D	mg/L	2 UJ		2 UJ	**180 J**	2 U	**98**	**2.8 J**	**20**	**2.8 J**	2 UJ	**20 J**	**64**	35 U
Chloride	Anions, Ion Chromatography	MCAWW 300.0	mg/L	**0.7 J**	**0.49 J**	**0.66 J**	**0.7 J**	**0.42 J**	**0.82 J**	**1.2**	**0.78 J**	**0.71 J**	**0.46 J**	**0.65 J**	**0.62 J**	**0.5 J**
Fluoride	Anions, Ion Chromatography	MCAWW 300.0	mg/L	**0.12**	**0.13**	**0.17**	**0.11**	**0.12**	**0.29**	**0.16**	**0.18**	**0.17**	**0.06 J**	**0.07 J**	**0.14**	**0.07 J**
Sulfate	Anions, Ion Chromatography	MCAWW 300.0	mg/L	**4.2**	**5.6**	8.9 U	11 U	**5.3**	70 U	170 U	40 U	**20**	**11**	**14**	32 U	1 U
Carbonate Alkalinity as CaCO3	Alkalinity	SM 2320B	mg/L	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Bicarbonate Alkalinity as CaCO3	Alkalinity	SM 2320B	mg/L	**57**	**110**	**180**	**81**	**78**	**280**	**270**	**200**	**180**	**52**	**99**	**310**	**40**
Hydroxide Alkalinity as CaCO3	Alkalinity	SM 2320B	mg/L	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Alkalinity	Alkalinity	SM 2320B	mg/L	**57**	**110**	**180**	**81**	**78**	**280**	**270**	**200**	**180**	**52**	**99**	**310**	**40**
Nitrate Nitrite as N	Nitrogen, Nitrate-Nitrite	MCAWW 353.2	mg/L	**0.35**	**0.12**	0.005 U	**0.054**	**0.02 J**	0.005 U	**0.069**	0.005 U	0.005 U	**1.2**	**0.17**	**0.012 J**	**0.038 J**
Field Water Quality Parameters																
Temperature	Field Measurement		Deg C	4.45	7.35	13.64	13.9	15.5	18.16	19.58	17.74	11.26	19.58	9.31	12.67	10.86
pH	Field Measurement		pH Units	6.25	6.91	7.65	6.28	6.21	6.78	6.32	7.13	6.31	5.73	6.35	6.47	5.99
Conductivity	Field Measurement		mS/cm	0.138	0.206	0.367	0.185	0.169	0.832	0.874	0.466	0.39	0.153	0.192	0.647	0.09
Turbidity	Field Measurement		NTU	0	0	0	171	0	0	21.4	7.9	12.9	0	12.3	40.6	6.7
Dissolved Oxygen	Field Measurement		mg/L	0	0	0	0	0	0	0	0	0	1.142	0	0	2.54
Oxidation-Reduction Potential	Field Measurement		mV	207	49	-115	60	91	-142	49	-84	-46	174	123	-29	119

Key

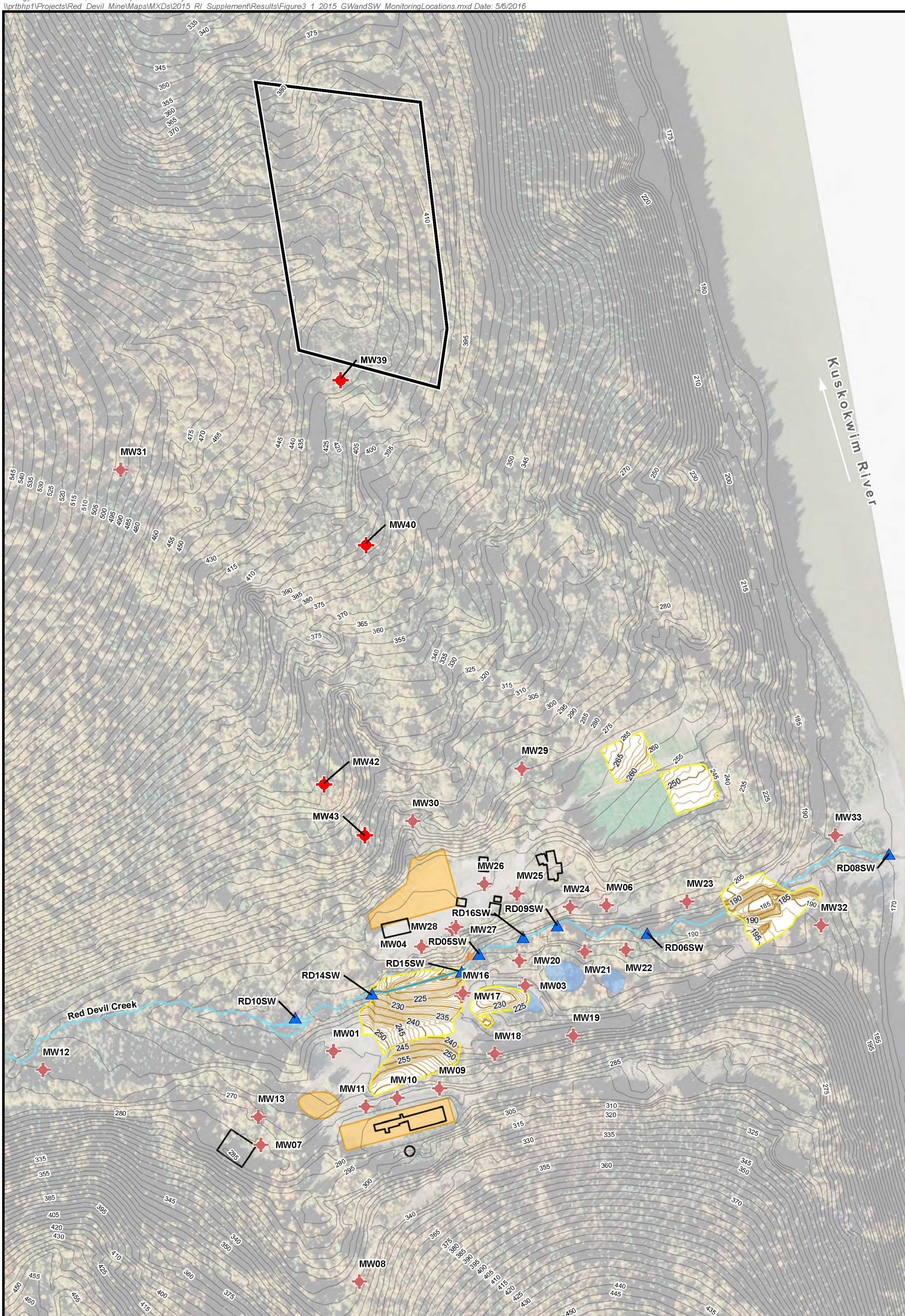
µg/L = Micrograms per liter
ADEC = Alaska Department of Environmental Conservation
Bold = Detected
Deg C = Degrees Celsius.
EPA = United States Environmental Protection Agency
GC/MS = Gas Chromatography/Mass Spectrometry
ICP/ MS = Inductively coupled plasma/mass spectrometry
J = The analyte was detected. The associated result is estimated.
mg/L = milligrams per liter
mS/cm = Millisiemens per centimeter
mV = Millivolts
ng/L = Nanograms per liter
NTU = Nephelometric turbidity units
U = The analyte was analyzed for but not detected. The value provided is the method detection limit.
UJ- = The analyte was analyzed for but not detected. The associated reporting limit is estimated with a low bias.
UJ = The analyte was analyzed for but not detected. The associated reporting limit is estimated.

Table 3-6 Groundwater Sample Results, Fall 2015

Analyte	Station ID		Units	MW08	MW09	MW19	MW10	MW01	MW16	MW17	MW22	MW26	MW27	MW28	MW06	MW32	MW33	MW40	MW42	MW43	MW29	MW31
	Geographic Area			Post-1955 MPA								Pre-1955 MPA				Red Devil Creek Downstream Alluvial Area and Delta		Surface Mined Area				Upland Area West of Surface Mined Area
	Sample ID / Method			0915MW08GW	0915MW09GW	0915MW19GW	0915MW10GW	0915MW01GW	0915MW16GW	0915MW17GW	0915MW22GW	0915MW26GW	0915MW27GW	0915MW28GW	0915MW06GW	0915MW32GW	0915MW33GW	0915MW40GW	0915MW42GW	0915MW43GW	0915MW29GW	0915MW31GW
Total Inorganic Elements																						
Aluminum	Metals (ICP)	SW846 6010B	µg/L	190 U	190 U	190 U	190 U	190 U	**380 J**	190 U	190 U	190 U	190 U	**940 J**	190 U	190 U	190 U	190 U	**230 J**	190 U	190 U	**1200 J**
Antimony	Metals (ICP/MS)	SW846 6020A	µg/L	**0.44**	**7.8**	**0.33 J**	0.56 U	1.8 U	**570**	**9.3**	**280**	**28**	**8.3**	**16**	**7.3**	**1.9**	**460**	**6.2**	**250**	**9.2**	0.23 U	0.14 U
Arsenic	Metals (ICP/MS)	SW846 6020A	µg/L	**0.39 J**	7.6 U	**0.62 J**	**100 J**	6.8 U	**1700**	5.3 U	**61**	**490**	**27**	**130**	**48**	**1**	**25**	**85**	**610**	**38**	**35**	0.82 U
Barium	Metals (ICP/MS)	SW846 6020A	µg/L	**47**	**510**	**49**	**86**	**82**	**72**	**49**	**55**	**560**	**44**	**69**	**80**	**21**	**28**	**110**	**95**	**86**	**250**	**25**
Beryllium	Metals (ICP/MS)	SW846 6020A	µg/L	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Cadmium	Metals (ICP/MS)	SW846 6020A	µg/L	**0.045 J**	**0.34 J**	**0.1 J**	0.037 U	0.2 U	0.5 U	0.13 U	**0.092 J**	0.076 U	0.13 UJ	0.03 U	**0.11 J**	**0.13 J**	**0.56**	**0.71**	**0.68**	**0.3 J**	0.028 U	0.028 UJ
Calcium	Metals (ICP)	SW846 6010B	µg/L	**13000**	**29000**	**19000**	**21000**	**21000**	**37000**	**26000**	**18000**	**62000**	**90000**	**41000**	**31000**	**17000**	**17000**	**44000**	**40000**	**22000**	**59000**	**8000**
Chromium	Metals (ICP/MS)	SW846 6020A	µg/L	**0.41**	0.47 U	**0.21 J**	0.17 U	1.2 U	1.2 U	0.53 U	**0.17 J**	0.8 U	0.68 UJ	3.3 U	**0.14 J**	**2**	**0.39 J**	0.37 U	1.6 U	1.3 U	0.32 U	2.8 U
Cobalt	Metals (ICP/MS)	SW846 6020A	µg/L	**0.037 J**	**2.5**	**0.055 J**	**0.079 J**	**1.4**	**10**	**0.18 J**	0.032 U	**12**	**2.5**	**3.5**	**1.2**	**0.19 J**	**0.035 J**	**31**	**8.1**	**33**	**0.67**	**0.31 J**
Copper	Metals (ICP/MS)	SW846 6020A	µg/L	0.6 U	1.7 U	0.6 U	0.6 U	2.9 U	1.6 U	0.6 U	0.6 U	0.87 U	0.6 U	1.8 U	0.6 U	**0.94 J**	**0.96 J**	0.6 U	1.4 U	0.75 U	0.6 U	**0.93 J**
Iron	Metals (ICP)	SW846 6010B	µg/L	180 U	**890**	180 U	**1000**	**14000**	**20000**	180 U	180 U	**40000**	180 U	**2900**	**2400**	180 U	180 U	180 U	**330 J**	**990**	**2200**	**690**
Lead	Metals (ICP/MS)	SW846 6020A	µg/L	**0.098 J**	**0.86**	**0.057 J**	0.11 U	0.39 U	0.34 U	0.33 U	**0.051 J**	0.11 U	0.034 U	0.45 U	**0.055 J**	**0.078 J**	**0.074 J**	0.075 U	0.18 U	0.1 U	0.034 U	0.33 U
Magnesium	Metals (ICP)	SW846 6010B	µg/L	**11000**	**21000**	**14000**	**32000**	**14000**	**66000**	**19000**	**15000**	**41000**	**56000**	**31000**	**31000**	**15000**	**13000**	**46000**	**31000**	**17000**	**59000**	**5900**
Manganese	Metals (ICP/MS)	SW846 6020A	µg/L	**1.2 J**	**5400**	**12 J**	**130**	**530**	**8300**	**16**	**2 J**	**6100**	**2300**	**940**	**580**	**32 J**	**2.3**	**340**	**730**	**2500 J**	**460**	**13**
Mercury	Mercury (CVAA)	SW846 7470A	µg/L	0.041 U	**0.32**	0.041 U	0.041 U	0.041 U	**1.7**	**0.19 J**	**0.1 J**	**0.067 J**	**0.075 J**	**0.41**	0.041 U	0.041 U	0.041 U	0.041 U	0.041 U	0.041 U	0.041 U	0.041 U
Nickel	Metals (ICP/MS)	SW846 6020A	µg/L	**0.85 J**	**3.7**	0.4 U	0.4 U	4.2 U	**4.7**	0.56 U	**0.8 J**	**11**	**52**	10 U	**2 J**	**8.4**	**0.89 J**	**120**	**37**	**100**	**2.1 J**	1.4 U
Potassium	Metals (ICP)	SW846 6010B	µg/L	**480 J**	**540 J**	**300 J**	**940 J**	**440 J**	**2400 J**	**390 J**	**360 J**	**3400**	**1300 J**	**1200 J**	**770 J**	**480 J**	**630 J**	**840 J**	**1000 J**	**510 J**	**1000 J**	**510 J**
Selenium	Metals (ICP/MS)	SW846 6020A	µg/L	**0.65 J**	0.3 U	**1.1**	0.3 U	**0.87 J**	0.3 U	**0.76 J**	**1.2**	0.3 U	0.3 U	0.3 U	0.3 U	**1.3**	**0.47 J**	0.3 U	**0.49 J**	0.3 U	0.3 U	**0.37 J**
Silver	Metals (ICP/MS)	SW846 6020A	µg/L	0.03 U	0.03 U	**0.05 J**	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	**0.048**	0.03 U	**0.06 J**	**0.05 J**	0.03 U	0.03 U
Sodium	Metals (ICP)	SW846 6010B	µg/L	**1600 J**	**2700**	**2600**	**3300**	**3600**	**6100**	**3100**	**2800**	**7000**	**17000**	**11000**	**4400**	**2000**	**4200**	**1900 J**	**2700**	**5300**	**2200**	**1300 J**
Thallium	Metals (ICP/MS)	SW846 6020A	µg/L	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U
Vanadium	Metals (ICP/MS)	SW846 6020A	µg/L	0.98 U	**1.2 J**	0.98 U	0.98 U	**1.6 J**	**2 J**	0.98 U	0.98 U	0.98 U	0.98 U	**4**	0.98 U	0.98 U	**1.1 J**	**1.2 J**	**2.5 J**	**0.99 J**	0.98 U	**4.3**
Zinc	Metals (ICP/MS)	SW846 6020A	µg/L	1.9 U	5.3 U	**2.5 J**	1.9 U	16 U	7.7 U	2.4 U	**1.9 J**	4.2 U	22 UJ	5.1 U	**2.8 J**	**25**	**2.5 J**	5 U	12 U	6 U	2.2 U	3.5 U
Total Low Level Mercury																						
Mercury	Total Mercury by EPA 1631	EPA 1631	ng/L	**8.49**	**1020**	**3.29**	26.1 U	16.9 U	**1540**	**361 J**	**401**	**216**	**401**	**1320 J**	**12.9**	**114**	**8.21**	30.9 U	259 U	74.3 U	11.7 U	35.5 U
Dissolved Low Level Mercury																						
Mercury	Dissolved Mercury by EPA 1631	EPA 1631	ng/L	0.45 U	**5.46**	1.15 U	**32.3 J**	**53.8**	**702**	**7.98**	**323**	**34.7**	**253**	**294**	**0.19**	**35.9**	**3.02**	1.87 U	**48.2**	**7.55 J**	**5.69**	1.12 U
Semivolatile Organic Compounds																						
Butyl benzyl phthalate	Semivolatile Organic Compounds (GC/MS)	SW846 8270D	µg/L			0.19 UJ-					**0.21 J**											
Di-n-butyl phthalate	Semivolatile Organic Compounds (GC/MS)	SW846 8270D	µg/L			**0.14 J**					**0.15 J**											
2-Fluorobiphenyl	Semivolatile Organic Compounds (GC/MS)	SW846 8270D	µg/L			**72**					**65**											
Benzene, Toluene, Ethylbenzene, and Xylenes																						
Benzene	Volatile Organic Compounds (GC/MS)	SW846 8260C	µg/L			0.025 U					0.025 U											
Toluene	Volatile Organic Compounds (GC/MS)	SW846 8260C	µg/L			0.025 U					0.025 U											
Ethylbenzene	Volatile Organic Compounds (GC/MS)	SW846 8260C	µg/L			0.03 U					0.03 U											
m-Xylene & p-Xylene	Volatile Organic Compounds (GC/MS)	SW846 8260C	µg/L			0.05 U					0.05 U											
o-Xylene	Volatile Organic Compounds (GC/MS)	SW846 8260C	µg/L			0.06 U					0.06 U											
Gasoline Range Organics and Diesel Range Organics																						
Gasoline Range Organics (GRO)-C6-C10	Alaska - Gasoline Range Organics (GC)	ADEC AK101	mg/L			**0.055**					0.015 U											
DRO (nC10-<nC25)	Alaska - Diesel Range Organics & Residual Range Organics (GC)	ADEC AK102 & 103	mg/L			0.052 UJ-					**0.19**											
General Chemistry																						
Total Suspended Solids	Solids, Total Suspended (TSS)	SM 2540D	mg/L	2 U	**2.4**	2 U	**2.4**	**5.2**	**42**	**4.4**	2 U	**70**	2 U	**22**	**3.4**	2 U	2 U	2 U	**6.2**	**3.2**	**5**	**4.8**
Chloride	Anions, Ion Chromatography	MCAWW 300.0	mg/L	**0.77**	**0.81**	**0.59 J+**	**0.76**	**0.75**	**0.82**	**0.72**	**0.61**	**0.75**	**1.1**	**0.82**	**0.77**	**0.44 J**	**0.55**	**0.8**	**1**	**1.3**	**0.68**	**0.62**
Fluoride	Anions, Ion Chromatography	MCAWW 300.0	mg/L	**0.12 J**	0.1 U	**0.13 J+**	**0.16 J**	0.13 U	**0.3**	0.12 U	**0.11 J**	**0.35**	**0.16 J**	**0.17 J**	**0.17 J**	**0.08 J**	**0.09 J**	0.23 U	0.16 U	0.19 U	0.14 U	0.09 U
Sulfate	Anions, Ion Chromatography	MCAWW 300.0	mg/L	**4.3**	6.9 U	**4.8 J+**	7.9 U	10 U	220 U	7.1 U	**6.5**	45 U	**170 J**	37 U	**20**	**12**	**11**	9.3 U	17 U	15 U	32 U	0.78 U
Carbonate Alkalinity as CaCO3	Alkalinity	SM 2320B	mg/L	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Bicarbonate Alkalinity as CaCO3	Alkalinity	SM 2320B	mg/L	**66**	**150**	**110**	**170**	**110**	**130**	**130**	**97**	**270**	**280**	**200**	**170**	**76**	**86**	**280**	**210**	**120**	**340**	**42**
Hydroxide Alkalinity as CaCO3	Alkalinity	SM 2320B	mg/L	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Alkalinity	Alkalinity	SM 2320B	mg/L	**66**	**150**	**110**	**170**	**110**	**130**	**130**	**97**	**270**	**280**	**200**	**170**	**76**	**86**	**280**	**210**	**120**	**340**	**42**
Nitrate Nitrite as N	Nitrogen, Nitrate-Nitrite	MCAWW 353.2	mg/L	**0.44**	0.005 U	**0.082**	0.005 U	0.005 U	0.005 U	**0.057**	**1.4**	0.005 U	0.005 U	0.005 U	0.005 U	**1.1**	**0.088**	0.005 U	**330**	0.005 U	0.005 U	**0.066**
Field Water Quality Parameters																						
Temperature	Field Measurement		Deg C	5.5	9.06	7.20		10.21	8.1	5.73	7.43	8.59	7.87	6.49	7.45	8.76	9.91				6.37	
pH	Field Measurement		pH Units	6.41	6.88	7.28		6.04	6.56	7.28	6.07	6.76	6.42	7.06	6.9	5.98	6.57				6.67	
Conductivity	Field Measurement		mS/cm	0.164	0.221	0.227		0.173	0.736	0.293	0.233	0.456	0.567	0.315	0.407	0.201	0.199				0.501	
Turbidity	Field Measurement		NTU	0	3.9	0		6.3	12.2	0	0	0	0	28.9	0	0	0				0.1	
Dissolved Oxygen	Field Measurement		mg/L	0	0	0		0	0	0	0	0	0	0	0	0	0				0	
Oxidation-Reduction Potential	Field Measurement		mV	2.91	-71	88		-26	-81	27	164	-111	71	-63	-73	213	8.9				-45	

Key
µg/L = Micrograms per liter
ADEC = Alaska Department of Environmental Conservation
Bold = Detected
Deg C = Degrees Celsius.
EPA = United States Environmental Protection Agency
GC/MS = Gas Chromatography/Mass Spectrometry
ICP/ MS = Inductively coupled plasma/mass spectrometry
J = The analyte was detected. The associated result is estimated.
mg/L = milligrams per liter
mS/cm = Millisiemens per centimeter
mV = Millivolts
ng/L = Nanograms per liter
NTU = Nephelometric turbidity units
U = The analyte was analyzed for but not detected. The value provided is the method detection limit.
UJ+ = The analyte was analyzed for but not detected. The associated reporting limit is estimated with a high bias.
UJ- = The analyte was analyzed for but not detected. The associated reporting limit is estimated with a low bias.
UJ = The analyte was analyzed for but not detected. The associated reporting limit is estimated.

Ecology & Environment, Inc. GIS Department Project: \\prtbhp1\Projects\Red_Devil_Mine\Maps\MXDs\2015_RI_Supplement\Results\Figure3_1_2015_GWandSW_MonitoringLocations.mxd Date: 5/6/2016



2015 Monitoring Locations

- New 2015 Monitoring Well
- Existing RI Monitoring Well
- Surface Water
- 2014 5-foot Contour
- 2014 1-foot Contour
- Area of 2014 NTCRA Re-grading
- 2010 5-foot Contour
- Post-NTCRA Stream Alignment
- Red Devil Creek
- Settling Pond
- Monofill
- Historical Structure
- Approximate Location of Proposed Repository Footprint
- Seep Location

Digital 2010 5-foot topographic contours based on the aerial orthophotograph taken on September 21, 2010 (AeroMetric 2012)

Digital 2014 5-foot and 1-foot topographic contours based on Marsh Creek (2014)

RED DEVIL MINE

Red Devil, Alaska

Figure 3-1
2015 Groundwater and Surface Water Monitoring Locations

0 50 100 200 300 400
Feet
0 12.5 25 50 75 100 125
Meters
Scale 1:2,500

2015 Monitoring Locations

- New 2015 Monitoring Well
- Existing RI Monitoring Well Spring 2015 Groundwater Elevation
- Surface Water
- 210 Groundwater Potentiometric Surface Elevation Contour (hatch mark on downgradient side)
- 2014 5-foot Contour
- 2014 1-foot Contour
- Area of 2014 NTCRA Re-grading
- 2010 5-foot Contour
- Post-NTCRA Stream Alignment
- Red Devil Creek
- Settling Pond
- Monofill
- Historical Structure
- Approximate Location of Proposed Repository Footprint
- Seep Location

Digital 2010 5-foot topographic contours based on the aerial orthophotograph taken on September 21, 2010 (AeroMetric 2012)

Digital 2014 5-foot and 1-foot topographic contours based on Marsh Creek (2014)

RED DEVIL MINE

Red Devil, Alaska

Figure 3-2
Groundwater Potentiometric Surface, Spring 2015

0 50 100 200 300 400 Feet
0 12.5 25 50 75 100 125 Meters
Scale 1:2,500

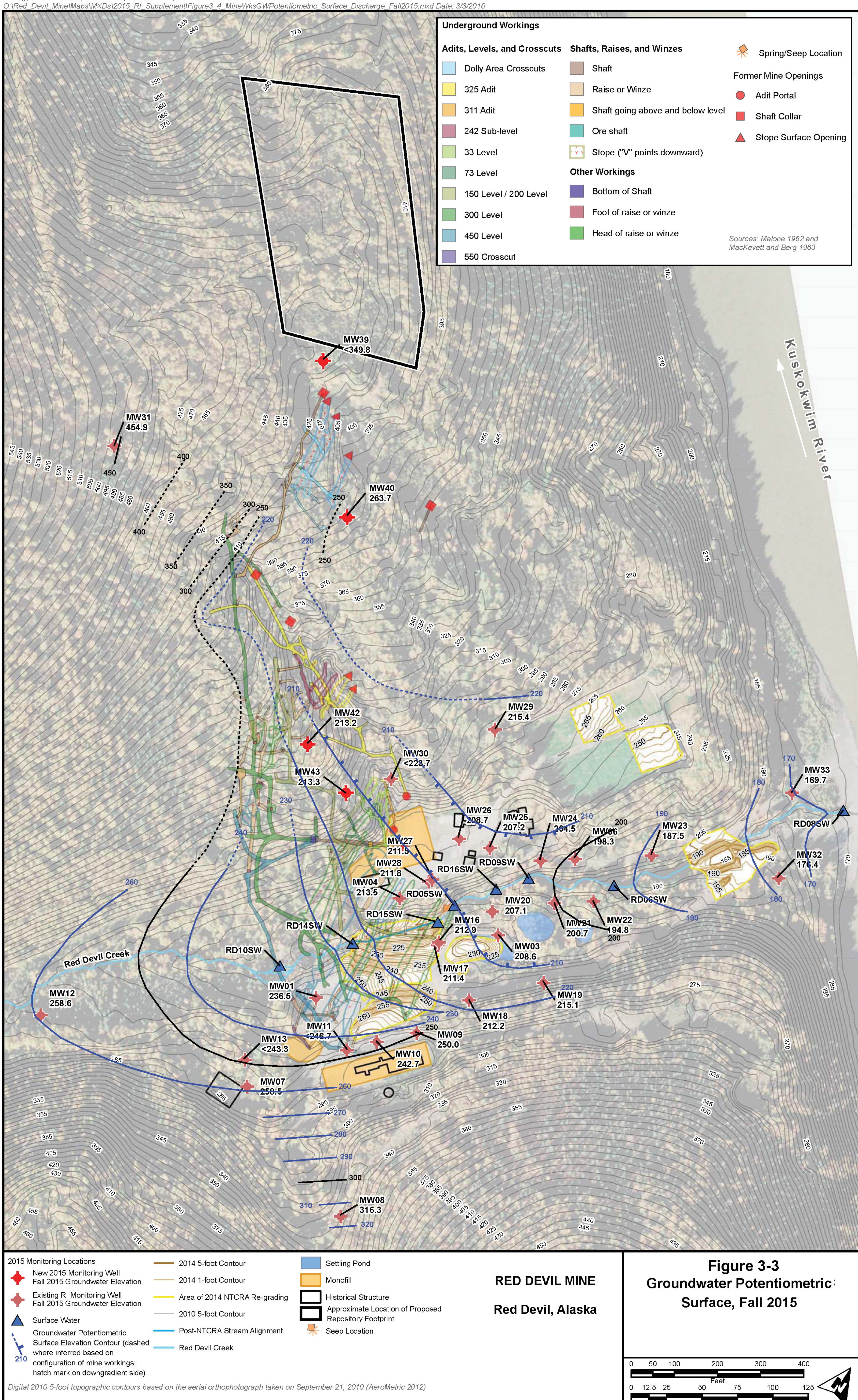
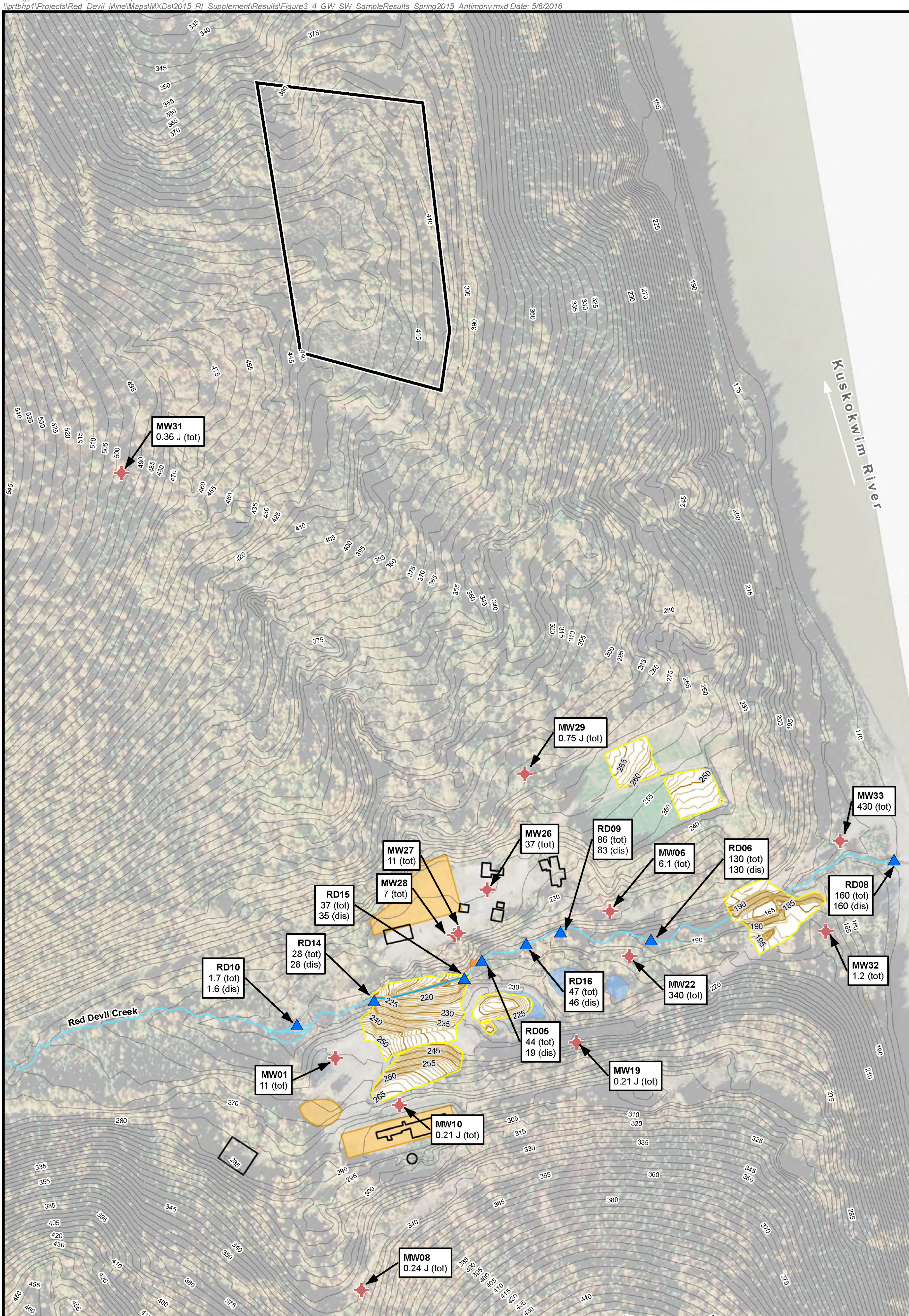


Figure 3-3
Groundwater Potentiometric Surface, Fall 2015

Ecology & Environment, Inc. GIS Department Project:
\\prtbhp1\Projects\Red_Devil_Mine\Maps\MXDs\2015_RI_Supplement\Results\Figure3_4_GW_SW_SampleResults_Spring2015_Antimony.mxd Date: 5/6/2016



2015 Monitoring Locations

- Existing RI Monitoring Well
- Surface Water

Water sample results for total (tot) and dissolved (dis) antimony in µg/L

- 2014 5-foot Contour
- 2014 1-foot Contour
- Area of 2014 NTCRA Re-grading
- 2010 5-foot Contour
- Post-NTCRA Stream Alignment
- Red Devil Creek
- Settling Pond
- Monofill
- Historical Structure
- Approximate Location of Proposed Repository Footprint
- Seep Location

RED DEVIL MINE

Red Devil, Alaska

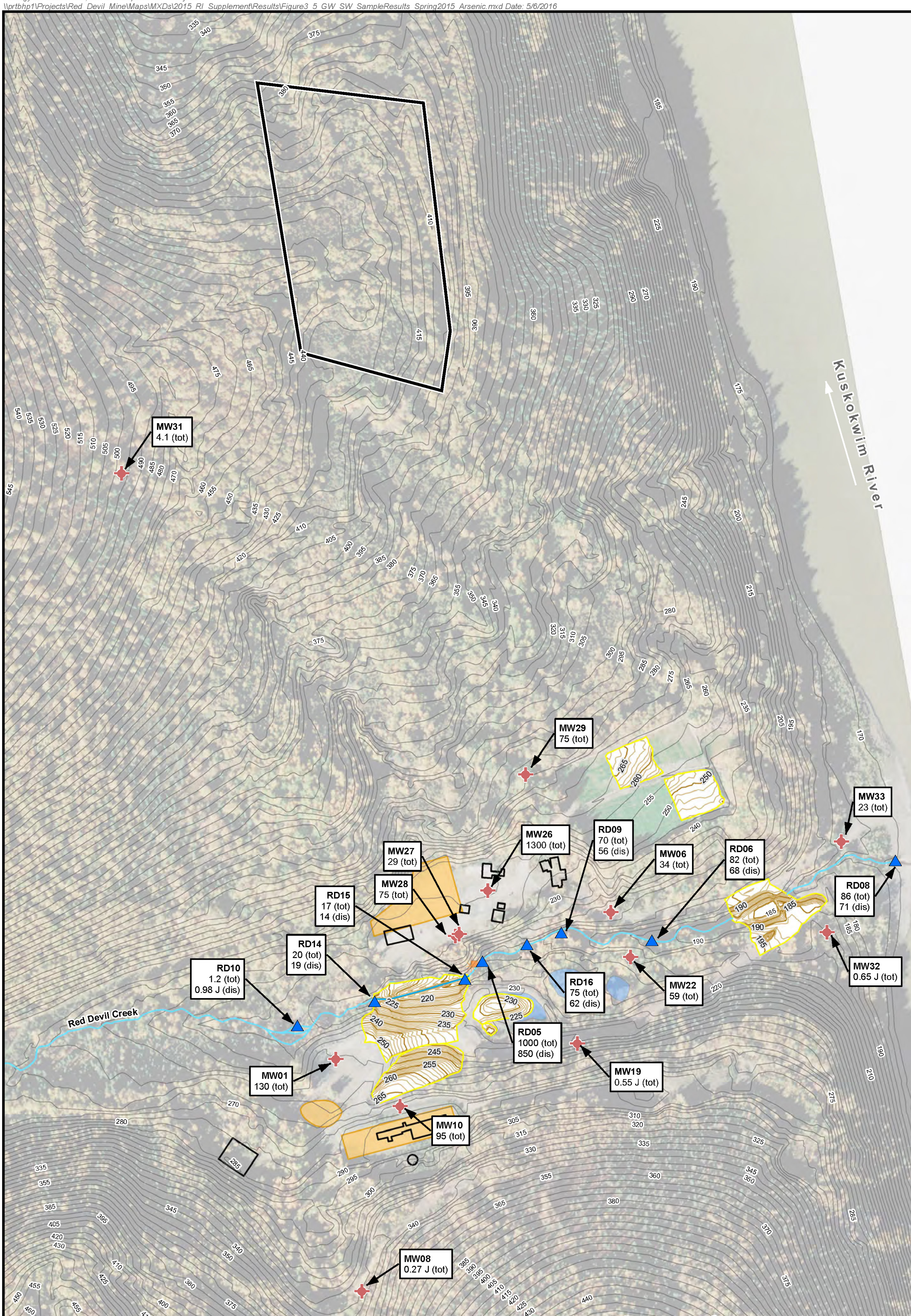
Figure 3-4
Groundwater and Surface Water Sample Results, Spring 2015, Total and Dissolved Antimony

0 50 100 200 300 400
Feet
0 12.5 25 50 75 100 125
Meters
Scale 1:2,500

Digital 2010 5-foot topographic contours based on the aerial orthophotograph taken on September 21, 2010 (AeroMetric 2012)

Digital 2014 5-foot and 1-foot topographic contours based on Marsh Creek (2014)

Ecology & Environment, Inc. GIS Department Project:
\\prtbhp1\Projects\Red_Devil_Mine\Maps\MXDs\2015_RI_Supplement\Results\Figure3_5_GW_SW_SampleResults_Spring2015_Arsenic.mxd Date: 5/6/2016



2015 Monitoring Locations

- Existing RI Monitoring Well
- Surface Water

Water sample results for total (tot) and dissolved (dis) arsenic in µg/L

- 2014 5-foot Contour
- 2014 1-foot Contour
- Area of 2014 NTCRA Re-grading
- 2010 5-foot Contour
- Post-NTCRA Stream Alignment
- Red Devil Creek
- Settling Pond
- Monofill
- Historical Structure
- Approximate Location of Proposed Repository Footprint
- Seep Location

Digital 2010 5-foot topographic contours based on the aerial orthophotograph taken on September 21, 2010 (AeroMetric 2012)

Digital 2014 5-foot and 1-foot topographic contours based on Marsh Creek (2014)

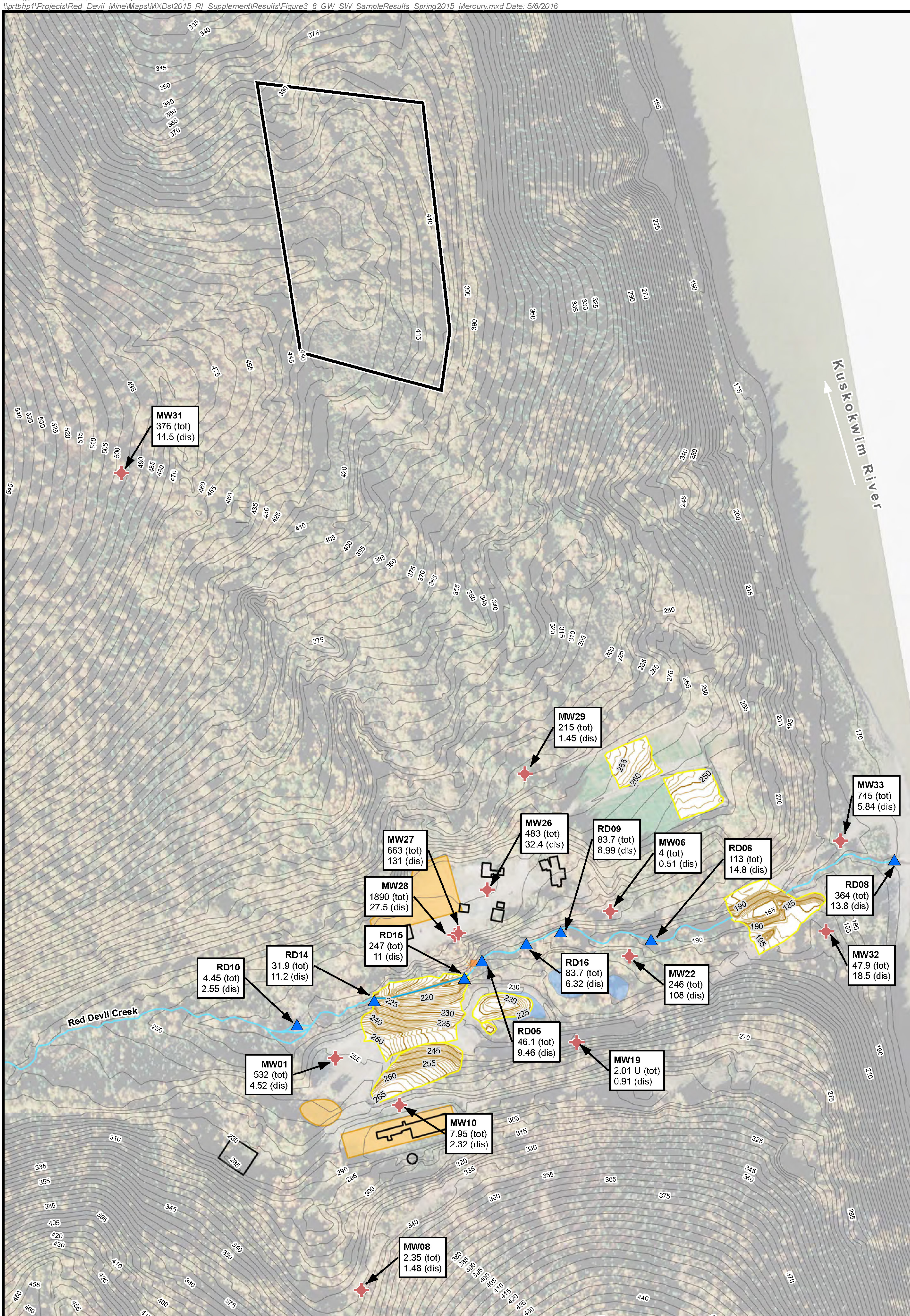
RED DEVIL MINE

Red Devil, Alaska

Figure 3-5
Groundwater and Surface Water Sample Results, Spring 2015, Total and Dissolved Arsenic

0 50 100 200 300 400
Feet
0 12.5 25 50 75 100 125
Meters
Scale 1:2,500

Ecology & Environment, Inc. GIS Department Project:
\\prtbhp1\Projects\Red_Devil_Mine\Maps\MXDs\2015_RI_Supplement\Results\Figure3_6_GW_SW_SampleResults_Spring2015_Mercury.mxd Date: 5/6/2016



2015 Monitoring Locations

- Existing RI Monitoring Well
- Surface Water

Water sample results for total (tot) and dissolved (dis) mercury in ng/L

- 2014 5-foot Contour
- 2014 1-foot Contour
- Area of 2014 NTCRA Re-grading
- 2010 5-foot Contour
- Post-NTCRA Stream Alignment
- Red Devil Creek
- Settling Pond
- Monofill
- Historical Structure
- Approximate Location of Proposed Repository Footprint
- Seep Location

Digital 2010 5-foot topographic contours based on the aerial orthophotograph taken on September 21, 2010 (AeroMetric 2012)

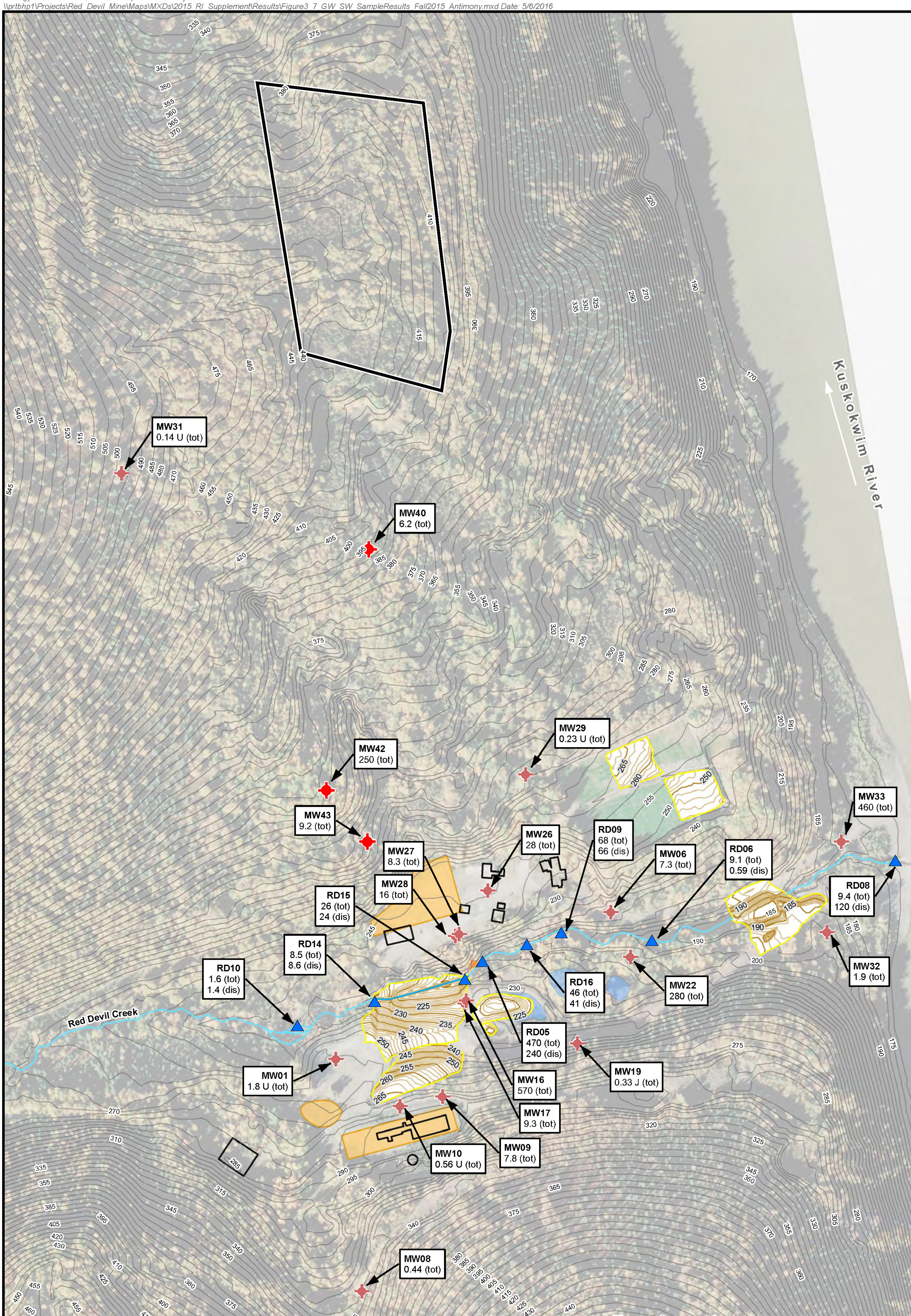
Digital 2014 5-foot and 1-foot topographic contours based on Marsh Creek (2014)

RED DEVIL MINE

Red Devil, Alaska

Figure 3-6
Groundwater and Surface Water Sample Results, Spring 2015, Total and Dissolved Mercury

0 50 100 200 300 400
Feet
0 12.5 25 50 75 100 125
Meters
Scale 1:2,500



2015 Monitoring Locations
- New 2015 Monitoring Well
- Existing RI Monitoring Well
- Surface Water

Water sample results for total (tot) and dissolved (dis) antimony in µg/L

- 2014 5-foot Contour
- 2014 1-foot Contour
- Area of 2014 NTCRA Re-grading
- 2010 5-foot Contour
- Post-NTCRA Stream Alignment
- Red Devil Creek
- Settling Pond
- Monofill
- Historical Structure
- Approximate Location of Proposed Repository Footprint
- Seep Location

RED DEVIL MINE

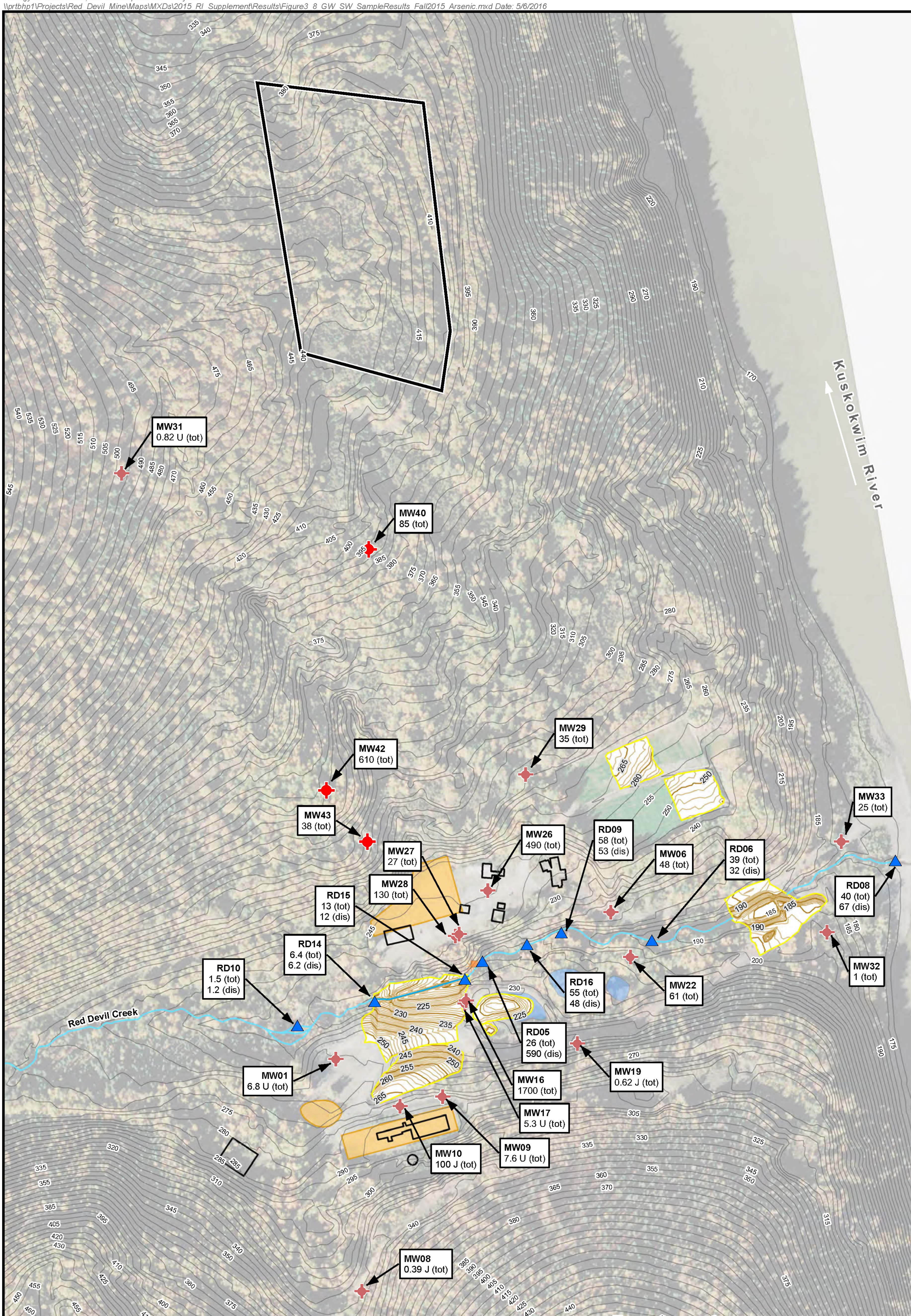
Red Devil, Alaska

Figure 3-7
Groundwater and Surface Water Sample Results, Fall 2015, Total and Dissolved Antimony

0 50 100 200 300 400
Feet
0 12.5 25 50 75 100 125
Meters
Scale 1:2,500

Digital 2010 5-foot topographic contours based on the aerial orthophotograph taken on September 21, 2010 (AeroMetric 2012)

Digital 2014 5-foot and 1-foot topographic contours based on Marsh Creek (2014)



2015 Monitoring Locations

- New 2015 Monitoring Well
- Existing RI Monitoring Well
- Surface Water

Water sample results for total (tot) and dissolved (dis) arsenic in µg/L

- 2014 5-foot Contour
- 2014 1-foot Contour
- Area of 2014 NTCRA Re-grading
- 2010 5-foot Contour
- Post-NTCRA Stream Alignment
- Red Devil Creek
- Settling Pond
- Monofill
- Historical Structure
- Approximate Location of Proposed Repository Footprint
- Seep Location

RED DEVIL MINE

Red Devil, Alaska

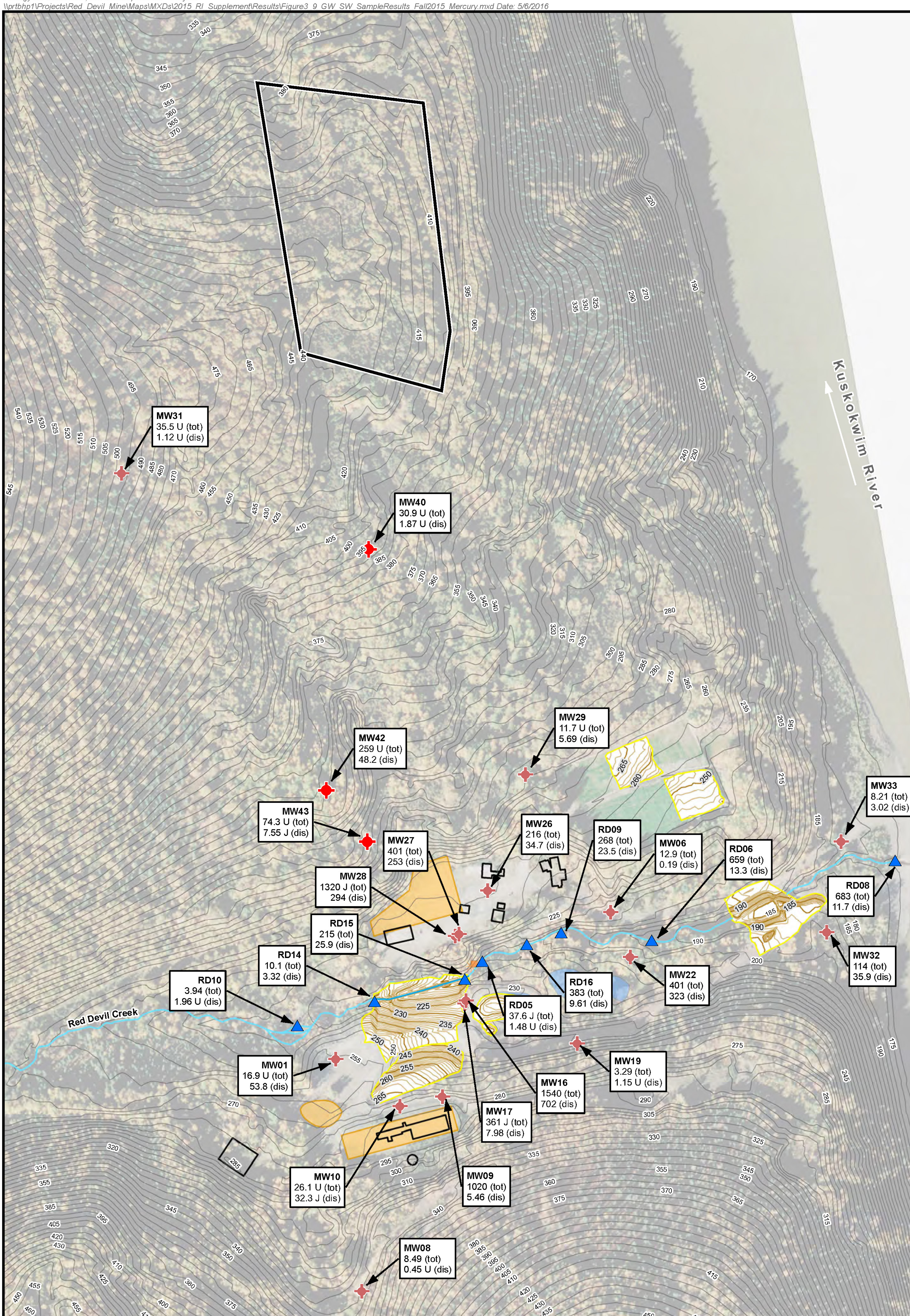
Figure 3-8
Groundwater and Surface Water Sample Results, Fall 2015, Total and Dissolved Arsenic

0 50 100 200 300 400 Feet
0 12.5 25 50 75 100 125 Meters
Scale 1:2,500

Digital 2010 5-foot topographic contours based on the aerial orthophotograph taken on September 21, 2010 (AeroMetric 2012)

Digital 2014 5-foot and 1-foot topographic contours based on Marsh Creek (2014)

Ecology & Environment, Inc. GIS Department Project:
\\prtbhp1\Projects\Red_Devil_Mine\Maps\MXDs\2015_RI_Supplement\Results\Figure3_9_GW_SW_SampleResults_Fall2015_Mercury.mxd Date: 5/6/2016



2015 Monitoring Locations
- New 2015 Monitoring Well
- Existing RI Monitoring Well
- Surface Water

Water sample results for total (tot) and dissolved (dis) mercury in ng/L

- 2014 5-foot Contour
- 2014 1-foot Contour
- Area of 2014 NTCRA Re-grading
- 2010 5-foot Contour
- Post-NTCRA Stream Alignment
- Red Devil Creek

- Settling Pond
- Monofill
- Historical Structure
- Approximate Location of Proposed Repository Footprint
- Seep Location

Digital 2010 5-foot topographic contours based on the aerial orthophotograph taken on September 21, 2010 (AeroMetric 2012)

Digital 2014 5-foot and 1-foot topographic contours based on Marsh Creek (2014)

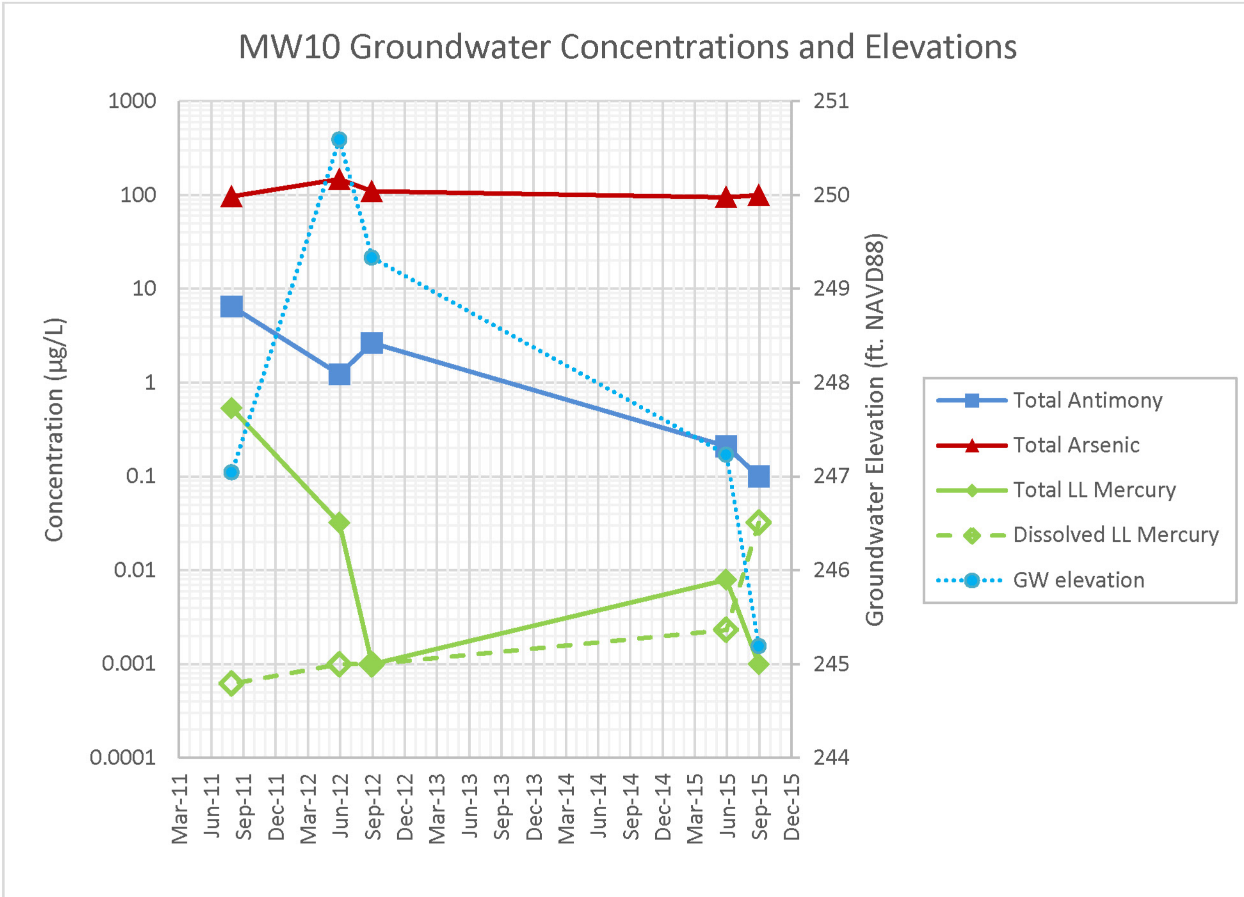
RED DEVIL MINE

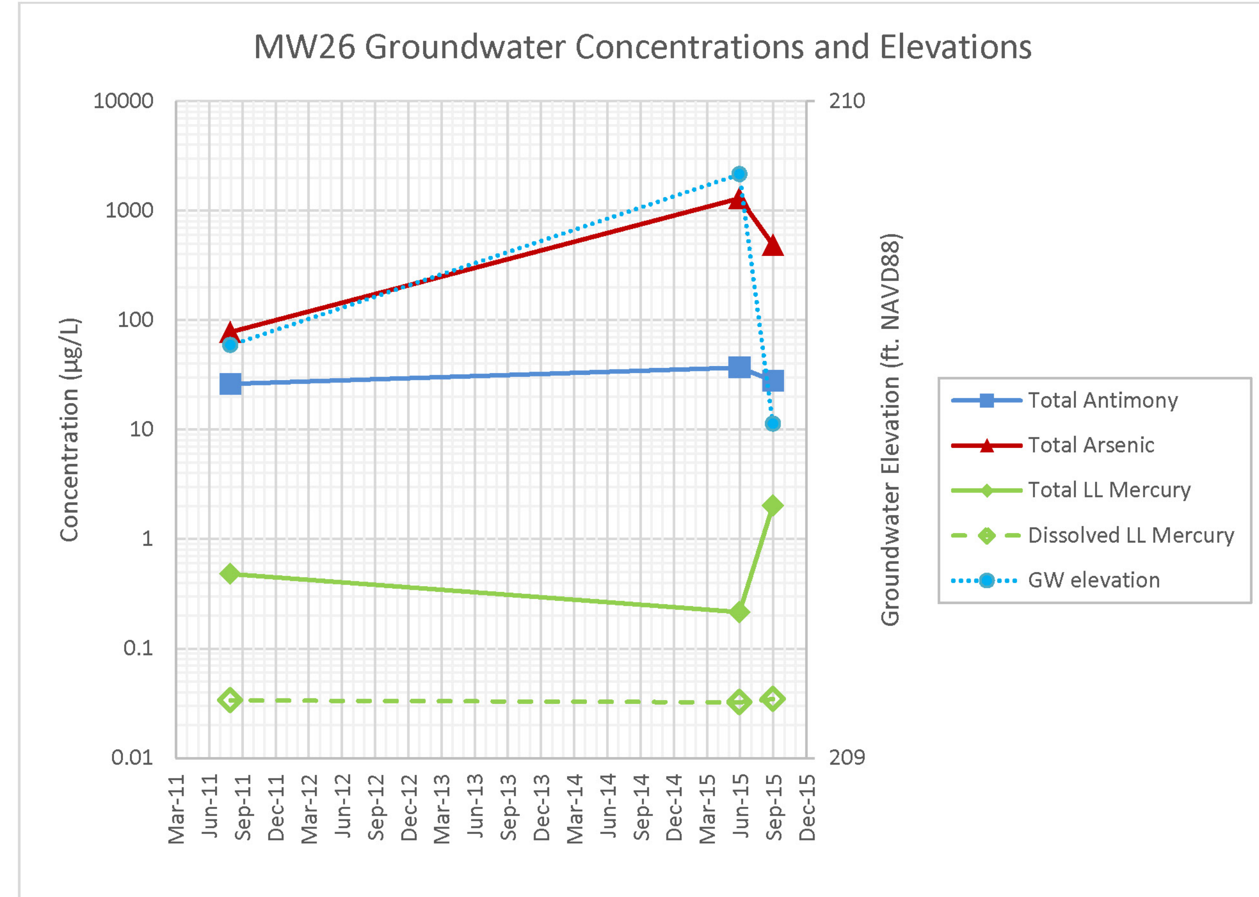
Red Devil, Alaska

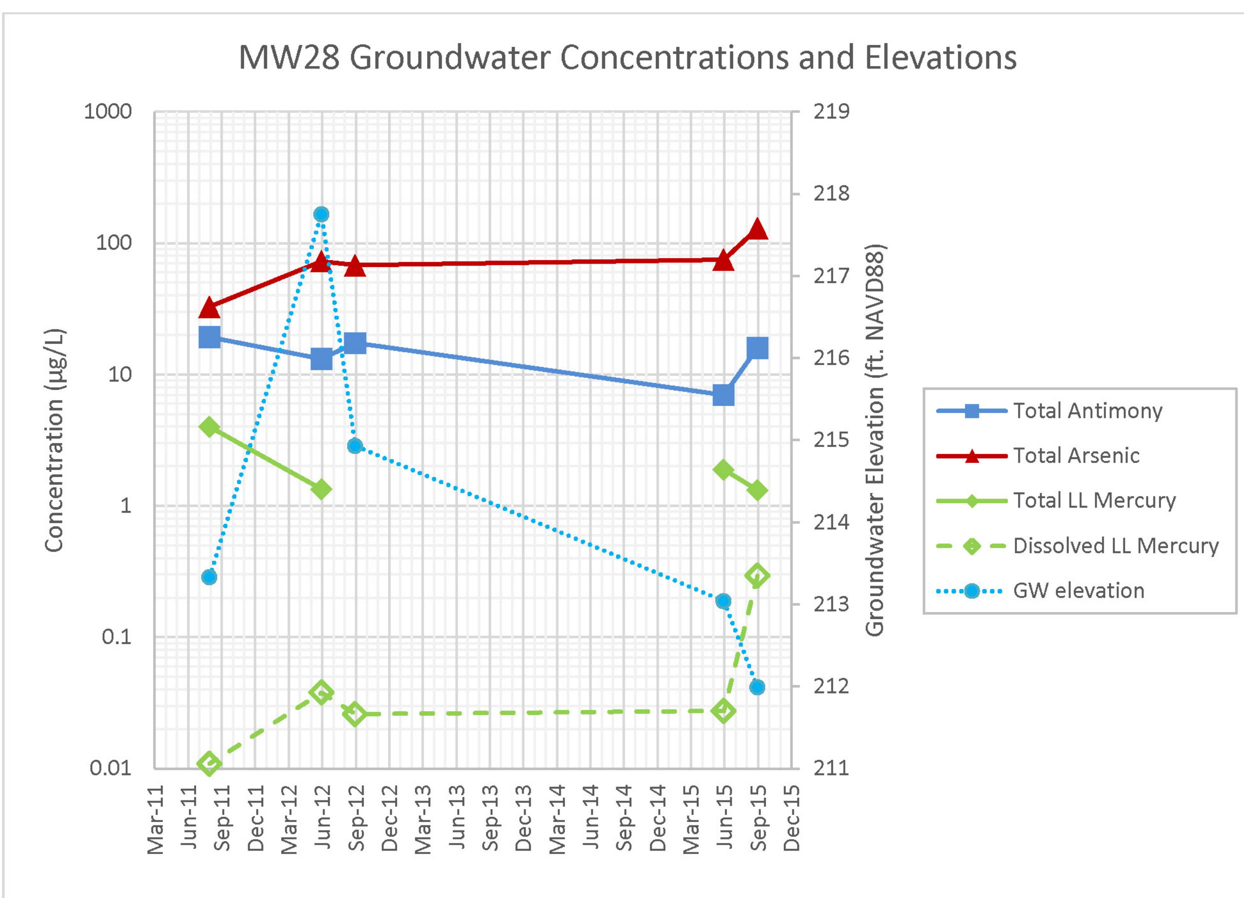
Figure 3-9
Groundwater and Surface Water Sample Results, Fall 2015, Total and Dissolved Mercury

0 50 100 200 300 400
Feet
0 12.5 25 50 75 100 125
Meters
Scale 1:2,500

Fig 3-10 Groundwater Concentrations and Elevations Over Time for Selected Wells







4 Surface Water Investigation

4.1 Surface Water Investigations

The RI Supplement surface water characterization activities were designed to address data gaps associated with surface water in Red Devil Creek and a seep located on the northwest bank of the creek. Additional surface water characterization was performed to gather the types of additional information identified in Section 3.3 of the RI Supplement Work Plan. The supplemental RI surface water characterization was designed to meet the following objectives:

- Assess potential impacts on surface water quality and flow rate by flow of groundwater that is impacted by naturally mineralized bedrock and underground mine workings in the Surface Mined Area.
- Assess groundwater quality and flow rate in the area affected by the 2014 NTCRA construction.
- Provide additional information on baseline surface water conditions at the site.

Additional surface water characterization was performed using a combination of field data collection and the results of laboratory analysis for selected analytical parameters. Surface water monitoring was performed during two sampling events in 2015—the spring event in June and the fall event in September at the locations listed in Tables 4-1 and 4-2, respectively. Surface water monitoring locations are shown in Figure 3-1.

Sampling and other field procedures were performed in accordance with the Field Sampling Plan, except as noted below. A brief description of field sampling and other procedures is provided below.

4.1.1 Stream Gaging

At the selected surface water monitoring locations along Red Devil Creek and the seep, discharge rates were measured during the spring and fall 2015 field events on June 19 and September 2, 2015, respectively.

4.1.2 Surface Water Sampling

At the selected surface water monitoring locations along Red Devil Creek and the seep, surface water was sampled for field and laboratory water quality parameters. Surface water samples were collected for field water quality parameters (pH, specific conductance, oxidation reduction potential, turbidity, dissolved oxygen, and temperature) and the following laboratory analyses: total TAL inorganic elements and low-level mercury; dissolved TAL inorganic elements and low-level mercury; total organic carbon (TOC); total suspended solids; total dissolved solids; inorganic ions (chloride, fluoride, and sulfate); nitrate-nitrite as N; and alkalinity (as carbonate/bicarbonate). Surface water samples collected for the various laboratory analyses for the two monitoring events are listed in Tables 4-1 and 4-2. Surface water samples were submitted to TestAmerica, Seattle, Washington, for laboratory analysis. TestAmerica performed analysis for all analyses except total and dissolved low-level mercury analyses, which were performed under sub-subcontract to TestAmerica by Brooks Rand Labs, Seattle, Washington.

4.1.3 Deviations from the Field Sampling Plan

There were no deviations from the Field Sampling Plan for the surface water monitoring.

4.2 Surface Water Investigation Results

The RI Supplement surface water characterization was performed using a combination of field data collection and the results of laboratory analysis for selected analytical parameters. The objectives of the groundwater investigation are listed in Section 4.1. Results of surface water characterization are summarized below.

4.2.1 Stream Discharge

Estimated surface water discharge calculations for Red Devil Creek surface water stations monitored during the spring and fall 2015 surface water monitoring events are presented in Table 4-3. For comparison, stream gaging data collected previously also are presented in Table 4-3.

Estimated Red Devil Creek surface water discharge ranged from 1.3 to 1.9 cubic feet per second on June 19, 2015, and from 0.48 to 0.81 cubic feet per second on September 2, 2015. During each monitoring event, the stream discharge generally increased from upstream to downstream, consistent with gaining conditions and the conclusion that groundwater in the Main Processing Area and part of the Surface Mines Area emerges as surface water in the creek (see Section 3.2.2).

The estimated discharge rates during both the spring and fall 2015 monitoring events were substantially lower than during all previous monitoring events, consisting of the RI event (August 18, 2011), spring 2012 baseline event (May 26, 2012), and fall 2012 baseline event (September 12, 2012). Such lower discharge is consistent with the lower groundwater elevations observed during the spring and fall 2015 groundwater monitoring (see Section 3.2.2).

4.2.2 Surface Water Sample Results

At the selected surface water monitoring locations along Red Devil Creek and the seep, surface water was sampled for field and laboratory water quality parameters. Laboratory results and field water quality measurements of surface water sampling conducted during the spring and fall 2015 monitoring events are presented in Tables 4-4 and 4-5, respectively. Results for key constituents—total and dissolved antimony, total and dissolved arsenic, and total and dissolved mercury—are presented in Figures 3-4 through 3-6, for the spring 2015 event, and Figures 3-7 through 3-9 for the fall 2015 event. Concentrations of total and dissolved antimony, total and dissolved arsenic, total and dissolved mercury, and sulfate also in Red Devil Creek and seep surface water samples also are presented graphically in Figures 4-1a through 4-1l. In each of these figures the locations of Red Devil Creek samples are arrayed from upstream (left) to downstream (right), with the samples collected from the seep positioned on the figures at the locations where the seep drains into the creek channel.

Surface water results for spring and fall 2015 sampling indicate generally increasing total and dissolved antimony, arsenic, and mercury concentrations along Red Devil Creek with distance downstream beginning at approximately station RD10, located near the upstream end of the Main Processing Area. Overall, the trends of increasing concentrations along Red Devil Creek in spring and fall 2015 surface water samples are similar to those documented in the RI and 2012 baseline monitoring events, although the magnitude of the increases varied. Concentrations trends were evaluated by comparing the 2015 and historical results for the same stations, as discussed below.

Spring

Concentrations of total and dissolved antimony in samples from Red Devil Creek and the seep were lower in the spring 2015 samples than in the spring 2012 samples. Total arsenic concentrations in samples from Red Devil Creek and the seep were lower in the spring 2015 samples than in the spring 2012 samples. Dissolved arsenic concentrations in samples from Red Devil Creek were lower in the spring 2015 samples than in the spring 2012 samples, but the concentration in the sample from the seep was higher. Total and dissolved mercury concentrations in samples from Red Devil Creek were lower in the spring 2015 samples than in the spring 2012 samples, but the concentrations in the sample from the seep were higher.

Fall

Concentrations of total and dissolved antimony in samples from Red Devil Creek were lower in the fall 2015 samples than in the 2011 RI and fall 2012 samples, but the concentrations in the sample from the seep were higher than in the 2011 RI and fall 2012 samples. For samples downstream of station RD10, concentrations of total and dissolved arsenic in samples from Red Devil Creek and the seep were lower in the fall 2015 samples than in the 2011 RI and fall 2012 samples. For samples downstream of station RD10, concentrations of total mercury in samples from Red Devil Creek and the seep were higher in the fall 2015 samples than in fall 2012 samples. The 2015 total mercury concentrations were higher than those in two of the 2011 RI Red Devil Creek samples but lower in the other two creek samples and the seep sample. The dissolved mercury concentrations were higher in most of the fall 2015 samples than in the 2011 RI and fall 2012 samples from the same stations.

4.3 Surface Water Investigation Conclusions

The RI Supplement surface water characterization activities were designed to address data gaps associated with surface water in Red Devil Creek and a seep located on the northwest bank of the creek. Additional surface water characterization was performed to gather the types of additional information identified in Section 3.3 of the RI Supplement Work Plan and meet the objectives listed in Section 4.1. Results of surface water characterization are detailed in Section 4.2. Key findings are summarized below.

4.3.1 Stream Discharge

Estimated Red Devil Creek surface water discharge ranged from 1.3 to 1.9 cubic feet per second on June 19, 2015, and from 0.48 to 0.81 cubic feet per second on September 2, 2015. During each monitoring event, the stream discharge generally increased from upstream to downstream, consistent with overall gaining conditions and the conclusion that groundwater in the Main Processing Area and part of the Surface Mines Area emerges as surface water in the creek.

The estimated discharge rates during both the spring and fall 2015 monitoring events were substantially lower than during all previous monitoring events. Such lower discharge is consistent with the comparatively lower groundwater elevations observed during the spring and fall 2015 groundwater monitoring.

4.3.2 Surface Water Sample Results

Surface water results for spring and fall 2015 sampling indicate generally increasing total and dissolved antimony, arsenic, and mercury concentrations along Red Devil Creek moving downstream beginning at approximately station RD10, located near the upstream end of the Main Processing Area. Overall, the trends of increasing concentrations along Red Devil Creek in spring and fall 2015 surface water samples are similar to those documented in the RI and 2012 baseline monitoring events, although the magnitudes varied. The spring 2015 concentrations in Red Devil Creek were generally lower than concentrations seen in previous sampling events. This may be attributable to lower groundwater elevations observed in the spring 2015. The fall 2015 concentrations of antimony and arsenic in Red Devil Creek and the seep were generally lower than concentrations seen in previous sampling events. As suggested for the spring 2015 sample results, this may be attributable to lower groundwater elevations observed in the spring 2015. The total and dissolved mercury results did not exhibit an obvious trend relative to previous results. No obvious trends that could be attributed to the 2014 NTCRA regrading have been noted to date.

4.3.3 Surface Water Contaminant Transport

The RI Supplement results and RI results show that transport of contaminants in surface water is occurring presently at the RDM. Contaminant loading (e.g., antimony, arsenic, mercury, and methylmercury) along Red Devil Creek as it flows through the Main Processing Area is attributable to groundwater migration into the stream along gaining reaches and erosion and entrainment of particulates. Groundwater emerges to surface water as baseflow within the Main Processing Area as well as at a seep located adjacent to the creek in the Main Processing Area.

Sources of inorganics in groundwater include leaching from mine wastes, as well as naturally mineralized bedrock and native soils. Based on results of the Surface Mined Area groundwater evaluation (see Section 3.3.1), groundwater flow in portions of the Surface Mined Area is controlled by the system of interconnected underground mine workings. The mine workings provide a preferential flow pathway of groundwater in areas drained by the mine workings from the Surface Mined Area to shallow depths below Red Devil Creek. The results also support the conclusion that much of the groundwater within the Red Devil Creek valley, including groundwater in the Main Processing Area and the area downstream of the Main Processing Area, emerges into Red Devil Creek and enters the Kuskokwim River as surface water rather than via groundwater flow. The groundwater investigation results also demonstrate that the groundwater that flows into the underground mine workings network is impacted by the natural sub-ore grade mineralization associated with the Red Devil ore zones, and that much of this groundwater emerges into Red Devil Creek within the Main Processing Area and is a source of impacts to Red Devil Creek.

Surface water loading along the creek also is attributable to entrainment of contaminants within or adsorbed to particulates and dissolution/desorption of contaminants from bed and suspended sediment. The 2014 NTCRA was undertaken to address the active erosion of tailings/waste rock along Red Devil Creek and transport of those materials to the Kuskokwim River. It is noted that no post-NTCRA sampling was performed to determine if all tailings/waste rock material in the NTCRA area was removed.

During RI and 2012 baseline monitoring, total concentrations of antimony and arsenic were typically only slightly higher than the dissolved concentrations at each sample location throughout most of Red Devil Creek. This was interpreted in the final RI report to indicate that transport of antimony and arsenic in Red Devil Creek surface water was dominated by dissolved phase transport at the times of monitoring. This is further evidenced by field measurements of turbidity and laboratory analysis of total suspended solids, which indicate low turbidity and total suspended solids concentrations at the times of sampling. Such dissolved phase transport also was concluded to be the dominant transport mechanism at the times of sampling for the RI and 2012 baseline monitoring events. Additional data collected during the spring and fall 2015 monitoring show similar trends in total and dissolved antimony and arsenic concentrations, as well as turbidity and total suspended solids. It is concluded that transport of antimony and arsenic was dominated by dissolved transport at the times of sampling in 2015.

During the RI and 2012 baseline monitoring events, total concentrations of mercury were substantially higher (up to more than an order of magnitude) than the dissolved concentrations at each surface water sample location within and downstream of the Main Processing Area. As was concluded in the RI (see final RI report Section 5.6.2.1), this is interpreted to indicate that mercury transport in surface water in Red Devil Creek included substantial transport by particulate phases that are larger than 0.45 micrometers (the pore size of the filters used to collect the dissolved phase aliquots) at the times of sampling. It also was concluded in the final RI that colloidal transport of mercury occurs in groundwater at the RDM (see final RI report Section 5.4.4). These conclusions are supported by several related lines of evidence discussed in final RI report sections 5.3.1, 5.4.1, 5.4.4, 5.6.1, and 5.6.2. Additional data collected during the spring and fall 2015 surface water and groundwater monitoring show similar trends. It is concluded that transport of mercury included substantial transport as particulates, including mobile colloids, at the times of sampling in 2015.

Table 4-1 Surface Water Sample Collection - Spring 2015

Sample Location ID	Sample ID	Location Description	Sample Date	Sample Description	Sample Analyses and Methods									
					Total TAL Metals EPA 6010B/6020 A/ 7470A	Dissolved TAL Metals EPA 6010B/6020 A/7470A	Total Low-Level Hg EPA 1631E	Dissolved Low-Level Hg EPA 1631E	Total Organic Carbon SW846 9060	Total Suspended Solids SM 2540D	Total Dissolved Solids SM 2540C	Inorganic Ions MCAWW 300.0	Nitrate Nitrite as N MCAWW 353.2	Carbonate Alkalinity as CaCO3 SM 2320B
RD10	0615RD10SW	Red Devil Creek, near upstream end of the Main Processing Area	6/18/2015	Field Sample	X	X	X	X	X	X	X	X	X	X
RD14	0615RD14SW	Red Devil Creek, new station immediately upstream of the newly aligned section (post-NTCRA) of Red Devil Creek, near former station RD04SW	6/18/2015	Field Sample	X	X	X	X	X	X	X	X	X	X
RD15	0615RD15SW	Red Devil Creek, new station immediately downstream of the newly aligned section (post-NTCRA) of Red Devil Creek, near former baseline monitoring station RD13SW	6/18/2015	Field Sample	X	X	X	X	X	X	X	X	X	X
	0615RD50SW		6/18/2015	Field Duplicate of 0615RD15SW	X	X	X	X	X	X	X	X	X	X
RD05	0615RD05SW	Seep on left bank of Red Devil Creek	6/18/2015	Field Sample	X	X	X	X	X	X	X	X	X	X
RD16	0615RD16SW	Red Devil Creek, new station downstream of seep area between RD12 and RD09	6/18/2015	Field Sample	X	X	X	X	X	X	X	X	X	X
RD09	0615RD09SW	Red Devil Creek, near Settling Pond #2	6/18/2015	Field Sample	X	X	X	X	X	X	X	X	X	X
RD06	0615RD06SW	Red Devil Creek, near Settling Pond #3	6/17/2015	Field Sample	X	X	X	X	X	X	X	X	X	X
RD08	0615RD08SW	Red Devil Creek, near confluence of Red Devil Creek and Kuskokwim River, downstream of sediment trap constructed during NTCRA	6/17/2015	Field Sample	X	X	X	X	X	X	X	X	X	X

Key:
EPA = Environmental Protection Agency
Hg = Mercury
MCAWW = Methods for Chemical Analysis of Water and Wastes
TAL = Target Analyte List

Table 4-2 Surface Water Sample Collection - Fall 2015

Sample Location ID	Sample ID	Location Description	Sample Date	Sample Description	Sample Analyses and Methods									
					Total TAL Metals EPA 6010B/6020 A/ 7470A	Dissolved TAL Metals EPA 6010B/6020 A/7470A	Total Low-Level Hg EPA 1631E	Dissolved Low-Level Hg EPA 1631E	Total Organic Carbon SW846 9060	Total Suspended Solids SM 2540D	Total Dissolved Solids SM 2540C	Inorganic Ions MCAWW 300.0	Nitrate Nitrite as N MCAWW 353.2	Carbonate Alkalinity as CaCO3 SM 2320B
RD10SW	0915RD10SW	Red Devil Creek, near upstream end of the Main Processing Area	9/9/2015	Field Sample	X	X	X	X	X	X	X	X	X	X
RD14SW	0915RD14SW	Red Devil Creek, new station immediately upstream of the newly aligned section (post-NTCRA) of Red Devil Creek, near former station RD04SW	9/9/2015	Field Sample	X	X	X	X	X	X	X	X	X	X
	0915RD25SW		9/9/2015	Field Duplicate of 0915RD14SW	X	X	X	X	X	X	X	X	X	X
RD15SW	0915RD15SW	Red Devil Creek, new station immediately downstream of the newly aligned section (post-NTCRA) of Red Devil Creek, near former baseline monitoring station RD13SW	9/9/2015	Field Sample	X	X	X	X	X	X	X	X	X	X
RD05SW	0915RD05SW	Seep on left bank of Red Devil Creek	9/9/2015	Field Sample	X	X	X	X	X	X	X	X	X	X
RD16SW	0915RD16SW	Red Devil Creek, new station downstream of seep area between RD12 and RD09	9/9/2015	Field Sample	X	X	X	X	X	X	X	X	X	X
RD09SW	0915RD09SW	Red Devil Creek, near Settling Pond #2	9/9/2015	Field Sample	X	X	X	X	X	X	X	X	X	X
RD06SW	0915RD06SW	Red Devil Creek, near Settling Pond #3	9/9/2015	Field Sample	X	X	X	X	X	X	X	X	X	X
RD08SW	0915RD08SW	Red Devil Creek, near confluence of Red Devil Creek and Kuskokwim River, downstream of sediment trap constructed during NTCRA	9/9/2015	Field Sample	X	X	X	X	X	X	X	X	X	X

Key:
EPA = Environmental Protection Agency
Hg = Mercury
MCAWW = Methods for Chemical Analysis of Water and Wastes
TAL = Target Analyte List

Table 4-3 Red Devil Creek and Seep Discharge

Monitoring Location	Estimated Discharge (cfs)				
	August 18, 2011	May 26, 2012	September 12, 2012	June 19, 2015	September 2, 2015
RD10	5.5	12.2	4.6	1.3	0.48
RD014	Station not established	Station not established	Station not established	1.4	0.67
RD04	5.9	12.7	3.5	Station not monitored	Station not monitored
RD05 (seep)	0.18	Station not monitored	0.16	0.23	0.19
RD13	Station not established	10.5	3.8	Station not monitored	Station not monitored
RD15	Station not established	Station not established	Station not established	1.4	0.54
RD12	8.2	Station not monitored	Station not monitored	Station not monitored	Station not monitored
RD16	Station not established	Station not established	Station not established	1.6	0.60
RD09	6.0	13.4	3.4	1.4	0.78
RD06	6.8	14.5	3.8	1.5	0.79
RD08	7.2	14.2	3.1	1.9	0.81

Key:

cfs = Cubic feet per second

Table 4-4 Surface Water Sample Results, Spring 2015

Analyte	Station ID		Units	Water Quality Comparison Criteria					RD10	RD14	RD15	RD05	RD16	RD09	RD06	RD08
	Geographic Area			Hardness-Dependent Aquatic Life Water Quality Criterion	National Recommended Water Quality Criteria; Fresh Water; Aquatic Life Criteria; CMC - Acute (1)	National Recommended Water Quality Criteria; Fresh Water; Aquatic Life Criteria; CCC - Chronic (2)	Alaska Water Quality Criteria for Toxics and Other Deleterious Substances; Aquatic Life for Fresh Water; Acute - CMC (3)	Alaska Water Quality Criteria for Toxics and Other Deleterious Substances; Aquatic Life for Fresh Water; Chronic - CCC (4)	Red Devil Creek	Red Devil Creek	Red Devil Creek	Seep	Red Devil Creek	Red Devil Creek	Red Devil Creek	Red Devil Creek
	Sample ID								0615RD10SW	0615RD14SW	0615RD15SW	0615RD05SW	0615RD16SW	0615RD09SW	0615RD06SW	0615RD08SW
	Method															
Total Inorganic Elements																
Aluminum	Metals (ICP)	SW846 6010B	µg/L						190 U	190 U	190 U	190 U	190 U	190 U	190 U	190 U
Antimony	Metals (ICP/MS)	SW846 6020A	µg/L						**1.7**	**28**	**37**	**44**	**47**	**86**	**130**	**160**
Arsenic	Metals (ICP/MS)	SW846 6020A	µg/L						**1.2**	**20**	**17**	**1000**	**75**	**70**	**82**	**86**
Barium	Metals (ICP/MS)	SW846 6020A	µg/L						**22**	**23**	**23**	**96**	**27**	**26**	**27**	**29**
Beryllium	Metals (ICP/MS)	SW846 6020A	µg/L						0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Cadmium	Metals (ICP/MS)	SW846 6020A	µg/L						**0.038 J**	0.028 U	0.028 U	0.028 U	0.028 U	0.028 U	0.028 U	0.028 U
Calcium	Metals (ICP)	SW846 6010B	µg/L						**16000**	**16000**	**16000**	**37000**	**17000**	**17000**	**16000**	**17000**
Chromium	Metals (ICP/MS)	SW846 6020A	µg/L						**0.32 J**	**0.46**	**0.34 J**	**0.26 J**	**0.28 J**	**0.3 J**	**0.3 J**	**0.31 J**
Cobalt	Metals (ICP/MS)	SW846 6020A	µg/L						**0.045 J**	**0.046 J**	**0.081 J**	**4.5**	**0.31 J**	**0.24 J**	**0.26 J**	**0.23 J**
Copper	Metals (ICP/MS)	SW846 6020A	µg/L						0.6 U	0.6 U	0.6 U	0.6 U	**1.2 J**	0.6 U	**0.61 J**	0.6 U
Iron	Metals (ICP)	SW846 6010B	µg/L						180 U	**180 J**	180 U	**2200**	**230 J**	**190 J**	**200 J**	**200 J**
Lead	Metals (ICP/MS)	SW846 6020A	µg/L						**0.071 J**	**0.07 J**	**0.065 J**	**0.11 J**	**0.072 J**	**0.061 J**	**0.062 J**	**0.078 J**
Magnesium	Metals (ICP)	SW846 6010B	µg/L						**8800**	**8400**	**8500**	**38000**	**10000**	**10000**	**9900**	**10000**
Manganese	Metals (ICP/MS)	SW846 6020A	µg/L						**8.8**	**13**	**17**	**300**	**38**	**30**	**35**	**28**
Mercury	Mercury (CVAA)	SW846 7470A	µg/L						0.041 U	0.041 U	**0.07 J**	0.041 U	**0.053 J**	**0.056 J**	**0.43**	**0.17 J**
Nickel	Metals (ICP/MS)	SW846 6020A	µg/L						**0.42 J**	**0.48 J**	**0.57 J**	**17**	**1.6 J**	**1.2 J**	**1.3 J**	**1.3 J**
Potassium	Metals (ICP)	SW846 6010B	µg/L						**240 J**	**260 J**	**250 J**	**1200 J**	**290 J**	**310 J**	**330 J**	**320 J**
Selenium	Metals (ICP/MS)	SW846 6020A	µg/L						0.3 U	**0.3 J**	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U
Silver	Metals (ICP/MS)	SW846 6020A	µg/L						0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
Sodium	Metals (ICP)	SW846 6010B	µg/L						**1800 J**	**1700 J**	**1700 J**	**11000**	**2300**	**2200**	**2300**	**2400**
Thallium	Metals (ICP/MS)	SW846 6020A	µg/L						**0.16 J**	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U
Vanadium	Metals (ICP/MS)	SW846 6020A	µg/L						**0.99 J**	0.98 U	**0.98 J**	0.98 U	0.98 U	0.98 U	0.98 U	**1 J**
Zinc	Metals (ICP/MS)	SW846 6020A	µg/L						1.9 U	**2.3 J**	**6.8 J**	**2.9 J**	**5.1 J**	**5.4 J**	**4.7 J**	**7.1**
Total Low Level Mercury																
Mercury	Total Mercury by EPA 1631	EPA 1631	ng/L						**4.45**	**31.9**	**247**	**46.1**	**83.7**	**83.7**	**113**	**364**
Dissolved Inorganic Elements																
Aluminum	Metals (ICP) (DISSOLVED)	SW846 6010B	µg/L		750	87	750	87	190 U	190 U	190 U	190 U	190 U	190 U	190 U	190 U
Antimony	Metals (ICP/MS) (DISSOLVED)	SW846 6020A	µg/L						**1.6**	**28**	**35**	**19**	**46**	**83**	**130**	**160**
Arsenic	Metals (ICP/MS) (DISSOLVED)	SW846 6020A	µg/L		340	150	340	150	**0.98 J**	**19**	**14**	**850**	**62**	**56**	**68**	**71**
Barium	Metals (ICP/MS) (DISSOLVED)	SW846 6020A	µg/L						**22**	**24**	**22**	**100**	**28**	**26**	**28**	**29**
Beryllium	Metals (ICP/MS) (DISSOLVED)	SW846 6020A	µg/L						0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Cadmium	Metals (ICP/MS) (DISSOLVED)	SW846 6020A	µg/L	H (5)(6)	1.5	0.63	1.7	0.22	0.028 U	0.028 U	0.028 U	0.028 U	0.028 U	0.028 U	0.028 U	0.028 U
Calcium	Metals (ICP) (DISSOLVED)	SW846 6010B	µg/L						**16000**	**17000**	**16000**	**39000**	**18000**	**17000**	**18000**	**18000**
Chromium	Metals (ICP/MS) (DISSOLVED)	SW846 6020A	µg/L	H (5)(6)	497	65	497	65	**0.17 J**	**0.2 J**	**0.15 J**	0.14 U	**0.16 J**	**0.15 J**	**0.16 J**	**0.15 J**
Cobalt	Metals (ICP/MS) (DISSOLVED)	SW846 6020A	µg/L						0.032 U	0.032 U	0.032 U	**3.2**	**0.23 J**	**0.15 J**	**0.16 J**	**0.13 J**
Copper	Metals (ICP/MS) (DISSOLVED)	SW846 6020A	µg/L	H (5)(6)	11	7.8	11	7.8	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U	0.6 U
Iron	Metals (ICP) (DISSOLVED)	SW846 6010B	µg/L			1000		1000	180 U	180 U	180 U	**2000**	180 U	180 U	180 U	180 U
Lead	Metals (ICP/MS) (DISSOLVED)	SW846 6020A	µg/L	H (5)(6)	54	2.1	54	2.1	0.034 U	0.034 U	0.034 U	0.034 U	0.034 U	0.034 U	0.034 U	0.034 U
Magnesium	Metals (ICP) (DISSOLVED)	SW846 6010B	µg/L						**8900**	**9300**	**8800**	**42000**	**11000**	**11000**	**11000**	**11000**
Manganese	Metals (ICP/MS) (DISSOLVED)	SW846 6020A	µg/L						**3.1**	**6.5**	**11**	**300**	**32**	**24**	**28**	**22**
Mercury	Mercury (CVAA) (DISSOLVED)	SW846 7470A	µg/L		1.4	0.77	1.4	0.77	0.041 U	0.041 U	0.041 U	0.041 U	0.041 U	0.041 U	0.041 U	0.041 U
Nickel	Metals (ICP/MS) (DISSOLVED)	SW846 6020A	µg/L	H (5)(6)	406	45	406	45	0.4 U	0.4 U	0.4 U	**13**	**1.1 J**	**0.81 J**	**0.91 J**	**0.83 J**
Potassium	Metals (ICP) (DISSOLVED)	SW846 6010B	µg/L						**240 J**	**290 J**	**260 J**	**1200 J**	**330 J**	**310 J**	**350 J**	**360 J**
Selenium	Metals (ICP/MS) (DISSOLVED)	SW846 6020A	µg/L						**0.63 J**	**0.51 J**	**0.48 J**	0.3 U	**0.54 J**	**0.36 J**	**0.49 J**	**0.44 J**
Silver	Metals (ICP/MS) (DISSOLVED)	SW846 6020A	µg/L	H (5)	2.4	—	2.4	—	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
Sodium	Metals (ICP) (DISSOLVED)	SW846 6010B	µg/L						**1600 J**	**1700 J**	**1600 J**	**11000**	**2300**	**2100**	**2300**	**2300**
Thallium	Metals (ICP/MS) (DISSOLVED)	SW846 6020A	µg/L						0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U
Vanadium	Metals (ICP/MS) (DISSOLVED)	SW846 6020A	µg/L						0.98 U	0.98 U	0.98 U	0.98 U	0.98 U	0.98 U	0.98 U	0.98 U
Zinc	Metals (ICP/MS) (DISSOLVED)	SW846 6020A	µg/L	H (5)(6)	102	103	102	103	1.9 U	1.9 U	**5.7 J**	1.9 U	**5.1 J**	**4 J**	**4.6 J**	**5.5 J**
Dissolved Low Level Mercury																
Mercury	Dissolved Mercury by EPA 1631	EPA 1631	ng/L		1400	770	1400	770	**2.55**	**11.2**	**11**	**9.46**	**6.32**	**8.99**	**14.8**	**13.8**

Table 4-4 Surface Water Sample Results, Spring 2015

Analyte	Station ID		Units	Water Quality Comparison Criteria					RD10	RD14	RD15	RD05	RD16	RD09	RD06	RD08
	Geographic Area			Hardness-Dependent Aquatic Life Water Quality Criterion	National Recommended Water Quality Criteria; Fresh Water; Aquatic Life Criteria; CMC - Acute (1)	National Recommended Water Quality Criteria; Fresh Water; Aquatic Life Criteria; CCC - Chronic (2)	Alaska Water Quality Criteria for Toxics and Other Deleterious Substances; Aquatic Life for Fresh Water; Acute - CMC (3)	Alaska Water Quality Criteria for Toxics and Other Deleterious Substances; Aquatic Life for Fresh Water; Chronic - CCC (4)	Red Devil Creek	Red Devil Creek	Red Devil Creek	Seep	Red Devil Creek	Red Devil Creek	Red Devil Creek	Red Devil Creek
	Sample ID								0615RD10SW	0615RD14SW	0615RD15SW	0615RD05SW	0615RD16SW	0615RD09SW	0615RD06SW	0615RD08SW
	Method															
General Chemistry																
Total Organic Carbon	Organic Carbon, Total (TOC)	SW846 9060	mg/L						**1.9**	**1.5**	**1.5**	**1.2**	**1.4**	**1.6**	**1.7**	**1.6**
Total Dissolved Solids	Solids, Total Dissolved (TDS)	SM 2540C	mg/L						**73 J**	**79 J**	**79 J**	**270 J**	**94 J**	**110 J**	**120 J**	**120 J**
Total Suspended Solids	Solids, Total Suspended (TSS)	SM 2540D	mg/L						**2 J**	2 UJ	2 UJ	2 UJ	2 UJ	**2 J**	2 UJ	**40 J**
Chloride	Anions, Ion Chromatography	MCAWW 300.0	mg/L						**0.41 J**	**0.4 J**	**0.39 J**	**0.68 J**	**0.39 J**	**0.41 J**	**0.41 J**	**0.45 J**
Fluoride	Anions, Ion Chromatography	MCAWW 300.0	mg/L						**0.05 J**	**0.05 J**	**0.05 J**	**0.14**	**0.06 J**	**0.05 J**	**0.06 J**	**0.06 J**
Sulfate	Anions, Ion Chromatography	MCAWW 300.0	mg/L						**8**	**8.3**	**8.4**	**29**	**9.8**	**9.6**	**9.8**	**10**
Carbonate Alkalinity as CaCO3	Alkalinity	SM 2320B	mg/L						5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Bicarbonate Alkalinity as CaCO3	Alkalinity	SM 2320B	mg/L						**76**	**70**	**69**	**250**	**100**	**81**	**79**	**79**
Hydroxide Alkalinity as CaCO3	Alkalinity	SM 2320B	mg/L						5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Alkalinity	Alkalinity	SM 2320B	mg/L						**76**	**70**	**69**	**250**	**100**	**81**	**79**	**79**
Nitrate Nitrite as N	Nitrogen, Nitrate-Nitrite	MCAWW 353.2	mg/L						**0.12**	**0.13**	**0.13**	0.005 U	**0.12**	**0.13**	**0.12**	**0.17**
Hardness	Hardness as CaCO3	Calculated	mg/L						**77**	**81**	**76**	**271**	**90**	**88**	**90**	**90**
Field Water Quality Parameters																
Temperature	Field Measurement		Deg C						9.61	9.18	8.29	2.7	6.96	6.34	9.63	10.31
pH	Field Measurement		pH Units						7.94	7.8	7.99	7.13	7.63	7.4	6.04	7.6
Conductivity	Field Measurement		mS/cm						0.16	0.16	0.162	0.547	0.186	0.181	0.171	0.076
Turbidity	Field Measurement		NTU						0	0	0	0.3	0.1	0.1	0	0
Dissolved Oxygen	Field Measurement		mg/L						10.83	9.85	11.27	0	8.55	9.24	12.16	8.63
Oxidation-Reduction Potential	Field Measurement		mV						71	75	80	-93	78	151	67	183

Key
µg/L = Micrograms per liter
ADEC = Alaska Department of Environmental Conservation
Bold = Detected
CCC = Criteria Continuous Concentration
CMC = Criteria Maximum Concentration
Deg C = Degrees Celsius.
EPA = United States Environmental Protection Agency
GC/MS = Gas Chromatography/Mass Spectrometry
H = Hardness-dependent water quality criterion for aquatic life.
ICP/ MS = Inductively coupled plasma/mass spectrometry
J = The analyte was detected. The associated result is estimated.
mg/L = milligrams per liter
mS/cm = Millisiemens per centimeter
mV = Millivolts
ng/L = Nanograms per liter
NTU = Nephelometric turbidity units
U = The analyte was analyzed for but not detected. The value provided is the method detection limit.
UJ = The analyte was analyzed for but not detected. The associated reporting limit is estimated.

Notes
(1) USEPA. 2016. National Recommended Water Quality Criteria - Aquatic Life Criteria. Accessed on August 23, 2016 at: https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table#table
(2) USEPA. 2016. National Recommended Water Quality Criteria - Aquatic Life Criteria. Accessed on August 23, 2016 at: https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table#table
(3) ADEC. 2008. Alaska Water Quality Criteria Manual for Toxic and Other Deleterious Organic and Inorganic Substances (as amended through December 12, 2008). ADEC, Anchorage, Alaska
(4) ADEC. 2008. Alaska Water Quality Criteria Manual for Toxic and Other Deleterious Organic and Inorganic Substances (as amended through December 12, 2008). ADEC, Anchorage, Alaska
(5) Calculated total hardness as CaCO3 = Calcium Hardness (mg/L as CaCO3) + Magnesium Hardness (mg/L as CaCO3)
(6) Hardness-adjusted criterion value was calculated following EPA 2016 and ADEC 2008. A total hardness value of 84.6 mg/L as CaCO3, based on the average value for Red Devil Creek surface water samples, is assumed.

Table 4-5 Surface Water Sample Results, Fall 2015

Analyte	Station ID		Units	Water Quality Comparison Criteria					RD10	RD14	RD15	RD05	RD16	RD09	RD06	RD08
	Geographic Area			Hardness-Dependent Aquatic Life Water Quality Criterion	National Recommended Water Quality Criteria; Fresh Water; Aquatic Life Criteria; CMC - Acute (1)	National Recommended Water Quality Criteria; Fresh Water; Aquatic Life Criteria; CCC - Chronic (2)	Alaska Water Quality Criteria for Toxics and Other Deleterious Substances; Aquatic Life for Fresh Water; Acute - CMC (3)	Alaska Water Quality Criteria for Toxics and Other Deleterious Substances; Aquatic Life for Fresh Water; Chronic - CCC (4)	Red Devil Creek	Red Devil Creek	Red Devil Creek	Seep	Red Devil Creek	Red Devil Creek	Red Devil Creek	Red Devil Creek
	Sample ID								0915RD10SW	0915RD14SW	0915RD15SW	0915RD05SW	0915RD16SW	0915RD09SW	0915RD06SW	0915RD08SW
	Method															
Total Inorganic Elements																
Aluminum	Metals (ICP)	SW846 6010B	µg/L						190 U	190 U	190 U	190 U	190 U	190 U	190 U	190 U
Antimony	Metals (ICP/MS)	SW846 6020A	µg/L						**1.6**	**8.5**	**26**	**470**	**46**	**68**	**9.1**	**9.4**
Arsenic	Metals (ICP/MS)	SW846 6020A	µg/L						**1.5**	**6.4**	**13**	**26**	**55**	**58**	**39**	**40**
Barium	Metals (ICP/MS)	SW846 6020A	µg/L						**27**	**25**	**27**	**28**	**30**	**30**	**84**	**88**
Beryllium	Metals (ICP/MS)	SW846 6020A	µg/L						0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Cadmium	Metals (ICP/MS)	SW846 6020A	µg/L						**0.051 J**	0.028 U	0.028 U	**0.33 J**	0.028 U	**0.1 J**	**0.08 J**	**0.14 J**
Calcium	Metals (ICP)	SW846 6010B	µg/L						**20000**	**20000**	**21000**	**40000**	**21000**	**21000**	**20000**	**21000**
Chromium	Metals (ICP/MS)	SW846 6020A	µg/L						**0.27 J**	**0.83**	**0.38 J**	**0.34 J**	**0.28 J**	**0.23 J**	**1.3**	**0.31 J**
Cobalt	Metals (ICP/MS)	SW846 6020A	µg/L						**0.045 J**	**0.057 J**	**0.069 J**	0.032 U	**0.24 J**	**0.21 J**	**32**	**33**
Copper	Metals (ICP/MS)	SW846 6020A	µg/L						0.6 U	0.6 U	0.6 U	**0.66 J**	0.6 U	0.6 U	0.6 U	0.6 U
Iron	Metals (ICP)	SW846 6010B	µg/L						**270 J**	**300 J**	**300 J**	**3200**	**390 J**	**320 J**	**330 J**	**320 J**
Lead	Metals (ICP/MS)	SW846 6020A	µg/L						0.034 U	0.034 U	0.034 U	**0.066 J**	0.034 U	0.034 U	**0.074 J**	**0.077 J**
Magnesium	Metals (ICP)	SW846 6010B	µg/L						**11000**	**11000**	**12000**	**43000**	**12000**	**13000**	**12000**	**13000**
Manganese	Metals (ICP/MS)	SW846 6020A	µg/L						**20**	**20**	**24**	**2.3**	**40**	**38**	**2600**	**2600**
Mercury	Mercury (CVAA)	SW846 7470A	µg/L						0.041 U	0.041 U	**0.056 J**	0.041 U	**0.12 J**	0.041 U	**0.054 J**	0.041 U
Nickel	Metals (ICP/MS)	SW846 6020A	µg/L						0.4 U	0.4 U	0.4 U	**0.9 J**	**1 J**	**0.97 J**	**100**	**100**
Potassium	Metals (ICP)	SW846 6010B	µg/L						**290 J**	**280 J**	**320 J**	**1200 J**	**330 J**	**360 J**	**380 J**	**370 J**
Selenium	Metals (ICP/MS)	SW846 6020A	µg/L						**0.46 J**	**0.44 J**	**0.46 J**	**0.33 J**	**0.39 J**	**0.43 J**	0.3 U	0.3 U
Silver	Metals (ICP/MS)	SW846 6020A	µg/L						0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
Sodium	Metals (ICP)	SW846 6010B	µg/L						**1600 J**	**1700 J**	**1800 J**	**13000**	**2100**	**2100**	**2300**	**2300**
Thallium	Metals (ICP/MS)	SW846 6020A	µg/L						0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U
Vanadium	Metals (ICP/MS)	SW846 6020A	µg/L						0.98 U	0.98 U	0.98 U	0.98 U	0.98 U	0.98 U	0.98 U	0.98 U
Zinc	Metals (ICP/MS)	SW846 6020A	µg/L						1.9 U	1.9 U	**6.2 J**	**2.4 J**	**6.4 J**	**6.1 J**	**5.7 J**	**6.1 J**
Total Low Level Mercury																
Mercury	Total Mercury by EPA 1631	EPA 1631	ng/L						**3.94**	**10.1**	**215**	**37.6 J**	**383**	**268**	**659**	**683**
Dissolved Inorganic Elements																
Aluminum	Metals (ICP) (DISSOLVED)	SW846 6010B	µg/L		750	87	750	87	190 U	190 U	190 U	190 U	190 U	190 U	190 U	190 U
Antimony	Metals (ICP/MS) (DISSOLVED)	SW846 6020A	µg/L						**1.4**	**8.6**	**24**	**240**	**41**	**66**	**0.59**	**120**
Arsenic	Metals (ICP/MS) (DISSOLVED)	SW846 6020A	µg/L		340	150	340	150	**1.2**	**6.2**	**12**	**590**	**48**	**53**	**32**	**67**
Barium	Metals (ICP/MS) (DISSOLVED)	SW846 6020A	µg/L						**25**	**26**	**25**	**88**	**28**	**29**	**84**	**30**
Beryllium	Metals (ICP/MS) (DISSOLVED)	SW846 6020A	µg/L						0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Cadmium	Metals (ICP/MS) (DISSOLVED)	SW846 6020A	µg/L	H (5)(6)	1.8	0.72	2.0	0.25	**0.043 J**	**0.028 U**	**0.028 U**	**0.47**	**0.3 J**	**0.028 U**	**0.28 J**	**0.32 J**
Calcium	Metals (ICP) (DISSOLVED)	SW846 6010B	µg/L						**20000**	**20000**	**20000**	**39000**	**20000**	**21000**	**21000**	**21000**
Chromium	Metals (ICP/MS) (DISSOLVED)	SW846 6020A	µg/L	H (5)(6)	570	74	572	74	**0.32 J**	**0.32 J**	**0.17 J**	**1.3**	**0.18 J**	**0.19 J**	**0.19 J**	**0.2 J**
Cobalt	Metals (ICP/MS) (DISSOLVED)	SW846 6020A	µg/L						0.032 U	**0.056 J**	**0.047 J**	**7.6**	**0.16 J**	**0.15 J**	**0.071 J**	**0.14 J**
Copper	Metals (ICP/MS) (DISSOLVED)	SW846 6020A	µg/L	H (5)(6)	14	9.0	14	9.0	0.6 U	0.6 U	0.6 U	**1.2 J**	0.6 U	0.6 U	0.6 U	0.6 U
Iron	Metals (ICP) (DISSOLVED)	SW846 6010B	µg/L			1000		1000	180 U	180 U	**200 J**	**2600**	**240 J**	**250 J**	**200 J**	180 U
Lead	Metals (ICP/MS) (DISSOLVED)	SW846 6020A	µg/L	H (5)(6)	65	2.5	65	2.5	0.034 U	0.034 U	0.034 U	**0.15 J**	**0.047 J**	0.034 U	**0.054 J**	0.034 U
Magnesium	Metals (ICP) (DISSOLVED)	SW846 6010B	µg/L						**11000**	**11000**	**11000**	**42000**	**12000**	**13000**	**13000**	**13000**
Manganese	Metals (ICP/MS) (DISSOLVED)	SW846 6020A	µg/L						**8.7**	**15**	**18**	**740**	**33 J**	**33**	**130**	**30**
Mercury	Mercury (CVAA) (DISSOLVED)	SW846 7470A	µg/L		1.4	0.77	1.4	0.77	0.041 U	0.041 U	0.041 U	0.041 U	0.041 U	0.041 U	0.041 U	0.041 U
Nickel	Metals (ICP/MS) (DISSOLVED)	SW846 6020A	µg/L	H (5)(6)	470	52	470	52	0.4 U	0.4 U	0.4 U	**35**	**0.83 J**	**0.82 J**	0.4 U	**0.92 J**
Potassium	Metals (ICP) (DISSOLVED)	SW846 6010B	µg/L						**260 J**	**270 J**	**300 J**	**1200 J**	**330 J**	**350 J**	**340 J**	**370 J**
Selenium	Metals (ICP/MS) (DISSOLVED)	SW846 6020A	µg/L						**0.38 J**	**0.42 J**	**0.41 J**	**0.59 J**	**0.36 J**	**0.47 J**	0.3 U	**0.44 J**
Silver	Metals (ICP/MS) (DISSOLVED)	SW846 6020A	µg/L	H (5)	3.2	—	3.2	—	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U
Sodium	Metals (ICP) (DISSOLVED)	SW846 6010B	µg/L						**1600 J**	**1700 J**	**1700 J**	**13000**	**2000**	**2100**	**2300**	**2400**
Thallium	Metals (ICP/MS) (DISSOLVED)	SW846 6020A	µg/L						0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U	0.14 U
Vanadium	Metals (ICP/MS) (DISSOLVED)	SW846 6020A	µg/L						0.98 U	0.98 U	0.98 U	**1.7 J**	0.98 U	0.98 U	0.98 U	0.98 U
Zinc	Metals (ICP/MS) (DISSOLVED)	SW846 6020A	µg/L	H (5)(6)	118	119	118	119	1.9 U	1.9 U	**5.4 J**	**11**	**5.9 J**	**5.2 J**	1.9 U	**7.8**
Dissolved Low Level Mercury																
Mercury	Dissolved Mercury by EPA 1631	EPA 1631	ng/L		1400	770	1400	770	1.96 U	**3.32**	**25.9**	1.48 U	**9.61**	**23.5**	**13.3**	**11.7**

Table 4-5 Surface Water Sample Results, Fall 2015

Analyte	Station ID		Units	Water Quality Comparison Criteria					RD10	RD14	RD15	RD05	RD16	RD09	RD06	RD08
	Geographic Area			Hardness-Dependent Aquatic Life Water Quality Criterion	National Recommended Water Quality Criteria; Fresh Water; Aquatic Life Criteria; CMC - Acute (1)	National Recommended Water Quality Criteria; Fresh Water; Aquatic Life Criteria; CCC - Chronic (2)	Alaska Water Quality Criteria for Toxics and Other Deleterious Substances; Aquatic Life for Fresh Water; Acute - CMC (3)	Alaska Water Quality Criteria for Toxics and Other Deleterious Substances; Aquatic Life for Fresh Water; Chronic - CCC (4)	Red Devil Creek	Red Devil Creek	Red Devil Creek	Seep	Red Devil Creek	Red Devil Creek	Red Devil Creek	Red Devil Creek
	Sample ID								0915RD10SW	0915RD14SW	0915RD15SW	0915RD05SW	0915RD16SW	0915RD09SW	0915RD06SW	0915RD08SW
	Method															
General Chemistry																
Total Organic Carbon	Organic Carbon, Total (TOC)	SW846 9060	mg/L						**2.3**	**2.4**	**2.4**	**1.2**	**2.5**	**2.4**	**2.4**	**2.4**
Total Dissolved Solids	Solids, Total Dissolved (TDS)	SM 2540C	mg/L						**98**	**120**	**110**	**290**	**130**	**130**	**120**	**110**
Total Suspended Solids	Solids, Total Suspended (TSS)	SM 2540D	mg/L						2 U	2 U	2 U	**5.4**	2 U	2 U	2 U	2 U
Chloride	Anions, Ion Chromatography	MCAWW 300.0	mg/L						**0.55**	**0.57**	**0.5**	**0.72**	**0.56**	**0.58**	**0.57**	**0.55**
Fluoride	Anions, Ion Chromatography	MCAWW 300.0	mg/L						**0.05 J**	**0.05 J**	**0.05 J**	**0.14 J**	**0.05 J**	**0.07 J**	**0.05 J**	**0.07 J**
Sulfate	Anions, Ion Chromatography	MCAWW 300.0	mg/L						**8.1**	**8.4**	**8.7**	**26**	**9.6**	**9.8**	**10**	**10**
Carbonate Alkalinity as CaCO3	Alkalinity	SM 2320B	mg/L						5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Bicarbonate Alkalinity as CaCO3	Alkalinity	SM 2320B	mg/L						**87**	**86**	**81**	**250**	**87**	**89**	**91**	**110**
Hydroxide Alkalinity as CaCO3	Alkalinity	SM 2320B	mg/L						5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Alkalinity	Alkalinity	SM 2320B	mg/L						**87**	**86**	**81**	**250**	**87**	**89**	**91**	**110**
Nitrate Nitrite as N	Nitrogen, Nitrate-Nitrite	MCAWW 353.2	mg/L						**0.14**	**0.14**	**0.14**	0.005 U	**0.13**	**0.13**	**0.12**	**0.12**
Hardness	Hardness as CaCO3	Calculated	mg/L						**95**	**95**	**95**	**271**	**99**	**106**	**106**	**106**
Field Water Quality Parameters																
Temperature	Field Measurement		Deg C						8.22	7.95	8.04	4.09	7.96	8.01	7.94	8.46
pH	Field Measurement		pH Units						7.63	7.74	7.78	7.35	7.67	7.58	7.57	7.19
Conductivity	Field Measurement		mS/cm						0.212	0.213	0.213	0.594	0.231	0.229	0.235	0.231
Turbidity	Field Measurement		NTU						0	0	0	1.5	0	0	0	0
Dissolved Oxygen	Field Measurement		mg/L						17.15	24.44	4.44	0	5.4	12.3	31.07	29.01
Oxidation-Reduction Potential	Field Measurement		mV						3	-77	-88	-69	-56	-23	-1	45

Key
µg/L = Micrograms per liter
ADEC = Alaska Department of Environmental Conservation
Bold = Detected
CCC = Criteria Continuous Concentration
CMC = Criteria Maximum Concentration
Deg C = Degrees Celsius.
EPA = United States Environmental Protection Agency
GC/MS = Gas Chromatography/Mass Spectrometry
H = Hardness-dependent water quality criterion for aquatic life.
ICP/ MS = Inductively coupled plasma/mass spectrometry
J = The analyte was detected. The associated result is estimated.
mg/L = milligrams per liter
mS/cm = Millisiemens per centimeter
mV = Millivolts
ng/L = Nanograms per liter
NTU = Nephelometric turbidity units
U = The analyte was analyzed for but not detected. The value provided is the method detection limit.
UJ = The analyte was analyzed for but not detected. The associated reporting limit is estimated.
Shading = Sample concentration exceeds one or more WQC value.

Notes
(1) USEPA. 2016. National Recommended Water Quality Criteria - Aquatic Life Criteria. Accessed on August 23, 2016 at: https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table#table
(2) USEPA. 2016. National Recommended Water Quality Criteria - Aquatic Life Criteria. Accessed on August 23, 2016 at: https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table#table
(3) ADEC. 2008. Alaska Water Quality Criteria Manual for Toxic and Other Deleterious Organic and Inorganic Substances (as amended through December 12, 2008). ADEC, Anchorage, Alaska
(4) ADEC. 2008. Alaska Water Quality Criteria Manual for Toxic and Other Deleterious Organic and Inorganic Substances (as amended through December 12, 2008). ADEC, Anchorage, Alaska
(5) Calculated total hardness as CaCO3 = Calcium Hardness (mg/L as CaCO3) + Magnesium Hardness (mg/L as CaCO3)
(6) Hardness-adjusted criterion value was calculated following EPA 2016 and ADEC 2008. A total hardness value of 100.5 mg/L as CaCO3, based on the average value for Red Devil Creek surface water samples, is assumed.

Figure 4-1. Concentration Versus Distance, Red Devil Creek and Seep Surface Water

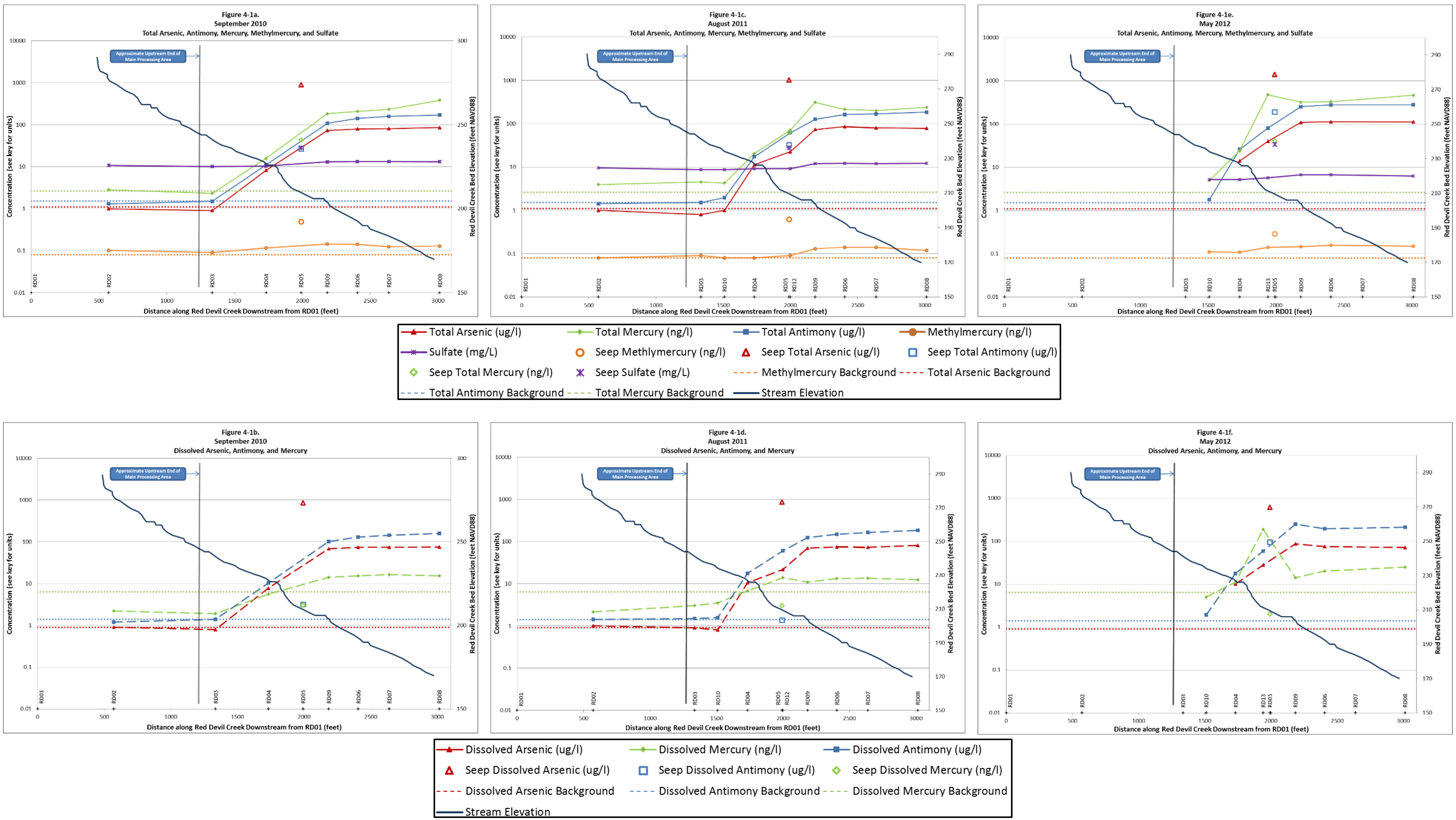
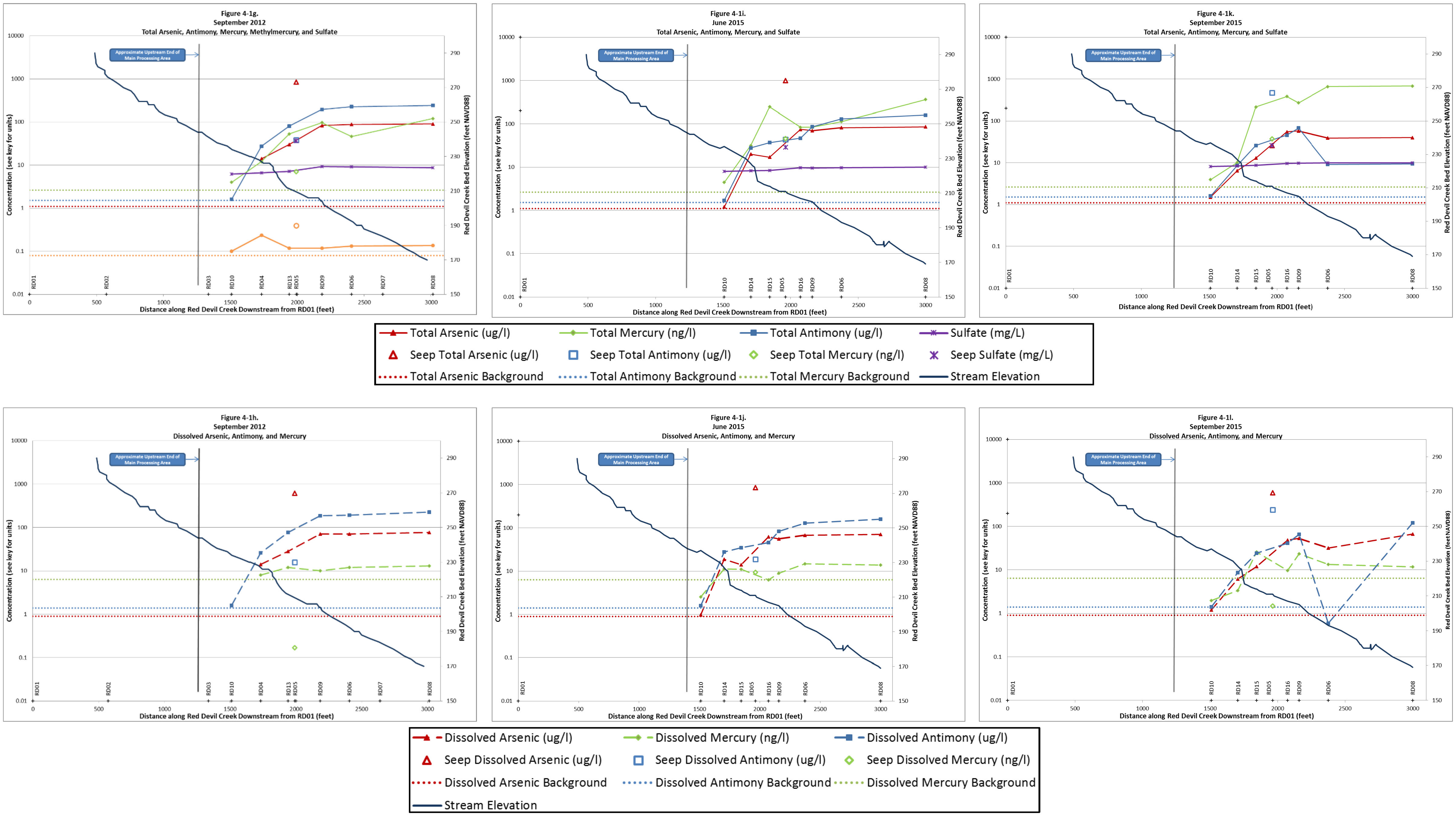


Figure 4-1. Concentration Versus Distance, Red Devil Creek and Seep Surface Water



5 Kuskokwim River Investigations

This chapter discusses the results and conclusions derived from sediment characterization performed as part of the RI Supplement and RI as well as BLM studies addressing Kuskokwim River biota. Project-specific data were used to assess contaminant transport into and between media in Red Devil Creek, the Kuskokwim River, and other contaminant source areas. As previously noted, the project area lies within a larger mineralized region, which locally contributes to naturally high concentrations of mercury and other metals in the environment. Where possible, multiple lines of evidence were used to address critical questions and maximize use of existing data. Of particular interest is the question of whether methylmercury is bioaccumulating in the Kuskokwim River food chain, particularly in upper trophic-level fish that may be consumed by local residents.

5.1 Kuskokwim River Sediment RI Supplement Investigations

During the RI, bed surface sediment samples were collected at 17 locations along the shoreline of the Kuskokwim River in 2010 and 2011, and from 55 offshore locations in 2011 and 2012. The RI sediment sample results showed relatively low concentrations of COCs in background samples located upriver of the Red Devil Creek delta, and elevated concentrations at the Red Devil Creek delta and downriver locations. The COC concentrations were generally highest at the Red Devil Creek delta and exhibited trends of generally decreasing concentrations with distance downriver and cross-river from the delta. These results support the RI conclusion that materials that enter Red Devil Creek by erosion and mass wasting are subject to surface water transport downstream within Red Devil Creek, and that some of the materials transported via Red Devil Creek to its mouth have been subject to further downriver transportation and deposition in the Kuskokwim River (E & E 2014).

The RI Supplement sediment characterization activities were designed to address data gaps associated with sediment in the Kuskokwim River near and downriver of Red Devil Creek. Additional sediment characterization was performed to gather the types of additional information identified in Section 3.3 of the RI Supplement Work Plan. The supplemental RI sediment characterization was designed to meet the following objectives:

- Assess the cross-river and downriver extents of contamination in Kuskokwim River sediment.
- Assess the turbidity of Kuskokwim River water.

- Assess the toxicity of sediments to benthic macroinvertebrates.
- Assess the potential for methylation and bioaccumulation of mercury.

Data collected to meet these objectives, in conjunction with data collected during the RI and BLM Kuskokwim River investigations, are used to inform site-wide remedial decision making.

Additional sediment characterization was performed using a combination of field data collection and the results of laboratory analysis for selected analytical parameters of sediment samples collected at offshore sediment sample locations in the Kuskokwim River. The sediment sampling and laboratory analysis included the following:

- Twelve sediment samples were collected from the area upriver of, in the vicinity of, and downriver of Red Devil Creek delta. These samples were analyzed for total TAL inorganic elements, TOC, and grain size distribution. These samples also were analyzed for toxicity using a *Hyallela azteca* 28-day test. Six of the samples also were analyzed for methylmercury and mercury SSE.
- Twelve sediment samples were collected from locations cross-river and downriver from the areas of elevated concentrations of antimony, arsenic, and mercury documented during the RI. Each of these samples was analyzed for total TAL inorganic elements, TOC, and grain size distribution. In addition, eight of these samples also were analyzed for methylmercury.
- Four sediment samples were collected from locations near the northeast bank of the Kuskokwim River along two previously defined RI sample transects near the Red Devil Creek delta. Two samples were collected from one transect located upstream of Red Devil Creek, and two samples were collected from one transect located a short distance downstream of Red Devil Creek. Along each transect, one sample was collected from shallow water near the shore approximately 10 to 20 feet from the northeast bank, and a second sample was collected approximately 50 feet from the northeast bank. All four samples were analyzed for TAL inorganic elements only.

In addition to collection of sediment samples, the water column at all sampling locations was analyzed in the field for turbidity.

It should be noted that sediment samples were not analyzed for acid volatile sulfides (AVS):simultaneously extracted metals (SEM) because AVS are formed in anoxic sediments. Anoxic sediments occur in quiescent environments and typically contain high concentrations of fines and organic carbon. Such sediments are not prevalent in the Kuskokwim River near the RDM site due to the high energy of the river near the site.

5.1.1 RI Supplement Sediment Sampling

Sediment samples were collected during the September 2015 RI Supplement field event. The locations of the samples are described in Table 5-1 and shown in Figures 5-1 and 5-2. As described in the RI Supplement Work Plan, selection of planned sample locations was based in part on results of previous RI sediment samples, collected in 2010, 2011, and 2012, and locations and BLM periphyton samples collected in 2014 (see Section 5.2.2). Locations of RI sediment samples are illustrated in Figures 5-1 and 5-2. A summary of laboratory analytical results for the 2010, 2011, and 2012 RI Kuskokwim River sediment samples is presented in Table 4-33 of the final RI report and Table 4-1 of the final RI Supplement Work Plan. RI sediment sample results also are discussed in Section 5.3. Locations of BLM 2014 periphyton samples that are within the area of the 2015 RI Supplement sediment sampling are shown in Figures 5-1 and 5-2. Locations of all of the BLM 2014 periphyton samples, including those within the extent of the RI Supplement sampling as well as those collected further upriver and downriver, are shown in Figure 5-3. It is noted that the provided periphyton sample location data that were used to generate figures in the RI Supplement Work Plan contained several errors; the corrected location information is represented in Figures 5-1 through 5-3. Collection of the 2014 periphyton samples is described in Section 5.2.2.

The sampling team attempted to collect each sediment sample at the location identified in the RI Supplement Work Plan. For some samples, the actual sample locations varied from planned locations due to conditions encountered at the time of sampling. Significant deviations in the sample locations are discussed in Section 5.1.3.

Sediment sampling and other field procedures were performed in accordance with the Field Sampling Plan, except as noted below. Samples were collected from a flat-bottomed vessel outfitted with an A-frame and electric winch, fathometer, and Global Positioning System. The vessel and sampling equipment were operated by operators under subcontract to E & E. The vessel was positioned over the sampling stations by either anchoring or live-boating. Sediment samples were collected with a hand-auger; van Veen sampler; or clean, dedicated plastic scoop. As necessary, multiple grabs were collected to obtain adequate sample volume for the planned laboratory analyses. The type of sampling equipment used for each sample is identified in Table 5-1. E & E staff collected the samples for the laboratory analyses listed in Table 5-1. Sediment samples were submitted to TestAmerica, Seattle, Washington, for laboratory analysis. TestAmerica performed analysis for total TAL inorganic elements, TOC, and grain size distribution. Brooks Rand Labs, Seattle, Washington, under sub-subcontract to TestAmerica, performed analyses for methylmercury and mercury SSE. Northwestern Aquatic Sciences, Newport, Oregon, under sub-subcontract to TestAmerica performed sediment toxicity testing.

5.1.2 River Turbidity Measurement

At each RI Supplement sediment sample location the turbidity of river water was measured with a calibrated field water quality meter. At each sample location the water quality probe was lowered to approximately mid-depth and turbidity was measured in situ.

5.1.3 Deviations from the Field Sampling Plan

The sediment sample from location KR086 was collected at a location approximately 150 feet from the planned location, which was co-located with RI sample location KR54. The proposed sampling location KR086 was located near the downstream end of the Red Devil Creek delta in an area of relatively swift current. This current had apparently resulted in relatively heavy armoring of the river bottom (i.e., very gravelly/cobbly conditions). More than 12 attempts were made to collect a sample at this location. Subsequently, sampling was attempted at three alternate nearby locations. The attempts at the first three alternate locations also were unsuccessful due to swift current and armoring. A sample was eventually collected at a fifth location in a relatively calm and shallow eddy downriver of the Red Devil Creek delta.

The sediment toxicity sample planned for collection at location KR101, located on the northeast bank downriver of the RDM, was not collected at that location. At location KR101, the current was relatively swift and the bottom was relatively heavily armored (i.e., very gravelly/cobbly conditions), with little finer-grained sediment. Although it was feasible to collect enough sediment at KR101 for the other analyses (see Table 5-1), it was not feasible to collect adequate sediment volume for the toxicity test. Therefore, a sample for toxicity testing was collected at alternate location KR099, which is also located on the northeast bank downriver of the RDM. Location KR099 is the next location upriver from KR101, and is situated on the inside of the river bend in a lower energy environment with more abundant, finer-grained sediment. Collection of the toxicity sample at location KR100 also was considered prior to toxicity sample collection at location KR99. However, location KR100 is situated near a landing for small watercraft, and petroleum odors and sheens were observed at that location at the time of sampling. Due to the concern that such petroleum impacts could potentially affect the toxicity testing results, location KR100 was not selected for collection of the toxicity test sample. The nature of the petroleum odor and sheen at location KR100 was not investigated as part of the RI Supplement. However, it is noted that the odor and sheen were noted at a boat landing near Red Devil village, and no other observations of petroleum contamination were noted at any of the other RI Supplement sediment sampling locations or RI sediment sampling locations. Based on these observations, it is likely that the petroleum contamination noted at KR100 is not related to the RDM.

5.2 BLM Kuskokwim River Investigations

Beginning in 2010, BLM began a study to comprehensively examine mercury, methylmercury, and other metals in the Kuskokwim River basin in proximity to the RDM. Those studies pertinent to the present evaluation of Kuskokwim River sediment near the RDM are summarized below.

5.2.1 Fish Movement and Tissue Sampling

In 2010 and 2011, the BLM in cooperation with the U.S. Fish and Wildlife Service (USFWS) and Alaska Department of Fish and Game measured mercury concentrations in small muscle biopsies from norther pike (*Esox lucius*) and burbot (*Lota lota*) equipped with radio transmitters, and related the concentrations to fish location and movements in the middle Kuskokwim River region.

The goal of the study was to establish a baseline condition of several different metals in fish tissue, including mercury and methylmercury, along a roughly 270-mile stretch of the Kuskokwim River and selected tributaries between the Aniak and Takotna Rivers (Matz et al. 2017).

The study design and methods are described in Matz et al. (2017). Matz et al. (2017) divided the mainstream Kuskokwim River and major tributaries within the study area into eight watersheds or reaches (see Figure 5-4). These watersheds or reaches are:

1) Kusko-Aniak: Mainstem Kuskokwim River from Aniak to George River, including Aniak and Oskawalik Rivers;
2) George: George River, including East and South Forks;
3) Kusko above George: Mainstem Kuskokwim River upstream of George River to Sleetmute, Alaska (the reach that includes the RDM);
4) Holitna: Holitna and Hoholitna Rivers;
5) Kusko-Stony: Mainstem Kuskokwim River from Holitna River to Stony River and including Stony River and Moose Creek;
6) Kusko above Sleetmute: Mainstem Kuskokwim River from Stony River to Selatna River, including Swift and Tatlawiksuk Rivers;
7) Kusko above Selatna: Mainstem Kuskokwim River from Selatna River to North Fork of Kuskokwim River; and
8) Takotna: The Takotna River including the Nixon Fork.

As shown in Figure 5-4, the river and tributary reaches evaluated ranged in length from approximately 50 kilometers to over 200 kilometers. Matz et al. (2017) did not report exact estimates of reach length or watershed area.

Matz et al. (2017) collected small muscle biopsy samples from and put radio tags in northern pike and burbot from these watersheds during several sampling events in June to October 2011 and June to November 2012. Northern pike ranged in length from 510 to 1068 millimeters (20 to 42 inches) and burbot ranged in length from 500 to 870 millimeters (19 to 34 inches). The numbers of fish sampled and tagged per watershed are listed in Table 5-2.

Radio-tagged fish were located using a combination of four ground-based tracking stations and aerial surveys. Ground stations were located on the mainstem Kuskokwim River near Aniak, the mouth of the George River, on the mainstem Kuskokwim River 5 kilometers downstream from the Stoney River, and on the Holitna River 1.5 kilometers upstream from its mouth. Ground tracking stations were operational from mid-March to mid-November. Tracking flights were conducted between late October 2011 and February 2014 with a fixed wing aircraft equipped with a Lotek SRX600 receiver with internal Global Positioning System that recorded time and location data. Flights were timed before and after periods of major movements during freeze-up and break-up.

Muscle biopsy samples were analyzed for total mercury by Physis Environmental Laboratories, Anaheim, California and Frontier Global Science, Seattle, Washington following EPA methods. Analytical chemistry results underwent a third-party quality assurance review using EPA Validation Level IV criteria. All data were considered valid based on the quality assurance review.

5.2.2 Periphyton Sampling

In 2014, the BLM collected periphyton samples from the Kuskokwim River for analysis for metals and methylmercury to assess the potential bioaccumulation of these constituents in river and stream biota. The objective of the study was to determine the influence of Red Devil Creek outflow and mine tailings in the Kuskokwim River on the levels of mercury in periphyton and/or macroinvertebrates in the near shore environment of the Kuskokwim River (BLM 2014). Periphyton can be an important component of the diet of benthic macroinvertebrates (Hill et al. 1996, Minshall et al. 1992, and Vannote et al. 1980). Scraper/grazer functional feeding groups forage on periphyton and would be expected to occur in the Kuskokwim River along with collector-filterers, which collect fine particulate organic matter from the water column. Thirteen periphyton samples were collected both upstream and downstream from the Red Devil Creek delta. One sample also was collected from Red Devil Creek. Sample locations over the entire periphyton sampling area are shown in Figure 5-3. The periphyton samples collected within the area of the Red Devil RI and RI Supplement sediment sampling are shown in Figures 5-1 and 5-2.

Sampling methods are discussed in the *Field Operations Plan – 2014, Quantification of Fish and Aquatic Insect Tissue Contaminants in the Middle Kuskokwim River, Alaska* (Field Operations Plan; BLM 2014). In brief, the periphyton samples were collected by brushing the upper surface of cobbles and other substrate within the littoral zone near shore. At each site, a clean nylon brush was used to dislodge periphyton from the substrate, and stream water was used to wash the dislodged periphyton into a clean plastic pan. The resulting slurry was transferred to a pre-cleaned sample container, labeled, and placed on ice. Two composite samples were collected at each site; each sample was composed of periphyton from 5 to 10 individual pieces of substrate. Periphyton was plentiful in the nearshore zone of the Kuskokwim River, and sufficient biomass for analysis was readily collectable. The periphyton samples were analyzed for 20 metals, methylmercury, inorganic arsenic, and percent solids. A list of analytes and analytical methods is shown below.

Total Inorganic Elements

Analyte	**Method**
Aluminum	EPA 6020
Antimony	EPA 6020
Arsenic	EPA 6020
Barium	EPA 6020
Beryllium	EPA 6020
Boron	EPA 6020
Cadmium	EPA 6020
Chromium	EPA 6020
Copper	EPA 6020
Iron	EPA 6020
Lead	EPA 6020
Magnesium	EPA 6020
Manganese	EPA 6020
Mercury	EPA 245.7
Molybdenum	EPA 6020
Nickel	EPA 6020
Selenium	EPA 6020
Strontium	EPA 6020
Vanadium	EPA 6020
Zinc	EPA 6020
Percent Solids	
Percent Solids	SM 2540 B
Methylmercury	
Methylmercury (as Mercury)	EPA 1630 Mod/FGS-070
Inorganic Arsenic	
Inorganic Arsenic	EPA 1632

5.2.3 Benthic Macroinvertebrate Sampling

In 2014, the BLM attempted to collect benthic macroinvertebrates from the Kuskokwim River from five locations both upstream and downstream from the RDM, but was unsuccessful. The objectives of the study were to determine the influence of Red Devil Creek outflow and mine tailings in the Kuskokwim River on the levels of mercury in periphyton and/or macroinvertebrates in the near shore environment of the Kuskokwim River, and to determine if macroinvertebrate assemblages vary upstream and downstream of Red Devil Creek based on various biotic indices (BLM 2014).

Sampling methods were described in the Field Operations Plan (BLM 2014) and were similar to those used successfully in Red Devil Creek and other small tributary creeks to the Kuskokwim River in prior years. Some benthic macroinvertebrates were collected from the Kuskokwim River during the 2014 sampling event at a few locations after extensive sampling effort, but the total biomass and number of organisms was insufficient for analysis, and the larger effort was abandoned. The BLM suggested that the scarcity of benthic macroinvertebrates in the near-shore environment of the Kuskokwim River may be due to excessive turbidity.

During the 2015 RI Supplement sediment sampling event (see Section 5.1), field turbidity measurements of Kuskokwim River water were made to assess river turbidity at those locations at the time of sampling (see Section 5.1.2). Results are presented in Section 5.3.6 and briefly summarized below. In situ turbidity averaged 328 nephelometric turbidity units (NTU; range 14 to 575 NTU) in the near-shore environment of the Kuskokwim River. In contrast, field turbidity in Red Devil Creek typically was undetectable or in the low single digit NTU range. Habitat quality in the near-shore zone of the Kuskokwim River also may be affected by ice scour and seasonal changes in water level. For these reasons, it is not surprising that a diverse and abundant benthic macroinvertebrate community is not present in the near-shore zone of the Kuskokwim River.

5.3 Kuskokwim River Investigation Results

The RI Supplement Kuskokwim River sediment characterization was performed using a combination of field data collection and the results of laboratory analysis for selected analytical parameters. The objectives of the sediment investigation are listed in Section 5.1. The RI Supplement sediment characterization built upon sediment investigations performed as part of the RI. Results of the RI Supplement and RI Kuskokwim River investigation activities are presented below.

5.3.1 Total Inorganic Elements in Sediment

In Kuskokwim River sediment samples collected during the RI (in 2010, 2011, and 2012), antimony, arsenic, and mercury concentrations were the COCs most highly elevated above background values.

The Kuskokwim River RI and RI Supplement background samples are located upriver of the Red Devil Creek delta, and thus outside of the area expected to be influenced by the RDM. Although the RDM is located within a region containing mercury and other mineral occurrences, the mineralization at the RDM and other mineral occurrences in the area (see Section 5.4.2) is localized. The nearest known mineral occurrence upriver of the RDM is located approximately 12 kilometers upriver from the RDM. Therefore, it is expected that any impacts on sediment quality from mineral occurrences upriver of the RDM at the RDM background Kuskokwim River sediment sample locations would be negligible, and that sediment samples collected at the RI and Supplement background locations are representative of background conditions for the RDM.

The recommended RI background sediment values (see RI report, Table 4-10) for these COCs are: total antimony, 0.473 milligrams per kilogram (mg/kg); arsenic, 12.7 mg/kg; and mercury, 0.143 mg/kg. Concentrations of antimony, arsenic, and mercury in RI samples generally decreased downriver from the mouth of Red Devil Creek. Locations of RI sediment samples, including background samples, are illustrated in Figure 5-1. The total antimony, arsenic, and mercury concentrations for the RI sediment samples are presented in Table 4-22 and illustrated in Figures 4-41 and 4-42 of the final RI report. These results also are presented graphically in Figures 5-5 through 5-10 and Figures 5-13a through 5-13c of this report. The samples in Figures 5-13a through 5-13c are arranged generally from upriver (left) to downriver (right). Sediment sample location KR15, located near the upriver end of the Red Devil Creek delta, is indicated on each figure. Upriver locations (including RI background locations KR01, KR18, KR19, KR20, KR21, KR22, KR12, KR23, KR24, KR25, KR26, KR27, and KR13, and KR14) are shown to the left of KR15. Downriver sample locations are shown to the right of KR15. The samples collected from some of the RI sample locations furthest downriver and distant from the shore exceeded one or more of the recommended RI background values for antimony, arsenic, and mercury. The extent of antimony, arsenic, and mercury contamination (defined as exceeding background levels) in river sediments thus was not defined by RI sampling in the downriver and/or the cross-river directions.

As part of the 2015 RI Supplement, additional sediment sampling for total inorganic elements was performed to further assess the cross-river and downriver extents of contamination in Kuskokwim River sediment. Laboratory results of sediment samples collected in 2015 are presented in Table 5-3a. Locations of the 2015 sediment samples, as well as the RI samples, are illustrated in Figures 5-1 and 5-2. Background samples are shown in each figure. The total antimony, arsenic, and mercury results of the 2015 RI Supplement and 2010, 2011, and 2012 RI sediment samples are illustrated in Figures 5-5 thru 5-10. The results for total antimony, arsenic, and mercury for the 2015 sediment samples also are presented graphically in Figures 5-14a through 5-14c. The 2015 results for other inorganic elements are illustrated in Figures 5-14e through 5-14n. The samples in Figures 5-14a through 5-14n are arranged generally from upriver (left) to downriver (right). Sediment sample location KR084, located near the upriver end of the Red Devil Creek delta, is indicated on each figure. RI Supplement background locations (KR082 and KR083) are shown left of KR084. Downriver sample locations are shown to the right of KR084. Sample locations KR106, KR107, KR108, and KR109, which are located near the northeast bank across the river from the Red Devil Creek delta area, are shown to the left of location KR084.

The 2015 sediment sample results show that concentrations of total antimony, arsenic, and mercury further decrease with distance from the southwest bank, as indicated by results for samples from locations KR094 and KR095 (see Table 5-3a and Figures 5-5, 5-7, and 5-9. Concentrations in these samples are below the recommended RI background sediment concentrations for total antimony, arsenic, and mercury.

Concentrations of total antimony, arsenic, and mercury generally decrease with distance downriver from the Red Devil Creek delta area (see Table 5-3a and Figures 5-5 through 5-10 and 5-14a through 5-14c). Concentrations of total arsenic and mercury are generally near or slightly above recommended RI background levels in the downriver samples. Concentrations of total antimony are above the recommended RI background level at most of the downriver sample locations.

The background Kuskokwim River sediment background values were updated to include results of background sediment samples collected in 2015. Results of the RI background samples (see RI report, Tables 4-9 and 4-10) were combined with 2015 background samples collected at locations KR082 and KR083. The combined RI and RI Supplement background sample results are presented in Table 5-3b. The summary statistics and updated background concentrations are summarized in Table 5-3c. Updated background values for the primary COCs – 0.583 mg/kg for total antimony, 13.4 mg/kg for total arsenic, and 0.141 mg/kg (outlier excluded) for total mercury. These values are somewhat higher than the recommended RI values for antimony and arsenic and the same for mercury. The downriver extent of Kuskokwim River sediment with COC concentrations above background levels is discussed further below.

5.3.2 Methylmercury in Sediment

During the RI, 26 bed sediment samples collected in September 2010, September 2011, and September 2012 were analyzed for methylmercury (see final RI report Section 5.3.6). The methylmercury analyses were performed under subcontracts with Analytical Resources, Inc. (2010), Columbia Analytical Services (2011), and Frontier Global Sciences (2012). Locations of RI sediment samples are illustrated in Figure 5-1. RI results are presented in Table 4-22 and illustrated in Figures 4-41 and 4-42 of the final RI report. These results are also presented graphically in Figures 5-11, 5-12, and 5-13d of this report. Methylmercury was detected in RI samples at concentrations ranging from 0.15 to 3.73 nanograms per gram (ng/g), and was detected above the recommended RI background level of 0.49 ng/g in 14 of the 26 samples.

As part of the RI Supplement effort to further evaluate the potential for methylation of mercury in sediment, additional samples were analyzed directly for methylmercury. A total of 14 regular samples (and 2 field duplicate samples) RI Supplement samples were collected in September 2015 and analyzed for methylmercury by Brooks Rand Labs. Locations of all 2015 sediment samples are illustrated in Figures 5-1 and 5-2. The samples selected for methylmercury analysis are identified in Table 5-1. Laboratory results of methylmercury analyses of 2015 sediment samples are presented in Table 5-3a. The methylmercury concentrations for the 2015 sediment samples are graphically represented in Figures 5-11, 5-12, and 5-14d. For the 2015 sediment samples, methylmercury concentrations were below the method detection limit in six samples. Only the samples from KR084 (0.788 ng/g, estimated), KR092 (0.605 ng/g, estimated), and KR104 (0.667 ng/g, estimated) were greater than the recommended RI background level of 0.49 ng/g for methylmercury.

The background Kuskokwim River sediment values for methylmercury were updated to include results of background sediment samples collected in 2015. Results of the RI background samples (see RI report, Tables 4-9 and 4-10) were combined with 2015 background samples collected at locations KR082 and KR083. The combined RI and RI Supplement background sample results are presented in Table 5-3b. The summary statistics and updated background concentration for methylmercury are presented in Table 5-3c. The updated background value for methylmercury is 0.49 ng/g (0.00049 mg/kg), which is identical to the recommended RI value.

Concentrations of methylmercury in the RI and RI Supplement Kuskokwim River sediment samples are generally low compared to the national average for rivers (1.6 ng/g; Scudder 2009). Concentrations in all 14 RI Supplement samples are below the national average, and for the 26 RI samples, concentrations in only 4 samples were above the national average. These results are not unexpected considering the generally coarse sediment and well-oxygenated conditions, which are generally not conducive to mercury methylation, in the Kuskokwim River in the reach near the RDM.

It should be noted that, although mercury methylation most commonly occurs under anoxic conditions, small amounts of methylmercury also can be formed in aerobic conditions. It also should be noted that the degree of biomagnification of methylmercury in food webs depends less on the amount of methylmercury in sediment and more on the ability of methylmercury to irreversibly bind with sulfhydryl moieties of proteins, the concentration of which increases in higher trophic level species as they consume lower trophic level prey with bound to their tissue.

5.3.3 Mercury Selective Sequential Extraction in Sediment

Several approaches were taken during the RI to evaluate the potential for methylation of mercury in Kuskokwim River sediments. Several types of data were collected to evaluate the amount of mercury that is soluble and bioavailable. Several Kuskokwim River RI sediment samples were collected for mercury SSE analysis. A general discussion of mercury SSE analysis is presented in Sections 5.3.5.1 and 5.3.5.2 of the final RI report, and in Section 2.2.3.2 of this report.

As part of the RI Supplement effort to further evaluate the potential for methylation of mercury in Kuskokwim River sediment, seven samples were collected for mercury SSE analysis. The sediment samples were analyzed by Brooks Rand Labs using a mercury SSE procedure following Brooks Rand Labs' SOP BR-0013. The sediment sample aliquots analyzed for mercury SSE analysis consisted of mixtures predominantly of silt, with some gravel. Results of the mercury SSE analysis are presented in Table 5-3a. Interpretation of these results is presented in Section 5.3.7.3.

It should be noted that separate aliquots of sediment samples analyzed for mercury SSE were analyzed for total mercury via EPA Method 1631 and SW846 7471A. Any significant differences between the sum of SSE fractions F0-F5 and the results for total mercury are most likely attributable to differences in total mercury between the separate aliquots, reflecting heterogeneity of the sample material.

5.3.4 Grain Size and Total Organic Carbon in Sediment

RI Supplement sediment samples were analyzed for grain size and TOC to provide additional information on the physical and chemical characteristics of the sediment and to support the interpretation of the sediment toxicity testing results (see Section 5.3.5). Laboratory results of grain size and TOC analyses of 2015 sediment samples are presented in Table 5-3a.

5.3.5 Sediment Toxicity Testing

In September 2015, sediment samples for toxicity testing were collected from 12 locations in the Kuskokwim River near the RDM, including:

- Nine locations at or downstream from the Red Devil Creek delta (KR084, KR085, and KR087 to KR093);
- One location downstream from the Red Devil Creek delta on the opposite back of the river (KR099); and
- Two (reference) locations upstream from the Red Devil Creek delta (KR082 and KR083).

Sample locations are shown in Figures 5-1 and 5-2. The samples were sent to Northwestern Aquatic Sciences, Newport, Oregon, where a 28-day growth and survival tests with *Hyalella azteca* (amphipod) was conducted with each sample following EPA Method 100.4. Methylmercury was not measured at the beginning or end of the tests in the sediment sample aliquots submitted for toxicity testing. The full Northwestern Aquatic Sciences testing report is provided in Appendix C. Section 7.4.2 provides a summary and interpretation of the testing results.

5.3.6 River Turbidity Measurement

In situ measurements of Kuskokwim River water turbidity are presented in Table 5-3a. In situ river water turbidity averaged 328 NTU and ranged from 14 to 575 NTU.

5.3.7 BLM 2014 Periphyton Tissue Sampling

This section presents the results of the periphyton sampling performed by the BLM in 2014 (see Section 5.2.2).

5.3.7.1 Spatial Distribution of Metals in Periphyton

The periphyton analytical results are presented in Table 5-4. To evaluate the spatial distribution of inorganic elements in periphyton, the sample results were plotted from upstream to downstream with the sample collected in Red Devil Creek located at the center of each figure (see Figures 5-15a to 5-15p). Antimony, arsenic, and mercury in the periphyton sample from Red Devil Creek were noticeably greater than in samples from the Kuskokwim River (see Figures 5-15a through 5-15d and Figures 5-15g and 5-15h). These results are not unexpected given the nature of contamination at the RDM. Selenium and zinc in the Red

Devil Creek periphyton sample also were elevated compared with the Kuskokwim River samples (see Figures 5-15n and 5-15p).

The Mann-Whitney U-test was used to test for differences in metals concentrations between periphyton samples collected upstream and downstream from the Red Devil Creek delta. Total antimony, arsenic, and mercury (but not selenium and zinc) were significantly elevated ($p < 0.05$) in periphyton samples collected downstream from the Red Devil Creek delta compared with upstream samples (see Table 5-5). The greatest difference was for total mercury, which was 20 times greater on average in periphyton samples collected downstream from the Red Devil Creek delta compared with upstream samples (see Table 5-5). In contrast, the average difference in total arsenic levels between downstream and upstream periphyton samples was only 20% (see Table 5-5). In contrast to total arsenic, inorganic arsenic was not elevated in samples collected downstream from the Red Devil Creek delta (see Table 5-5 and Figures 5-15e and 5-15f).

5.3.7.2 Methylmercury in Periphyton

Methylmercury was not detected (< 0.5 ng/g wet weight) in the periphyton samples (see Table 5-4). The methylmercury detection limit was adequately low to detect methylmercury in the periphyton samples if it was present at 1 to 2% or lower than total mercury in the samples. Hence, despite the fact the total mercury levels were greater in periphyton samples collected downstream from the Red Devil Creek delta compared with upstream samples, there is no indication that this pattern of total mercury contamination resulted in greater methylmercury levels at the base of the benthic food web. This result is not unexpected given that methylmercury production occurs most commonly in anoxic sediment environments, not in the aerobic environment from which the periphyton samples were collected.

Studies of periphyton in other river systems suggest that contaminant levels in periphyton might vary with the substrate that the periphyton grows on. For example, Bell and Scudder (2007) observed that periphyton collected from fine-grained sediment contain greater mercury levels than periphyton collected from hard substrates, such as cobble or woody snags. However, it was not clear from their work if greater levels of mercury in sediment periphyton was the result of inadvertent inclusion of sediment fines in the periphyton samples, differences in periphyton species among substrate types, or greater mercury bioaccumulation by sediment periphyton compared with periphyton growing on hard substrates. Periphyton samples from the Kuskokwim River were collected only from hard substrates (cobble or woody snags) because hard substrates are prevalent in the reach of the river near the RDM site. Some river areas with sediment fines also occur near the RDM site, but periphyton were not collected from such areas to avoid collecting periphyton samples containing sediment fines, which would introduce a high bias to the sample results (see Section 5.2.2).

It could be argued that the 2014 Kuskokwim River periphyton samples do not reflect the greatest bioaccumulation of methylmercury into periphyton because only hard substrates were sampled, not areas with fine-grained sediment; however, for the reasons discussed above, such an argument is not supported based on available information. In the 2014 study, mercury levels in periphyton were clearly elevated in samples collected downriver from the Red Devil Creek delta compared with upriver samples (see Figure 5-15h and Section 5.3.7.1), suggesting that the appropriate substrates and locations were sampled to detect a site-related impact for methylmercury, if such an impact was present.

5.3.7.3 Metals Bioavailability

Three parameters that were analyzed in Kuskokwim River samples collected in 2014 or 2015 are relevant for understanding contaminant bioavailability at the base of the aquatic food web. These parameters are: (1) methylmercury in periphyton; (2) inorganic arsenic in periphyton; and (3) mercury SSE results for sediment. These parameters are discussed in turn below.

Methylmercury in Periphyton

As noted above, methylmercury was not detected in periphyton samples collected from the Kuskokwim River by the BLM in 2014 (see Table 5-4). These results may suggest that mercury releases from the RDM have not resulted in greater methylmercury levels at the base of the benthic food web in the Kuskokwim River. It should be noted that periphyton represents an important component in aquatic ecosystems; however, it is likely less important in the Kuskokwim River where fine particulate organic matter likely serves as the foundation for the food web. Concentrations of mercury in periphyton are affected by mercury in bottom sediment, suspended sediment, and dissolved in water; therefore, to the extent that periphyton are an element of the river's foodweb, the results are informative as to the role that RDM plays in influencing mercury levels at the base of the foodweb in the river downstream from the mine compared with the upstream area.

Inorganic Arsenic in Periphyton

In general, inorganic arsenic compounds are more toxic than organic arsenic compounds. In the Kuskokwim River, inorganic arsenic was not elevated in periphyton samples collected downstream from the Red Devil Creek delta compared with upstream samples (see Table 5-4 and Figures 5-15e and 5-15f). In fact, inorganic arsenic levels in periphyton were significantly lower in samples collected downstream from the Red Devil Creek delta than in upstream samples ($p < 0.0406$, Mann-Whitney U-test).

Mercury SSE Results for Sediment

Several approaches were taken during the RI to evaluate the potential for methylation of mercury in Kuskokwim River sediments. Several types of data were collected that indicate that a large fraction of total mercury in site soil and sediment is sparingly soluble. For example, mercury SSE data indicate that a small fraction of total mercury in site soil (see final RI report Section 5.3.5.1) and sediment derived in part from site soil (see final RI report Section 5.3.5.2) is water soluble (F1) or stomach acid soluble (F2) and that the proportion of these soluble fractions relative to the total mercury decreases with increasing total mercury concentration. The comparably less soluble SSE fraction F5, which includes cinnabar, generally comprised most of the mercury in RI samples with relatively higher concentrations of total mercury. Similarly, synthetic precipitation leaching procedure results for RI soil samples suggest that a small fraction of the total mercury concentration in site soil samples is soluble under slightly acidic conditions procedure (see final RI report Section 5.3.4.1). The soluble portion of the total mercury pool is the portion subject to methylation. Cinnabar is not likely used by bacteria during methylation of mercury.

For the RI Supplement, additional sampling and analysis of Kuskokwim River sediment for mercury SSE was performed to gather additional information on the potential for methylation of mercury in Kuskokwim River sediments. Seven sediment samples were analyzed for mercury SSE. Sample results are presented in Table 5-3a and 5-6. Table 5-6 uses the mercury SSE results for the RI Supplement sediment samples to estimate the fraction of total mercury in Kuskokwim River sediment that is readily bioavailable. The sums of the F0, F1, and F2 mercury SSE fractions were used to represent readily bioavailable mercury in each sample. These SSE fractions represent mercury forms that are soluble in water (F0 and F1) or weak acid (F2). These are the mercury forms most likely to be subject to microbial methylation in the environment.

Kuskokwim River sediment samples collected at or within 800 meters of the Red Devil Creek delta contained elevated levels of total mercury (740 to 17,000 ng/g or 0.74 to 17 mg/kg). For those samples, the fraction of readily bioavailable mercury (mercury SSE fractions F0 through F2) ranged from 4.1 ng/g to 65 ng/g in samples collected downriver from the Red Devil Creek delta and was 274 ng/g in the sample from the Red Devil Creek delta. The percentage of readily bioavailable mercury in these samples was low—typically less than 1% of total mercury (see Table 5-6). These results are consistent with mercury SSE results for sediment, soil, and mine wastes presented in Sections 5.3.5.1 and 5.3.5.2 of the final RI report. Those results showed that mercury in site soils and mine waste was largely present as cinnabar or other comparably less soluble mercury forms. Such mercury forms are sparingly bioavailable. Because the total mercury concentration was high in some samples, the absolute concentration of bioavailable mercury was relatively high even though only a small fraction was bioavailable. Nonetheless, methylmercury levels in Kuskokwim River sediment near the RDM typically were low because conditions near the site are not favorable for mercury methylation.

In contrast, the Kuskokwim River sediment sample collected at downriver location KR097 contained low total mercury (18 ng/g or 0.018 mg/kg) and a greater percentage of bioavailable mercury – 4.1 ng/g, representing 22% of total mercury – compared with the six samples collected near the RDM (see Table 5-6).

5.3.8 BLM Fish Movement and Tissue Sampling

This section discusses results from Matz et al. (2017) as they related to understanding the potential for the RDM to affect mercury levels in game fish of harvestable size from the middle Kuskokwim River region.

5.3.8.1 Comparison of Mercury Levels in Fish among Watersheds

Average total mercury levels in northern pike and burbot from the Kuskokwim River reaches studied by Matz et al. (2017) are presented in Figure 5-16. The average total mercury levels in pike and burbot from the Kuskokwim River reach that includes the RDM (Kusko above George) were among the lowest measured.

The greatest average total mercury concentration in pike was found in the Takotna watershed (see Figure 5-16), which is well upriver from the RDM (see Figure 5-4). The greatest total mercury concentration in burbot was found in the George River watershed (see Figure 5-16), a tributary to the Kuskokwim River not affected by releases from the RDM. The George River watershed also had a high average total mercury concentration in pike, as did the Holitna River watershed (see Figure 5-16).

High total mercury levels in pike from the Takotna, Holitna, and George River watersheds likely are the result of the physical and biological characteristics of these watersheds. All three watersheds have extensive areas of oxbows with abundant wetland habitat, ideal habitat for pike and other fish and important sites for mercury methylation.

5.3.8.2 Fish Movement

According to Matz et al. (2017), most pike (78 to 100%) captured in the George River, Holitna, Kusko-Stony, Kusko-Swift, and Takotna watersheds stayed in the watershed where they were captured. Hence, mercury exposure for pike in these watersheds comes from their native watershed. In contrast, only about 40% of northern pike captured in the Kuskokwim River reach that includes the RDM (Kusko-above-George) stayed in that river reach. The movement of pike out of this river reach has the effect of reducing their exposure to mercury from the RDM.

Low fidelity of pike to the Kusko-above-George reach may be due to the physical and biological characteristics of this reach. This reach is characterized by linear shorelines, strong current, high turbidity, and low density of shoreline wetlands. These characteristics make the reach unattractive to pike, and few pike were captured in this river reach (see Table 5-2). As a result, residents of nearby villages prefer fishing for pike in other river reaches where better pike habitat and more pike occur. This situation reduces the potential for human exposure to mercury and other contaminants from the RDM via the fish consumption pathway.

Information regarding burbot movement is available for three Kuskokwim River reaches (Kusko-Aniak, Kusko-above-George, and Kusko-Stoney). Eighty percent

(80%) of burbot that were captured in the Kusko-Aniak reach (the most downstream reach included in the study) stayed in that reach. In contrast, only about 10% of burbot captured in the Kusko-above-George reach (where the RDM is located) and the Kusko-Stoney reach stayed in those reaches. Movement of burbot out of the reach where the RDM is located has the effect of minimizing burbot exposure to mercury from the RDM.

5.3.9 Kuskokwim River Surface Water

No surface water quality data for the Kuskokwim River near the RDM are available. However, contribution of COC loading from the RDM via surface water flow from Red Devil Creek can be indirectly evaluated based on Red Devil Creek surface water quality data collected as part of the RI and baseline monitoring (E & E 2014) and RI Supplement (see Chapter 4) combined with discharge data for Red Devil Creek and the Kuskokwim River, as described below.

Concentrations of COCs in surface water collected from Red Devil Creek and the seep located on the bank of the creek in the Main Processing Area (station RD05) during the RI Supplement are presented in Tables 4-4 and 4-5, and concentrations observed over the course of the RI, baseline monitoring, and RI Supplement are presented graphically in Figure 4-1. Maximum COC concentrations in surface water from Red Devil Creek at station RD08—the creek sampling station located near the confluence with the Kuskokwim River—over the course of these studies are as follows. Total and dissolved arsenic concentrations have ranged as high as 112 and 80.9 µg/L, respectively. Total and dissolved antimony concentrations have ranged as high as 281 and 226 µg/L, respectively. Total and dissolved mercury concentrations have ranged as high as 683 and 25 ng/L, respectively.

Surface water discharge rates for Red Devil Creek at station RD08 have ranged from 0.81 to 14.2 cfs during the RI, baseline monitoring, and RI Supplement monitoring events (see Table 4-3). Discharge rates for the Kuskokwim River at U.S. Geological Survey (USGS) gaging station 15304000—Kuskokwim River at Crooked Creek, Alaska, for the same dates as the Red Devil Creek monitoring events have ranged from 43,610 to 97,384 cfs (USGS 2017). For any given Red Devil Creek discharge monitoring date, the Kuskokwim River discharge was 4 to 5 orders of magnitude greater than Red Devil Creek discharge. Contribution of COC loading from Red Devil Creek to COC concentrations in the Kuskokwim River would, therefore, be indiscernible. It is expected that contributions of COC loading to the Kuskokwim River via groundwater discharge would be similarly low. Flux of groundwater and COCs in groundwater from the RDM into the Kuskokwim River is a data gap that will be addressed in a separate report on site groundwater to be provided for agency review.

Water monitoring has been performed recently in the Georgetown area by the Georgetown Tribal Council. Objectives of the monitoring include providing baseline water quality data for the Kuskokwim River (Georgetown Tribal Council 2014a). Surface water samples were collected from monitoring site KR-1, located on the Kuskokwim River near the village of Georgetown. Monitoring station KR-1 is located approximately 18 river miles downriver of the Red Devil Creek delta. Samples have been analyzed for various field and laboratory water quality parameters, including concentrations of antimony, arsenic, and mercury. Because of the large distance from the RDM to station KR-1, surface water quality data from this station are not useful for directly assessing potential impacts to Kuskokwim River surface water quality resulting from the RDM. Results of the monitoring are presented in this report to provide general information on Kuskokwim River water quality in the area. Available arsenic, antimony, and mercury laboratory results for surface water samples collected at station KR-1 are summarized below:

- **Total Arsenic.** From 2008 to 2013, samples analyzed for total arsenic were reported (Georgetown Tribal Council 2014b) to have concentrations ranging from 0 to 0.005 mg/L (5 µg/L). Based on the 2016 water quality report (Georgetown Tribal Council 2017) and data obtained via the online Georgetown Tribal Council Water Quality Web Mapper (Georgetown Tribal Council 2018), total arsenic was detected in samples collected from 2014 to 2017 at concentrations ranging from 0.0028 mg/L (2.8 µg/L) to 0.011 mg/L (11 µg/L).
- **Dissolved Arsenic.** From 2015 to 2017, samples analyzed for dissolved arsenic were reported (Georgetown Tribal Council 2018) to have concentrations ranging from 0 to 0.0019 mg/L (1.9 µg/L).
- **Total Antimony.** From 2015 to 2017, samples analyzed for total antimony were reported (Georgetown Tribal Council 2018) to have concentrations ranging from 0.0006 mg/L (0.6 µg/L) to 0.00067 mg/L (0.67 µg/L).
- **Total Mercury.** From 2014 to 2017, samples analyzed for total mercury were reported (Georgetown Tribal Council 2018) to be nondetect.

5.4 Kuskokwim River Investigation Summary

The RI Supplement sediment characterization activities were designed to address data gaps associated with sediment in the Kuskokwim River near and downriver of Red Devil Creek. This section summarizes the RI Supplement investigations and complementary investigations conducted by BLM and the USFWS.

5.4.1 Cross-River and Downriver Extent of Sediment Contamination

As part of the RI Supplement, sediment sampling and analysis for total inorganic elements was performed to assess the cross-river and downriver extents of contamination in Kuskokwim River sediment. Concentrations of total antimony, arsenic, and mercury decrease with distance away from the riverbank near the RDM, and with distance downriver from the Red Devil Creek delta. Increases in concentrations of total antimony, arsenic, and mercury above background levels at the Red Devil Creek delta (e.g., sample KR084) into the Kuskokwim River are considered to be due to inputs from the RDM area.

Concentrations of antimony, arsenic, and mercury generally decrease with distance downriver from the Red Devil Creek delta area (see Table 5-3 and

Figures 5-5 through 5-10 and 5-14a through 5-14c). These trends are further illustrated in Figures 5-17a through 5-17c, which are similar to Figures 5-14a through 5-14c except that the concentration scale is logarithmic rather than linear. Concentrations generally decrease to values near background levels for total antimony, arsenic, and mercury in the most downriver samples.

The general trends toward decreasing concentrations downriver from the Red Devil Creek delta change to less regular patterns farther downriver. The change in pattern includes increases in concentrations at location KR096 (located approximately 1 kilometer downriver from the Red Devil Creek delta) and an even more pronounced increase in concentrations at location KR103 (located approximately 4.4 kilometers downriver from the Red Devil Creek delta). Deviations from the general trend of decreasing concentrations with distance downriver are likely attributable to other sources of these metals. Such other sources are discussed in Section 5.4.2.

5.4.2 Mineral Occurrences near Red Devil Mine

The RDM lies within a mineralized region (e.g., Miller et al. 1989). This regional mineralization influences the concentrations of antimony, arsenic, mercury, and other metals in the environment, including sediment in the Kuskokwim River and some of its tributaries. Table 5-7 presents information on mineral occurrences in the area near the RDM based on Miller et al. (1989). The table indicates the type of occurrence (i.e., lode or placer), degree of development (e.g., occurrence of mineralization, prospect, mine), production, and minerals present, including cinnabar (mercury sulfide), stibnite (antimony sulfide), and realgar and orpiment (arsenic sulfides), which are the primary sources of mercury, antimony, and arsenic at the RDM. Table 5-7 also identifies the nearest surface water body hydraulically downgradient of each mineral occurrence. All the surface water bodies drain to the Kuskokwim River. The mineral occurrences are arranged in Table 5-7 in order from upriver to downriver along the Kuskokwim River. Figure 5-18 illustrates the locations of the mineral occurrences described by Miller et al. (1989).

Most of the mineral occurrences identified in Table 5-7 drain into a reach of the Kuskokwim River that lies within the extent of sediment samples collected during the 2015 Kuskokwim River sediment sampling event. For each mineral occurrence identified in Table 5-7, the nearest downriver 2015 Kuskokwim River sediment sample is identified.

As indicated in Table 5-7, location KR096 is the nearest sediment sample location downriver from the mouth of McCally Creek, which is a watershed containing six mineral occurrences identified by Miller et al. (1989). Location KR103 is the nearest sediment sample location downriver from three mineral occurrences, including the Alice and Bessie claim group (formerly known as the Parks prospect), located near the northeast bank of the river. It is likely that increases in total antimony, arsenic, and mercury concentrations in Kuskokwim River sediment at locations KR096 and KR103 are attributable, in part, to inputs from these other mineral occurrences.

5.4.3 Methylmercury in Sediment

Methylmercury was detected in eight of the 14 2015 RI Supplement sediment samples at concentrations ranging up to 0.788 ng/g (estimated). Concentrations in three of the samples were greater than the recommended RI background level of 0.49 ng/g for methylmercury. Methylmercury was detected in RI samples from 2010 to 2012 in closer proximity to the RDM at concentrations ranging from 0.15 to 3.73 ng/g. The methylmercury concentration in 14 of 26 of the 2010 to 2012 samples exceeded the recommended RI background level of 0.49 ng/g.

In general, concentrations of methylmercury in the RI and RI Supplement Kuskokwim River sediment samples are low compared with the national average for rivers (1.6 ng/g; Scudder 2009). Concentrations in all 14 RI Supplement samples are below the national average, and for the 26 RI samples, concentrations in only 4 samples were above the national average.

These results are consistent with the observation that the environmental conditions of the Kuskokwim River near the RDM generally are not conducive to mercury methylation. Finally, to help understand possible controls on methylmercury levels at the site, E & E evaluated the methylmercury and TOC data for the Kuskokwim River sediment samples for possible relationships. Methylmercury levels in Kuskokwim River sediment are not significantly correlated with TOC when all available samples (including upriver reference samples) are considered ($n = 45$, $R^2 = 0.1432$, $p = 0.3481$).

5.4.4 Sediment Toxicity

A 28-day growth and survival test with *Hyalella azteca* (freshwater amphipod) was conducted with sediment from 10 locations in the Kuskokwim River downstream from the Red Devil Creek delta and from two upstream reference locations. The test results are presented and discussed in the BERA Supplement (Chapter 7) and used therein to evaluate potential risks to the benthic macroinvertebrate community in the Kuskokwim River near the RDM.

5.4.5 Kuskokwim River Periphyton

In 2014, the BLM collected periphyton samples from the near-shore environment of the Kuskokwim River at 13 locations downstream from the Red Devil Creek delta and 13 locations upstream form the Red Devil Creek delta. Sampling methods are discussed in the BLM Field Operations Plan (BLM 2014). The samples were analyzed for metals, methylmercury, inorganic arsenic, and percent solids. The following results are noteworthy:

- Antimony, arsenic, and mercury were elevated in periphyton samples collected downstream from the Red Devil Creek delta compared with upstream samples. The greatest difference was for mercury, which was about 20 times greater on average in periphyton samples collected downstream from the Red Devil Creek delta compared with upstream samples. In contrast, the average difference in total arsenic levels between downstream and upstream periphyton samples was 20%. Inorganic arsenic was not elevated in samples collected downstream from the Red Devil Creek delta.

- Methylmercury was not detected in the periphyton samples. Hence, despite the fact the total mercury levels were elevated in periphyton samples collected downstream from the Red Devil Creek delta, there is no indication that this pattern of total mercury contamination resulted in greater methylmercury levels at the base of the benthic food web.

5.4.6 Kuskokwim River Fish

Between 2011 and 2014, the BLM Alaska State Office, in cooperation with the USFWS and Alaska Department of Fish and Game, measured mercury concentrations in small muscle biopsies from northern pike and burbot equipped with radio transmitters, and related the concentrations to fish location and movements in the middle Kuskokwim River region. The study design and methods are described in Matz et al. (2017). Matz et al. (2017) divided the mainstream Kuskokwim River and major tributaries within the study area into eight watersheds or reaches for their investigation. The following results are noteworthy:

- Total mercury levels in pike and burbot from the Kuskokwim River reach that includes the RDM were among the lowest measured in the study.
- Only about 10% of burbot and 40% of pike captured in the Kuskokwim River reach that includes the RDM remained in that river reach. Low fidelity of burbot and pike to this reach has the effect of reducing their exposure to mercury and other contaminants from the RDM.
- Low fidelity of pike to the Kuskokwim River reach near the RDM likely is due to the physical and biological characteristics of the reach. The reach is characterized by strong current, high turbidity, linear shorelines, and low density of shoreline wetlands. These characteristics make the reach unattractive to pike.
- The greatest total mercury levels in pike were found in the Takotna, Holitna, and George River watersheds. All three watersheds have extensive areas of oxbows with abundant wetland habitat, ideal habitat for pike and other fish, and important sites for mercury methylation.
- Across the study area, mercury levels in pike increased with fish length and age, as would be expected for a bioaccumulative contaminant.
- Matz et al. (2017) found no relationship between pike total mercury levels and the number of mercury-containing mines or mercury-containing occurrences and prospects in a given watershed. This result led them to suggest that other factors, such as wetland area (a measure of watershed methylation potential), should be further investigated to understand controls on mercury levels in game fish from the middle Kuskokwim River region.

Table 5-1 Kuskokwim River Sediment Sample Collection

General Location	Sample Location ID	Sample ID	Sample Location Description	Sample Date	Sample Collection Equipment	Sample Description	Sample Analyses and Methods					
							Total TAL Metals	Methylmercury	Mercury SSE	Grain Size	Total Organic Carbon	Toxicity - Hyalella Azteca (28 day)
							EPA 6010B/6020A 7471A	EPA 1630 Modified	Hg SSE (F0 - F5) with Total Hg	ASTM D422	9060	EPA 100.4 Chronic
Upriver of Red Devi Creek Delta	KR082	15KR082SD	Near BLM periphyton sample location Kusko-14-PERI-1	9/2/2015	Hand auger	Field Sample	X			X	X	X
	KR083	15KR083SD	Near RI sediment sample location KR26	9/2/2015	Van Veen	Field Sample	X			X	X	X
Near Right Bank of Kuskokwim River Across from Red Devil Mine Area	KR106	15KR106SD	Approximately 50 feet from right bank opposite area of RI sample location KR29 upriver from Red Devil Creek	9/4/2015	Hand auger	Field Sample	X					
	KR107	15KR107SD	Approximately 10 to 20 feet from right bank opposite area of RI sample location KR29 upriver from Red Devil Creek	9/4/2015	Hand auger	Field Sample	X					
	KR108	15KR108SD	Approximately 50 feet from right bank opposite area of RI sample location KR54 downriver from Red Devil Creek	9/4/2015	Scoop	Field Sample	X					
	KR109	15KR109SD	Approximately 10 to 20 feet from right bank opposite area of RI sample location KR54 downriver from Red Devil Creek	9/4/2015	Hand auger	Field Sample	X					
Red Devil Creek Delta Area	KR084	15KR084SD	Near RI sediment sample locations KR29 and KR28	9/5/2015	Hand auger	Field Sample	X	X	X	X	X	X
		15KR202SD		9/5/2015	Hand auger	Field Duplicate of 15KR084SD	X	X	X	X	X	
	KR085	15KR085SD	Near RI sediment sample location KR02	9/2/2015	Hand auger	Field Sample	X			X	X	X
	KR086	15KR086SD	Near RI sediment sample locations KR34 and KR35 (deviation)	9/6/2015	Hand auger	Field Sample	X			X	X	
Downriver of Red Devil Creek Delta	KR087	15KR087SD	Near RI sediment sample location KR37	9/2/2015	Van Veen	Field Sample	X			X	X	X
	KR088	15KR088SD	Near BLM periphyton sample location Kusko-14-PERI-13	9/2/2015	Hand auger	Field Sample	X	X	X	X	X	X
	KR089	15KR089SD	Near RI sediment sample location KR43	9/6/2015	Hand auger	Field Sample	X	X	X	X	X	X
	KR090	15KR090SD	Near RI sediment sample locations KR45 and KR44	9/3/2015	Hand auger	Field Sample	X			X	X	X
	KR091	15KR091SD	Near RI sediment sample location KR60	9/6/2015	Hand auger	Field Sample	X	X	X	X	X	X
	KR092	15KR092SD	Near BLM periphyton sample location Kusko-14-PERI-14	9/3/2015	Hand auger	Field Sample	X	X	X	X	X	X
	KR093	15KR093SD	Near RI sediment sample location KR72	9/6/2015	Hand auger	Field Sample	X	X	X	X	X	X
	KR094	15KR094SD	Outboard of RI sediment sample locations, near locations KR55 and KR56	9/3/2015	Hand auger	Field Sample	X			X	X	
	KR095	15KR095SD	Outboard of RI sediment sample locations, near location KR73	9/3/2015	Hand auger	Field Sample	X			X	X	
	KR096	15KR096SD	Downriver of RI sediment sample locations, near BLM periphyton sample location Kusko-14-PERI-15	9/3/2015	Hand auger	Field Sample	X	X		X	X	
	KR097	15KR097SD	Downriver of RI sediment sample locations, near right bank	9/4/2015	Hand auger	Field Sample	X	X	X	X	X	
	KR098	15KR098SD	Downriver of RI sediment sample locations, near BLM periphyton sample location Kusko-14-PERI-16	9/4/2015	Hand auger	Field Sample	X	X		X	X	
		15KR200SD		9/4/2015	Hand auger	Field Duplicate of 15KR098SD	X	X		X	X	
	KR099	15KR099SD	Downriver of RI sediment sample locations, near right bank	9/5/2015	Hand auger	Field Sample	X			X	X	X (Originally planned for location KR101)
		15KR201SD		9/5/2015	Hand auger	Field Duplicate of 15KR099SD	X			X	X	

Table 5-1 Kuskokwim River Sediment Sample Collection

General Location	Sample Location ID	Sample ID	Sample Location Description	Sample Date	Sample Collection Equipment	Sample Description	Sample Analyses and Methods					
							Total TAL Metals	Methylmercury	Mercury SSE	Grain Size	Total Organic Carbon	Toxicity - Hyalella Azteca (28 day)
							EPA 6010B/6020A 7471A	EPA 1630 Modified	Hg SSE (F0 - F5) with Total Hg	ASTM D422	9060	EPA 100.4 Chronic
Downriver of Red Devil Creek Delta	KR100	15KR100SD	Downriver of RI sediment sample locations, near BLM periphyton sample location Kusko-14-PERI-18	9/4/2015	Hand auger	Field Sample	X	X		X	X	
	KR101	15KR101SD	Downriver of RI sediment sample locations, near right bank	9/4/2015	Hand auger	Field Sample	X	X		X	X	Not collected at this location; collected at KR099.
	KR102	15KR102SD	Downriver of RI sediment sample locations, near BLM periphyton sample location Kusko-14-PERI-21	9/5/2015	Hand auger	Field Sample	X	X		X	X	
	KR103	15KR103SD	Downriver of RI sediment sample locations, near right bank	9/5/2015	Hand auger	Field Sample	X			X	X	
	KR104	15KR104SD	Downriver of RI sediment sample locations, near BLM periphyton sample location Kusko-14-PERI-25	9/5/2015	Hand auger	Field Sample	X	X		X	X	
	KR105	15KR105SD	Downriver of RI sediment sample locations, near right bank	9/5/2015	Hand auger	Field Sample	X	X		X	X	

Key:
EPA = United States Environmental Protection Agency
Hg SSE = Mercury Selective Sequential Extraction
TAL = Target Analyte List

Table 5-2 Number of Fish Sampled per Watershed in the Middle Kuskokwim River Region, Alaska, by Matz et al. (2017) for Fish Telemetry Study

Watershed or Reach Name[a]	Watershed or Reach Number[a]	Number of Northern Pike Sampled[c]	Number of Burbot Sampled[c]
Kusko-Aniak	1	0	20
George River	2	23	0
Kusko above George River[d]	3[d]	7	21
Holitna	4	104	0
Kusko-Stony	5	18	22
Kusko Swift	6	0	0
Kusko above Selatna	7	26	0
Takotna	8	32	0

Notes:

(a) = From page 12 from Matz et al. (2017).

(b) = See Figure 5-4 for reach length information and watershed location.

(c) = From Table 7 from Matz et al. (2017).

(d) = Includes Red Devil Mine site.

Table 5-3a Kuskokwim River Sediment Sample Results, Fall 2015

Analyte	Sample Location ID / General Location Description / Sample ID / Method		Units	KR082 Upriver of Red 15KR082SD	KR083 Upriver of Red 15KR083SD	KR106 Near Right Bank 15KR106SD	KR107 Near Right Bank 15KR107SD	KR108 Near Right Bank 15KR108SD	KR109 Near Right Bank 15KR109SD	KR084 Red Devil Creek 15KR084SD	KR085 Red Devil Creek 15KR085SD	KR086 Red Devil Creek 15KR086SD	KR087 Downriver of 15KR087SD	KR088 Downriver of Red 15KR088SD	KR089 Downriver of Red 15KR089SD
Total Inorganic Elements															
Aluminum	Metals (ICP)	SW846 6010B	mg/kg dry	7900	5500	6900	6200	6900	6000	5200	6600	7700	6300	3900	8600
Antimony	Metals (ICP/MS)	SW846 6020A	mg/kg dry	0.79	0.27	2.1	0.58	1.1	0.43	920	3100	120	40	100	19 J+
Arsenic	Metals (ICP/MS)	SW846 6020A	mg/kg dry	9.8	6.9	36	11	21	8.5	510	2100	100	40	230	31 J+
Barium	Metals (ICP/MS)	SW846 6020A	mg/kg dry	150	61	300	88	160	85	120	520	160	120	82	110 J+
Beryllium	Metals (ICP/MS)	SW846 6020A	mg/kg dry	0.45	0.2	0.79	0.24	0.4	0.2	0.29	0.64	0.41	0.44	0.58	0.59
Cadmium	Metals (ICP/MS)	SW846 6020A	mg/kg dry	0.47	0.12	0.91	0.19	0.42	0.14	0.18	0.34	0.34	0.2	0.35	0.39
Calcium	Metals (ICP)	SW846 6010B	mg/kg dry	1800	2200	5600	5500	11000	2400	1600	3300	3800	3600	1600	3300
Chromium	Metals (ICP/MS)	SW846 6020A	mg/kg dry	29	14	49	16	24	15	19	35	27	23	17	27 J+
Cobalt	Metals (ICP/MS)	SW846 6020A	mg/kg dry	15	6.9	18	6.3	9.1	5.6	8	15	10	8.8	15	19
Copper	Metals (ICP/MS)	SW846 6020A	mg/kg dry	50	16	57	16	25	12	19	51	26	17	45	46 J+
Iron	Metals (ICP)	SW846 6010B	mg/kg dry	29000	15000	17000	16000	18000	15000	19000	27000	20000	16000	37000	66000
Lead	Metals (ICP/MS)	SW846 6020A	mg/kg dry	12	2.7	19	5	9.8	3.7	6.7	11	8.7	6	9.8	10
Magnesium	Metals (ICP)	SW846 6010B	mg/kg dry	4000	2800	3900	3700	4200	3500	2500	4200	3600	3000	1300	6600
Manganese	Metals (ICP/MS)	SW846 6020A	mg/kg dry	1200	380	590	310	510	300	350	580	460	470	590	3800
Mercury	Mercury (CVAA)	SW846 7471A	mg/kg dry	0.098 J	0.016 J	0.054	0.021	0.041	0.01 J	31	310	1.4	2.9	9.9	2.1
Nickel	Metals (ICP/MS)	SW846 6020A	mg/kg dry	51	20	59	20	28	18	27	55	31	28	41	55 J+
Potassium	Metals (ICP)	SW846 6010B	mg/kg dry	590	420	870	730	1000	610	590	1600	690	480	490	720
Selenium	Metals (ICP/MS)	SW846 6020A	mg/kg dry	1.9	0.69	4.2	0.98	1.6	0.88	0.88	1.7	1.6	1.2	1.6	2.9
Silver	Metals (ICP/MS)	SW846 6020A	mg/kg dry	0.14	0.0078 J	0.33	0.081 J	0.17	0.072 J	0.038 J	0.15	0.11	0.049	0.098 J	0.2
Sodium	Metals (ICP)	SW846 6010B	mg/kg dry	70 J	110	130	100	150	89 J	65 J	140	110	79	41 UJ	65 J
Thallium	Metals (ICP/MS)	SW846 6020A	mg/kg dry	0.098 J	0.056 U	0.29 J	0.089 J	0.16	0.07 U	0.12 J	0.33	0.14	0.099	0.086 J	0.066 UJ
Vanadium	Metals (ICP/MS)	SW846 6020A	mg/kg dry	33	22	68	23	33	25	23	29	35	31	29	40 J+
Zinc	Metals (ICP/MS)	SW846 6020A	mg/kg dry	110	41	170	51	83	44	54	85	87	71	93	100 J+
Methylmercury															
Methylmercury	Total Mercury by EPA 1631	EPA 1630 Modified	ng/g dry							0.788 J				0.01 UJ	0.01 UJ-
Mercury Selective Sequential Extraction															
F0	Hg SSE (F0 - F5) with Total Hg	Hg SSE (F0 - F5) with Total Hg	ng/g dry							4.77 UJ				9.28 J	4.63 UJ
F1	Hg SSE (F0 - F5) with Total Hg	Hg SSE (F0 - F5) with Total Hg	ng/g dry							271 J				58.5 UJ	2.37 UJ
F2	Hg SSE (F0 - F5) with Total Hg	Hg SSE (F0 - F5) with Total Hg	ng/g dry							1.16 UJ				12.1 J	1.13 UJ
F3	Hg SSE (F0 - F5) with Total Hg	Hg SSE (F0 - F5) with Total Hg	ng/g dry							1680 J				528 J	30.8 J
F4	Hg SSE (F0 - F5) with Total Hg	Hg SSE (F0 - F5) with Total Hg	ng/g dry							6000 J				1530 J	605 J
F5	Hg SSE (F0 - F5) with Total Hg	Hg SSE (F0 - F5) with Total Hg	ng/g dry							9140 J				4410 J	6810 J
Total Mercury	Low Level Mercury	EPA 1631 Appendix	ng/g dry							18700 J				63200 J	4250 J
Grain Size															
Gravel	Grain Size	ASTM D422	%	60.9	76.5					48.3	61.5	5.3	0.2	37.3	30.3
Coarse Sand	Grain Size	ASTM D422	%	13	14.7					9.1	16.1	1.8	0	18.1	17.5
Medium Sand	Grain Size	ASTM D422	%	6.1	5.1					10.4	13.5	2.3	1.1	13.3	16.4
Fine Sand	Grain Size	ASTM D422	%	10.6	3.5					25.3	6.3	31	73.5	20.2	11.6
Silt	Grain Size	ASTM D422	%	8.3	0.1					5.5	2.2	50.4	20.7	9.5	19.5
Clay	Grain Size	ASTM D422	%	1.1	0.1					1.5	0.4	9.2	4.4	1.6	4.6
Total Organic Carbon															
Total Organic Carbon	Organic Carbon, Total (TOC)	SW846 9060	mg/kg	8700	7600					4500	7000	15000	6500	4300	17000
Sediment Toxicity															
Toxicity - *Hyalella Azteca* (28 day)	Percent Survival (Mean +/- SD)	EPA 100.4 Chronic	%	81.3 ± 15.5	96.3 ± 5.2					92.5 ± 10.4	92.5 ± 8.9		90.0 ± 14.1	88.8 ± 12.5	61.3 ± 17.3
Toxicity - *Hyalella Azteca* (28 day)	Average Dry Weight/Amphipod (Mean +/- SD)	EPA 100.4 Chronic	mg	0.26 ± 0.06	0.25 ± 0.04					0.24 ± 0.02	0.28 ± 0.04		0.23 ± 0.05	0.28 ± 0.03	0.23 ± 0.03
Field Parameters															
Turbidity, Kuskokwim River Water	In situ field measurement		NTU	495	575	468	453	404	449	134	309	125	497	493	135

Table 5-3a Kuskokwim River Sediment Sample Results, Fall 2015

Analyte	Sample Location ID		Units	KR090	KR091	KR092	KR093	KR094	KR095	KR096	KR097	KR098	KR099	KR100	KR101	KR102	KR103	KR104	KR105
	General Location Description			Downriver of	Downriver of	Downriver of Red	Downriver of Red	Downriver of	Downriver of	Downriver of Red	Downriver of Red	Downriver of Red	Downriver of	Downriver of	Downriver of	Downriver of	Downriver of	Downriver of	Downriver of
	Sample ID			15KR090SD	15KR091SD	15KR092SD	15KR093SD	15KR094SD	15KR095SD	15KR096SD	15KR097SD	15KR098SD	15KR099SD	15KR100SD	15KR101SD	15KR102SD	15KR103SD	15KR104SD	15KR105SD
	Method																		
Total Inorganic Elements																			
Aluminum	Metals (ICP)	SW846 6010B	mg/kg dry	5700	5000	7000	5600	3700	3400	6500	4700	3700	5300	4400	11000	4800	5100	3800	7400
Antimony	Metals (ICP/MS)	SW846 6020A	mg/kg dry	75	16	30	3.8	0.21	0.2	4.2	0.39	0.85	0.51	2	0.53	1.2	55	2.6	1.5
Arsenic	Metals (ICP/MS)	SW846 6020A	mg/kg dry	57	24	47	16	5.8	4.5	23	8.1	8.6	8.4	9.8	9.1	7.5	46	21	24
Barium	Metals (ICP/MS)	SW846 6020A	mg/kg dry	100	92	140	57	50	50	82	74 J+	58	70	60	66	96	480	330	260
Beryllium	Metals (ICP/MS)	SW846 6020A	mg/kg dry	0.33	0.46	0.44	0.32	0.13	0.15	0.32	0.17	0.14	0.25	0.18	0.41	0.17	0.7	0.6	0.57
Cadmium	Metals (ICP/MS)	SW846 6020A	mg/kg dry	0.26	0.46	0.38	0.43	0.13	0.12	0.16	0.15	0.14	0.14 J	0.13	2.8	0.16	0.82	0.51	0.54
Calcium	Metals (ICP)	SW846 6010B	mg/kg dry	3200	4600	2500	2300	1800	1100	1700	2400 J+	1000	1700	1600	2200	1500	2800	1500	4300
Chromium	Metals (ICP/MS)	SW846 6020A	mg/kg dry	20	23	26	18	9.3	9.5	17	15 J+	12	17	15	25	13	64	30	40
Cobalt	Metals (ICP/MS)	SW846 6020A	mg/kg dry	10	15	12	12	4.3	3.7	9.9	5.7	4.8	6.7	5.4	14	5.2	24	13	14
Copper	Metals (ICP/MS)	SW846 6020A	mg/kg dry	26	58	28	30	6.9	5.2	23	9.3 J+	7	12	12	64	7.3	45	30	34
Iron	Metals (ICP)	SW846 6010B	mg/kg dry	20000	41000	22000	20000	9300	8000	21000	12000	9800	12000	11000	24000	12000	22000	8500	18000
Lead	Metals (ICP/MS)	SW846 6020A	mg/kg dry	7.1	11	9.8	7	2.2	1.9	6.6	3.4	2.6	4.6	3	9.9	2.6	14	10	12
Magnesium	Metals (ICP)	SW846 6010B	mg/kg dry	3000	6600	3300	3600	2200	1900	3000	2800 J+	2100	3000	2300	5100	2600	2900	1300	4100
Manganese	Metals (ICP/MS)	SW846 6020A	mg/kg dry	510	1800	570	420	300	330	510	340	310	180	250	420	600	1400	560	1200
Mercury	Mercury (CVAA)	SW846 7471A	mg/kg dry	5.1	1.3	0.41	2	0.0064 U	0.0073 J	0.15	0.012 J	0.37	0.011 J	0.24	0.18	0.14	1.7	0.26	0.025
Nickel	Metals (ICP/MS)	SW846 6020A	mg/kg dry	31	56	38	40	12	11	26	18 J+	15	22	15	43	17	66	36	49
Potassium	Metals (ICP)	SW846 6010B	mg/kg dry	540	820	560	670	450	400	420	480 J+	410	510	420	540	520	600	260	780
Selenium	Metals (ICP/MS)	SW846 6020A	mg/kg dry	1.2	2	1.8	2.8	0.58	0.46 J	0.99	0.8	0.49 J	0.89	0.56	1.3	0.59	2.8	2.7	2
Silver	Metals (ICP/MS)	SW846 6020A	mg/kg dry	0.062	0.15	0.089 J	0.093 J	0.022 J	0.023 J	0.082 J	0.042 J	0.022 J	0.051 J	0.034 J	0.14	0.033 J	0.15 J	0.15 J	0.19 J
Sodium	Metals (ICP)	SW846 6010B	mg/kg dry	84	52 J	94	42 J	44 J	43 J	39 UJ	67 J	39 UJ	72 J	120	37 UJ	65 J	85 J	39 UJ	120
Thallium	Metals (ICP/MS)	SW846 6020A	mg/kg dry	0.094	0.076 J	0.12 J	0.069 J	0.066 U	0.067 U	0.068 U	0.071 U	0.072 U	0.082 U	0.068 U	0.072 J	0.069 U	0.19 J	0.25 U	0.2 J
Vanadium	Metals (ICP/MS)	SW846 6020A	mg/kg dry	30	38	37	29	15	13	24	22 J+	17	24	18	37	18	67	47	58
Zinc	Metals (ICP/MS)	SW846 6020A	mg/kg dry	85	100	90	82	27	25	56	40	29	52	30	110	36	150	95	120
Methylmercury																			
Methylmercury	Total Mercury by EPA 1631	EPA 1630 Modified	ng/g dry		0.135 J	0.605 J	0.078 J			0.053 J	0.01 UJ	0.01 UJ		0.019 J	0.01 UJ	0.01 UJ		0.667 J	0.016 J
Mercury Selective Sequential Extraction																			
F0	Hg SSE (F0 - F5) with Total Hg	Hg SSE (F0 - F5) with Total Hg	ng/g dry		4.68 UJ	5.64 UJ	4.63 UJ				4.66 UJ								
F1	Hg SSE (F0 - F5) with Total Hg	Hg SSE (F0 - F5) with Total Hg	ng/g dry		12 UJ	14.5 UJ	61.8 J				2.39 UJ								
F2	Hg SSE (F0 - F5) with Total Hg	Hg SSE (F0 - F5) with Total Hg	ng/g dry		1.14 UJ	1.37 UJ	1.13 UJ				1.14 UJ								
F3	Hg SSE (F0 - F5) with Total Hg	Hg SSE (F0 - F5) with Total Hg	ng/g dry		45.2 J	446 J	98.3 J				5.55 J								
F4	Hg SSE (F0 - F5) with Total Hg	Hg SSE (F0 - F5) with Total Hg	ng/g dry		817 J	2190 J	299 J				4.94 J								
F5	Hg SSE (F0 - F5) with Total Hg	Hg SSE (F0 - F5) with Total Hg	ng/g dry		145 J	829 J	279 J				3.62 J								
Total Mercury	Low Level Mercury	EPA 1631 Appendix	ng/g dry		1270 J	923 J	776 J				13.4 J								
Grain Size																			
Gravel	Grain Size	ASTM D422	%	53.8	41.1	4.7	31.7	67.4	75.1	71.3	38.3	43.2	10.4	61	42.1	56.3	54.3	0.7	57.4
Coarse Sand	Grain Size	ASTM D422	%	6.6	11.5	3	16.2	12.6	12.1	6.4	15.2	15.1	3.5	6.6	25.2	7.1	8.1	1.1	6.2
Medium Sand	Grain Size	ASTM D422	%	3	14.9	5.3	19.9	7.8	4.8	5	14.5	17.1	4.6	14.9	15	15.6	10.2	4.9	11.4
Fine Sand	Grain Size	ASTM D422	%	27.5	9	53.8	12.5	12.3	8.1	15.9	28.4	23.1	73.4	15.5	10.4	20.2	21.3	52.4	18.2
Silt	Grain Size	ASTM D422	%	8.8	19.3	28.4	15.7	-0.1	0	1.4	2.1	1.1	4.5	1.7	6.7	0.8	5.8	35.4	6.3
Clay	Grain Size	ASTM D422	%	0.4	4.2	4.8	4.1	0	0	0	1.6	0.4	3.6	0.3	0.6	0	0.3	5.4	0.6
Total Organic Carbon																			
Total Organic Carbon	Organic Carbon, Total (TOC)	SW846 9060	mg/kg	5400	17000	9300	9000	1300 J	1200 J	4900	2900	2400	4200	2200	5500	1800 J	4700	41000	3100
Sediment Toxicity																			
Toxicity - *Hyalella Azteca* (28 day)	Percent Survival (Mean +/- SD)	EPA 100.4 Chronic	%	92.5 ± 17.5	61.3 ± 12.5	90.0 ± 12.0	70.0 ± 26.2						90.0 ± 10.7						
Toxicity - *Hyalella Azteca* (28 day)	Average Dry Weight/Amphipod (Mean +/- SD)	EPA 100.4 Chronic	mg	0.22 ± 0.04	0.24 ± 0.04	0.23 ± 0.02	0.20 ± 0.03						0.28 ± 0.04						
Field Parameters																			
Turbidity, Kuskokwim River Water	In situ field measurement		NTU	300	125	286	97	543	564	262	561	226	562	316	304	102	176	14	198

Key:
% = Percent
Bold = Detected
Hg = Mercury
ICP/ MS = Inductively coupled plasma/mass spectrometry
J = The analyte was detected. The associated result is estimated.
J+ = The analyte was detected. The associated result is estimated with a high bias.
mg = Milligrams
mg/kg = Milligrams per kilogram
ng/g = Nanograms per gram
NTU = Nephelometric turbidity units
SSE = Selective Sequential Extraction
U = The analyte was analyzed for but not detected. The value provided is the method detection limit.
UJ- = The analyte was analyzed for but not detected. The associated reporting limit is estimated with a low bias.
UJ = The analyte was analyzed for but not detected. The associated reporting limit is estimated.

Table 5-3b. Background Kuskokwim River Sediment Results (2010, 2011, and 2015)

Analyte	Units	10KR13SD	11KR01SD	11KR12SD	11KR18SD	11KR19SD	11KR20SD	11KR21SD	11KR22SD	11KR23SD	11KR24SD	11KR25SD	11KR26SD	11KR27SD	11KR72SD	15KR082SD	15KR083SD
Total Inorganic Elements																	
Aluminum	mg/kg	11600	12500 J	6340 J	10700	2160	5470	5710	10200	10300	6180	9090	11000	6400	6250	7900	5500
Antimony	mg/kg	0.56 U	0.234	0.271	0.185	0.133 J	0.239 J	0.189 J	0.22 J	0.188	0.137	0.171	0.45 J	0.473 J	0.114	0.79	0.27
Arsenic	mg/kg	15	10.4 J	8.77 J	4.75	6.06 J	3.67 J	3.67 J	12.7 J	6.32	6.21	5.03	4.93 J	5.98 J	5.6	9.8	6.9
Barium	mg/kg	152	142 J	138 J	146 J	77.5	58.6	55.6	79.5	141 J	95.5 J	158 J	113	70.3	75.2 J	150	61
Beryllium	mg/kg	0.5	0.383	0.538	0.343	0.352	0.146	0.13	0.196	0.408	0.265	0.28	0.314	0.157	0.291	0.45	0.2
Cadmium	mg/kg	0.5	0.288 J	0.42	0.263 J	0.82	0.099	0.069	0.12	0.268 J	0.164 J	0.221 J	0.231	0.127	0.157 J	0.47	0.12
Calcium	mg/kg	4800	2390 J	2250 J	2960	762	1610	1700	2930	2670	1930	2220	2930	1880	1490	1800	2200
Chromium	mg/kg	25.3	16.6 J	17.7 J	22.2 J	13.6 J	11.1 J	10.7 J	15.8 J	20.2 J	15.7 J	20.1 J	21.4 J	14.4 J	12 J	29	14
Cobalt	mg/kg	10.9	12.5 J	14.8 J	8.91	11.5	4.54	3.83	4.94	13.5	8.38	7.47	8.2	5.69	7.29	15	6.9
Copper	mg/kg	25.3 J	29.4	56.2 J	20.9 J	36.9 J	7.15 J	4.62 J	10.4 J	28 J	16.7 J	14.5 J	16.9 J	7.69 J	19.2 J	50	16
Iron	mg/kg	27100	33900	31200	21800	8170	13500	13400	21900	32300	18000	18100	20700	17200	16500	29000	15000
Lead	mg/kg	7	11.4 J	12.3 J	7.11	13.5	2.4	1.82	3.35	10.5	4.43	5.06	5.73	2.41	4.89	12	2.7
Magnesium	mg/kg	4840	5040	2950	4440 J	1400	2860	3190	5900	4400 J	3270 J	4020 J	5000	3460	2830 J	4000	2800
Manganese	mg/kg	451	740	280	395 J	465	246	197	366	536 J	385 J	253 J	261	743	281 J	1200	380
Mercury	mg/kg	0.09 J	0.081 J	0.374 J	0.089 J	0.143 J	0.013 J	0.013 J	0.03 J	0.126 J	0.078 J	0.053 J	0.044 J	0.015 J	0.05 J	0.098 J	0.016 J
Nickel	mg/kg	32	29.2	51.7	25.3 J	37	13	10.7	14.4	36.2 J	23 J	22.2 J	23.9	14.8	22.4 J	51	20
Potassium	mg/kg	1280	721	853	668 J	418	637	508	614	773 J	899 J	685 J	961	718	521 J	590	420
Selenium	mg/kg	0.81 U	0.31	0.74	0.42	1.03	0.08 J	0.04 J	0.22	0.45	0.17	0.19	0.28	0.06 J	0.12	1.9	0.69
Silver	mg/kg	0.055 U	0.092	0.123	0.124	0.035	0.043	0.034	0.062	0.113	0.046	0.084	0.105	0.044	0.058	0.14	0.0078 J
Sodium	mg/kg	170	37.9 J	57.3	79.3	35.9 J	70.3	71.4	86.5	60.9	42.5	83.1	125	89.3	37.2 J	70 J	110
Thallium	mg/kg	0.34 U	0.075	0.077	0.096	0.105	0.051	0.035	0.075	0.07	0.052	0.092	0.089	0.059	0.049	0.098 J	0.056 U
Vanadium	mg/kg	36.3	21.9 J	27.8 J	29.8	23.8	15.7	11.9	27.3	28.9	21.8	27.1	29.8	19.8	16.3	33	22
Zinc	mg/kg	84	74.3 J	116 J	69.5 J	174 J	30.9 J	21.8 J	36.2 J	78 J	52.4 J	56.4 J	62 J	35.3 J	57.4 J	110	41
Methylmercury																	
Methylmercury	ng/g	0.184	0.06 J	0.49 J	0.28 J						0.05 U				0.07 J		

Key

J	The analyte was detected. The associated result is estimated.
mg/kg	milligrams per kilogram
ng/g	nanograms per gram
U	The analyte was analyzed for but not detected. The value provided the reporting limit.

Table 5-3c. Background Statistics for Kuskokwim River Sediments.

Analyte	Number of Observations	Number of Detections	Minimum Detected Concentration (mg/kg)	Maximum Detected Concentration (mg/kg)	Distribution	95% UPL	95% UPL Statistic	Recommended Background Level (mg/kg)	Background Rationale
Aluminum	15	15	2160	12500	Normal	13426	95% UPL (t)	12500	Max Det Conc
Antimony	15	14	0.114	0.79	Approx. Gamma	0.583	95% KM WH Approx. Gamma UPL	0.583	95% UPL
Arsenic	15	15	3.67	15	Normal	13.4	95% UPL (t)	13.4	95% UPL
Barium	15	15	55.6	158	Not Discernable	158	95% UPL	158	95% UPL
Beryllium	15	15	0.13	0.538	Normal	0.547	95% UPL (t)	0.538	Max Det Conc
Cadmium	15	15	0.069	0.82	Approx. Normal	0.645	95% UPL (t)	0.645	95% UPL
Calcium	15	15	762	4800	Normal	3985	95% UPL (t)	3985	95% UPL
Chromium	15	15	10.7	29	Normal	27.36	95% UPL (t)	27.36	95% UPL
Cobalt	15	15	3.83	15	Normal	15.88	95% UPL (t)	15	Max Det Conc
Copper	15	15	4.62	56.2	Normal	50.55	95% UPL (t)	50.55	95% UPL
Iron	15	15	8170	33900	Normal	35551	95% UPL (t)	33900	Max Det Conc
Lead	15	15	1.82	13.5	Normal	14.3	95% UPL (t)	13.5	Max Det Conc
Magnesium	15	15	1400	5900	Normal	5935	95% UPL (t)	5900	Max Det Conc
Manganese	15	15	197	1200	Approx. Normal	937.3	95% UPL (t)	937.3	95% UPL
Mercury	15	15	0.013	0.374	Gamma	0.258	95% WH Approx. Gamma UPL	0.258	95% UPL
Mercury (no outlier)	14	14	0.013	0.143	Normal	0.141	95% UPL (t)	0.141	95% UPL
Methylmercury	6	5	0.00006	0.00049	Normal	0.000532	95% KM UPL (t)	0.00049	Max Det Conc
Nickel	15	15	10.7	51.7	Normal	50.11	95% UPL (t)	50.11	95% UPL
Potassium	15	15	418	1280	Normal	1093	95% UPL (t)	1093	95% UPL
Selenium	15	14	0.04	1.9	Gamma	1.434	95% KM WH Approx. Gamma UPL	1.434	95% UPL
Silver	15	14	0.0078	0.14	Normal	0.145	95% KM UPL (t)	0.14	Max Det Conc
Sodium	15	15	35.9	170	Normal	143.9	95% UPL (t)	143.9	95% UPL
Thallium	15	13	0.035	0.105	Normal	0.111	95% KM UPL (t)	0.105	Max Det Conc
Vanadium	15	15	11.9	36.3	Normal	37.16	95% UPL (t)	36.3	Max Det Conc
Zinc	15	15	21.8	174	Normal	142.2	95% UPL (t)	142.2	95% UPL

Key:

mg/kg	milligrams per kilogram
UPL	Upper Prediction Limit
Max Det Conc	Maximum Detected Concentration

Table 5-4 Periphyton Sample Results, BLM 2014

Analyte		Units																		
	Sample Location ID		Kusko-14-PERI-27		Kusko-14-PERI-12		Kusko-14-PERI-11		Kusko-14-PERI-10		Kusko-14-PERI-9		Kusko-14-PERI-8		Kusko-14-PERI-7		Kusko-14-PERI-6		Kusko-14-PERI-5	
	General Location Description		Upriver of Red Devil Creek Delta		Upriver of Red Devil Creek Delta		Upriver of Red Devil Creek Delta		Upriver of Red Devil Creek Delta		Upriver of Red Devil Creek Delta		Upriver of Red Devil Creek Delta		Upriver of Red Devil Creek Delta		Upriver of Red Devil Creek Delta		Upriver of Red Devil Creek Delta	
	Nearby RI Supplement Sediment Sample Location																			
	Sample ID		Kusko-14-PERI-27A	Kusko-14-PERI-27B	Kusko-14-PERI-12A	Kusko-14-PERI-12B	Kusko-14-PERI-11A	Kusko-14-PERI-11B	Kusko-14-PERI-10A	Kusko-14-PERI-10B	Kusko-14-PERI-9A	Kusko-14-PERI-9B	Kusko-14-PERI-8A	Kusko-14-PERI-8B	Kusko-14-PERI-7A	Kusko-14-PERI-7B	Kusko-14-PERI-6A	Kusko-14-PERI-6B	Kusko-14-PERI-5A	Kusko-14-PERI-5B
	Method																			
Total Inorganic Elements																				
Aluminum	EPA 6020	µg/g dry	30907		22703		23697	30781	32708	9587	36258	13345	35519	37973	24663	31040	34537	29596	31431	15281
Antimony	EPA 6020	µg/g dry	1.5		1.2		1.7	3.7	1.6	0.7	1.7	1.0	1.3	1.4	1.0	1.4	1.5	1.2	1.6	0.7
Arsenic	EPA 6020	µg/g dry	23.4		22.0		24.0	33.3	23.8	12.5	23.0	18.2	22.2	22.8	15.8	18.3	25.5	19.0	23.7	11.0
Barium	EPA 6020	µg/g dry	434.0		357.6		311.7	443.2	477.4	138.1	519.3	233.7	562.0	657.7	355.1	440.7	523.8	422.7	494.5	226.9
Beryllium	EPA 6020	µg/g dry	0.9		0.8		0.8	1.1	1.0	0.4	1.0	0.6	1.2	1.1	0.8	0.9	1.0	0.9	0.9	0.5
Boron	EPA 6020	µg/g dry	21.4		14.6		13.8	20.2	23.3	3.6	28.6	6.6	27.3	29.3	19.0	23.3	24.5	21.8	24.7	14.2
Cadmium	EPA 6020	µg/g dry	0.5		0.4		0.4	0.8	0.3	0.2	0.4	0.3	0.4	0.4	0.2	0.3	0.5	0.3	0.4	0.18 J
Chromium	EPA 6020	µg/g dry	47.7		41.1		45.4	54.9	50.2	18.7	57.2	27.2	62.4	59.9	39.9	47.6	55.0	47.8	52.7	24.6
Copper	EPA 6020	µg/g dry	29.4		28.1		28.1	45.5	28.1	16.2	32.5	25.3	28.9	30.7	20.8	21.6	30.1	23.0	26.6	13.0
Iron	EPA 6020	µg/g dry	32052		29002		32780	44167	34699	18396	38544	25446	35060	35178	23889	29874	35449	30348	35211	16343
Lead	EPA 6020	µg/g dry	11.2		8.7		9.4	15.5	10.5	5.2	16.1	8.1	9.7	10.5	7.9	8.3	10.3	7.8	10.5	5.0
Magnesium	EPA 6020	µg/g dry	7870		7431		7535	9541	8137	4289	8875	5711	8595	8788	5883	7205	8690	7391	8200	3741
Manganese	EPA 6020	µg/g dry	551.0		672.3		544.1	792.1	610.4	361.2	794.7	511.4	882.3	829.8	431.8	527.2	688.7	557.6	708.5	316.1
Mercury	EPA 245.7	µg/g dry	0.07		0.04		0.08	0.17	0.06	0.03	0.08	0.04	0.04	0.04	0.04	0.06	0.12	0.03	0.07	0.04
Molybdenum	EPA 6020	µg/g dry	1.2		1.1		1.2	1.6	1.2	0.6	1.3	1.1	1.1	1.3	0.9	0.9	1.3	1.0	1.4	0.6
Nickel	EPA 6020	µg/g dry	30.6		32.4		32.8	44.5	32.5	19.0	36.1	27.4	36.3	35.9	22.3	28.1	33.4	29.6	30.5	14.4
Selenium	EPA 6020	µg/g dry	0.7		0.5		0.6	0.9	0.6	0.3	0.5	0.5	0.4	0.5	0.4	0.5	0.6	0.4	0.4	0.3
Strontium	EPA 6020	µg/g dry	62.5		75.7		54.3	75.2	59.0	33.2	71.9	45.3	87.4	85.3	47.5	57.1	96.3	76.5	76.4	31.4
Vanadium	EPA 6020	µg/g dry	78.0		69.1		71.2	88.9	88.2	28.4	106.0	44.8	102.9	104.9	69.2	82.5	96.6	85.3	93.3	41.9
Zinc	EPA 6020	µg/g dry	96.6		89.9		98.3	149.8	97.1	55.1	104.0	77.4	96.1	96.6	67.4	82.6	96.7	85.2	93.0	43.2
Percent Solids																				
Percent Solids	SM 2540 B	% Dry	17.1	15	54.7	18.9	19.4	7.8	28.9	35.2	35.9	39.2	49.5	45.1	22.1	23.2	24.1	32.4	21.1	19.6
Methylmercury																				
Methylmercury (as Mercury)	EPA 1630 Mod/FGS-070	ng/g wet	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.4 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Inorganic Arsenic																				
Inorganic Arsenic	EPA 1632	mg/kg wet	4.23	3.24	6.53	2.07	2.94	1.67	2.19	7.26	1.69	3.12	8.15	4.48	1.03	2.1	2.58	3.1	1.5	0.723

Table 5-4 Periphyton Sample Results, BLM 2014

Analyte	Sample Location ID	Units	Kusko-14-PERI-4		Kusko-14-PERI-3		Kusko-14-PERI-2		Kusko-14-PERI-1		RD-14-PERI-1		Kusko-14-PERI-13		Kusko-14-PERI-14		Kusko-14-PERI-15		Kusko-14-PERI-16	
	General Location Description		Upriver of Red Devil Creek Delta		Upriver of Red Devil Creek Delta		Upriver of Red Devil Creek Delta		Upriver of Red Devil Creek Delta		Red Devil Creek		Downriver of Red Devil Creek Delta		Downriver of Red Devil Creek Delta		Downriver of Red Devil Creek Delta		Downriver of Red Devil Creek Delta	
	Nearby RI Supplement Sediment Sample Location								KR082				KR088		KR092		KR096		KR098	
	Sample ID		Kusko-14-PERI-4A	Kusko-14-PERI-4B	Kusko-14-PERI-3A	Kusko-14-PERI-3B	Kusko-14-PERI-2A	Kusko-14-PERI-2B	Kusko-14-PERI-1A	Kusko-14-PERI-1B	RD-14-PERI-1A	RD-14-PERI-1B	Kusko-14-PERI-13A	Kusko-14-PERI-13B	Kusko-14-PERI-14A	Kusko-14-PERI-14B	Kusko-14-PERI-15A	Kusko-14-PERI-15B	Kusko-14-PERI-16A	Kusko-14-PERI-16B
	Method																			
Total Inorganic Elements																				
Aluminum	EPA 6020	µg/g dry	**26820**	**38410**	**30280**	**32989**	**27857**	**23814**	**36763**	**37328**	**17384**	**21114**	**22753**	**15290**	**22941**	**16629**		**19708**	**16406**	**17043**
Antimony	EPA 6020	µg/g dry	**1.2**	**1.8**	**0.7**	**1.2**	**1.4**	**2.3**	**1.3**	**1.4**	**1267.7**	**1570.7**	**13.9**	**13.7**	**3.3**	**4.5**		**57.9**	**3.1**	**3.2**
Arsenic	EPA 6020	µg/g dry	**24.3**	**27.4**	**14.9**	**19.2**	**23.8**	**35.5**	**19.0**	**20.8**	**1637.1**	**1570.5**	**35.7**	**26.0**	**26.8**	**23.0**		**34.1**	**24.3**	**22.2**
Barium	EPA 6020	µg/g dry	**401.6**	**568.7**	**439.9**	**485.9**	**421.5**	**640.7**	**524.9**	**536.2**	**298.0**	**348.3**	**308.1**	**230.1**	**326.5**	**228.6**		**273.2**	**231.9**	**237.0**
Beryllium	EPA 6020	µg/g dry	**0.8**	**1.1**	**0.8**	**1.0**	**0.9**	**1.4**	**1.0**	**1.0**	0.7 U	0.7 U	**0.9**	**0.6**	**0.9**	**0.6**		**0.8**	**0.6**	**0.6**
Boron	EPA 6020	µg/g dry	**20.6**	**31.1**	**22.0**	**23.9**	**22.6**	**33.3**	**26.5**	**25.9**	**25.2**	**31.2**	**10.9**	**7.9**	**12.8**	**7.8**		**10.2**	**6.4**	**7.4**
Cadmium	EPA 6020	µg/g dry	**0.4**	**0.4**	**0.2**	**0.3**	**0.5**	**0.6**	**0.4**	**0.4**	0.7 U	0.7 U	**0.5**	**0.4**	**0.4**	**0.4**		**0.3**	**0.4**	**0.4**
Chromium	EPA 6020	µg/g dry	**47.7**	**60.7**	**49.5**	**53.4**	**44.1**	**68.2**	**59.0**	**57.0**	**31.3**	**38.9**	**43.2**	**32.6**	**45.7**	**33.9**		**39.6**	**35.2**	**34.2**
Copper	EPA 6020	µg/g dry	**22.5**	**44.3**	**17.5**	**23.1**	**30.7**	**73.2**	**27.1**	**26.9**	**45.0**	**45.3**	**32.9**	**25.5**	**30.9**	**27.0**		**32.2**	**31.2**	**25.2**
Iron	EPA 6020	µg/g dry	**32124**	**39836**	**27425**	**31780**	**30157**	**26778**	**34253**	**34146**	**27563**	**27134**	**35081**	**27875**	**33621**	**27419**		**31926**	**31925**	**27740**
Lead	EPA 6020	µg/g dry	**8.1**	**12.0**	**5.9**	**8.3**	**10.3**	**15.8**	**9.2**	**10.0**	**11.8**	**13.2**	**11.3**	**8.3**	**10.0**	**9.0**		**10.1**	**10.0**	**8.3**
Magnesium	EPA 6020	µg/g dry	**7265**	**9464**	**6931**	**7992**	**7546**	**6611**	**8516**	**8644**	**3434**	**3786**	**8600**	**6459**	**8471**	**6782**		**7619**	**7438**	**6843**
Manganese	EPA 6020	µg/g dry	**650.6**	**806.8**	**501.3**	**636.6**	**575.2**	**894.8**	**613.8**	**789.8**	**362.5**	**418.2**	**646.3**	**514.0**	**616.6**	**493.4**		**575.5**	**516.9**	**485.1**
Mercury	EPA 245.7	µg/g dry	**0.04**	**0.06**	**0.04**	**0.03**	**0.04**	**0.03**	**0.04**	**0.05**	**181.79**	**225.06**	**5.99**	**6.87**	**0.25**	**0.19**		**4.56**	**0.40**	**0.47**
Molybdenum	EPA 6020	µg/g dry	**1.0**	**1.4**	**0.6**	**1.3**	**1.6**	**1.7**	**1.0**	**1.0**	**0.92 J**	**0.77 J**	**1.4**	**1.0**	**1.3**	**1.1**		**1.2**	**1.4**	**1.0**
Nickel	EPA 6020	µg/g dry	**29.2**	**36.7**	**27.0**	**30.6**	**29.4**	**48.9**	**33.9**	**34.4**	**29.6**	**35.4**	**37.2**	**29.0**	**36.3**	**31.1**		**34.2**	**32.5**	**29.1**
Selenium	EPA 6020	µg/g dry	**0.3**	**0.4**	**0.3**	**0.5**	**0.35 J**	**0.8**	**0.6**	**0.7**	**2.7**	**2.4**	**0.6**	**0.5**	**0.6**	**0.5**		**0.4**	**0.5**	**0.4**
Strontium	EPA 6020	µg/g dry	**65.8**	**80.6**	**67.5**	**70.3**	**72.1**	**127.6**	**73.9**	**72.5**	**46.2**	**47.5**	**90.6**	**60.2**	**80.0**	**67.2**		**64.0**	**70.1**	**76.6**
Vanadium	EPA 6020	µg/g dry	**83.5**	**104.6**	**84.7**	**93.5**	**77.3**	**118.5**	**104.5**	**100.8**	**48.0**	**57.4**	**65.6**	**49.2**	**71.5**	**50.4**		**60.8**	**50.3**	**52.0**
Zinc	EPA 6020	µg/g dry	**85.6**	**115.6**	**72.9**	**89.2**	**96.5**	**147.0**	**107.9**	**101.5**	**215.7**	**202.0**	**109.2**	**83.1**	**107.5**	**89.6**		**98.3**	**96.5**	**84.5**
Percent Solids																				
Percent Solids	SM 2540 B	% Dry	**24.6**	**13.1**	**71.8**	**46.6**	**12.8**	**20.5**	**36.1**	**41.9**	**3.8**	**3.5**	**34.4**	**33.6**	**34.6**	**38**	**19.3**	**24.9**	**37.8**	**50**
Methylmercury																				
Methylmercury (as Mercury)	EPA 1630 Mod/FGS-070	ng/g wet	0.5 U	0.5 U	0.5 U	0.5 U	0.4 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Inorganic Arsenic																				
Inorganic Arsenic	EPA 1632	mg/kg wet	**2.77**	**1.42**	**8.16**	**3.69**	**2.84**	**0.641**	**4.67**	**5.7**	**66.6**	**70.4**	**2.82**	**2.59**	**4.65**	**2.05**	**4.21**	**3.15**	**4.58**	**3.69**

Table 5-4 Periphyton Sample Results, BLM 2014

Analyte		Units																		
	Sample Location ID		Kusko-14-PERI-26		Kusko-14-PERI-18		Kusko-14-PERI-19		Kusko-14-PERI-20		Kusko-14-PERI-21		Kusko-14-PERI-22		Kusko-14-PERI-23		Kusko-14-PERI-24		Kusko-14-PERI-25	
	General Location Description		Downriver of Red Devil Creek Delta		Downriver of Red Devil Creek Delta		Downriver of Red Devil Creek Delta		Downriver of Red Devil Creek Delta		Downriver of Red Devil Creek Delta		Downriver of Red Devil Creek Delta		Downriver of Red Devil Creek Delta		Downriver of Red Devil Creek Delta		Downriver of Red Devil Creek Delta	
	Nearby RI Supplement Sediment Sample Location				KR100						KR102								KR104	
	Sample ID		Kusko-14-PERI-26A	Kusko-14-PERI-26B	Kusko-14-PERI-18A	Kusko-14-PERI-18B	Kusko-14-PERI-19A	Kusko-14-PERI-19B	Kusko-14-PERI-20A	Kusko-14-PERI-20B	Kusko-14-PERI-21A	Kusko-14-PERI-21B	Kusko-14-PERI-22A	Kusko-14-PERI-22B	Kusko-14-PERI-23A	Kusko-14-PERI-23B	Kusko-14-PERI-24A	Kusko-14-PERI-24B	Kusko-14-PERI-25A	Kusko-14-PERI-25B
	Method																			
Total Inorganic Elements																				
Aluminum	EPA 6020	µg/g dry	**23988**	**44024**	**20691**	**29048**	**13718**	**19853**	**15136**	**32103**	**33489**	**39784**	**36391**	**38221**	**29009**	**37141**	**29586**	**37859**		**24269**
Antimony	EPA 6020	µg/g dry	**2.6**	**3.1**	**2.2**	**2.3**	**1.9**	**1.6**	**2.2**	**2.3**	**2.2**	**2.7**	**2.8**	**2.5**	**2.1**	**2.7**	**2.1**	**2.5**		**1.0**
Arsenic	EPA 6020	µg/g dry	**38.2**	**37.7**	**30.9**	**26.4**	**15.7**	**17.3**	**22.2**	**22.8**	**21.8**	**27.7**	**26.8**	**30.7**	**27.0**	**28.3**	**26.7**	**32.9**		**11.6**
Barium	EPA 6020	µg/g dry	**351.6**	**683.4**	**299.8**	**451.2**	**190.3**	**276.2**	**199.8**	**446.6**	**484.8**	**557.7**	**511.7**	**555.1**	**422.2**	**544.8**	**427.8**	**547.5**		**334.3**
Beryllium	EPA 6020	µg/g dry	**0.9**	**1.4**	**0.8**	**1.0**	**0.4**	**0.7**	**0.5**	**0.9**	**1.0**	**1.1**	**1.1**	**1.1**	**0.9**	**1.2**	**0.9**	**1.1**		**0.7**
Boron	EPA 6020	µg/g dry	**10.1**	**33.3**	**8.9**	**21.0**	**8.5**	**13.6**	**6.0**	**23.2**	**25.1**	**28.1**	**27.9**	**27.4**	**19.7**	**26.5**	**20.4**	**26.4**		**15.4**
Cadmium	EPA 6020	µg/g dry	**0.6**	**0.6**	**0.5**	**0.4**	**0.2**	**0.3**	**0.3**	**0.4**	**0.3**	**0.4**	**0.3**	**0.5**	**0.5**	**0.5**	**0.4**	**0.4**		**0.188 J**
Chromium	EPA 6020	µg/g dry	**50.1**	**76.2**	**39.8**	**52.3**	**25.8**	**34.8**	**30.0**	**52.8**	**53.8**	**65.3**	**59.2**	**63.5**	**48.4**	**61.2**	**49.4**	**60.3**		**36.9**
Copper	EPA 6020	µg/g dry	**44.0**	**45.5**	**34.7**	**31.9**	**18.0**	**21.2**	**26.3**	**26.1**	**24.5**	**30.6**	**26.0**	**36.5**	**31.0**	**34.5**	**27.8**	**29.7**		**14.7**
Iron	EPA 6020	µg/g dry	**43206**	**45073**	**35277**	**32999**	**18971**	**25417**	**27888**	**31458**	**32023**	**39272**	**35602**	**39535**	**33100**	**37823**	**32684**	**37957**		**25524**
Lead	EPA 6020	µg/g dry	**14.8**	**16.1**	**11.5**	**11.6**	**6.2**	**7.6**	**8.8**	**9.3**	**9.2**	**11.9**	**10.0**	**13.6**	**11.2**	**12.4**	**9.6**	**10.7**		**6.3**
Magnesium	EPA 6020	µg/g dry	**10690**	**11795**	**8622**	**8293**	**4463**	**6064**	**6554**	**7761**	**7890**	**9566**	**8527**	**10252**	**8330**	**9667**	**8008**	**9391**		**5030**
Manganese	EPA 6020	µg/g dry	**930.6**	**1013.8**	**730.8**	**633.6**	**338.9**	**489.9**	**447.6**	**541.8**	**545.7**	**661.1**	**647.7**	**709.1**	**653.3**	**688.4**	**608.6**	**721.6**		**514.9**
Mercury	EPA 245.7	µg/g dry	**0.14**	**0.16**	**0.23**	**0.15**	**0.21**	**0.11**	**0.22**	**0.13**	**0.09**	**0.12**	**0.12**	**0.12**	**0.09**	**0.14**	**0.11**	**0.14**		**0.10**
Molybdenum	EPA 6020	µg/g dry	**1.7**	**1.8**	**1.3**	**1.4**	**1.0**	**0.9**	**1.0**	**1.0**	**1.1**	**1.4**	**1.2**	**1.5**	**1.3**	**1.4**	**1.1**	**1.1**		**0.7**
Nickel	EPA 6020	µg/g dry	**46.7**	**46.8**	**36.9**	**32.8**	**19.0**	**24.8**	**29.0**	**31.0**	**30.4**	**37.3**	**32.0**	**39.8**	**32.7**	**37.2**	**32.3**	**36.1**		**20.9**
Selenium	EPA 6020	µg/g dry	**0.9**	**0.9**	**0.7**	**0.4**	**0.4**	**0.5**	**0.5**	**0.6**	**0.5**	**0.5**	**0.7**	**0.8**	**0.6**	**0.6**	**0.5**	**0.5**		**0.3**
Strontium	EPA 6020	µg/g dry	**88.9**	**93.0**	**72.9**	**73.0**	**26.9**	**45.1**	**42.3**	**62.4**	**70.0**	**70.7**	**64.7**	**85.1**	**67.7**	**83.4**	**69.3**	**83.4**		**49.1**
Vanadium	EPA 6020	µg/g dry	**75.7**	**125.3**	**63.3**	**84.8**	**39.8**	**58.1**	**44.0**	**88.0**	**92.2**	**106.0**	**97.0**	**102.0**	**80.8**	**100.4**	**82.7**	**102.8**		**65.3**
Zinc	EPA 6020	µg/g dry	**139.7**	**140.6**	**110.6**	**101.3**	**59.8**	**71.8**	**86.7**	**91.1**	**90.2**	**108.9**	**98.2**	**119.4**	**100.1**	**111.6**	**95.6**	**104.4**		**61.4**
Percent Solids																				
Percent Solids	SM 2540 B	% Dry	**41.6**	**24.7**	**36.1**	**28.7**	**36**	**39.7**	**32.2**	**41.4**	**40.6**	**33.4**	**32.3**	**22.5**	**23.3**	**31.1**	**40.4**	**41.7**	**20.4**	**25.5**
Methylmercury																				
Methylmercury (as Mercury)	EPA 1630 Mod/FGS-070	ng/g wet	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.4 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Inorganic Arsenic																				
Inorganic Arsenic	EPA 1632	mg/kg wet	**4.37**	**1.76**	**2.2**	**2.28**	**3.53**	**2.63**	**2.64**	**1.72**	**3.78**	**3.35**	**4.43**	**2.48**	**1.2**	**2.91**	**2.56**	**2**	**1.46**	**3.3**

Key:
EPA = Environmental Protection Agency
µg/g = micrograms per kilogram
mg/kg = miligrams per kilogram
% = percent

Table 5-5 Comparison of Metals Concentrations in Periphyton from the Kuskokwim River Upstream and Downstream from the Red Devil Creek Delta

Analyte	Upstream Periphyton Concentration (µg/g dry weight)			Downstream Periphyton Concentration (µg/g dry weight)			Is Downstream Significantly Greater than Upstream ($p < 0.05$)?*	
	Mean	SD	Median	Mean	SD	Median	(Yes/No)	p value
Antimony	1.42	0.44	1.32	7.6	15.5	2.43	Yes	0.0005
Arsenic (total)	21.9	4.2	22	26.3	7.0	27.7	Yes	0.0241
Inorganic Arsenic	12.1	5.2	11.9	9.1	2.4	8.8	No	0.9637
Mercury	0.057	0.024	0.051	0.99	2.03	0.16	Yes	0.00002
Cadmium	0.39	0.10	0.38	0.39	0.11	0.39	No	0.4388
Copper	28.9	8.6	28.1	29.0	7.1	29.0	No	0.3598
Iron	31307	3966	31995	32571	5520	31926	No	0.2691
Manganese	634	111	653	608	137	580	No	0.7475
Nickel	31.5	5.0	31.7	32.7	6.4	33.8	No	0.2364
Selenium	0.51	0.14	0.48	0.54	0.14	0.53	No	0.2691
Vanadium	83	14	80	74	19	66	No	0.9244
Zinc	94	17	91	97	19	99	No	0.2525

Notes:

* Mann-Whitney U-test for difference in medians.

Key:

p = probability

SD = standard deviation

Table 5-6 Summary of Mercury Selective Sequential Extraction (SSE) Results for 2015 Kuskokwim River Sediment Samples

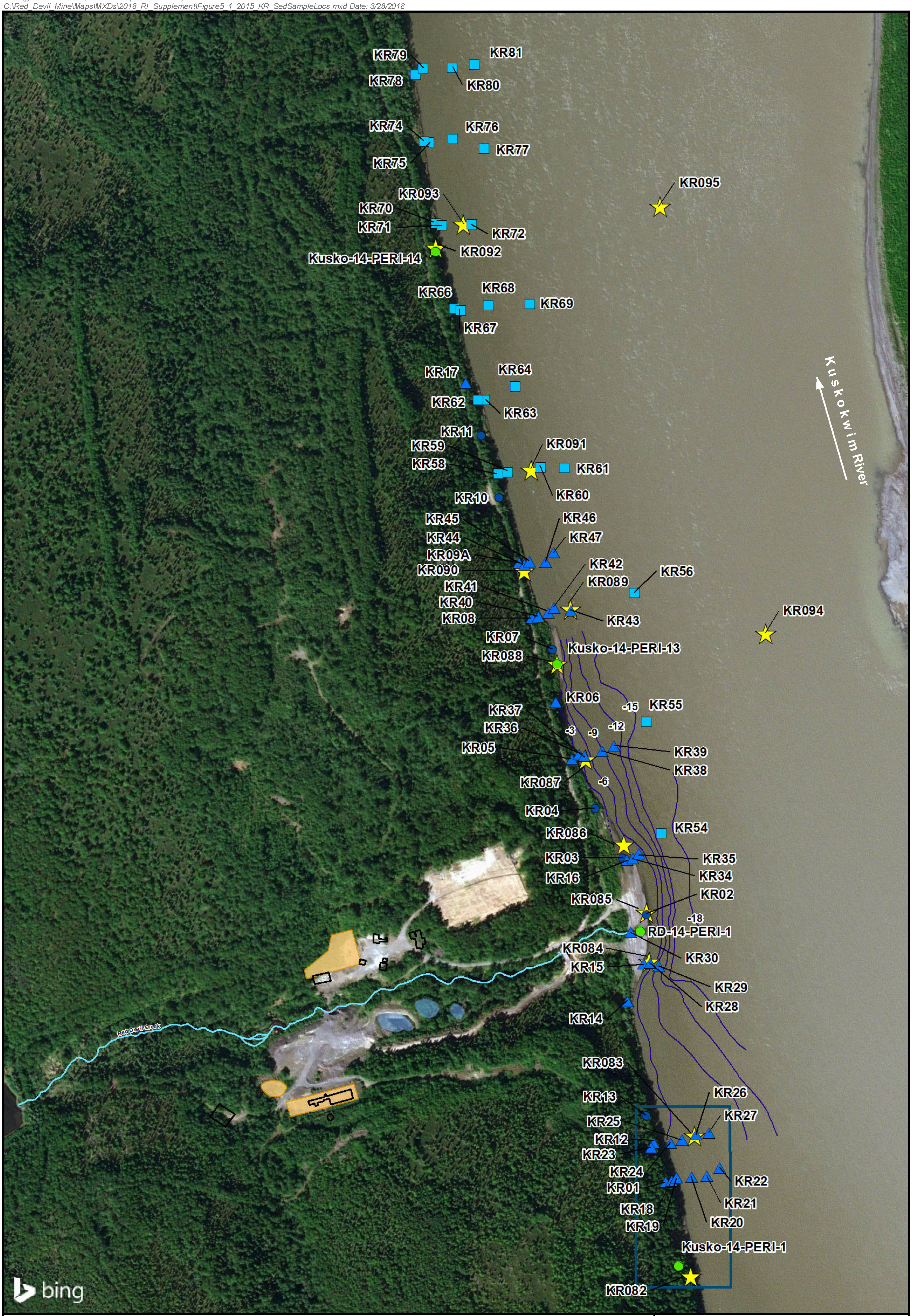
Analyte / SSE Fraction	SSE Extractant	SSE Fraction Description	Units	Sample Location and Number													
				KR084 Red Devil Creek (RDC) Delta Area 15KR084SD		KR088 300 m Downriver of RDC Delta 15KR088SD		KR089 360 m Downriver of RDC Delta 15KR089SD		KR091 510 m Downriver of RDC Delta 15KR091SD		KR092 775 m Downriver of RDC Delta 15KR092SD		KR093 800 m Downriver of RDC Delta 15KR093SD		KR097 1,300 m Downriver of RDC Delta (other bank) 15KR097SD	
Mercury SSE Results																	
Fraction 0 (F0)	De-ionized Water	Volatile	ng/g dry	4.77	UJ	9.28	J	4.63	UJ	4.68	UJ	5.64	UJ	4.63	UJ	4.66	UJ
Fraction 1 (F1)	De-ionized Water	Water soluble	ng/g dry	271	J	58.5	UJ	2.37	UJ	12	UJ	14.5	UJ	61.8	J	2.39	UJ
Fraction 2 (F2)	pH 2 Stomach Acid	Weak Acid Soluble	ng/g dry	1.16	UJ	12.1	J	1.13	UJ	1.14	UJ	1.37	UJ	1.13	UJ	1.14	UJ
Fraction 3 (F3)	I Molar KOH	Organic Complexed	ng/g dry	1680	J	528	J	30.8	J	45.2	J	446	J	98.3	J	5.55	J
Fraction 4 (F4)	12 Molar HNO_3	Strongly Complexed	ng/g dry	6000	J	1530	J	605	J	817	J	2190	J	299	J	4.94	J
Fraction 5 (F5)	Aqua Regia	Cinnabar	ng/g dry	9140	J	4410	J	6810	J	145	J	829	J	279	J	3.62	J
Sum F0 to F5 (ND= 0.5DL)	see above	Total Mercury	ng/g dry	17,094		6,519		7,450		1,016		3,476		741		18	
Bioavailable Fraction Estimate																	
Sum F0 to F2 (ND=0.5DL)	see above	Readily Bioavailable	ng/g dry	274		51		4.1		8.9		11		65		4.1	
% F0 to F2 of F0 to F5	see above	Readily Bioavailable	%	1.6%		0.8%		0.1%		0.9%		0.3%		8.7%		22%	

Key:
DL = detection limit
ND = non-detect
RDC = Red Devil Creek
SSE = Selective Sequential Extraction

Table 5-7 Mineral Occurrences near Red Devil Mine

Mineral Occurrence Name	Nearest Receiving Surface Water Body	Nearest Downriver 2015 Kuskokwim River Sediment Sample	Type	Ore Minerals	Production	Location Description
Landru	Kuskokwim River	KR082	Lode and placer (staked)	Cinnabar	None reported.	None reported
Mellick's	Kuskokwim River	KR082	Lode, prospect (staked)	Cinnabar	None reported.	None reported
Red Devil Mine	Red Devil Creek	KR084	Lode, mine	Cinnabar, stibnite (realgar, orpiment)	Total = 36,141 +/- 408 flasks Hg from 1933-71. Of this, 2,972 +/- 8 flasks were produced from 1933-1946 (Webber and others 1947), 29,369 + /- 405 flasks from 1953-1963 (Jasper 1961), and 3,800 flasks from 1969-1971 (T.K. Bundtzen, pers. comm., 1988). In 1970 stibnite was recovered in flotation.	Red Devil Creek
McCally Creek	McCally Creek	KR096	Lode, occurrence	Cinnabar	None	Head of McCally Creek on NE slope of Barometer Mountain at 1,000 ft.
Fairview	McCally Creek	KR096	Lode, prospect	Cinnabar, stibnite	None reported; Webber and others (1947) stated there was no production of any consequence.	South of Kuskokwim River
Unnamed	McCally Creek	KR096	Lode, prospect (?)	Cinnabar, stibnite	None reported.	SW of head of small creek that flows past Barometer Mine
Vermillion	McCally Creek	KR096	Lode, prospect	Cinnabar	None reported.	South side of Kuskokwim River, west side of McCally Creek (Cobb, 1972, gave this property the same locality number as the nearby Barometer mine).
Mercury	McCally Creek	KR096	Lode, prospect	Cinnabar	None reported.	South side of Kuskokwim River, west side of McCally Creek (Cobb, 1972, gave this property the same locality number as the nearby Barometer mine).
Barometer	McCally Creek	KR096	Lode, mine	Cinnabar, stibnite, realgar, orpiment (?)	Total = 14 or 16 flasks of mercury. Webber and others (1947) stated 10 flasks were produced in 1938; Malone (1962) stated only 8 flasks came from 25 tons or ore. In 1940, 6 more flasks were produced in connection with assessment work (Cady and others 1955).	South of Kuskokwim River
Two Genevieves	Cribby Creek	KR101	Lode, occurrence	Cinnabar	None	West of Cribby Creek, but not well located. Only location is from plate 3 of Cady and others (1955) which does not have modern topography.
Number 1 Discovery Claim	Kuskokwim River	KR103	Lode, occurrence (?)	Probably cinnabar	None	Unknown. Although a claim was staked, we have listed the locality as an occurrence, because the claim was later abandoned.
Alice & Bessie (claim group) formerly known as Parks prospect or property	Kuskokwim River	KR103	Lode, mine	Cinnabar, stibnite, native mercury	Total = 175 flasks of mercury by end of 1961 (Malone 1965). Of this, 130 flasks were produced by 1959 (Malone 1962), 120 flasks by 1923 (Webber and others 1947), and 700 Ibs (a little more than 9 flasks) from 1906-1914 (Smith 1917).	North side of Kuskokwim River. Cobb (1972) gave the same locality number to the Alice and Bessie and nearby Ammeline prospect (#11, herein).
Ammeline	Parks Creek	KR103	Lode, mine	Cinnabar, and perhaps some stibnite	None reported.	North of Kuskokwim River, north of Alice and Bessie mine, east along Parks Creek.
Willis	Kuskokwim River	KR105	Lode, mine (small production)	Cinnabar, stibnite	Total = a few flasks of mercury. Several references state that a few flasks of Hg were produced by Oswald Willis in a homemade retort; Cady and others (1955) stated production took place during World War I (1914-18)	North side of Kuskokwim River.
Fuller Creek	Fuller Creek	KR104	Pacer, prospect(?)	Gold	None reported.	Fuller Creek
Cinnabar Chief	Fuller Creek	KR104	Lode, prospect	Cinnabar	None reported.	West of Fuller Creek

Source: Miller et al. (1989)



2015 Sediment Sample Location
2014 BLM Periphyton Sample Location
2012 RI Sediment Sample Location
2011 RI Sediment Sample Location
2010 RI Sediment Sample Location
Bathymetric contour (feet)

Area of RI and RI Supplement Background Kuskokwim River Sediment Samples
Settling Pond
Monofill
Historical Structure

Bathymetric contours represent approximate depths below river surface on September 25, 2011

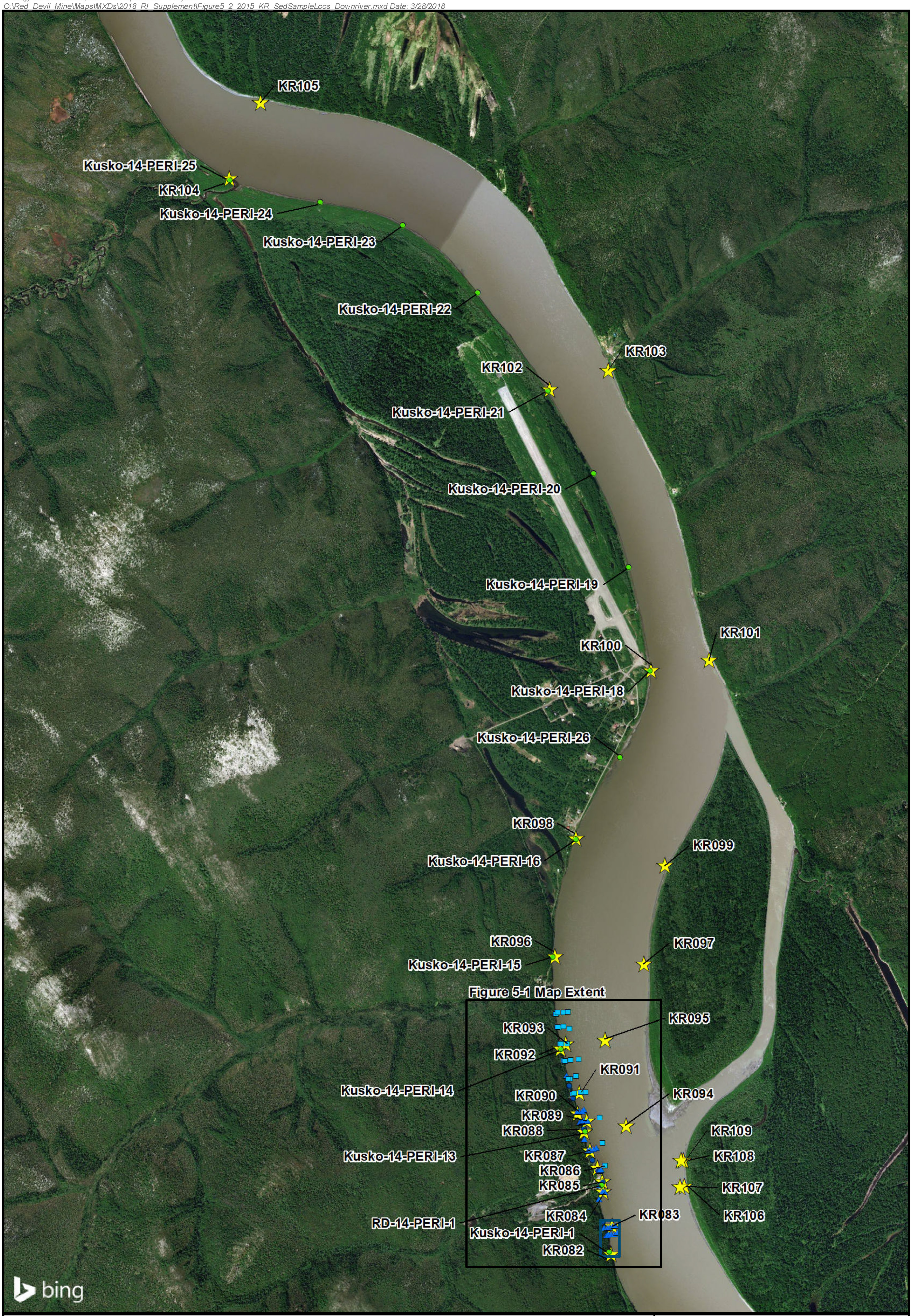
RED DEVIL MINE

Red Devil, Alaska

Figure 5-1
Kuskokwim River Sediment and Periphyton Sample Locations - Near Red Devil Mine Site

0 75 150 300 450 600
Feet
0 15 30 60 90 120 150
Meters
Scale 1:2,500

Ecology & Environment, Inc. GIS Department Project:
O:\Red_Devil_Mine\Maps\MXDs\2018_RI_Supplement\Figure5_2_2015_KR_SedSampleLocs_Downriver.mxd Date: 3/28/2018



2015 Sediment Sample Locations
2014 BLM Periphyton Sample Locations
2012 RI Sediment Sample Locaiton
2011 RI Sediment Sample Location
2010 RI Sediment Sample Location
Area of RI and RI Supplement Background Kuskokwim River Sediment Samples

RED DEVIL MINE

Red Devil, Alaska

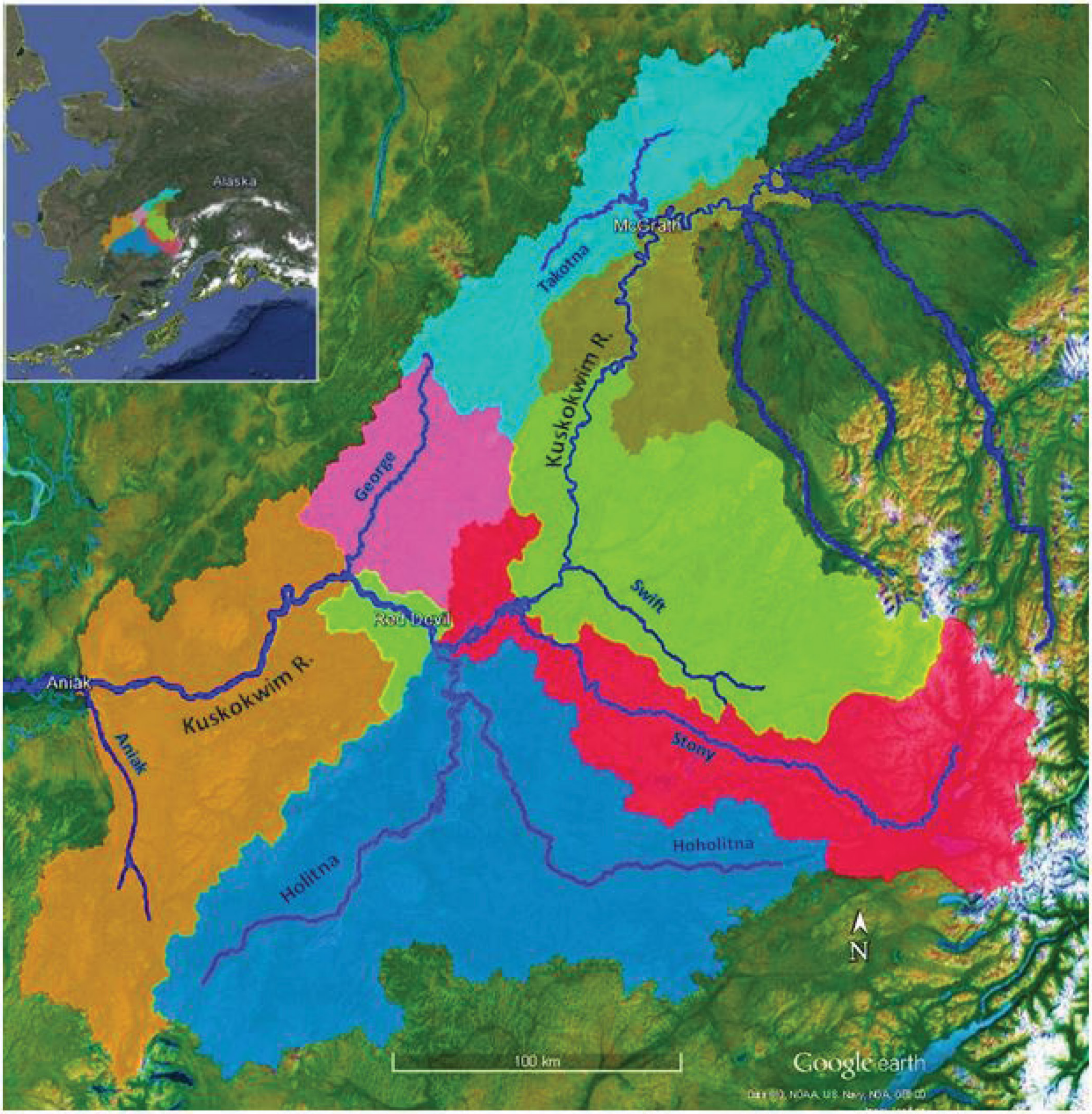
Figure 5-2
Kuskokwim River Sediment and Periphyton Sample Locations - Near Red Devil Mine Site and Downriver

0 0.075 0.15 0.3 0.45 0.6
Miles
0 0.125 0.25 0.5 0.75 1
Kilometers
Scale 1:2,500

RED DEVIL MINE

Red Devil, Alaska

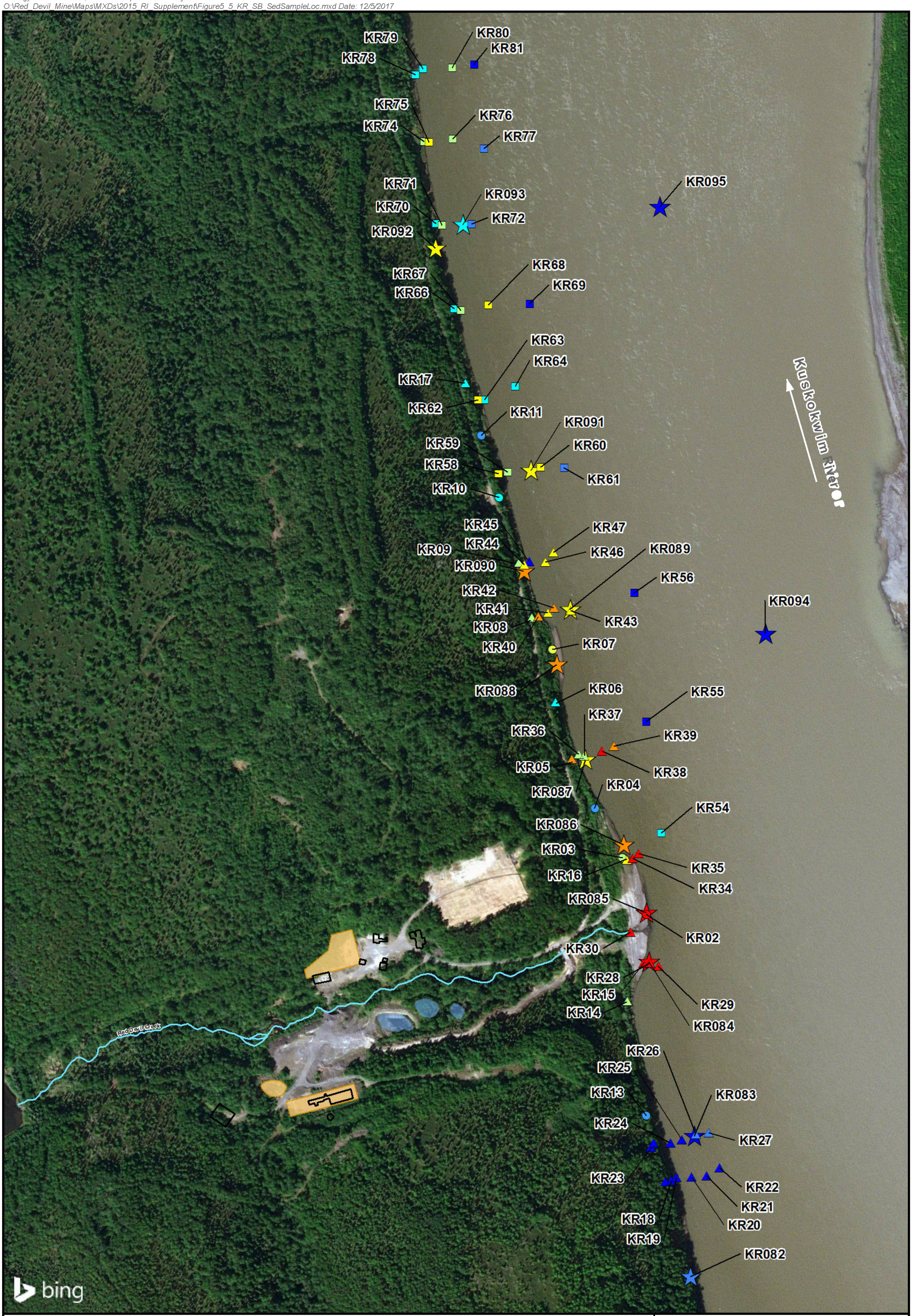
Figure 5-3
2014 Kuskokwim River Periphyton Sample Locations



- *Kusko-Aniak*: Kuskokwim River – Aniak R. (incl.) to George R.
- *George*: George River
- *Kusko above George*: Kuskokwim River – George R. to Sleetmute
- *Holitna*: Holitna and Hoholitna Rivers
- *Kusko-Stony*: Kuskokwim River – Holitna R. to Stony R (incl.)
- *Kusko –Swift*: Kuskokwim River –Stony River to Selatna, incl. Swift R.
- *Kusko above Selatna*: Kuskokwim River – Selatna R. to Middle/North Forks
- *Takotna*: Takotna River and Nixon Fork

Note: Adapted from Matz at al. (2017) Figure 7.

RED DEVIL MINE Red Devil, Alaska	Figure 5-4 Watersheds in the Middle Kuskokwim Region



2010 Total Antimony (mg/kg)	2011 Total Antimony (mg/kg)	2012 Total Antimony (mg/kg)	2015 Total Antimony (mg/kg)
> 150	> 150	> 150	> 150
50 to 150	50 to 150	50 to 150	50 to 150
15 to 50	15 to 50	15 to 50	15 to 50
5 to 15	5 to 15	5 to 15	5 to 15
1 to 5	1 to 5	1 to 5	1 to 5
0.446 to 1	0.446 to 1	0.446 to 1	0.446 to 1
≤ 0.446 background	≤ 0.446 background	≤ 0.446 background	≤ 0.446 background

RED DEVIL MINE

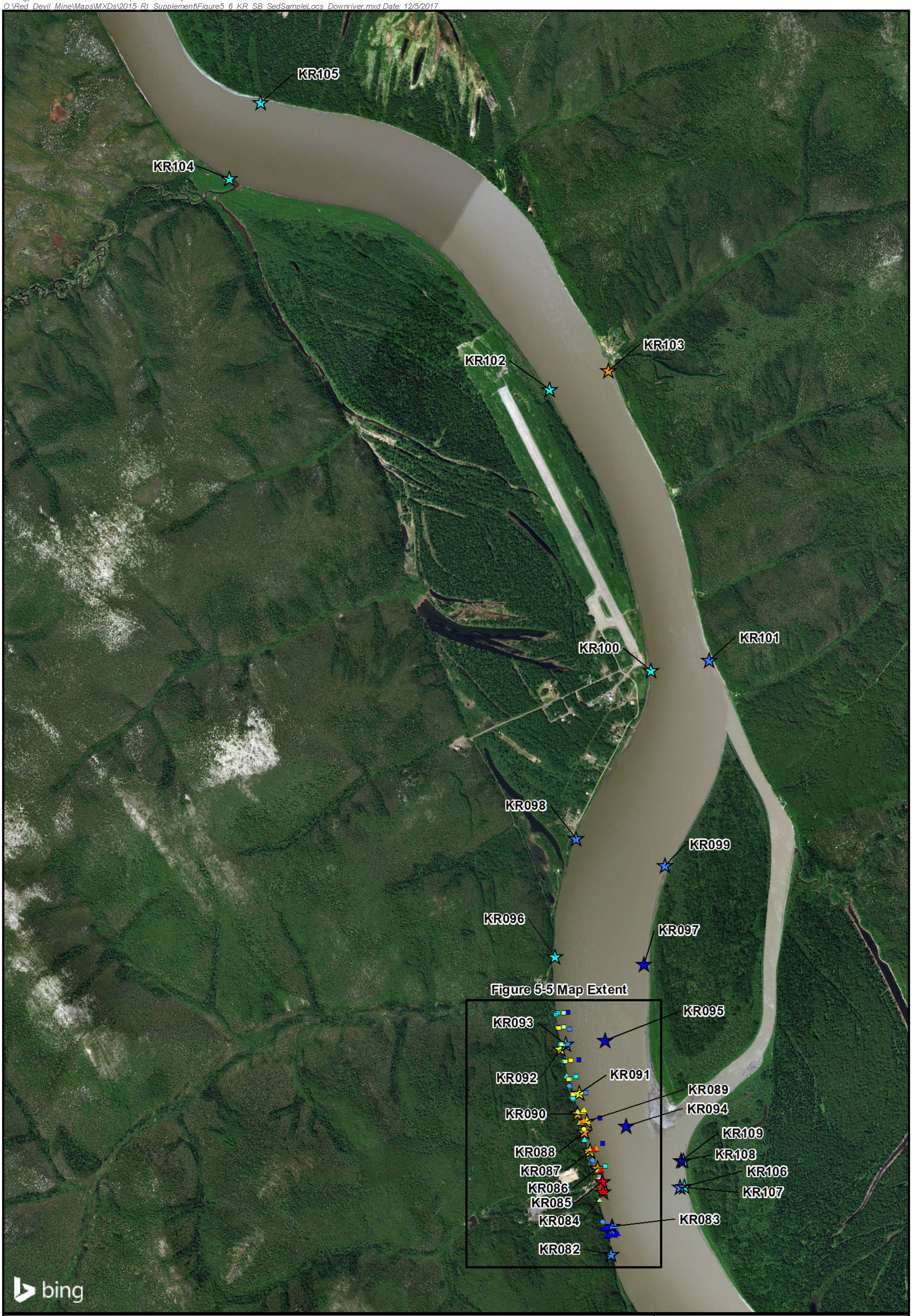
Red Devil, Alaska

Bathymetric contour (feet)
Settling Pond
Monofill
Historical Structure

Figure 5-5

Total Antimony in Sediment, RI (2010-2012) and RI Supplement (2015) – Near Red Devil Mine Site

0 75 150 300 450 600
Feet
0 15 30 60 90 120 150
Meters
Scale 1:2,500



2010 Total Antimony (mg/kg)	2011 Total Antimony (mg/kg)	2012 Total Antimony (mg/kg)	2015 Total Antimony (mg/kg)
> 150	> 150	> 150	> 150
50 to 150	50 to 150	50 to 150	50 to 150
15 to 50	15 to 50	15 to 50	15 to 50
5 to 15	5 to 15	5 to 15	5 to 15
1 to 5	1 to 5	1 to 5	1 to 5
0.446 to 1	0.446 to 1	0.446 to 1	0.446 to 1
≤ 0.446 background	≤ 0.446 background	≤ 0.446 background	≤ 0.446 background

RED DEVIL MINE

Red Devil, Alaska

Figure 5-6

Total Antimony in Sediment, RI (2010-2012) and RI Supplement (2015) – Near Red Devil Mine Site and Downriver

0 0.075 0.15 0.3 0.45 0.6 Miles

0 0.125 0.25 0.5 0.75 1 Kilometers

Scale 1:2,500

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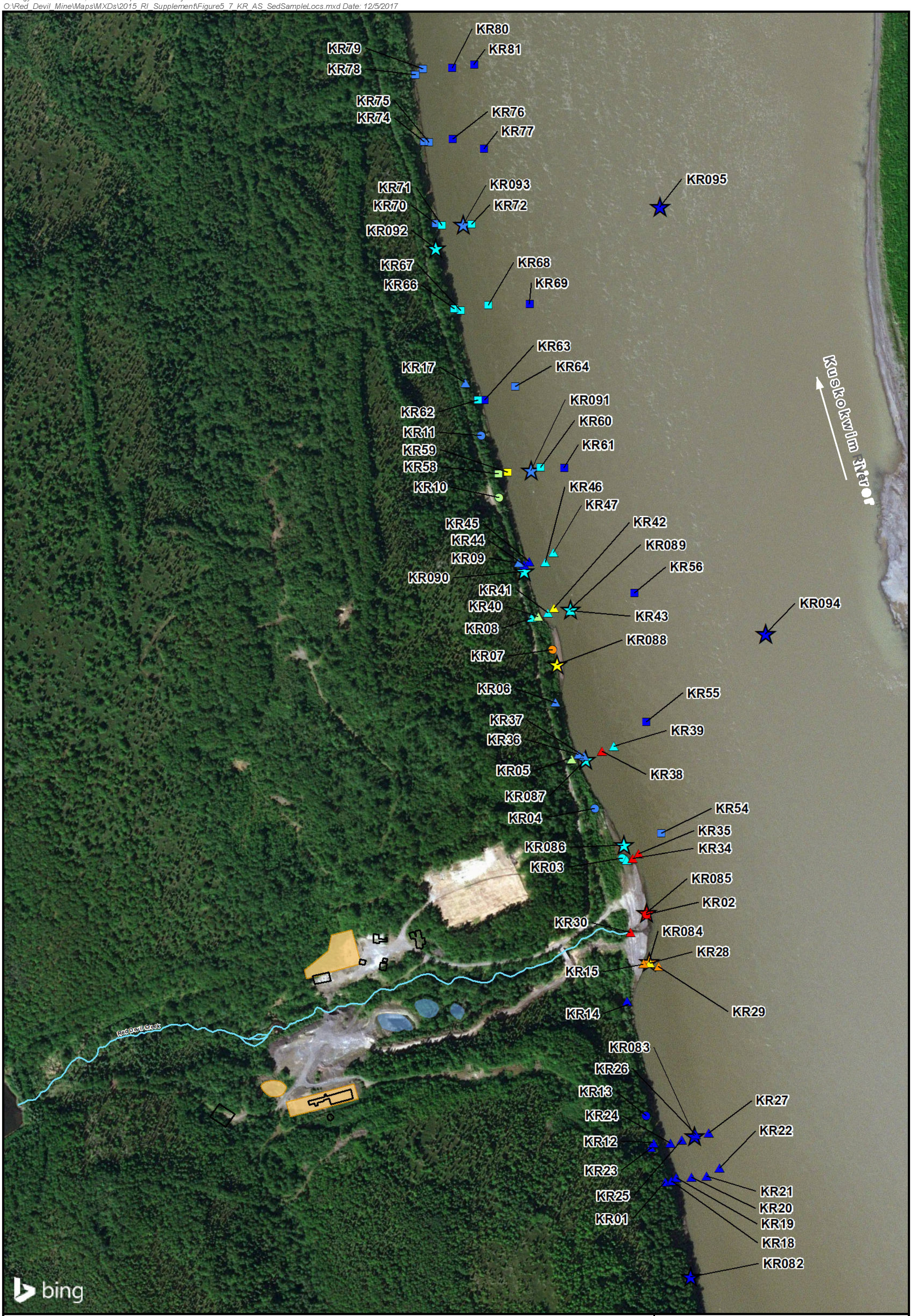
O:\Red_Devil_Mine\Maps\MXDs\2015_RI_Supplement\Figure5_7_KR_AS_SedSampleLocs.mxd Date: 12/5/2017



2010 Total Arsenic (mg/kg)	2011 Total Arsenic (mg/kg)	2012 Total Arsenic (mg/kg)	2015 Total Arsenic (mg/kg)
> 800	> 800	> 800	> 800
400 to 800	400 to 800	400 to 800	400 to 800
200 to 400	200 to 400	200 to 400	200 to 400
100 to 200	100 to 200	100 to 200	100 to 200
30 to 100	30 to 100	30 to 100	30 to 100
15 to 30	15 to 30	15 to 30	15 to 30
≤ 15 background	≤ 15 background	≤ 15 background	≤ 15 background

RED DEVIL MINE

Red Devil, Alaska

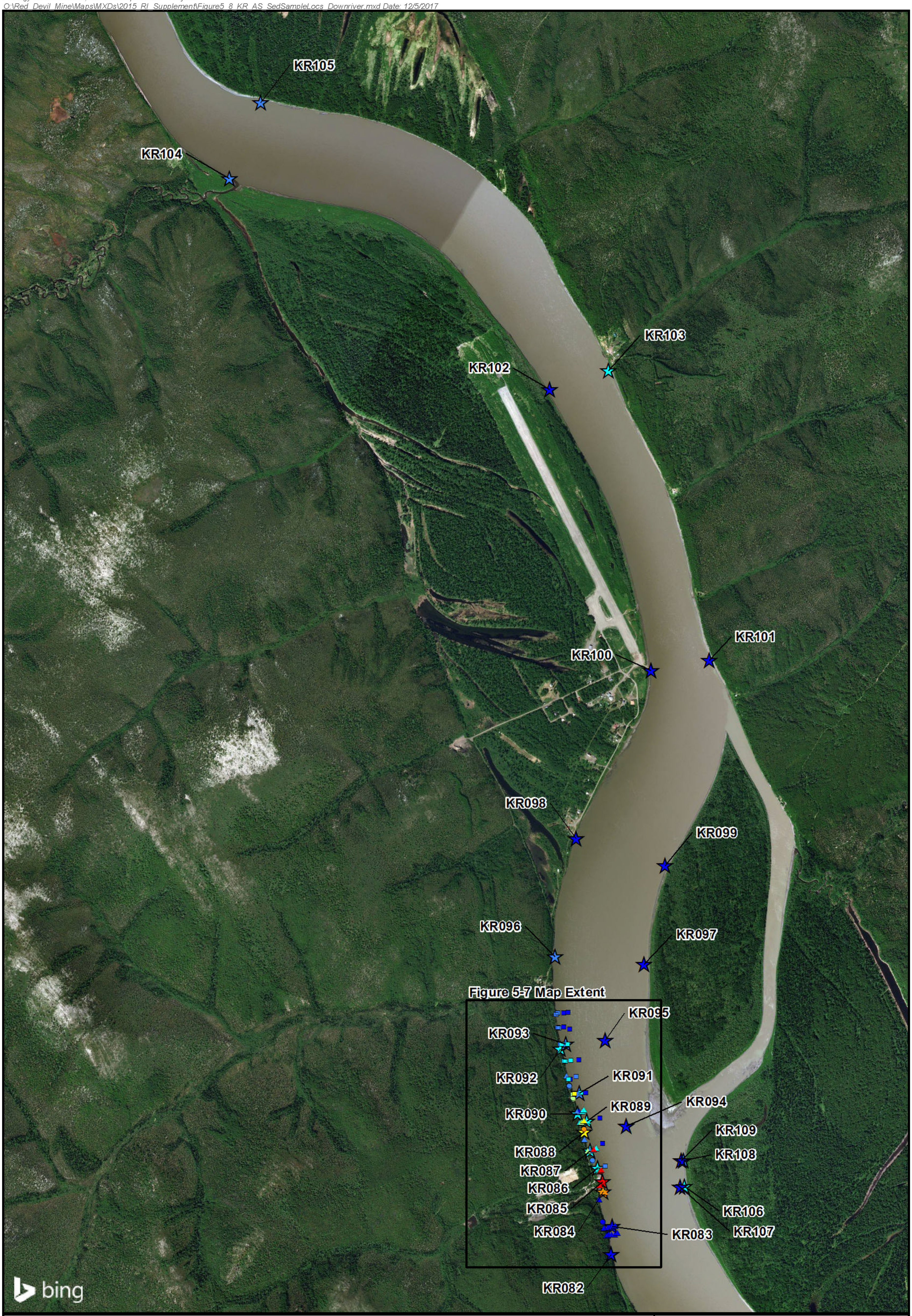
Bathymetric contour (feet)
Settling Pond
Monofill
Historical Structure

Figure 5-7

Total Arsenic in Sediment, RI (2010-2012) and RI Supplement (2015) – Near Red Devil Mine Site

0 75 150 300 450 600
Feet
0 15 30 60 90 120 150
Meters
Scale 1:2,500

Ecology & Environment, Inc. GIS Department Project:
O:\Red_Devil_Mine\Maps\MXDs\2015_RI_Supplement\Figure5_8_KR_AS_SedSampleLocs_Downriver.mxd Date: 12/5/2017



2010 Total Arsenic (mg/kg)	2011 Total Arsenic (mg/kg)	2012 Total Arsenic (mg/kg)	2015 Total Arsenic (mg/kg)
> 800	> 800	> 800	> 800
400 to 800	400 to 800	400 to 800	400 to 800
200 to 400	200 to 400	200 to 400	200 to 400
100 to 200	100 to 200	100 to 200	100 to 200
30 to 100	30 to 100	30 to 100	30 to 100
15 to 30	15 to 30	15 to 30	15 to 30
≤ 15 background	≤ 15 background	≤ 15 background	≤ 15 background

RED DEVIL MINE

Red Devil, Alaska

Figure 5-8

Total Arsenic in Sediment, RI (2010-2012) and RI Supplement (2015) – Near Red Devil Mine Site and Downriver

0 0.075 0.15 0.3 0.45 0.6
Miles
0 0.125 0.25 0.5 0.75 1
Kilometers
Scale 1:2,500

Ecology & Environment, Inc. GIS Department Project:
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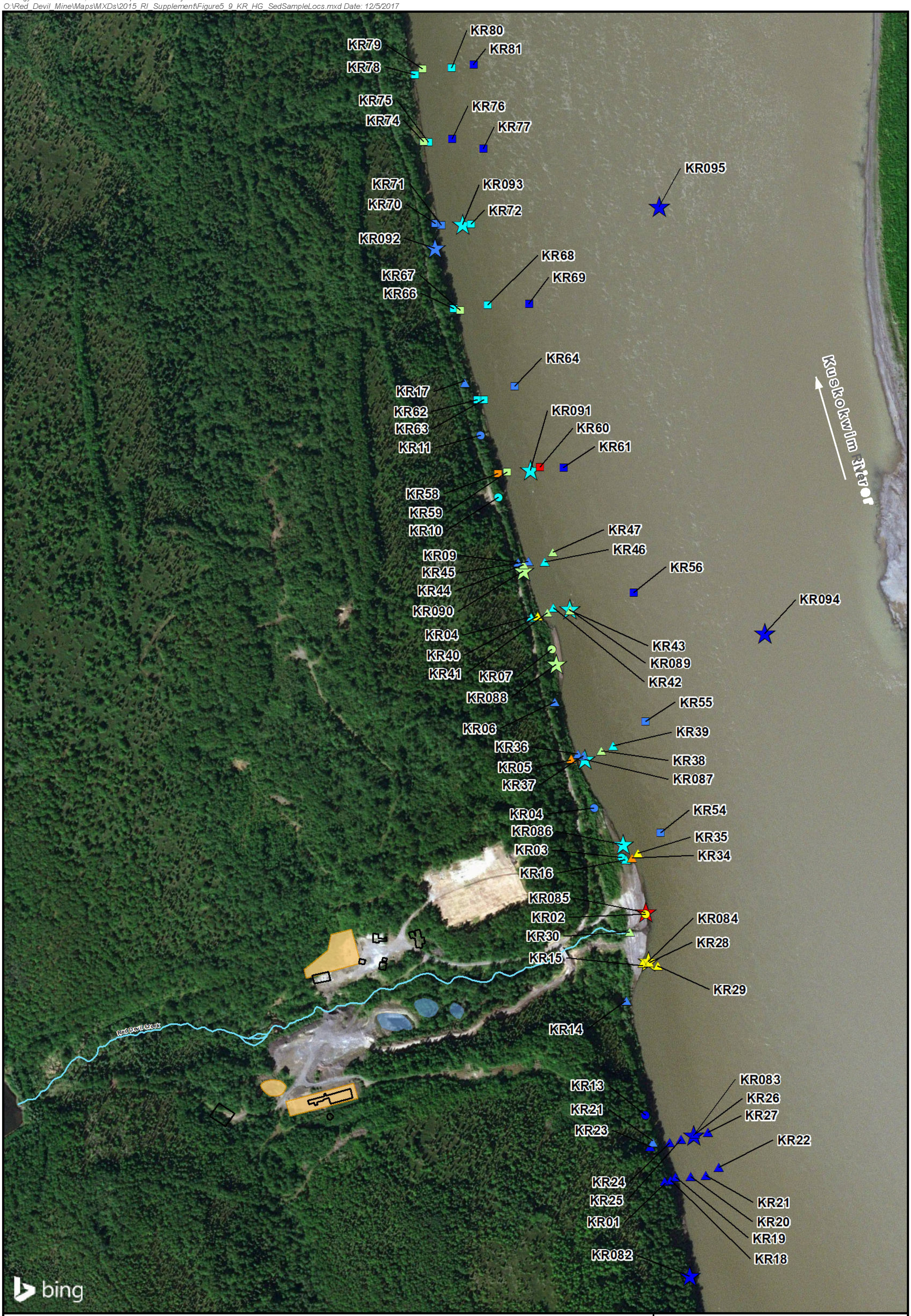


2010 Total Mercury (mg/kg)	2011 Total Mercury (mg/kg)	2012 Total Mercury (mg/kg)	2015 Total Mercury (mg/kg)
> 300	> 300	> 300	> 300
100 to 300	100 to 300	100 to 300	100 to 300
25 to 100	25 to 100	25 to 100	25 to 100
5 to 25	5 to 25	5 to 25	5 to 25
1 to 5	1 to 5	1 to 5	1 to 5
.144 to 1	.144 to 1	.144 to 1	.144 to 1
≤ .144 background	≤ .144 background	≤ .144 background	≤ .144 background

RED DEVIL MINE

Red Devil, Alaska

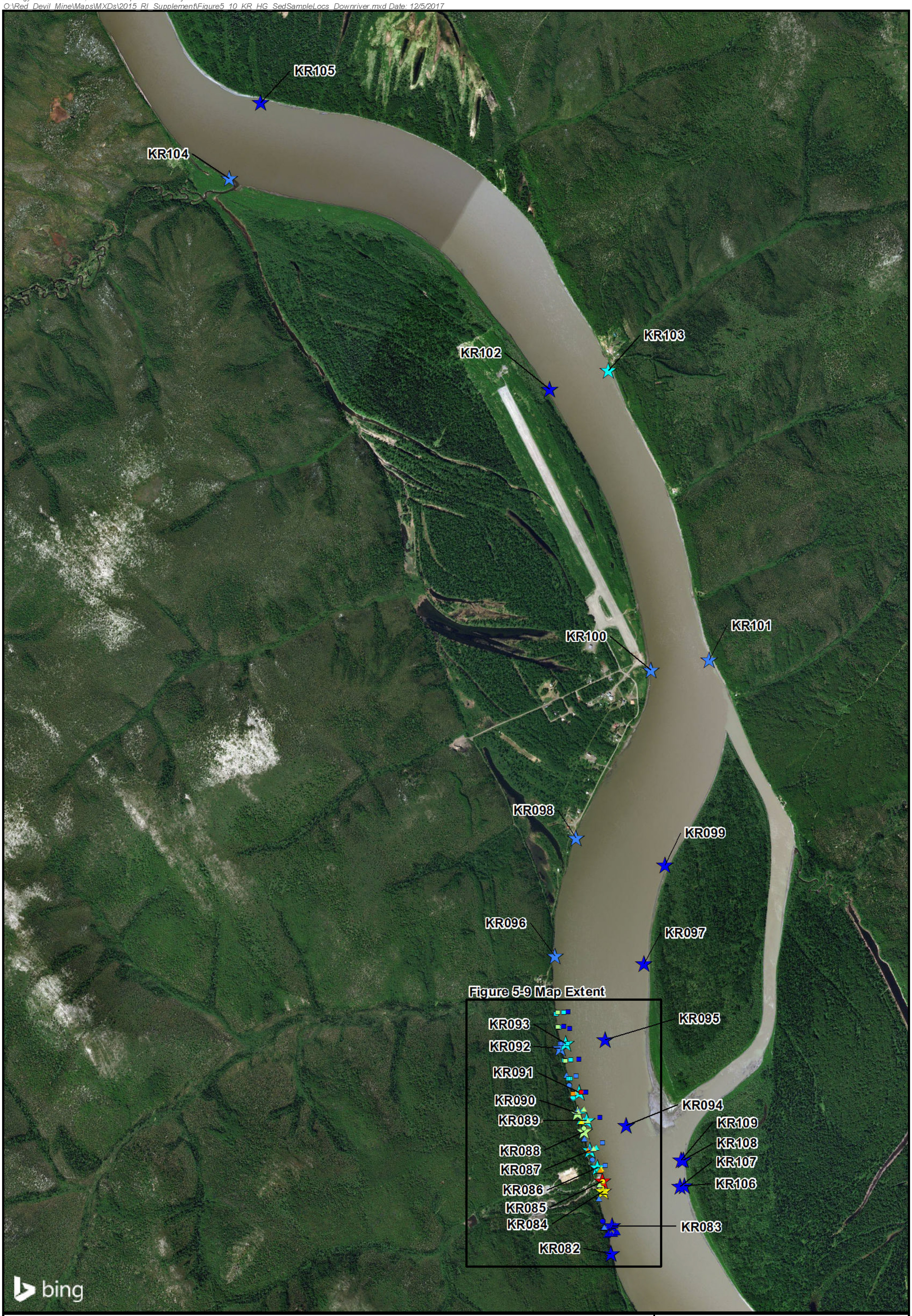
Bathymetric contour (feet)
Settling Pond
Monofill
Historical Structure

Figure 5-9

Total Mercury in Sediment, RI (2010-2012) and RI Supplement (2015) – Near Red Devil Mine Site

0 75 150 300 450 600
Feet
0 15 30 60 90 120 150
Meters
Scale 1:2,500

Ecology & Environment, Inc. GIS Department Project:
O:\Red_Devil_Mine\Maps\MXDs\2015_RI_Supplement\Figure5_10_KR_HG_SedSampleLocs_Downriver.mxd Date: 12/5/2017



2010 Total Mercury (mg/kg)	2011 Total Mercury (mg/kg)	2012 Total Mercury (mg/kg)	2015 Total Mercury (mg/kg)
> 300	> 300	> 300	> 300
100 to 300	100 to 300	100 to 300	100 to 300
25 to 100	25 to 100	25 to 100	25 to 100
5 to 25	5 to 25	5 to 25	5 to 25
1 to 5	1 to 5	1 to 5	1 to 5
.144 to 1	.144 to 1	.144 to 1	.144 to 1
≤ .144 background	≤ .144 background	≤ .144 background	≤ .144 background

RED DEVIL MINE

Red Devil, Alaska

Figure 5-10

Total Mercury in Sediment, RI (2010-2012) and RI Supplement (2015) – Near Red Devil Mine Site and Downriver

0 0.075 0.15 0.3 0.45 0.6
Miles
0 0.125 0.25 0.5 0.75 1
Kilometers
Scale 1:2,500

Ecology & Environment, Inc. GIS Department Project:
O:\Red_Devil_Mine\Maps\MXDs\2015_RI_Supplement\Figure5_11_KR_MM_SedSampleLoc.mxd Date: 12/5/2017

2010 Methylmercury (ng/g)	2011 Methylmercury (ng/g)	2012 Methylmercury (ng/g)	2015 Methylmercury (ng/g)
> 3.0	> 3.0	> 3.0	> 3.0
2.5 to 3.0	2.5 to 3.0	2.5 to 3.0	2.5 to 3.0
2.0 to 2.5	2.0 to 2.5	2.0 to 2.5	2.0 to 2.5
1.5 to 2.0	1.5 to 2.0	1.5 to 2.0	1.5 to 2.0
1.0 to 1.5	1.0 to 1.5	1.0 to 1.5	1.0 to 1.5
0.49 to 1.0	0.49 to 1.0	0.49 to 1.0	0.49 to 1.0
≤ 0.49 background	≤ 0.49 background	≤ 0.49 background	≤ 0.49 background

RED DEVIL MINE

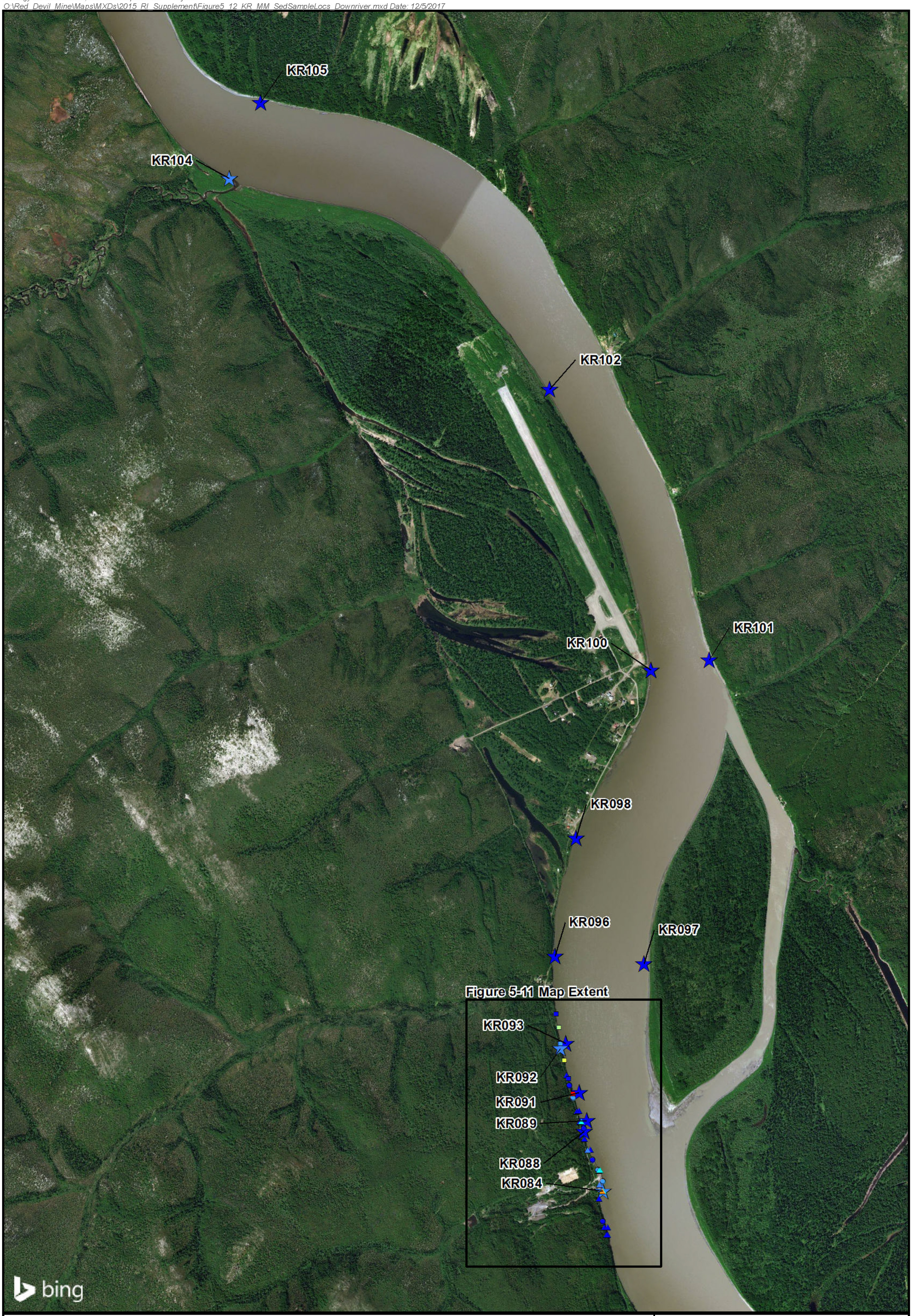
Red Devil, Alaska

Bathymetric contour (feet)
Settling Pond
Monofill
Historical Structure

Figure 5-11
Methylmercury in Sediment, RI (2010-2012) and RI Supplement (2015) – Near Red Devil Mine Site

0 75 150 300 450 600
Feet
0 15 30 60 90 120 150
Meters
Scale 1:2,500

Ecology & Environment, Inc. GIS Department Project:
O:\Red_Devil_Mine\Maps\MXDs\2015_RI_Supplement\Figure5_12_KR_MM_SedSampleLocs_Downriver.mxd Date: 12/5/2017



2010 Methylmercury (ng/g)	2011 Methylmercury (ng/g)	2012 Methylmercury (ng/g)	2015 Methylmercury (ng/g)
> 3.0	> 3.0	> 3.0	> 3.0
2.5 to 3.0	2.5 to 3.0	2.5 to 3.0	2.5 to 3.0
2.0 to 2.5	2.0 to 2.5	2.0 to 2.5	2.0 to 2.5
1.5 to 2.0	1.5 to 2.0	1.5 to 2.0	1.5 to 2.0
1.0 to 1.5	1.0 to 1.5	1.0 to 1.5	1.0 to 1.5
0.49 to 1.0	0.49 to 1.0	0.49 to 1.0	0.49 to 1.0
≤ 0.49 background	≤ 0.49 background	≤ 0.49 background	≤ 0.49 background

RED DEVIL MINE

Red Devil, Alaska

Figure 5-12

Methylmercury in Sediment, RI (2010-2012) and RI Supplement (2015) – Near Red Devil Mine Site and Downriver

0 0.075 0.15 0.3 0.45 0.6
Miles
0 0.125 0.25 0.5 0.75 1
Kilometers
Scale 1:2,500

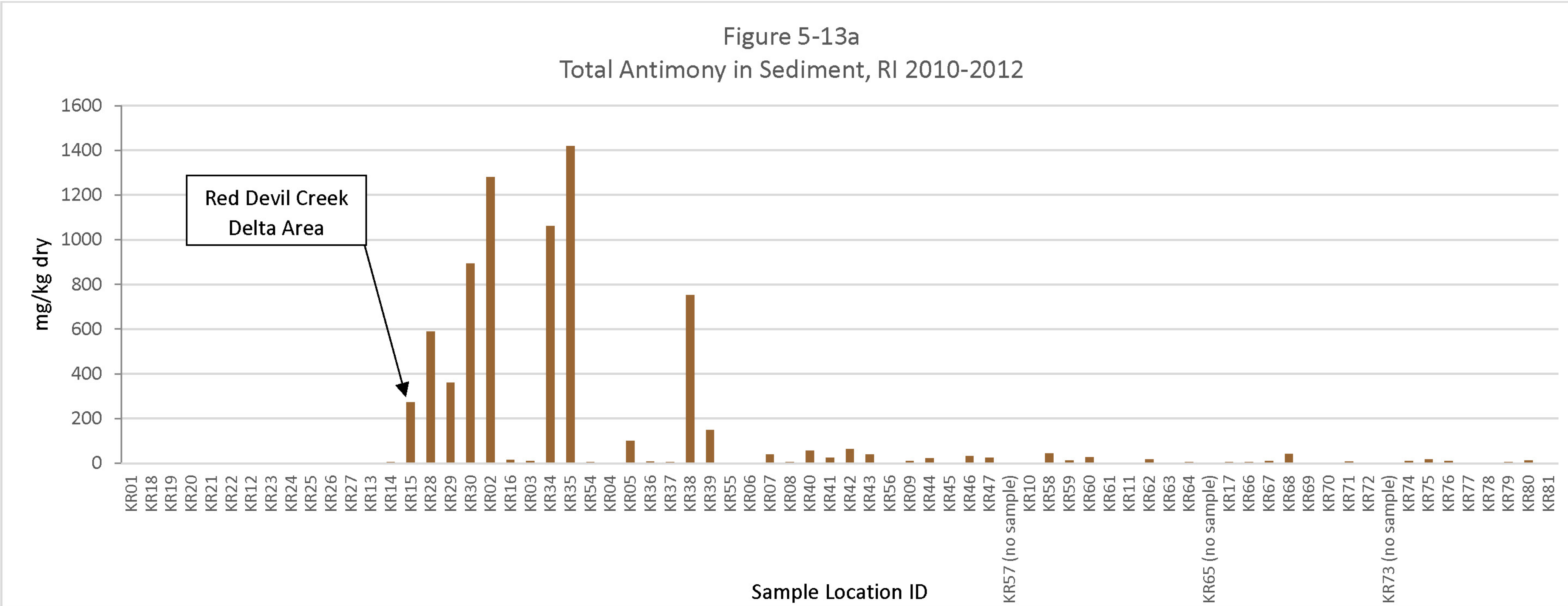


Figure 5-13a
Total Antimony in Sediment, RI 2010-2012
mg/kg dry
0
200
400
600
800
1000
1200
1400
1600
Red Devil Creek Delta Area
KR01 KR18 KR19 KR20 KR21 KR22 KR12 KR23 KR24 KR25 KR26 KR27 KR13 KR14 KR15 KR28 KR29 KR30 KR02 KR16 KR03 KR34 KR35 KR54 KR04 KR05 KR36 KR37 KR38 KR39 KR55 KR06 KR07 KR08 KR40 KR41 KR42 KR43 KR56 KR09 KR44 KR45 KR46 KR47 KR57 (no sample) KR10 KR58 KR59 KR60 KR61 KR11 KR62 KR63 KR64 KR65 (no sample) KR17 KR66 KR67 KR68 KR69 KR70 KR71 KR72 KR73 (no sample) KR74 KR75 KR76 KR77 KR78 KR79 KR80 KR81
Sample Location ID

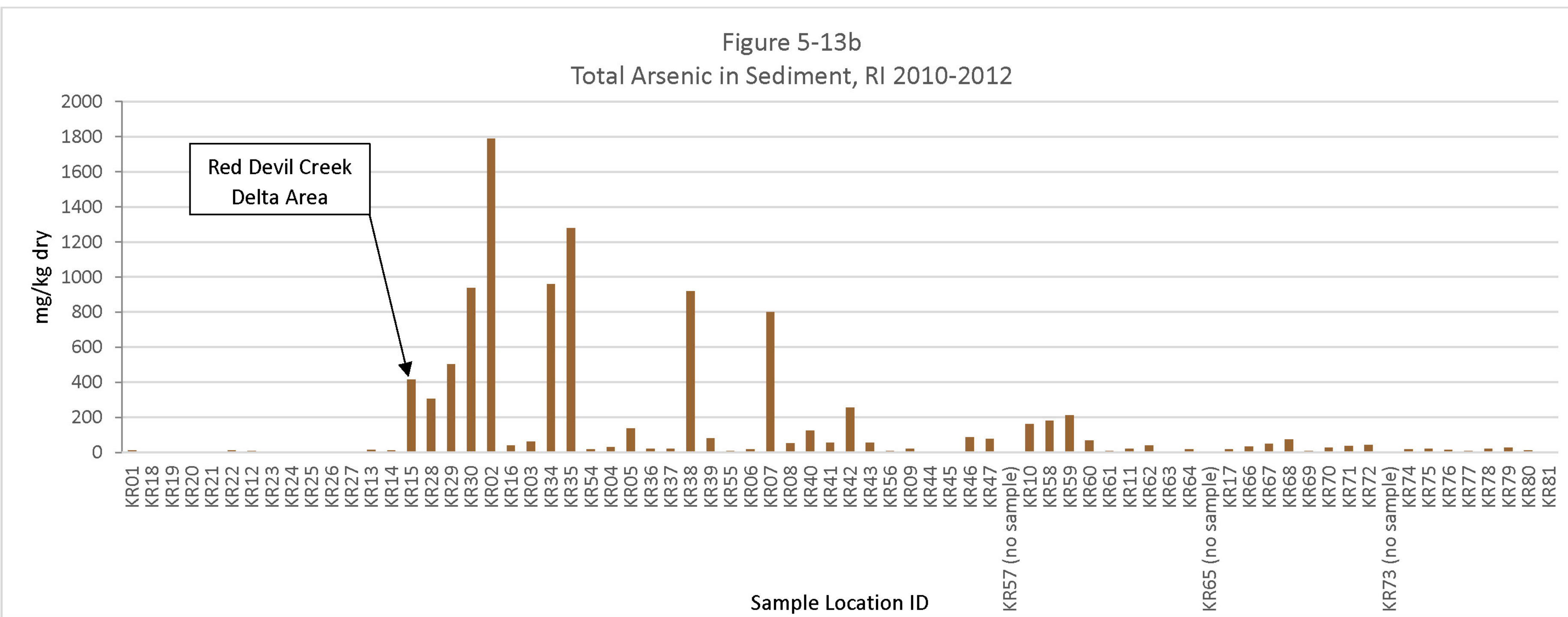


Figure 5-13b
Total Arsenic in Sediment, RI 2010-2012
mg/kg dry
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Red Devil Creek Delta Area
KR01 KR18 KR19 KR20 KR21 KR22 KR12 KR23 KR24 KR25 KR26 KR27 KR13 KR14 KR15 KR28 KR29 KR30 KR02 KR16 KR03 KR34 KR35 KR54 KR04 KR05 KR36 KR37 KR38 KR39 KR55 KR06 KR07 KR08 KR40 KR41 KR42 KR43 KR56 KR09 KR44 KR45 KR46 KR47 KR57 (no sample) KR10 KR58 KR59 KR60 KR61 KR11 KR62 KR63 KR64 KR65 (no sample) KR17 KR66 KR67 KR68 KR69 KR70 KR71 KR72 KR73 (no sample) KR74 KR75 KR76 KR77 KR78 KR79 KR80 KR81
Sample Location ID

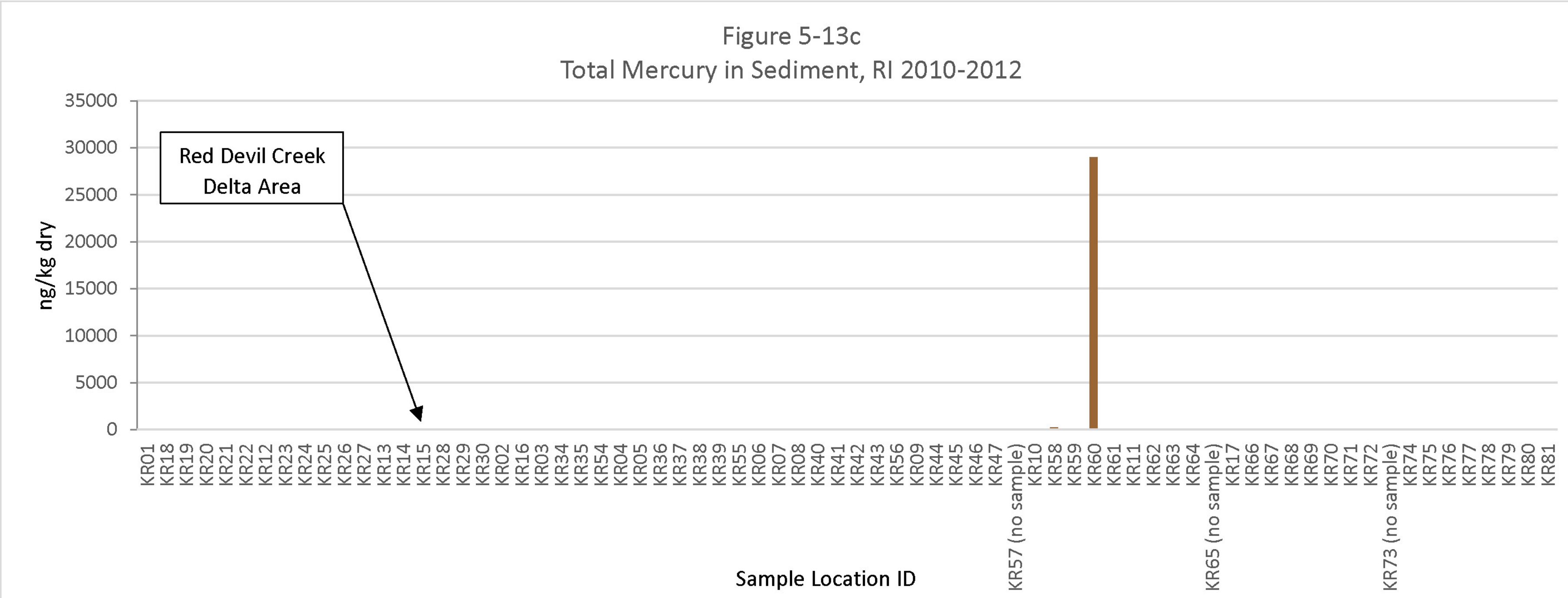


Figure 5-13c
Total Mercury in Sediment, RI 2010-2012
ng/kg dry
Red Devil Creek Delta Area
Sample Location ID
KR57 (no sample)
KR65 (no sample)
KR73 (no sample)

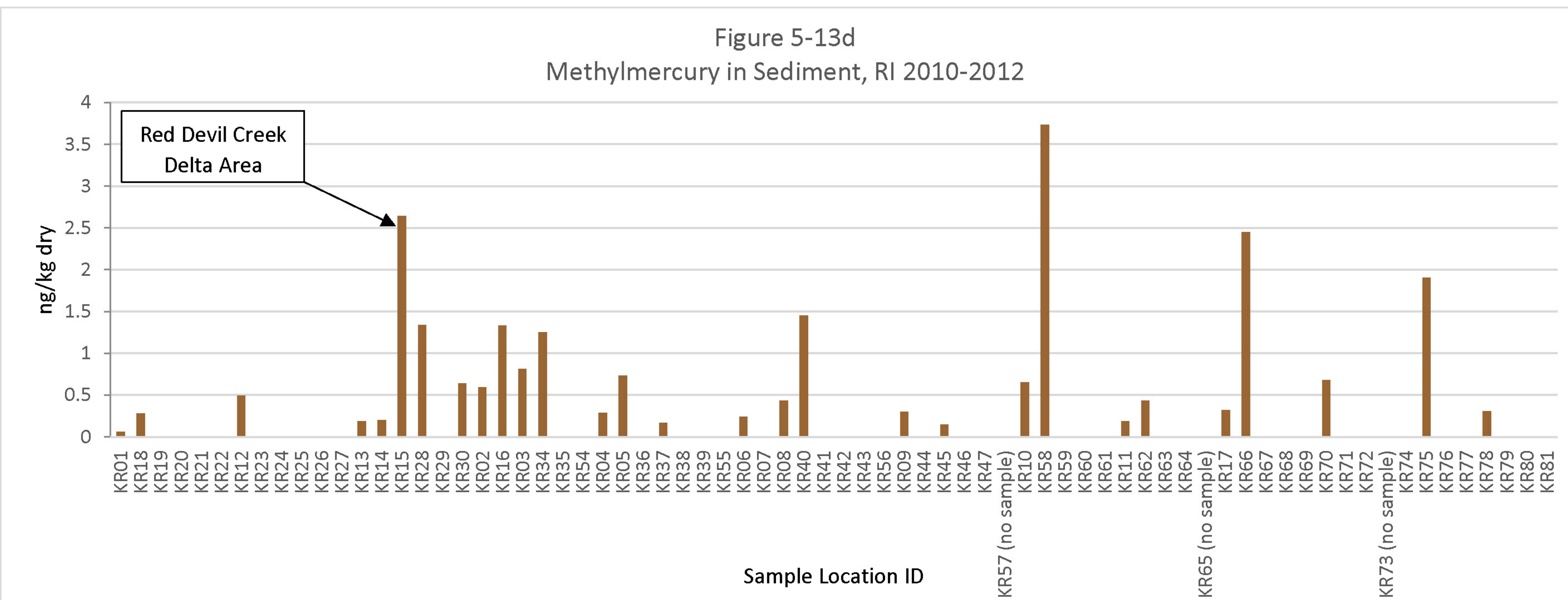


Figure 5-13d
Methylmercury in Sediment, RI 2010-2012
ng/kg dry
Red Devil Creek Delta Area
Sample Location ID
KR57 (no sample)
KR65 (no sample)
KR73 (no sample)

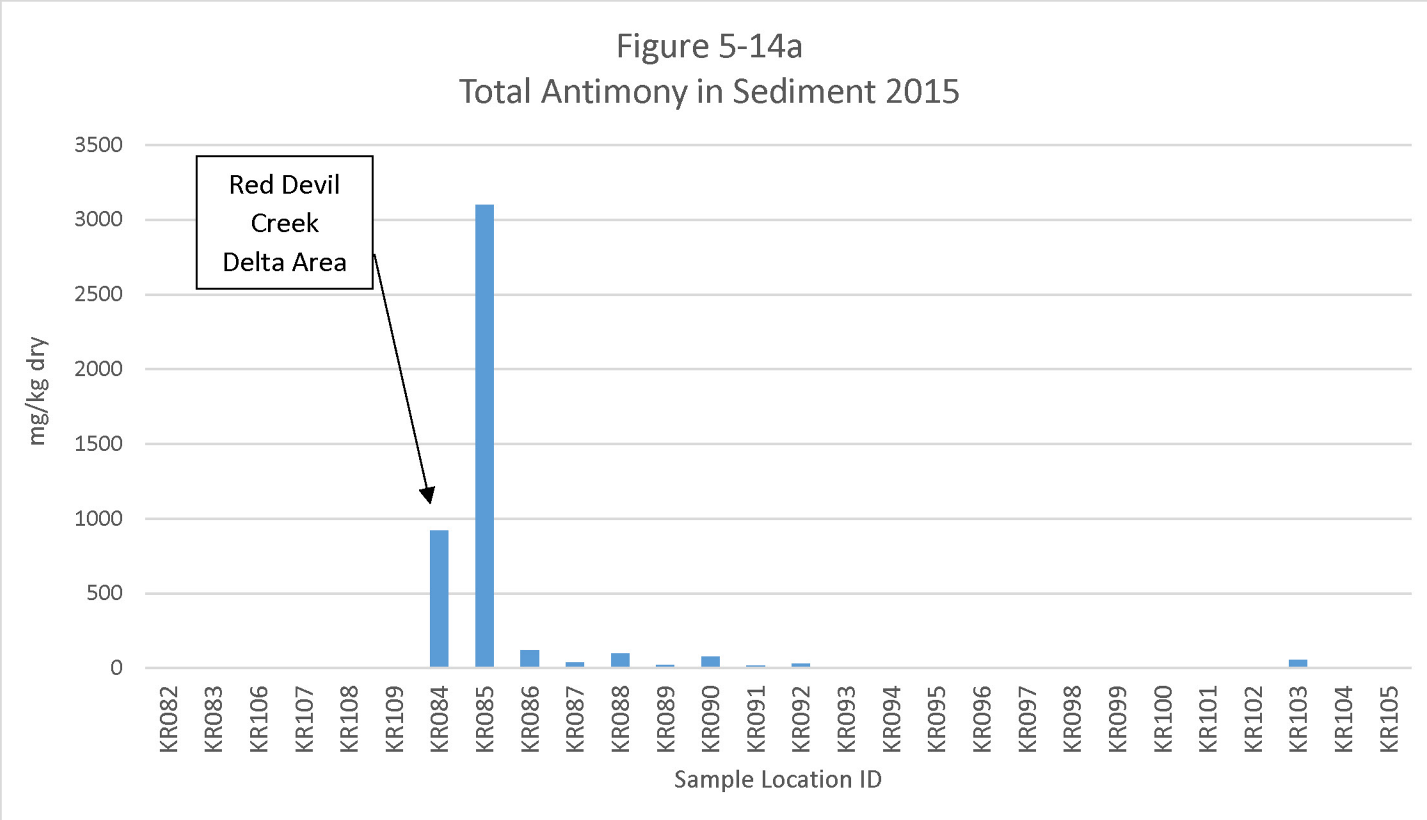


Figure 5-14a
Total Antimony in Sediment 2015
3500
3000
2500
2000
1500
1000
500
0
mg/kg dry
Red Devil Creek Delta Area
KR082
KR083
KR106
KR107
KR108
KR109
KR084
KR085
KR086
KR087
KR088
KR089
KR090
KR091
KR092
KR093
KR094
KR095
KR096
KR097
KR098
KR099
KR100
KR101
KR102
KR103
KR104
KR105
Sample Location ID

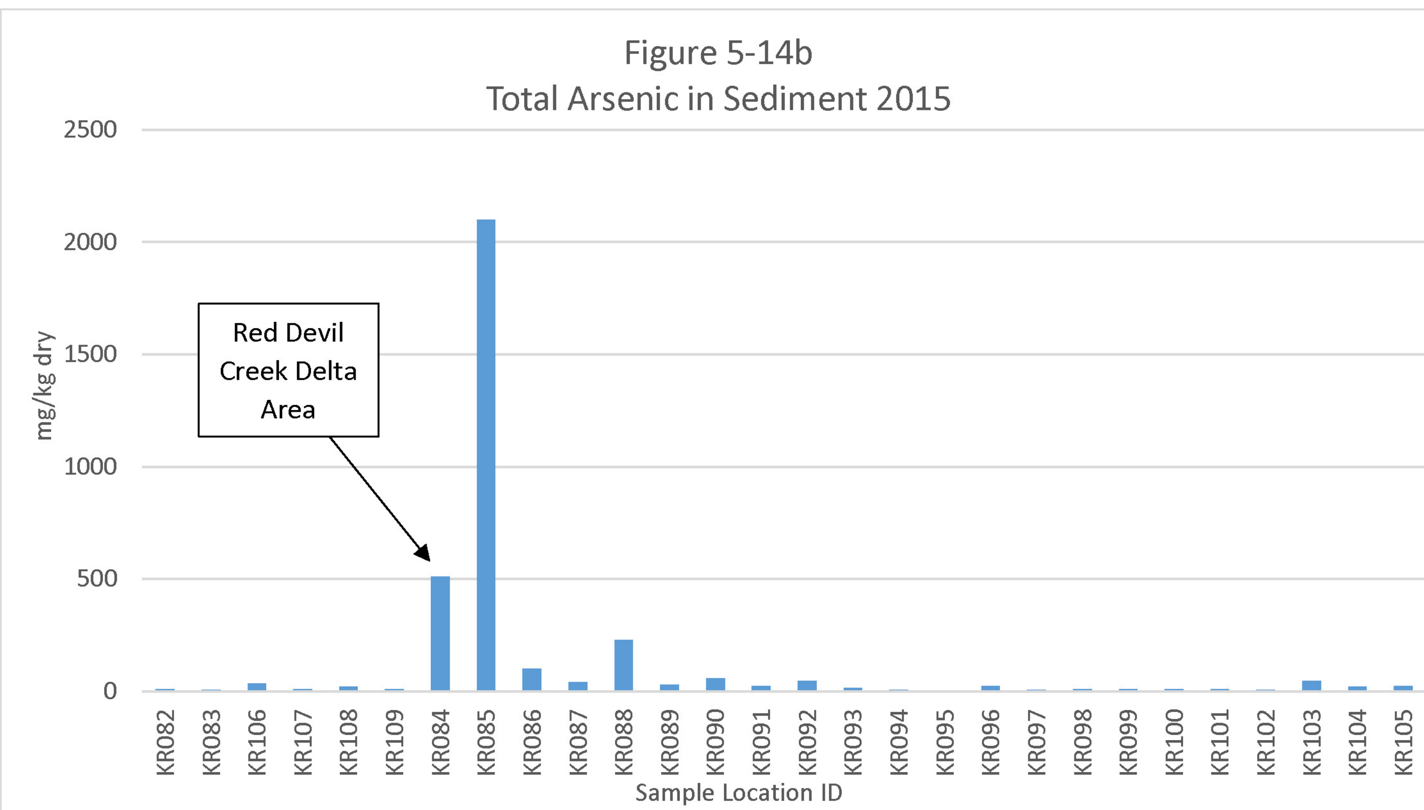


Figure 5-14b
Total Arsenic in Sediment 2015
2500
2000
1500
1000
500
0
mg/kg dry
Red Devil Creek Delta Area
KR082
KR083
KR106
KR107
KR108
KR109
KR084
KR085
KR086
KR087
KR088
KR089
KR090
KR091
KR092
KR093
KR094
KR095
KR096
KR097
KR098
KR099
KR100
KR101
KR102
KR103
KR104
KR105
Sample Location ID

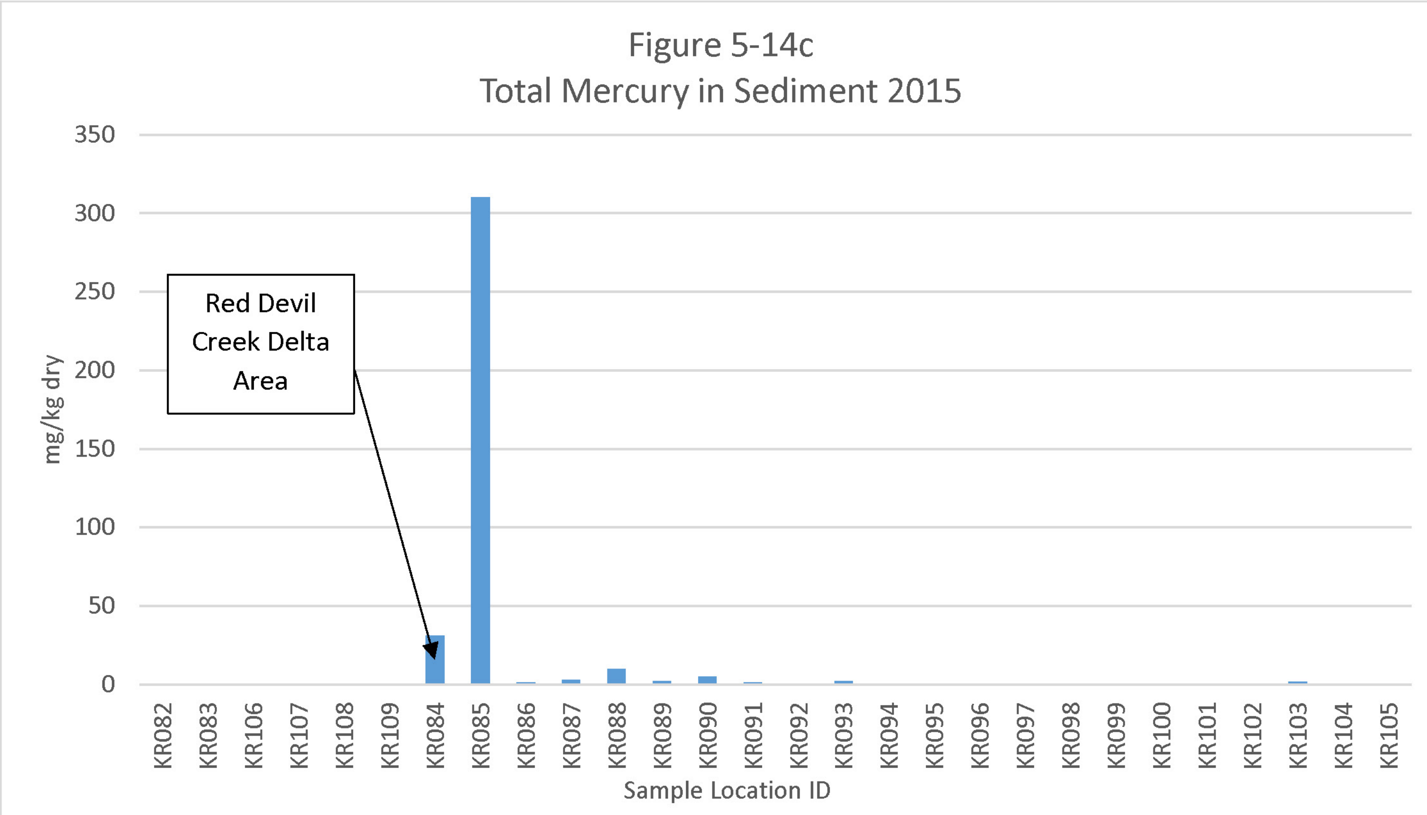


Figure 5-14c
Total Mercury in Sediment 2015
350
300
250
200
150
100
50
0
mg/kg dry
Red Devil Creek Delta Area
KR082
KR083
KR106
KR107
KR108
KR109
KR084
KR085
KR086
KR087
KR088
KR089
KR090
KR091
KR092
KR093
KR094
KR095
KR096
KR097
KR098
KR099
KR100
KR101
KR102
KR103
KR104
KR105
Sample Location ID

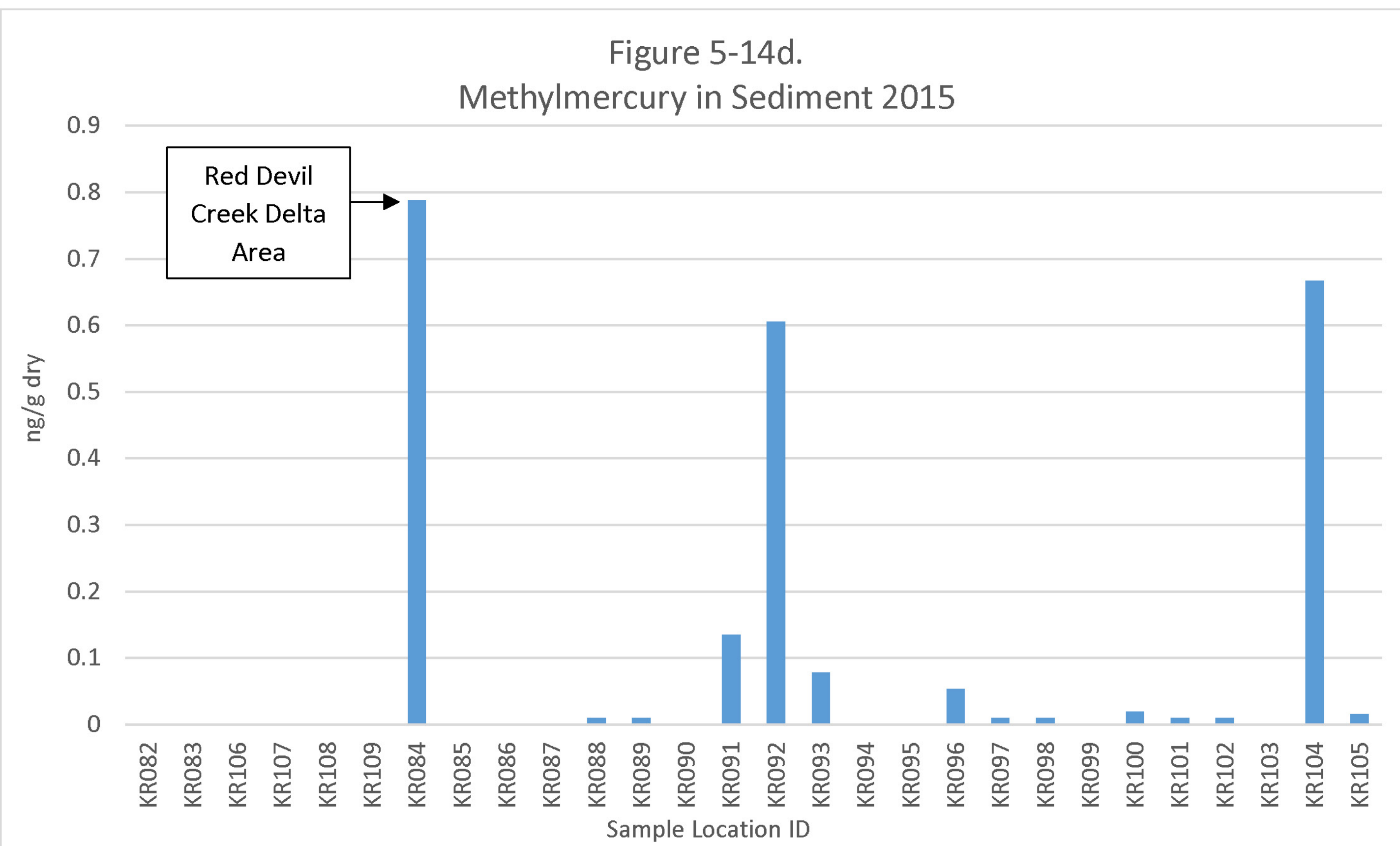


Figure 5-14d.
Methylmercury in Sediment 2015
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
ng/g dry
Red Devil Creek Delta Area
KR082
KR083
KR106
KR107
KR108
KR109
KR084
KR085
KR086
KR087
KR088
KR089
KR090
KR091
KR092
KR093
KR094
KR095
KR096
KR097
KR098
KR099
KR100
KR101
KR102
KR103
KR104
KR105
Sample Location ID

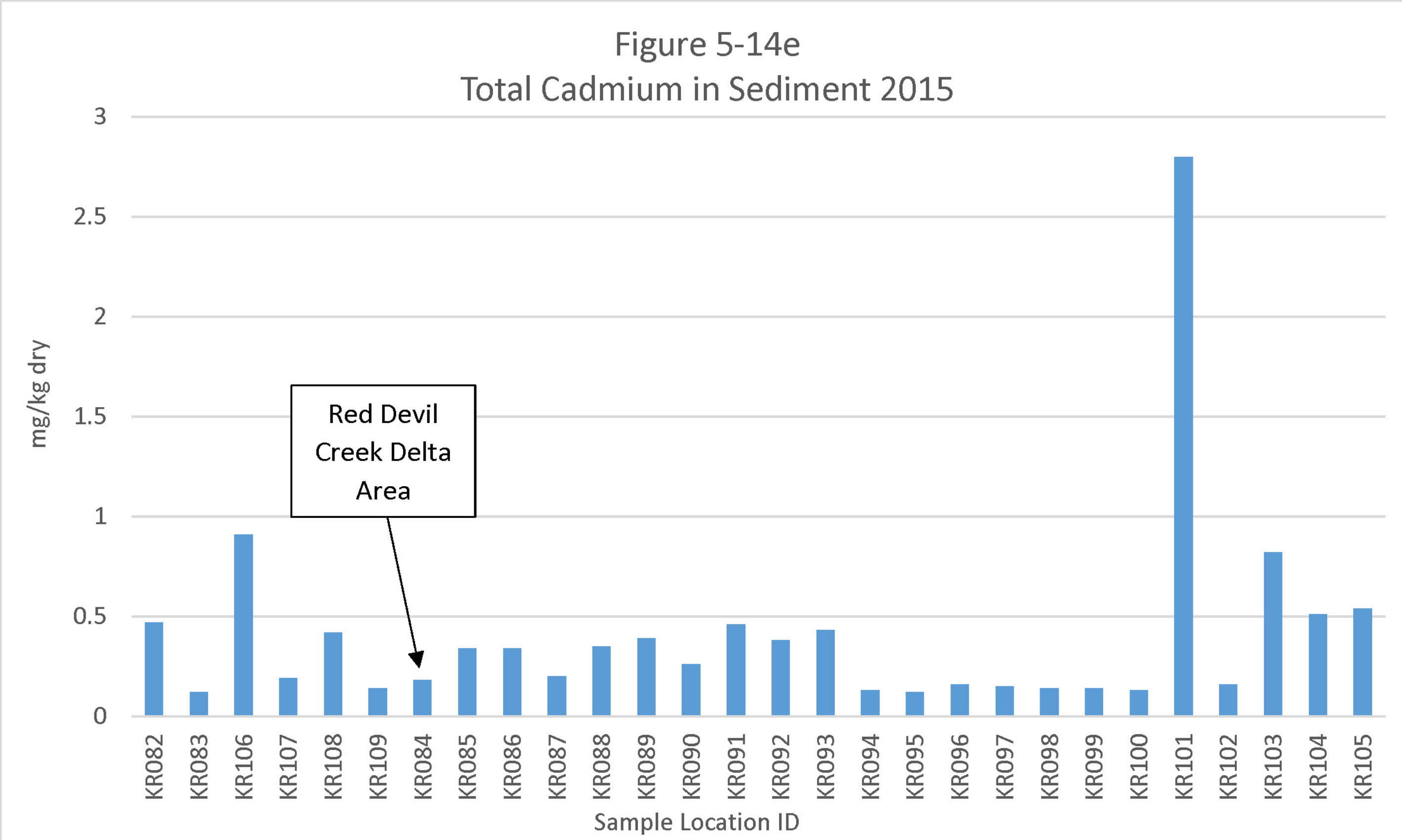


Figure 5-14e
Total Cadmium in Sediment 2015
3
2.5
2
1.5
1
0.5
0
mg/kg dry
Red Devil Creek Delta Area
KR082
KR083
KR106
KR107
KR108
KR109
KR084
KR085
KR086
KR087
KR088
KR089
KR090
KR091
KR092
KR093
KR094
KR095
KR096
KR097
KR098
KR099
KR100
KR101
KR102
KR103
KR104
KR105
Sample Location ID

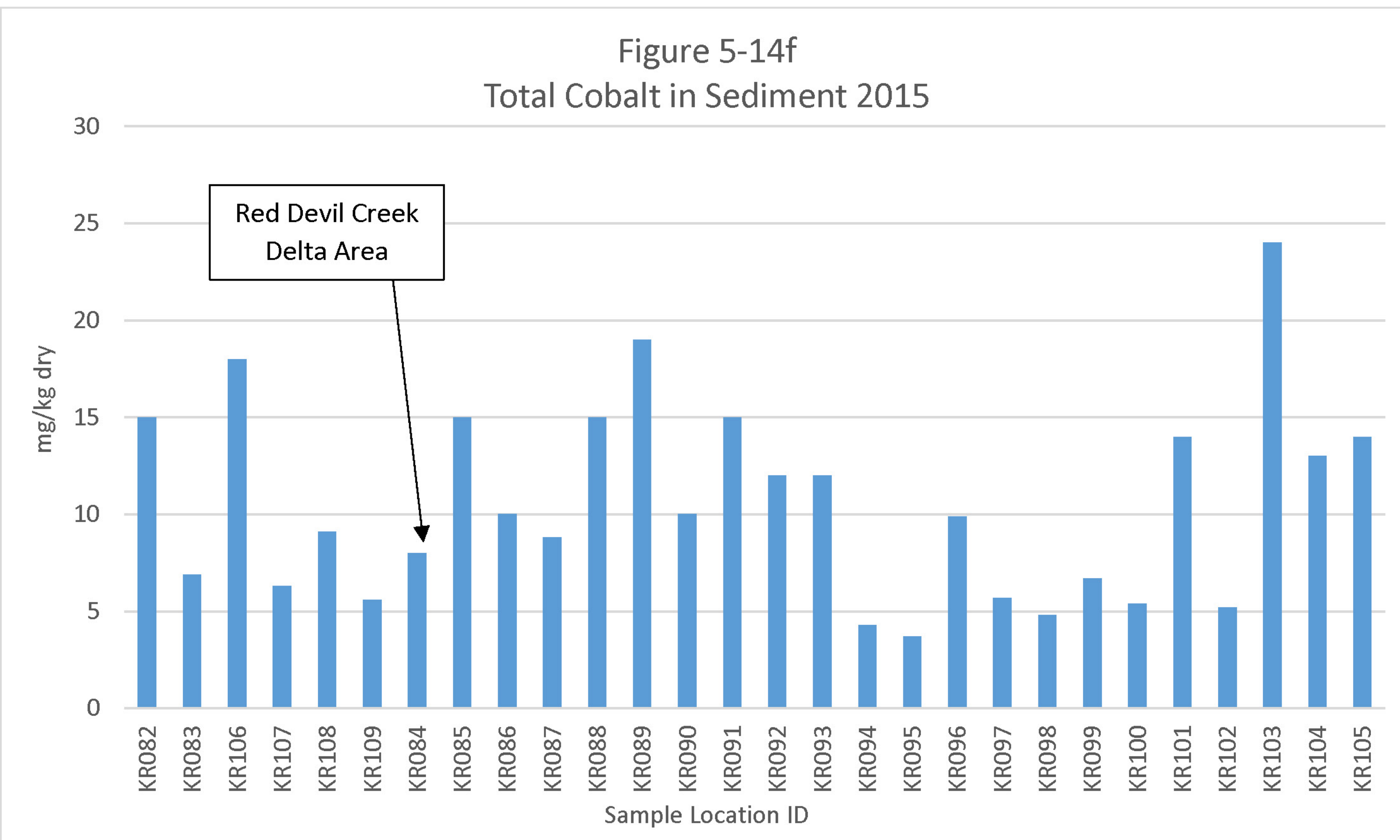


Figure 5-14f
Total Cobalt in Sediment 2015
30
25
20
15
10
5
0
mg/kg dry
Red Devil Creek Delta Area
KR082
KR083
KR106
KR107
KR108
KR109
KR084
KR085
KR086
KR087
KR088
KR089
KR090
KR091
KR092
KR093
KR094
KR095
KR096
KR097
KR098
KR099
KR100
KR101
KR102
KR103
KR104
KR105
Sample Location ID

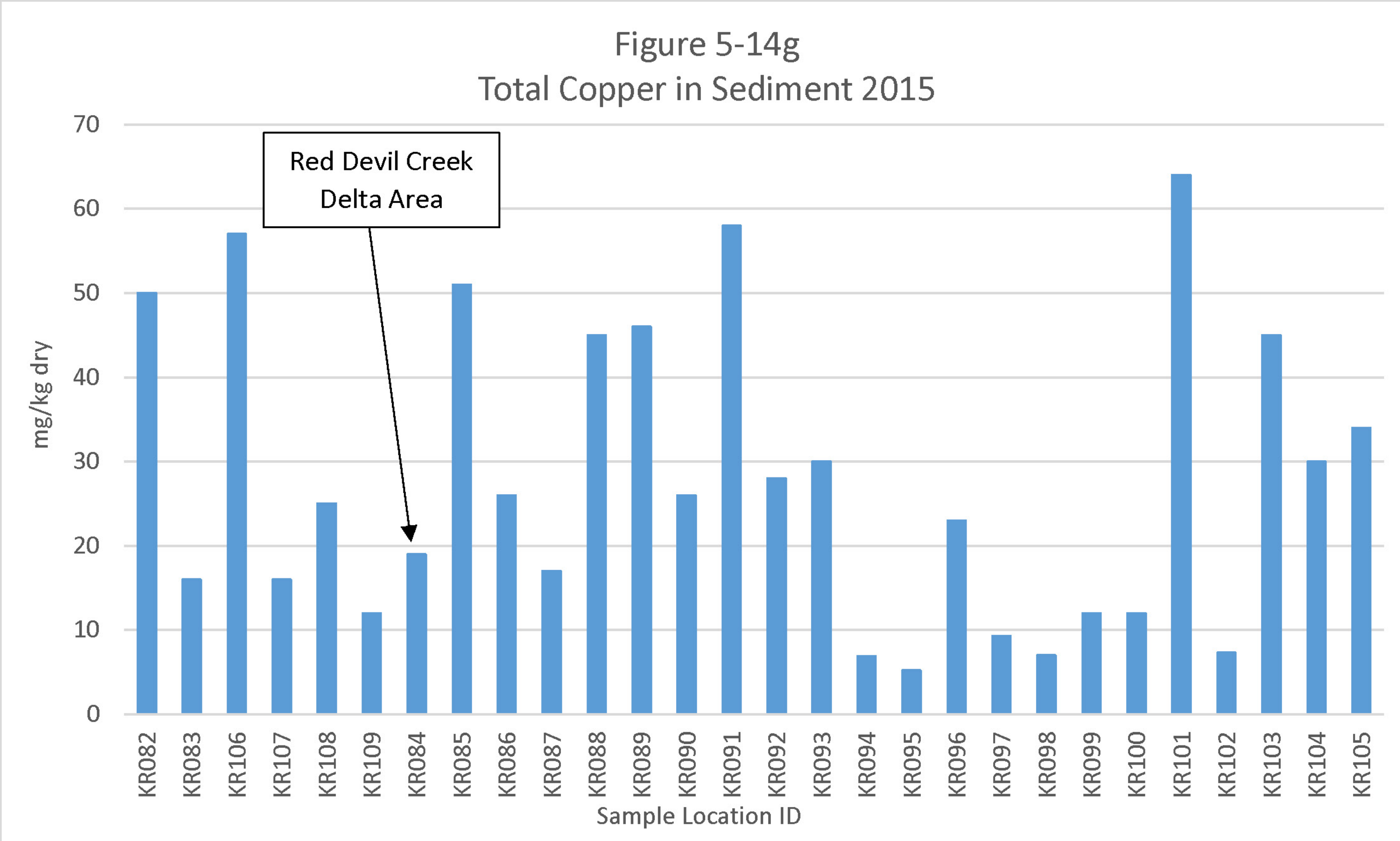


Figure 5-14g
Total Copper in Sediment 2015
mg/kg dry
Red Devil Creek Delta Area
Sample Location ID
KR082
KR083
KR106
KR107
KR108
KR109
KR084
KR085
KR086
KR087
KR088
KR089
KR090
KR091
KR092
KR093
KR094
KR095
KR096
KR097
KR098
KR099
KR100
KR101
KR102
KR103
KR104
KR105

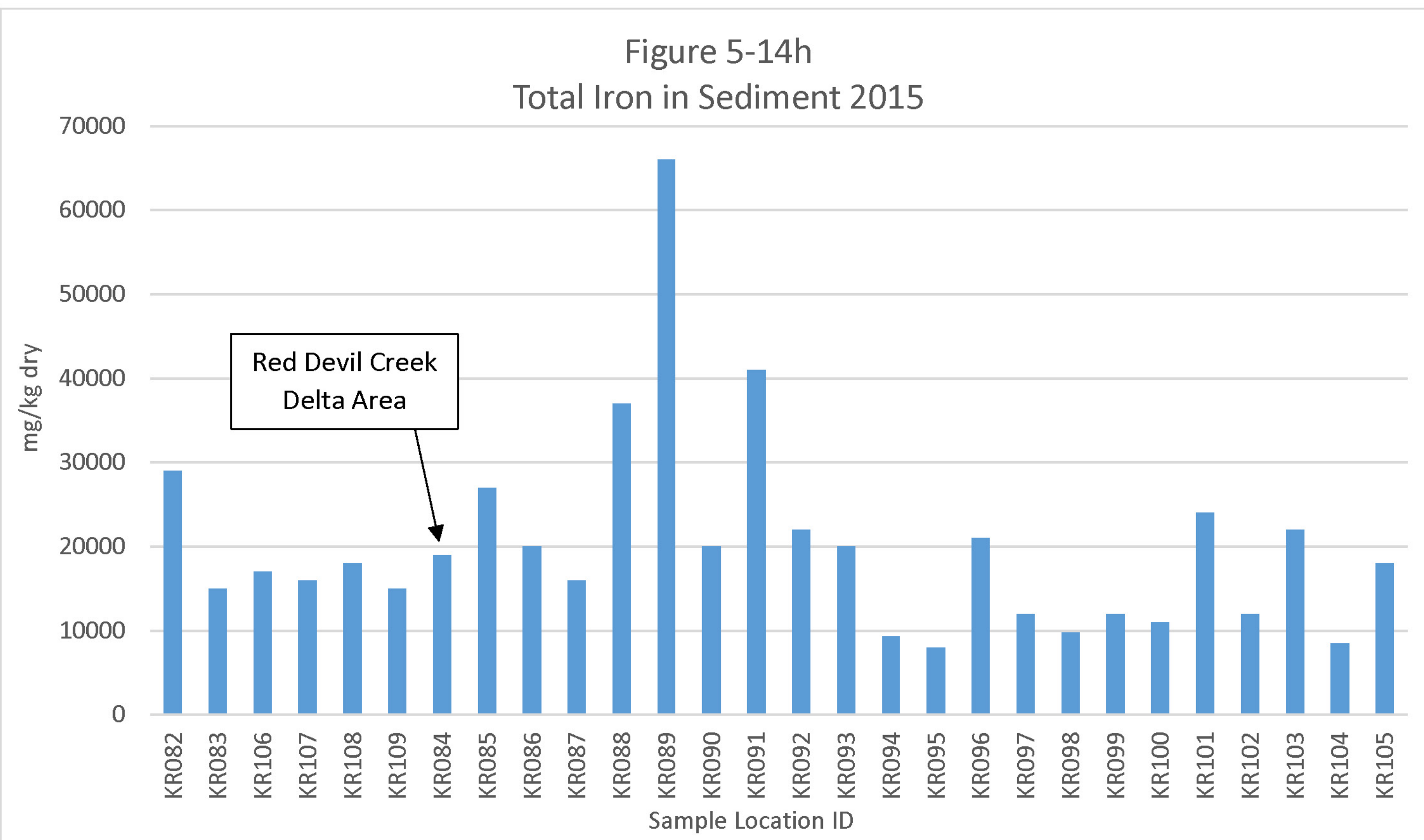


Figure 5-14h
Total Iron in Sediment 2015
mg/kg dry
Red Devil Creek Delta Area
Sample Location ID
KR082
KR083
KR106
KR107
KR108
KR109
KR084
KR085
KR086
KR087
KR088
KR089
KR090
KR091
KR092
KR093
KR094
KR095
KR096
KR097
KR098
KR099
KR100
KR101
KR102
KR103
KR104
KR105

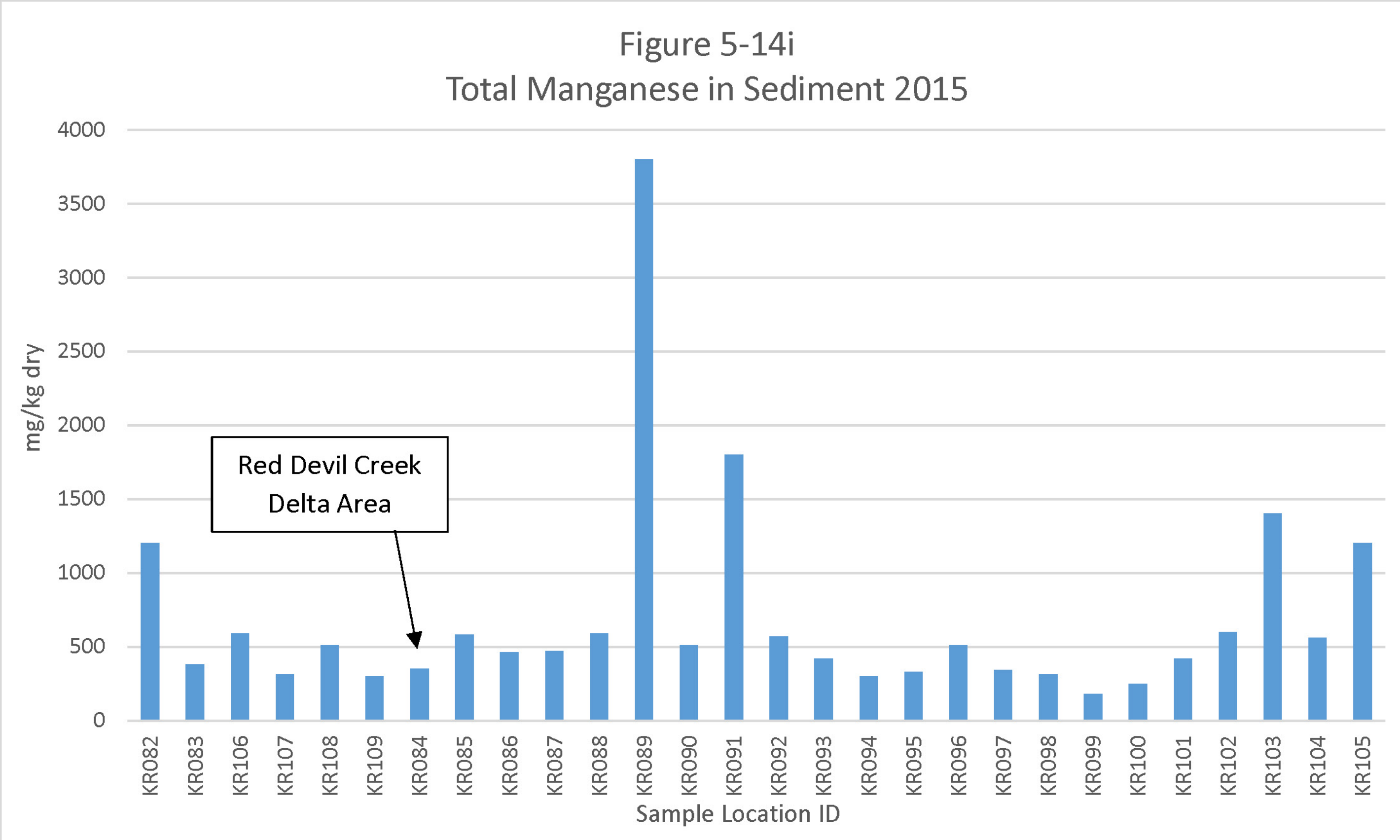


Figure 5-14i
Total Manganese in Sediment 2015
4000
3500
3000
2500
2000
1500
1000
500
0
mg/kg dry
Red Devil Creek Delta Area
KR082
KR083
KR106
KR107
KR108
KR109
KR084
KR085
KR086
KR087
KR088
KR089
KR090
KR091
KR092
KR093
KR094
KR095
KR096
KR097
KR098
KR099
KR100
KR101
KR102
KR103
KR104
KR105
Sample Location ID

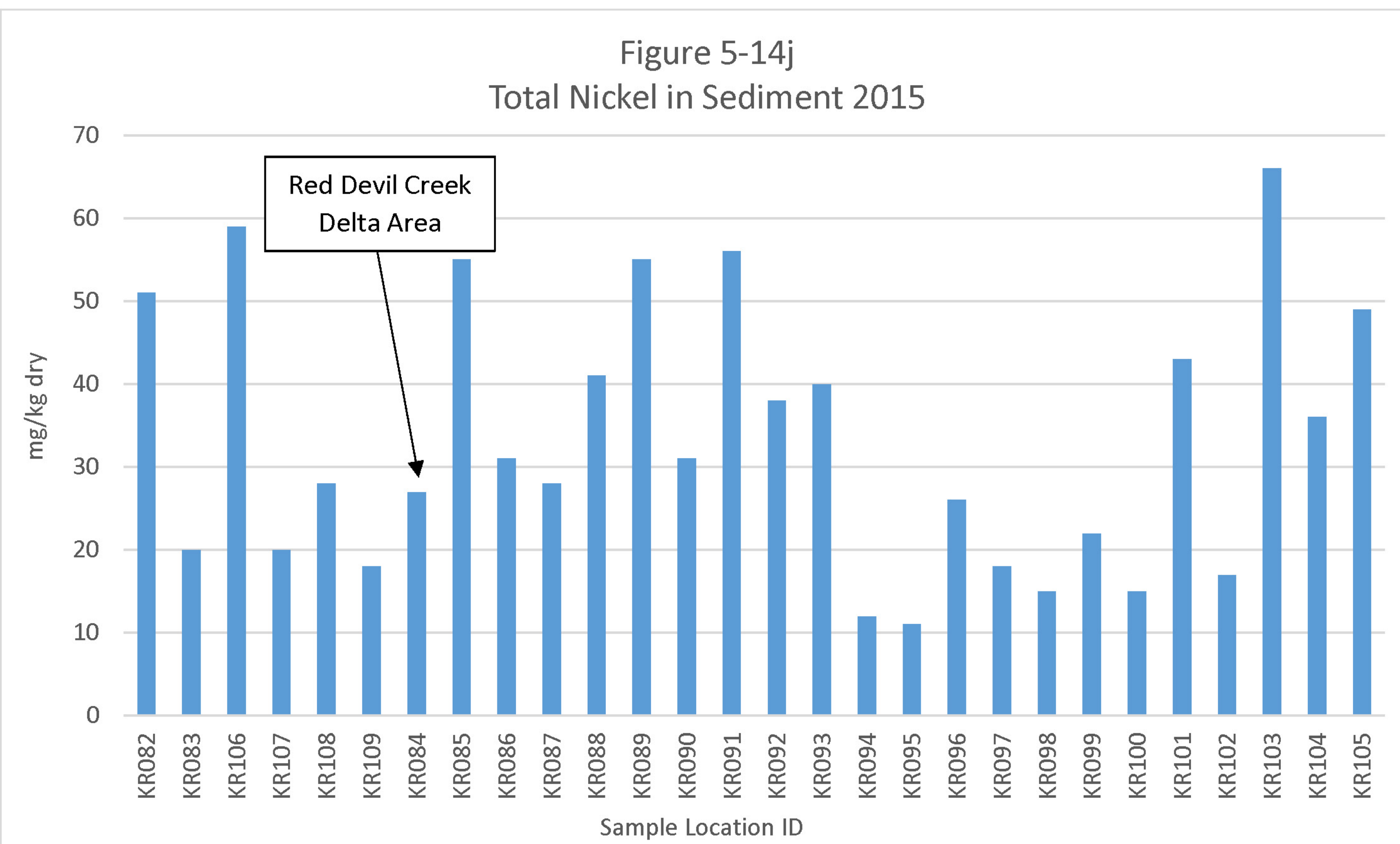


Figure 5-14j
Total Nickel in Sediment 2015
70
60
50
40
30
20
10
0
mg/kg dry
Red Devil Creek Delta Area
KR082
KR083
KR106
KR107
KR108
KR109
KR084
KR085
KR086
KR087
KR088
KR089
KR090
KR091
KR092
KR093
KR094
KR095
KR096
KR097
KR098
KR099
KR100
KR101
KR102
KR103
KR104
KR105
Sample Location ID

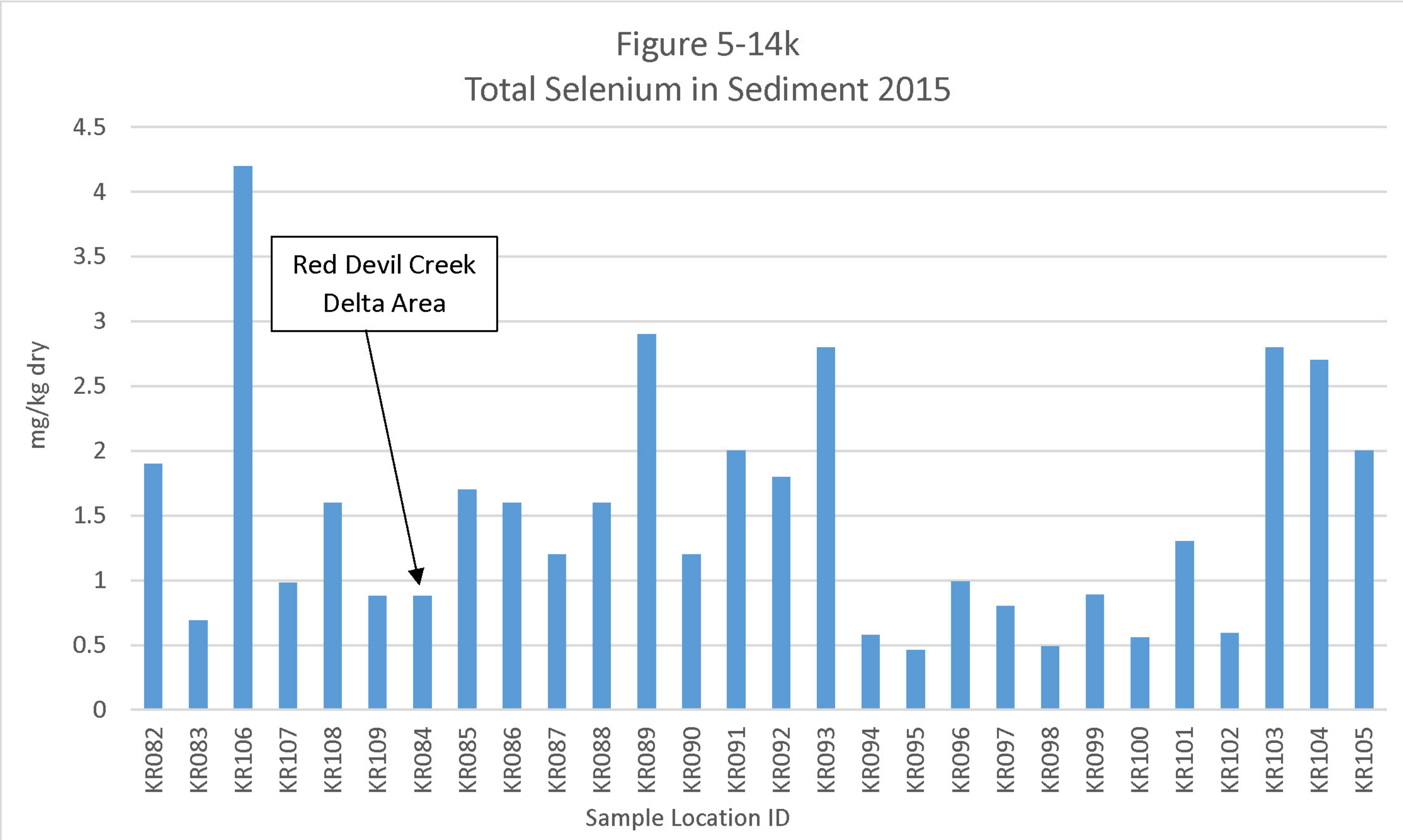


Figure 5-14k
Total Selenium in Sediment 2015
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
mg/kg dry
Red Devil Creek Delta Area
KR082
KR083
KR106
KR107
KR108
KR109
KR084
KR085
KR086
KR087
KR088
KR089
KR090
KR091
KR092
KR093
KR094
KR095
KR096
KR097
KR098
KR099
KR100
KR101
KR102
KR103
KR104
KR105
Sample Location ID

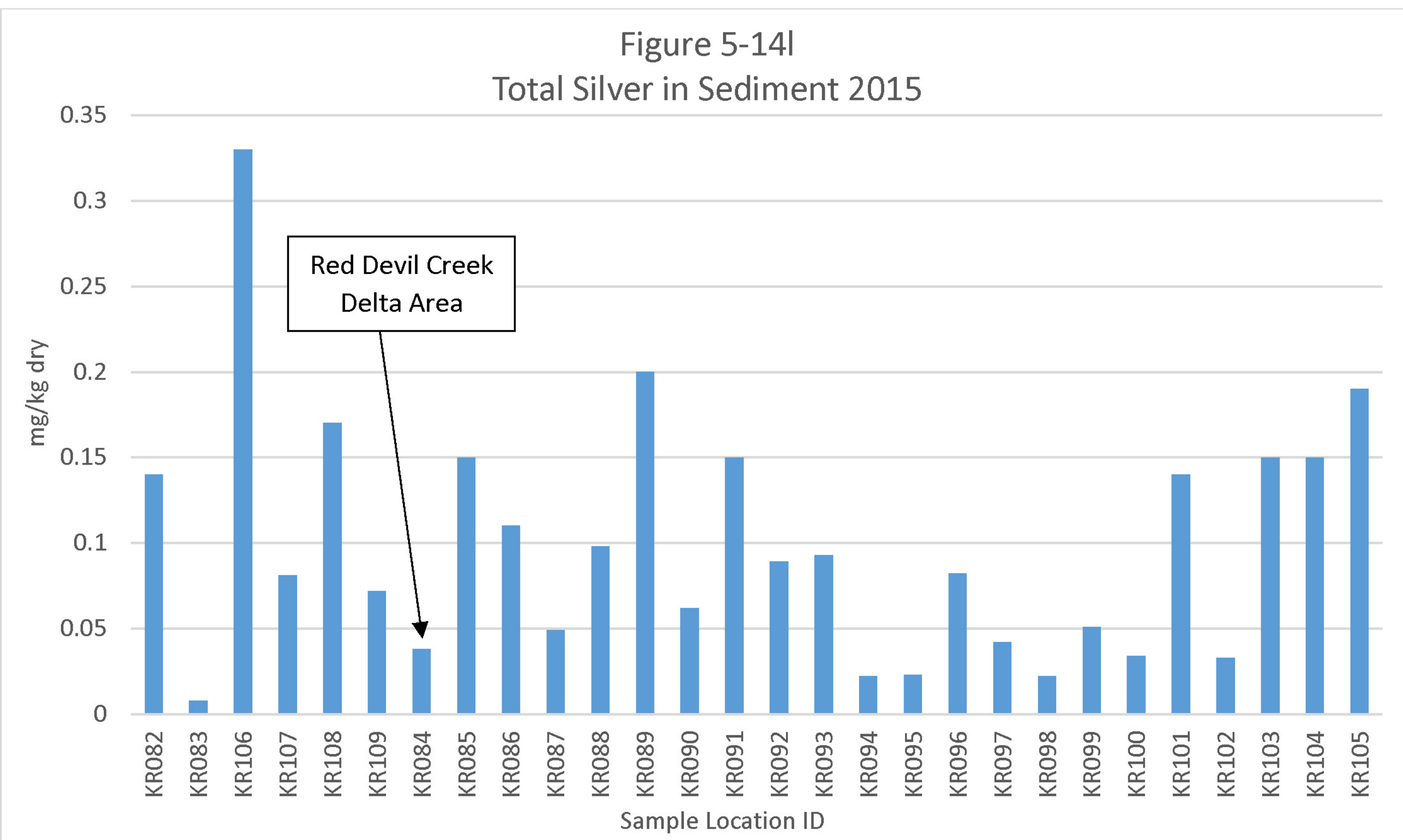


Figure 5-14l
Total Silver in Sediment 2015
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
mg/kg dry
Red Devil Creek Delta Area
KR082
KR083
KR106
KR107
KR108
KR109
KR084
KR085
KR086
KR087
KR088
KR089
KR090
KR091
KR092
KR093
KR094
KR095
KR096
KR097
KR098
KR099
KR100
KR101
KR102
KR103
KR104
KR105
Sample Location ID

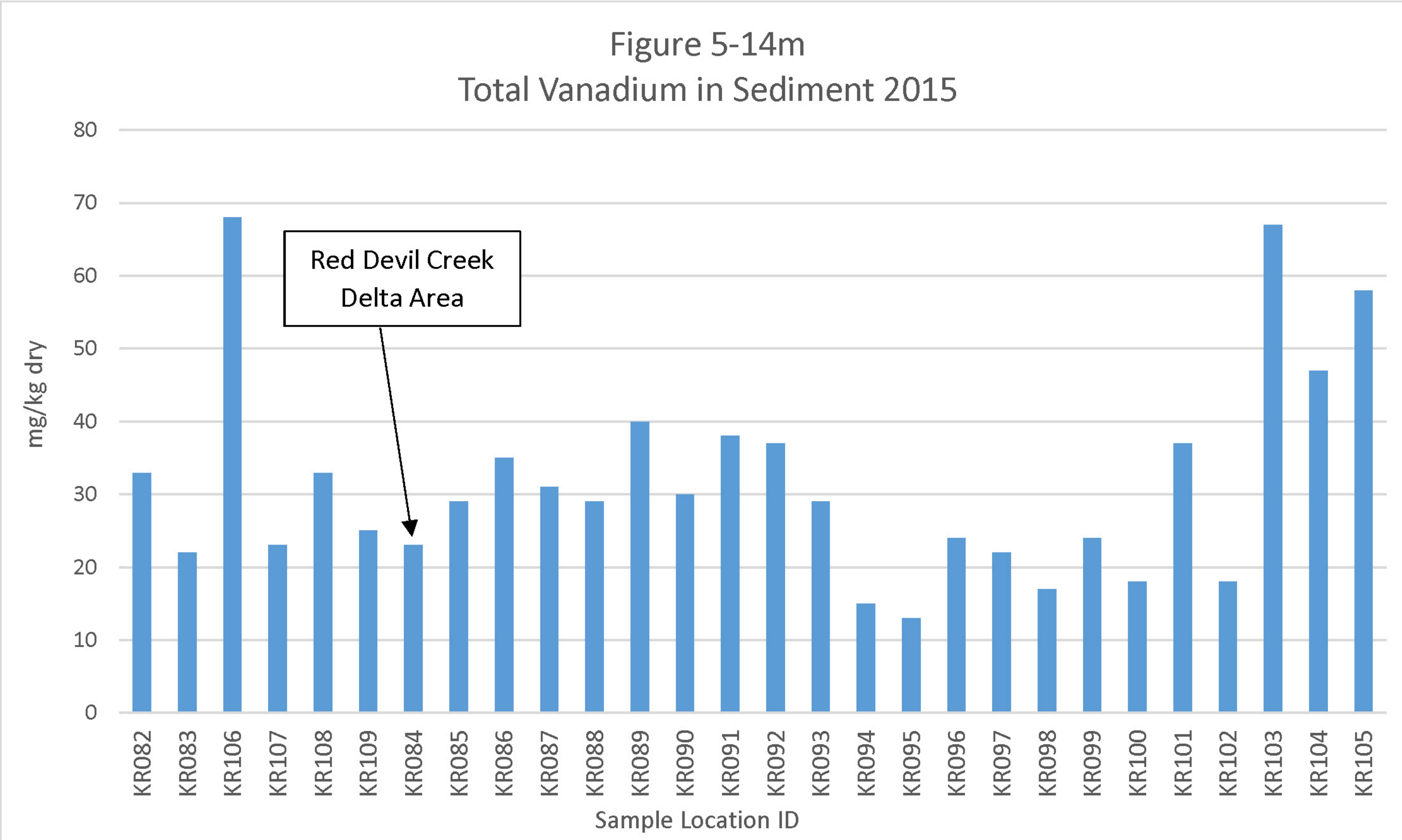


Figure 5-14m
Total Vanadium in Sediment 2015
80
70
60
50
40
30
20
10
0
mg/kg dry
Red Devil Creek
Delta Area
KR082
KR083
KR106
KR107
KR108
KR109
KR084
KR085
KR086
KR087
KR088
KR089
KR090
KR091
KR092
KR093
KR094
KR095
KR096
KR097
KR098
KR099
KR100
KR101
KR102
KR103
KR104
KR105
Sample Location ID

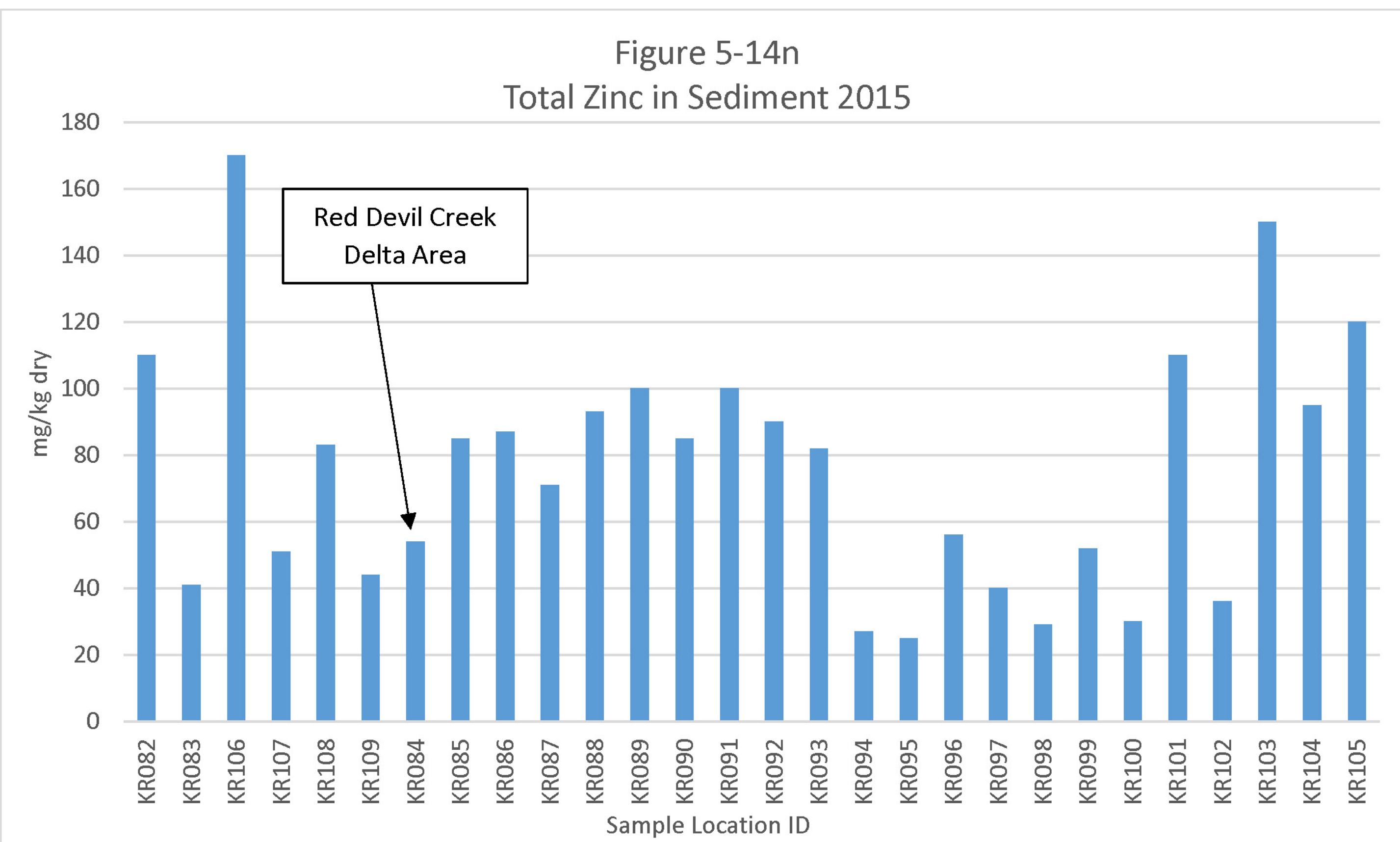


Figure 5-14n
Total Zinc in Sediment 2015
180
160
140
120
100
80
60
40
20
0
mg/kg dry
Red Devil Creek
Delta Area
KR082
KR083
KR106
KR107
KR108
KR109
KR084
KR085
KR086
KR087
KR088
KR089
KR090
KR091
KR092
KR093
KR094
KR095
KR096
KR097
KR098
KR099
KR100
KR101
KR102
KR103
KR104
KR105
Sample Location ID

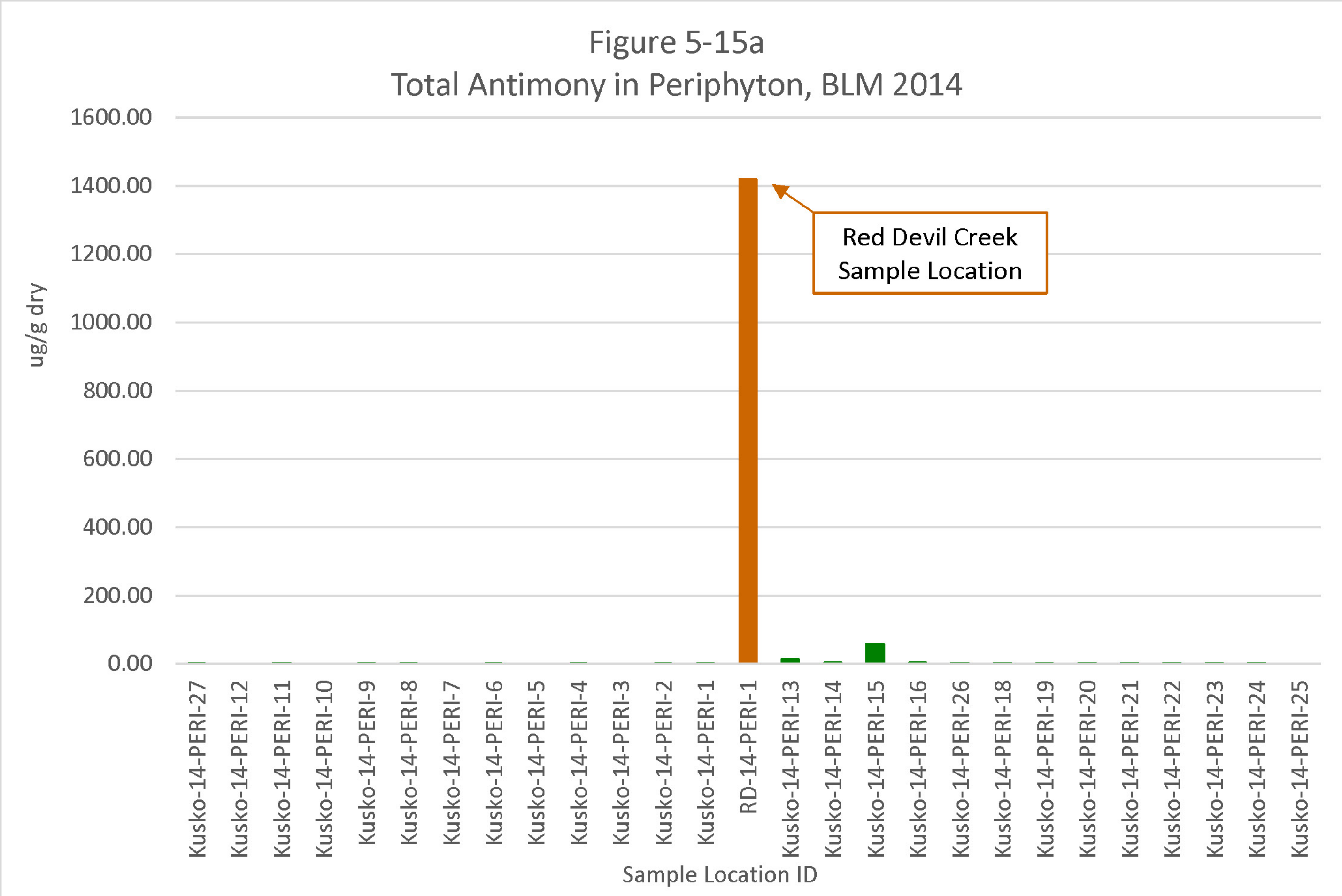


Figure 5-15a
Total Antimony in Periphyton, BLM 2014
1600.00
1400.00
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
ug/g dry
Red Devil Creek Sample Location
Kusko-14-PERI-27
Kusko-14-PERI-12
Kusko-14-PERI-11
Kusko-14-PERI-10
Kusko-14-PERI-9
Kusko-14-PERI-8
Kusko-14-PERI-7
Kusko-14-PERI-6
Kusko-14-PERI-5
Kusko-14-PERI-4
Kusko-14-PERI-3
Kusko-14-PERI-2
Kusko-14-PERI-1
RD-14-PERI-1
Kusko-14-PERI-13
Kusko-14-PERI-14
Kusko-14-PERI-15
Kusko-14-PERI-16
Kusko-14-PERI-26
Kusko-14-PERI-18
Kusko-14-PERI-19
Kusko-14-PERI-20
Kusko-14-PERI-21
Kusko-14-PERI-22
Kusko-14-PERI-23
Kusko-14-PERI-24
Kusko-14-PERI-25
Sample Location ID

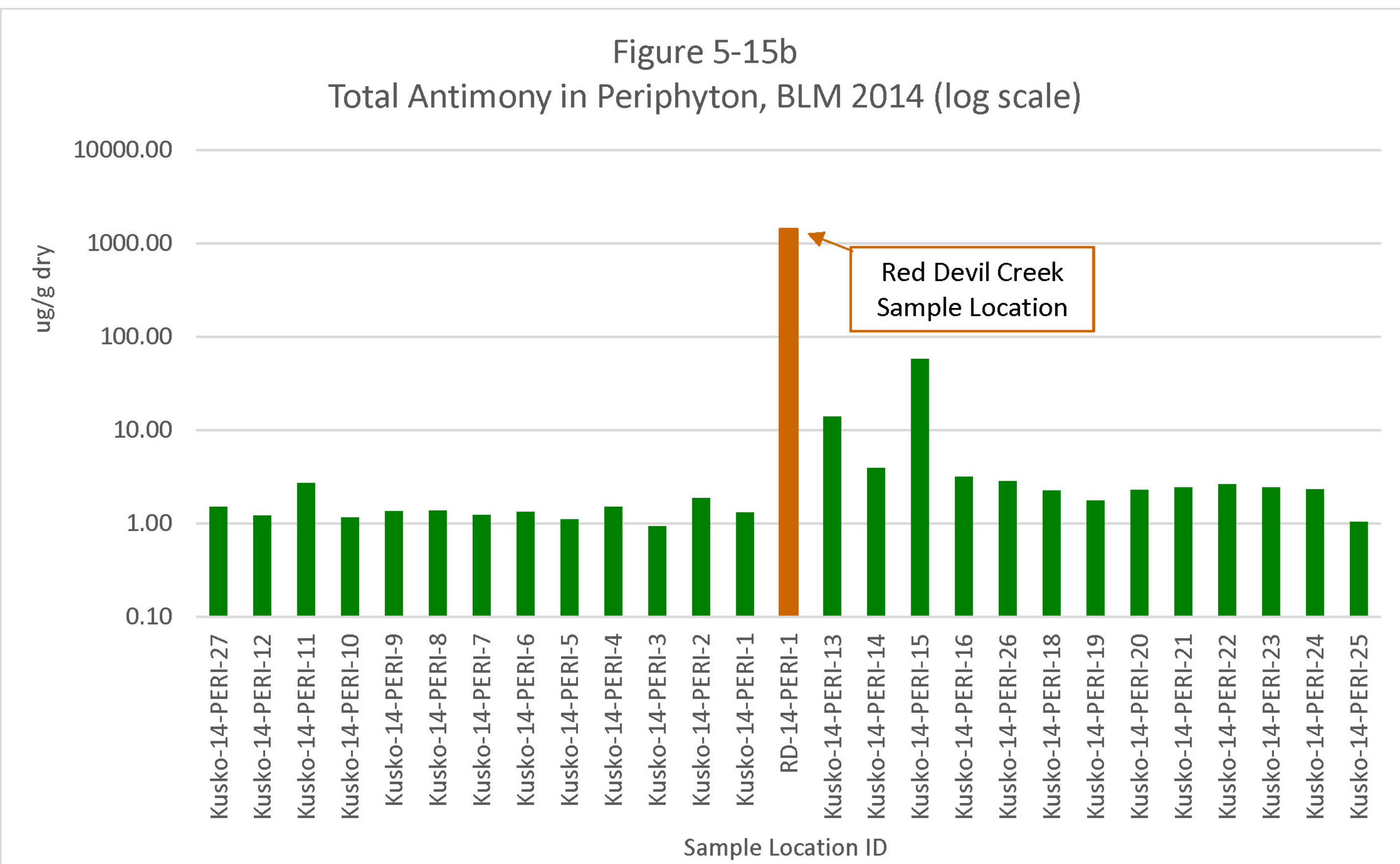


Figure 5-15b
Total Antimony in Periphyton, BLM 2014 (log scale)
10000.00
1000.00
100.00
10.00
1.00
0.10
ug/g dry
Red Devil Creek Sample Location
Kusko-14-PERI-27
Kusko-14-PERI-12
Kusko-14-PERI-11
Kusko-14-PERI-10
Kusko-14-PERI-9
Kusko-14-PERI-8
Kusko-14-PERI-7
Kusko-14-PERI-6
Kusko-14-PERI-5
Kusko-14-PERI-4
Kusko-14-PERI-3
Kusko-14-PERI-2
Kusko-14-PERI-1
RD-14-PERI-1
Kusko-14-PERI-13
Kusko-14-PERI-14
Kusko-14-PERI-15
Kusko-14-PERI-16
Kusko-14-PERI-26
Kusko-14-PERI-18
Kusko-14-PERI-19
Kusko-14-PERI-20
Kusko-14-PERI-21
Kusko-14-PERI-22
Kusko-14-PERI-23
Kusko-14-PERI-24
Kusko-14-PERI-25
Sample Location ID

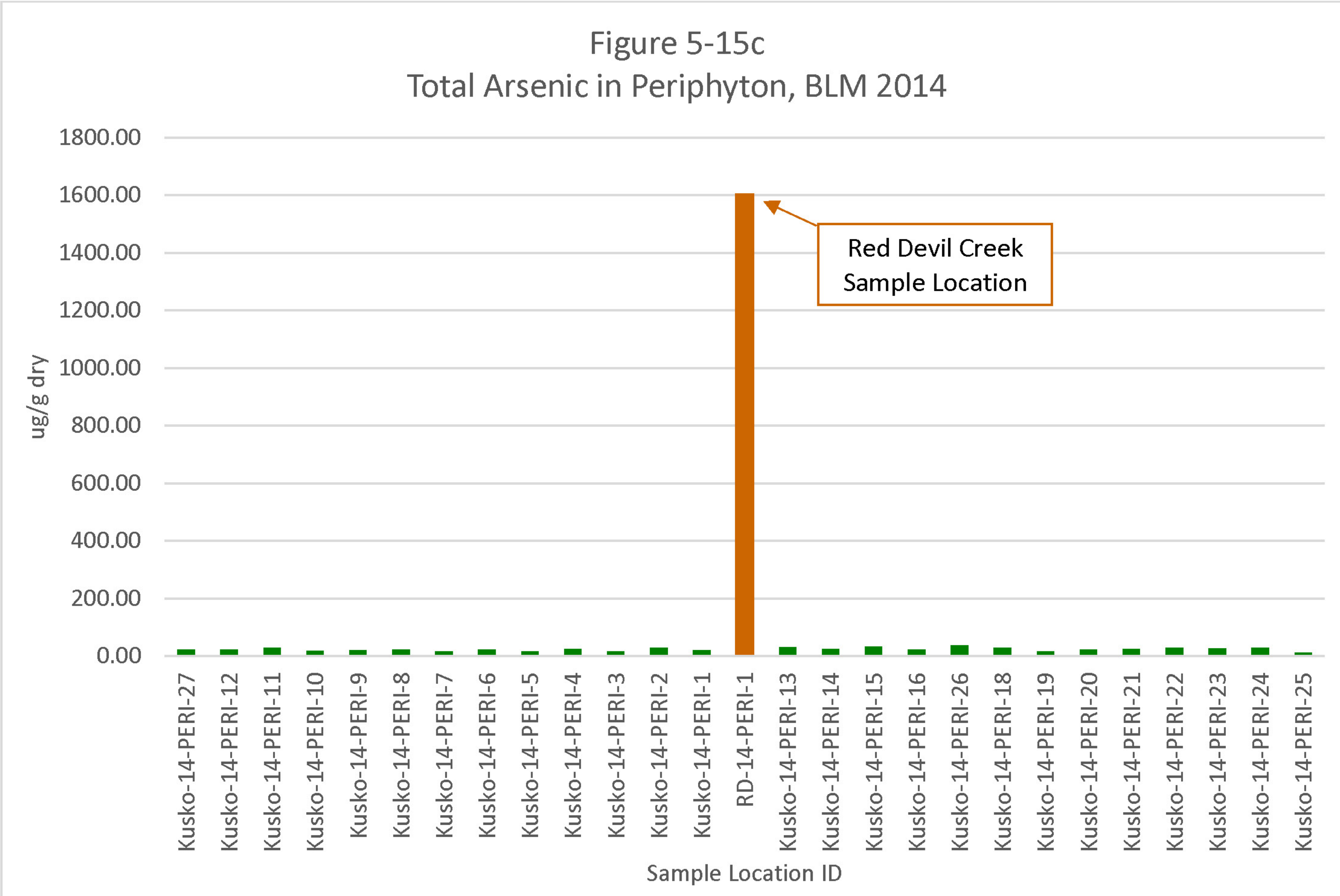


Figure 5-15c
Total Arsenic in Periphyton, BLM 2014
ug/g dry
1800.00
1600.00
1400.00
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
Red Devil Creek Sample Location
Kusko-14-PERI-27
Kusko-14-PERI-12
Kusko-14-PERI-11
Kusko-14-PERI-10
Kusko-14-PERI-9
Kusko-14-PERI-8
Kusko-14-PERI-7
Kusko-14-PERI-6
Kusko-14-PERI-5
Kusko-14-PERI-4
Kusko-14-PERI-3
Kusko-14-PERI-2
Kusko-14-PERI-1
RD-14-PERI-1
Kusko-14-PERI-13
Kusko-14-PERI-14
Kusko-14-PERI-15
Kusko-14-PERI-16
Kusko-14-PERI-26
Kusko-14-PERI-18
Kusko-14-PERI-19
Kusko-14-PERI-20
Kusko-14-PERI-21
Kusko-14-PERI-22
Kusko-14-PERI-23
Kusko-14-PERI-24
Kusko-14-PERI-25
Sample Location ID

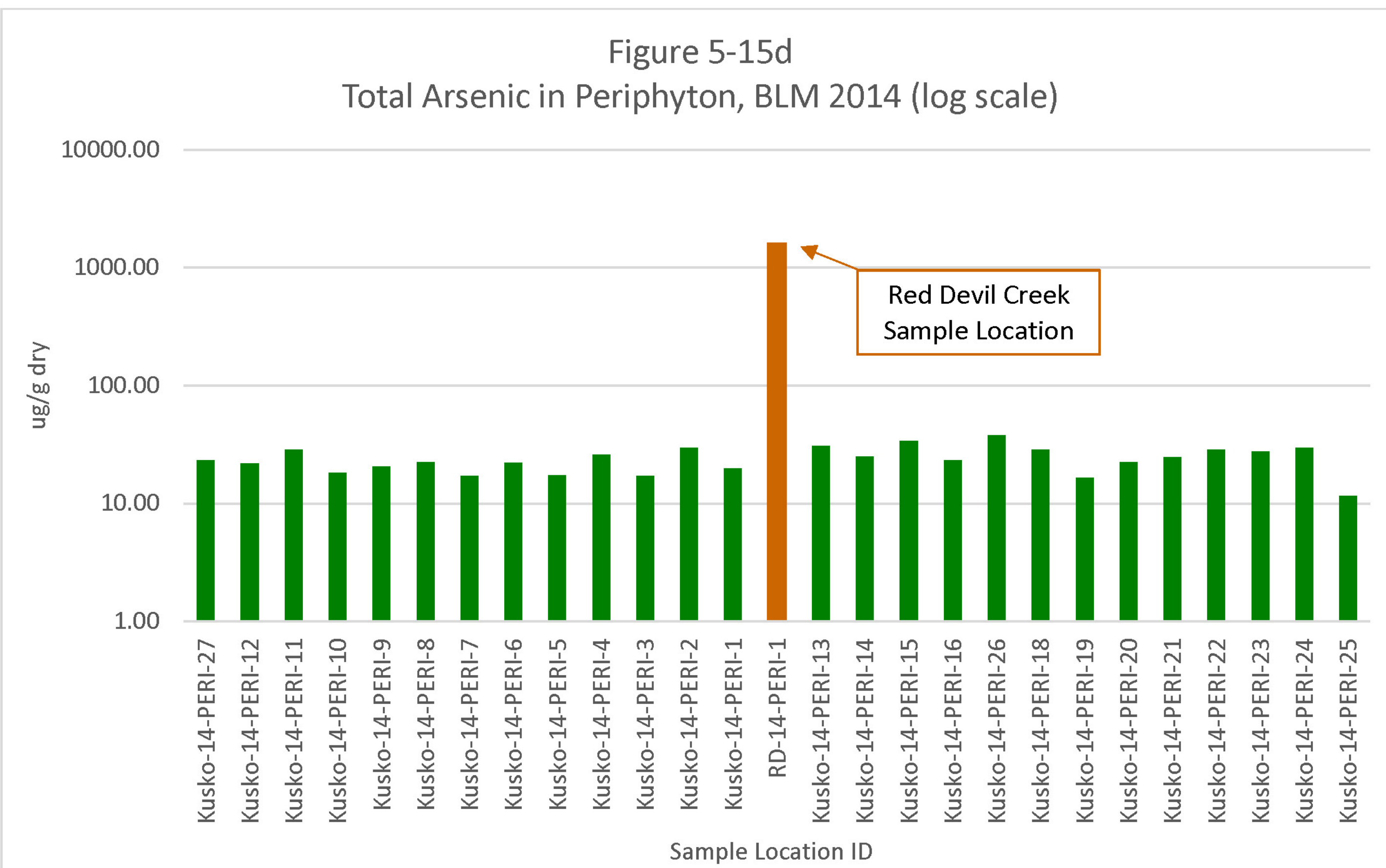


Figure 5-15d
Total Arsenic in Periphyton, BLM 2014 (log scale)
ug/g dry
10000.00
1000.00
100.00
10.00
1.00
Red Devil Creek Sample Location
Kusko-14-PERI-27
Kusko-14-PERI-12
Kusko-14-PERI-11
Kusko-14-PERI-10
Kusko-14-PERI-9
Kusko-14-PERI-8
Kusko-14-PERI-7
Kusko-14-PERI-6
Kusko-14-PERI-5
Kusko-14-PERI-4
Kusko-14-PERI-3
Kusko-14-PERI-2
Kusko-14-PERI-1
RD-14-PERI-1
Kusko-14-PERI-13
Kusko-14-PERI-14
Kusko-14-PERI-15
Kusko-14-PERI-16
Kusko-14-PERI-26
Kusko-14-PERI-18
Kusko-14-PERI-19
Kusko-14-PERI-20
Kusko-14-PERI-21
Kusko-14-PERI-22
Kusko-14-PERI-23
Kusko-14-PERI-24
Kusko-14-PERI-25
Sample Location ID

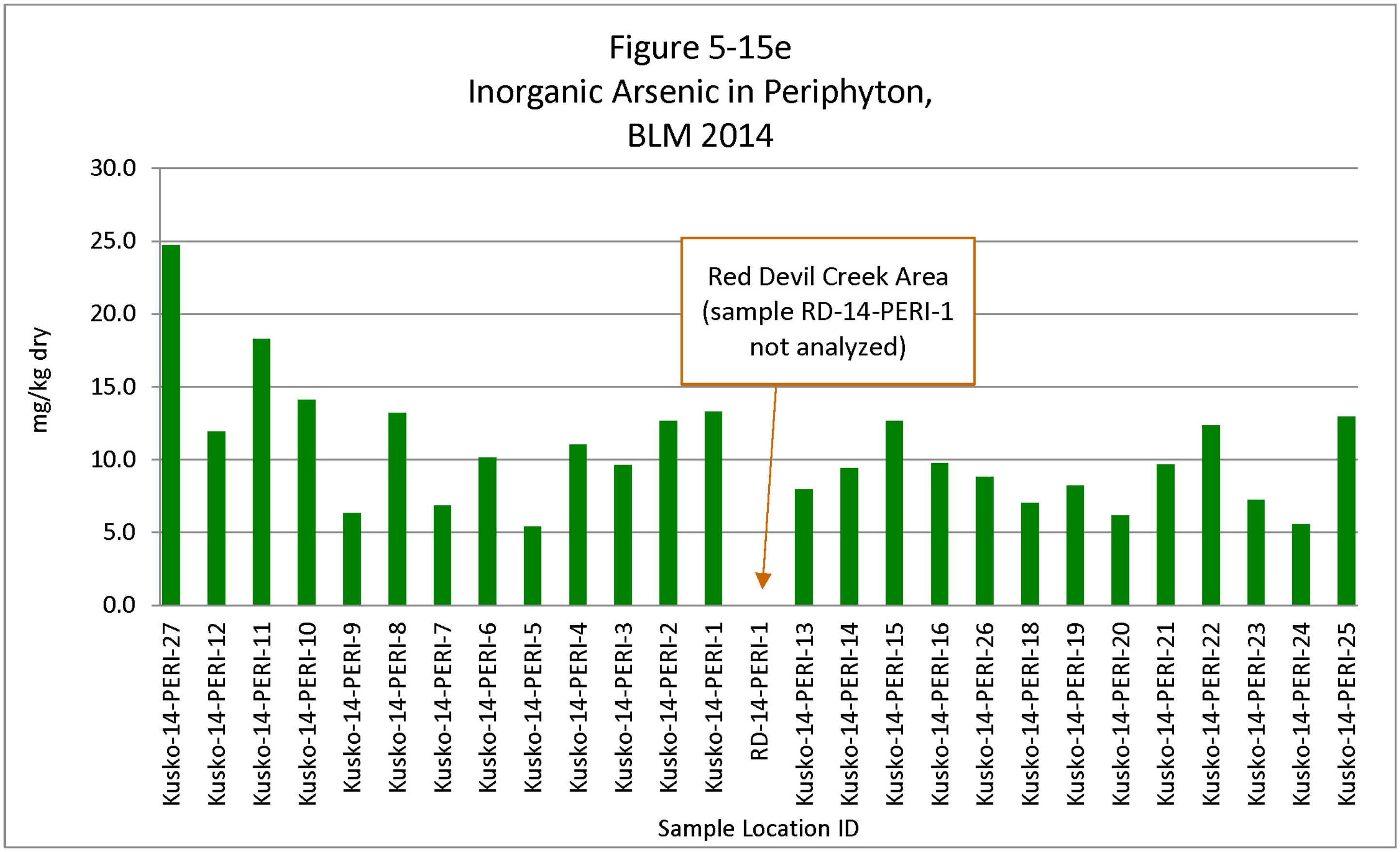


Figure 5-15e
Inorganic Arsenic in Periphyton,
BLM 2014
30.0
25.0
20.0
15.0
10.0
5.0
0.0
mg/kg dry
Red Devil Creek Area
(sample RD-14-PERI-1
not analyzed)
Kusko-14-PERI-27
Kusko-14-PERI-12
Kusko-14-PERI-11
Kusko-14-PERI-10
Kusko-14-PERI-9
Kusko-14-PERI-8
Kusko-14-PERI-7
Kusko-14-PERI-6
Kusko-14-PERI-5
Kusko-14-PERI-4
Kusko-14-PERI-3
Kusko-14-PERI-2
Kusko-14-PERI-1
RD-14-PERI-1
Kusko-14-PERI-13
Kusko-14-PERI-14
Kusko-14-PERI-15
Kusko-14-PERI-16
Kusko-14-PERI-26
Kusko-14-PERI-18
Kusko-14-PERI-19
Kusko-14-PERI-20
Kusko-14-PERI-21
Kusko-14-PERI-22
Kusko-14-PERI-23
Kusko-14-PERI-24
Kusko-14-PERI-25
Sample Location ID

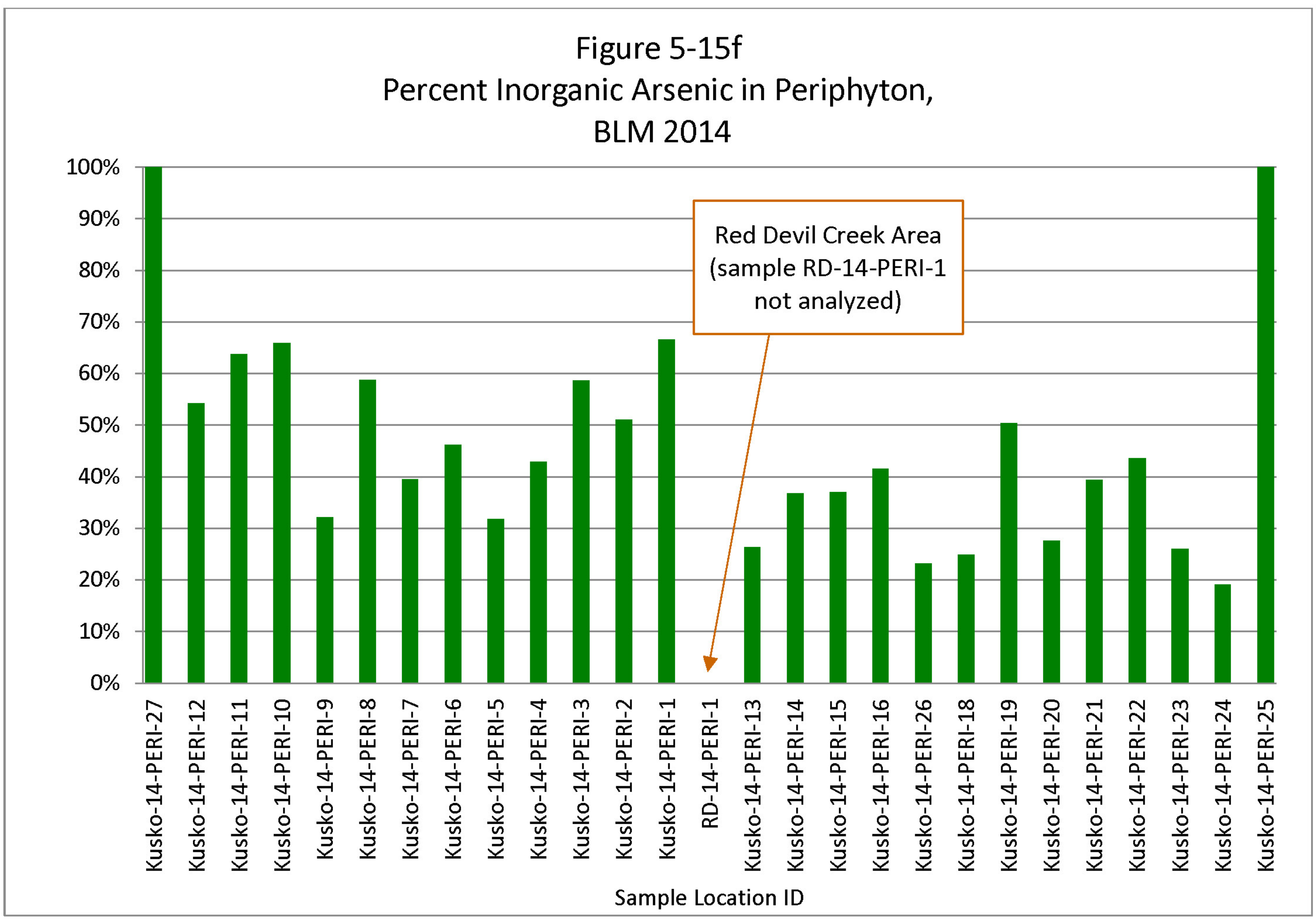


Figure 5-15f
Percent Inorganic Arsenic in Periphyton,
BLM 2014
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Red Devil Creek Area
(sample RD-14-PERI-1
not analyzed)
Kusko-14-PERI-27
Kusko-14-PERI-12
Kusko-14-PERI-11
Kusko-14-PERI-10
Kusko-14-PERI-9
Kusko-14-PERI-8
Kusko-14-PERI-7
Kusko-14-PERI-6
Kusko-14-PERI-5
Kusko-14-PERI-4
Kusko-14-PERI-3
Kusko-14-PERI-2
Kusko-14-PERI-1
RD-14-PERI-1
Kusko-14-PERI-13
Kusko-14-PERI-14
Kusko-14-PERI-15
Kusko-14-PERI-16
Kusko-14-PERI-26
Kusko-14-PERI-18
Kusko-14-PERI-19
Kusko-14-PERI-20
Kusko-14-PERI-21
Kusko-14-PERI-22
Kusko-14-PERI-23
Kusko-14-PERI-24
Kusko-14-PERI-25
Sample Location ID

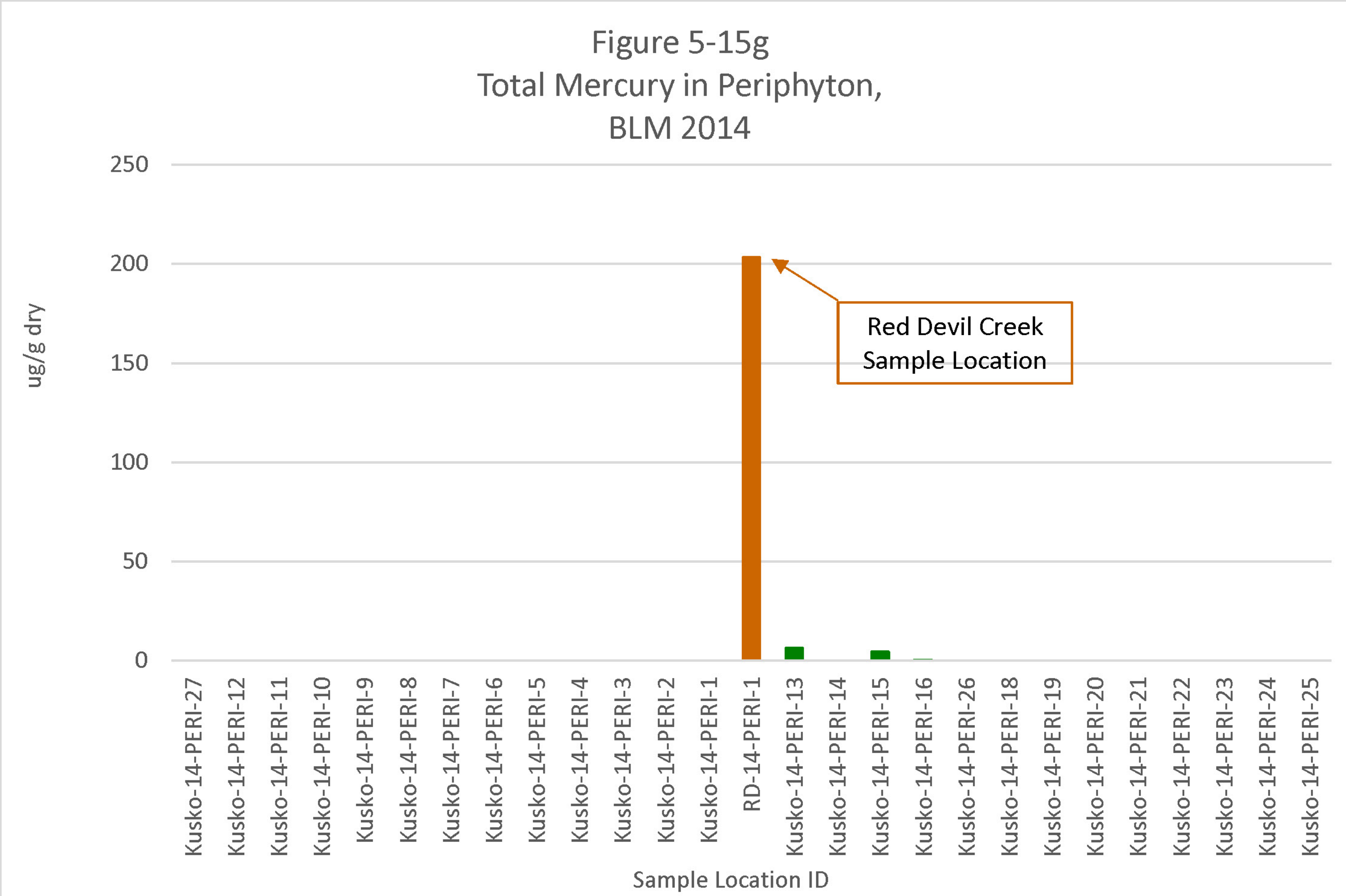


Figure 5-15g
Total Mercury in Periphyton,
BLM 2014
250
200
150
100
50
0
ug/g dry
Red Devil Creek
Sample Location
Kusko-14-PERI-27
Kusko-14-PERI-12
Kusko-14-PERI-11
Kusko-14-PERI-10
Kusko-14-PERI-9
Kusko-14-PERI-8
Kusko-14-PERI-7
Kusko-14-PERI-6
Kusko-14-PERI-5
Kusko-14-PERI-4
Kusko-14-PERI-3
Kusko-14-PERI-2
Kusko-14-PERI-1
RD-14-PERI-1
Kusko-14-PERI-13
Kusko-14-PERI-14
Kusko-14-PERI-15
Kusko-14-PERI-16
Kusko-14-PERI-26
Kusko-14-PERI-18
Kusko-14-PERI-19
Kusko-14-PERI-20
Kusko-14-PERI-21
Kusko-14-PERI-22
Kusko-14-PERI-23
Kusko-14-PERI-24
Kusko-14-PERI-25
Sample Location ID

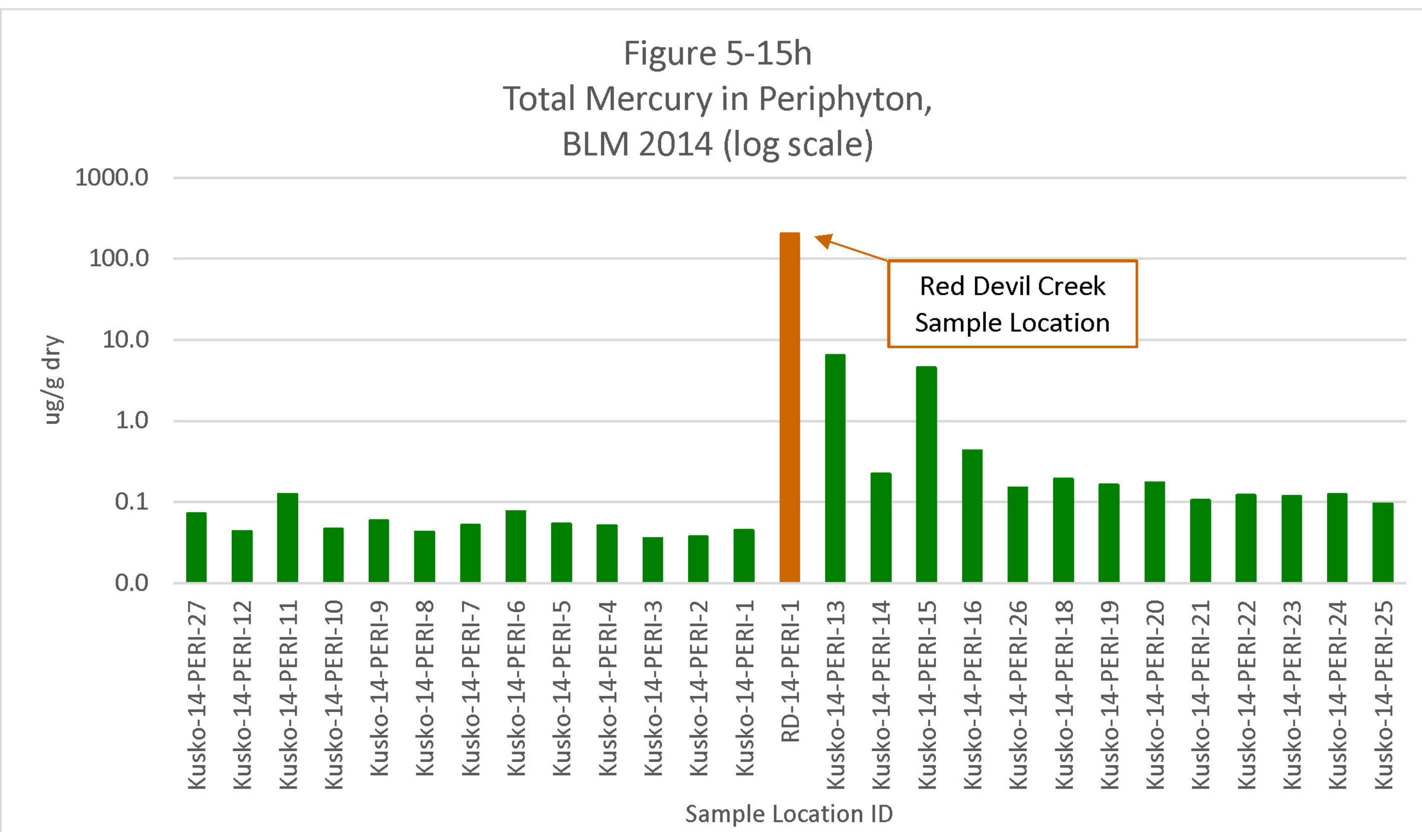


Figure 5-15h
Total Mercury in Periphyton,
BLM 2014 (log scale)
1000.0
100.0
10.0
1.0
0.1
0.0
ug/g dry
Red Devil Creek
Sample Location
Kusko-14-PERI-27
Kusko-14-PERI-12
Kusko-14-PERI-11
Kusko-14-PERI-10
Kusko-14-PERI-9
Kusko-14-PERI-8
Kusko-14-PERI-7
Kusko-14-PERI-6
Kusko-14-PERI-5
Kusko-14-PERI-4
Kusko-14-PERI-3
Kusko-14-PERI-2
Kusko-14-PERI-1
RD-14-PERI-1
Kusko-14-PERI-13
Kusko-14-PERI-14
Kusko-14-PERI-15
Kusko-14-PERI-16
Kusko-14-PERI-26
Kusko-14-PERI-18
Kusko-14-PERI-19
Kusko-14-PERI-20
Kusko-14-PERI-21
Kusko-14-PERI-22
Kusko-14-PERI-23
Kusko-14-PERI-24
Kusko-14-PERI-25
Sample Location ID

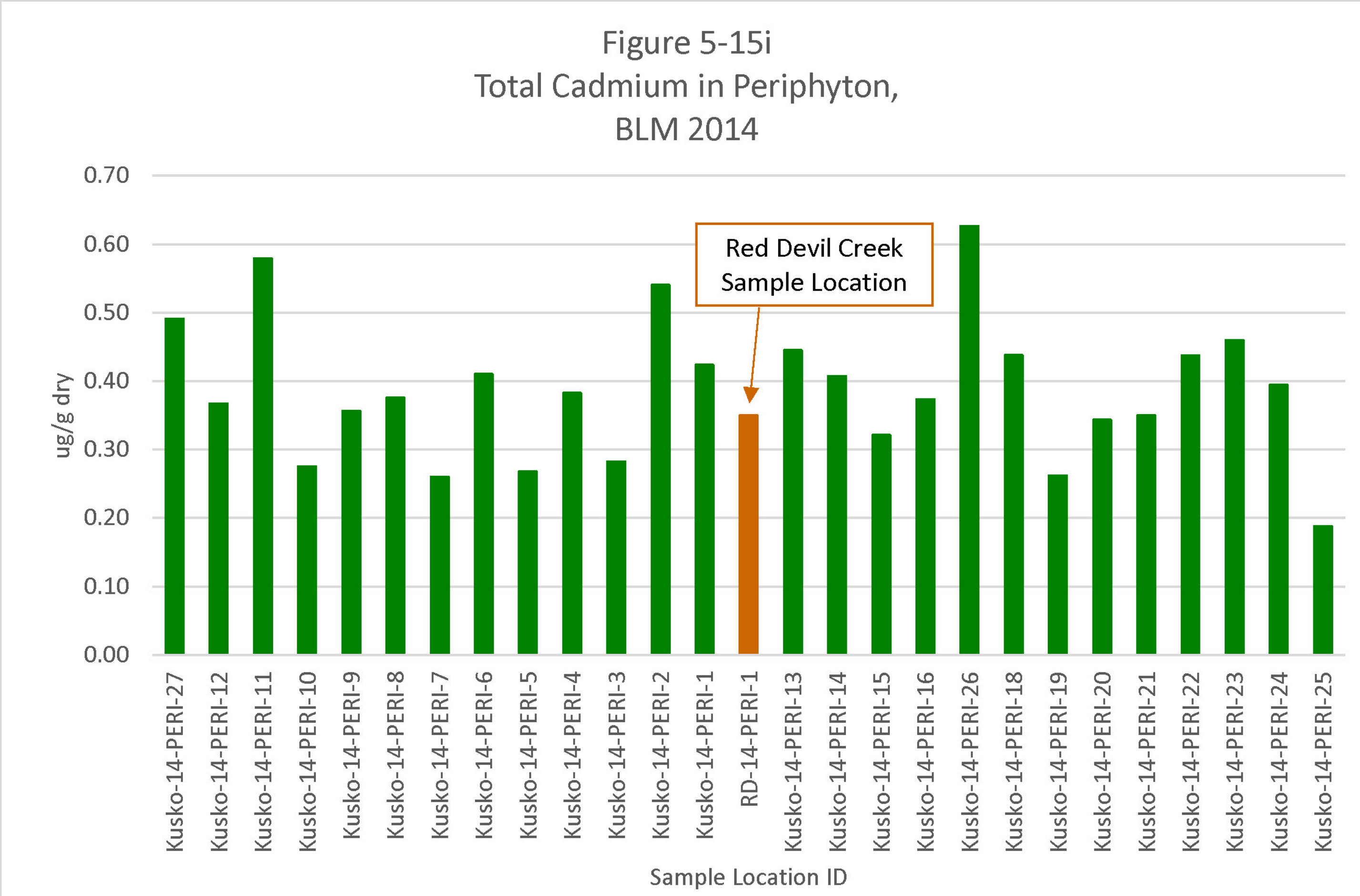


Figure 5-15i
Total Cadmium in Periphyton,
BLM 2014
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
ug/g dry
Red Devil Creek Sample Location
Kusko-14-PERI-27
Kusko-14-PERI-12
Kusko-14-PERI-11
Kusko-14-PERI-10
Kusko-14-PERI-9
Kusko-14-PERI-8
Kusko-14-PERI-7
Kusko-14-PERI-6
Kusko-14-PERI-5
Kusko-14-PERI-4
Kusko-14-PERI-3
Kusko-14-PERI-2
Kusko-14-PERI-1
RD-14-PERI-1
Kusko-14-PERI-13
Kusko-14-PERI-14
Kusko-14-PERI-15
Kusko-14-PERI-16
Kusko-14-PERI-26
Kusko-14-PERI-18
Kusko-14-PERI-19
Kusko-14-PERI-20
Kusko-14-PERI-21
Kusko-14-PERI-22
Kusko-14-PERI-23
Kusko-14-PERI-24
Kusko-14-PERI-25
Sample Location ID

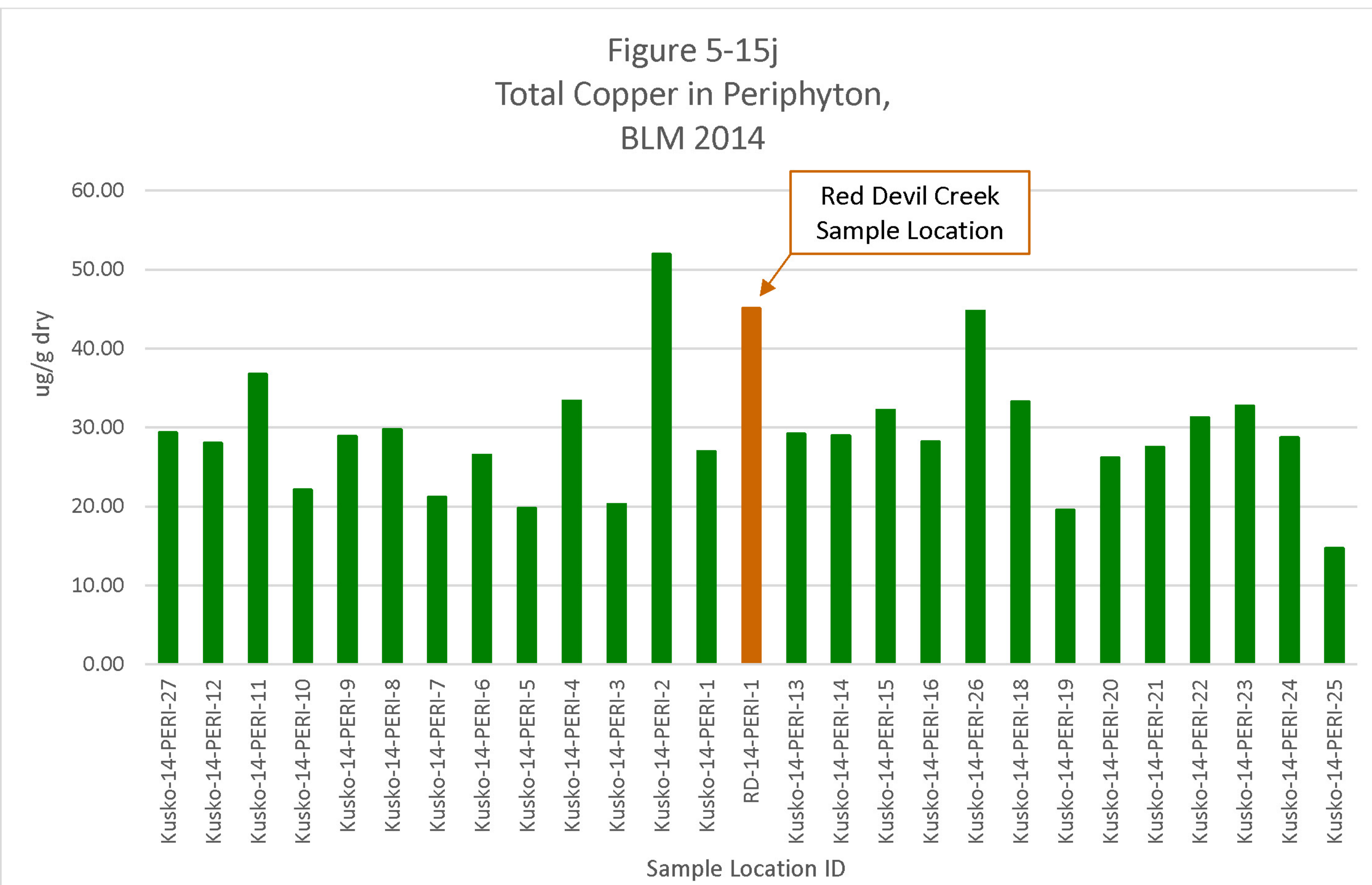


Figure 5-15j
Total Copper in Periphyton,
BLM 2014
60.00
50.00
40.00
30.00
20.00
10.00
0.00
ug/g dry
Red Devil Creek Sample Location
Kusko-14-PERI-27
Kusko-14-PERI-12
Kusko-14-PERI-11
Kusko-14-PERI-10
Kusko-14-PERI-9
Kusko-14-PERI-8
Kusko-14-PERI-7
Kusko-14-PERI-6
Kusko-14-PERI-5
Kusko-14-PERI-4
Kusko-14-PERI-3
Kusko-14-PERI-2
Kusko-14-PERI-1
RD-14-PERI-1
Kusko-14-PERI-13
Kusko-14-PERI-14
Kusko-14-PERI-15
Kusko-14-PERI-16
Kusko-14-PERI-26
Kusko-14-PERI-18
Kusko-14-PERI-19
Kusko-14-PERI-20
Kusko-14-PERI-21
Kusko-14-PERI-22
Kusko-14-PERI-23
Kusko-14-PERI-24
Kusko-14-PERI-25
Sample Location ID

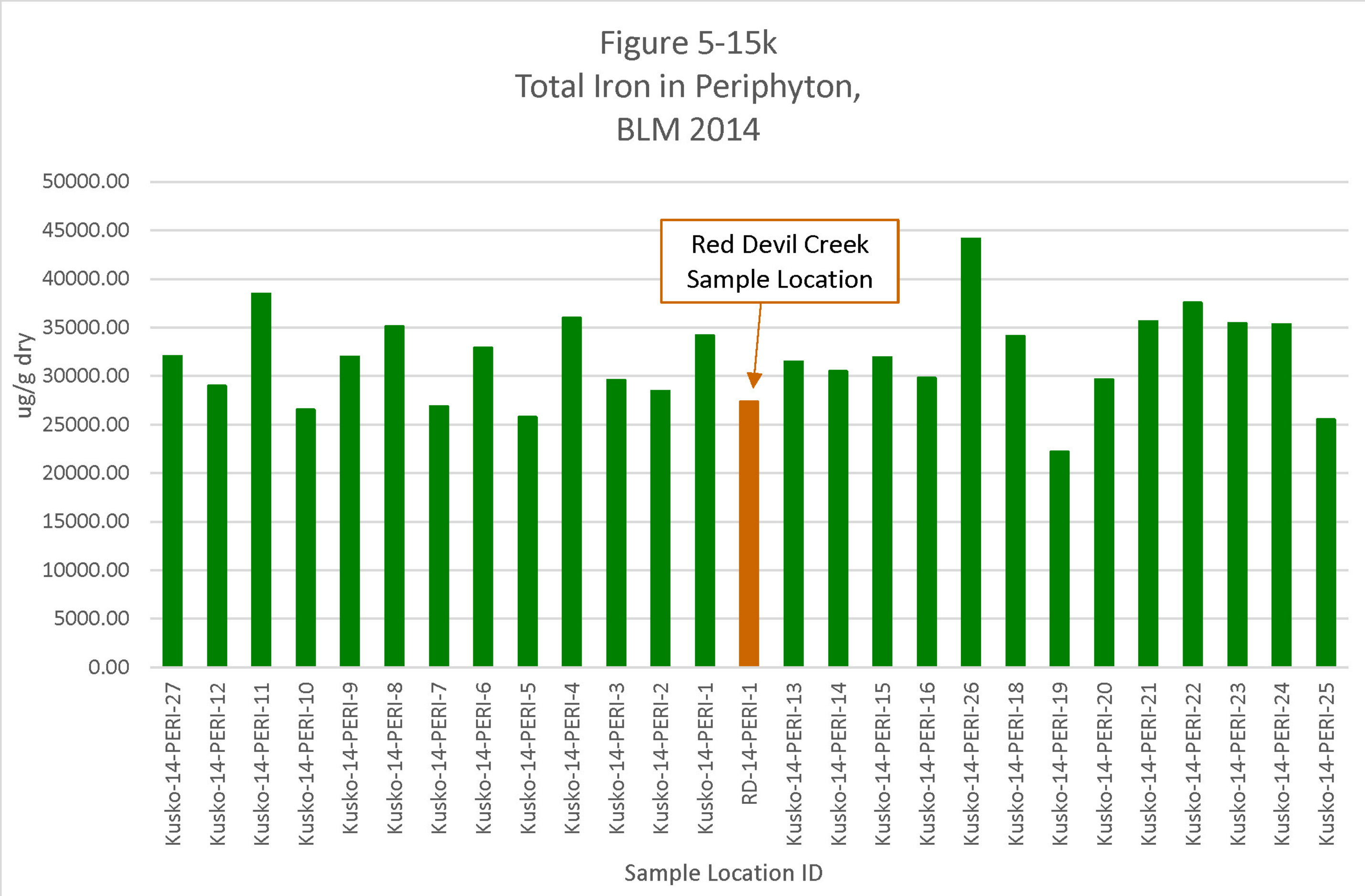


Figure 5-15k
Total Iron in Periphyton,
BLM 2014
50000.00
45000.00
40000.00
35000.00
30000.00
25000.00
20000.00
15000.00
10000.00
5000.00
0.00
ug/g dry
Red Devil Creek
Sample Location
Kusko-14-PERI-27
Kusko-14-PERI-12
Kusko-14-PERI-11
Kusko-14-PERI-10
Kusko-14-PERI-9
Kusko-14-PERI-8
Kusko-14-PERI-7
Kusko-14-PERI-6
Kusko-14-PERI-5
Kusko-14-PERI-4
Kusko-14-PERI-3
Kusko-14-PERI-2
Kusko-14-PERI-1
RD-14-PERI-1
Kusko-14-PERI-13
Kusko-14-PERI-14
Kusko-14-PERI-15
Kusko-14-PERI-16
Kusko-14-PERI-26
Kusko-14-PERI-18
Kusko-14-PERI-19
Kusko-14-PERI-20
Kusko-14-PERI-21
Kusko-14-PERI-22
Kusko-14-PERI-23
Kusko-14-PERI-24
Kusko-14-PERI-25
Sample Location ID

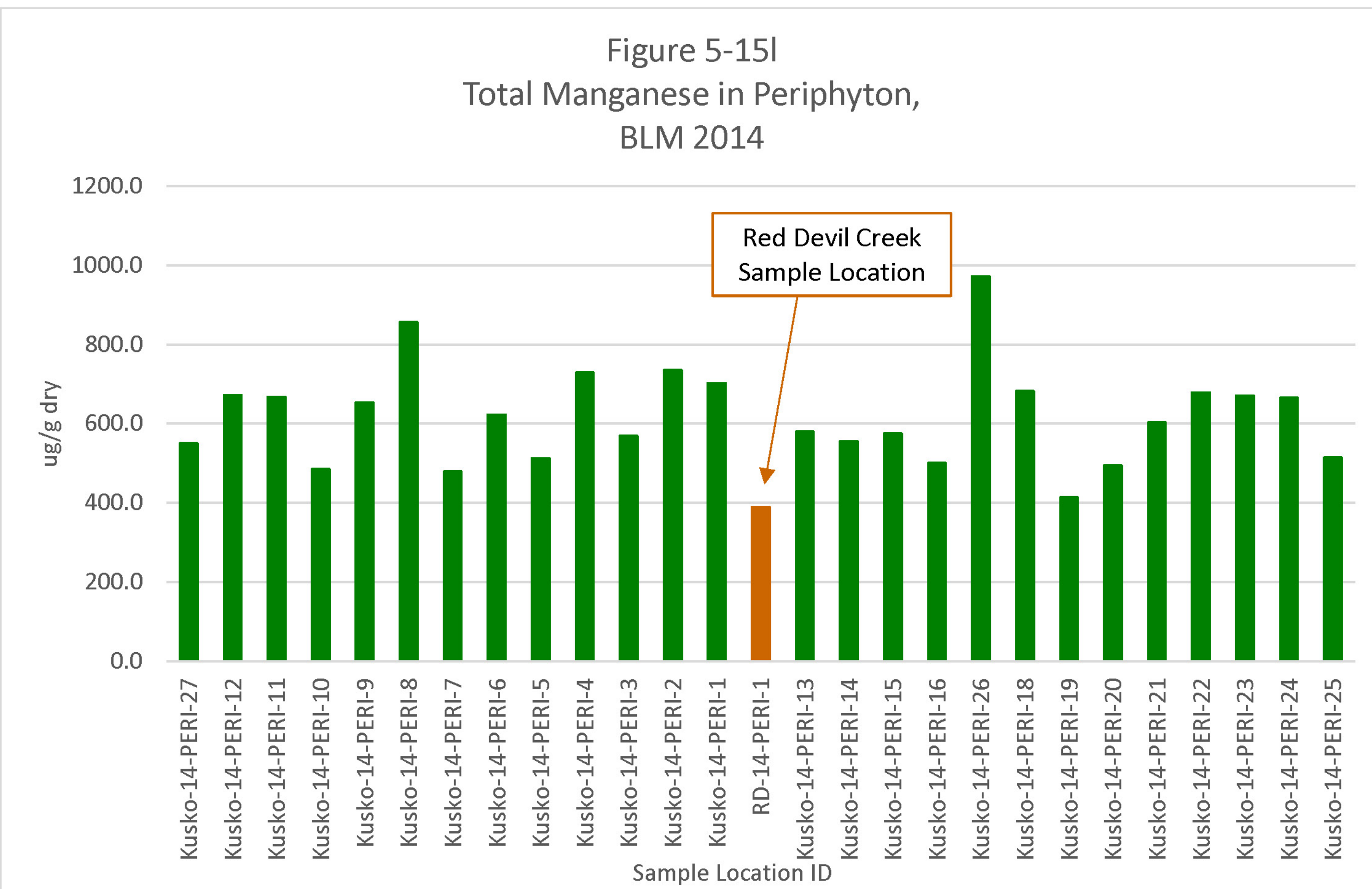


Figure 5-15l
Total Manganese in Periphyton,
BLM 2014
1200.0
1000.0
800.0
600.0
400.0
200.0
0.0
ug/g dry
Red Devil Creek
Sample Location
Kusko-14-PERI-27
Kusko-14-PERI-12
Kusko-14-PERI-11
Kusko-14-PERI-10
Kusko-14-PERI-9
Kusko-14-PERI-8
Kusko-14-PERI-7
Kusko-14-PERI-6
Kusko-14-PERI-5
Kusko-14-PERI-4
Kusko-14-PERI-3
Kusko-14-PERI-2
Kusko-14-PERI-1
RD-14-PERI-1
Kusko-14-PERI-13
Kusko-14-PERI-14
Kusko-14-PERI-15
Kusko-14-PERI-16
Kusko-14-PERI-26
Kusko-14-PERI-18
Kusko-14-PERI-19
Kusko-14-PERI-20
Kusko-14-PERI-21
Kusko-14-PERI-22
Kusko-14-PERI-23
Kusko-14-PERI-24
Kusko-14-PERI-25
Sample Location ID

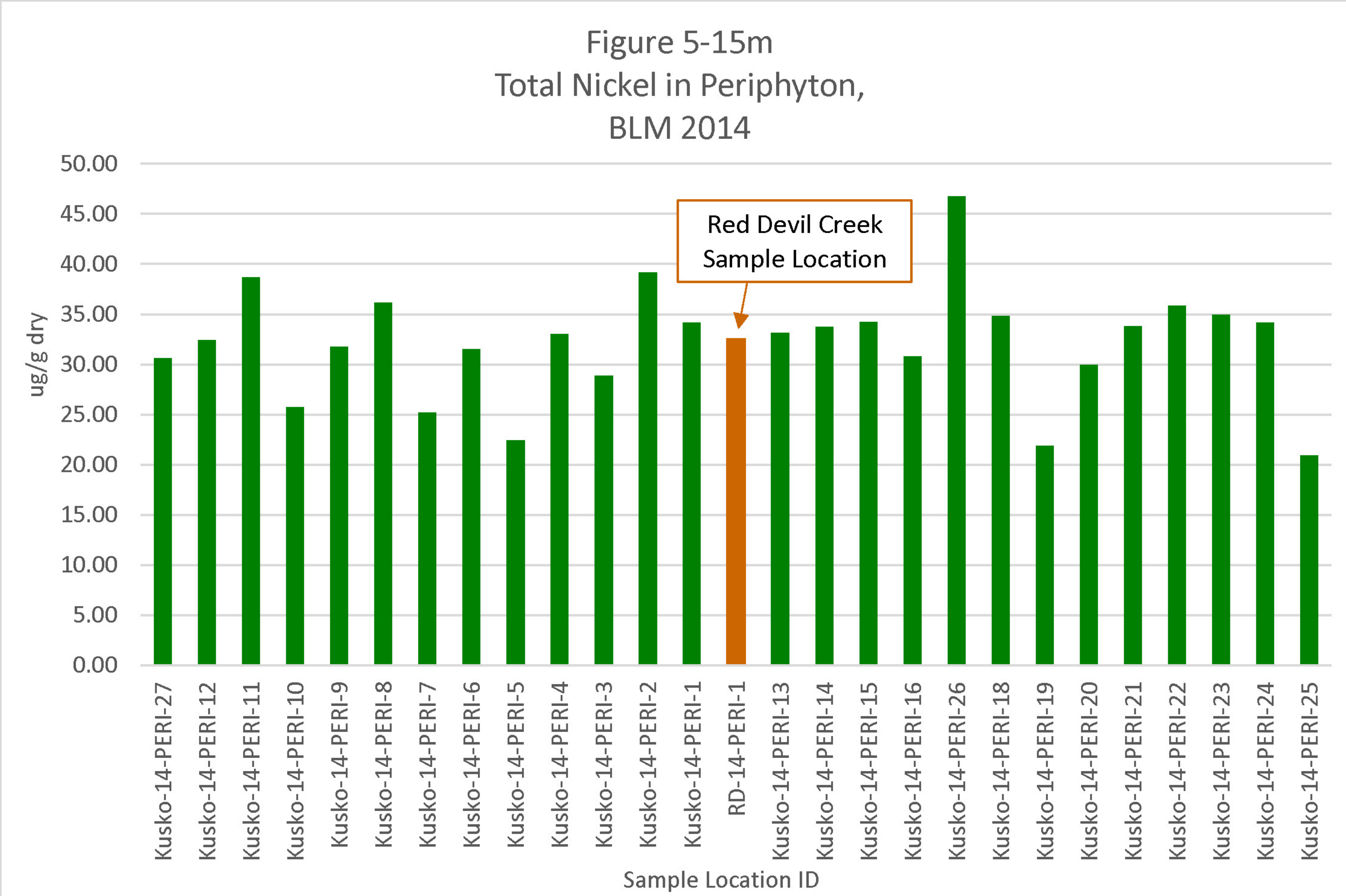


Figure 5-15m
Total Nickel in Periphyton,
BLM 2014
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
ug/g dry
Red Devil Creek
Sample Location
Kusko-14-PERI-27
Kusko-14-PERI-12
Kusko-14-PERI-11
Kusko-14-PERI-10
Kusko-14-PERI-9
Kusko-14-PERI-8
Kusko-14-PERI-7
Kusko-14-PERI-6
Kusko-14-PERI-5
Kusko-14-PERI-4
Kusko-14-PERI-3
Kusko-14-PERI-2
Kusko-14-PERI-1
RD-14-PERI-1
Kusko-14-PERI-13
Kusko-14-PERI-14
Kusko-14-PERI-15
Kusko-14-PERI-16
Kusko-14-PERI-26
Kusko-14-PERI-18
Kusko-14-PERI-19
Kusko-14-PERI-20
Kusko-14-PERI-21
Kusko-14-PERI-22
Kusko-14-PERI-23
Kusko-14-PERI-24
Kusko-14-PERI-25
Sample Location ID

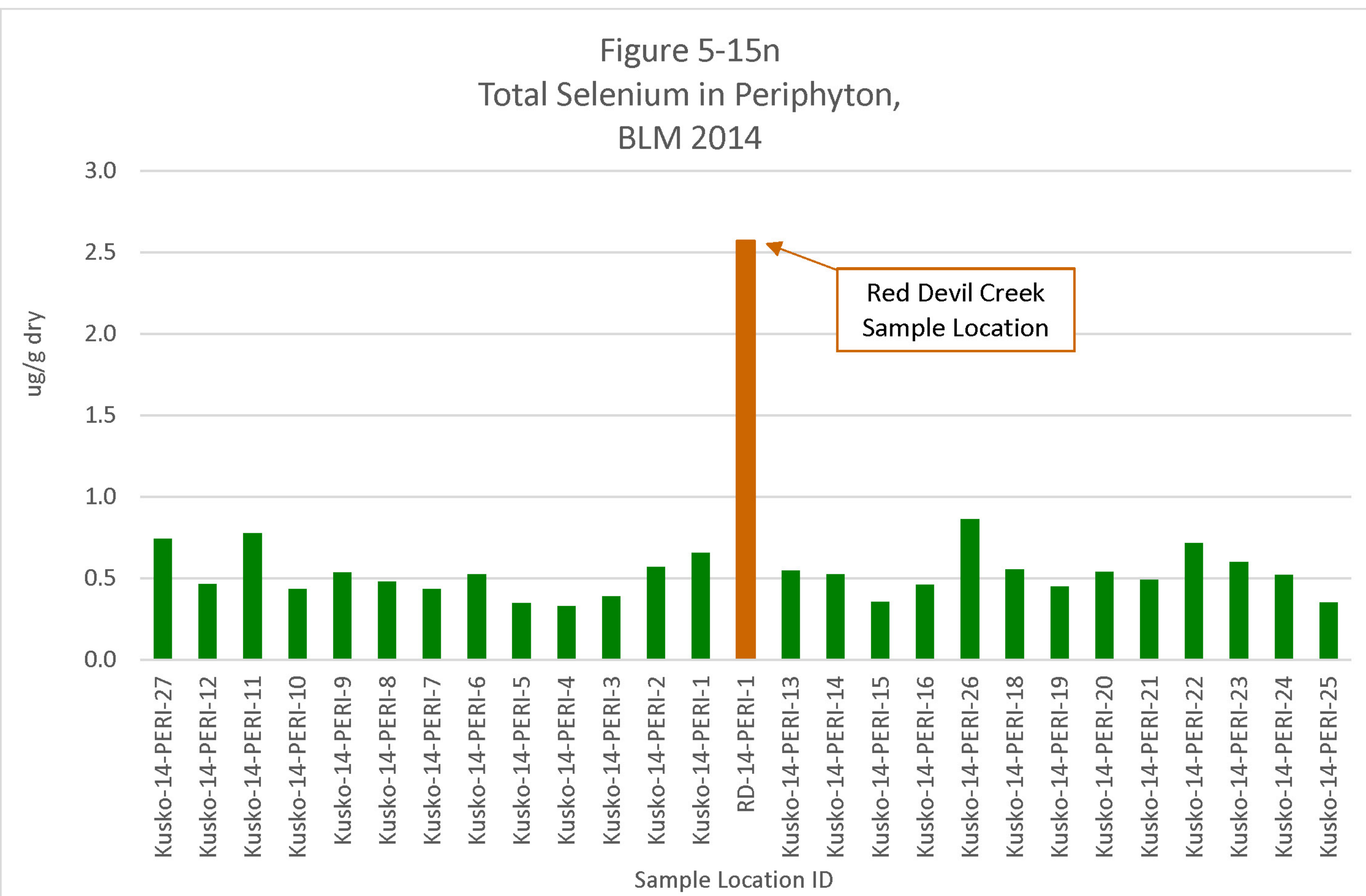


Figure 5-15n
Total Selenium in Periphyton,
BLM 2014
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ug/g dry
Red Devil Creek
Sample Location
Kusko-14-PERI-27
Kusko-14-PERI-12
Kusko-14-PERI-11
Kusko-14-PERI-10
Kusko-14-PERI-9
Kusko-14-PERI-8
Kusko-14-PERI-7
Kusko-14-PERI-6
Kusko-14-PERI-5
Kusko-14-PERI-4
Kusko-14-PERI-3
Kusko-14-PERI-2
Kusko-14-PERI-1
RD-14-PERI-1
Kusko-14-PERI-13
Kusko-14-PERI-14
Kusko-14-PERI-15
Kusko-14-PERI-16
Kusko-14-PERI-26
Kusko-14-PERI-18
Kusko-14-PERI-19
Kusko-14-PERI-20
Kusko-14-PERI-21
Kusko-14-PERI-22
Kusko-14-PERI-23
Kusko-14-PERI-24
Kusko-14-PERI-25
Sample Location ID

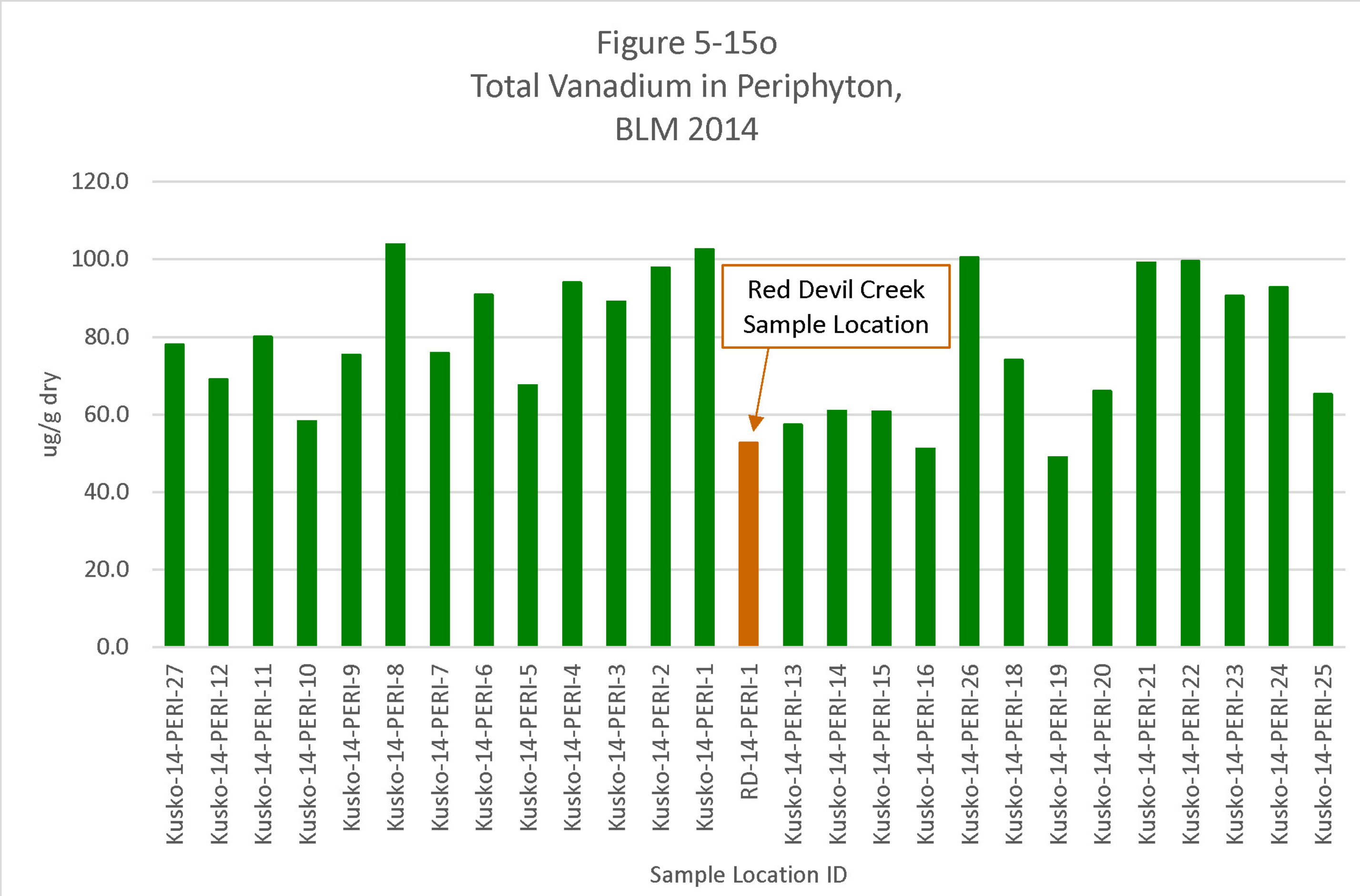


Figure 5-15o
Total Vanadium in Periphyton,
BLM 2014
120.0
100.0
80.0
60.0
40.0
20.0
0.0
ug/g dry
Red Devil Creek
Sample Location
Kusko-14-PERI-27
Kusko-14-PERI-12
Kusko-14-PERI-11
Kusko-14-PERI-10
Kusko-14-PERI-9
Kusko-14-PERI-8
Kusko-14-PERI-7
Kusko-14-PERI-6
Kusko-14-PERI-5
Kusko-14-PERI-4
Kusko-14-PERI-3
Kusko-14-PERI-2
Kusko-14-PERI-1
RD-14-PERI-1
Kusko-14-PERI-13
Kusko-14-PERI-14
Kusko-14-PERI-15
Kusko-14-PERI-16
Kusko-14-PERI-26
Kusko-14-PERI-18
Kusko-14-PERI-19
Kusko-14-PERI-20
Kusko-14-PERI-21
Kusko-14-PERI-22
Kusko-14-PERI-23
Kusko-14-PERI-24
Kusko-14-PERI-25
Sample Location ID

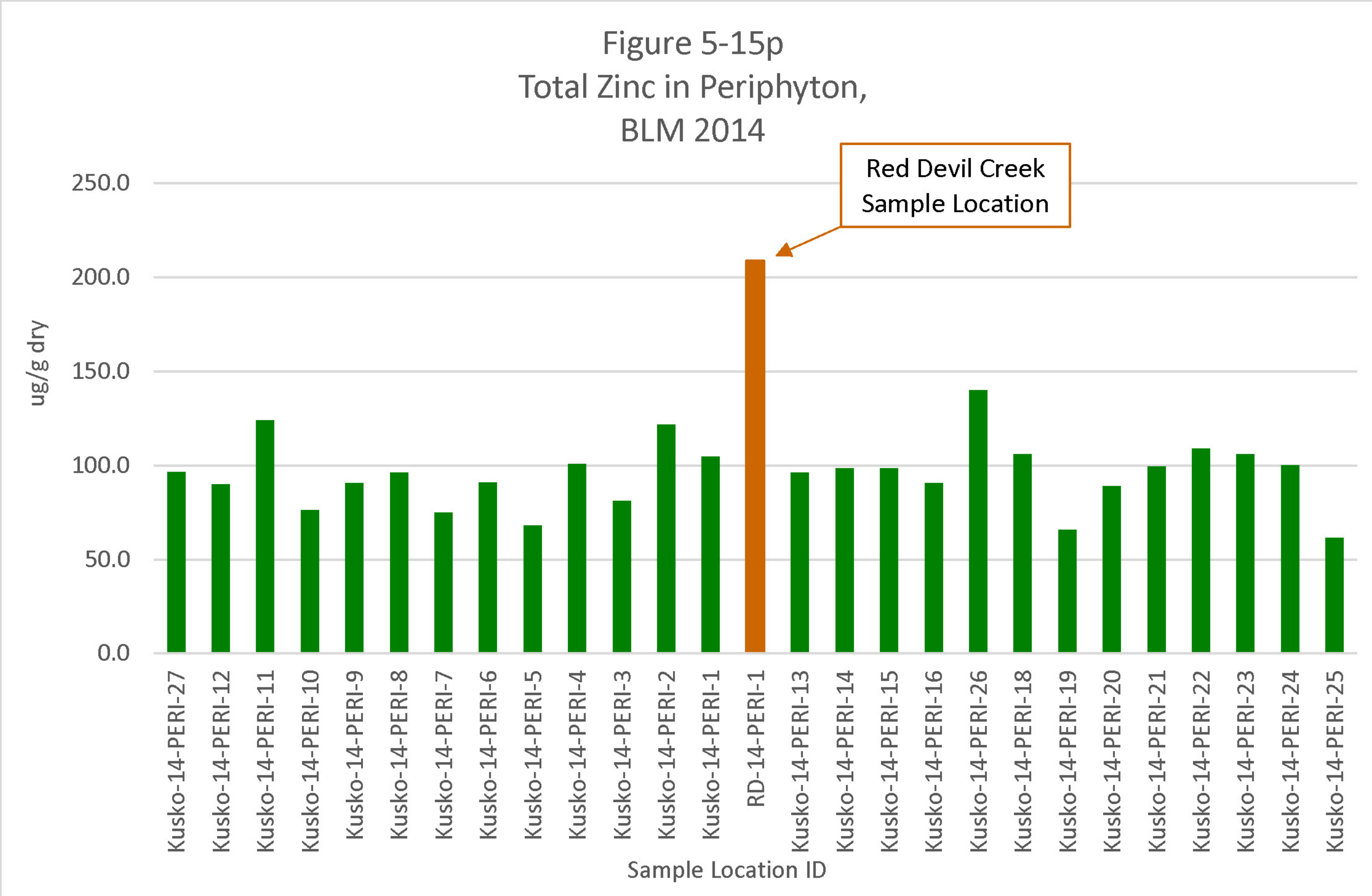
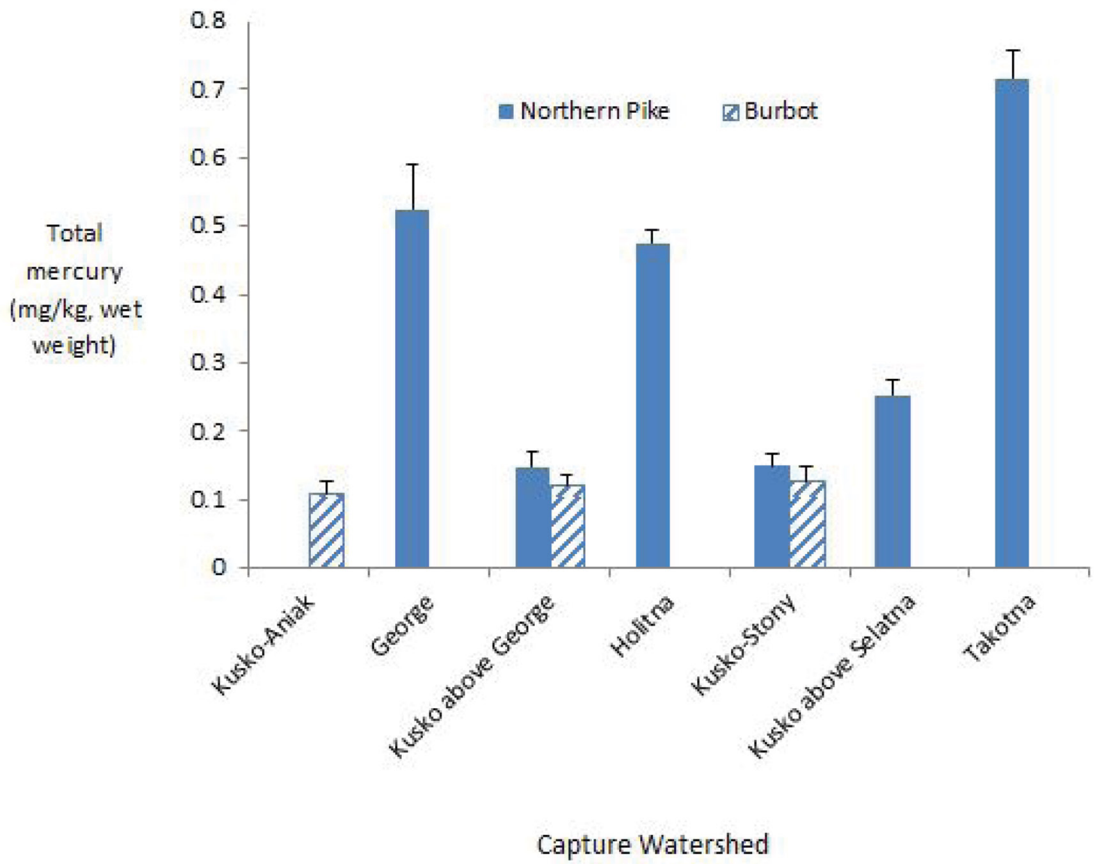


Figure 5-15p
Total Zinc in Periphyton,
BLM 2014
Red Devil Creek
Sample Location
ug/g dry
250.0
200.0
150.0
100.0
50.0
0.0
Kusko-14-PERI-27
Kusko-14-PERI-12
Kusko-14-PERI-11
Kusko-14-PERI-10
Kusko-14-PERI-9
Kusko-14-PERI-8
Kusko-14-PERI-7
Kusko-14-PERI-6
Kusko-14-PERI-5
Kusko-14-PERI-4
Kusko-14-PERI-3
Kusko-14-PERI-2
Kusko-14-PERI-1
RD-14-PERI-1
Kusko-14-PERI-13
Kusko-14-PERI-14
Kusko-14-PERI-15
Kusko-14-PERI-16
Kusko-14-PERI-26
Kusko-14-PERI-18
Kusko-14-PERI-19
Kusko-14-PERI-20
Kusko-14-PERI-21
Kusko-14-PERI-22
Kusko-14-PERI-23
Kusko-14-PERI-24
Kusko-14-PERI-25
Sample Location ID



Note: Adapted from Matz at al. (2017) Figure 14.

RED DEVIL MINE Red Devil, Alaska	**Figure 5-16** **Mean (+ Standard Error) Total Mercury Concentrations in Muscle Biopsies of Radio-Tagged Northern Pike and Burbot Across Capture Watersheds in the Middle Kuskokwim Region, 2011-2013**

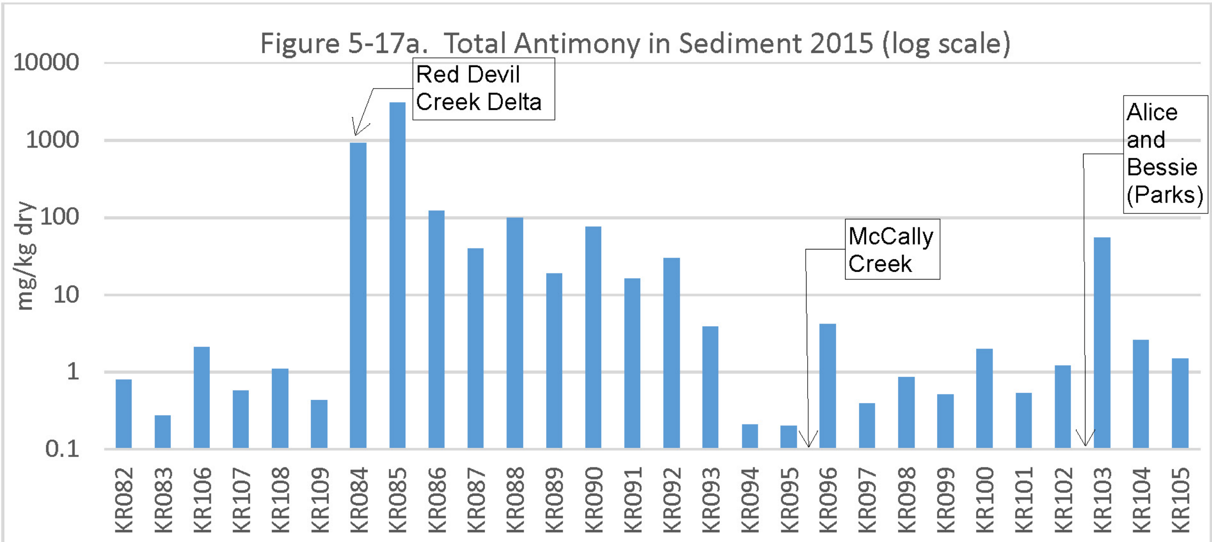


Figure 5-17a. Total Antimony in Sediment 2015 (log scale)
mg/kg dry
10000
1000
100
10
1
0.1
Red Devil Creek Delta
McCally Creek
Alice and Bessie (Parks)
KR082
KR083
KR106
KR107
KR108
KR109
KR084
KR085
KR086
KR087
KR088
KR089
KR090
KR091
KR092
KR093
KR094
KR095
KR096
KR097
KR098
KR099
KR100
KR101
KR102
KR103
KR104
KR105

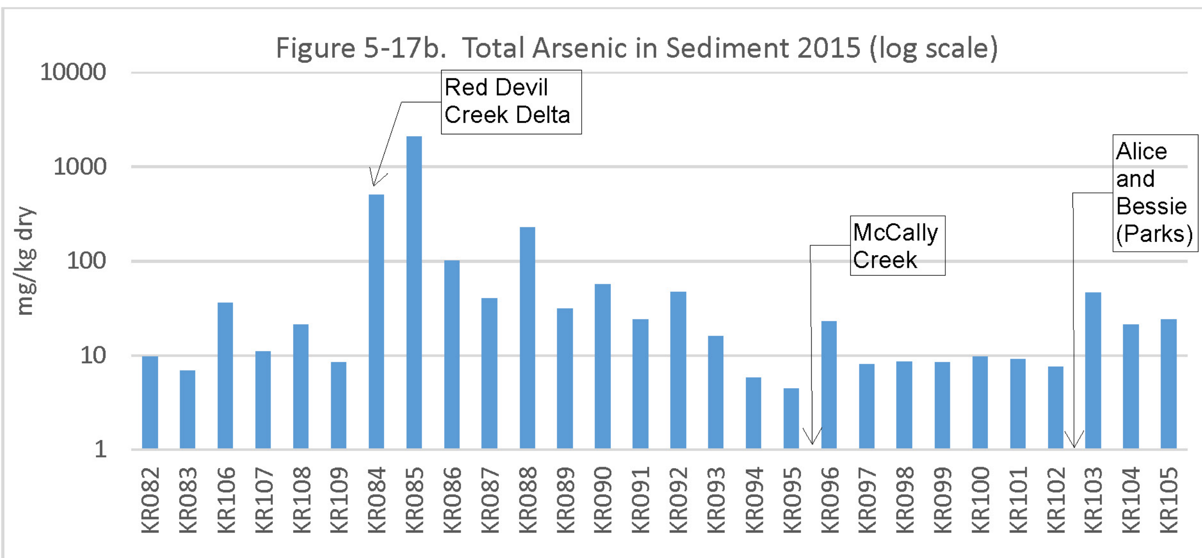


Figure 5-17b. Total Arsenic in Sediment 2015 (log scale)
mg/kg dry
10000
1000
100
10
1
Red Devil Creek Delta
McCally Creek
Alice and Bessie (Parks)
KR082
KR083
KR106
KR107
KR108
KR109
KR084
KR085
KR086
KR087
KR088
KR089
KR090
KR091
KR092
KR093
KR094
KR095
KR096
KR097
KR098
KR099
KR100
KR101
KR102
KR103
KR104
KR105

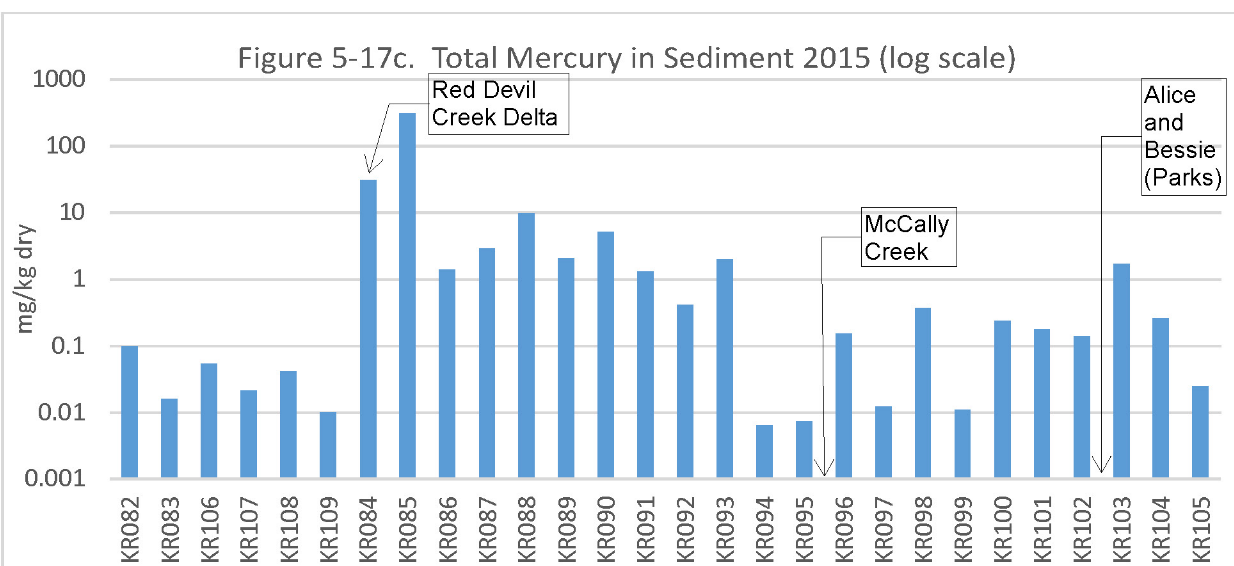
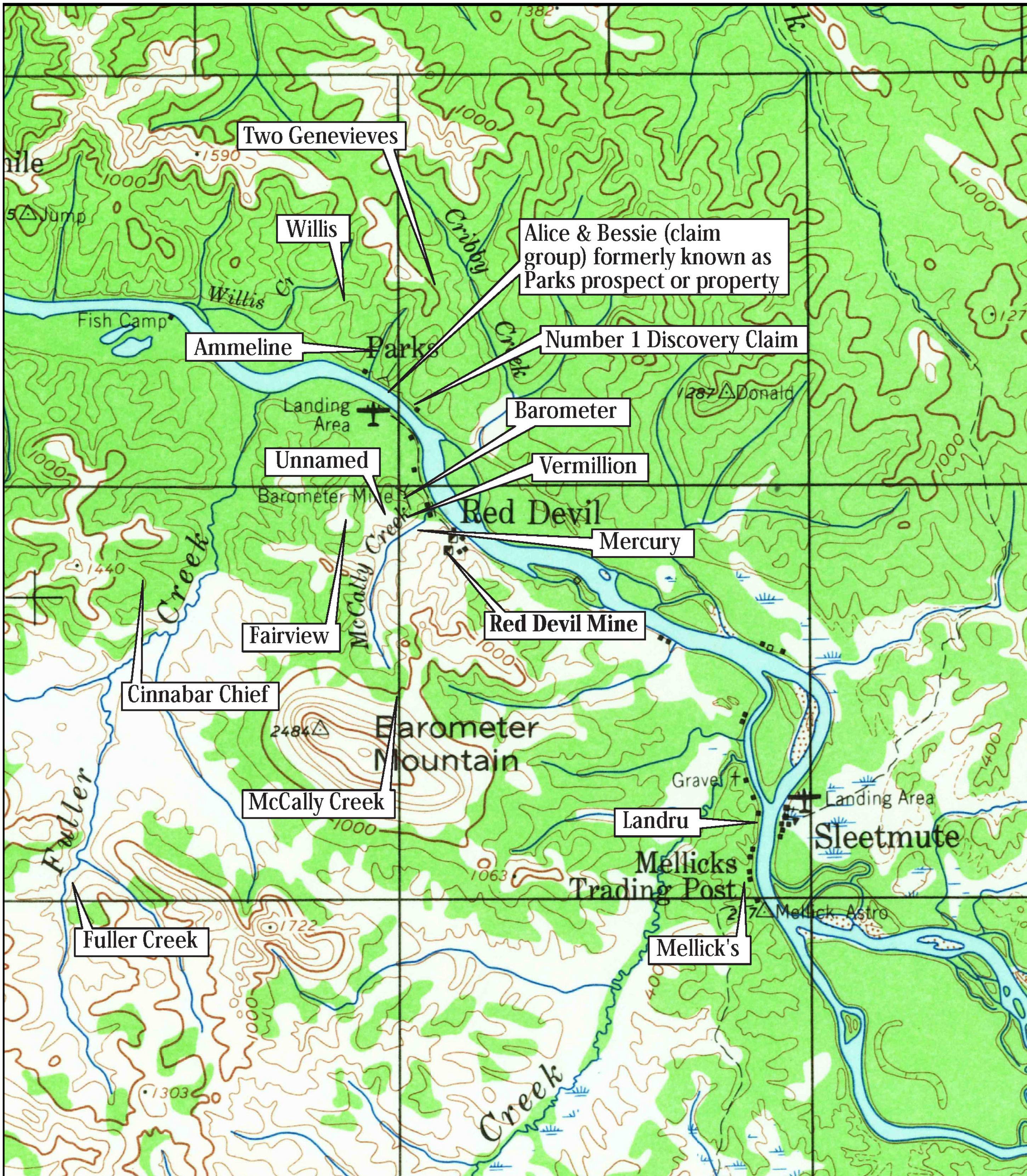


Figure 5-17c. Total Mercury in Sediment 2015 (log scale)
mg/kg dry
1000
100
10
1
0.1
0.01
0.001
Red Devil Creek Delta
McCally Creek
Alice and Bessie (Parks)
KR082
KR083
KR106
KR107
KR108
KR109
KR084
KR085
KR086
KR087
KR088
KR089
KR090
KR091
KR092
KR093
KR094
KR095
KR096
KR097
KR098
KR099
KR100
KR101
KR102
KR103
KR104
KR105



RED DEVIL MINE

Red Devil, Alaska

Figure 5-18
Mines, Prospects, and Other Mineral Occurrences in the Red Devil Area, Alaska

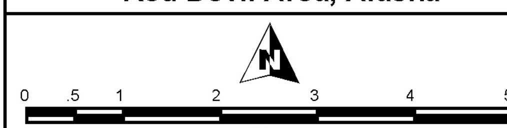


Image Source: Miller at al. (1989); USGS (1954).

6 Kuskokwim River Human Health Risk Assessment

6.1 Introduction

This Human Health Risk Assessment (HHRA) Supplement was performed for the Kuskokwim River in the area of the RDM, located in Red Devil, Alaska. The RDM consists of an abandoned mercury mine and ore processing facility located on public lands managed by the BLM in southwest Alaska. The BLM initiated an RI/FS at the RDM in 2009 pursuant to its delegated CERCLA lead agency authority. The RI results presented in the Final Remedial Investigation Report, Red Devil Mine, Alaska (E & E 2014) were used to assess risk to human health and the environment due to exposure to site contaminants. Results of the final Baseline HHRA and Baseline Ecological Risk Assessment (BERA) for the RDM are included in the final RI report (E & E 2014). Results of the FS are presented in the Final Feasibility Study, Red Devil Mine, Alaska (E & E 2016). Neither the RI nor the FS fully evaluated possible site impacts to the adjacent Kuskokwim River.

This HHRA Supplement was performed to address data gaps associated with Kuskokwim River sediments that were not addressed as part of the initial RI effort, specifically to assess the risks and hazards from potential exposure to contaminants of potential concern (COPCs) through direct contact and incidental ingestion of sediment, and consumption of fish from the Middle Kuskokwim River region. Additional results from sediment sampling and fish tissue sampling from the following reports are used to develop the HHRA Supplement:

- 2015 Kuskokwim River Sediment results, Chapter 5.
- Technical Report 61: Mercury, Arsenic, and Antimony in Aquatic Biota from the Middle Kuskokwim River Region, Alaska, 2010–2014 (Matz et al. 2017).

These data are used to help understand potential risks to human receptors that use the Kuskokwim River near and downstream from the RDM, as described in the *Proposed Technical Approach for the Kuskokwim River Risk Assessment Supplement* (BLM 2017). For direct exposure to sediment, the HHRA Supplement was limited to the area of the Kuskokwim River for which RI and RI Supplement sediment sample results indicate elevated levels of total antimony, arsenic, and mercury that are likely attributable to the RDM (see Figure 6-1 and discussion in Section 6.1.4). A regional assessment of consumption of subsistence fish is conducted in this HHRA Supplement and addresses subsistence fish caught from watersheds within the middle Kuskokwim River area (see Figure 6-2 and Section 6.1.2). The results of the HHRA Supplement and Baseline Ecological Risk Assessment (BERA) Supplement (Chapter 7) will be used, along with other lines of evidence (see Chapter 9), to support risk management decisions for site-related contaminants in the Kuskokwim River near the RDM.

6.1.1 Baseline Human Health Risk Assessment

The part of the baseline HHRA pertaining to the Kuskokwim River addressed potential risk to various receptors via direct exposure (via dermal contact) to sediment in Red Devil Creek and the near-shore of the Kuskokwim River, and via indirect exposure through ingestion of native wild foods, including fish from the Kuskokwim River and, potentially, to a lesser extent, from Red Devil Creek.

The HHRA risk characterization results indicated that consumption of fish contributes significantly to the potential risk posed to all receptors at the site. To a lesser degree, direct exposure to sediment also contributed to potential risk to the receptors. Section 6.2.6 of the final RI report identified uncertainties associated with the risk assessment. Two areas of significant uncertainty associated with the Kuskokwim River are the estimation of concentrations of COCs in fish consumed by receptors and the assumption that all wild food is harvested from the site.

For the baseline HHRA, the concentrations of COCs in adult, subsistence fish were estimated using a health-protective food chain multiplier (FCM) approach and the results of a regional study of Kuskokwim River, Red Devil Creek, and other tributaries to the Kuskokwim River near the RDM, which included collection and analysis of forage fish (e.g., slimy sculpin [*Cottus cognatus*] [whole body fish samples]) for site-related chemicals. The resulting sculpin whole-fish tissue data from Red Devil Creek were used in the baseline HHRA to estimate concentrations of COCs in subsistence fish consumed by receptors. For methylmercury, an FCM of 3 was assumed to account for biomagnification (i.e., the subsistence fish concentration of methylmercury is set equal to three times the concentration in sculpin). For inorganic mercury and other metals, an FCM of 1 was assumed. It was assumed that the subsistence fish of interest—Dolly Varden (*Salvelinus malma*), sheefish (*Stenodus nelma*), round whitefish, whitefish (other), burbot, grayling (*Thymallus arcticus*), and northern pike (*Esox lucius*)—are one trophic level above the slimy sculpin, except for grayling, which feed at a slightly lower trophic level than sculpin.

6.1.2 Middle Kuskokwim River Investigations

Between 2010 and 2015, subsistence fish, forage fish, benthic macroinvertebrates, and periphyton were collected from the middle Kuskokwim River region by the BLM in cooperation with the USFWS and Alaska Department of Fish and Game (ADF&G) and analyzed for inorganic contaminants. To improve the understanding of fish residence in the Kuskokwim River and its tributaries, the BLM also conducted fish movement studies (Matz et al. 2017). Specifically, the following sample types were collected:

- Adult subsistence fish, including northern pike, burbot, grayling, and sheefish, were collected from the main stem Kuskokwim River from Aniak to just upstream of McGrath and from large tributary rivers to the main stem Kuskokwim River, including the Oskawalik, George, Holitna, Tatlawiksuk, and Stony Rivers. Fillet (muscle tissue) samples from the gamefish were analyzed for mercury, arsenic, antimony, and other metals. A subset of the fillet samples was analyzed for methylmercury. Sampling reaches are shown in Figure 5 of Matz et al. (2017).
- Forage fish, including slimy sculpin, juvenile Arctic grayling, and juvenile Dolly Varden, and benthic macroinvertebrates were collected from small tributary creeks to the middle Kuskokwim River, including Ice, Downey, California, No Name, Fuller, McCally, Red Devil, Vreeland, and Cinnabar Creeks. The forage fish and benthic macroinvertebrate samples were analyzed for mercury, arsenic, antimony, and other metals. A subset of the samples was analyzed for methylmercury and inorganic arsenic. Also, benthic surveys were conducted in the creeks to evaluate benthic community health, and creek sediment and water samples were collected and analyzed for contaminants. Tributary creek locations are shown in Figure 4 of Matz et al. (2017).
- Periphyton samples were collected from the near-shore zone of the Kuskokwim River upstream and downstream from the confluence of Red Devil Creek with the river. The samples were analyzed for mercury, arsenic, antimony, and other metals. A subset of the samples was analyzed for methylmercury and inorganic arsenic.
- Northern pike and burbot from eight reaches or watersheds in the middle Kuskokwim River region (see Figure 6 of Matz et al. 2017) were captured, fitted with radio transmitters, and sampled using non-lethal methods to determine levels of mercury and other metals in muscle tissue. Fish movement was tracked using ground-based and aerial surveys. This study was undertaken to relate mercury concentrations in pike and burbot to fish location and movement in the middle Kuskokwim River region.

Collectively, this biota sampling has resulted in an extensive database for mercury and other metals in subsistence fish, forage fish, and other biota from the middle Kuskokwim River region. The turbid and swift conditions of the Kuskokwim River near RDM provide limited habitat for pike or conditions conducive to mercury methylation (wetlands). The highest mercury concentrations were observed in resident pike of the George, Holitna, and Takotna watersheds, whereas the mainstem Kuskokwim River near RDM had some of the lowest concentrations in sampled pike (Varner 2017).

From 2011to 2012, 245 northern pike, 154 burbot, and 170 Arctic grayling were tagged and tracked throughout the middle Kuskokwim River region. The tracking data and individual fish contaminant levels provided essential information for understanding the exposure pathways in the Kuskokwim River Basin (Matz et al. 2017). Concentrations of mercury in northern pike collected from the George River were higher than samples taken from the mainstem Kuskokwim River

(Matz et al. 2017). Telemetry data has shown that most of the summer tagged northern pike in the George River are yearlong residents in the George River and spend the winter there, as well. In the George River, the known mercury sources and abundant wetland habitat (i.e., methylation sites) likely are key factors contributing to the high concentrations of mercury in resident northern pike in this system. The Holitna and Hoholitna Rivers have been shown through the telemetry data to be important habitat for northern pike in the Kuskokwim River Basin. Most tagged northern pike do not stray much from these large tributary rivers. Additionally, the watersheds of these tributaries have been shown to be a source of mercury within the basin and the aquatic food web and to have extensive wetland habitat favorable for mercury methylation. Pike tagged in the mainstem Kuskokwim River largely winter downstream of Stony River or in the Holitna River and consistently show lower concentrations than pike that remain in the larger tributaries year-round (Varner 2017).

Burbot mercury levels were highly variable, with higher concentrations in fish sampled in the summer (average 0.45 mg/kg; range 0.09 to 1.05 mg/kg; n = 35) versus fish sampled in the winter (average 0.16 mg/kg; range 0.05 to 0.57 mg/kg; n = 54) (Matz et al. 2017). Based on the tracking data, most of the tagged burbot spent the summer in the lower river, with many staying within the tidally influenced section downstream of Bethel. During the fall, burbot make major movements upstream to spawn under the ice. Some of the burbot moved several hundred river miles (the average was 300 miles, and several exceeded 500 miles) in a period of a few weeks during fall and then also during spring breakup. These data help explain why high variability in burbot concentrations were observed (Varner 2017).

Based on the telemetry data, the exposure to mercury and other metals in fish tissue cannot be captured by one point-in-time fish tissue sample, especially for species that are highly mobile and migratory. Therefore, a regional assessment of consumption of fish from the middle Kuskokwim River is conducted in this HHRA Supplement. This HHRA Supplement uses subsistence fish contaminant data for the middle Kuskokwim River region along with information regarding fish harvest practices and fish movement to estimate exposure for residents of Red Devil Village to contaminants in fish.

Available information indicates that residents of Red Devil Village are exposed to contaminants in subsistence fish from the middle Kuskokwim River region as a whole, and not only from the river near the RDM or from Red Devil Creek, as was assumed for the baseline HHRA for the RDM (E & E 2014). For example, the fish telemetry data for pike and burbot from Matz et al. (2017) suggest that pike and burbot spend little time in the reach of the Kuskokwim River near the RDM, likely due to limited habitat availability and food resources. Also, based on information regarding fishing practices near Red Devil Village obtained from the ADF&G Subsistence Survey (Brown et al. 2012), contact reports based on conversations with three Red Devil Village residents who are knowledgeable about fishing practices in the community and participate in subsistence and sport fishing (Talaia-Murray 2017; Reeve 2016), and multiple conversations between residents of Red Devil Village and Sleetmute and representatives of the BLM (Matt Varner and Mike McCrum), residents of these villages prefer fishing for pike and other subsistence fish in the portions of the middle Kuskokwim River region where subsistence fish are most abundant. For pike, most fishing occurs in the George and Holitna Rivers and in the Kuskokwim River upstream from Sleetmute, where flow velocity and turbidity are low and shoreline wetland habitat is abundant, providing good habitat for pike. Hence, for the Kuskokwim River HHRA Supplement, a regional estimate of exposure to metals through the consumption of subsistence fish is derived using fish contaminant data in Matz et al. (2017) and applying an estimate of consumption rates for residents in Red Devil Village. Fish contaminant data used in the HHRA Supplement are based on tissue samples collected from northern pike, burbot, Arctic grayling, and sheefish (Matz et al. 2017), all of which are consumed by residents of Red Devil Village (Brown et al. 2012).

The purpose of the Matz et al. (2017) study was not to support the CERCLA investigation at the RDM. Thus, the designated reaches in the study were not designed to support the remedial investigation at this site. While it is recognized that the data is the best available, it should also be recognized that this study is not designed for the CERCLA investigation at the RDM.

6.1.3 Human Health Risk Assessment Supplement Approach

The methodologies used for the Kuskokwim River HHRA Supplement are consistent with the protocols outlined in Section 6.2 of the RI HHRA (E & E 2014), the risk assessment work plan submitted as Appendix B of the Work Plan, Remedial Investigation/Feasibility Study, Red Devil Mine, Alaska (E & E 2011), the technical memorandum, Proposed Approach to Evaluating Consumption of Wild Foods at the Red Devil Mine Site, Alaska, Version 2 (Appendix G of E & E 2014), and Proposed Technical Approach for the Kuskokwim River Risk Assessment Supplement (BLM 2017), unless otherwise stated in this document.

As discussed in Section 6.1, the Kuskokwim River HHRA Supplement incorporates additional sediment sampling and fish tissue sampling results from the following reports:

- 2015 Kuskokwim River Sediment results, Chapter 5.
- Technical Report 61: Mercury, Arsenic, and Antimony in Aquatic Biota from the Middle Kuskokwim River Region, Alaska, 2010–2014 (Matz et al. 2017).

The Kuskokwim River HHRA Supplement was developed consistent with federal and state guidance including, but not limited to, the following documents:

- Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A), Interim Final (EPA 1989);

- Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part E: Supplemental Guidance for Dermal Risk Assessment (EPA 2004);
- Framework for Metals Risk Assessment (EPA 2007b);
- Exposure Factors Handbook – 2011 Edition (EPA 2011b);
- Human Health Evaluation Manual, Supplemental Guidance: Update on Standard Default Exposure Factors (EPA 2014);
- ProUCL Version 5.1 Technical Guide (EPA 2015a);
- ProUCL Version 5.1 User Guide (EPA 2015b); and
- Risk Assessment Procedures Manual (ADEC 2015).

6.1.4 Area of Kuskokwim River HHRA Supplement

The HHRA Supplement and BERA Supplement (see Chapter 7) are limited to the reach of the Kuskokwim River for which RI and RI Supplement sediment sample results indicate elevated levels of total antimony, arsenic, and mercury that are likely attributable to the RDM and not to other mineral occurrences (see Sections 5.4.1 and 5.4.2). That area encompasses the reach of the river extending from the Red Devil Creek delta downriver to a short distance upriver of the Alice and Bessie Mine. The area is illustrated in Figure 6-1. Concentrations of total antimony, arsenic, mercury, and methylmercury in Kuskokwim River sediment for the project area are presented in Figures 5-5 through 5-12. A regional assessment of consumption of subsistence fish is conducted in this HHRA Supplement and addresses subsistence fish caught from watersheds within the middle Kuskokwim River area (see Figure 6-2).

6.2 Exposure Assessment

The purpose of the exposure assessment is to quantify potential exposures of human populations that could result from contact with COPCs from the RDM site. Each complete exposure pathway contains four necessary components:

- A contaminant source and a mechanism of COPC release;
- An environmental medium and mechanism of COPC transport within the medium;
- A potential point of human contact with the affected environmental media, also called the exposure point; and
- An exposure route.

The exposure assessment characterizes the exposure setting, identifies receptors that may be exposed and direct and indirect pathways by which exposures could occur (i.e., pathways for direct ingestion of COPCs from soil and indirect uptake from ingestion of harvested wild food items), and describes how the rate, frequency, and duration of these exposures is estimated. The exposure assessment includes the following subsection components:

- A conceptual site model (CSM);
- Exposure scenarios; and

- A quantification of exposure.

6.2.1 Human Health Conceptual Site Model

The focus of the Kuskokwim River HHRA Supplement is to assess potential risk and hazards from exposure to Kuskokwim River sediment, incorporating new sediment data (E & E 2016), and from consumption of fish from the middle Kuskokwim River region, incorporating BLM data (Matz et al. 2017). Exposure to contaminants in Kuskokwim River sediment is assessed specific to the area near the RDM site. A regional assessment of consumption of fish from the middle Kuskokwim River is conducted in this HHRA Supplement because of the highly mobile and migratory nature of the fish most often consumed by residents of Red Devil Village.

The exposure routes and human receptors evaluated in the Baseline HHRA are presented in Figure 6-3, with the exposure pathways that are updated in this HHRA Supplement highlighted. For the HHRA Supplement, the following receptors were selected to represent current or potential future use of the site (these receptors are the same receptors evaluated in the Baseline HHRA):

- Future Resident (adult and child);
- Recreational or Subsistence User (adult and child); and
- Industrial/Mine Worker (adult only).

The following pathways are the focus of the Kuskokwim River HHRA Supplement and pertain to all receptors:

- Dermal (skin) contact with sediments from the near-shore of the Kuskokwim River;
- Incidental ingestion of sediment from the near-shore of the Kuskokwim River, and
- Consumption of fish harvested from the Kuskokwim River.

Quantification from potential exposure through these pathways were evaluated in the Kuskokwim River HHRA Supplement. Other complete exposure pathways (e.g., soil, groundwater, and surface water ingestion, etc.) were not updated in this Supplement.

6.2.2 Estimation of Exposure Point Concentration

The final list of COPCs in the RI Baseline HHRA (see Table 6-6 in E & E 2014), was used as the list of COPCs for the HHRA Supplement. That list is presented in Table 6-1a of this report. The concentrations of COPCs to which human receptors potentially are exposed over time were estimated according to EPA guidance (EPA 2006b, 2015a, 2015b). EPA (1992) and the Alaska Department of Environmental Conservation (ADEC 2015) indicate that a 95% upper confident limit (UCL) on the mean of COPC concentrations should be used as the exposure point concentration (EPC). Inherent in this approach is the assumption that receptors that contact an environmental medium containing a COPC do so randomly. Thus, an estimate of average concentration (or, in this case, the upper bound of the average) is the concentration to which a receptor might be exposed.

To determine the 95% UCLs in sediment and fish tissue, EPA's ProUCL program, version 5.1 was used (EPA 2015a, 2015b). Table 6-1b includes a list of near-shore sediment samples (identified as being submerged in less than 2 feet of water for at least part of the summer; see Section 6.2.2.1) used to calculate the sediment EPC. The calculated sediment EPCs for samples taken near-shore of the Kuskokwim River, including distribution and EPC statistics as derived using ProUCL, are provided in Tables 6-2 through 6-4. The calculated fish tissue EPCs for northern pike, burbot, sheefish, and Arctic grayling from the middle Kuskokwim River region, including distribution and EPC statistics as derived using ProUCL, are provided in Tables 6-5 through 6-8. Calculation of EPCs for near-shore sediments and fish tissue is discussed in Sections 6.2.2.1 and 6.2.2.2, respectively.

Analytical data generated from the RI Supplement were validated by an E & E chemist in accordance with EPA protocols (EPA 2008b, 2011a). The results of laboratory analytical data validation are summarized in Appendix A. In general, all sediment data generated for the RI Supplement are considered usable, with qualifications, for evaluation of the nature and extent of contamination and assessment of potential risk to human health and ecological receptors. Data collected as part of the regional BLM aquatic biota study (Matz et al. 2017) underwent a third-party quality assurance review using EPA Validation Level IV criteria. No BLM data were considered invalid after the quality assurance review (Matz et al. 2017).

For analytes that were not detected in fish tissue, the maximum method detection limit was used as the EPC. This applies to antimony, cadmium, and vanadium in sheefish and Arctic grayling tissue. Although EPA uses one-half the method detection limit for the EPC when a contaminant is not detected, use of the maximum method detection limit as the EPC for antimony, cadmium and vanadium in sheefish and Arctic grayling is a health-protective approach.

Thallium is the only COPC not detected in sediment samples. The maximum detection limit in near-shore down-river sediment for thallium is 0.074 mg/kg. The EPA Regional Screening Level (EPA 2017) for thallium (soluble salts) for residential soil is 0.078 mg/kg at a hazard quotient of 0.1. The residential soil RSL is protective of the sediment exposure pathways at the RDM for direct human exposure. The detection limit is less than the RSL, indicating that the detection limit is sufficiently low.

6.2.2.1 Estimation of Exposure Point Concentration in Near-Shore Sediment

Residents, recreational/subsistence users, and mine workers may all come in contact with sediment near the shore. Sediment was considered near-shore if it was submerged in less than 2 feet of water for at least part of the time between early June through late August. This time period generally corresponds to when the salmon runs are most plentiful and residents would most likely be harvesting salmon and other fish species (Talaia-Murray 2017; ADF&G 2017). This time period is also consistent with an exposure duration of 90 days.

Samples were identified as submerged in less than 2 feet of water based on comparison with median daily gage height data for the USGS gaging station 15304000 – Kuskokwim River at Crooked Creek, Alaska for the period of 1980 to 2016 (USGS 2017). Eighteen samples were identified to fit this criterion within the assessment area identified in Section 6.1.4. Of the 18 samples, two were excluded from the EPC calculations. Sample KR200 is a duplicate of sample 15KR098SD. Field duplicate results were treated as per guidance from Alaska Department of Environmental Conservation (ADEC 2008) (i.e., the more conservative result from the primary and duplicate sample was used). Samples KR085 and KR02 were taken at the same sample location in different years (KR085 was taken in 2015 and KR02 was taken in 2010). Sample results from KR085 were used in the EPC calculation to avoid double counting the sample location and biasing the EPC result. Sample KR085 is the more recent sample and exhibited higher concentrations of arsenic, antimony and mercury. Methylmercury was not analyzed in sample KR085; therefore, for the methylmercury EPC in near-shore sediment, the results from KR02 were used. The total number of near-shore samples used in this HHRA Supplement is 16 (see Table 6-1).

For the analytes evaluated in this assessment, a weighted 95% upper confidence limit (UCL) on the average concentration was used as the EPC for near-shore sediment. A weighted UCL is recommended in situations where sampling density and contaminant levels vary markedly across the area being evaluated (ITRC 2017). In the Kuskokwim River assessment area, sampling density is high near the RDM and low in other parts of the assessment area (see Figure 6-1). And, levels of site-related metals in sediment typically are high near the RDM and low in downriver and cross-river areas (see Chapter 5). For these reasons, the sediment data were divided into two areas for calculation of a weighted UCL:

1) Area near the RDM where sampling density is high, including samples from 2010, 2011, and 2012 and the few 2015 samples interspersed with the earlier samples; henceforth, referred to as the near-RDM area (see Figure 5-1).
2) Downriver, mid-river, and cross-river area that includes only widely spaced 2015 samples; henceforth, referred to as the downriver area (see Figure 5-2).

To develop EPCs for the entire assessment area, ProUCL was first used to calculate a UCL for the near-RDM area samples. Maximum concentration was used to characterize the downriver sample area, which included too few samples to calculate a UCL. A weighted average of the near-RDM UCL and downriver area maximum concentration was then calculated based on the fraction of the total assessment area shoreline length (4.11 miles) represented by the near-RDM area (0.65 mile) and downriver area (3.46 miles, both banks summed). For example, for antimony, the near-RDM and downriver UCLs are 2,464 and 2 mg/kg, respectively. The length-weighted UCL for antimony for the entire assessment area is 391 mg/kg, calculated as follows:

(2,464 mg/kg x [0.65 mi. / 4.11 mi]) +
(2 mg/kg x [3.46 mi. / 4.11 mi.]) =
391 mg/kg

This approach was used to calculate EPCs for all COPCs. Tables 6-2 and 6-3 list the sediment EPCs for all analytes for the near-shore sediment dataset. ProUCL input and output files for the near-RDM sediments EPC calculations are provided in Appendix D.

Outlier tests were conducted and Q-Q plots reviewed for the near-RDM sediment data set. Results from sample KR085 were identified as an outlier for antimony, arsenic, and mercury at the 1%, 5%, and 10% significance levels. Near-RDM sediment EPCs and weighted EPCs were calculated with and without the outliers included and are presented in Tables 6-3 and 6-4, respectively. All Q-Q plots and outlier test results are provided in Appendix D.

6.2.2.2 Estimation of Exposure Point Concentration in Fish Tissue

As discussed in Section 6.1.2, between 2010 and 2015, subsistence fish, forage fish, benthic macroinvertebrates, and periphyton were collected from the middle Kuskokwim River region by the BLM in cooperation with the ADF&G and analyzed for inorganic contaminants (Matz et al. 2017). As part of this study, liver and muscle tissue samples from adult subsistence fish, including northern pike, burbot, grayling, and sheefish, from the mainstem Kuskokwim River and large tributary rivers of the Kuskokwim River were analyzed for mercury, arsenic, antimony, and other metals. A subset of the tissue samples was analyzed for methylmercury. In addition, northern pike and burbot from eight reaches or watersheds of the middle Kuskokwim Region were captured, and punch samples of muscle tissue were taken and analyzed for mercury, arsenic, antimony and other metals (Matz et al. 2017). Muscle tissue samples, both punch and fillet, were combined and used in the calculation of fish tissue EPCs for the HHRA Supplement. This results in an extensive database for mercury, arsenic, antimony, and other metals in subsistence fish. For most analytes, there are 457 northern pike samples, 293 burbot samples, 38 sheefish samples, and 25 Arctic grayling samples. This data is used to develop individual regional muscle tissue EPCs for northern pike, burbot, sheefish and Arctic grayling for the middle Kuskokwim River region. Outliers and Q-Q plots for antimony, arsenic, and mercury were reviewed in northern pike and one outlier was identified for both antimony and arsenic. Outliers and Q-Q plots for antimony, arsenic and mercury were reviewed in burbot, and one outlier was identified for both antimony and arsenic. Due to the large sample size, no outliers were removed for northern pike or burbot samples prior to calculations of EPCs. Outlier tests and Q-Q plots for antimony, arsenic, and mercury were reviewed and were run for sheefish and Arctic grayling; however, no outliers were identified. All Q-Q plots and outlier test results are provided in Appendix D. Replicates were removed from the dataset.

Tables 6-5 through 6-8 list the EPCs for fish muscle tissue for northern pike, burbot, sheefish, and Arctic grayling. ProUCL input and output files for the fish tissue EPC calculations are provided in Appendix D.

6.2.3 Estimation of Intake

Potential exposures to the receptors identified in the CSM were quantified using intakes (or dose), which are expressed as the amount of COPCs (in milligrams) internalized per unit body weight (in kilograms) per unit time (in days). That is, estimated intakes are generally provided in units of milligrams per kilogram per day (mg/kg-day). When evaluating carcinogenic COPCs, the intake is referred to as the lifetime average daily intake (LADI), because the intake is averaged over a lifetime.

The generic equation and variables for calculating chemical intakes are described below:

$$I = \frac{C \times CR \times EF \times ED}{BW \times AT}$$

Where:

I	=	Intake; the amount of chemical (mg/kg body weight/day)
C	=	EPC in specific media (e.g., mg/kg)
CR	=	Contact rate; the amount of contaminated medium contacted per unit time or event (e.g., milligrams per day [mg/day]).
EF	=	Exposure frequency, which describes how often exposure occurs (days per year)
ED	=	Exposure duration, which describes how long exposure occurs (years)
BW	=	Body weight; the average body weight over the exposure period (kilograms)
AT	=	Averaging time; the period over which exposure is averaged (days)

Exposure to carcinogenic compounds was evaluated based on exposure for a combined child and adult receptor. The LADI was calculated using age adjustments to account for the total exposure duration. Specifically, the LADI was calculated as shown in the following general intake equation:

$$LADI = \frac{C}{AT} \times \left(\frac{EDc \times EFc \times CRc}{BWc} + \frac{(EDa - EDc) \times EFa \times CRa}{BWa} \right)$$

Where:

$CR_{a\ or\ c}$ = Contact rate for adult or child

$EF_{a\ or\ c}$ = Exposure frequency for adult or child (days/year)
$ED_{a\ or\ c}$ = Exposure duration for adult or child (years)
$BW_{a\ or\ c}$ = Body weight for adult or child (kilograms)

These generic equations were modified to account for exposure pathway-specific exposures to COPCs and are presented in Tables 6-9 through 6-11.

To assess dermal exposure to contaminants in sediment, the contaminant-specific fraction of contaminant absorbed dermally from soil/sediment is used. The dermal absorption values (ABS_{dermal}) were obtained from the EPA Risk Assessment Guidance for Superfund, Volume 1, Part E, Exhibit 3-4 (EPA 2004) and are presented in Table 6-12. Absorption values are available for only two of the sediment COPCs, arsenic and cadmium. The dermal pathway was not evaluated quantitatively for compounds without ABS_{dermal} values. This approach is consistent with the EPA's recommendations (2004) and EPA's Regional Screening Level User's Guide (2017).

The intake calculated for each exposure scenario is intended to represent the reasonable maximum exposure (RME) conditions. An RME scenario is a combination of high-end and average exposure values and is used to represent the highest exposure that is reasonably expected to occur. The RME scenario is a health-protective exposure scenario that is plausible, yet well above the average exposure level.

Exposure route and media-specific intake equations and proposed values for exposure parameters are presented in Tables 6-9 through 6-11 and are discussed in this section.

6.2.4 Exposure Factors

Exposure factors for body weight (BW), exposure frequency (EF), exposure duration (ED), and averaging time (AT) are included in the intake equation and the values for each vary among scenarios. For exposure via dermal contact with sediment, additional variables for skin surface area (SA) and adherence factors (AF) are included in the intake equation. Intake rates for incidental ingestion of sediment and consumption of fish are discussed in Sections 6.2.4.6 and 6.2.4.7, respectively.

6.2.4.1 Body Weight

A body weight value of 80 kilograms is used for all adults and is based on a weighted mean values for adults aged 21 to 79 (EPA 2011b). The average body weight for children is 15 kilograms for a child up to age 6 and is based on the weighted average of mean body weights from birth to less than 6 years of age (EPA 2011b). These values are consistent with EPA (2011b, 2014) and ADEC (2015) guidance.

6.2.4.2 Exposure Frequency and Time

The baseline HHRA was completed assuming that 100% of the incidental ingestion of contaminants was of contaminants in soil. This was a conservative assumption since the soil concentrations of arsenic and mercury are about an order of magnitude greater than the concentrations in the sediment samples that were available at that time (E & E 2014). In this HHRA Supplement, incidental ingestion of sediment is quantitatively evaluated. To incorporate the incidental ingestion of sediment pathway into this HHRA Supplement, a time-weighted approach is used to account for the time spent exposed to sediment versus soil.

The exposure frequency describes how often someone may have contact with affected media over a one-year period. For sediment exposure through both incidental ingestion and dermal exposure, an exposure frequency of 90 days for all exposure scenarios is used. This value represents the seasonal nature of exposure of bare skin to sediment, which would only reasonably occur in the summer months. Since both dermal and incidental ingestion of sediment would occur from similar activities, 90 days will also be used as the exposure frequency for incidental ingestion of sediment. Much of the time spent potentially exposed to sediment is during fishing activities along the shore of the Kuskokwim River. Most of the fishing around Red Devil Village is for salmon species. In Red Devil Village, salmon species (Chinook, sockeye, and chum salmon) represents 40% the top resources of wild food harvest by edible weight (Brown et al. 2012). The 90-day exposure frequency corresponds with salmon fishing, which generally runs from June through late August, as identified by residents in Red Devil Village (Talaia-Murray 2017, ADF&G 2017).

To evaluate the incidental ingestion of sediment pathway, the variable FI is used to weigh the time spent exposed to sediment versus soil. Residents in Red Devil Village engage in a number of outdoor activities including fishing, hunting, harvesting, boating, and other recreational and subsistence activities. To determine the value for FI, the amount of hours per day spent in activities where people may be exposed to sediment, such as fishing from the shore or shore play, is divided by total amount of time spent in outdoor activities per day. Most of the fishing around Red Devil Village is for salmon. Based on the subsistence harvest survey (Brown et al. 2012), the majority (71%) of the total subsistence fish harvest was taken by gillnet. Rod and reel accounted for only 28% of the total fish harvest. Gillnets accounted for 74% of the salmon harvest and 66% of the non-salmon fish species harvested (Brown et al. 2012). Fishing from shore around Red Devil Village by rod and reel is recreational and infrequent; most residents in Red Devil Village use drift-netting from a boat for subsistence fishing, in which the net does not come in contact with the shore (Talaia-Murray 2017). Other shore activities include dressing fish at the shore and embarking/disembarking from boats on the shore. Limited all-terrain vehicle (ATV) use along the river bank also may take place, but this is thought to be infrequent and takes place from the Red Devil lodge to the north of Fuller Creek; the shoreline topography south of the lodge leading towards the mine site is not conducive to ATV traffic (Talaia-Murray 2017). During the summer, it is reasonable to assume people would spend a significant amount of time outdoors, possibly 16 hours per day. When the fish are running, people may spend more time per day in shore activities, such as cleaning fish or rod and reel fishing, than other days of the summer. For the HHRA Supplement, it is assumed that people spend, on average, 2 hours a day fishing from the shore, recreating along the shoreline, or cleaning fish on the shore during the summer months. (Note: This is an average value for the June through August time period. During some parts of the summer, this value will be higher and other times it will be lower.) This results an FI of 0.125, indicating 12.5% of the time spent in outdoor activities are when people are potentially exposed to sediment versus soil.

Because fish harvest rates are provided on an annual basis, the exposure frequency for fish consumption is equal to a full year—365 days per year for residents and recreational/subsistence users. This value is consistent with ADEC (2015) guidance. Mine workers are only expected to engage in consumption of local fish while onsite; therefore, the exposure frequency for mine workers is 250 days per year.

6.2.4.3 Exposure Duration

The exposure duration is the length of time (in years) for which someone may be exposed through a specific exposure pathway. An exposure duration of 6 years was assumed for all child scenarios (EPA 1991, 2014; ADEC 2015) representing a child up to 6 years of age. Exposures occurring beyond age 6 are accounted for in the adult exposure scenarios.

The default exposure duration for the adults is 20 years (26 years with adult and child combined) for onsite residents (EPA 2011, 2014; ADEC 2015); however, a site-specific exposure duration was calculated for the Baseline HHRA that is used in the HHRA Supplement. Each household in Red Devil Village was surveyed in 2009 as part of the ADF&G harvest survey and asked questions about how many years each individual in the household was a resident in the community and from where he or she moved (i.e., from a community in Alaska or state in the United States or other country) (Brown et al. 2012). It is assumed that the residential patterns of a new community established near the RDM site would be similar to the pattern seen in residents of Red Devil Village. This question was designed to include the sum of all periods the member had been resident, rather than just the most recent period (Koster 2013). Based on the ADF&G report, on average, residents lived in Red Devil approximately 23 years (Brown et al. 2012). In late 2013, at the request of EPA, ADF&G calculated the 90th percentile for residence time for adults in Red Devil Village (Koster 2013). Based on responses from 13 households reporting on 27 residents in Red Devil Village, the 90th percentile was calculated at 54 years (Kissinger 2013). Based on this evaluation, 54 years is used as the exposure duration for residents and recreational/subsistence users.

The default exposure duration for a commercial/industrial worker is 25 years (ADEC 2015; EPA 2014), although the time in mining occupations is substantially less than that. The median occupational tenure for mining activities is 8.6 years (EPA 1997a). For consistency with EPA (2015a, 2015b) and ADEC (2015) guidance, an exposure duration of 25 years is used for the mine worker scenario.

For carcinogens, the exposure duration for residential and recreational/subsistence user scenarios is calculated as an aggregate of child and adult exposure; the first 6 years of the exposure duration is based on the child intake and the remaining time is based on an adult intake (48 years), as described in Section 6.2.4.3.

6.2.4.4 Averaging Time

The averaging time is the number of days over which exposure is averaged. The averaging time varies depending on whether the COPC in the affected media is a carcinogen or noncarcinogen. A longer averaging time is used for carcinogenic COPCs to account for the long latency period before exposure effects are seen. The EPA (1989) recommends an averaging time of 70 years multiplied by 365 days per year, or 25,550 days, for exposure to carcinogenic COPCs for the residential scenarios. For noncarcinogenic COPCs, the EPA (1989) recommends using an averaging time equal to the exposure duration. These averaging time values are used in the risk assessment.

6.2.4.5 Surface Area of Skin and Adherence Factor

COPCs are absorbed by the skin through contact with sediment. Exposure to COPCs is affected by the surface area of skin coming into contact with the contaminated sediment and the adherence of the sediment to the skin. There are no recommended values for the skin surface area for exposure to sediment or the adherence factor for sediment so value for soil are used.

For skin surface area, a value of 6,032 square centimeters (cm^2) are used (ADEC 2015; EPA 2011b, 2014) for an adult resident and recreational/ subsistence user. This value corresponds to the weighted average of mean values for head, hands, forearms, lower legs, and feet exposed. This would be the equivalent to someone wearing a short-sleeved shirt, shorts, and no shoes. The recommended skin surface area for children of 2,373 cm^2 is used and corresponds to weighted average of mean values for head, hand, forearms, lower legs, and feet for males and females from birth to less than 6 years of age (ADEC 2015; EPA 2011b). The surface area of 3,527 cm^2 (ADEC 2015; EPA 2011b) for an industrial and outdoor worker is used for the mine worker scenario. This represents exposure to the head, hands, and forearms (EPA 2011b).

As mentioned, there are no sediment-to-skin adherence factor values available; therefore, soil-to-skin adherence factor values are used for dermal exposure to sediment. Adherence factor values are based on values provided by the ADEC (2015), EPA (2014), and EPA's Supplemental Guidance for Dermal Risk Assessment (2004), and are consistent with residential and industrial scenarios, as appropriate. Based on EPA (2004), the adherence factor of 0.07 milligrams per square centimeter (mg/cm^2) for adults and 0.2 mg/cm^2 for children in a residential setting is based on activities such as landscaping and gardening and a child playing in the soil. The residential (adult and child) default values were chosen for the recreational/subsistence user, as well. The mine worker scenario used the default commercial/industrial value of 0.12 mg/cm^2, which includes construction and utility work. These are appropriate assumptions of activities that would occur on site.

6.2.4.6 Incidental Ingestion of Sediment

There are no default or site-specific values available for incidental ingestion of sediment. There is also a lack of scientifically justified approaches for assessing sediment ingestion rates of people exposed to contaminated sediments. As previously mentioned, most residents in Red Devil Village use drift-netting from a boat for subsistence fishing, in which the net does not come in contact with the shore, and fishing from shore is recreational and infrequent (Talaia-Murray 2017). Depending on where the net is set, there is not much chance of a person being exposed to sediment when checking the net in a deep eddy. Other shore activities include dressing fish at the shore and embarking/disembarking from boats on the shore. Limited ATV use along the river bank also may take place, but this is thought to be infrequent because the shoreline topography south of the lodge leading towards the mine site is not conducive to ATV traffic (Talaia-Murray 2017).

The adult incidental ingestion rate for sediment is estimated using two mass balance studies following tribal subsistence activities to derive an estimate on adult daily soil ingestion rate (Doyle et al. 2012) (Irvine et al. 2014), as documented in EPA's March 9, 2017, memorandum, Region 10 Adult Subsistence/High Contact Outdoor Soil Ingestion Rate Approach (Stifelman 2017). In one of the studies, seven subjects participated in activities such as dip netting, setting seine nets along the shore, cleaning fish, rod and reel fishing from the shore, collecting firewood, eating, cleaning up, hunting, and attending gatherings (Doyle et al. 2012). In the other study, nine subjects participated in activities such as living at an outdoor base camp and sleeping in tents, fishing, hunting, food gathering, attending rodeos, and setting traps and snares (Irvine et al. 2014). Aluminum and silicon tracers were used to estimate daily soil ingestion with an average estimated ingestion rate of 48 mg/day for the two tracers combined and an estimated ingestion rate of 184 mg/day for the 90th percentile user (Stifelman 2017). This data is specific to soil ingestion rather than sediment exposure, but the soil ingestion results are used as surrogates to estimate sediment ingestion rates. The 90th percentile user value, rounded to two significant figures, of 180 mg/day is used for the HHRA Supplement for the sediment ingestion rate for the all adult exposure scenarios (residential, recreational/subsistence, and mine worker). A sediment ingestion rate of 200 mg/day is used for child exposure, based on the 2011 EPA Exposure Factors Handbook: 2011 Edition recommended value for soil ingestion; this rate is consistent with ADEC (2015) and EPA (2014) recommended default values for soil.

6.2.4.7 Consumption of Fish

Potential exposure to contaminants from consumption of fish harvested from the middle Kuskokwim River region was assessed by evaluating the muscle tissue concentrations (see Section 6.2.2.2) and using consumption rates from Red Devil Village (as estimated from harvest rates from Brown et al. 2012), described in this section.

Between January and December 2010, residents of Aniak, Chuathbaluk, Crooked Creek Lower, Kalskag, Red Devil, Sleetmute, Stony River, and Upper Kalskag were surveyed regarding the subsistence and harvest use of wild foods in those communities (Brown et al. 2012). The principal questions addressed the number of wild foods that were harvested for subsistence, the harvest amounts, and how these foods were distributed within and between communities. The survey represents a 12-month recall study, covering 2009, which was used to estimate subsistence harvests and uses of wild fish, game, and plant resources. Information was obtained on a household basis. The survey questions are provided in the ADF&G report (Brown et al. 2012). Maps of the area used for hunting, fishing, and gathering during the study year were developed.

Eleven of 13 households from Red Devil Village participated in the ADF&G survey. Of the households surveyed, 100% used some kind of wild food, and 82% reported that they harvested wild food. Of the top 10 resources making up the majority of the wild foods harvested by edible weight, salmon species contributed 40%, whitefish species contributed 27%, other non-salmon fish species contributed 11% (Brown et al. 2012).

Although salmon represent a majority of the wild food harvested, salmon spend most of their lives in the ocean, where they acquire most of their body burden of lipophilic contaminants and methylmercury from the marine food web. Upon returning to freshwater rivers to spawn, salmon stop feeding and hence experience little or no additional bioaccumulation of lipophilic contaminants or methylmercury. Direct uptake of contaminants, including metals such as arsenic and antimony, from surface water typically is a minor exposure route for fish compared with diet, largely due to the much greater concentration of metals and other contaminants in dietary items compared with water. For example, EPA (2000a) reports that arsenic is taken up by aquatic organisms primarily through diet. Also, available information indicates that antimony does not bioaccumulate or bioconcentrate in fish based on the magnitude of reported bioconcentration and bioaccumulation factors (BCFs/BAFs), which typically are less than 10 liters per kilogram (L/kg) and often are less than 1 L/kg (Oorts 2014; Obiakor et al. 2017). Therefore, exposure to mercury and other contaminants through consumption of salmon is not included in this Kuskokwim River regional assessment.

Per ADEC (2015), high-end user rates from ADF&G should be used to estimate ingestion rates for specific resources. The high-end user is represented by the 95th percentile per capita use, which is the amount of wild food used by the consumer at the 95th percentile rank in a rural population during a survey year, expressed as a per person measure of grams per day (Wolfe and Utermohle 2000). The 95th percentile use value for Red Devil Village based on the data obtained in ADF&G harvest survey (Brown et al. 2012) was calculated by ADF&G consistent with the methodology outlined in Wolfe and Utermohle (2000) and provided to the BLM (Koster 2012).

Harvest rates for northern pike, burbot, whitefish, and Arctic grayling were calculated by ADF&G and are used to estimate non-salmon fish ingestion rates. Mean harvest rates and associated estimated intake rates are provide in Table 6-13. The whitefish food category is a sum of harvest rates for sheefish, broad whitefish, Bering Cisco, Least Cisco, humpback whitefish and unknown whitefish. Harvest rates for northern pike, burbot, whitefish, and Arctic grayling represent 92% of the total non-salmon fish harvest rates. The harvest data were collected on a household basis and divided by the number of individuals in a household to derive an estimate of per capita consumption. The survey did not obtain data on an individual basis. At the time of the survey, the age of people from households surveyed ranged from 10 to 90 years of age, with an average age of 41 years old. Therefore, the values obtained from the survey are representative of an adult exposure scenario. No child rates were available.

A ratio of children to adult estimated energy requirements (EERs) is used to develop estimates of children's consumption of subsistence resources from adult consumption data based on the approach presented in the National Academies of Science Institution of Medicine's (2002) Dietary Reference Intakes for Energy, Carbohydrates, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids. This approach assumes that caloric intake and energy requirements are directly related to each other and are further described in the Baseline HHRA (E & E 2014). For this HHRA Supplement, the adult consumption rates are multiplied by 0.48 to produce estimates of children's consumption. This value is consistent with the value used in the Baseline HHRA (E & E 2014) is similar to the value derived from the Columbia River Inter-Tribal Fish Commission (1994) study based on a ratio of child to adult consumption rates for fish of 0.4. Child non-salmon fish ingestion rates are provided in Table 6-13.

6.3 Toxicity Assessment

The objectives of the toxicity assessment are to compile information on the nature of the adverse health effects of COPCs and to provide an estimate of the dose-response relationship for each COPC selected (i.e., determine the relationship between the extent of exposure and the likelihood and/or severity of adverse effects).

For the risk assessment, COPCs are divided into two groups: agents known or suspected to be human carcinogens (carcinogens) and noncarcinogens. As used here, the term "carcinogen" denotes any chemical for which there is sufficient evidence that exposure may result in continuing uncontrolled cell division (cancer) in humans and/or laboratory animals. The risks posed by these two groups are assessed differently because noncarcinogenic chemicals generally exhibit a threshold dose below which no adverse effects occur. Both linear and nonlinear modes of action are recognized for carcinogens. The simplifying assumption has been made that most carcinogenic responses are linearly related to dosage, even in the unobservable area of the dose-response curve. Nonlinear methods are to be used if there is sufficient evidence to support a nonlinear mode of action.

6.3.1 Quantitative Indices of Toxicity

The EPA toxicity indices (e.g., chronic reference doses [RfDs] and carcinogenic slope factors) were used in the assessment. Toxicity values were obtained using the following hierarchy (EPA 2003a; ADEC 2015):

- **Tier 1:** EPA's Integrated Risk Information System (IRIS).
- **Tier 2:** EPA's Provisional Peer Reviewed Toxicity Values (PPRTVs).
- **Tier 3:** Other resources as needed and as approved by ADEC on a case-by-case basis. Other resources that may be considered are California Environmental Protection Agency (Cal/EPA), Agency for Toxic Substances and Disease Registry (ATSDR) Minimal Risk Levels (MRLs), or EPA's Health Effects Assessment Summary Table (HEAST) values.

The 2003 EPA guidance and ADEC 2015 Risk Assessment Procedures Manual did not rank the Tier 3 sources into a hierarchy of their own. EPA's Risk Screening Level (2017) establishes a hierarchy among the Tier 3 sources. If a value is not obtained from the three tiers identified above, the Risk Screening Level Tier 3 hierarchies are used and explained in the table or text.

6.3.2 Assessment of Non-carcinogens

To evaluate noncarcinogenic effects, the EPA (1989) defines acceptable exposure levels as those to which the human population, including sensitive subgroups, may be exposed without adverse effects during a lifetime or part of a lifetime, incorporating an adequate margin of safety. The potential for adverse health effects associated with noncarcinogens (e.g., organ damage, immunological effects, and birth defects) usually is assessed by comparing the estimated average daily intake to an RfD for oral or dermal.

RfDs are expressed in units of mg/kg-day and is an estimate (with uncertainty possibly spanning an order of magnitude) of the daily intake to humans (including sensitive subgroups) that should not result in an appreciable risk of deleterious effects. The EPA assigns a qualitative level of confidence (low, medium, or high) to the study used to derive the toxicity value, database, and RfD. The relative degree of uncertainty associated with the RfDs and the level of confidence that the EPA assigns to the data and the toxicity value are considered when evaluating the quantitative results of the risk assessment.

The EPA has not developed RfDs for dermal exposure to all chemicals, but it has provided a method for extrapolating dermal RfDs from oral RfDs. If adequate data regarding the gastrointestinal absorption of a COPC are available, then dermal RfDs may be derived by applying a gastrointenstinal absorbance factor to the oral toxicity value (EPA 2004). For chemicals lacking a gastrointestinal absorbance value, absorbance is assumed to be 100%, and the oral RfDs are used to estimate toxicity via dermal absorption.

Oral and dermal toxicity data, including oral and dermal RfDs and the gastrointestinal absorption factor, are presented in Table 6-14.

6.3.3 Assessment of Carcinogens

The EPA uses a weight-of-evidence approach to evaluate the likelihood that a substance is a carcinogen. The EPA uses standard descriptors as part of the hazard narrative to express the conclusion regarding the weight-of-evidence for carcinogenic hazard potential. The EPA recommends five standard hazard descriptors: “Carcinogenic to Humans,” “Likely to Be Carcinogenic to Humans,” “Suggestive Evidence of Carcinogenic Potential,” “Inadequate Information to Assess Carcinogenic Potential,” and “Not Likely to Be Carcinogenic to Humans.” The carcinogenic potency is represented by a COPC’s SF for oral exposure and is expressed as risk per $(mg/kg\text{-}day)^{-1}$.

The EPA has not developed SFs for dermal exposure to all chemicals, but it has provided a method for extrapolating dermal SFs from oral SFs. This route-to-route extrapolation has a scientific basis because an absorbed chemical’s distribution, metabolism, and elimination patterns are usually similar, regardless of exposure route. However, dermal toxicity values are typically based on absorbed dose, whereas oral exposures are usually expressed in terms of administered dose. Consequently, if adequate data on the gastrointestinal absorption of a COPC are available, then dermal SFs may be derived by applying a gastrointestinal absorbance factor to the oral toxicity value (EPA 2004). For chemicals lacking a gastrointestinal absorbance value, absorbance is assumed to be 100%, and the oral SF is used to estimate toxicity via dermal absorption.

Table 6-15 includes SFs for oral and dermal exposure. Some cancer-causing analytes operate by a mutagenic mode of action for carcinogenesis, and would exhibit a greater effect in early-life versus later-life exposure (EPA 2005k). Early life stage mutagenic considerations are not relevant to this assessment, as arsenic is the only carcinogen present, and it is not mutagenic.

6.3.4 Assessment of Arsenic

Arsenic occurs naturally in soil and minerals. Exposure to arsenic can cause decreased production of red and white blood cells, abnormal heart rhythm, damage to blood vessels, hyperpigmentation, possible vascular complications, and a sensation of “pins and needles” in hands and feet. Long-term exposure to arsenic in children may result in lower IQ scores. Several studies have shown that ingestion of inorganic arsenic can increase the risk of skin cancer and cancer in the liver, bladder, and lungs (ATSDR 2007, 2016; EPA 2002a). The EPA has determined that inorganic arsenic is a known human carcinogen (EPA 2002a).

The EPA is in the process of updating both the cancer and noncancer assessment for inorganic arsenic.

Inorganic arsenic has been implicated as the primary toxic form to both aquatic life and humans. The toxicity data (i.e., reference dose and slope factor) for arsenic is based on the inorganic form. Fish can accumulate arsenic, but arsenic does not biomagnify in the food chain. Most of the arsenic in fish is in the organic form (i.e., arsenobetaine), which is less toxic that inorganic arsenic. Total arsenic was analyzed in samples collected in sediment and fish tissue. Inorganic arsenic analysis was also conducted on a subset of the fish tissue samples.

The total arsenic results are used to determine the hazards and risks posed by arsenic in sediment. Consistent with the EPA recommendations on assessing bioavailability of arsenic in soil (EPA 2017), a relative bioavailability factor (RBA) of 0.6 is used to adjust the total arsenic concentration in sediment to a bioavailable concentration in sediment. RBA accounts for differences in the bioavailability of a contaminant between the medium of exposure (e.g., sediment) and the media associated with the toxicity value. The 60% oral RBA for arsenic in soil is empirically based and represents upper-bound estimates from numerous studies where the oral RBA of soil or sediment-borne arsenic in samples collected from across the United States was experimentally determined against the water-soluble form. This RBA does not apply to dermal exposures to arsenic in soil for which the absorbed dose is calculated using a dermal absorption fraction (ABSd) of 0.03 (EPA 2017).

In 2012, 91 muscle punch samples were taken from fish within the Kuskokwim River or the large tributary rivers to the Kuskokwim (Takotna, Holitna and George Rivers) and analyzed for both total arsenic and inorganic arsenic (Matz et al. 2017). Of the 91 samples analyzed, only 12 had detected levels of inorganic arsenic ranging from 0.004-J mg/kg wet-weight to 0.012 mg/kg wet-weight. Nine of the 12 samples with detected levels of inorganic arsenic were of burbot caught from the Kuskokwim River, two were from northern pike from the Kuskokwim River, and one was a northern pike from the George River. Of the samples with detected levels of inorganic arsenic, the percent inorganic arsenic compared to total arsenic ranged from 0.1% to 8.3%. When evaluating the percent inorganic arsenic using the detection limits, all samples showed less than 10% inorganic arsenic. The percent inorganic arsenic in fish tissue samples from the Middle Kuskokwim River region are presented in Table 6-16. The EPA has stated that approximately 85 to 90% of the arsenic found in the edible parts of fish and shellfish is organic arsenic (e.g., arsenobetaine, arsenochloline, dimethylarsinic acid), and approximately 10% is inorganic arsenic (EPA 2003b). The percent inorganic arsenic levels found in burbot and northern pike from the Middle Kuskokwim River region supports the use of 10% of the total arsenic concentration in fish muscle tissue in the inorganic form. Therefore, total arsenic concentrations in fish tissue were multiplied by 10% to estimate the inorganic arsenic levels.

6.3.5 Assessment of Mercury

Mercury is a naturally occurring metal in the environment. Inorganic mercury (metallic mercury and inorganic mercury compounds) enters the air from mining ore deposits, burning coal and waste, and from manufacturing plants. Mercury can be methylated in water and soil/sediment by bacteria. Exposure to mercury may damage the brain, kidneys, and developing fetus. (ATSDR 1999). Exposure to methylmercury may cause neurological development impairment (EPA 2002b). Neither elemental mercury or methylmercury are classified as a human carcinogen (EPA 2002b, 2002c).

Both mercury and methylmercury were identified as COPCs in fish based on sediment detections compared to sediment screening criteria. Methylmercury, unlike inorganic mercury, biomagnifies in the food chain. All 14 near-shore sediment samples were analyzed for both total and methylmercury. Methylmercury accounted for less than 1% of the total mercury in all near-shore sediment samples included in the analysis. For hazards, potential exposure to both total mercury and methylmercury were evaluated. Although this may overestimate hazards since methylmercury is accounted for in both the methylmercury and total mercury samples, because methylmercury accounts for less than 1% of the total mercury concentration the overall overestimation is small.

Over 800 muscle fish samples have been analyzed for total mercury. In 2010 and 2011, a small number of fish tissue samples from the Kuskokwim River and large river tributaries were analyzed for methylmercury. Based on these sample results, it was determined that the methylmercury to total mercury ratios ranged from 1.0 to 1.2, indicating the primary form of mercury in fish tissue was methylmercury (Matz et al. 2017). For the HHRA Supplement, risks and hazards are assessed using the total mercury results in fish, assuming 100% of total mercury is in the methylmercury form.

6.3.6 Assessment of Chromium

Chromium is an element existing in several different forms. Trivalent chromium is naturally occurring and is essential for good health. Hexavalent chromium rarely occurs naturally and is primarily produced by certain industrial processes. Hexavalent chromium is the most toxic form of chromium.

Total chromium was identified as a COPC in sediment and biota based on comparisons of site concentrations to health-protective screening levels for hexavalent chromium. However, there are no known sources of release of hexavalent chromium at the site, and the site concentrations indicate no source releases and are consistent with the surface soil background concentration (E & E 2014). In the near-shore sediment, the site EPC (16.1 mg/kg) and the 95% UCL (25 mg/kg) for the area near Red Devil Mine are both below the background concentration of 29 mg/kg, indicating chromium is not a site-related contaminant.

Chromium sediment samples were not speciated in the laboratory because of the cost, technical difficulties with conducting the analysis, and because there was no known release of hexavalent or trivalent chromium at the site. Since hexavalent chromium compounds are reduced to the trivalent form in the presence of oxidizable organic matter (ATSDR 2012) and studies indicate that nearly all of the chromium in sediments is likely present in the trivalent form (Canadian Council of Ministers of the Environment 1999), chromium in sediment and fish tissue at the site are evaluated assuming the trivalent form. The uncertainties associated with this approach are discussed in Section 6.5.

6.4 Risk Characterization

Risk characterization, the final component of the risk assessment process, integrates the findings of the first two components (exposure and toxicity) by quantitative estimation of human health risks. For each scenario evaluated, incremental lifetime cancer probability is estimated for an RME scenario.

6.4.1 Characterization of Carcinogens

Although both linear and nonlinear modes of action are recognized for carcinogens, the EPA generally takes the public health-protective, default position that most cancer risks are assumed to conform with low dose linearity (EPA 2005j). As another health-protective measure, the EPA uses the upper 95% UCL on the dose-response relationship from animal or human studies data to estimate a low-dose SF.

Using the SF (oral and dermal), excess lifetime cancer risks (ELCR) can be estimated by:

$$ELCR = \sum LADI_i \times SF_i$$

Where:

LADIi = Exposure route-specific lifetime average daily intake (mg/kg-day).
SFi = Route-specific (oral and dermal) slope factor (mg/kg-day)-1.

Assuming risk additivity, the ELCR for the oral and dermal routes of exposure are summed for exposure to sediment, and the ingestion of all fish species evaluated is summed to determine the ELCR for fish consumption. For carcinogens, the residential and recreational/subsistence user scenarios are calculated as an aggregate of child and adult exposure; the first six years of the exposure duration is determined based on the child intake and the remaining time for intake as an adult.

Calculated ELCR for the resident, recreational/subsistence user, and mine worker for the pathways evaluated in the HHRA Supplement are provided in Tables 6-17a and 6-18 and presented as one significant figure. The ADEC has set acceptable target levels at 1×10^{-5} for multiple exposure pathways. The EPA allows for a risk range of 10^{-6} to 10^{-4}.

Arsenic is the only carcinogenic COPC in sediment and, therefore, drives all carcinogenic risks from potential exposure to sediment. The ELCR for residential and recreational/subsistence users (see Table 6-17a) are 2 x 10^{-5} (2 in 100,000) from exposure to sediment through incidental ingestion and 2 x 10^{-5} (2 in 100,000) from dermal exposure to sediment. The overall risk from potential direct exposure to sediment is 4 x 10^{-5} (4 in 100,000), which is greater than ADEC's standard of 1 x 10^{-5} (1 in 100,000) but within the EPA's allowable cancer risk range of 10^{-6} to 10^{-4}. The ELCR for future mine workers potentially exposed to sediment (see Table 6-18) is 1 x 10^{-5} (1 in 100,000), with 7 x 10^{-6} (7 in 1,000,000) from potential incidental ingestion of sediment and 6 x 10^{-6} (6 in 1,000,000) from potential dermal exposure to sediment. The ELCR for mine workers is below both ADEC and EPA cancer risk standards.

Arsenic is also the only carcinogenic COPC in fish tissue and, therefore, drives all carcinogenic risk from potential exposure to fish. The ELCR for residential and recreational/subsistence users (see Table 6-17a) are 9 x 10^{-4} (9 in 10,000) from consumption of fish from the Middle Kuskokwim River region. This cancer risk level is greater than the ADEC and EPA cancer risk standards. The cancer risk level is primarily driven from consumption of whitefish, which represents over 90% of the total ELCR for this pathway. Whitefish in the area are anadromous and may be exposed to arsenic and other metals from numerous locations during their life. The ELCR for future mine workers consuming fish from the Middle Kuskokwim River region (see Table 6-18) is 2 x 10^{-4} (2 in 10,000), above both ADEC and EPA cancer risk standards. Again, the cancer risk level for this receptor is primarily driven from consumption of whitefish, which represents over 90% of the total ELCR for this pathway.

The overall site cumulative ELCR for all exposure pathways and mediums is provided in Table 6-19. Only risks from exposure to sediment and fish have been updated in the HHRA Supplement; the risks from other exposure pathways were developed in the Baseline HHRA (E & E 2014). As discussed in Section 6.2.4.2, the incidental ingestion of soil pathway was also reduced by 12.5% to account for the incidental ingestion of contaminants in sediment. Since cumulative site ELCRs are primarily driven by potential exposure to COPCs in soil and groundwater, the results from potential exposure to sediment and fish tissue assessed in this HHRA Supplement do not greatly impact the overall cumulative cancer risk at the site.

The arsenic concentration result for sediment sample KR085 was found to be an outlier with respect to the rest of the sediment sample data set. This sample is located in the Red Devil Creek delta area. To evaluate the effect of this outlier result on risk, risks for residential and recreational/subsistence users potentially exposed to sediment were also calculated using EPCs with the outliers removed. Results are presented in Table 6-17b.

With the outlier removed, the ELCRs for residential and recreational/subsistence users (see Table 6-17b) are 6 x 10^{-6} (6 in 1,000,000) from exposure to sediment through incidental ingestion and 5 x 10^{-6} (5 in 1,000,000) from dermal exposure to sediment. The overall risk from potential direct exposure to sediment is 1 x 10^{-5} (1 in 100,000), which is equal to the ADEC's standard of 1 x 10^{-5} (1 in 100,000) and within the EPA's allowable cancer risk ranger of 10^{-6} (1 in 1,000,000) to 10^{-4} (1 in 10,000).

6.4.2 Characterization of Noncarcinogens

In accordance with EPA guidelines (EPA 1989), an HQ for noncarcinogenic risks is derived for each chemical and exposure route and, based on the assumption of dose additivity, the individual HQs are summed over all contaminants to determine the hazard index (HI).

Risks associated with noncancer effects (e.g., organ damage, immunological effects, birth defects, and skin irritation) are usually assessed by comparing the estimated reasonable maximum exposure to an acceptable daily dose. Noncancer hazards are assessed by calculating an HQ, which is the ratio of the estimated exposure to the RfD (oral and dermal), as follows:

Where:

$$HQ = \frac{CDIi}{RfDi}$$

CDIi = Chronic Daily Intake (mg/kg-day).
RfDi = Reference Dose (mg/kg-day).

The HI calculated for a single mode of action is a measure of how close the estimated exposure comes to the RfD. If the HI is less than 1, adverse effects would not be expected. If the HI is greater than 1, adverse effects are possible, but not certain. Calculated HIs for the resident, recreational/subsistence user, and mine worker for the pathways evaluated in the HHRA Supplement are provided in Tables 6-20a and 6-21, presented as two significant figures for HIs at 10 and below and as whole numbers above 10. The ADEC and EPA have set the HI standard at 1.0.

The total HI for residential and recreational/subsistence users (see Table 6-20a) directly exposed to sediment is 0.2 for adults, with 0.1 from incidental ingestion of sediment and 0.04 from dermal exposure to sediment (accounting for rounding, as described above). For children, the total HI is 1.0, with 0.7 from incidental ingestion of sediment and 0.2 from dermal exposure to sediment. The total HIs from potential direct exposure to sediment for both adults and children are below the ADEC and EPA standard of 1.0, indicating direct exposure to sediment at the site does not pose an unacceptable non-carcinogenic hazard. For mine workers directly exposed to sediment (see Table 6-21), the total sediment HI is 0.16, with 0.13 from incidental ingestion of sediment and 0.04 from dermal exposure sediment. All HIs from exposure to sediment for mine workers are below both the ADEC and EPA standard of 1.0, as well.

The HI for residential and recreational/subsistence users from consumption of fish from the Middle Kuskokwim River region is 13 for adults and 33 for children, driven primarily by arsenic and methylmercury in whitefish and methylmercury in northern pike. The HI for consumption of fish is greater than ADEC's and EPA's HI standard of 1.0. The HI for future mine workers consuming fish from the Middle Kuskokwim River region is 8.9, which is above both ADEC and EPA HI standards. The HI for this receptor is primarily driven from arsenic and methylmercury in whitefish and methylmercury in northern pike.

The overall site cumulative HI for all exposure pathways and mediums is provided in Table 6-22. Only hazards from exposure to sediment and fish have been updated in the HHRA Supplement; the hazards from other exposure pathways were developed in the Baseline HHRA (E & E 2014). As discussed in Section 6.2.4.2, the incidental ingestion of soil pathway was also reduced by 12.5% to account for the incidental ingestion of contaminants in sediment. Since cumulative site HIs are primarily driven by potential exposure to COPCs in soil and groundwater, the risk from potential exposure to sediment and fish tissue assessed in this HHRA Supplement does not greatly impact the overall cumulative noncancer hazard at the site.

If the HI exceeds 1.0, major chemical-specific effects identified in the derivation of the RfD by mechanisms of action and target organ can be reviewed. Upon segregation, HIs can be recalculated for specific effects or target organs to further define potential risks. Arsenic and methylmercury primarily contributed to the HI and have different primary targets. The primary target for arsenic toxicity is the cardiovascular system and the skin, whereas the primary target for methylmercury toxicity is the nervous and developmental systems. The HI from exposure to arsenic and the HI from exposure to methylmercury are shown separately in Table 6-23. The HI for both arsenic and methylmercury is greater than ADEC and EPA hazard standards for all receptors.

Arsenic, antimony, and mercury concentration results for sediment sample KR085 (collected from the Red Devil Creek delta area) were found to be outliers with respect to the concentrations in the rest of the data set. To evaluate the effect of these outlier results on risk, hazards for residential and recreational/subsistence users potentially exposed to sediment was also calculated using EPCs with the outliers removed. Results are presented in Table 6-20b.

With the outliers removed, the total HI for residential and recreational/subsistence users directly exposed to sediment is 0.04 for adults, with 0.03 from incidental ingestion of sediment and 0.01 from dermal exposure to sediment (see Table 6-20b). For children, the total HI is 0.2, with 0.2 from incidental ingestion of sediment and 0.06 from dermal exposure to sediment. The total HIs from potential direct exposure to sediment for both adults and children are below the ADEC and EPA standard of 1.0.

6.4.3 Assessment of Background Contribution to Risk

Background EPCs for inorganic elements were calculated consistent with the methodology set out in Section 6.2.2. and are based on the 95% UCL of background Kuskokwim River sediment results (presented in Table 5-3b). Background EPCs in Kuskokwim River sediment are presented in Table 6-24 and are used to determine the risks and hazards for residents and subsistence/ recreational users, the most highly exposed receptors, from exposure to background levels of Kuskokwim River sediments. The exposure scenarios, equations, and parameters presented in Tables 6-9 and 6-10 are used to estimate cancer risks and noncancer hazards from potential direct exposure to chemicals in sediment at local background levels immediately upriver of the RDM (see Section 5.3.1). The cancer risks and hazards for incidental ingestion and dermal exposure to background Kuskokwim River sediments are provided in Table 6-25a and Table 6-25b, respectively. Comparison of total, background, and site-related risks and hazards for the resident and subsistence/recreational user scenarios is presented in Tables 6-26a and 6-26b. The cancer risk from direct exposure (i.e., incidental ingestion and dermal exposure) to background levels of arsenic in sediment represent approximately 3% of the site risk for those pathways for residents and subsistence/recreational users. The noncancer hazard from direct exposure to background levels of inorganics in sediment represents 7% of the site risks for those pathways for residents and subsistence/recreational users.

6.4.4 Risk Characterization Conclusions

Noncancer hazards and excess cancer risk from potential exposure to COPCs in Kuskokwim River sediments are presented on a total, background, and site-related basis in Tables 6-26a and 6-26b. Noncancer hazards from exposure to Kuskokwim River sediment near the RDM site, including the downriver portion, do not exceed acceptable hazards as defined by EPA and ADEC. Cancer risks from exposure to Kuskokwim River sediment for all receptors are within the acceptable EPA cancer risk range. For residents and recreational/ subsistence users, the cancer risk is slightly above the ADEC acceptable risk standard, but when the outlier results are removed, the cancer risks are within acceptable cancer risk range for both the ADEC and EPA. Localized background sediment levels contribute approximately 3% to the overall site cancer risk from direct exposure to sediment and approximately 7% to the overall noncarcinogenic hazard from this pathway.

Noncancer hazards and excess cancer risk from potential exposure to COPCs in fish tissue are presented on a regional basis. Potential exposure to methylmercury and arsenic in muscle samples from fish collected from the middle Kuskokwim River region resulted in cancer risk levels above both ADEC and EPA cancer risk and noncancer hazards above ADEC or EPA standards. The cancer risks are primarily driven by arsenic in northern pike and whitefish. The noncancer hazards are primarily driven by methylmercury in northern pike, and arsenic and methylmercury in whitefish. These results are consistent with the Alaska Department of Health and Social Services (2016) consumption guidelines of pike from the Kuskokwim River based on the methylmercury levels in pike.

As described previously, assessment of potential cancer risks and noncancer hazards from exposure to fish on a regional basis, are not specifically tied to the RDM site. Northern pike are mobile and migratory. In the BLM study (Matz et al. 2017), northern pike tended to stay in tributaries of the mainstem Kuskokwim and had greater mercury concentrations when they were in more mineralized watersheds, although northern pike that stayed in the mainstem Kuskokwim had overall lower mercury concentrations in spite of being in proximity to mercury sources. The turbid and swift conditions of the Kuskokwim River provide limited habitat for pike or conditions conducive to mercury methylation (wetlands). There were no spatial differences identified in mercury concentrations in sheefish (inconnu), which are anadromous in the area (Matz et al. 2017).

6.5 Uncertainty Analysis

There are multiple sources of uncertainty in the risk assessment and decision making processes at contaminated sites. The National Academies of Science Institution of Medicine (2013) studied the impact of uncertainty in the decision making process and identified three primary areas of uncertainty:

- Variability and heterogeneity is uncertainty related to the natural variations in the environment, exposure pathway and susceptibility of subpopulations.
- Model and parameter uncertainty describes the uncertainty due to the limited knowledge about true exposure patterns and fate and transport of contaminants at a site.
- Deep uncertainty is uncertainty when underlying environmental processes are not understood.

Many reports regarding uncertainty emphasize the need to quantify the uncertainties inherent in human health risk estimates. These reports recommend moving away from the presentation of health risk as point estimates and, instead, to capture uncertainties in risk assessments and to take uncertainty into consideration when making decisions at a site (National Academies of Science Institutions of Medicine 2013).

Uncertainty is inherent in every step of the risk assessment process. This section addresses uncertainty and its impact on the risk assessment results. The risk characterization combines and integrates the results of data collection and evaluation, the exposure assessment, and the toxicity assessment to obtain quantitative estimates of the potential risks posed by site contamination. The following sections present some uncertainties associated with each step of the process and the ways they are likely to affect the overall risk estimates.

6.5.1 Environmental Sampling and Analysis Uncertainty

Sediment samples collected during the investigations were primarily intended to characterize the nature and extent, and fate and transport, of contamination at the site. While this sampling approach is sound for site characterization, it can result in uncertainties in estimating the average concentration, or EPC, that people may contact over time.

Characterization of background concentrations of metals at mine sites is important because mines are developed in naturally mineralized areas. In such areas, the concentrations of the metals targeted by the mining, but also other metals, are commonly elevated. Characterization of background conditions at mine sites may be complicated by the mining and ore processing activities that occur in the vicinity of the site. The RDM site is located in the middle Kuskokwim River region, in part of an area referred to as Alaska's "mercury belt" because of the mercury mineral deposits in the watershed (Gray et al. 2000). The Kuskokwim River runs through a highly mineralized region of Alaska that contains mercury, antimony, gold, silver, and polymetallic deposits (Matz et al. 2017). In this HHRA Supplement and RI Supplement, background levels are depicted by upgradient, localized Kuskokwim River sediment, but areas of elevated levels of metal concentrations are expected in areas throughout the Kuskokwim River area. Risks and hazards from exposure to natural mineralized areas within the region, and their contribution to overall risks and hazards, are likely underestimated.

This HHRA Supplement was performed to address data gaps associated with Kuskokwim River sediments that were not addressed as part of the initial RI effort. Risks and hazards from potential exposure to COPCs through direct contact and incidental ingestion of sediment and consumption of fish from the Middle Kuskokwim River region were evaluated. Ingestion of surface water from the Kuskokwim River was not evaluated in this HHRA Supplement because ingestion of surface water was evaluated in the Baseline HHRA (E & E 2014) using surface water samples from Red Devil Creek, and because no surface water quality data for the Kuskokwim River near the RDM are available. Not evaluating the ingestion of surface water from the Kuskokwim River in this HHRA Supplement,therefore, represents a potential data gap.

For the Baseline HHRA (E & E 2014), ingestion of surface water was assessed assuming ingestion of surface water from Red Devil Creek and the seep located on the bank of the creek (station RD05; see Chapter 4). The EPCs were calculated based on results for surface water samples collected from both the creek and the seep. In the Baseline HHRA, potential exposure to COPCs through ingestion of surface resulted in cancer risk for recreational/subsistence users of 1×10^{-3} (1 in 1,000), with risks driven by inorganic arsenic concentrations in surface water. The HI for this pathway is 0.0003 for adults and 0.0008 for children, both orders of magnitude below acceptable hazards as defined by EPA and ADEC.

As described in Section 5.3.9, Kuskokwim River water monitoring has been performed by the Georgetown Tribal Council in the Georgetown area, located approximately 18 river miles downriver of the Red Devil Creek delta. The maximum total arsenic concentrations in Kuskokwim River surface water were over 50 times less than the arsenic surface water EPC used in the Baseline HHRA.

As discussed in Section 5.3.9, contribution of COC loading from Red Devil Creek to COC concentrations in the Kuskokwim River, which has discharge rates 4 to 5 orders of magnitude greater than Red Devil Creek, would be indiscernible. As also discussed in Section 5.3.9, it is expected that contributions of COC loading to the Kuskokwim River via groundwater discharge would be similarly low. Flux of groundwater and COCs in groundwater from the RDM into the Kuskokwim River is a data gap that will be addressed in a separate report on site groundwater to be provided for agency review. If Kuskokwim River water sample concentrations near RDM were similar to surface water concentrations in the Georgetown area, cancer risks would also be approximately 50 times less than those estimated in the Baseline HHRA, assuming consumption of water from Red Devil Creek and the seep. Therefore, evaluation of risks and hazards of ingestion COPCs using surface water concentrations from Red Devil Creek and the seep would overestimate risks and hazards of ingesting COPCs in Kuskokwim River water near RDM.

6.5.2 Exposure Point Concentration Uncertainty

Because of the variability and uncertainty inherent in the sampling and analysis processes, uncertainty is introduced by the use of estimated, or J-qualified, results, which may not have the same precision and accuracy as data meeting all standard quality control criteria. There is also uncertainty associated with the use of nondetect results, or assuming that COPC concentrations are based on the reported limits, which may overestimate or underestimate the true concentrations present.

There were very few non-detected analytes in Kuskokwim River sediment or fish tissue. For analytes that were not detected in fish tissue, the maximum reporting limit was used as the EPC. This applies to antimony, cadmium, and vanadium in sheefish and Arctic grayling tissue. Although EPA uses one-half the method detection limit for the EPC when a contaminant is not detected, use of the maximum method detection limit as the EPC for antimony, cadmium, and vanadium in sheefish and Arctic grayling is a health-protective approach. Use of the maximum reporting limit could potentially overestimate risks and hazards at the site. Thallium is the only COPC with nondetect results for Kuskokwim River sediment samples; nondetect results were reported only for downriver sediment samples. The maximum detection limit for thallium is less than the residential soil RSL, which was used for comparison based on the complete sediment exposure pathways for direct human exposure. Therefore, not quantitatively evaluating thallium in downriver sediment would potentially minimally underestimate risks and hazards at the site.

The EPC in sediment was calculated using a weighted approach that addresses bias sampling and frequency. This approach results in the high concentration, higher sampling density area to impact the overall EPC based on the percentage of length of the shoreline in that area compared to the overall exposure area for sediment. In this approach the lower density area is represented by only two sample points. The concentrations of metals in the downriver and cross-river areas do not vary much in sediment samples from this area (see Chapter 5); however, based on the small number of samples for this area, the true EPC could be higher or lower than what was calculated.

Fish EPCs were developed from a regional fish study. As described in Section 7.3.2, sediment data near the site were also used to model concentrations of metals in slimy sculpin using site and background biota sediment accumulation factors (BSAFs) and trophic transfer factors (TTFs) (see Tables 7-7a and 7-7b for modeled slimy sculpin tissue concentrations). To estimate concentrations of chemicals in subsistence fish, a FCM approach was used. The concentration of COPCs in subsistence fish is estimated from the slimy sculpin modeled concentration multiplied by an FCM. For methylmercury, an FCM of 3 is assumed to account for biomagnification (i.e., the subsistence fish concentration of methylmercury is set equal to three times the concentration in sculpin). This approach is supported by the fact that the biomagnification of methylmercury typically is three-fold with each trophic transfer (McGeer et al. 2004). For inorganic mercury and other metals, an FCM of 1 is assumed. This approach is defensible because biomagnification of metals (other than methylmercury) in aquatic organisms is rare. In fact, an inverse relationship has been shown for the trophic transfer of metals (except methylmercury) via the diet—that is, concentrations decrease from one trophic level to the next (McGeer et al. 2004). Hence, use of an FCM of one for inorganic mercury and other metals is health-protective. Modeled subsistence fish EPCs based on site and background BSAFs and TTFs compared to fish tissue concentrations from northern pike, burbot, sheefish, and Arctic grayling from the Kuskokwim River region are presented in Tables 6-27a and 6-27b, respectively. Actual COPC concentrations of fish tissue from the Kuskokwim River region are greater for arsenic, mercury and methylmercury, as well as chromium, copper, nickel and vanadium, than the modeled subsistence fish EPCs based on site BSAFs and TTFs.

6.5.3 Exposure Assessment Uncertainty

Selection of appropriate exposure parameters is typically a challenging exercise in conducting an HHRA because often site-specific exposure patterns are not known. Nevertheless, the risk assessor must make the best assumptions possible based on available information. While there are limited studies available for contact with soil, even fewer studies have been conducted to estimate exposures to sediment, in terms of frequency of contact, adherence of sediment to skin, and incidental ingestion of sediment through hand-to-mouth contact. For this reason, many sediment ingestion and dermal exposure parameters are based on studies of human contact with soil, which may result in an under- or overestimation of risk.

The individual exposure parameter values used in the RME calculations were selected to represent a high-end estimate of exposure for an individual that is a health-protective estimate of actual exposures. The exposure values selected were either standard default values consistent with ADEC and EPA guidelines or were health-protective estimates selected based on best professional judgment. As a result, the calculated potential exposures probably overestimate the actual exposure for most individuals in the receptor populations.

As briefly mentioned above, additional uncertainty is associated with the procedures used to estimate dermal absorption of chemicals from sediment, specifically ABSdermal and adherence factors. Uncertainties with this approach arise from the limited information available on sediment-specific values and the application of soil values to represent exposure to sediment. Dermal absorption of COPCs in sediment was estimated using conservative absorption factors for soil recommended by the EPA. The recommended default values, which generally fall at the upper ends of the ranges that have been observed in absorption studies, may not reflect actual dermal absorption for sediment.

Quantitative estimates of sediment incidental ingestion or the amount of time spent exposed to sediment along the shores of the Kuskokwim River do not exist. Sediment ingestion rates for adults were estimated based on soil ingestion studies for traditional or wilderness exposure. In one study (Doyle et al. 2012), daily activities included clearing spawning streams, collecting fish through dip or seine nets, cleaning fish, hiking, rod and reel fishing, hunting, and collecting and cutting firewood. In the other study (Irvine et al. 2014), an outdoor base camp was established and participants slept in a tent. Daily activities included hunting through setting traps and snares, fishing and set fishing, collecting medicinal plants, and harvesting berries and plants. The sample sizes were small in both studies and the standard deviations of calculated soil ingestion rates had high standard deviation compared to mean, showing high variability in sample results (Irvine et al. 2014) (Doyle et al. 2012). The mean soil ingestion rate was calculated by EPA to be 48 mg/kg and the 50th percentile was 29 mg/kg (Stifelman 2017). The 90th percentile of 184 mg/kg rounded to 200 mg/kg was used for this assessment. If mean ingestion rates from EPA (Stifelman 2017) are used for adult residential exposure, the cancer risk from incidental ingestion of sediment goes from 2×10^{-5} under the currently scenario to 1×10^{-5}, and the overall risk from direct exposure to sediment goes from 4×10^{-5} to 3×10^{-5}.

A sediment ingestion rate of 200 mg/day is used for child exposure, based on the EPA (2011b) Exposure Factors Handbook: 2011 Edition’s recommended value for soil ingestion. Again, no sediment-specific ingestion rate is available for children, nor are the ingestion rate estimates reflective of the types of activities that would be typical of a rural, wilderness area.

According to local residents of Red Devil Village (Talaia-Murray 2017), drift-netting from a boat for subsistence fishing, in which the net does not come in contact with the shore, is the typical method of fishing in the area. Other shore activities include dressing fish at the shore and embarking/disembarking from boats on the shore. This would result in limited exposure to sediment along the shore of the Kuskokwim River. Although the true exposure is not known, based on the type of activities and range of values, the adult and child incidental ingestion rate used in this HHRA Supplement likely overestimates risks and hazards at the site.

Another variable associated with direct sediment exposure is the amount of time people engage in activities where they are likely to be exposed to sediment versus soil. This value was based on best professional judgment and discussions with local residents. The value could be higher or lower than what was estimated in the HHRA Supplement and represents an area of uncertainty.

Ingestion rates for consumption of fish used in this HHRA Supplement are based on a 12-month recall survey of harvested data. The survey was conducted on a household basis, and an estimate of per capita consumption was calculated based on household size. Harvest data significantly overestimates consumption for some resources (IDM 1997). The harvest rates were adjusted to estimate ingestion on an individual basis. Only household harvest data were available, and energy requirement estimates were used to assign an ingestion rate for children. These adjustments likely overestimate true ingestion of fish from the area. In addition, the residential scenario was determined based on the assumption that all wild food was harvested from the middle Kuskokwim River region. Based on Brown et al. (2012), this assumption greatly overestimates actual harvest patterns. In addition, for all fish species, 95th percentile use values were used as an estimate for consumption. This represents a high-end user, which would overestimate risks and hazards at the site.

The exposure duration used for residents (54 years) and mine workers (25 years) for both direct exposure to sediment and consumption of fish may overestimate the true amount of time spent at exposure to these media. The average time a resident lives in Red Devil Village is approximately 23 years (Brown et al. 2012). Although the 90th percentile for residence time for adults in Red Devil Village is higher, it is based on responses from only 15 households, and is a source of uncertainty. The median occupational tenure for mining activities is 8.6 years and the use of the default commercial/industrial value overestimates that expected for a future mine worker.

6.5.4 Toxicity Assessment Uncertainty

The basic uncertainties associated with the derivation of toxicity values in the toxicity assessment include:

- Uncertainties arising from the design, execution, or relevance of the scientific studies that form the basis of the assessment.

- Uncertainties involved in extrapolation from the underlying scientific studies to the exposure situation being evaluated, including variable responses to chemical exposure within human and animal populations between species and between routes of exposure.

These uncertainties could result in a toxicity estimate based directly on the underlying studies that either underestimates or overestimates the true toxicity of a chemical. The toxicity assessment process compensates for these basic uncertainties through the use of uncertainty factors and modifying factors in the derivation of RfDs for assessing noncarcinogenic effects and the method of calculating the 95% UCL value from the linearized multistage model to derive low-dose SFs for assessing cancer risks. This approach ensures that the potential toxicity of a chemical to humans is unlikely to be underestimated; however, actual toxicity may be substantially overestimated as a result. There is significant uncertainty in how to address risks from mutagenic compounds.

The use of adjusted oral toxicity values to evaluate dermal risks is an additional source of uncertainty to the dermal risk estimates because the biokinetics (uptake, distribution, metabolism, and elimination) from dermal exposure may differ from ingestion.

In the absence of information to the contrary, EPA guidelines indicate that carcinogenic risks should be treated as additive and that HIs for similar noncarcinogenic effects should also be treated as additive. The assumption of risk additivity ignores possible synergisms or antagonisms among different chemicals, which would increase or decrease their toxic effects and could tend to underestimate or overestimate total site risks.

The inorganic arsenic levels in sediment and fish were estimated based on health-protective assumptions. It was assumed that 100% of the arsenic in sediment was in the more toxic, inorganic form, and that 10% of the arsenic in fish tissue was in the inorganic form. True levels of inorganic arsenic in sediment and fish tissue were measured in a small number of samples and those results indicates inorganic levels are below 100% in sediment and below 10% in fish tissue. The estimate of 60% oral relative bioavailability for arsenic in soil is empirically-based and represents an upper-bound estimate from numerous soil studies (EPA 2012).

In 2011, a small subset of fish from Red Devil, Cinnabar and Egnaty Creeks were analyzed for inorganic arsenic (Matz et al. 2017). The average ratios of inorganic to total arsenic were 0.65 (or 65% inorganic arsenic) for Arctic grayling and 0.62 for slimy sculpin. By site, the ratio was 0.66 for Red Devil Creek. The inorganic to total arsenic ratios from the creek fish samples are much higher than the ratios of subsistence fish from the Kuskokwim River and large tributary rivers to the Kuskokwim, which ranged from 0.1% to 8.3% inorganic to total arsenic. Sculpin and grayling samples from Red Devil, Cinnabar, and Egnaty Creeks are not representative of inorganic arsenic levels in subsistence fish collected from the middle Kuskokwim region by Matz et al. (2017). Inorganic arsenic levels measured in subsistence fish from the middle Kuskokwim River are most representative of the fish that people harvest and consume, and the inorganic arsenic percentages from those fish were lower than the 10% value assumed in this HHRA Supplement, demonstrating that the approach used is conservative.

A limited number of methylmercury samples in sediment and fish tissue were analyzed for methylmercury. Both total and methylmercury were assessed in sediment, which results in double-counting for the methylmercury attributing to the total mercury levels. In addition, much of the total mercury in sediment is sparingly soluble, limiting the amount available for methylation. The readily bioavailable mercury in sediment samples is low (see Chapter 5). All of the mercury measured in fish tissue was assumed to be in the more toxic methylmercury form, which is a health-protective assumption supported by the methylmercury to total mercury ratios found in northern pike, burbot, sheefish, and Arctic grayling in the middle Kuskokwim River region and major river tributaries (Matz et al. 2017).

The species of chromium was not measured in sediment or fish tissue. Since there are no sources of hexavalent chromium at the site and because of the stability of trivalent chromium in sediment and fish tissue, it was assumed that all of the chromium in sediments is likely present in the trivalent form. The true levels of trivalent or naturally occurring hexavalent chromium were not measured at the site and, therefore, pose a level of uncertainty.

6.5.5 Risk Characterization Uncertainty

As explained earlier, intentionally health-protective assumptions are used throughout the risk assessment process so that the true risk is unlikely to be underestimated. The cumulative effect of this approach could be to overestimate the true risk at the site.

The excess lifetime cancer risk levels from potential exposure to sediment were within the EPA acceptable risk range and only slightly above ADEC's cancer risk standard of 1 in 100,000. Noncancer hazards from exposure to sediment were below both ADEC and EPA standards. Arsenic, antimony and mercury results from sediment sample KR085 (taken in the Red Devil Creek delta area) were found to be outliers with respect to the rest of the data set. When the outlier results are removed, the cancer risks and noncancer hazards are within acceptable levels with respect to both ADEC and EPA standards.

The highest concentrations of sediment are found within the delta area near the RDM site, an area planned for future remediation and removal. Remediation and removal of the near-shore tailings mine waste at the Red Devil Creek delta are expected to reduce the risk estimates, since they will lower the concentrations of arsenic that a person may be exposed to via direct exposure.

Risks and hazards from consumption of fish from the middle Kuskokwim River region are above ADEC and EPA standards. Risk from exposure to fish is characterized based on a regional approach and is not tied to the site and site-related contaminants. Sources of mercury in the area can come from natural erosion of the underlying geology, permafrost degradation, and region and global atmospheric deposition. In addition, there are numerous mercury deposits and mines throughout this region that could contribute to the metal concentrations in the fish tissue. Despite the elevated level of metals in Red Devil Creek, the turbid and swift conditions of the Kuskokwim River near the RDM site provide limited habitat for pike. Burbot traveled widely across the entire study area and had lower and less variable mercury concentrations compared to pike (Matz et al. 2017).

Movement of sheefish, which drove much of the arsenic and methylmercury risk, was not studied by Matz et al. (2017). A previous USFWS report—Spawning Locations, Seasonal Distribution, and Migratory Timing of Kuskokwim River Sheefish using Radiotelemetry, 2007–2011 Final Report for Study—indicates that sheefish tend to winter in the lower Kuskokwim River, migrate to feeding areas in May, and then return to spawning areas in late summer to early fall (USFWS 2012). The spawning areas identified in the USFWS (2012) report are upstream of McGrath and in the Holitna. The sheefish return to the lower river in October. The sheefish remain relatively stationary, presumably to feed, during the summer months near the mouths of major tributaries such as the George, Holitna, and Tatlawiksuk Rivers.

Table 6-1a Final Compounds of Potential Concern, Red Devil Mine Site

Analyte[a]	Surface Soils	Subsurface Soils	Sediment	Surface Water	Groundwater
Metals					
Aluminum	X	X	X	-	-
Antimony	X	X	X	X	X
Arsenic	X	X	X	X	X
Arsenic (Inorganic)	X	X	X	X	X
Barium	X	-	X		X
Cadmium	-	-	BIO	BIO	-
Chromium	X	X	X	X	X
Cobalt	X	X	X	X	X
Copper	-	-	BIO	BIO	-
Iron	X	X	X	X	X
Lead	X	X	BIO	BIO	X
Manganese	X	X	X	X	X
Mercury	X	X	X	X	X
Methylmercury	-	-	BIO	BIO	-
Nickel	-	-	X	X	X
Selenium	-	-	BIO	BIO	X
Silver	-	-	BIO	BIO	-
Thallium	-	X	X	-	X
Vanadium	X	X	X	-	-
Zinc	-	-	BIO	BIO	-
Other Semivolatile Organic Compounds (SVOCs)					
4-Bromophenyl phenyl ether	X	-	-	-	-
1-Methylnaphthalene	-	-	-	X	-
Naphthalene	-	X	-	X	-
Bis(2-ethylhexyl)phthalate	-	-	-	-	X

Source: Table 6-6 of RI HHRA (E & E 2014).

Key:

BIO COPC based on bioaccumulative properties.

COPC Contaminant of Potential Concern

SVOC Semivolatile Organic Compound

X COPC based on screening.

Table 6-1b Near-Shore Sediment Samples Used to Determine Exposure Point Concentration[1]

General Location	Shoreline vs. Offshore	Sample ID	Station ID	Field Duplicate
Near-RDM	Shoreline	10KR04SD	KR04	
Near-RDM	Shoreline	11KR05SD	KR05	
Near-RDM	Shoreline	11KR06SD	KR06	
Near-RDM	Shoreline	10KR07SD	KR07	
Near-RDM	Shoreline	11KR08SD	KR08	
Near-RDM	Shoreline	11KR09SD	KR09 (KR09A)	
Near-RDM	Shoreline	10KR10SD	KR10	
Near-RDM	Shoreline	10KR11SD	KR11	
Near-RDM	Shoreline	11KR17SD	KR17	
Near-RDM	Shoreline	10KR03SD	KR03	
Near-RDM	Shoreline	11KR14SD	KR14	
Near-RDM	Shoreline	11KR15SD	KR15	
Near-RDM	Shoreline	11KR16SD	KR16	
Near-RDM	Offshore	15KR085SD	KR085	
Downriver	Offshore	15KR098SD	KR098	15KR200SD
Downriver	Offshore	15KR100SD	KR100	

Key:

RDM = Red Devil Mine

ID = Identification

Notes:

1 - Sediment was considered near-shore if it was submerged in less than 2 feet of water for at least part of the time between early June through late August.

Table 6-2 Near-Shore Down River Sediment Exposure Point Concentration Summary

Scenario Timeframe: Current/Future
Medium: Near-Shore Kuskokwim River Sediments
Area: Down River Sediments[1]

Contaminant of Potential Concern	Number of Samples	Number of Detections	Max. Detected Conc.	95% UCL	Units	Reasonable Maximum Exposure		
						EPC Value	EPC Distribution	EPC Statistics
Aluminum	2	2	4,400	NA	mg/kg	4,400	NA	Maximum Detected Value
Antimony	2	2	2	NA	mg/kg	2	NA	Maximum Detected Value
Arsenic	2	2	14	NA	mg/kg	14	NA	Maximum Detected Value
Barium	2	2	65	NA	mg/kg	65	NA	Maximum Detected Value
Cadmium	2	2	0.2	NA	mg/kg	0.2	NA	Maximum Detected Value
Chromium	2	2	15.0	NA	mg/kg	15	NA	Maximum Detected Value
Cobalt	2	2	8	NA	mg/kg	8	NA	Maximum Detected Value
Copper	2	2	12.0	NA	mg/kg	12	NA	Maximum Detected Value
Iron	2	2	11,000	NA	mg/kg	11,000	NA	Maximum Detected Value
Manganese	2	2	420	NA	mg/kg	420	NA	Maximum Detected Value
Mercury	2	2	2.1	NA	mg/kg	2.1	NA	Maximum Detected Value
Nickel	2	2	22	NA	mg/kg	22	NA	Maximum Detected Value
Selenium	2	2	0.75	NA	mg/kg	0.75	NA	Maximum Detected Value
Silver	2	2	0.061	NA	mg/kg	0.061	NA	Maximum Detected Value
Thallium	2	0	NA	NA	mg/kg	NA	NA	Not-detected
Vanadium	2	2	23	NA	mg/kg	23	NA	Maximum Detected Value
Zinc	2	2	43	NA	mg/kg	43	NA	Maximum Detected Value
Methylmercury	2	1	0.000019	NA	mg/kg	0.000019	NA	Maximum Detected Value

Key:

EPC= Exposure Point Concentration
mg/kg = milligrams per kilogram
NA = Not available
UCL = Upper Confidence Limit

Notes:

1 - Includes samples 15KR098SD and 15KR100SD, see Table 6-1.

Table 6-3 Near-Shore Near-Red Devil Mine Sediment Exposure Point Concentration Summary

Scenario Timeframe: Current/Future
Medium: Near-Shore Kuskokwim River Sediments
Area: Near-Red Devil Mine[1]

Contaminant of Potential Concern	Number of Samples	Number of Detections	Max. Detected Conc.	95% UCL	Units	Reasonable Maximum Exposure		
						EPC Value	EPC Distribution	EPC Statistics
Aluminum	14	14	17,000	1.135E+04	mg/kg	11,350	Normal	95% Student-t
Antimony	14	11	3,100	2.464E+03	mg/kg	2,464	Lognormal	95% KM(Chebyshev)
Antimony (outlier removed)[2]	13	10	272	2.481E+02	mg/kg	248	Lognormal	99% KM(Chebyshev)
Arsenic	14	14	2,100	1.789E+03	mg/kg	1,789	Non-parametric	99% Chebyshev (Mean, Sd)
Arsenic (outlier removed)[2]	13	13	800	4.121E+02	mg/kg	412.1	Lognormal	95% Chebyshev (Mean, Sd)
Barium	14	14	520	2.154E+02	mg/kg	215	Non-parametric	95% Student-t
Cadmium	14	12	0.600	3.640E-01	mg/kg	0.364	Non-parametric	95% KM(t)
Chromium	14	14	36.0	2.477E+01	mg/kg	25	Lognormal	95% Student-t
Cobalt	14	14	18.0	1.218E+01	mg/kg	12	Normal	95% Student-t
Copper	14	14	12.67	3.557E+01	mg/kg	12.67	Gamma	Maximum Detected Value
Iron	14	14	48,100	3.210E+04	mg/kg	32,096	Normal	95% Student-t
Manganese	14	14	5,410	2.433E+03	mg/kg	2,433	Non-parametric	99% Chebyshev (Mean, Sd)
Mercury	14	14	310	2.621E+02	mg/kg	262	Lognormal	99% Chebyshev (Mean, Sd)
Mercury (outlier removed)[2]	13	13	119	1.060E+02	mg/kg	106	Lognormal	99% Chebyshev (Mean, Sd)
Nickel	14	14	55	3.735E+01	mg/kg	37	Gamma	95% Adjusted Gamma
Selenium	14	9	1.7	7.130E-01	mg/kg	0.71	Non-parametric	95% KM(t)
Silver	14	9	0.229	1.520E-01	mg/kg	0.15	Normal	95% KM(t)
Thallium	14	9	0.33	1.780E-01	mg/kg	0.18	Non-parametric	95% KM(t)
Vanadium	14	14	8.5	3.285E+01	mg/kg	8.5	Lognormal	Maximum Detected Value
Zinc	14	14	119	9.054E+01	mg/kg	91	Normal	95% Student-t
Methylmercury	14	13	0.002640	0.00121	mg/kg	0.00121	Gamma	95% Adjusted Gamma

Key:

EPC= Exposure Point Concentration
KM = Kaplan-Meier (statistical evaluation)
mg/kg = milligrams per kilogram
UCL = Upper Confidence Limit

Notes:

1 - Includes samples 10KR04SD, 11KR05SD, 11KR06SD, 10KR07SD, 11KR08SD, 11KR09SD, 10KR10SD, 10KR11SD, 11KR17SD, 10KR03SD, 11KR14SD, 11KR15SD, 11KR16SD, 15KR085SD. See Table 6-1.
2 - Result from Sample KR085 were identified as an outlier and EPC was calculated with and without the outlier result included.

Table 6-4 Weighted Near-Shore Sediment Exposure Point Concentration Summary

Analyte	Near-RDM		Downriver Area		Area-Weighted EPC (mg/kg)
	EPC (mg/kg)	Length (mi.)	EPC (mg/kg)	Length (mi.)	
Aluminum	11,350	0.65	4,400	3.46	5499.15
Antimony	2,464	0.65	2	3.46	391.37
Arsenic	1,789.0	0.65	14.0	3.46	294.72
Barium	215.4	0.65	65.0	3.46	88.79
Cadmium	0.364	0.65	0.190	3.46	0.22
Chromium	24.77	0.65	15.00	3.46	16.55
Cobalt	12.18	0.65	7.60	3.46	8.32
Copper	12.67	0.65	12.00	3.46	12.11
Iron	32,096	0.65	11,000	3.46	14336.35
Manganese	2,433	0.65	420	3.46	738.36
Mercury	262	0.65	2.1	3.46	43.22
Nickel	37.35	0.65	22.00	3.46	24.43
Selenium	0.713	0.65	0.750	3.46	0.74
Silver	0.152	0.65	0.061	3.46	0.08
Thallium	0.178	0.65	NA	3.46	0.03
Vanadium	8.5	0.65	23	3.46	20.71
Zinc	90.5	0.65	43	3.46	50.52
Methylmercury	0.00121	0.65	0.000019	3.46	0.00021
Antimony (outlier removed)	248.1	0.65	2	3.46	40.92
Arsenic (outlier removed)	412.1	0.65	14.0	3.46	76.96
Mercury (outlier removed)	106	0.65	2.1	3.46	18.53

Key:

EPC= Exposure Point Concentration

mg/kg = milligrams per kilogram

mi. = miles

Table 6-5 Fish Tissue Exposure Point Concentration Summary – Northern Pike

Scenario Timeframe: Current/Future
Medium: Northern Pike

Contaminant of Potential Concern	Number of Samples	Number of Detections	Max. Detected Conc.	95% UCL	Units	Reasonable Maximum Exposure		
						EPC Value	EPC Distribution	EPC Statistic
Aluminum	457	161	2.420E+02	9.254E+00	mg/kg-wet	9.254E+00	Non-parametric	95% KM(Chebyshev)
Antimony	297	25	6.700E-02	9.160E-03	mg/kg-wet	9.160E-03	Lognormal	KM-H
Arsenic	457	195	2.634E+00	2.430E-01	mg/kg-wet	2.430E-01	Non-parametric	95% KM(Chebyshev)
Barium	457	222	4.250E+00	1.670E-01	mg/kg-wet	1.670E-01	Non-parametric	95% KM(Chebyshev)
Cadmium	457	19	6.600E-02	3.890E-03	mg/kg-wet	3.890E-03	Non-parametric	95% KM(Chebyshev)
Chromium	457	30	3.570E+00	1.300E-01	mg/kg-wet	1.300E-01	Non-parametric	95% KM(Chebyshev)
Cobalt	NA	NA	NA	NA		NA	NA	NA
Copper	457	430	5.853E+00	4.620E-01	mg/kg-wet	4.620E-01	Non-parametric	95% KM(Chebyshev)
Iron	457	219	1.740E+02	8.545E+00	mg/kg-wet	8.545E+00	Non-parametric	95% KM(Chebyshev)
Manganese	457	357	3.260E+00	3.050E-01	mg/kg-wet	3.050E-01	Non-parametric	95% KM(Chebyshev)
Mercury	456	456	1.380E+00	4.570E-01	mg/kg-wet	4.570E-01	Gamma	95% Approx. Gamma
Nickel	457	71	1.180E+01	3.790E-01	mg/kg-wet	3.790E-01	Non-parametric	95% KM(Chebyshev)
Selenium	457	215	1.030E+00	3.340E-01	mg/kg-wet	3.340E-01	Normal	95% KM(t)
Silver	NA	NA	NA	NA		NA	NA	NA
Thallium	NA	NA	NA	NA		NA	NA	NA
Vanadium	457	4	5.700E-02	2.480E-02	mg/kg-wet	2.480E-02	Normal	95% KM(t)
Zinc	458	458	3.940E+01	8.436E+00	mg/kg-wet	8.436E+00	Non-parametric	95% Student-t

Key:
EPC= Exposure Point Concentration
KM = Kaplan-Meier (statistical evaluation)
mg/kg-wet = milligrams per kilogram wet weight
NA = Not available
UCL = Upper Confidence Limit

Table 6-6 Fish Tissue Exposure Point Concentration Summary – Burbot

Scenario Timeframe: Current/Future
Medium: Burbot

Contaminant of Potential Concern	Number of Samples	Number of Detections	Max. Detected Conc.	95% UCL	Units	Reasonable Maximum Exposure		
						EPC Value	EPC Distribution	EPC Statistic
Aluminum	293	77	5.900E+01	2.380E+00	mg/kg-wet	2.380E+00	Lognormal	KM H-UCL
Antimony	175	16	1.480E-01	1.510E-02	mg/kg-wet	1.510E-02	Non-parametric	95% KM(Chebyshev)
Arsenic	293	260	1.129E+01	2.659E+00	mg/kg-wet	2.659E+00	Non-parametric	95% KM(Chebyshev)
Barium	293	196	8.250E+00	3.120E-01	mg/kg-wet	3.120E-01	Non-parametric	95% KM(Chebyshev)
Cadmium	293	7	8.000E-03	2.110E-03	mg/kg-wet	2.110E-03	Lognormal	KM H-UCL
Chromium	293	40	1.260E+01	4.210E-01	mg/kg-wet	4.210E-01	Non-parametric	95% KM(Chebyshev)
Cobalt	NA	NA	NA	NA		NA	NA	NA
Copper	293	293	2.000E+00	4.430E-01	mg/kg-wet	4.430E-01	Non-parametric	95% KM(Chebyshev)
Iron	293	278	1.060E+03	2.841E+01	mg/kg-wet	2.841E+01	Non-parametric	95% KM(Chebyshev)
Manganese	293	293	2.180E+01	7.580E-01	mg/kg-wet	7.580E-01	Non-parametric	95% KM(Chebyshev)
Mercury	293	292	1.048E+00	3.420E-01	mg/kg-wet	3.420E-01	Non-parametric	95% KM(Chebyshev)
Nickel	294	240	1.050E+01	3.120E-01	mg/kg-wet	3.120E-01	Non-parametric	95% KM(Chebyshev)
Selenium	293	275	1.473E+00	5.870E-01	mg/kg-wet	5.870E-01	Non-parametric	95% KM(Chebyshev)
Silver	NA	NA	NA	NA		NA	NA	NA
Thallium	NA	NA	NA	NA		NA	NA	NA
Vanadium	293	291	1.820E+00	8.800E-02	mg/kg-wet	8.800E-02	Non-parametric	95% KM(Chebyshev)
Zinc	293	293	1.040E+01	5.743E+00	mg/kg-wet	5.743E+00	Lognormal	95% Approx. Gamma

Key:

EPC= Exposure Point Concentration
KM = Kaplan-Meier (statistical evaluation)
mg/kg-wet = milligrams per kilogram wet weight
NA = Not available
UCL = Upper Confidence Limit

Table 6-7 Fish Tissue Exposure Point Concentration Summary – Sheefish

Scenario Timeframe: Current/Future
Medium: Sheefish

Contaminant of Potential Concern	Number of Samples	Number of Detections	Max. Detected Conc.	95% UCL	Units	Reasonable Maximum Exposure		
						EPC Value	EPC Distribution	EPC Statistic
Aluminum	38	17	1.600E+00	1.126E+00	mg/kg-wet	1.126E+00	Non-parametric	95% KM(t)
Antimony	38	0	--	--	mg/kg-wet	2.500E-02	--	Detection Limit
Arsenic	38	38	6.846E+00	3.659E+00	mg/kg-wet	3.659E+00	Normal	95% Student-t
Barium	38	38	3.400E-01	1.810E-01	mg/kg-wet	1.810E-01	Normal	95% Student-t
Cadmium	38	0	--	--	mg/kg-wet	2.500E-02	--	Detection Limit
Chromium	38	2	4.600E-02	--	mg/kg-wet	4.600E-02	--	Maximum Detected Value
Cobalt	NA	NA	NA	NA		NA	NA	NA
Copper	39	39	1.459E+00	6.280E-01	mg/kg-wet	6.280E-01	Normal	95% Student-t
Iron	38	38	1.640E+01	8.371E+00	mg/kg-wet	8.371E+00	Normal	95% Student-t
Manganese	38	38	1.690E-01	1.390E-01	mg/kg-wet	1.390E-01	Normal	95% Student-t
Mercury	38	38	3.200E-01	2.280E-01	mg/kg-wet	2.280E-01	Normal	95% Student-t
Nickel	38	3	3.470E-01	--	mg/kg-wet	3.470E-01	--	Maximum Detected Value
Selenium	38	38	7.760E-01	6.190E-01	mg/kg-wet	6.190E-01	Normal	95% Student-t
Silver	NA	NA	NA	NA		NA	NA	NA
Thallium	NA	NA	NA	NA		NA	NA	NA
Vanadium	38	0	--	--		2.500E-02	--	Detection Limit
Zinc	38	38	6.570E+00	4.894E+00	mg/kg-wet	4.894E+00	Normal	95% Student-t

Key:

-- = Not calculated due to insufficient number of detected results.
EPC= Exposure Point Concentration
KM = Kaplan-Meier (statistical evaluation)
mg/kg-wet = milligrams per kilogram wet weight
NA = Not available
UCL = Upper Confidence Limit

Table 6-8 Fish Tissue Exposure Point Concentration Summary – Arctic Grayling

Scenario Timeframe: Current/Future
Medium: Arctic grayling

Contaminant of Potential Concern	Number of Samples	Number of Detections	Max. Detected Conc.	95% UCL	Units	Reasonable Maximum Exposure		
						EPC Value	EPC Distribution	EPC Statistic
Aluminum	25	3	1.200E+00	--	mg/kg-wet	1.200E+00	NA	Maximum Detected Value
Antimony	25	0	--	--	mg/kg-wet	2.500E-02	--	Detection Limit
Arsenic	25	17	6.400E-02	3.730E-02	mg/kg-wet	3.730E-02	Normal	95% KM(t)
Barium	25	25	2.020E-01	1.420E-01	mg/kg-wet	1.420E-01	Normal	95% Student-t
Cadmium	25	0	--	--	mg/kg-wet	2.500E-02	--	Detection Limit
Chromium	25	7	2.250E-01	6.220E-02	mg/kg-wet	6.220E-02	Gamma	Gamma Adjusted KM-UCL
Cobalt	NA	NA	NA	NA		NA	NA	NA
Copper	26	26	3.470E+00	8.980E-01	mg/kg-wet	8.980E-01	Lognormal	95% Student-t
Iron	25	25	1.270E+01	8.225E+00	mg/kg-wet	8.225E+00	Normal	95% Student-t
Manganese	25	25	5.670E-01	2.790E-01	mg/kg-wet	2.790E-01	Non-parametric	95% Student-t
Mercury	25	25	4.860E-01	2.630E-01	mg/kg-wet	2.630E-01	Normal	95% Student-t
Nickel	25	2	2.600E-02	--	mg/kg-wet	2.600E-02	NA	Maximum Detected Value
Selenium	25	25	1.547E+00	1.207E+00	mg/kg-wet	1.207E+00	Normal	95% Student-t
Silver	NA	NA	NA	NA		NA	NA	NA
Thallium	NA	NA	NA	NA		NA	NA	NA
Vanadium	25	0	--	--	mg/kg-wet	2.500E-02	--	Detection Limit
Zinc	25	25	9.200E+00	6.949E+00	mg/kg-wet	6.949E+00	Normal	95% Student-t

Key:

-- = Not calculated due to insufficient number of detected results.
EPC= Exposure Point Concentration
KM = Kaplan-Meier (statistical evaluation)
mg/kg-wet = milligrams per kilogram wet weight
NA = Not available
UCL = Upper Confidence Limit

Table 6-9 Calculation of COPC Intake from Incidental Ingestion of Sediment

A. Intake Equation[1]:

$$Intake(mg/kg/day) = \frac{C_s \; x \; IR \; x \; CF \; x \; EF \; x \; ED \times FI}{BW \; x \; AT}$$

B. Variables and Assumptions:

Variables	Exposure Case: Future Residential	Exposure Case: Recreational/ Subsistence User	Exposure Case: Mine Worker	Units	Description/Source
C_s	Chemical-specific			mg/kg	Concentration of COPC in sediment calculated using weighted exposure point concentration
IR_a	180	180	180	mg/day	Adult ingestion rate (Stifelman 2017)
IR_c	200	200	–	mg/day	Child ingestion rate (ADEC 2015; EPA 2011b, 2014)
CF	$1x10^{-6}$	$1x10^{-6}$	$1x10^{-6}$	kg/mg	Unit correction factor
EF_a	90	90	90	day/year	Adult exposure frequency
EF_c	90	90	–	day/year	Child exposure frequency
ED_a	54	54	25	years	Adult exposure duration (ADEC 2015; EPA 1991, 2014; Kissinger 2013)
ED_c	6	6	–	years	Child exposure duration (ADEC 2015, EPA 2002)
FI	0.125	0.125	0.125	unitless	Fraction ingested from sediment
BW_a	80	80	80	kg	Adult body weight (ADEC 2015; EPA 2011b, 2014)
BW_c	15	15	–	kg	Child body weight (ADEC 2015; EPA 2011b, 2014)
AT_c	25,550			days	Averaging time – carcinogens (EPA 1989)
AT_{nc}	ED x 365			days	Averaging time – noncarcinogens (EPA 1989)

Key:

ADEC	Alaska Department of Environmental Conservation
COPC	contaminant of potential concern
EPA	U.S. Environmental Protection Agency
kg	kilogram
kg/mg	kilograms to milligrams
mg/kg	milligrams per kilogram
UCL	upper confidence limit

Note

1 - For carcinogens, intake for the residential and recreational/subsistence user scenarios is calculated as an aggregate of child and adult exposure, as described in Section 6.2.4.3.

Table 6-10 Calculation of COPC Intake from Dermal Sediment Contact

A. Intake Equation[1]:

$$DAD\,(mg/kg/day) = \frac{C_s \; x \; SA \; x \; AF \; x \; ABS \; x \; CF \; x \; EF \; x \; ED}{BW \; x \; AT}$$

B. Variables and Assumptions:

Variables	Exposure Case			Citation	Description/Source
	Future Residential	Recreational/ Subsistence User	Mine Worker		
C_s	Chemical-specific			mg/kg	Concentration of COPC in sediment calculated using the weighted exposure point concentration
SA_a	6,032	6,032	3,527	cm^2	Adult exposed body surface area (ADEC 2015; EPA 2011b, 2014)
SA_c	2,373	2,373	–	cm^2	Child exposed body surface area (ADEC 2015; EPA 2011b, 2014)
CF	1×10^{-6}			kg/mg	Conversion factor
AF_a	0.07	0.07	0.12	mg/cm^2	Adult skin adherence factor (ADEC 2015; EPA 2004, 2014)
AF_c	0.2	0.2	–	mg/cm^2	Child skin adherence factor (ADEC 2015; EPA 2004, 2014)
ABS	Chemical-specific			unitless	Dermal absorption fraction (Obtained from Table 12)
EF_a	90	90	90	day/year	Adult exposure frequency
EF_c	90	90	–	day/year	Child exposure frequency
ED_a	54	54	25	years	Adult exposure duration (ADEC 2015; EPA 1991, 2014; Kissinger 2013)
ED_c	6	6	–	years	Child exposure duration (ADEC 2015; EPA 2002)
BW_a	80	80	80	kg	Adult body weight (ADEC 2015; EPA 2011b, 2014)
BW_c	15	15	–	kg	Child body weight (ADEC 2015; EPA 2011b, 2014)
AT_c	25,550			days	Averaging time – carcinogens (EPA 1989)
AT_{nc}	ED x 365			days	Averaging time – noncarcinogens (EPA 1989)

Key:

ADEC	Alaska Department of Environmental Conservation
cm^2	square centimeters
COPC	contaminant of potential concern
DAD	Dermally Absorbed Dose
EPA	U.S. Environmental Protection Agency
kg	kilogram
kg/mg	kilograms to milligrams
mg/cm^2	milligrams per square centimeter
mg/kg	milligrams per kilogram

Note

1 - For carcinogens, intake for the residential and recreational/subsistence user scenarios is calculated as an aggregate of child and adult exposure, as described in Section 6.2.4.3.

Table 6-11 Calculation of COPC Intake from Fish Consumption

A. Intake Equation[1, 2]:

$$Intake(mg/kg/day) = \frac{C_s \; x \; IR \; x \; CF \; x \; EF \; x \; ED \times FI}{BW \; x \; AT}$$

B: Variables and Assumptions:

Variables	Exposure Case			Units	Description/Source
	Future Residential	Recreational/ Subsistence User	Mine Worker		
Cf_{NP}	Chemical-specific			mg/kg	Concentration of COPC in northern pike
Cf_{B}	Chemical-specific			mg/kg	Concentration of COPC in burbot
Cf_{WF}	Chemical-specific			mg/kg	Concentration of COPC in whitefish
Cf_{AG}	Chemical-specific			mg/kg	Concentration of COPC in Arctic grayling
IR_{NP-a}	0.096	0.096	0.096	kg/day	Adult ingestion rate of northern pike based on the 95th percentile use estimates from Red Devil Village(Brown et al. 2012; Koster 2012)
IR_{NP-c}	0.046	0.046	0.046	kg/day	Child ingestion rate of northern Pike
IR_{B-a}	0.004	0.004	0.004	kg/day	Adult ingestion rate of burbot based on the 95th percentile use estimates from Red Devil Village (Brown et al. 2012; Koster 2012)
IR_{B-c}	0.002	0.002	0.002	kg/day	Child ingestion rate of burbot
IR_{WF-a}	0.133	0.133	0.133	kg/day	Adult ingestion rate of whitefish based on the 95th percentile use estimates from Red Devil Village (Brown et al. 2012; Koster 2012)
IR_{WF-c}	0.064	0.064	0.064	kg/day	Child ingestion rate of whitefish
IR_{AG-a}	0.017	0.017	0.017	kg/day	Adult ingestion rate of Arctic grayling based on the 95th percentile use estimates from Red Devil Village(Brown et al. 2012; Koster 2012)
IR_{AG-c}	0.008	0.008	0.008	kg/day	Child ingestion rate of Arctic grayling
EF_a	365	365	250	day/year	Adult residential user exposure frequency (ADEC 2015)
EF_c	365	365	–	day/year	Child residential exposure frequency (ADEC 2015)
ED_a	54	54	25	years	Adult exposure duration (ADEC 2015; EPA 1991, 2014; Kissinger 2013)
ED_c	6	6	_	years	Child exposure duration (ADEC 2015; EPA 2002)
BW_a	80	80	80	kg	Adult body weight (ADEC 2015; EPA 2011, 2014)
BW_c	15	15	_	kg	Child body weight (ADEC 2015; EPA 2011, 2014)
AT_c	25,550			days	Averaging time – carcinogens (EPA 1989)
AT_{nc}	ED x 365			days	Averaging time – noncarcinogens (EPA 1989)

Key:

ADEC	Alaska Department of Environmental Conservation
COPC	contaminant of potential concern
EPA	U.S. Environmental Protection Agency
kg/day	kilograms per day
mg/kg	milligrams per kilogram

Note

1 - For carcinogens, intake for the residential and recreational/subsistence user scenarios is calculated as an aggregate of child and adult exposure, as described in 6.2.4.3.

2 – Intake is calculated separately by fish species and category (northern pike, burbot, whitefish, Arctic grayling) and summed for the fish consumption pathway.

Table 6-12 Dermal Absorption Fractions

Compound of Potential Concern	ABSd Value
Aluminum	NA
Antimony	NA
Arsenic	0.03
Barium	NA
Cadmium	0.001
Chromium	NA
Cobalt	NA
Copper	NA
Iron	NA
Manganese	NA
Mercury	NA
Nickel	NA
Selenium	NA
Silver	NA
Thallium	NA
Vanadium	NA
Zinc	NA

Key:
ABSd = Dermal Absorption Fraction, from RAGS Part E (EPA 2004)
NA = Not available

Table 6-13 Harvest and 95th Percentile Use Estimates for Fish Ingestion Rates, Red Devil Village[1]

Food Source Category	Indicator Species	Estimated Pounds Harvested in 2009		Estimated Ingestion Rate (kg/day)	
		Mean per household	Mean per capita	Adult[2]	Child[3]
Northern pike	Northern pike (*Esox Lucius*)	851 lbs	65.5 lbs	0.096	0.046
Burbot	Burbot (*Lota lota*)	14 lbs	0.4 lbs	0.004	0.002
Whitefish	Sheefish, Broad whitefish, Bering Cisco, Least Cisco, Humpback whitefish, unknown whitefish	207 lbs	84.3 lbs	0.133	0.064
Arctic grayling	Arctic grayling (*Thymallus arcticus*)	17.2 lbs	7.0 lbs	0.017	0.008

Notes:

1 –From Table 7-1 of Brown et al. (2012).
2 – Calculated per Koster (2012).
3 - Child rates set a 48% of adult ingestion rate, see Section 6.2.4.7.

Key:
lbs = pounds
kg/day = kilograms per day

Table 6-14 Noncancer Toxicity Data - Oral/Dermal

Compound of Potential Concern	Oral RfD Value	GI Absorption Factor[5]	Adjusted Dermal RfD[1]	Units	Primary Target Organ	Sources of RfD: Target Organ	Notes
Aluminum	1.0E+00	1	1.0E+00	mg/kg-d	Nervous System	PPRTV	
Antimony	4.0E-04	0.15	6.0E-05	mg/kg-d	Whole Body	IRIS	
Arsenic	3.0E-04	1	3.0E-04	mg/kg-d	Cardiovascular, Skin	IRIS	Surrogate = Arsenic (Inorganic)
Barium	2.0E-01	0.07	1.4E-02	mg/kg-d	Kidney	IRIS	
Cadmium (Diet)[3]	1.0E-03	0.025	2.5E-05	mg/kg-d	Kidney	IRIS	
Chromium (trivalent)	1.5E+00	0.013	2.0E-02	mg/kg-d		IRIS	
Cobalt	3.0E-04	1	3.0E-04	mg/kg-d	Hematologic System	PPRTV	
Copper	4.0E-02	1	4.0E-02	mg/kg-d	GI Tract	HEAST	
Iron	7.0E-01	1	7.0E-01	mg/kg-d		PPRTV	
Manganese[4]	2.4E-02	0.04	9.6E-04	mg/kg-d	Nervous System	RSL User's Guide	Non-diet contribution
Manganese[4]	1.4E-01	1	1.4E-01	mg/kg-d	Nervous System	IRIS	Diet contribution
Methyl mercury	1.0E-04	1	1.0E-04	mg/kg-d	Nervous System, Developmental	IRIS	
Mercury	3.0E-04	0.07	2.1E-05	mg/kg-d	Immune System, Nervous System, Kidney	IRIS	Mercuric Chloride (and other Mercury salts)
Nickel	2.0E-02	0.04	8.0E-04	mg/kg-d		IRIS	Soluble salts
Selenium	5.0E-03	1	5.0E-03	mg/kg-d	Skin	IRIS	
Silver	5.0E-03	0.04	2.0E-04	mg/kg-d	Skin	IRIS	
Thallium	1.0E-05	1	1.0E-05	mg/kg-d	Skin	PPRTV - Appendix	Soluble salts
Vanadium[2]	5.0E-03	0.026	1.3E-04	mg/kg-d	Kidney	RSL User's Guide	Derived from vanadium pentoxide
Zinc	3.0E-01	1	3.0E-01	mg/kg-d	Hematologic System	IRIS	

Key:
ATSDR = Agency of Toxic Substances and Disease Registry
GI = gastrointestinal
IRIS = Integrated Risk Information System.
mg/kg-d = milligrams per kilogram per day
PPRTV = Provisional Peer-Reviewed Toxicity Value
RfD = Reference Dose.

Notes:
1 - Dermal RfD = Oral RfD x GI Absorption Factor.
2 - Derived from vanadium pentoxide RfD based on molecular weight comparison, consistent with EPA's RSL User Guide (EPA, 2017).
3 - Diet value used for soil and biota. Water value used for surface water and groundwater exposure, consistent with EPA's RSL User Guide (EPA, 2017).
4 - Value for diet used for fish and value for non-diet used for sediment, consistent with the EPA's RSL User Guide (EPA, 2017)
5 - Values for the GI Absoprtion Factor obtained from Exhibit 4-1 of Risk Assessment Guidance for Superfund Volume 1: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment)(EPA 2004).

Table 6-15 Cancer Toxicity Data - Oral/Dermal

Compound of Potential Concern	Oral Cancer Slope Factor	GI Absorption Factor	Adjusted Dermal[1] Cancer Slope Factor	Units	Mutagen (Yes/No)	Source	Notes
Arsenic	1.5	1	1.5	(mg/kg-d)-1	No	IRIS	Surrogate = Arsenic (Inorganic)

Key:
GI = Gastrointestinal
IRIS = Integrated Risk Information System.
mg/kg-d = milligrams per kilograms per day

Notes:
1 - Dermal SF = Oral SF/GI Absorption factor.

Table 6-16 Percent Inorganic Arsenic in Fish Tissue

Waterbody	Species	Sample Number	Number Inorganic Arsenic Detections	Percent Inorganic Arsenic Range[1]
George	Northern Pike	5	1	3.0 - 6.7 %
Holitna	Northern Pike	15	0	0.3 - 6.7 %
Kuskokwim	Burbot	30	9	0.1 - 8.0 %
Kuskokwim	Northern Pike	28	2	0.4 - 8.3 %
Takotna	Northern Pike	13	0	2.3 - 7.1 %

Notes:

1 - Percent inorganic arsenic calculated as inorganic arsenic (wet weight) divided by total arsenic (wet weight). For non-detected results, the reported detection limited was used for the calculation.

Table 6-17a Calculation of Cancer Risks – Resident and Recreational/Subsistence User

Scenario Timeframe: Current/Future
Receptor Population: Residential and Recreational/Subsistence User
Receptor Age: Combined Adult/Child

Medium	Exposure Route	Contaminant of Potential Concern	Medium EPC Value	Medium EPC Units	Route EPC Value	Route EPC Units	EPC Selected for Risk Calculation	Intake	Intake Units	Slope Factor	Slope Factor Units	Cancer Risk
Sediment	Ingestion	Arsenic	2.95E+02	mg/kg	1.77E+02	mg/kg	1.77E+02	1.46E-05	mg/kg-d	1.5E+00	$(mg/kg\text{-}d)^{-1}$	**2E-05**
Sediment	Dermal	Arsenic	2.95E+02	mg/kg	2.95E+02	mg/kg	2.95E+02	1.38E-05	mg/kg-d	1.5E+00	$(mg/kg\text{-}d)^{-1}$	**2E-05**
											Cancer Risk (Sediment)	**4E-05**

Medium	Exposure Route	Contaminant of Potential Concern	Medium EPC Value	Medium EPC Units	Route EPC Value	Route EPC Units	EPC Selected for Risk Calculation	Intake	Intake Units	Slope Factor	Slope Factor Units	Cancer Risk
Northern Pike	Ingestion	Arsenic (Inorganic)	2.43E-01	mg/kg	2.43E-02	mg/kg	2.43E-02	2.64E-05	mg/kg-d	1.5E+00	$(mg/kg\text{-}d)^{-1}$	**4E-05**
Burbot	Ingestion	Arsenic (Inorganic)	2.66E+00	mg/kg	2.66E-01	mg/kg	2.66E-01	1.22E-05	mg/kg-d	1.5E+00	$(mg/kg\text{-}d)^{-1}$	**2E-05**
Whitefish[1]	Ingestion	Arsenic (Inorganic)	3.66E+00	mg/kg	3.66E-01	mg/kg	3.66E-01	5.51E-04	mg/kg-d	1.5E+00	$(mg/kg\text{-}d)^{-1}$	**8E-04**
Arctic grayling	Ingestion	Arsenic (Inorganic)	3.73E-02	mg/kg	3.73E-03	mg/kg	3.73E-03	7.14E-07	mg/kg-d	1.5E+00	$(mg/kg\text{-}d)^{-1}$	1E-06
											Cancer Risk (Fish)	**9E-04**

Notes:

1 - The whitefish category is based on the sheefish tissue concentration and an ingestion rate estimated from the sum of ingestion rates for sheefish, broad whitefish, Bering Cisco, Least Cisco, humpback whitefish and unknown whitefish.

Key:
EPC = exposure point concentration
mg/kg = milligrams per kilogram
mg/kg-d = milligram per kilogram per day

Table 6-17b Calculation of Cancer Risks with Outliers Removed[1] – Resident and Recreational/Subsistence User

Scenario Timeframe: Current/Future
Receptor Population: Residential and Recreational/Subsistence User
Receptor Age: Combined Adult/Child

Medium	Exposure Route	Contaminant of Potential Concern	Medium EPC Value	Medium EPC Units	Route EPC Value	Route EPC Units	EPC Selected for Risk Calculation	Intake	Intake Units	Slope Factor	Slope Factor Units	Cancer Risk
Sediment	Ingestion	Arsenic	7.70E+01	mg/kg	4.62E+01	mg/kg	4.62E+01	3.82E-06	mg/kg-d	1.5E+00	$(mg/kg\text{-}d)^{-1}$	6E-06
Sediment	Dermal	Arsenic	7.70E+01	mg/kg	7.70E+01	mg/kg	7.70E+01	3.60E-06	mg/kg-d	1.5E+00	$(mg/kg\text{-}d)^{-1}$	5E-06
											Cancer Risk (Sediment)	**1E-05**

Notes:

1 - Result from Sample KR085 were identified as an outlier. Risks were calculated with EPC for arsenic (shaded) that did not include the outlier result.

Key:
EPC = exposure point concentration
mg/kg = milligrams per kilogram
mg/kg-d = milligram per kilogram per day

Table 6-18 Calculation of Cancer Risks – Mine Worker

Scenario Timeframe: Future
Receptor Population: Mine Worker
Receptor Age: Combined Adult

Medium	Exposure Route	Contaminant of Potential Concern	Medium EPC Value	Medium EPC Units	Route EPC Value	Route EPC Units	EPC Selected for Risk Calculation	Intake	Intake Units	Slope Factor	Slope Factor Units	Cancer Risk
Sediment	Ingestion	Arsenic	2.95E+02	mg/kg	1.77E+02	mg/kg	1.77E+02	4.38E-06	mg/kg-d	1.5E+00	$(mg/kg\text{-}d)^{-1}$	7E-06
Sediment	Dermal	Arsenic	2.95E+02	mg/kg	2.95E+02	mg/kg	2.95E+02	4.12E-06	mg/kg-d	1.5E+00	$(mg/kg\text{-}d)^{-1}$	6E-06
											Cancer Risk (Sediment)	**1E-05**

Medium	Exposure Route	Contaminant of Potential Concern	Medium EPC Value	Medium EPC Units	Route EPC Value	Route EPC Units	EPC Selected for risk Calculation	Intake	Intake Units	Slope Factor	Slope Factor Units	Cancer Risk
Northern Pike	Ingestion	Arsenic (Inorganic)	2.43E-01	mg/kg	2.43E-02	mg/kg	2.43E-02	7.13E-06	mg/kg-d	1.5E+00	$(mg/kg\text{-}d)^{-1}$	**1E-05**
Burbot	Ingestion	Arsenic (Inorganic)	2.66E+00	mg/kg	2.66E-01	mg/kg	2.66E-01	3.25E-06	mg/kg-d	1.5E+00	$(mg/kg\text{-}d)^{-1}$	5E-06
Whitefish[1]	Ingestion	Arsenic (Inorganic)	3.66E+00	mg/kg	3.66E-01	mg/kg	3.66E-01	1.49E-04	mg/kg-d	1.5E+00	$(mg/kg\text{-}d)^{-1}$	**2E-04**
Arctic grayling	Ingestion	Arsenic (Inorganic)	3.73E-02	mg/kg	3.73E-03	mg/kg	3.73E-03	1.94E-07	mg/kg-d	1.5E+00	$(mg/kg\text{-}d)^{-1}$	3E-07
											Cancer Risk (Fish)	**2E-04**

Notes:

1 - The whitefish category is based on the sheefish tissue concentration and an ingestion rate estimated from the sum of ingestion rates for sheefish, broad whitefish, Bering Cisco, Least Cisco, humpback whitefish and unknown whitefish.

Key:
EPC = exposure point concentration
mg/kg = milligrams per kilogram
mg/kg-d = milligram per kilogram per day

Table 6-19 Summary of Excess Lifetime Cancer Risks for Red Devil Mine Region[1]

Medium	Exposure Route	Future Resident	Recreational/ Subsistence User	Mine Worker
Soil[2]	Ingestion	**1E-02**	**2E-03**	**2E-03**
	Dermal	**2E-03**	**4E-04**	**4E-04**
Sediment	Ingestion	**2E-05**	**2E-05**	7E-06
	Dermal	**2E-05**	**2E-05**	6E-06
Groundwater	Ingestion	**2E-01**	--	**6E-02**
	Dermal	**9E-04**	--	**4E-04**
Surface Water	Ingestion	--	**1E-03**	--
	Dermal	**1E-05**	3E-06	5E-06
Air	Inhalation of Fugitive Dust/Volatiles from Soil	**2E-05**	2E-06	8E-06
Fish	Ingestion	**9E-04**	**9E-04**	**2E-04**
Large Land Mammals	Ingestion	**4E-05**	6E-07	2E-07
Small Land Mammals	Ingestion	**4E-04**	7E-06	2E-06
Birds	Ingestion	**2E-03**	**5E-04**	**2E-04**
Berries and Plants	Ingestion	**1E-02**	**9E-05**	**3E-05**
Total Excess Lifetime Cancer Risk		**2E-01**	**6E-03**	**6E-02**

Notes:

Bolded text indicates excess lifetime cancer risk grater than 10^{-5} and shaded cell indicates greater than 10^{-4}.

1 - Only risks from exposure to sediment and fish have been updated in the HHRA Supplement. All other risks from Baseline HHRA (E & E, 2014).

2 - Hazards from Mine Processing Area from Baseline HHRA (E & E 2014), reduced by 12.5% to account for incidental ingestion of sediment pathway.

Table 6-20a Calculation of Noncancer Hazards – Resident and Recreational/Subsistence User

Scenario Timeframe: Current/Future
Receptor Population: Residential and Recreational/Subsistence User
Receptor Age: Adult/Child

Medium	Exposure Route	Contaminant of Potential Concern	Medium EPC Value	Medium EPC Units	Route EPC Value	Route EPC Units	EPC Selected for Risk Calculation	Adult Intake	Child Intake	Intake Units	Chronic Reference Dose	Chronic Reference Dose Units	Adult Hazard Quotient	Child Hazard Quotient
Sediment	Ingestion	Aluminum	5.50E+03	mg/kg	5.50E+03	mg/kg	5.50E+03	3.81E-04	2.26E-03	mg/kg-d	1.0E+00	mg/kg-d	3.81E-04	2.3E-03
		Antimony	3.91E+02	mg/kg	3.91E+02	mg/kg	3.91E+02	2.71E-05	1.61E-04	mg/kg-d	4.0E-04	mg/kg-d	6.79E-02	4.0E-01
		Arsenic	2.95E+02	mg/kg	1.77E+02	mg/kg	1.77E+02	1.23E-05	7.27E-05	mg/kg-d	3.0E-04	mg/kg-d	4.09E-02	2.4E-01
		Barium	8.88E+01	mg/kg	8.88E+01	mg/kg	8.88E+01	6.16E-06	3.65E-05	mg/kg-d	2.0E-01	mg/kg-d	3.08E-05	1.8E-04
		Cadmium	2.18E-01	mg/kg	2.18E-01	mg/kg	2.18E-01	1.51E-08	8.94E-08	mg/kg-d	1.0E-03	mg/kg-d	1.51E-05	8.9E-05
		Chromium	1.65E+01	mg/kg	1.65E+01	mg/kg	1.65E+01	1.15E-06	6.80E-06	mg/kg-d	1.5E+00	mg/kg-d	7.65E-07	4.5E-06
		Cobalt	8.32E+00	mg/kg	8.32E+00	mg/kg	8.32E+00	5.77E-07	3.42E-06	mg/kg-d	3.0E-04	mg/kg-d	1.92E-03	1.1E-02
		Copper	1.21E+01	mg/kg	1.21E+01	mg/kg	1.21E+01	8.40E-07	4.98E-06	mg/kg-d	4.0E-02	mg/kg-d	2.10E-05	1.2E-04
		Iron	1.43E+04	mg/kg	1.43E+04	mg/kg	1.43E+04	9.94E-04	5.89E-03	mg/kg-d	7.0E-01	mg/kg-d	1.42E-03	8.4E-03
		Manganese	7.38E+02	mg/kg	7.38E+02	mg/kg	7.38E+02	5.12E-05	3.03E-04	mg/kg-d	2.4E-02	mg/kg-d	2.13E-03	1.3E-02
		Methylmercury	2.10E-04	mg/kg	2.10E-04	mg/kg	2.10E-04	1.46E-11	8.63E-11	mg/kg-d	1.0E-04	mg/kg-d	1.46E-07	8.6E-07
		Mercury	4.32E+01	mg/kg	4.32E+01	mg/kg	4.32E+01	3.00E-06	1.78E-05	mg/kg-d	3.0E-04	mg/kg-d	9.99E-03	5.9E-02
		Nickel	2.44E+01	mg/kg	2.44E+01	mg/kg	2.44E+01	1.69E-06	1.00E-05	mg/kg-d	2.0E-02	mg/kg-d	8.47E-05	5.0E-04
		Selenium	7.44E-01	mg/kg	7.44E-01	mg/kg	7.44E-01	5.16E-08	3.06E-07	mg/kg-d	5.0E-03	mg/kg-d	1.03E-05	6.1E-05
		Silver	7.54E-02	mg/kg	7.54E-02	mg/kg	7.54E-02	5.23E-09	3.10E-08	mg/kg-d	5.0E-03	mg/kg-d	1.05E-06	6.2E-06
		Thallium	2.82E-02	mg/kg	2.82E-02	mg/kg	2.82E-02	1.95E-09	1.16E-08	mg/kg-d	1.0E-05	mg/kg-d	1.95E-04	1.2E-03
		Vanadium	2.07E+01	mg/kg	2.07E+01	mg/kg	2.07E+01	1.44E-06	8.51E-06	mg/kg-d	5.0E-03	mg/kg-d	2.87E-04	1.7E-03
		Zinc	5.05E+01	mg/kg	5.05E+01	mg/kg	5.05E+01	3.50E-06	2.08E-05	mg/kg-d	3.0E-01	mg/kg-d	1.17E-05	6.9E-05
												Hazard Index	0.1	0.7
Sediment	Dermal	Arsenic	2.95E+02	mg/kg	2.95E+02	mg/kg	2.95E+02	1.15E-05	6.90E-05	mg/kg-d	3.0E-04	mg/kg-d	3.84E-02	2.3E-01
		Cadmium	2.18E-01	mg/kg	2.18E-01	mg/kg	2.18E-01	2.83E-10	1.70E-09	mg/kg-d	2.5E-05	mg/kg-d	1.13E-05	6.8E-05
												Hazard Index	0.04	0.2
												Total Hazard Index (Sediment)	0.2	1.0

Table 6-20a Calculation of Noncancer Hazards – Resident and Recreational/Subsistence User

Scenario Timeframe: Current/Future
Receptor Population: Residential and Recreational/Subsistence User
Receptor Age: Adult/Child

Medium	Exposure Route	Contaminant of Potential Concern	Medium EPC Value	Medium EPC Units	Route EPC Value	Route EPC Units	EPC Selected for Risk Calculation	Adult Intake	Child Intake	Intake Units	Chronic Reference Dose	Chronic Reference Dose Units	Adult Hazard Quotient	Child Hazard Quotient
Northern Pike	Ingestion	Aluminum	9.25E+00	mg/kg	9.25E+00	mg/kg	9.25E+00	1.11E-02	2.84E-02	mg/kg-d	1.0E+00	mg/kg-d	1.11E-02	2.8E-02
		Antimony	9.16E-03	mg/kg	9.16E-03	mg/kg	9.16E-03	1.10E-05	2.81E-05	mg/kg-d	4.0E-04	mg/kg-d	2.75E-02	7.0E-02
		Arsenic (Inorganic)	2.43E-01	mg/kg	2.43E-02	mg/kg	2.43E-02	2.92E-05	7.45E-05	mg/kg-d	3.0E-04	mg/kg-d	9.72E-02	2.5E-01
		Barium	1.67E-01	mg/kg	1.67E-01	mg/kg	1.67E-01	2.00E-04	5.12E-04	mg/kg-d	2.0E-01	mg/kg-d	1.00E-03	2.6E-03
		Cadmium	3.89E-03	mg/kg	3.89E-03	mg/kg	3.89E-03	4.67E-06	1.19E-05	mg/kg-d	1.0E-03	mg/kg-d	4.67E-03	1.2E-02
		Chromium	1.30E-01	mg/kg	1.30E-01	mg/kg	1.30E-01	1.56E-04	3.99E-04	mg/kg-d	1.5E+00	mg/kg-d	1.04E-04	2.7E-04
		Copper	4.62E-01	mg/kg	4.62E-01	mg/kg	4.62E-01	5.54E-04	1.42E-03	mg/kg-d	4.0E-02	mg/kg-d	1.39E-02	3.5E-02
		Iron	8.55E+00	mg/kg	8.55E+00	mg/kg	8.55E+00	1.03E-02	2.62E-02	mg/kg-d	7.0E-01	mg/kg-d	1.46E-02	3.7E-02
		Manganese	3.05E-01	mg/kg	3.05E-01	mg/kg	3.05E-01	3.66E-04	9.35E-04	mg/kg-d	1.4E-01	mg/kg-d	2.61E-03	6.7E-03
		Methyl Mercury	4.57E-01	mg/kg	4.57E-01	mg/kg	4.57E-01	5.48E-04	1.40E-03	mg/kg-d	1.0E-04	mg/kg-d	**5.48E+00**	**1.4E+01**
		Nickel	3.79E-01	mg/kg	3.79E-01	mg/kg	3.79E-01	4.55E-04	1.16E-03	mg/kg-d	2.0E-02	mg/kg-d	2.27E-02	5.8E-02
		Selenium	3.34E-01	mg/kg	3.34E-01	mg/kg	3.34E-01	4.01E-04	1.02E-03	mg/kg-d	5.0E-03	mg/kg-d	8.02E-02	2.0E-01
		Vanadium	2.48E-02	mg/kg	2.48E-02	mg/kg	2.48E-02	2.98E-05	7.61E-05	mg/kg-d	5.0E-03	mg/kg-d	5.95E-03	1.5E-02
		Zinc	8.44E+00	mg/kg	8.44E+00	mg/kg	8.44E+00	1.01E-02	2.59E-02	mg/kg-d	3.0E-01	mg/kg-d	3.37E-02	8.6E-02
												Hazard Index	**5.8**	**14.8**
Burbot	Ingestion	Aluminum	2.38E+00	mg/kg	2.38E+00	mg/kg	2.38E+00	1.19E-04	3.17E-04	mg/kg-d	1.0E+00	mg/kg-d	1.19E-04	3.2E-04
		Antimony	1.51E-02	mg/kg	1.51E-02	mg/kg	1.51E-02	7.55E-07	2.01E-06	mg/kg-d	4.0E-04	mg/kg-d	1.89E-03	5.0E-03
		Arsenic (Inorganic)	2.66E+00	mg/kg	2.66E-01	mg/kg	2.66E-01	1.33E-05	3.55E-05	mg/kg-d	3.0E-04	mg/kg-d	4.43E-02	1.2E-01
		Barium	3.12E-01	mg/kg	3.12E-01	mg/kg	3.12E-01	1.56E-05	4.16E-05	mg/kg-d	2.0E-01	mg/kg-d	7.80E-05	2.1E-04
		Cadmium	2.11E-03	mg/kg	2.11E-03	mg/kg	2.11E-03	1.06E-07	2.81E-07	mg/kg-d	1.0E-03	mg/kg-d	1.06E-04	2.8E-04
		Chromium	4.21E-01	mg/kg	4.21E-01	mg/kg	4.21E-01	2.11E-05	5.61E-05	mg/kg-d	1.5E+00	mg/kg-d	1.40E-05	3.7E-05
		Copper	4.43E-01	mg/kg	4.43E-01	mg/kg	4.43E-01	2.22E-05	5.91E-05	mg/kg-d	4.0E-02	mg/kg-d	5.54E-04	1.5E-03
		Iron	2.84E+01	mg/kg	2.84E+01	mg/kg	2.84E+01	1.42E-03	3.79E-03	mg/kg-d	7.0E-01	mg/kg-d	2.03E-03	5.4E-03
		Manganese	7.58E-01	mg/kg	7.58E-01	mg/kg	7.58E-01	3.79E-05	1.01E-04	mg/kg-d	1.4E-01	mg/kg-d	2.71E-04	7.2E-04
		Methyl Mercury	3.42E-01	mg/kg	3.42E-01	mg/kg	3.42E-01	1.71E-05	4.56E-05	mg/kg-d	1.0E-04	mg/kg-d	1.71E-01	4.6E-01
		Nickel	3.12E-01	mg/kg	3.12E-01	mg/kg	3.12E-01	1.56E-05	4.16E-05	mg/kg-d	2.0E-02	mg/kg-d	7.80E-04	2.1E-03
		Selenium	5.87E-01	mg/kg	5.87E-01	mg/kg	5.87E-01	2.94E-05	7.83E-05	mg/kg-d	5.0E-03	mg/kg-d	5.87E-03	1.6E-02
		Vanadium	8.80E-02	mg/kg	8.80E-02	mg/kg	8.80E-02	4.40E-06	1.17E-05	mg/kg-d	5.0E-03	mg/kg-d	8.80E-04	2.3E-03
		Zinc	5.74E+00	mg/kg	5.74E+00	mg/kg	5.74E+00	2.87E-04	7.66E-04	mg/kg-d	3.0E-01	mg/kg-d	9.57E-04	2.6E-03
												Hazard Index	0.23	0.61
Whitefish[1]	Ingestion	Aluminum	1.13E+00	mg/kg	1.13E+00	mg/kg	1.13E+00	1.87E-03	4.80E-03	mg/kg-d	1.0E+00	mg/kg-d	1.87E-03	4.8E-03
		Antimony	2.50E-02	mg/kg	2.50E-02	mg/kg	2.50E-02	4.16E-05	1.07E-04	mg/kg-d	4.0E-04	mg/kg-d	1.04E-01	2.7E-01
		Arsenic (inorganic)	3.66E+00	mg/kg	3.66E-01	mg/kg	3.66E-01	6.08E-04	1.56E-03	mg/kg-d	3.0E-04	mg/kg-d	**2.03E+00**	**5.2E+00**
		Barium	1.81E-01	mg/kg	1.81E-01	mg/kg	1.81E-01	3.01E-04	7.72E-04	mg/kg-d	2.0E-01	mg/kg-d	1.50E-03	3.9E-03
		Cadmium	2.50E-02	mg/kg	2.50E-02	mg/kg	2.50E-02	4.16E-05	1.07E-04	mg/kg-d	1.0E-03	mg/kg-d	4.16E-02	1.1E-01
		Chromium	4.60E-02	mg/kg	4.60E-02	mg/kg	4.60E-02	7.65E-05	1.96E-04	mg/kg-d	1.5E+00	mg/kg-d	5.10E-05	1.3E-04
		Copper	6.28E-01	mg/kg	6.28E-01	mg/kg	6.28E-01	1.04E-03	2.68E-03	mg/kg-d	4.0E-02	mg/kg-d	2.61E-02	6.7E-02
		Iron	8.37E+00	mg/kg	8.37E+00	mg/kg	8.37E+00	1.39E-02	3.57E-02	mg/kg-d	7.0E-01	mg/kg-d	1.99E-02	5.1E-02
		Manganese	1.39E-01	mg/kg	1.39E-01	mg/kg	1.39E-01	2.31E-04	5.93E-04	mg/kg-d	1.4E-01	mg/kg-d	1.65E-03	4.2E-03
		Methyl Mercury	2.28E-01	mg/kg	2.28E-01	mg/kg	2.28E-01	3.79E-04	9.73E-04	mg/kg-d	1.0E-04	mg/kg-d	**3.79E+00**	**9.7E+00**
		Nickel	3.47E-01	mg/kg	3.47E-01	mg/kg	3.47E-01	5.77E-04	1.48E-03	mg/kg-d	2.0E-02	mg/kg-d	2.88E-02	7.4E-02
		Selenium	6.19E-01	mg/kg	6.19E-01	mg/kg	6.19E-01	1.03E-03	2.64E-03	mg/kg-d	5.0E-03	mg/kg-d	2.06E-01	5.3E-01
		Vanadium	2.50E-02	mg/kg	2.50E-02	mg/kg	2.50E-02	4.16E-05	1.07E-04	mg/kg-d	5.0E-03	mg/kg-d	8.31E-03	2.1E-02
		Zinc	4.89E+00	mg/kg	4.89E+00	mg/kg	4.89E+00	8.14E-03	2.09E-02	mg/kg-d	3.0E-01	mg/kg-d	2.71E-02	7.0E-02
												Hazard Index	**6.3**	**16.1**

Table 6-20a Calculation of Noncancer Hazards – Resident and Recreational/Subsistence User

Scenario Timeframe: Current/Future
Receptor Population: Residential and Recreational/Subsistence User
Receptor Age: Adult/Child

Medium	Exposure Route	Contaminant of Potential Concern	Medium EPC Value	Medium EPC Units	Route EPC Value	Route EPC Units	EPC Selected for Risk Calculation	Adult Intake	Child Intake	Intake Units	Chronic Reference Dose	Chronic Reference Dose Units	Adult Hazard Quotient	Child Hazard Quotient
Arctic grayling	Ingestion	Aluminum	1.20E+00	mg/kg	1.20E+00	mg/kg	1.20E+00	2.55E-04	6.40E-04	mg/kg-d	1.0E+00	mg/kg-d	2.55E-04	6.4E-04
		Antimony	2.50E-02	mg/kg	2.50E-02	mg/kg	2.50E-02	5.31E-06	1.33E-05	mg/kg-d	4.0E-04	mg/kg-d	1.33E-02	3.3E-02
		Arsenic (inorganic)	3.73E-02	mg/kg	3.73E-03	mg/kg	3.73E-03	7.93E-07	1.99E-06	mg/kg-d	3.0E-04	mg/kg-d	2.64E-03	6.6E-03
		Barium	1.42E-01	mg/kg	1.42E-01	mg/kg	1.42E-01	3.02E-05	7.57E-05	mg/kg-d	2.0E-01	mg/kg-d	1.51E-04	3.8E-04
		Cadmium	2.50E-02	mg/kg	2.50E-02	mg/kg	2.50E-02	5.31E-06	1.33E-05	mg/kg-d	1.0E-03	mg/kg-d	5.31E-03	1.3E-02
		Chromium	6.22E-02	mg/kg	6.22E-02	mg/kg	6.22E-02	1.32E-05	3.32E-05	mg/kg-d	1.5E+00	mg/kg-d	8.81E-06	2.2E-05
		Copper	8.98E-01	mg/kg	8.98E-01	mg/kg	8.98E-01	1.91E-04	4.79E-04	mg/kg-d	4.0E-02	mg/kg-d	4.77E-03	1.2E-02
		Iron	8.23E+00	mg/kg	8.23E+00	mg/kg	8.23E+00	1.75E-03	4.39E-03	mg/kg-d	7.0E-01	mg/kg-d	2.50E-03	6.3E-03
		Manganese	2.79E-01	mg/kg	2.79E-01	mg/kg	2.79E-01	5.93E-05	1.49E-04	mg/kg-d	1.4E-01	mg/kg-d	4.23E-04	1.1E-03
		Methyl Mercury	2.63E-01	mg/kg	2.63E-01	mg/kg	2.63E-01	5.59E-05	1.40E-04	mg/kg-d	1.0E-04	mg/kg-d	5.59E-01	**1.4E+00**
		Nickel	2.60E-02	mg/kg	2.60E-02	mg/kg	2.60E-02	5.53E-06	1.39E-05	mg/kg-d	2.0E-02	mg/kg-d	2.76E-04	6.9E-04
		Selenium	1.21E+00	mg/kg	1.21E+00	mg/kg	1.21E+00	2.56E-04	6.44E-04	mg/kg-d	5.0E-03	mg/kg-d	5.13E-02	1.3E-01
		Vanadium	2.50E-02	mg/kg	2.50E-02	mg/kg	2.50E-02	5.31E-06	1.33E-05	mg/kg-d	5.0E-03	mg/kg-d	1.06E-03	2.7E-03
		Zinc	6.95E+00	mg/kg	6.95E+00	mg/kg	6.95E+00	1.48E-03	3.71E-03	mg/kg-d	3.0E-01	mg/kg-d	4.92E-03	1.2E-02
												Hazard Index	0.65	**1.62**
												Total Hazard Index (Fish)	**13**	**33**

Notes:

1 - The whitefish category is based on the sheefish tissue concentration and an ingestion rate estimated from the sum of ingestion rates for sheefish, broad whitefish, Bering Cisco, Least Cisco, humpback whitefish and unknown whitefish.

Key:
EPC = exposure point concentration
mg/kg = milligrams per kilogram
mg/kg-d = milligram per kilogram per day

Table 6-20b Calculation of Noncancer Hazards with Outliers Removed – Resident and Recreational/Subsistence User[1]

Scenario Timeframe: Current/Future
Receptor Population: Residential and Recreational/Subsistence User
Receptor Age: Adult/Child

Medium	Exposure Route	Contaminant of Potential Concern	Medium EPC Value	Medium EPC Units	Route EPC Value	Route EPC Units	EPC Selected for Risk Calculation	Adult Intake	Child Intake	Intake Units	Chronic Reference Dose	Chronic Reference Dose Units	Adult Hazard Quotient	Child Hazard Quotient
Sediment	Ingestion	Aluminum	5.50E+03	mg/kg	5.50E+03	mg/kg	5.50E+03	3.81E-04	2.26E-03	mg/kg-d	1.0E+00	mg/kg-d	3.81E-04	2.3E-03
		Antimony	4.09E+01	mg/kg	4.09E+01	mg/kg	4.09E+01	2.84E-06	1.68E-05	mg/kg-d	4.0E-04	mg/kg-d	7.09E-03	4.2E-02
		Arsenic	7.70E+01	mg/kg	4.62E+01	mg/kg	4.62E+01	3.20E-06	1.90E-05	mg/kg-d	3.0E-04	mg/kg-d	1.07E-02	6.3E-02
		Barium	8.88E+01	mg/kg	8.88E+01	mg/kg	8.88E+01	6.16E-06	3.65E-05	mg/kg-d	2.0E-01	mg/kg-d	3.08E-05	1.8E-04
		Cadmium	2.18E-01	mg/kg	2.18E-01	mg/kg	2.18E-01	1.51E-08	8.94E-08	mg/kg-d	1.0E-03	mg/kg-d	1.51E-05	8.9E-05
		Chromium	1.65E+01	mg/kg	1.65E+01	mg/kg	1.65E+01	1.15E-06	6.80E-06	mg/kg-d	1.5E+00	mg/kg-d	7.65E-07	4.5E-06
		Cobalt	8.32E+00	mg/kg	8.32E+00	mg/kg	8.32E+00	5.77E-07	3.42E-06	mg/kg-d	3.0E-04	mg/kg-d	1.92E-03	1.1E-02
		Copper	1.21E+01	mg/kg	1.21E+01	mg/kg	1.21E+01	8.40E-07	4.98E-06	mg/kg-d	4.0E-02	mg/kg-d	2.10E-05	1.2E-04
		Iron	1.43E+04	mg/kg	1.43E+04	mg/kg	1.43E+04	9.94E-04	5.89E-03	mg/kg-d	7.0E-01	mg/kg-d	1.42E-03	8.4E-03
		Manganese	7.38E+02	mg/kg	7.38E+02	mg/kg	7.38E+02	5.12E-05	3.03E-04	mg/kg-d	2.4E-02	mg/kg-d	2.13E-03	1.3E-02
		Methylmercury	2.10E-04	mg/kg	2.10E-04	mg/kg	2.10E-04	1.46E-11	8.63E-11	mg/kg-d	1.0E-04	mg/kg-d	1.46E-07	8.6E-07
		Mercury	1.85E+01	mg/kg	1.85E+01	mg/kg	1.85E+01	1.29E-06	7.62E-06	mg/kg-d	3.0E-04	mg/kg-d	4.28E-03	2.5E-02
		Nickel	2.44E+01	mg/kg	2.44E+01	mg/kg	2.44E+01	1.69E-06	1.00E-05	mg/kg-d	2.0E-02	mg/kg-d	8.47E-05	5.0E-04
		Selenium	7.44E-01	mg/kg	7.44E-01	mg/kg	7.44E-01	5.16E-08	3.06E-07	mg/kg-d	5.0E-03	mg/kg-d	1.03E-05	6.1E-05
		Silver	7.54E-02	mg/kg	7.54E-02	mg/kg	7.54E-02	5.23E-09	3.10E-08	mg/kg-d	5.0E-03	mg/kg-d	1.05E-06	6.2E-06
		Thallium	2.82E-02	mg/kg	2.82E-02	mg/kg	2.82E-02	1.95E-09	1.16E-08	mg/kg-d	1.0E-05	mg/kg-d	1.95E-04	1.2E-03
		Vanadium	2.07E+01	mg/kg	2.07E+01	mg/kg	2.07E+01	1.44E-06	8.51E-06	mg/kg-d	5.0E-03	mg/kg-d	2.87E-04	1.7E-03
		Zinc	5.05E+01	mg/kg	5.05E+01	mg/kg	5.05E+01	3.50E-06	2.08E-05	mg/kg-d	3.0E-01	mg/kg-d	1.17E-05	6.9E-05
												Hazard Index	0.03	0.2
Sediment	Dermal	Arsenic	7.70E+01	mg/kg	7.70E+01	mg/kg	7.70E+01	3.00E-06	1.80E-05	mg/kg-d	3.0E-04	mg/kg-d	1.00E-02	6.0E-02
		Cadmium	2.18E-01	mg/kg	2.18E-01	mg/kg	2.18E-01	2.83E-10	1.70E-09	mg/kg-d	2.5E-05	mg/kg-d	1.13E-05	6.8E-05
												Hazard Index	0.01	0.06
												Total Hazard Index (Sediment)	0.04	0.2

Notes:

1 - Result from Sample KR085 were identified as an outlier. Hazards were calculated with EPC for antimony, arsenic, and mercury (shaded) that did not include the outlier result.

Key:
EPC = exposure point concentration
mg/kg = milligrams per kilogram
mg/kg-d = milligram per kilogram per day

Table 6-21 Calculation of Noncancer Hazards – Mine Worker

Scenario Timeframe: Current
Receptor Population: Mine Worker
Receptor Age: Adult

Medium	Exposure Route	Contaminant of Potential Concern	Medium EPC Value	Medium EPC Units	Route EPC Value	Route EPC Units	EPC Selected for Risk Calculation	Adult Intake	Intake Units	Chronic Reference Dose	Chronic Reference Dose Units	Adult Hazard Quotient
Sediment	Ingestion	Aluminum	5.50E+03	mg/kg	5.50E+03	mg/kg	5.50E+03	3.81E-04	mg/kg-d	1.0E+00	mg/kg-d	3.81E-04
		Antimony	3.91E+02	mg/kg	3.91E+02	mg/kg	3.91E+02	2.71E-05	mg/kg-d	4.0E-04	mg/kg-d	6.79E-02
		Arsenic	2.95E+02	mg/kg	1.77E+02	mg/kg	1.77E+02	1.23E-05	mg/kg-d	3.0E-04	mg/kg-d	4.09E-02
		Barium	8.88E+01	mg/kg	8.88E+01	mg/kg	8.88E+01	6.16E-06	mg/kg-d	2.0E-01	mg/kg-d	3.08E-05
		Cadmium	2.18E-01	mg/kg	2.18E-01	mg/kg	2.18E-01	1.51E-08	mg/kg-d	1.0E-03	mg/kg-d	1.51E-05
		Chromium	1.65E+01	mg/kg	1.65E+01	mg/kg	1.65E+01	1.15E-06	mg/kg-d	1.5E+00	mg/kg-d	7.65E-07
		Cobalt	8.32E+00	mg/kg	8.32E+00	mg/kg	8.32E+00	5.77E-07	mg/kg-d	3.0E-04	mg/kg-d	1.92E-03
		Copper	1.21E+01	mg/kg	1.21E+01	mg/kg	1.21E+01	8.40E-07	mg/kg-d	4.0E-02	mg/kg-d	2.10E-05
		Iron	1.43E+04	mg/kg	1.43E+04	mg/kg	1.43E+04	9.94E-04	mg/kg-d	7.0E-01	mg/kg-d	1.42E-03
		Manganese	7.38E+02	mg/kg	7.38E+02	mg/kg	7.38E+02	5.12E-05	mg/kg-d	2.4E-02	mg/kg-d	2.13E-03
		Methylmercury	2.10E-04	mg/kg	2.10E-04	mg/kg	2.10E-04	1.46E-11	mg/kg-d	1.0E-04	mg/kg-d	1.46E-07
		Mercury	4.32E+01	mg/kg	4.32E+01	mg/kg	4.32E+01	3.00E-06	mg/kg-d	3.0E-04	mg/kg-d	9.99E-03
		Nickel	2.44E+01	mg/kg	2.44E+01	mg/kg	2.44E+01	1.69E-06	mg/kg-d	2.0E-02	mg/kg-d	8.47E-05
		Selenium	7.44E-01	mg/kg	7.44E-01	mg/kg	7.44E-01	5.16E-08	mg/kg-d	5.0E-03	mg/kg-d	1.03E-05
		Silver	7.54E-02	mg/kg	7.54E-02	mg/kg	7.54E-02	5.23E-09	mg/kg-d	5.0E-03	mg/kg-d	1.05E-06
		Thallium	2.82E-02	mg/kg	2.82E-02	mg/kg	2.82E-02	1.95E-09	mg/kg-d	1.0E-05	mg/kg-d	1.95E-04
		Vanadium	2.07E+01	mg/kg	2.07E+01	mg/kg	2.07E+01	1.44E-06	mg/kg-d	5.0E-03	mg/kg-d	2.87E-04
		Zinc	5.05E+01	mg/kg	5.05E+01	mg/kg	5.05E+01	3.50E-06	mg/kg-d	3.0E-01	mg/kg-d	1.17E-05
											Hazard Index	0.13
Sediment	Dermal	Arsenic	2.95E+02	mg/kg	2.95E+02	mg/kg	2.95E+02	1.15E-05	mg/kg-d	3.0E-04	mg/kg-d	3.84E-02
		Cadmium	2.18E-01	mg/kg	2.18E-01	mg/kg	2.18E-01	2.84E-10	mg/kg-d	2.5E-05	mg/kg-d	1.14E-05
											Hazard Index	0.038
											Total Hazard Index (Sediment)	0.16

Table 6-21 Calculation of Noncancer Hazards – Mine Worker

Scenario Timeframe: Current
Receptor Population: Mine Worker
Receptor Age: Adult

Medium	Exposure Route	Contaminant of Potential Concern	Medium EPC Value	Medium EPC Units	Route EPC Value	Route EPC Units	EPC Selected for Risk Calculation	Adult Intake	Intake Units	Chronic Reference Dose	Chronic Reference Dose Units	Adult Hazard Quotient
Northern Pike	Ingestion	Aluminum	9.25E+00	mg/kg	9.25E+00	mg/kg	9.25E+00	7.61E-03	mg/kg-d	1.0E+00	mg/kg-d	7.61E-03
		Antimony	9.16E-03	mg/kg	9.16E-03	mg/kg	9.16E-03	7.53E-06	mg/kg-d	4.0E-04	mg/kg-d	1.88E-02
		Arsenic (Inorganic)	2.43E-01	mg/kg	2.43E-02	mg/kg	2.43E-02	2.00E-05	mg/kg-d	3.0E-04	mg/kg-d	6.66E-02
		Barium	1.67E-01	mg/kg	1.67E-01	mg/kg	1.67E-01	1.37E-04	mg/kg-d	2.0E-01	mg/kg-d	6.86E-04
		Cadmium	3.89E-03	mg/kg	3.89E-03	mg/kg	3.89E-03	3.20E-06	mg/kg-d	1.0E-03	mg/kg-d	3.20E-03
		Chromium	1.30E-01	mg/kg	1.30E-01	mg/kg	1.30E-01	1.07E-04	mg/kg-d	1.5E+00	mg/kg-d	7.12E-05
		Copper	4.62E-01	mg/kg	4.62E-01	mg/kg	4.62E-01	3.80E-04	mg/kg-d	4.0E-02	mg/kg-d	9.49E-03
		Iron	8.55E+00	mg/kg	8.55E+00	mg/kg	8.55E+00	7.02E-03	mg/kg-d	7.0E-01	mg/kg-d	1.00E-02
		Manganese	3.05E-01	mg/kg	3.05E-01	mg/kg	3.05E-01	2.51E-04	mg/kg-d	1.4E-01	mg/kg-d	1.79E-03
		Methyl Mercury	4.57E-01	mg/kg	4.57E-01	mg/kg	4.57E-01	3.76E-04	mg/kg-d	1.0E-04	mg/kg-d	**3.76E+00**
		Nickel	3.79E-01	mg/kg	3.79E-01	mg/kg	3.79E-01	3.12E-04	mg/kg-d	2.0E-02	mg/kg-d	1.56E-02
		Selenium	3.34E-01	mg/kg	3.34E-01	mg/kg	3.34E-01	2.75E-04	mg/kg-d	5.0E-03	mg/kg-d	5.49E-02
		Vanadium	2.48E-02	mg/kg	2.48E-02	mg/kg	2.48E-02	2.04E-05	mg/kg-d	5.0E-03	mg/kg-d	4.08E-03
		Zinc	8.44E+00	mg/kg	8.44E+00	mg/kg	8.44E+00	6.93E-03	mg/kg-d	3.0E-01	mg/kg-d	2.31E-02
											Hazard Index	**4.0**
Burbot	Ingestion	Aluminum	2.38E+00	mg/kg	2.38E+00	mg/kg	2.38E+00	8.15E-05	mg/kg-d	1.0E+00	mg/kg-d	8.15E-05
		Antimony	1.51E-02	mg/kg	1.51E-02	mg/kg	1.51E-02	5.17E-07	mg/kg-d	4.0E-04	mg/kg-d	1.29E-03
		Arsenic (Inorganic)	2.66E+00	mg/kg	2.66E-01	mg/kg	2.66E-01	9.11E-06	mg/kg-d	3.0E-04	mg/kg-d	3.04E-02
		Barium	3.12E-01	mg/kg	3.12E-01	mg/kg	3.12E-01	1.07E-05	mg/kg-d	2.0E-01	mg/kg-d	5.34E-05
		Cadmium	2.11E-03	mg/kg	2.11E-03	mg/kg	2.11E-03	7.23E-08	mg/kg-d	1.0E-03	mg/kg-d	7.23E-05
		Chromium	4.21E-01	mg/kg	4.21E-01	mg/kg	4.21E-01	1.44E-05	mg/kg-d	1.5E+00	mg/kg-d	9.61E-06
		Copper	4.43E-01	mg/kg	4.43E-01	mg/kg	4.43E-01	1.52E-05	mg/kg-d	4.0E-02	mg/kg-d	3.79E-04
		Iron	2.84E+01	mg/kg	2.84E+01	mg/kg	2.84E+01	9.73E-04	mg/kg-d	7.0E-01	mg/kg-d	1.39E-03
		Manganese	7.58E-01	mg/kg	7.58E-01	mg/kg	7.58E-01	2.60E-05	mg/kg-d	1.4E-01	mg/kg-d	1.85E-04
		Methyl Mercury	3.42E-01	mg/kg	3.42E-01	mg/kg	3.42E-01	1.17E-05	mg/kg-d	1.0E-04	mg/kg-d	1.17E-01
		Nickel	3.12E-01	mg/kg	3.12E-01	mg/kg	3.12E-01	1.07E-05	mg/kg-d	2.0E-02	mg/kg-d	5.34E-04
		Selenium	5.87E-01	mg/kg	5.87E-01	mg/kg	5.87E-01	2.01E-05	mg/kg-d	5.0E-03	mg/kg-d	4.02E-03
		Vanadium	8.80E-02	mg/kg	8.80E-02	mg/kg	8.80E-02	3.01E-06	mg/kg-d	5.0E-03	mg/kg-d	6.03E-04
		Zinc	5.74E+00	mg/kg	5.74E+00	mg/kg	5.74E+00	1.97E-04	mg/kg-d	3.0E-01	mg/kg-d	6.56E-04
											Hazard Index	0.16

Table 6-21 Calculation of Noncancer Hazards – Mine Worker

Scenario Timeframe: Current
Receptor Population: Mine Worker
Receptor Age: Adult

Medium	Exposure Route	Contaminant of Potential Concern	Medium EPC Value	Medium EPC Units	Route EPC Value	Route EPC Units	EPC Selected for Risk Calculation	Adult Intake	Intake Units	Chronic Reference Dose	Chronic Reference Dose Units	Adult Hazard Quotient
Whitefish[1]	Ingestion	Aluminum	1.13E+00	mg/kg	1.13E+00	mg/kg	1.13E+00	1.28E-03	mg/kg-d	1.0E+00	mg/kg-d	1.28E-03
		Antimony	2.50E-02	mg/kg	2.50E-02	mg/kg	2.50E-02	2.85E-05	mg/kg-d	4.0E-04	mg/kg-d	7.12E-02
		Arsenic (inorganic)	3.66E+00	mg/kg	3.66E-01	mg/kg	3.66E-01	4.17E-04	mg/kg-d	3.0E-04	mg/kg-d	**1.39E+00**
		Barium	1.81E-01	mg/kg	1.81E-01	mg/kg	1.81E-01	2.06E-04	mg/kg-d	2.0E-01	mg/kg-d	1.03E-03
		Cadmium	2.50E-02	mg/kg	2.50E-02	mg/kg	2.50E-02	2.85E-05	mg/kg-d	1.0E-03	mg/kg-d	2.85E-02
		Chromium	4.60E-02	mg/kg	4.60E-02	mg/kg	4.60E-02	5.24E-05	mg/kg-d	1.5E+00	mg/kg-d	3.49E-05
		Copper	6.28E-01	mg/kg	6.28E-01	mg/kg	6.28E-01	7.15E-04	mg/kg-d	4.0E-02	mg/kg-d	1.79E-02
		Iron	8.37E+00	mg/kg	8.37E+00	mg/kg	8.37E+00	9.53E-03	mg/kg-d	7.0E-01	mg/kg-d	1.36E-02
		Manganese	1.39E-01	mg/kg	1.39E-01	mg/kg	1.39E-01	1.58E-04	mg/kg-d	1.4E-01	mg/kg-d	1.13E-03
		Methyl Mercury	2.28E-01	mg/kg	2.28E-01	mg/kg	2.28E-01	2.60E-04	mg/kg-d	1.0E-04	mg/kg-d	**2.60E+00**
		Nickel	3.47E-01	mg/kg	3.47E-01	mg/kg	3.47E-01	3.95E-04	mg/kg-d	2.0E-02	mg/kg-d	1.98E-02
		Selenium	6.19E-01	mg/kg	6.19E-01	mg/kg	6.19E-01	7.05E-04	mg/kg-d	5.0E-03	mg/kg-d	1.41E-01
		Vanadium	2.50E-02	mg/kg	2.50E-02	mg/kg	2.50E-02	2.85E-05	mg/kg-d	5.0E-03	mg/kg-d	5.69E-03
		Zinc	4.89E+00	mg/kg	4.89E+00	mg/kg	4.89E+00	5.57E-03	mg/kg-d	3.0E-01	mg/kg-d	1.86E-02
											Hazard Index	**4.3**
Arctic grayling	Ingestion	Aluminum	1.20E+00	mg/kg	1.20E+00	mg/kg	1.20E+00	1.75E-04	mg/kg-d	1.0E+00	mg/kg-d	1.75E-04
		Antimony	2.50E-02	mg/kg	2.50E-02	mg/kg	2.50E-02	3.64E-06	mg/kg-d	4.0E-04	mg/kg-d	9.10E-03
		Arsenic (inorganic)	3.73E-02	mg/kg	3.73E-03	mg/kg	3.73E-03	5.43E-07	mg/kg-d	3.0E-04	mg/kg-d	1.81E-03
		Barium	1.42E-01	mg/kg	1.42E-01	mg/kg	1.42E-01	2.07E-05	mg/kg-d	2.0E-01	mg/kg-d	1.03E-04
		Cadmium	2.50E-02	mg/kg	2.50E-02	mg/kg	2.50E-02	3.64E-06	mg/kg-d	1.0E-03	mg/kg-d	3.64E-03
		Chromium	6.22E-02	mg/kg	6.22E-02	mg/kg	6.22E-02	9.05E-06	mg/kg-d	1.5E+00	mg/kg-d	6.04E-06
		Copper	8.98E-01	mg/kg	8.98E-01	mg/kg	8.98E-01	1.31E-04	mg/kg-d	4.0E-02	mg/kg-d	3.27E-03
		Iron	8.23E+00	mg/kg	8.23E+00	mg/kg	8.23E+00	1.20E-03	mg/kg-d	7.0E-01	mg/kg-d	1.71E-03
		Manganese	2.79E-01	mg/kg	2.79E-01	mg/kg	2.79E-01	4.06E-05	mg/kg-d	1.4E-01	mg/kg-d	2.90E-04
		Methyl Mercury	2.63E-01	mg/kg	2.63E-01	mg/kg	2.63E-01	3.83E-05	mg/kg-d	1.0E-04	mg/kg-d	3.83E-01
		Nickel	2.60E-02	mg/kg	2.60E-02	mg/kg	2.60E-02	3.78E-06	mg/kg-d	2.0E-02	mg/kg-d	1.89E-04
		Selenium	1.21E+00	mg/kg	1.21E+00	mg/kg	1.21E+00	1.76E-04	mg/kg-d	5.0E-03	mg/kg-d	3.51E-02
		Vanadium	2.50E-02	mg/kg	2.50E-02	mg/kg	2.50E-02	3.64E-06	mg/kg-d	5.0E-03	mg/kg-d	7.28E-04
		Zinc	6.95E+00	mg/kg	6.95E+00	mg/kg	6.95E+00	1.01E-03	mg/kg-d	3.0E-01	mg/kg-d	3.37E-03
											Hazard Index	0.44
											Total Hazard Index (Fish)	**8.9**

Notes:

1 - The whitefish category is based on the sheefish tissue concentration and an ingestion rate estimated from the sum of ingestion rates for sheefish, broad whitefish, Bering Cisco, Least Cisco, humpback whitefish and unknown whitefish.

Key:
EPC = exposure point concentration
mg/kg = milligrams per kilogram
mg/kg-d = milligram per kilogram per day

Table 6-22 Summary of Hazard Indices for Red Devil Mine Region[1]

Medium	Exposure Route	Future Resident		Recreational/ Subsistence User		Mine Worker
		Adult	Child	Adult	Child	Adult
Soil[2]	Ingestion	27	248	7	65	19
	Dermal	2.9	19	0.72	4.7	3.3
Sediment	Ingestion	0.13	0.74	0.13	0.74	0.13
	Dermal	0.038	0.23	0.038	0.23	0.038
Groundwater	Ingestion	1330	3102	--	--	950
	Dermal	35	103	--	--	25
Surface Water	Ingestion	--	--	0.00034	0.00078	--
	Dermal	0.06	0.13	0.020	0.045	0.039
Air	Inhalation of Fugitive Dust/Volatiles from Soil	56	56	14	14	13
	Inhalation of Volatiles from Groundwater	2.8	2.8	--	--	--
Fish	Ingestion	13.0	33	13.0	33	8.9
Large Land Mammals	Ingestion	8.1	18	0.11	0.25	0.078
Small Land Mammals	Ingestion	10	22	0.19	0.43	0.13
Birds	Ingestion	14	30	4.5	10	3.1
Berries and Plants	Ingestion	170	381	1.3	3.0	0.91
	Total Hazard Index	1667	4016	41	131	1023

Notes:

Shaded cell indicates HI greater than 1.0.

1 - Only hazards from exposure to sediment and fish have been updated in the HHRA Supplement. All other hazards from Baseline HHRA (E & E 2014).

2 - Hazards from Mine Processing Area from Baseline HHRA (E & E 2014), reduced by 12.5% to account for incidental ingestion of sediment pathway.

Table 6-23 Inorganic Arsenic and Methylmercury Hazards

COPC	Fish Species	HQ				
		Resident - Adult	Resident - Child	Recreational/ Subsisnce User - Adult	Recreational/ Subsisnce User - Child	Mine Worker - Adult
Arsenic (Inorganic)	Sediment	0.08	0.47	0.08	0.47	0.08
	Northern Pike	0.10	0.25	0.10	0.25	0.07
	Burbot	0.04	0.12	0.04	0.12	0.03
	Whitefish	**2.0**	**5.2**	**2.0**	**5.2**	**1.4**
	Arctic Grayling	0.003	0.007	0.003	0.007	0.002
	Total Arsenic HI	**2.3**	**6.0**	**2.3**	**6.0**	**1.6**
Methylmercury	Sediment	1.5E-07	8.6E-07	1.5E-07	8.6E-07	1.5E-07
	Northern Pike	**5.5**	**14.0**	**5.5**	**14.0**	**3.8**
	Burbot	0.17	0.46	0.17	0.46	0.12
	Whitefish	**3.8**	**9.7**	**3.8**	**9.7**	**2.6**
	Arctic Grayling	0.56	**1.40**	0.56	**1.40**	0.38
	Total Fish Consumption HI	**10.0**	**25.6**	**10.0**	**25.6**	**6.9**

Key:

COPC = compound of potential concern

HI = hazard index

HQ = hazard quotient

Bolded text indicates HQ or HI is above ADEC and EPA standard of 1.0.

Table 6-24 Background Exposure Point Concentration for Kuskokwim River Sediments

Analyte	Number of Observations	Number of Detections	Minium Detected Concentration (mg/kg)	Maximum Detected Concentration (mg/kg)	Distribution	Background Exposure Point Concentration			
						95% UCL	95% UCL Statistic	Recommened Background EPC (mg/kg)	Background Rationale
Aluminum	15	15	2,160	12,500	Normal	9,409	95% Students-t	9,409	95% UCL
Antimony	15	14	0.133	0.79	Lognormal	0.357	KM H-UCL	0.357	95% UCL
Arsenic	15	15	3.67	15	Normal	8.83	95% Students-t	8.83	95% UCL
Barium	15	15	55.6	158	Not Discernable	126.1	95% Students-t	126.1	95% UCL
Beryllium	15	15	0.13	0.538	Normal	0.37	95% Students-t	0.37	95% UCL
Cadmium	15	15	0.069	0.82	Normal	0.37	95% Students-t	0.37	95% UCL
Calcium	15	15	762	4,800	Normal	2726	95% Students-t	2,726	95% UCL
Chromium	15	15	10.7	29	Normal	20.05	95% Students-t	20.05	95% UCL
Cobalt	15	15	3.83	15	Normal	10.77	95% Students-t	10.77	95% UCL
Copper	15	15	4.62	56.2	Normal	29.67	95% Students-t	29.67	95% UCL
Iron	15	15	8,170	33,900	Normal	24,876	95% Students-t	24,876	95% UCL
Lead	15	15	1.82	13.5	Normal	8.66	95% Students-t	8.66	95% UCL
Magnesium	15	15	1,400	5,900	Normal	4,340	95% Students-t	4,340	95% UCL
Manganese	15	15	197	1,200	Normal	574	95% Students-t	574	95% UCL
Mercury	15	15	0.013	0.374	Gamma	0.14	95% Adjusted Gamma	0.14	95% UCL
Methylmercury	5	4	0.00006	0.00049	Normal	0.000392	95% KM (t)	0.000392	95% UCL
Nickel	15	15	10.7	51.7	Normal	32.72	95% Students-t	32.72	95% UCL
Potassium	15	15	418	1,280	Normal	791.7	95% Students-t	791.7	95% UCL
Selenium	15	14	0.04	1.9	Gamma	0.854	Adjusted KM-UCL	0.854	95% UCL
Silver	15	14	0.0078	0.14	Normal	0.0913	95% KM (t)	0.0913	95% UCL
Sodium	15	15	35.9	170	Normal	95.18	95% Students-t	95.18	95% UCL
Thallium	15	13	0.035	0.105	Normal	0.0832	95% KM (t)	0.0832	95% UCL
Vanadium	15	15	11.9	36.3	Normal	27.86	95% Students-t	27.86	95% UCL
Zinc	15	15	21.8	174	Normal	87.65	95% Students-t	87.65	95% UCL

Key:

mg/kg = milligrams per kilogram

EPC = exposure point concentration

UCL = Upper Confidence Limit

Table 6-25a Calculation of Cancer Risks at Background Levels - Residential and Recreational/Subsistence User

Scenario Timeframe: Current/Future
Receptor Population: Residential and Recrecation/Subsistence User
Receptor Age: Combined Adult/Child

Medium	Exposure Route	Contaminant of Potential Concern[1]	Medium EPC Value	Medium EPC Units	Route EPC Value	Route EPC Units	EPC Selected for Risk Calculation	Intake	Intake Units	Slope Factor	Slope Factor Units	Cancer Risk
Sediment	Ingestion	Arsenic	8.83E+00	mg/kg	5.30E+00	mg/kg	5.30E+00	4.39E-07	mg/kg-d	1.5E+00	$(mg/kg\text{-}d)^{-1}$	6.6E-07
Sediment	Dermal	Arsenic	8.83E+00	mg/kg	8.83E+00	mg/kg	8.83E+00	4.14E-07	mg/kg-d	1.5E+00	$(mg/kg\text{-}d)^{-1}$	6.2E-07
											Cancer Risk (Background Sediment)	1.3E-06

Notes:

1 - Sediment EPC value based on recommended background levels from Table 6-24.

Key:
EPC = exposure point concentration
mg/kg = milligrams per kilogram
mg/kg-d = milligram per kilogram per day

Table 6-25b Calculation of Noncancer Hazards at Background Levels - Residential and Recreational/Subsistence User

Scenario Timeframe: Current/Future
Receptor Population: Residential and Recreational/Subsistence User
Receptor Age: Adult/Child

Medium	Exposure Route	Contaminant of Potential Concern[1]	Medium EPC Value[1]	Medium EPC Units	Route EPC Value	Route EPC Units	EPC Selected for Risk Calculation	Adult Intake	Child Intake	Intake Units	Chronic Reference Dose	Chronic Reference Dose Units	Adult Hazard Quotient	Child Hazard Quotient
Sediment	Ingestion	Aluminum	9.41E+03	mg/kg	9.41E+03	mg/kg	9.41E+03	6.53E-04	3.87E-03	mg/kg-d	1.0E+00	mg/kg-d	6.53E-04	3.9E-03
		Antimony	3.57E-01	mg/kg	3.57E-01	mg/kg	3.57E-01	2.48E-08	1.47E-07	mg/kg-d	4.0E-04	mg/kg-d	6.19E-05	3.7E-04
		Arsenic	8.83E+00	mg/kg	5.30E+00	mg/kg	5.30E+00	3.67E-07	2.18E-06	mg/kg-d	3.0E-04	mg/kg-d	1.22E-03	7.3E-03
		Barium	1.26E+02	mg/kg	1.26E+02	mg/kg	1.26E+02	8.74E-06	5.18E-05	mg/kg-d	2.0E-01	mg/kg-d	4.37E-05	2.6E-04
		Cadmium	3.70E-01	mg/kg	3.70E-01	mg/kg	3.70E-01	2.57E-08	1.52E-07	mg/kg-d	1.0E-03	mg/kg-d	2.57E-05	1.5E-04
		Chromium	2.01E+01	mg/kg	2.01E+01	mg/kg	2.01E+01	1.39E-06	8.24E-06	mg/kg-d	1.5E+00	mg/kg-d	9.27E-07	5.5E-06
		Cobalt	1.08E+01	mg/kg	1.08E+01	mg/kg	1.08E+01	7.47E-07	4.43E-06	mg/kg-d	3.0E-04	mg/kg-d	2.49E-03	1.5E-02
		Copper	2.97E+01	mg/kg	2.97E+01	mg/kg	2.97E+01	2.06E-06	1.22E-05	mg/kg-d	4.0E-02	mg/kg-d	5.14E-05	3.0E-04
		Iron	2.49E+04	mg/kg	2.49E+04	mg/kg	2.49E+04	1.73E-03	1.02E-02	mg/kg-d	7.0E-01	mg/kg-d	2.46E-03	1.5E-02
		Manganese	5.74E+02	mg/kg	5.74E+02	mg/kg	5.74E+02	3.98E-05	2.36E-04	mg/kg-d	2.4E-02	mg/kg-d	1.66E-03	9.8E-03
		Methyl Mercury	3.92E-04	mg/kg	3.92E-04	mg/kg	3.92E-04	2.72E-11	1.61E-10	mg/kg-d	1.0E-04	mg/kg-d	2.72E-07	1.6E-06
		Mercury	1.40E-01	mg/kg	1.40E-01	mg/kg	1.40E-01	9.71E-09	5.75E-08	mg/kg-d	3.0E-04	mg/kg-d	3.24E-05	1.9E-04
		Nickel	3.27E+01	mg/kg	3.27E+01	mg/kg	3.27E+01	2.27E-06	1.34E-05	mg/kg-d	2.0E-02	mg/kg-d	1.13E-04	6.7E-04
		Selenium	8.54E-01	mg/kg	8.54E-01	mg/kg	8.54E-01	5.92E-08	3.51E-07	mg/kg-d	5.0E-03	mg/kg-d	1.18E-05	7.0E-05
		Silver	9.13E-02	mg/kg	9.13E-02	mg/kg	9.13E-02	6.33E-09	3.75E-08	mg/kg-d	5.0E-03	mg/kg-d	1.27E-06	7.5E-06
		Thallium	8.32E-02	mg/kg	8.32E-02	mg/kg	8.32E-02	5.77E-09	3.42E-08	mg/kg-d	1.0E-05	mg/kg-d	5.77E-04	3.4E-03
		Vanadium	2.79E+01	mg/kg	2.79E+01	mg/kg	2.79E+01	1.93E-06	1.14E-05	mg/kg-d	5.0E-03	mg/kg-d	3.86E-04	2.3E-03
		Zinc	8.77E+01	mg/kg	8.77E+01	mg/kg	8.77E+01	6.08E-06	3.60E-05	mg/kg-d	3.0E-01	mg/kg-d	2.03E-05	1.2E-04
												Hazard Index	0.01	0.06
Sediment	Dermal	Arsenic	8.83E+00	mg/kg	8.83E+00	mg/kg	8.83E+00	3.45E-07	2.07E-06	mg/kg-d	3.0E-04	mg/kg-d	1.15E-03	6.9E-03
		Cadmium	3.70E-01	mg/kg	3.70E-01	mg/kg	3.70E-01	4.82E-10	2.89E-09	mg/kg-d	2.5E-05	mg/kg-d	1.93E-05	1.2E-04
												Hazard Index	0.001	0.007
												Total Hazard Index (Sediment)	0.01	0.07

Notes:

1 - Sediment EPC value based on recommended background levels from Table 6-24.

Key:
EPC = exposure point concentration
mg/kg = milligrams per kilogram
mg/kg-d = milligram per kilogram per day

Table 6-26a. Total, Background, and Site Cancer Risks for Future Residents and Recreational/Subsistence Users[1]

Medium	Exposure Route	Total Risk[2]	Background Risk[3]	Site-Related Risks[4]
Sediment	Ingestion	**2E-05**	7E-07	**2E-05**
	Dermal	**2E-05**	6E-07	**2E-05**

Notes:

Bolded text indicates excess lifetime cancer risk greater than 10^{-5}.

1 - Future Resident and Recreational/Subsisence User exposure and resulting cancer risk are equal for exposure to sediment.

2 - Total risk from Table 6-17a, includes outlier results.

3 - Background risk from Table 6-25a.

4 - Site-related risks are determined by subtracting the background risk from total risk.

Table 6-26b. Total, Background, and Site Hazards for Future Residents and Recreational/Subsistence Users[1]

Medium	Exposure Route	Total Hazard[2]		Background Hazard[3]		Site-Related Hazard[4]	
		Adult	Child	Adult	Child	Adult	Child
Sediment	Ingestion	0.13	0.74	0.01	0.06	0.12	0.68
	Dermal	0.038	0.230	0.001	0.007	0.037	0.223

Notes:

Bolded text indicates hazard index greater than 1.0.

1 - Future Resident and Recreational/Subsisence User exposure and resulting hazard index are equal for exposure to sediment.

2 - Total hazard from Table 6-20a, includes outlier results.

3 - Background hazards from Table 6-25b.

4 - Site-related hazards are determined by subtracting the background hazard from total hazard.

Table 6-27a Comparison of Modeled and Actual Subsistence Fish Concentrations Based on Site BSAFs and TTFs

Contaminant of Potential Concern	Sediment EPC (mg/kg)	Modeled Slimy Sculpin EPC (mg/kg-wet)			Food Chain Multiplier	Estimated Subsistence Fish EPC (mg/kg wet)	Subsistence Fish EPC (mg/kg wet)			
		Site BSAF	Site TTF	EPC (mg/kg)			Northern Pike	Burbot	Sheefish	Arctic Grayling
Aluminum	NA	NA	NA	NA	1	NA	9.254	2.380	1.126	1.200
Antimony	25.3	0.002	0.80	0.04	1	0.04	0.009	0.015	ND	ND
Arsenic	26.9	0.025	0.063	0.04	1	0.04	0.243	2.659	3.659	0.037
Barium	77.2	0.004	0.36	0.11	1	0.1	0.167	0.312	0.181	0.142
Cadmium	2.67	0.095	0.46	0.24	1	0.24	0.004	0.002	ND	ND
Chromium	18.7	0.003	0.37	0.021	1	0.021	0.130	0.421	0.046	0.062
Cobalt	9.6	--	--	9.6	1	9.6	NA	NA	NA	NA
Copper	29.5	0.120	0.12	0.42	1	0.420	0.462	0.443	0.628	0.898
Iron	NA	NA	NA	NA	1	NA	8.545	28.410	8.371	8.225
Manganese	449	0.023	0.14	1.44	1	1.44	0.305	0.758	0.139	0.279
Mercury	4.5	0.008	0.66	0.02	1	0.02	0.457	0.324	0.228	0.263
Methylmercury[2]	0.00011	0.081	2.74	0.00002	3	0.00006	0.457	0.324	0.228	0.263
Nickel	28.6	0.014	0.08	0.032	1	0.032	0.379	0.312	0.347	0.026
Selenium	0.98	2.180	0.46	0.99	1	0.99	0.334	0.587	0.619	1.207
Silver	0.086	--	--	0.09	1	0.09	NA	NA	NA	NA
Thallium	0.077	--	--	0.08	1	0.08	NA	NA	NA	NA
Vanadium	27.0	0.003	0.24	0.02	1	0.02	0.025	0.088	ND	ND
Zinc	67.9	0.314	0.57	12.15	1	12.15	8.436	5.743	4.894	6.949

Key:

BSAF = Biota sediment accumulation factor

EPC = Exposure Point Concentration

mg/kg = milligrams per kilogram

NA - Not available

ND - Not detected

TTF = Trophic transfer factor

Notes:

1 - Based on Site BSAFs and TTFs, see Table 7-7a.

2 - Assumes 100% of total mercury in fish tissue is methylmercury.

Red shaded indicates actual fish tissue concentration greater than modeled concentrations.

Table 6-27b Comparison of Modeled and Actual Subsistence Fish Concentrations Based on Background BSAFs and TTFs

Contaminant of Potential Concern	Sediment EPC (mg/kg)	Modeled Slimy Sculpin EPC (mg/kg-wet)			Food Chain Multiplier	Estimated Subsistence Fish EPC (mg/kg wet)	Subsistence Fish EPC (mg/kg wet)			
		Site BSAF	Site TTF	EPC (mg/kg)			Northern Pike	Burbot	Sheefish	Arctic Grayling
Aluminum	NA	NA	NA	NA	1	NA	9.254	2.380	1.126	1.200
Antimony	25.3	0.044	0.28	0.31	1	0.31	0.009	0.015	ND	ND
Arsenic	26.9	0.079	0.11	0.24	1	0.24	0.243	2.659	3.659	0.037
Barium	77.2	0.014	0.04	0.04	1	0.0	0.167	0.312	0.181	0.142
Cadmium	2.67	1.64	0.11	0.482	1	0.48	0.004	0.002	ND	ND
Chromium	18.7	0.015	0.08	0.024	1	0.024	0.130	0.421	0.046	0.062
Cobalt	9.6	--	--	9.60	1	9.6	NA	NA	NA	NA
Copper	29.5	0.530	0.10	1.53	1	1.53	0.462	0.443	0.628	0.898
Iron	NA	NA	NA	NA	1	NA	8.545	28.410	8.371	8.225
Manganese	449	0.097	0.08	3.31	1	3.31	0.305	0.758	0.139	0.279
Mercury	4.5	0.16	1.45	1.02	1	1.02	0.457	0.324	0.228	0.263
Methylmercury[2]	0.00011	17.8	3.17	0.00625	3	0.01875	0.457	0.324	0.228	0.263
Nickel	28.6	0.028	0.05	0.038	1	0.038	0.379	0.312	0.347	0.026
Selenium	0.98	2.68	0.85	2.24	1	2.24	0.334	0.587	0.619	1.207
Silver	0.086	--	--	0.09	1	0.09	NA	NA	NA	NA
Thallium	0.077	--	--	0.08	1	0.08	NA	NA	NA	NA
Vanadium	27.0	0.014	0.10	0.04	1	0.04	0.025	0.088	ND	ND
Zinc	67.9	0.38	0.47	12.12	1	12.12	8.436	5.743	4.894	6.949

Key:

BSAF = Biota sediment accumulation factor

EPC = Exposure Point Concentration

mg/kg = milligrams per kilogram

NA - Not available

ND - Not detected

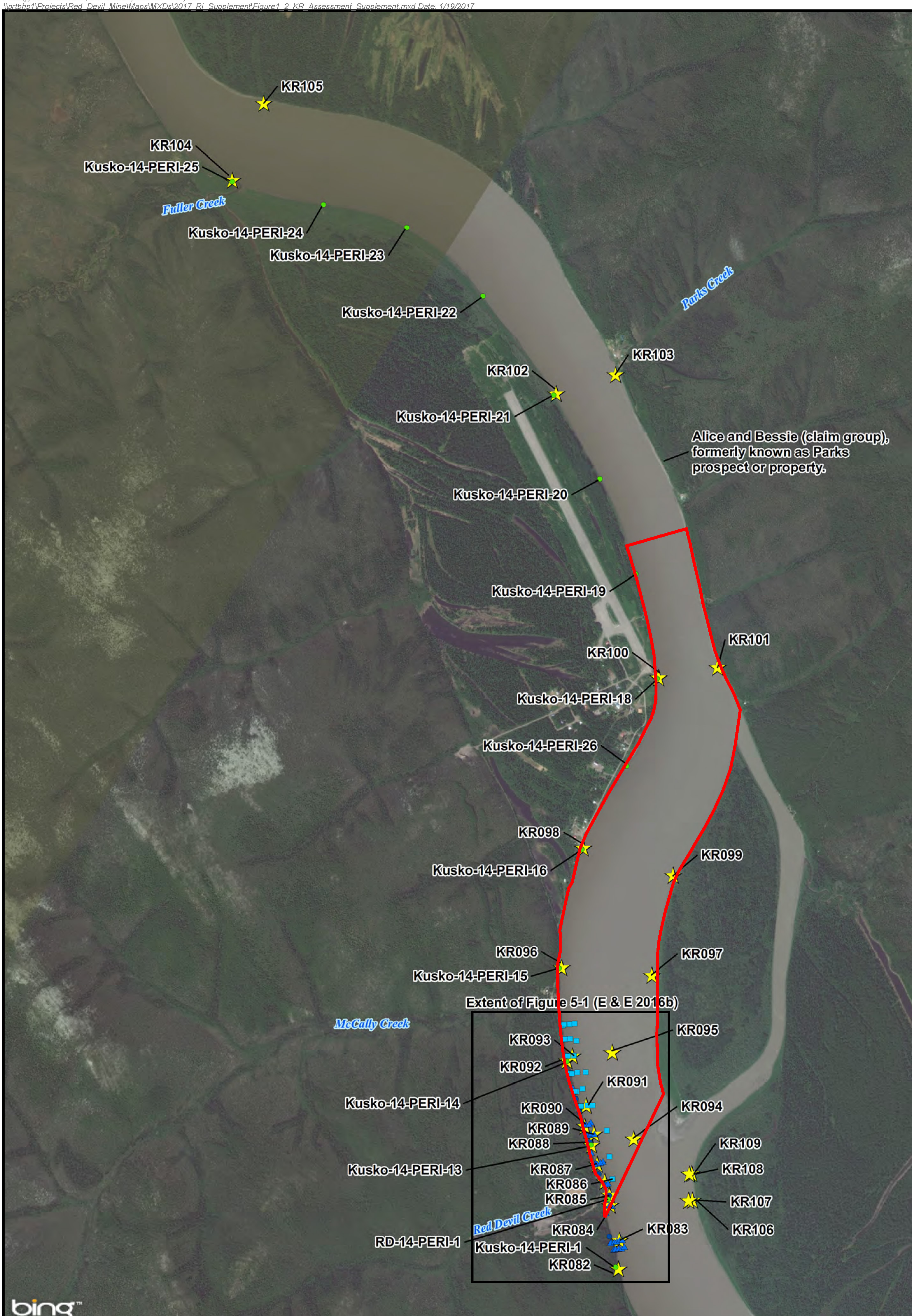
TTF = Trophic transfer factor

Notes:

1 - Based on Site BSAFs and TTFs, see Table 7-7b.

2 - Assumes 100% of total mercury in fish tissue is methylmercury.

Red shaded indicates actual fish tissue concentration greater than modeled concentrations.



2015 Sediment Sample Locations
2014 BLM Periphyton Sample Locations
2012 RI Sediment Sample Locaiton
2011 RI Sediment Sample Location
2010 RI Sediment Sample Location
Area Addressed in Kuskokwim River Risk Assessment Supplement

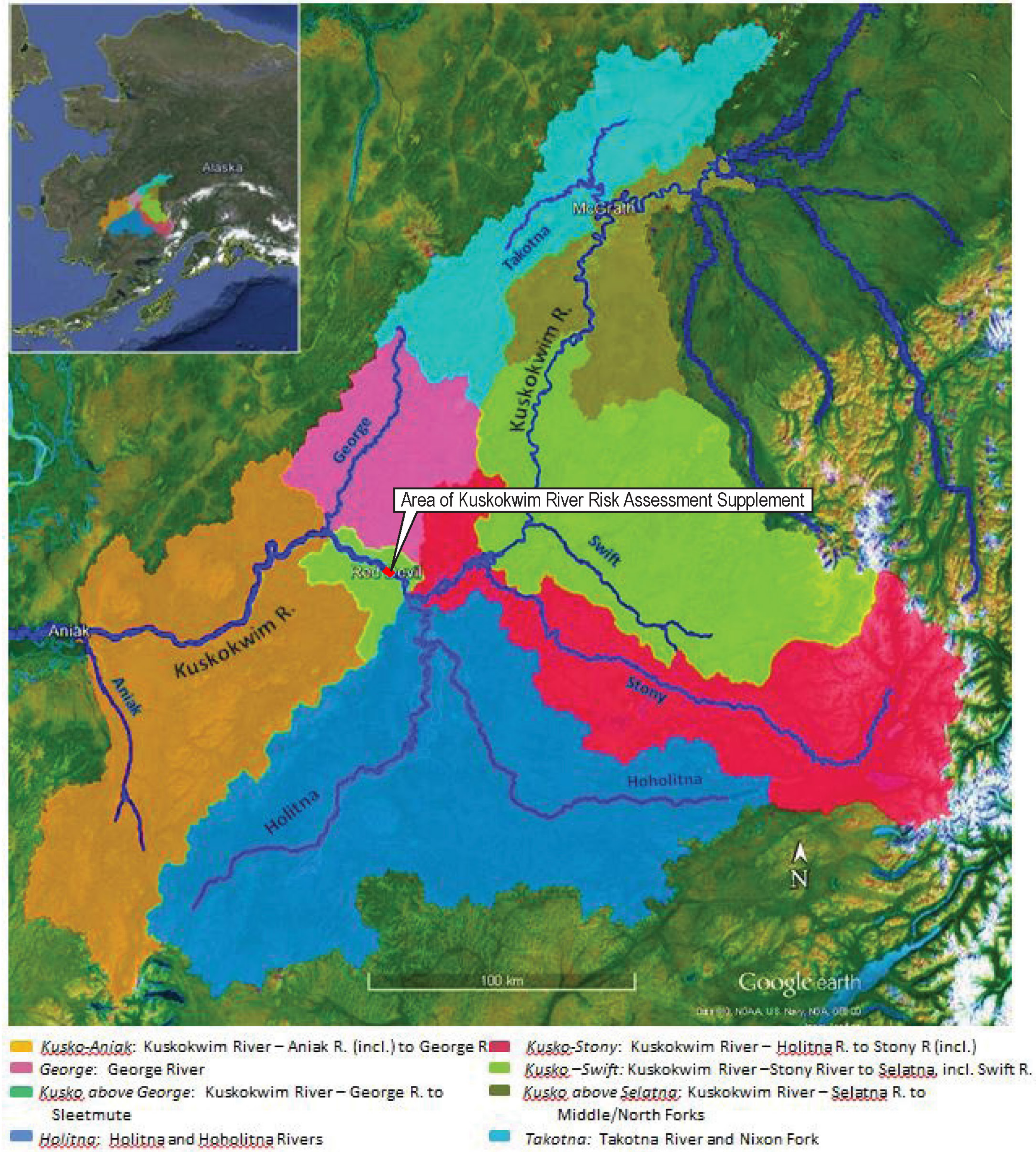
References: E & E (2016b), Miller et al. (1989)

RED DEVIL MINE

Red Devil, Alaska

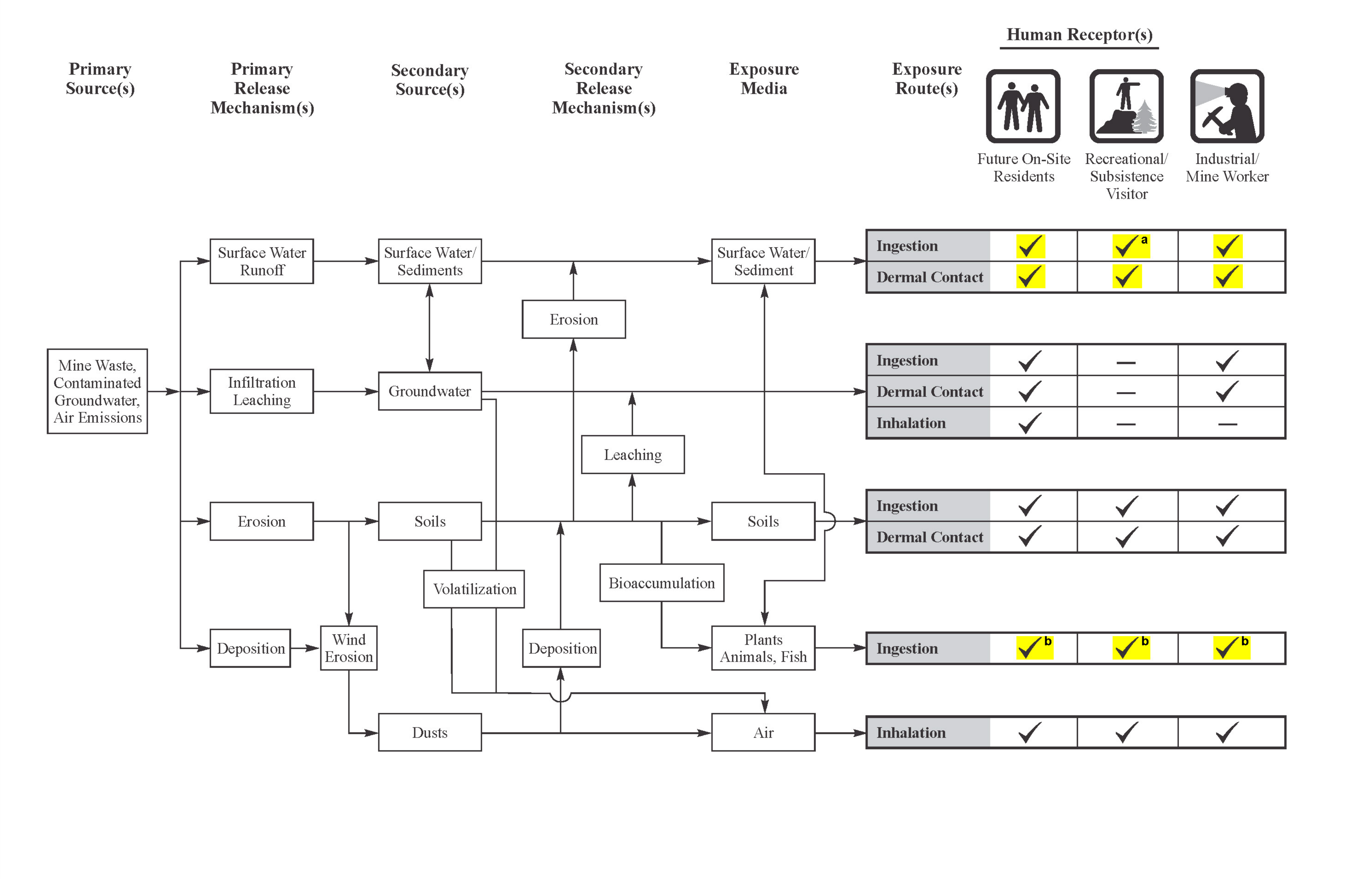
Figure 6-1
Kuskokwim River Sediment Exposure Area

0 0.075 0.15 0.3 0.45 0.6
Miles
0 0.125 0.25 0.5 0.75 1
Kilometers
Scale 1:2,500



Note: Adapted from Matz at al. (2017) Figure 7.

RED DEVIL MINE Red Devil, Alaska	**Figure 6-2** **Area of Kuskokwim River Risk Assessment Supplement and Watersheds in the Middle Kuskokwim Region**



Key:

→	Potentially Complete Pathway
✓	Complete Exposure Route
—	Incomplete/Insignificant Route
✓ (highlighted)	Complete Exposure Route and Receptor evaluated as part of Kuskokwim River Risk Assessment Supplement

a Ingestion of surface water was evaluated in the Baseline HHRA for the Recreational/Subsistence user. The HHRA Supplement evaluates incidental ingestion of sediment for all three receptor groups.

b Ingestion of fish updated in HHRA Supplement

RED DEVIL MINE

Red Devil, Alaska

Figure 6-3
HUMAN HEALTH CONCEPTUAL SITE MODEL FOR KUSKOKWIM RIVER RISK ASSESSMENT SUPPLEMENT

7 Kuskokwim River Ecological Risk Assessment

7.1 Introduction

This section presents the supplement to the final BERA for the RDM presented in the *Final Remedial Investigation Report, Red Devil Mine, Alaska* (E & E 2014). The BERA supplement is focused on aquatic-dependent receptors that may use the Kuskokwim River near the RDM, including benthos, fish, and wildlife. Since the final RI report was completed, substantial additional data were collected by E & E and the BLM from the Kuskokwim River near the RDM and from the middle Kuskokwim River region in general. These data were used to help understand potential risks to aquatic-dependent receptors that use the Kuskokwim River near and downstream from the RDM, as described in the Proposed Technical Approach for the Kuskokwim River Risk Assessment Supplement (BLM 2017), which was approved by the EPA and Alaska Department of Environmental Conservation (ADEC).

The BERA supplement for the Kuskokwim River was conducted in accordance with EPA and ADEC ERA guidance, including but not limited to:

- Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments (EPA 1997b);
- Guidelines for Ecological Risk Assessment (EPA 1998);
- Wildlife Exposure Factors Handbook (EPA 1993);
- State of Alaska Risk Assessment Procedures Manual (ADEC 2015); and
- Ecoscoping Guidance: A Tool for Developing an Ecological Conceptual Site Model (ADEC 2014).

The following sections present the problem formulation, exposure assessment, ecological effects assessment, risk characterization, discussion of uncertainties, and summary for the BERA supplement.

7.2 Problem Formulation

Problem formulation, the first step in the ERA process, identifies the goals, breadth, and focus of the assessment (EPA 1997b, 1998). The problem formulation step identifies site-related contaminants, potential ecological receptors, and potential exposure pathways. A CSM is then developed to illustrate the relationship between site-related contaminants and potential receptors. Lastly, assessment endpoints and measures are established to guide the remaining steps of the risk assessment process. The problem formulation and CSM for the BERA supplement are presented below.

7.2.1 Contaminant Sources, Migration Pathways, and Principal Site-Related Contaminants

As discussed in the RI and Chapter 2, mercury, antimony, and arsenic sulfides were the primary minerals associated with the mineralized zone targeted by mining at the RDM. Tailings, waste rock, and other wastes from the RDM have been exposed at the surface for decades. Mercury, arsenic, antimony, and other metals in these wastes have been subjected to transport by water erosion and other mechanisms. Elevated levels of mercury, arsenic, and antimony are present at the RDM in surface and subsurface soil, sediment and surface water in Red Devil Creek, and sediment in the Kuskokwim River (E & E 2014). Supplemental sampling in 2015 found elevated levels of mercury, arsenic, and antimony in Kuskokwim River sediment several kilometers downriver from the Red Devil Creek delta (see Chapter 5), some of which are likely attributable to non-RDM mineral occurrences.

7.2.2 Potential Ecological Receptors

Based on the ecology of the Kuskokwim River, the ecological receptor groups that have the potential to be exposed to site-related contaminants from the RDM include: (1) aquatic-dependent wildlife that use the river near and downstream from the RDM to satisfy their food and habitat needs; and (2) aquatic biota, including aquatic plants, benthos, and fish in the river.

7.2.3 Ecological Conceptual Site Model

Figure 7-1 provides a CSM for the BERA supplement. Aquatic-dependent wildlife using the Kuskokwim River near the RDM may be exposed to site-related contaminants through incidental ingestion of sediment, consumption of contaminated food items, and ingestion of contaminated surface water. It should be noted that surface water ingestion accounts for only a small fraction (typically < 1%) of total exposure for wildlife and, therefore, is considered a minor pathway. Dermal exposure of wildlife to contaminants in water and sediment also is considered to be a minor exposure pathway due to the protection provided by their external coverings (heavy fur and feathers). Fish and benthos in the Kuskokwim River may be exposed to site-related chemicals through direct contact with and ingestion of contaminated sediment and surface water and through the food chain. Periphyton and aquatic plants in the river may be exposed to contaminants in surface water and sediment.

7.2.4 Assessment Endpoints, Model Species, Risk Questions, and Measures

Assessment endpoints are expressions of the ecological resources that are to be protected (EPA 1997b). An assessment endpoint consists of an ecological entity and a characteristic of the entity that is important to protect. Measurements used to evaluate risks to assessment endpoints are termed “measures” and may include measures of effect, exposure, or ecosystem or receptor characteristics (EPA

1998). Based on the site ecology, principal site-related contaminants, and the CSM, the ecological resources potentially at risk in the Kuskokwim River near the RDM include aquatic-dependent wildlife and aquatic biota (fish, benthos, periphyton, and other aquatic organisms). The assessment endpoints, model species, risk questions, and measures for the BERA supplement are listed in Table 7-1. In total, two community-level assessment endpoints and four population-level assessment endpoints were selected. The community-level assessment endpoints are: (1) benthic macroinvertebrates; and (2) fish. The population level assessment endpoints are: (1) aquatic-dependent piscivorous mammals; (2) aquatic-dependent piscivorous birds; (3) aquatic-dependent invertivorous birds; and (4) aquatic-dependent herbivorous birds.

Community-level assessment endpoints were evaluated by comparing contaminant concentrations in sediment and fish tissue with media screening levels. In addition, the results from bioassays conducted with Kuskokwim River sediment in 2015 were used as a second measure for the benthic community. Wildlife population-level assessment endpoints were evaluated by calculating HQs (see Table 7-1, last column). Representative aquatic-dependent wildlife model species are listed in Table 7-1 and are the same as those used in the final BERA (E & E 2014). Aquatic plants are identified in the CSM as a potential receptor (see Figure 7-1); however, because there are no sediment benchmarks specific to aquatic plants, and because no surface water data are available for the Kuskokwim River near the RDM, a quantitative assessment of potential risks to aquatic plants from site-related contaminants could not be undertaken. Risk estimates that are acceptable for benthic macroinvertebrates also may be protective of aquatic plants, although this is an uncertainty (see Section 7.6).

7.3 Exposure Assessment

This section describes the sediment data that were used in the assessment, how contaminant levels in wildlife food items were modeled from sediment, and how exposure was estimated.

7.3.1 Sediment Contaminant Concentrations

Sediment samples collected from the Kuskokwim River in 2010, 2011, 2012, and 2015 from Red Devil Creek delta downstream to Red Devil Village were used in the BERA supplement. The assessment area is shown in Figure 6-1, and sediment sample locations are illustrated in Figures 5-1 and 5-2. Sediment samples collected from Red Devil Creek were not used because the focus of the BERA supplement is the Kuskokwim River near and downstream from the RDM. Red Devil Creek was evaluated in the original RI (E & E 2014), and remediation of the creek is planned based on the RI findings.

To satisfy EPA's risk assessment policy, all TAL elements, except calcium, magnesium, sodium, and potassium, were evaluated. For wildlife, iron and aluminum also were excluded from the evaluation. Iron was excluded from the wildlife assessment because it is an essential nutrient and typically is not evaluated as a toxicant (EPA 1989, 2005c). Aluminum was excluded from the wildlife assessment because it is naturally abundant in sediment and soil and of low toxicity (Gough et al. 1979).

For the analytes evaluated in this assessment, a weighted 95% UCL on the average concentration was used as the EPC for sediment. A weighted UCL is recommended in situations where sampling density and contaminant levels vary markedly across the area being evaluated (ITRC 2017). In the Kuskokwim River assessment area, sampling density is high near the RDM and low in other parts of the assessment area (see Figures 5-1 and 5-2). Levels of site-related metals in sediment typically are high near the RDM and low in downriver and cross-river areas (see Chapter 5). For these reasons, the sediment data were divided into two areas for calculation of a weighted UCL:

1) Area near the RDM where sampling density is high, including all samples from 2010, 2011, and 2012 and the few 2015 samples interspersed with the earlier samples (see Figure 5-1); henceforth, referred to as the near-RDM area.
2) Downriver, mid-river, and cross-river area that includes only widely spaced 2015 samples (see Figure 5-2); henceforth, referred to as the downriver area.

UCLs for these two sample groups were calculated using ProUCL version 5.1 (EPA 2015a, 2015b) and combined into a weighted UCL, as described in the following subsections. Outliers were identified and handled in a manner consistent with EPA (2015a) guidance. Field duplicate results were treated as per ADEC (2008) guidance (i.e., the higher result from the primary and duplicate sample was used). Two sets of weighted EPCs were developed—one set based on sediment samples collected from all depths in the assessment area and a second set based on shoreline and near-shore samples, as described below.

7.3.1.1 Complete Sediment Dataset (All Sample Depths)

To assess potential risks to fish-eating wildlife (mink and kingfisher), Kuskokwim River sediment samples collected from all water depths were used. The forage fish consumed by these receptors may consume benthic macroinvertebrates at any depth. Eighty sediment samples, including field duplicates, were included in this dataset (see Appendix E). To develop a weighted EPC for the entire assessment area, ProUCL first was used to calculate separate UCLs for the near-RDM and downriver sample groups. A weighted average of the near-RDM and downriver UCLs was then calculated based on the fraction of the total assessment area (156.2 hectares [ha]) represented by the near-RDM (8.24 ha) and downriver (147.96 ha) areas. For example, for antimony, the near-RDM and downriver UCLs were 415.8 mg/kg and 3.53 mg/kg, respectively. The area-weighted UCL for antimony for the entire assessment area was 25.4 mg/kg, calculated as follows:

(415.8 mg/kg x [8.24ha / 156.2ha]) +
(3.53 mg/kg x [147.96 ha / 156.2 ha]) = 25.4 mg/kg

Table 7-2 lists the sediment EPCs for all analytes for the complete (all depths) sediment dataset.

7.3.1.2 Shoreline and Nearshore Sediment Dataset

When assessing potential risks for invertivorous shorebirds (common snipe) and herbivorous waterfowl (green-winged teal), only shoreline and near-shore (< 2 feet water depth between early May and mid-October) sediment samples from the Kuskokwim River were used to estimate exposure. Twenty-five sediment samples, including field duplicates, were included in this dataset. To develop an EPC for the entire assessment area, ProUCL first was used to calculate separate UCLs for the near-RDM and downriver sample groups. A weighted average of the near-RDM and downriver UCLs was then calculated based on the fraction of the total assessment area shoreline length (4.11 miles) represented by the near-RDM area (0.65 mile) and downriver area (3.46 miles, both banks summed). For example, for antimony, the near-RDM and downriver UCLs were 1,281 and 1.75 mg/kg, respectively. The length-weighted UCL for antimony for the entire assessment area was 204 mg/kg, calculated as follows:

(1,281 mg/kg x [0.65 mi. / 4.11 mi]) +
(1.75 mg/kg x [3.46 mi. / 4.11 mi.]) = 204 mg/kg

Table 7-3 lists the sediment EPCs for all analytes for the shoreline/near-shore sediment dataset. ProUCL input and output files are provided in Appendix E.

7.3.2 Tissue Contaminant Concentrations

There are no analytical data for contaminant levels in benthic macroinvertebrates, forage fish, or aquatic macrophytes from the Kuskokwim River near the RDM. Hence, contaminant levels in these wildlife food items were modeled from sediment, as described below.

7.3.2.1 Benthic Macroinvertebrates

Contaminant levels in benthic macroinvertebrates from the Kuskokwim River assessment area were modeled from the Kuskokwim River sediment EPCs using BSAFs. The following equation was used:

$$C_b = EPC_s \times BSAF$$

Where:

C_b = Benthic macroinvertebrate contaminant concentration (mg/kg wet weight)
EPC_s = Sediment EPC (mg/kg dry weight)
BSAF = Biota Sediment Accumulation Factor

Site-specific BSAFs for arsenic, antimony, mercury, and methylmercury were developed from sediment and benthic-macroinvertebrate samples collected from Red Devil Creek by BLM and were presented in the final BERA (E & E 2014).

Site-specific BSAFs for other elements were similarly developed. For comparison, BSAFs also were developed using metals data for sediment and benthic macroinvertebrate samples from reference creeks in the middle Kuskokwim River region. Appendix F includes the sediment and benthic-macroinvertebrate sample data used to develop the BSAFs and resulting BSAFs. Modeled levels of contaminants in benthic macroinvertebrates from the Kuskokwim River were used to estimate dietary exposure for the common snipe, which is a shorebird that feeds on benthic organisms in shoreline and near-shore sediments. For this model species, dietary exposure was estimated using both site-specific and background BSAFs and then compared.

7.3.2.2 Forage Fish

Contaminant levels in forage fish (e.g., slimy sculpin) in the Kuskokwim River were modeled from contaminant levels in benthic macroinvertebrates (modeled as described above) using TTFs. The following equation was used:

$$C_f = C_b \times TTF$$

Where:

C_f	=	Forage fish contaminant concentration (mg/kg wet weight)
C_b	=	Benthic macroinvertebrate contaminant concentration (mg/kg wet weight)
TTF	=	Trophic Transfer Factor.

Site-specific TTFs were developed from metals data for benthic-macroinvertebrate and slimy-sculpin samples collected from Red Devil Creek by BLM and presented in the final BERA (E & E 2014). For example, a site-specific TTF for arsenic was estimated from the arsenic EPC for benthic macroinvertebrates (206 mg/kg, RI Table 6-47) and arsenic EPC for slimy sculpin from Red Devil Creek (13 mg/kg, RI Table 6-49). The resulting TTF is 13/206 = 0.063. Site-specific TTFs for other metals were estimated similarly (see Appendices G, H, and I for site sculpin EPCs, site benthos EPCs, and site TTFs, respectively). Also, background TTFs were developed from slimy-sculpin and benthic-macroinvertebrate data from six reference creeks (California, Downey, Fuller, Ice, No Name, and Vreeland Creeks) in the middle Kuskokwim River region (see Appendices L, M, and N for background benthos EPCs, background sculpin EPCs, and background TTFs, respectively). Modeled levels of contaminants in forage fish from the Kuskokwim River were used for two purposes: (1) to estimate exposure for fish-eating wildlife (mink and kingfisher); and (2) as a measure of fish exposure to contaminants. For these receptor groups, exposure was estimated using both the site and background TTFs and compared.

7.3.2.3 Aquatic Plants

Contaminant levels in aquatic plants in the Kuskokwim River were modeled from contaminant levels in sediment using sediment-to-plant uptake factors (UFs). The following equation was used:

$$C_p = C_s \times UF$$

Where:

C_p = Aquatic plant contaminant concentration (mg/kg dry weight)
C_s = Sediment contaminant concentration (mg/kg dry weight)
UF = Uptake factor (sediment-to-aquatic plant).

Site-specific UFs were developed from metals data for aquatic-plant (horsetail) and sediment samples collected from settling ponds in the former Main Processing Area of the RDM site and from a background pond (i.e., reservoir) located at the upstream end of Red Devil Creek. Metals data for pond plants and sediment and site-specific and background UFs are provided in Appendix J. Modeled levels of contaminants in aquatic plants were used to estimate exposure for herbivorous wildlife (green-winged teal). For this receptor, exposure was estimated using both the site-specific and background UFs and compared. Finally, exposure of herbivorous wildlife to site-related contaminants was estimated using metals data for periphyton samples collected from the Kuskokwim River within the assessment area (see Appendix K for periphyton metals data and EPCs).

7.3.3 Wildlife Exposure Estimation

This section describes the methods used to estimate exposure for aquatic-dependent wildlife using the Kuskokwim River near the RDM site. As noted above, a piscivorous mammal (mink), piscivorous bird (kingfisher), sediment-probing bird (common snipe), and herbivorous bird (green-winged teal) were evaluated. For these species, exposure from diet and incidental ingestion of sediment was estimated. Exposure from surface water was not assessed because no surface water contaminant data are available for the Kuskokwim River near the RDM site.

7.3.3.1 Exposure Point Concentrations

As described above, exposure of aquatic-dependent wildlife to site-related contaminants in the Kuskokwim River was based on measured levels of contaminants in sediment and modeled concentrations in wildlife food items. Sediment EPCs are presented in Tables 7-2 and 7-3. Modeled levels of contaminants in aquatic vegetation, benthic macroinvertebrates, and forage fish are presented in Tables 7-5a–c, 7-6a–b, and 7-7a–b.

7.3.3.2 Exposure Equations

Dietary exposure was calculated using the following equation:

$$EE_{diet} = ([(C_1 \times F_1) + (C_2 \times F_2) + \ldots (C_n \times F_n)] \times SUF \times ED \times IR)/BW$$

Where:

EE_{diet} = Estimated exposure from diet (mg/kg-day)

C_n	=	Chemical concentration in food item *n* (mg/kg, wet or dry weight)
F_n	=	Fraction of diet represented by food item *n*
SUF	=	Site use factor (unitless)
ED	=	Exposure duration (unitless)
IR	=	Ingestion rate of receptor (kg, wet or dry weight/day)
BW	=	Body weight of receptor (kg)

Food ingestion rates and body weights were taken from Sample and Suter (1994), EPA (1993), or other credible references (see Table 7-4). The diet of each receptor was assumed to exclusively consist of the food item that would maximize its exposure to site-related contaminants (see Table 7-4). For example, the diet of the mink and kingfisher were assumed to consist entirely of forage fish (e.g., slimy sculpin) from the Kuskokwim River.

The SUF indicates the portion (fraction) of an animal's home range represented by the site. If the home range is larger than the site, the SUF equals the site area divided by the home range area. If the site area is greater than or equal to the home range, the SUF equals 1. For all wildlife receptors, an SUF of 1 was deemed applicable given the size of the assessment areas relative to the home range size (see Table 7-4).

Exposure duration is the fraction of the year spent in the site area by the receptor. The snipe, teal, and kingfisher are migratory and were assumed to be present at the site for four months. An exposure duration value of 0.33 (4 months / 12 months) was used for these receptors (see Table 7-4). The mink was assumed to be present at the site year-round (ED = 1).

Home-range size, ingestion rate, diet composition, and body weight for the wildlife species being evaluated were taken from Sample and Suter (1994), EPA (1993), or other credible references (see Table 7-4).

Wildlife exposure via incidental sediment ingestion was estimated in a manner similar to that used for dietary exposure, as shown in the following equation:

$$EE_{sed} = (C_s \times IR_s \times SUF \times ED)/BW$$

Where:

EE_{sed}	=	Estimated exposure from incidental sediment ingestion (mg/kg-day)
C_s	=	Chemical concentration in sediment (mg/kg, dry weight)
IR_s	=	Sediment ingestion rate of receptor (kg, dry weight/day)

SUF, exposure duration, and body weight are as defined above.

Sediment ingestion rates were taken from the literature (Sample and Suter 1994) or based on professional judgment if a literature value could not be found (see Table 7-4).

The total exposure for a receptor was calculated as the sum of the exposure from diet and incidental sediment ingestion, as represented by the following equation:

$$EE_{total} = EE_{diet} + EE_{sed}$$

Where:

EE_{total} = Total exposure (mg/kg-day)
EE_{diet} = Estimated exposure from diet (mg/kg-day)
EE_{sed} = Estimated exposure from incidental sediment ingestion (mg/kg-day)

7.3.3.3 Exposure Estimates

Exposure estimates for the teal, snipe, kingfisher, and mink are presented in Tables 7-8a–c, 7-9a–b, 7-10a–b, and 7-11a–b, respectively.

7.3.4 Benthic Macroinvertebrate Exposure

As described in the technical approach memorandum (BLM 2017), exposure of benthos to contaminants in sediment was based on total concentrations of metals in Kuskokwim River sediment samples collected from 2010 to 2015. The full dataset is provided in Appendix E, and sediment EPCs for the Kuskokwim River assessment area are presented in Table 7-2. Data for sediment samples used in toxicity testing are discussed in Section 7.4.2. In addition, modeled levels of contaminants in benthic macroinvertebrates were used to estimate exposure. The modeling was conducted as described in Section 7.3.2.1, and modeled concentrations are provided in Tables 7-6a (based on site BSAFs) and 7-6b (based on background BSAFs).

7.3.5 Forage Fish Exposure

Contaminant levels in forage fish were modeled as described in Section 7.3.2.2 and are presented in Tables 7-7a (based on site TTFs) and 7-7b (based on background TTFs).

7.4 Ecological Effects Assessment

7.4.1 Wildlife Toxicity Reference Values

No Observed Adverse Effect Levels (NOAELs) and Lowest Observed Adverse Effect Levels (LOAELs) for effects of contaminants on birds and mammals were taken from the peer-reviewed literature. The values and sources are provided in Table 7-12. The NOAELs and LOAELs used in the BERA supplement were the same as those used in the final BERA (E & E 2014).

7.4.2 Benthic Macroinvertebrates

Three effect measures for the benthic-macroinvertebrate community were used in the BERA supplement: (1) sediment toxicity tests; (2) tissue screening concentrations (TSCs) for benthic macroinvertebrates; and (3) sediment screening levels (also known as sediment quality guidelines [SQGs]). Results from toxicity tests with Kuskokwim River sediment samples are discussed in Section 7.4.2.1. Sediment screening levels also are discussed in Section 7.4.2.1 in conjunction with the toxicity testing results. Site-specific TSCs for benthic macroinvertebrates were developed during the final BERA (E & E 2014) and are presented in Appendix P. The TSCs also are presented in the risk characterization for benthic macroinvertebrates (see Section 7.5.2).

7.4.2.1 Sediment Toxicity Testing

In September 2015, sediment samples for toxicity testing were collected from 12 locations in the Kuskokwim River near the RDM, including:

- Nine locations at or downstream from the Red Devil Creek delta (KR084, KR085, and KR087 to KR093);
- One location downstream from the Red Devil Creek delta on the opposite back of the river (KR099); and
- Two (reference) locations upstream from the Red Devil Creek delta (KR082 and KR083).

Sample locations are shown in Figures 5-1 and 5-2. The samples were sent to Northwestern Aquatic Sciences, Newport, Oregon, where a 28-day growth and survival test with *Hyalella azteca* (amphipod) was conducted with each sample following EPA Method 100.4. The full Northwestern Aquatic Sciences testing report is provided in Appendix C. This section provides a summary and interpretation of the testing results.

7.4.2.1.1 Survival Effects

Hyalella survival results are summarized in Table 7-13. Seven of ten samples collected downstream from the Red Devil Creek delta showed no effects on survival compared with the upstream reference samples or laboratory control sample. In these seven samples, survival ranged from 89 to 93%. In the remaining three samples, *Hyalella* survival was reduced by 10 to 30% compared with the reference samples and laboratory control.

7.4.2.1.2 Growth Effects

Table 7-13 also summarizes the *Hyalella* growth (average dry weight per amphipod at end of test) results. No effect on growth was observed in nine of ten samples collected downstream from the Red Devil Creek delta. In one downstream sample, growth was reduced by about 20% compared with the upstream reference samples and laboratory control. For reference, average amphipod weight at test initiation was 0.069 mg dry weight (see Appendix C, page 50 of 216).

7.4.2.1.3 Biomass Effects

Table 7-13 also summarizes the *Hyalella* biomass (combined dry weight of surviving amphipod at end of test) results. Seven of ten samples collected downstream from the Red Devil Creek delta showed no effects on biomass compared with the upstream reference samples or laboratory control sample. In these seven samples, biomass ranged from 2.04 to 2.55 mg. In the remaining three samples, *Hyalella* biomass was reduced by 30 to 40% compared with the reference samples and laboratory control.

7.4.2.1.4 Relationships between Sediment Chemistry and Toxicity

The sediment chemistry and *Hyalella* survival data were examined to identify sediment constituents negatively correlated with survival. Such constituents could be possible causative agents of the observed toxicity. This was done by calculating Pearson's and Spearman's correlation coefficients for *Hyalella* survival versus concentrations of total inorganic elements and other parameters in sediment. The Spearman correlation coefficient is a nonparametric analog of the usual correlation coefficient and is calculated by replacing the data values with their ranks and calculating the correlation coefficient of the ranks. *Hyalella* survival was not significantly correlated with antimony, arsenic, mercury, or methylmercury levels in sediment (see Tables 7-14 and 7-15 for Pearson and Spearman correlations, respectively, and significant levels). Furthermore, the sediment sample (15KR085SD) with the greatest levels of antimony (3,100 mg/kg), arsenic (2,100 mg/kg), and mercury (310 mg/kg) had the greatest survival (93%) of samples collected downstream from the delta. In addition, the sediment sample (15KR084SD) with the greatest level of bioavailable mercury, as measured by the sum of the F0 to F2 mercury SSE fractions (see Section 5.3.7.3), had equally high survival (93%). Collectively, these results suggest that reduced survival of *Hyalella* in Kuskokwim River sediment samples collected downstream from the Red Devil Creek delta was not due to antimony, arsenic, mercury, or methylmercury, the principal site-related contaminants.

Tables 7-14 and 7-15 list sediment constituents that were negatively correlated with *Hyalella* survival. These constituents include physical parameters associated with sediment texture (% medium sand, % silt, and % clay), TOC, two major elements (magnesium and sodium), and ten metals (cadmium, cobalt, copper, iron, manganese, nickel, selenium, silver, vanadium, and zinc). The correlations do not prove cause and effect; they simply indicate that there is a negative association between these parameters and *Hyalella* survival. There is more than one possible interpretation for these results.

One interpretation is that *Hyalella* survival was affected by one or more of the ten metals (cadmium, cobalt, copper, iron, manganese, nickel, selenium, silver, vanadium, and zinc) that were negatively correlated with survival. To explore this possibility, the concentrations of these ten metals in samples 15KR089SD, KR15091SD, and KR15093SD were compared with the screening levels for effects on freshwater benthos identified in BERA Table 6-45 in the final RI report (E & E 2014). Table 7-16 shows that seven of these metals (cadmium, cobalt, copper, selenium, silver, vanadium, and zinc) do not exceed their screening levels in these samples and, therefore, are unlikely to have affected *Hyalella* survival. In contrast, the concentrations of iron, manganese, and nickel in these samples did exceed their screening levels. However, one reference sample (15KR082SD) also contained iron, manganese, and nickel above the screening levels, suggesting that these metals may be naturally elevated in Kuskokwim River sediment. Furthermore, the 2015 sediment metals results discussed in Chapter 5 provide no indication that the site is a significant source or iron, manganese, or nickel to the Kuskokwim River. Based on results of a Mann-Whitney U-test (nonparametric equivalent of two sample t-test), sediment concentrations of iron, manganese, or nickel are not greater in samples collected downstream from the Red Devil Creek delta compared with upstream samples.

Another interpretation is that *Hyalella* survival was affected by TOC and/or sediment texture rather than metals concentrations. The three samples with significantly reduced *Hyalella* survival had higher TOC and less gravel than the two upstream reference samples (see Table 5-3). Further, the two samples with the lowest survival (15KR089SD and 15KR091SD) had the greatest TOC levels (see Table 5-3). The mechanism(s) by which sediment texture and/or TOC may have affected *Hyalella* survival is uncertain; however, it is known that sediment texture and TOC can affect toxicity-testing results and that reference samples and site samples should be similar for these parameters (Breneman et al. 2000; Reinhold-Dudok van Heel and den Besten 1999). TOC is a food source for many benthic organisms and affects sediment texture, as does grain size. These factors influence the suitability of the sediment as habitat for different types of benthic organisms, depending on the requirements of each species. For this study, TOC and grain size at the site and reference locations were matched as closely as possible given existing information and river conditions near the site, but nonetheless differed.

Lastly, is it interesting to note that the three stations with reduced *Hyalella* survival (KR089, KR091, KR093) are all located further offshore than were nearby stations with no significant toxicity (KR088, KR090, KR092), all of which were located close to the shoreline. No consistent difference in sediment parameters was apparent between the two sets of samples (see Table 5-3) that would explain the difference in toxicity between them; thus, the difference appears to be a coincidence.

In summary, it is likely that reduced survival of *Hyalella* in samples 15KR089SD, KR15091SD, and KR15093SD compared with upstream reference samples was the result of differences in sediment texture and/or TOC content between the site and reference samples, and/or the result of non-site-related metals that appear to be naturally elevated in Kuskokwim River sediment.

7.4.2.1.5 Mean Sediment Quality Guideline Quotient

To help understand the possible cumulative impact of multiple metals on *Hyalella* survival, growth, and biomass, the mean sediment quality guideline (mean SQG) quotient (Long and MacDonald 1998) was calculated for each sample used in the 28-day *Hyalella* test and compared with the survival, growth, and biomass results. Eighteen metals were included in the analysis (see Table 7-17). No relationship between the mean SQG quotient and sediment toxicity was observed. The highest mean SQG quotients were for site samples with high levels of antimony, arsenic, and mercury that showed no toxicity to *Hyalella* (102 for 15KR085SD and 23 for 15KR084SD). The lowest mean SQG quotients were for the upriver reference samples (0.32 for 15KR083SD and 0.76 for 15KR082SD) and sample collected cross-river from the RDM (0.33 for 15KR099SD), which also showed no toxicity to *Hyalella*. The three samples that showed effects on survival, growth, and/or biomass (15KR089SD, 15KR091SD, and 15KR093SD) had intermediate values for the mean sediment quality guidelines quotient (0.77 to 1.81). These results suggest that the low to moderate effects on survival, growth, or biomass in samples 15KR089SD, 15KR091SD, and 15KR093SD are unlikely to be related to the 18 metals considered when calculating the mean SQG quotient and is consistent with the results of the correlation analysis.

7.4.3 Tissue Screening Concentrations for Effects on Fish

TSCs were used to assess potential adverse effects on forage fish. TSCs were developed for the final BERA for the RDM site or taken from literature recommended by the EPA and are presented in Appendix O. The TSCs were used previously in the final BERA (E & E 2014) to evaluate potential effects on fish.

7.5 Risk Characterization

7.5.1 Wildlife

7.5.1.1 Risk Calculation Methodology

Potential risks posed by site-related contaminants were estimated by calculating an HQ for each contaminant for each wildlife model species. The HQ was determined by dividing the total exposure (EE_{total}) by the NOAEL or LOAEL, as shown in the following equations:

$$HQ\text{-}NOAEL = EE_{total}/NOAEL$$

$$HQ\text{-}LOAEL = EE_{total}/LOAEL$$

For a given receptor and chemical, an HQ-NOAEL greater than 1 indicates that the estimated exposure exceeds the highest dose at which no adverse effect was observed. An HQ-LOAEL greater than 1 suggests that a chronic adverse effect to survival, growth, and/or reproduction is possible to an individual receptor.

7.5.1.2 Risk Results for Aquatic-Dependent Wildlife

Tables 7-8 to 7-11 present the estimated risks for the four wildlife model species evaluated in the BERA supplement: green-winged teal, common snipe, belted kingfisher, and mink. The risk results for these species are discussed in turn below.

- **Green-winged teal:** The teal was selected to represent the aquatic-dependent herbivorous bird assessment endpoint. For this model species, no contaminants were predicted to pose a risk when the site or background sediment-to-plant UFs were used to model dietary exposure (see Tables

7-8a and 7-8b, respectively). When metals concentrations in Kuskokwim River periphyton were used to estimate dietary exposure, the HQ for vanadium exceeded 1 (see Table 7-8c). Lastly, it should be noted that potential risks to the teal could not be estimated for some contaminants (antimony, beryllium, and thallium) due to a lack of avian toxicity data (see Tables 7-8a through 7-8c).

- **Common snipe:** The snipe was selected to represent the aquatic-dependent invertivorous bird assessment endpoint. The snipe and related birds (e.g., sandpipers and curlews) feed by probing for benthic invertebrates in shoreline and near-shore sediment and are known to have a high rate of incidental sediment ingestion (Beyer et al. 1994). For the snipe, contaminant levels in food items were modeled using site and background BSAFs (see Section 7.3.2.1). When site BSAFs were used to estimate exposure, the HQ-NOAEL for selenium exceeded 1, but only marginally (see Table 7-9a). When background BSAFs were used to estimate exposure, the HQs for copper, mercury, and selenium exceeded 1, but only marginally (see Table 7-9b).

- **Belted kingfisher:** The kingfisher was selected to represent the aquatic-dependent avian piscivore assessment endpoint. For the kingfisher, contaminant levels in prey (forage fish) were modeled using both site and background BSAFs and TTFs (see Section 7.3.2.2). When site BSAFs and TTFs were used to estimate exposure, no HQs were greater than or equal to 1 (see Table 7-10a). When background BSAFs and TTFs were used to estimate exposure, the HQ-NOAEL for selenium exceeded 1, but only marginally, and the HQ-LOAEL for selenium equaled 1 (see Table 7-10b). Lastly, HQs could not be calculated for the kingfisher for some contaminants (antimony, beryllium, and thallium) due to a lack of avian toxicity data (see Table 7-10a and 7-10b).

- **Mink:** The mink was selected to represent the aquatic-dependent mammalian piscivore assessment endpoint. For this model species, no contaminants were predicted to pose a risk when site BSAFs and TTFs were used to estimate exposure (see Table 7-11a). When background BSAFs and TTFs were used to estimate exposure, the HQ-NOAEL and HQ-LOAEL for selenium and HQ-NOAEL for thallium exceeded 1, but only marginally (see Table 7-11b).

7.5.2 Benthic Macroinvertebrates

Three different measures were used to understand potential risks to benthic macroinvertebrates from contaminants in sediment: (1) sediment toxicity testing; (2) modeled contaminant levels in benthic macroinvertebrates compared with TSCs; and (3) total sediment contaminant concentrations compared with sediment screening levels or SQGs.

7.5.2.1 Sediment Toxicity Testing Results

The results of a 28-day sediment toxicity test with *Hyalella* are presented and discussed in Section 7.4.2.1. Evaluation of those results suggest that the effects on *Hyalella* survival, growth, and/or biomass at selected sample sites near the RDM (KR089, KR091 and KR093) compared with upstream reference samples was the result of differences in sediment texture and/or TOC content between the site and reference samples, the result of non-site-related metals that appear to be naturally elevated in Kuskokwim River sediment, and/or other factors related to habitat quality, but were not a result of antimony, arsenic, mercury, or methylmercury levels in sediment.

7.5.2.2 Tissue Screening Concentrations

Contaminant levels in benthos were modeled using both site and background BSAFs (see Section 7.3.2.1 and Tables 7-6a and 7-6b). Modeled concentrations are compared with site-specific TSCs in Table 7-18. When site BSAFs were used to model metals concentrations in benthos, no modeled concentrations exceeded the TSCs (i.e., all HQs were < 1), suggesting that benthos in the Kuskokwim River assessment area are not at risk from exposure to site-related metals in sediment. When background BSAFs were used to model metals concentrations in benthos, the modeled concentration for mercury exceeded the TSCs (HQ = 4.2; see Table 7-18), suggesting that mercury may pose a potential risk to benthos.

7.5.2.3 Screening Level Comparisons

Total contaminant concentrations in sediment were compared with sediment screening levels in Sections 7.4.2.1.3 (see Table 7-16) and 7.4.2.1.4 (see Table 7-17). Those comparisons showed that total concentrations of antimony, arsenic, mercury, and other metals exceeded screening levels, but those exceedances were not associated with adverse effects in sediment toxicity tests, despite the fact that total concentrations of antimony, arsenic, and mercury exceeded their respective screening levels by over a factor of 100 in some sediment samples near the RDM, particularly those collected from the Red Devil Creek delta. This result appears to be related to the limited availability of contaminants in sediment, as reflected in the selective sequential extraction results for mercury (see Table 5.3), despite high total concentrations.

7.5.3 Forage Fish

Potential risks to forage fish were estimated by comparing modeled whole-body levels of contaminants in forage fish with fish TSCs. The following equation was used:

$$HQ = (\text{modeled fish whole-body concentration}) / (TSC)$$

HQ values greater than or equal to 1 suggest that a potential risk may exist. When site BSAFs and TTFs were used to model contaminant levels in forage fish, no contaminants were found to pose a risk; that is, all HQs were less than 1 (see Table 7-19). When background BSAFs and TTFs were used to model contaminant levels in forage fish, all HQs were less than 1, except for mercury (HQ = 1.8. see Table 7-19).

7.5.4 Contribution of Background to Potential Risks

For the green-winged teal, a potential risk from vanadium was identified when the teal diet was assumed to consist entirely of periphyton from the Kuskokwim River assessment area (see Table 7-8c). A review of the periphyton data for vanadium shows that the EPC for vanadium in periphyton from the Kuskokwim River assessment area (92 mg/kg dry weight; see Table 7-5c) is less than the average concentration of vanadium in periphyton samples collected from the Kuskokwim River upriver from the RDM site (95 mg/kg dry weight; range 69 to 119 mg/kg dry weight). Hence, potential risks to the green-winged teal from vanadium are entirely due to background.

For the belted kingfisher and mink, a potential risk from selenium was identified when the concentration of selenium in the forage fish eaten by these receptors was modeled using background BSAFs and TTFs (see Tables 7-10b and 7-11b, respectively). A review of the sculpin data for reference creeks in the middle Kuskokwim River region shows that the modeled EPC for selenium in forage fish from the Kuskokwim River assessment area (2.24 mg/kg wet weight; see Table 7-7b) lies within the range of measured selenium levels in sculpin from the reference creeks (0.47 to 3.4 mg/kg wet weight; see Appendix M). Hence, exposure and risk to the kingfisher and mink from selenium lies within the range of background.

For the common snipe, a potential risk from selenium was identified when the concentration of selenium in the benthic macroinvertebrates eaten by this receptor was modeled using background BSAFs (see Table 7-9b). A review of the benthic-macroinvertebrate sample data for reference creeks in the middle Kuskokwim River region shows that the modeled EPC for selenium in benthic macroinvertebrates from the Kuskokwim River assessment area (3.1 mg/kg wet weight; see Table 7-6b) lies within the range of measured selenium levels in benthic macroinvertebrates from the reference creeks (0.42 to 3.7 mg/kg wet weight; see Appendix L). Hence, exposure and risk to the snipe from selenium lies within the range of background.

7.6 Uncertainties

The final BERA for the RDM site (E & E 2014) identified significant sources of uncertainty in that assessment, many of which still are present in the BERA supplement, including:

- An incomplete understanding of contaminant bioavailability in sediment, which lead to the assumption of 100% bioavailability of metals in sediment ingested by wildlife. However, for mercury, only a small fraction (typically < 1%) of the total sediment concentration is soluble in water or stomach acid (see Section 5.3.7.3). Hence, assuming 100% bioavailability of mercury in sediment overestimates wildlife exposure to mercury from incidental sediment ingestion.

- Lack of toxicity data for some contaminant-receptor pairs (e.g., antimony for birds), which prevented a complete assessment of site risks.
- The effect of biased sampling on EPCs, which typically results in EPCs that overestimate exposure. To minimize the effect of biased sampling in the BERA supplement, separate sediment UCLs were calculated for the near-RDM area and downriver area and combined into a weighted EPC, as described in Section 7.3.1. Based on available guidance (ITRC 2017), this approach is expected to provide realistic, defensible, sediment EPCs for the assessment area and help avoid overestimating exposure.
- Lack of actual data on contaminant concentrations in wildlife food items, which necessitated use of modeling approaches to estimate wildlife dietary exposure. In the BERA supplement, site and background BSAFs and TTFs were developed from sediment, benthos, and sculpin data for Red Devil Creek and nearby reference creeks. Using these BSAFs and TTFs in the BERA supplement is less uncertain that using literature-based values, but still involves uncertainty. For example, when modeling metals concentrations in benthos, the sediment EPC was multiplied by either the site or background BSAF. Ideally, one would not multiply the sediment EPC exclusively by either the site or background BSAF to arrive at a benthos EPC for the entire assessment area. A more realistic approach would be to multiply the near-RDM sediment UCL by the site BSAF and downriver sediment UCL by the background BSAF and then take a weighted average of the two modeled benthos concentrations. When this is done for mercury for the common snipe scenario, the estimated risk is reduced by a factor of four compared with using only the background BSAF to model bioaccumulation; specifically, the HQ-LOAEL for the snipe for mercury in Table 7-9b is reduced from 1.2 to 0.31 (see Tables 7-20 and 7-23). Similarly, for the benthic macroinvertebrate community, the mercury HQ of 4.2 in Table 7-18 (based on using the background BSAF to model bioaccumulation) is reduced by an order of magnitude (to an HQ of 0.38) when the weighted benthic macroinvertebrate tissue concentration is used to estimate risk (see Tables 7-21 and 7-23). The approach described here for modeling bioaccumulation into benthos also can be applied to forage fish. When this is done for mercury, the estimated risk to forage fish is reduced by a factor of two compared with using only the background BSAF and TTF to model bioaccumulation; specifically, the HQ for forage fish for mercury in Table 7-19 is reduced from 1.8 to 0.79 (see Tables 7-22 and 7-23). Weighted aquatic plant tissue concentrations were not developed for the BERA Supplement as described above for benthos and forage fish because no risks were predicted for herbivorous wildlife when using modeled aquatic plant tissue concentrations to calculate exposure.
- Incomplete knowledge of the actual diet of wildlife using the Kuskokwim River near the RDM site, which lead to the use of conservative

assumptions (e.g., diet consists entirely of the most contaminated food item) that may have overestimated exposure.

- Lack of surface water data for the Kuskokwim River. Hence, wildlife exposure to contaminants in Kuskokwim River water could not be quantified. However, this data gap is not expected to affect the conclusions of the BERA supplement because exposure of wildlife to contaminants in surface water typically is insignificant compared with exposure from diet and sediment ingestion.
- Lack of assessment of potential risks to aquatic plants for reasons discussed in Section 7.2.4, which prevented a complete assessment of site risks.
- For the green-winged teal, site use was assumed to be less than 100% because the teal home range (243 ha) is larger than the Kuskokwim River assessment area (156 ha) (see Table 7-4). When not present in the assessment area, it was assumed that the teal used nearby areas not affected by historical mercury mining. If instead, the teal used other mercury mining sites when not present in the assessment area, then its calculated exposure and risk would be 36% greater than shown in Tables 7-8a to 7-8c. However, increasing the calculated exposure and risk for the teal by 36% for antimony, arsenic, mercury, and methylmercury would not alter the conclusions of this assessment because the HQs for these RDM-related contaminants still would be less than 1.0. Hence, assuming a site-use factor less than 100% for the teal is not considered a significant source of uncertainty in the current assessment.

7.7 Summary of Potential Risks

Table 7-24 provides a summary of potential ecological risks, or lack thereof, identified in the BERA supplement. Overall, the BERA supplement for the Kuskokwim River assessment area identified only marginal risks to the assessment endpoints evaluated when conservative approaches were used to model bioaccumulation. The following points are noteworthy:

- When using site BSAFs and TTFs to model food-chain bioaccumulation, no risks were predicted for herbivorous birds (represented by the green-winged teal), invertivorous birds (represented but the common snipe), piscivorous birds (represented by the belted kingfisher), piscivorous mammals (represented by the mink), forage fish (represented by the slimy sculpin), and benthic macroinvertebrates.
- Because BSAFs often increase with decreasing contaminant concentrations in sediment, BSAFs and TTFs based on data from reference creeks in the middle Kuskokwim River region also were used to model bioaccumulation. When background BSAFs and TTFs were used to model bioaccumulation, marginal potential risks were predicted for invertivorous birds (common snipe) from mercury (HQ 1.2) and selenium (HQ 1.1), piscivorous birds (kingfisher) from selenium (HQ 1), piscivorous mammals (mink) from selenium (HQ 1.2), benthic macroinvertebrates from mercury (HQ 4.2), and forage fish from mercury

(HQ 1.8). However, as discussed in Section 7.5.4, selenium risks to the snipe, kingfisher, and mink are from background. And, as noted in Section 7.6, using only background BSAFs and TTFs to model bioaccumulation likely overestimates risk in the Kuskokwim River assessment area by a factor of two to four.

- By assuming that aquatic-dependent herbivorous birds (green-winged teal) feed only on periphyton from the Kuskokwim River, a potential risk was identified from vanadium (HQ 8). However, as discussed in Section 7.5.4, vanadium risks are from background.
- Sediment toxicity testing was the strongest line of evidence used to evaluate potential impacts to the benthic macroinvertebrate community in the Kuskokwim River near the RDM. Low to moderate effects on survival, growth, and/or biomass were identified in three of ten site samples, but there was no relationship between these effects and sediment concentrations of antimony, arsenic, mercury, and/or methylmercury, the principal site-related contaminants. Instead, the effects appeared to be the result of differences in sediment texture and/or TOC content between the site and reference samples, and/or the result of non-site-related metals (iron, manganese, and nickel) that appear to be naturally elevated in Kuskokwim River sediment.

Table 7-1 Assessment Endpoints, Model Species, Risk Questions, and Measures for the Red Devil Mine Site BERA Supplement for the Kuskokwim River Assessment Area.

Assessment Endpoint (Attribute)	Level of Organization	Model Species	Risk Question	Measure	Analysis Approach
Aquatic-Dependent Mammals					
Aquatic-dependent piscivorous mammals (survival, growth, reproduction [S,G,R])	Local Population	Mink	Does the daily dose of contaminants received from ingestion of forage fish and other media exceed TRVs for survival, growth, or reproduction of mammals?	Modeled contaminant concentrations in forage fish. Measured concentrations in other media.	Modeled dose from ingestion of forage fish and other media compared with literature-based TRVs.
Aquatic-Dependent Birds					
Aquatic-dependent piscivorous birds (S,G,R)	Local Populations	Kingfisher	Does the daily dose of contaminants received from ingestion of forage fish and other media exceed TRVs for survival, growth, or reproduction of birds?	Modeled contaminant concentrations in forage fish. Measured concentrations in other media.	Modeled dose from ingestion of forage fish and other media compared with literature-based TRVs.
Aquatic-dependent invertivorous birds (S,G,R)	Local Populations	Common snipe	Does the daily dose of contaminants received from ingestion of benthic macroinvertebrates and other media exceed TRVs for survival, growth, or reproduction of birds?	Modeled contaminant concentrations in benthic invertebrates. Measured concentrations in other media.	Modeled dose from ingestion of benthic macroinvertebrates and other media compared with literature-based TRVs.
Aquatic-dependent herbivorous birds (S,G,R)	Local Populations	Green-winged teal	Does the daily dose of contaminants received from ingestion of aquatic plants and other media exceed TRVs for survival, growth, or reproduction of birds?	Modeled contaminant concentrations in aquatic plants. Measured concentrations in other media.	Modeled dose from ingestion of aquatic plants and other media compared with literature-based TRVs.
Benthic Macroinvertebrates					
Benthic macroinvertebrates (S,G,R)	Local Community	Species present in habitat	Are contaminant concentrations in sediment greater than screening levels for effects on survival, growth, or reproduction of benthos?	Contaminant concentrations in sediment.	Compare sediment contaminant concentrations with literature-based sediment screening levels for effects on benthic macroinvertebrates.
			Are contaminant concentrations in Kuskokwim River benthos greater than tissue screening concentrations?	Modeled contaminant concentrations in benthos from the river.	Compare modeled contaminant levels in Kuskokwim River benthos with TSCs for effects on benthos.
			Are survival and growth of laboratory-reared benthic organisms in Kuskokwim River sediment less than in control and reference area sediment?	Sediment toxicity tests.	Compare survival and growth in Kuskokwim River sediment with the same endpoints in control and reference area sediment.
Fish					
Fish (S,G,R)	Local Communities	Species present in habitat	Are contaminant levels in Kuskokwim River fish greater than fish tissue screening concentrations?	Modeled contaminant concentrations in forage fish from the river.	Compare modeled contaminant levels in Kuskokwim River forage fish with TSCs for effects on fish.

Key:
BERA = Baseline Ecological Risk Assessment; S,G,R = Survival, growth, reproduction; TRV = Toxicity Reference Value

Table 7-2 Sediment Exposure Point Concentrations for Kuskokwim River Assessment Area Used in Red Devil Mine Site BERA Supplement to Assess Risks to Piscivorous Wildlife (Belted Kingfisher and Mink).

Analyte[a]	Near Red Devil Mine		Downriver Area		Area-Weighted EPC[b]
	UCL (mg/kg)	Area (ha)	UCL (mg/kg)	Area (ha)	
Antimony	415.8	8.2	3.53	148	25.3
Arsenic	254.1	8.2	14.25	148	26.9
Barium	165.5	8.2	72.27	148	77.2
Beryllium	0.418	8.2	0.29	148	0.30
Cadmium	0.345	8.2	2.8	148	2.67
Chromium	19.83	8.2	18.65	148	18.7
Cobalt	12.85	8.2	9.428	148	9.6
Copper	32.7	8.2	29.28	148	29.5
Lead	8.1	8.2	6.2	148	6.31
Manganese	1072	8.2	414	148	449
Mercury	48.1	8.2	2.1	148	4.53
Methylmercury	0.00115	8.2	0.000053	148	0.000111
Nickel	38.57	8.2	28	148	28.6
Selenium	0.954	8.2	0.984	148	0.98
Silver	0.133	8.2	0.0831	148	0.086
Thallium	0.174	8.2	0.072	148	0.077
Vanadium	27.57	8.2	26.94	148	27.0
Zinc	95.5	8.2	66.32	148	67.9

Key:

BERA = Baseline ecological risk assessment

Gray shading = Used in BERA Supplement.

RDM = Red Devil Mine

UCL = Upper confidence limit (on average concentration)

Notes:

a. All TAL inorganic analytes except major elements and nutrients (see Section 7.3.1)

b. Weighted average of near-RDM and downriver UCLs based on fraction of total assessment area (156.2 ha) represented by the near-RDM samples (8.2 ha) and downriver (148 ha) areas. See Appendix E and Section 7.3.1.1.

Table 7-3 Sediment Exposure Point Concentrations for Kuskokwim River Assessment Area Used in BERA Supplement to Assess Risks for Wildlife that may Forage in Shoreline and Nearshore Habitats (Green-Winged Teal and Common Snipe).

Analyte[a]	Near Red Devil Mine		Downriver Area		Length-Weighted EPC[b]
	UCL (mg/kg)	Length (mi.)	UCL (mg/kg)	Length (mi.)	
Antimony	1281	0.65	1.754	3.46	204
Arsenic	759.3	0.65	12.16	3.46	130
Barium	194.4	0.65	72.4	3.46	91.7
Beryllium	0.534	0.65	0.336	3.46	0.37
Cadmium	0.369	0.65	2.8	3.46	2.42
Chromium	24.05	0.65	21.53	3.46	21.9
Cobalt	13.74	0.65	11.24	3.46	11.6
Copper	37.59	0.65	64	3.46	59.8
Lead	6.207	0.65	9.9	3.46	9.3
Manganese	2069	0.65	420	3.46	681
Mercury	260.7	0.65	2.1	3.46	43.0
Methylmercury	0.00153	0.65	0.00001	3.46	0.00025
Nickel	39.08	0.65	34.51	3.46	35.2
Selenium	1.243	0.65	1.136	3.46	1.15
Silver	0.149	0.65	0.106	3.46	0.11
Thallium	0.156	0.65	0.072	3.46	0.09
Vanadium	32.74	0.65	31.66	3.46	31.8
Zinc	94.49	0.65	85.25	3.46	86.7

Key:

BERA = Baseline ecological risk assessment

Gray shading = Used in BERA Supplement.

mi. = mile

RDM = Red Devil Mine

UCL = Upper confidence limit (on average concentration)

Notes:

a. All TAL inorganic analytes except major elements and nutrients (see Section 7.3.1)

b. Weighted average of near-RDM and downriver UCLs based on fraction of total assessment area shoreline length (4.11 miles) represented by near-RDM segment (0.65 miles) and downriver segments (3.46 miles, both banks summed). See Appendix E and Section 7.3.1.2.

Table 7-4 Exposure Parameters for Wildlife Receptors, Red Devil Mine Site BERA Supplement for Kuskokwim River Assessment Area.

Species	Assumed Diet	Soil or Sediment Ingestion (kg/d) dry	Surface Water Ingestion (L/day)	Home Range (ha or km)	Site Use Factor [d]	Exposure Duration [e]	Food Ingestion Rate (kg/d) wet	Percent Water in Diet	Food Ingestion Rate (kg/d) dry	Body Weight (kg)
Aquatic-Dependent Wildlife										
Common Snipe[a, c]	100% benthic invertebrates	0.0016	0.014	0.1 to 48 ha	1.0	0.33	0.047	68%	0.015	0.116
Green Winged Teal[a]	100% pond vegetation	0.001	0.027	243 ha	0.64	0.33	--	--	0.053	0.32
Belted Kingfisher[b]	100% forage fish	0	0.016	2.2 km	1.0	0.33	0.075	68%	0.024	0.148
Mink[b]	100% forage fish	0	0.099	1.9 to 2.6 km	1.0	1.0	0.137	68%	0.044	1

Key:
-- = not applicable
BERA = baseline ecological risk assessment
ha = hectare
kg = kilogram
kg/d = kilograms per day
L/d = liters per day

Notes:
a. Exponent (2007).
b. Sample and Suter (1994).
c. Food moisture content of 68% based on EPA (1999) for carnivores. Wet food Ingestion rate = dry food ingestion rate / (1- food moisture content).
d. Site use factor (SUF) of 1 assumed for all receptors except green-winged teal. For the teal, the SUF equals assessment area size (156.2 ha) divided by the home range (243 ha).
e. Migratory birds (robin, shrike, snipe, teal, kingfisher) assumed to be present at site four months per year (4/12 = 0.33). Other species assumed to be present year-round.

Table 7-5a Green-Winged Teal Exposure Point Concentrations, Red Devil Mine Site BERA Supplement for Kuskokwim River Assessment Area: Site Uptake Factors Used.

Analyte[a]	Sediment EPC (mg/kg)[b]	Modeled Aquatic Vegetation EPC (mg/kg dry weight)		
		Uptake Factor[c]	Value (mg/kg)	Basis
Metals				
Antimony	204	0.048	9.8	Sediment EPC x Uptake Factor
Arsenic	130	0.016	2.1	Sediment EPC x Uptake Factor
Barium	92	0.197	18.1	Sediment EPC x Uptake Factor
Beryllium	0.37	0.008	0.003	Sediment EPC x Uptake Factor
Cadmium	2.42	3.729	9.0	Sediment EPC x Uptake Factor
Chromium	21.9	0.015	0.33	Sediment EPC x Uptake Factor
Cobalt	11.6	0.035	0.41	Sediment EPC x Uptake Factor
Copper	59.8	0.146	8.7	Sediment EPC x Uptake Factor
Lead	9.3	0.006	0.056	Sediment EPC x Uptake Factor
Manganese	681	0.183	125	Sediment EPC x Uptake Factor
Mercury	43	0.032	1.4	Sediment EPC x Uptake Factor
Methylmercury	0.00025	0.032	0.00001	Sediment EPC x Uptake Factor (for mercury)
Nickel	35.2	0.066	2.3	Sediment EPC x Uptake Factor
Selenium	1.15	0.476	0.55	Sediment EPC x Uptake Factor
Silver	0.11	0.068	0.0077	Sediment EPC x Uptake Factor
Thallium	0.09	0.035	0.0030	Sediment EPC x Uptake Factor
Vanadium	31.8	0.011	0.35	Sediment EPC x Uptake Factor
Zinc	86.7	0.502	43.5	Sediment EPC x Uptake Factor

Key:
BERA = baseline ecological risk assessment
EPC = Exposure point concentration
mg/kg = milligrams per kilogram
UF = uptake factor

Notes:
a. All TAL inorganic analytes except major elements and nutrients (see Section 7.3.1)
b. For shoreline/nearshore sediment (from Table 7-3).
c. Greatest site-specific sediment-to-aquatic plant uptake factor from on-site settling ponds (see Appendix J).

Table 7-5b Green-Winged Teal EPCs, Red Devil Mine Site BERA Supplement for Kuskokwim River Assessment Area: Background Uptake Factors Used.

Analyte[a]	Sediment EPC (mg/kg)[b]	Modeled Aquatic Vegetation EPC (mg/kg dry weight)		
		Uptake Factor[c]	Value (mg/kg)	Basis
Metals				
Antimony	204	1.269	259.0	Sediment EPC x Uptake Factor
Arsenic	130	0.034	4.4	Sediment EPC x Uptake Factor
Barium	92	0.35	32.1	Sediment EPC x Uptake Factor
Beryllium	0.37	0.011	0.004	Sediment EPC x Uptake Factor
Cadmium	2.42	0.074	0.2	Sediment EPC x Uptake Factor
Chromium	21.9	0.013	0.29	Sediment EPC x Uptake Factor
Cobalt	11.6	0.042	0.49	Sediment EPC x Uptake Factor
Copper	59.8	0.192	11.5	Sediment EPC x Uptake Factor
Lead	9.3	0.01	0.093	Sediment EPC x Uptake Factor
Manganese	681	1.504	1024	Sediment EPC x Uptake Factor
Mercury	43	0.245	10.5	Sediment EPC x Uptake Factor
Methylmercury	0.00025	22	0.006	Sediment EPC x Uptake Factor
Nickel	35.2	0.021	0.7	Sediment EPC x Uptake Factor
Selenium	1.15	0.209	0.24	Sediment EPC x Uptake Factor
Silver	0.11	0.039	0.0044	Sediment EPC x Uptake Factor
Thallium	0.09	0.342	0.0292	Sediment EPC x Uptake Factor
Vanadium	31.8	0.008	0.25	Sediment EPC x Uptake Factor
Zinc	86.7	0.393	34.1	Sediment EPC x Uptake Factor

Key:
-- = Not analyzed.
BERA = baseline ecological risk assessment
EPC = Exposure point concentration
mg/kg = milligrams per kilogram
µg/kg = micrograms per kilogram
UF = uptake factor

Notes:
a. All TAL inorganic analytes except major elements and nutrients (see Section 7.3.1)
b. For shoreline/nearshore sediment (from Table 7-3).
c. Site-specific sediment-to-aquatic plant UF from background pond (see Appendix J).

Table 7-5c Green-Winged Teal EPCs, Red Devil Mine Site BERA Supplement for Kuskokwim River Assessment Area: Downriver Periphyton Results Used.

Analyte[a]	Sediment EPC (mg/kg)[b]	Measured Periphyton EPC (mg/kg dry weight)	
		Value (mg/kg dry)	Basis
Metals			
Antimony	204	46.2	95% UCL for downriver periphyton (see Appendix K).
Arsenic	130	35.0	95% UCL for downriver periphyton (see Appendix K).
Barium	92	551.0	95% UCL for downriver periphyton (see Appendix K).
Beryllium	0.37	1.081	95% UCL for downriver periphyton (see Appendix K).
Cadmium	2.42	0.5	95% UCL for downriver periphyton (see Appendix K).
Chromium	21.9	57.26	95% UCL for downriver periphyton (see Appendix K).
Cobalt	11.6	--	Not analyzed in periphyton.
Copper	59.8	37.9	95% UCL for downriver periphyton (see Appendix K).
Lead	9.3	12.860	95% UCL for downriver periphyton (see Appendix K).
Manganese	681	786	95% UCL for downriver periphyton (see Appendix K).
Mercury	43	6.9	95% UCL for downriver periphyton (see Appendix K).
Methylmercury	0.00025	0.00025	Not detected in periphyton. One-half MDL used as EPC.
Nickel	35.2	40.4	95% UCL for downriver periphyton (see Appendix K).
Selenium	1.15	0.72	95% UCL for downriver periphyton (see Appendix K).
Silver	0.11	--	Not analyzed in periphyton.
Thallium	0.09	--	Not analyzed in periphyton.
Vanadium	31.8	92.35	95% UCL for downriver periphyton (see Appendix K).
Zinc	86.7	120.0	95% UCL for downriver periphyton (see Appendix K).

Key:

-- = Not analyzed.

BERA = baseline ecological risk assessment

EPC = Exposure point concentration

mg/kg = milligrams per kilogram

Notes:

a. All TAL inorganic analytes except major elements and nutrients (see Section 7.3.1)

b. For shoreline/nearshore sediment (from Table 7-3).

c. Site-specific sediment-to-aquatic plant UF from background pond (see Appendix J).

Table 7-6a Common Snipe Exposure Point Concentrations for Red Devil Mine Site BERA Supplement for Kuskokwim River Assessment Area: Site BSAFs Used to Estimate Dietary Exposure.

Analyte[a]	Sediment EPC (mg/kg)[b]	Modeled Benthic Macroinvertebrate EPC (mg/kg wet)		
		BSAF[c]	Value	Basis
Metals				
Antimony	204	0.002	0.41	Sediment EPC x BSAF
Arsenic	130	0.025	3.3	Sediment EPC x BSAF
Barium	92	0.004	0.37	Sediment EPC x BSAF
Beryllium	0.37	0.006	0.002	Sediment EPC x BSAF
Cadmium	2.42	0.195	0.47	Sediment EPC x BSAF
Chromium	21.9	0.003	0.066	Sediment EPC x BSAF
Cobalt	11.6	--	12	Not analyzed in benthos. See note d.
Copper	59.8	0.120	7.18	Sediment EPC x BSAF
Lead	9.3	0.004	0.037	Sediment EPC x BSAF
Manganese	681	0.023	15.7	Sediment EPC x BSAF
Mercury	43	0.008	0.34	Sediment EPC x BSAF
Methylmercury	0.00025	0.081	0.00002	Sediment EPC x BSAF
Nickel	35.2	0.014	0.49	Sediment EPC x BSAF
Selenium	1.15	2.180	2.5	Sediment EPC x BSAF
Silver	0.11	--	0.11	Not analyzed in benthos. See note d.
Thallium	0.09	--	0.09	Not analyzed in benthos. See note d.
Vanadium	31.8	0.003	0.095	Sediment EPC x BSAF
Zinc	86.7	0.314	27.2	Sediment EPC x BSAF

Key:
BERA = Baseline Ecological Risk Assessment
BSAF = Biota sediment accumulation factor
EPC = Exposure point concentration
mg/kg = milligrams per kilogram

Notes:
a. All TAL inorganic analytes except major elements and nutrients (see Section 7.3.1)
b. From Table 7-3.
c. Site BSAF from Appendix F.
d. Benthic macroinvertebrate EPC assumed to be equal to sediment EPC.

Table 7-6b Common Snipe Exposure Point Concentrations for Red Devil Mine Site BERA Supplement for Kuskokwim River Assessment Area: Background BSAFs Used to Estimate Dietary Exposure.

Analyte[a]	Sediment EPC (mg/kg)[b]	Modeled Benthic Macroinvertebrate EPC (mg/kg wet)		
		BSAF[c]	Value	Basis
Metals				
Antimony	204	0.044	8.98	Sediment EPC x BSAF
Arsenic	130	0.079	10.3	Sediment EPC x BSAF
Barium	92	0.014	1.28	Sediment EPC x BSAF
Beryllium	0.37	0.011	0.004	Sediment EPC x BSAF
Cadmium	2.42	1.64	3.97	Sediment EPC x BSAF
Chromium	21.9	0.015	0.329	Sediment EPC x BSAF
Cobalt	11.6	--	12	Not analyzed in benthos. See note d.
Copper	59.8	0.53	31.71	Sediment EPC x BSAF
Lead	9.3	0.032	0.298	Sediment EPC x BSAF
Manganese	681	0.097	66.0	Sediment EPC x BSAF
Mercury	43	0.155	6.66	Sediment EPC x BSAF
Methylmercury	0.00025	17.8	0.00446	Sediment EPC x BSAF
Nickel	35.2	0.028	0.99	Sediment EPC x BSAF
Selenium	1.15	2.68	3.1	Sediment EPC x BSAF
Silver	0.11	--	0.11	Not analyzed in benthos. See note d.
Thallium	0.09	--	0.09	Not analyzed in benthos. See note d.
Vanadium	31.8	0.014	0.446	Sediment EPC x BSAF
Zinc	86.7	0.38	33.0	Sediment EPC x BSAF

Key:
BERA = Baseline Ecological Risk Assessment
BSAF = Biota sediment accumulation factor
EPC = Exposure point concentration
mg/kg = milligrams per kilogram

Notes:
a. All TAL inorganic analytes except major elements and nutrients (see Section 7.3.1)
b. From Table 7-3.
c. Background BSAF from Appendix F.
d. Benthic macroinvertebrate EPC assumed to be equal to sediment EPC.

Table 7-7a Belted Kingfisher and Mink Exposure Point Concentrations, Red Devil Mine Site BERA Supplement for Kuskokwim River Assessment Area: Site BSAFs and TTFs used to Model Dietary Exposure.

Analyte[a]	Sediment EPC (mg/kg)[b]	Modeled Slimy Sculpin EPC (mg/kg wet)			
		Site BSAF[c]	Site TTF[d]	EPC (mg/kg)	Basis
Metals					
Antimony	25.3	0.002	0.80	0.04	Sediment EPC x BSAF x TTF
Arsenic	26.9	0.025	0.063	0.04	Sediment EPC x BSAF x TTF
Barium	77.2	0.004	0.36	0.11	Sediment EPC x BSAF x TTF
Beryllium	0.30	0.006	1.00	0.002	Sediment EPC x BSAF x TTF
Cadmium	2.67	0.195	0.46	0.240	Sediment EPC x BSAF x TTF
Chromium	18.7	0.003	0.37	0.021	Sediment EPC x BSAF x TTF
Cobalt	9.6	--	--	9.6	Not analyzed in biota. See note e.
Copper	29.5	0.120	0.12	0.42	Sediment EPC x BSAF x TTF
Lead	6.3	0.004	0.077	0.002	Sediment EPC x BSAF x TTF
Manganese	449	0.023	0.14	1.44	Sediment EPC x BSAF x TTF
Mercury	4.5	0.008	0.66	0.02	Sediment EPC x BSAF x TTF
Methylmercury	0.00011	0.081	2.74	0.00002	Sediment EPC x BSAF x TTF
Nickel	28.6	0.014	0.08	0.032	Sediment EPC x BSAF x TTF
Selenium	0.98	2.180	0.46	0.99	Sediment EPC x BSAF x TTF
Silver	0.086	--	--	0.09	Not analyzed in biota. See note e.
Thallium	0.077	--	--	0.08	Not analyzed in biota. See note e.
Vanadium	27.0	0.003	0.24	0.02	Sediment EPC x BSAF x TTF
Zinc	67.9	0.314	0.57	12.15	Sediment EPC x BSAF x TTF

Key:
BERA = baseline ecological risk assessment
BSAF = Biota sediment accumulation factor
EPC = Exposure Point Concentration
mg/kg = milligrams per kilogram
TTF = Trophic transfer factor

Notes:
a. All TAL inorganic analytes except major elements and nutrients (see Section 7.3.1)
b. From Table 7-2.
c. Site BSAF from Appendix F.
d. Site TTF From Appendix I.
e. Sculpin EPC assumed equal to sediment EPC.

Table 7-7b Belted Kingfisher and Mink Exposure Point Concentrations, Red Devil Mine Site BERA Supplement for Kuskokwim River Assessment Area: Background BSAFs and TTFs Used to Model Dietary Exposure.

Analyte[a]	Sediment EPC (mg/kg)[c]	Modeled Slimy Sculpin EPC (mg/kg wet)			
		Background BSAF[c]	Background TTF[d]	Value (mg/kg)	Basis
Metals					
Antimony	25.3	0.044	0.28	0.31	Sediment EPC x BSAF x TTF
Arsenic	26.9	0.079	0.11	0.24	Sediment EPC x BSAF x TTF
Barium	77.2	0.014	0.04	0.04	Sediment EPC x BSAF x TTF
Beryllium	0.30	0.011	0.45	0.001	Sediment EPC x BSAF x TTF
Cadmium	2.67	1.64	0.11	0.482	Sediment EPC x BSAF x TTF
Chromium	18.7	0.015	0.08	0.024	Sediment EPC x BSAF x TTF
Cobalt	9.6	--	--	9.6	Not analyzed in biota. See note e.
Copper	29.5	0.53	0.10	1.53	Sediment EPC x BSAF x TTF
Lead	6.3	0.032	0.063	0.013	Sediment EPC x BSAF x TTF
Manganese	449	0.097	0.08	3.31	Sediment EPC x BSAF x TTF
Mercury	4.5	0.16	1.45	1.02	Sediment EPC x BSAF x TTF
Methylmercury	0.00011	17.8	3.17	0.00625	Sediment EPC x BSAF x TTF
Nickel	28.6	0.028	0.05	0.038	Sediment EPC x BSAF x TTF
Selenium	0.98	2.68	0.85	2.24	Sediment EPC x BSAF x TTF
Silver	0.086	--	--	0.09	Not analyzed in biota. See note e.
Thallium	0.077	--	--	0.08	Not analyzed in biota. See note e.
Vanadium	27.0	0.014	0.10	0.04	Sediment EPC x BSAF x TTF
Zinc	67.9	0.38	0.47	12.12	Sediment EPC x BSAF x TTF

Key:
BERA = baseline ecological risk assessment
BSAF = Biota sediment accumulation factor
EPC = Exposure Point Concentration
mg/kg = milligrams per kilogram
TTF = Trophic transfer factor

Notes:
a. All TAL inorganic analytes except major elements and nutrients (see Section 7.3.1)
b. From Table 7-2.
c. Background BSAF from Appendix F.
d. Site TTF From Appendix N.
e. Sculpin EPC assumed equal to sediment EPC.

Table 7-8a Green Winged Teal Exposure Estimates and HQs, Red Devil Mine Site BERA Supplement for Kuskokwim River Assessment Area: Sediment-to-Aquatic Plant Uptake Factors for Settling Ponds (Appendix J) Used to Estimate Dietary Exposure.

Analyte[a]	EE-sediment (mg/kg/d)	EE-diet (mg/kg/d)	EE-total (mg/kg/d)	NOAEL (mg/kg/d)	LOAEL (mg/kg/d)	HQ-NOAEL	HQ-LOAEL
Metals							
Antimony	1.4E-01	3.5E-01	4.8E-01	--	--	--	--
Arsenic	8.7E-02	7.4E-02	1.6E-01	2.24	3.55	0.07	0.05
Barium	6.1E-02	6.4E-01	7.0E-01	20.8	41.7	0.03	0.02
Beryllium	2.5E-04	1.0E-04	3.5E-04	--	--	--	--
Cadmium	1.6E-03	3.2E-01	3.2E-01	1.47	2.37	0.22	0.14
Chromium	1.5E-02	1.2E-02	2.6E-02	2.66	2.78	0.01	0.01
Cobalt	7.8E-03	1.4E-02	2.2E-02	7.61	7.8	0.003	0.003
Copper	4.0E-02	3.1E-01	3.5E-01	4.05	4.68	0.09	0.07
Lead	6.2E-03	2.0E-03	8.2E-03	1.63	1.94	0.005	0.004
Manganese	4.6E-01	4.4E+00	4.9E+00	179	348	0.03	0.01
Mercury	2.9E-02	4.9E-02	7.8E-02	0.45	0.9	0.17	0.09
Methylmercury	1.7E-07	2.8E-07	4.5E-07	0.068	0.37	0.00001	0.00000
Nickel	2.4E-02	8.3E-02	1.1E-01	6.71	11.5	0.02	0.01
Selenium	7.7E-04	1.9E-02	2.0E-02	0.291	0.368	0.07	0.06
Silver	7.6E-05	2.7E-04	3.5E-04	2.02	20.2	0.0002	0.00002
Thallium	5.7E-05	1.1E-04	1.6E-04	--	--	--	--
Vanadium	2.1E-02	1.2E-02	3.4E-02	0.344	0.413	0.10	0.08
Zinc	5.8E-02	1.5E+00	1.6E+00	66.1	66.5	0.02	0.02

Key:
-- = Not available
BERA = baseline ecological risk assessment
EE-diet = estimated chemical exposure from diet
EE-sediment = estimated exposure from incidental sediment (i.e., dry surface soil) ingestion
EE-total = total chemical exposure
HQ = hazard quotient
LOAEL = lowest observed adverse effect level
NOAEL = no observed adverse effect level
mg/kg = milligrams per kilogram
mg/kg/day = milligrams per kilogram per day
UF = uptake factor (sediment-to-aquatic plant)
Grey shading = HQ > 1

Note:
a. All TAL inorganic analytes except major elements and nutrients (see Section 7.3.1)

Table 7-8b Green Winged Teal Exposure Estimates and HQs, Red Devil Mine Site BERA Supplement for Kuskokwim River Assessment Area: Background Sediment-to-Aquatic Plant Uptake Factors (Appendix J) Used to Estimate Dietary Exposure.

Analyte[a]	EE-sediment (mg/kg/d)	EE-diet (mg/kg/d)	EE-total (mg/kg/d)	NOAEL (mg/kg/d)	LOAEL (mg/kg/d)	HQ-NOAEL	HQ-LOAEL
Metals							
Antimony	1.4E-01	9.2E+00	9.3E+00	--	--	--	--
Arsenic	8.7E-02	1.6E-01	2.4E-01	2.24	3.55	0.11	0.07
Barium	6.1E-02	1.1E+00	1.2E+00	20.8	41.7	0.06	0.03
Beryllium	2.5E-04	1.4E-04	3.9E-04	--	--	--	--
Cadmium	1.6E-03	6.3E-03	8.0E-03	1.47	2.37	0.01	0.00
Chromium	1.5E-02	1.0E-02	2.5E-02	2.66	2.78	0.01	0.01
Cobalt	7.8E-03	1.7E-02	2.5E-02	7.61	7.8	0.003	0.003
Copper	4.0E-02	4.1E-01	4.5E-01	4.05	4.68	0.11	0.10
Lead	6.2E-03	3.3E-03	9.5E-03	1.63	1.94	0.006	0.005
Manganese	4.6E-01	3.6E+01	3.7E+01	179	348	0.21	0.11
Mercury	2.9E-02	3.7E-01	4.0E-01	0.45	0.9	0.9	0.4
Methylmercury	1.7E-07	2.0E-04	2.0E-04	0.068	0.37	0.003	0.001
Nickel	2.4E-02	2.6E-02	5.0E-02	6.71	11.5	0.01	0.004
Selenium	7.7E-04	8.6E-03	9.3E-03	0.291	0.368	0.03	0.03
Silver	7.6E-05	1.6E-04	2.3E-04	2.02	20.2	0.0001	0.00001
Thallium	5.7E-05	1.0E-03	1.1E-03	--	--	--	--
Vanadium	2.1E-02	9.0E-03	3.0E-02	0.344	0.413	0.09	0.07
Zinc	5.8E-02	1.2E+00	1.3E+00	66.1	66.5	0.02	0.02

Key:
-- = Not available
BERA = baseline ecological risk assessment
EE-diet = estimated chemical exposure from diet
EE-sediment = estimated exposure from incidental sediment (i.e., dry surface soil) ingestion
EE-total = total chemical exposure
HQ = hazard quotient
LOAEL = lowest observed adverse effect level
NOAEL = no observed adverse effect level
mg/kg = milligrams per kilogram
mg/kg/day = milligrams per kilogram per day
UF = uptake factor (sediment-to-aquatic plant)
Grey shading = HQ > 1

Note:
a. All TAL inorganic analytes except major elements and nutrients (see Section 7.3.1)

Table 7-8c Green Winged Teal Exposure Estimates and HQs, Red Devil Mine Site BERA Supplement for Kuskokwim River Assessment Area: Downriver Periphyton Results (Appendix K) Used to Estimate Dietary Exposure.

Analyte[a]	EE-sediment (mg/kg/d)	EE-diet (mg/kg/d)	EE-total (mg/kg/d)	NOAEL (mg/kg/d)	LOAEL (mg/kg/d)	HQ-NOAEL	HQ-LOAEL
Metals							
Antimony	1.4E-01	1.6E+00	1.8E+00	--	--	--	--
Arsenic	8.7E-02	1.2E+00	1.3E+00	2.24	3.55	0.59	0.37
Barium	6.1E-02	2.0E+01	2.0E+01	20.8	41.7	0.94	0.47
Beryllium	2.5E-04	3.8E-02	3.9E-02	--	--	--	--
Cadmium	1.6E-03	1.8E-02	2.0E-02	1.47	2.37	0.01	0.01
Chromium	1.5E-02	2.0E+00	2.0E+00	2.66	2.78	0.77	0.74
Cobalt	7.8E-03	--	7.8E-03	7.61	7.8	0.001	0.001
Copper	4.0E-02	1.3E+00	1.4E+00	4.05	4.68	0.34	0.30
Lead	6.2E-03	4.6E-01	4.6E-01	1.63	1.94	0.28	0.24
Manganese	4.6E-01	2.8E+01	2.8E+01	179	348	0.16	0.08
Mercury	2.9E-02	2.4E-01	2.7E-01	0.45	0.9	0.61	0.30
Methylmercury	1.7E-07	8.9E-06	9.0E-06	0.068	0.37	0.0001	0.00002
Nickel	2.4E-02	1.4E+00	1.5E+00	6.71	11.5	0.22	0.13
Selenium	7.7E-04	2.5E-02	2.6E-02	0.291	0.368	0.09	0.07
Silver	7.6E-05	--	7.6E-05	2.02	20.2	0.00004	0.000004
Thallium	5.7E-05	--	5.7E-05	--	--	--	--
Vanadium	2.1E-02	3.3E+00	3.3E+00	0.344	0.413	9.6	8.0
Zinc	5.8E-02	4.3E+00	4.3E+00	66.1	66.5	0.07	0.06

Key:
-- = Not available
BERA = baseline ecological risk assessment
EE-diet = estimated chemical exposure from diet
EE-sediment = estimated exposure from incidental sediment (i.e., dry surface soil) ingestion
EE-total = total chemical exposure
EPC = exposure point concentration
HQ = hazard quotient
LOAEL = lowest observed adverse effect level
NOAEL = no observed adverse effect level
mg/kg/day = milligrams per kilogram per day
Grey shading = HQ > 1

Note:
a. All TAL inorganic analytes except major elements and nutrients (see Section 7.3.1)

Table 7-9a Common Snipe Exposure Estimates and Hazard Quotients, Red Devil Mine Site BERA Supplement for Kuskokwim River Exposure Area: Site BSAFs (Appendix F) Used to Estimate Dietary Exposure.

Analyte[a]	EE-sediment (mg/kg/d)	EE-diet (mg/kg/d)	EE-total (mg/kg/d)	NOAEL (mg/kg/d)	LOAEL (mg/kg/d)	HQ-NOAEL	HQ-LOAEL
Metals							
Antimony	9.4E-01	5.5E-02	9.9E-01	--	--	--	--
Arsenic	6.0E-01	4.4E-01	1.0E+00	2.24	3.55	0.46	0.29
Barium	4.2E-01	4.9E-02	4.7E-01	20.8	41.7	0.02	0.01
Beryllium	1.7E-03	3.0E-04	2.0E-03	--	--	--	--
Cadmium	3.3E-02	6.3E-02	9.7E-02	1.47	2.37	0.07	0.04
Chromium	3.0E-01	8.9E-03	3.1E-01	2.66	2.78	0.12	0.11
Cobalt	1.6E-01	1.6E+00	1.7E+00	7.61	7.8	0.23	0.22
Copper	2.8E-01	9.7E-01	1.2E+00	4.05	4.68	0.31	0.27
Lead	1.3E-01	5.0E-03	1.3E-01	1.63	1.94	0.08	0.07
Manganese	9.4E+00	2.1E+00	1.1E+01	179	348	0.06	0.03
Mercury	2.0E-01	4.6E-02	2.4E-01	0.45	0.9	0.54	0.27
Methylmercury	3.5E-06	2.7E-06	6.2E-06	0.068	0.37	0.0001	0.00002
Nickel	4.9E-01	6.6E-02	5.5E-01	6.71	11.5	0.08	0.05
Selenium	5.3E-03	3.4E-01	3.4E-01	0.291	0.368	1.2	0.93
Silver	1.6E-03	1.5E-02	1.7E-02	2.02	20.2	0.01	0.001
Thallium	3.9E-04	1.1E-02	1.2E-02	--	--	--	--
Vanadium	1.5E-01	1.3E-02	1.6E-01	0.344	0.413	0.46	0.39
Zinc	1.2E+00	3.7E+00	4.9E+00	66.1	66.5	0.07	0.07

Key:
-- = not available
BERA = baseline ecological risk assessment
BSAF = Biota sediment accumulation factor
EE-diet = estimated chemical exposure from diet
EE-sediment = estimated chemical exposure from incidental sediment ingestion
EE-total = total chemical exposure
HQ = hazard quotient
mg/kg = milligrams per kilogram
mg/kg/day = milligrams per kilogram per day
NOAEL = no observed adverse effect level
Grey shading = HQ > 1.0

Note:
a. All TAL inorganic analytes except major elements and nutrients (see Section 7.3.1)

Table 7-9b Common Snipe Exposure Estimates and Hazard Quotients, Red Devil Mine Site BERA Supplement for Kuskokwim River Exposure Area: Background BSAFs (Appendix F) Used to Estimate Dietary Exposure.

Analyte[a]	EE-sediment (mg/kg/d)	EE-diet (mg/kg/d)	EE-total (mg/kg/d)	NOAEL (mg/kg/d)	LOAEL (mg/kg/d)	HQ-NOAEL	HQ-LOAEL
Metals							
Antimony	9.4E-01	1.2E+00	2.1E+00	--	--	--	--
Arsenic	6.0E-01	1.4E+00	2.0E+00	2.24	3.55	0.89	0.56
Barium	4.2E-01	1.7E-01	5.9E-01	20.8	41.7	0.03	0.01
Beryllium	1.7E-03	5.4E-04	2.2E-03	--	--	--	--
Cadmium	3.3E-02	5.3E-01	5.7E-01	1.47	2.37	0.39	0.24
Chromium	3.0E-01	4.4E-02	3.5E-01	2.66	2.78	0.13	0.12
Cobalt	1.6E-01	1.6E+00	1.7E+00	7.61	7.8	0.23	0.22
Copper	2.8E-01	4.3E+00	4.5E+00	4.05	4.68	1.1	0.97
Lead	1.3E-01	4.0E-02	1.7E-01	1.63	1.94	0.10	0.09
Manganese	9.4E+00	8.9E+00	1.8E+01	179	348	0.10	0.05
Mercury	2.0E-01	9.0E-01	1.1E+00	0.45	0.9	2.4	1.2
Methylmercury	3.5E-06	6.0E-04	6.0E-04	0.068	0.37	0.009	0.002
Nickel	4.9E-01	1.3E-01	6.2E-01	6.71	11.5	0.09	0.05
Selenium	5.3E-03	4.2E-01	4.2E-01	0.291	0.368	1.4	1.1
Silver	1.6E-03	1.5E-02	1.7E-02	2.02	20.2	0.01	0.001
Thallium	3.9E-04	1.1E-02	1.2E-02	--	--	--	--
Vanadium	1.5E-01	6.0E-02	2.1E-01	0.344	0.413	0.60	0.50
Zinc	1.2E+00	4.4E+00	5.6E+00	66.1	66.5	0.09	0.08

Key:
-- = not available
BERA = baseline ecological risk assessment
BSAF = Biota sediment accumulation factor
EE-diet = estimated chemical exposure from diet
EE-sediment = estimated chemical exposure from incidental sediment ingestion
EE-total = total chemical exposure
HQ = hazard quotient
LOAEL = lowest observed adverse effect level
mg/kg/day = milligrams per kilogram per day
NOAEL = no observed adverse effect level
Grey shading = HQ > 1.0

Note:
a. All TAL inorganic analytes except major elements and nutrients (see Section 7.3.1)

Table 7-10a Belted Kingfisher Exposure Estimates and Hazard Quotients, Red Devil Mine Site BERA Supplement for Kuskokwim River Assessment Area: Site BSAFs and TTFs Used to Estimate Dietary Exposure.

Analyte[a]	EE-sediment (mg/kg/d)	EE-diet (mg/kg/d)	EE-total (mg/kg/d)	NOAEL (mg/kg/d)	LOAEL (mg/kg/d)	HQ-NOAEL	HQ-LOAEL
Metals							
Antimony	0.0E+00	6.8E-03	6.8E-03	--	--	--	--
Arsenic	0.0E+00	7.2E-03	7.2E-03	2.24	3.55	0.003	0.002
Barium	0.0E+00	1.9E-02	1.9E-02	20.8	41.7	0.001	0.0005
Beryllium	0.0E+00	3.0E-04	3.0E-04	--	--	--	--
Cadmium	0.0E+00	4.0E-02	4.0E-02	1.47	2.37	0.028	0.017
Chromium	0.0E+00	3.5E-03	3.5E-03	2.66	2.78	0.001	0.001
Cobalt	0.0E+00	1.6E+00	1.6E+00	7.61	7.8	0.21	0.21
Copper	0.0E+00	7.2E-02	7.2E-02	4.05	4.68	0.018	0.015
Lead	0.0E+00	3.3E-04	3.3E-04	1.63	1.94	0.0002	0.0002
Manganese	0.0E+00	2.4E-01	2.4E-01	179	348	0.001	0.001
Mercury	0.0E+00	4.0E-03	4.0E-03	0.45	0.9	0.009	0.004
Methylmercury	0.0E+00	4.2E-06	4.2E-06	0.068	0.37	0.0001	0.00001
Nickel	0.0E+00	5.4E-03	5.4E-03	6.71	11.5	0.001	0.000
Selenium	0.0E+00	1.7E-01	1.7E-01	0.291	0.368	0.57	0.45
Silver	0.0E+00	1.4E-02	1.4E-02	2.02	20.2	0.007	0.001
Thallium	0.0E+00	1.3E-02	1.3E-02	--	--	--	--
Vanadium	0.0E+00	3.3E-03	3.3E-03	0.344	0.413	0.010	0.008
Zinc	0.0E+00	2.1E+00	2.1E+00	66.1	66.5	0.03	0.03

Key:
-- = not available
BERA = baseline ecological risk assessment
EE-diet = estimated chemical exposure from diet
EE-sediment = estimated chemical exposure from incidental sediment ingestion
EE-total = total chemical exposure
HQ = hazard quotient
mg/kg = milligrams per kilogram
mg/kg/day = milligrams per kilogram per day
NOAEL = no observed adverse effect level
Grey shading = HQ > 1.0

Note:
a. All TAL inorganic analytes except major elements and nutrients (see Section 7.3.1)

Table 7-10b Belted Kingfisher Exposure Estimates and Hazard Quotients, Red Devil Mine Site BERA Supplement for Kuskokwim River Assessment Area: Background BSAFs and TTFs Used to Estimate Dietary Exposure.

Analyte[a]	EE-sediment (mg/kg/d)	EE-diet (mg/kg/d)	EE-total (mg/kg/d)	NOAEL (mg/kg/d)	LOAEL (mg/kg/d)	HQ-NOAEL	HQ-LOAEL
Metals							
Antimony	0.0E+00	5.3E-02	5.3E-02	--	--	--	--
Arsenic	0.0E+00	4.0E-02	4.0E-02	2.24	3.55	0.018	0.011
Barium	0.0E+00	6.8E-03	6.8E-03	20.8	41.7	0.0003	0.0002
Beryllium	0.0E+00	2.5E-04	2.5E-04	--	--	--	--
Cadmium	0.0E+00	8.1E-02	8.1E-02	1.47	2.37	0.055	0.034
Chromium	0.0E+00	4.0E-03	4.0E-03	2.66	2.78	0.001	0.001
Cobalt	0.0E+00	1.6E+00	1.6E+00	7.61	7.8	0.21	0.21
Copper	0.0E+00	2.6E-01	2.6E-01	4.05	4.68	0.064	0.055
Lead	0.0E+00	2.1E-03	2.1E-03	1.63	1.94	0.0013	0.0011
Manganese	0.0E+00	5.6E-01	5.6E-01	179	348	0.003	0.002
Mercury	0.0E+00	1.7E-01	1.7E-01	0.45	0.9	0.382	0.191
Methylmercury	0.0E+00	1.1E-03	1.1E-03	0.068	0.37	0.016	0.003
Nickel	0.0E+00	6.3E-03	6.3E-03	6.71	11.5	0.001	0.001
Selenium	0.0E+00	3.8E-01	3.8E-01	0.291	0.368	1.3	1.0
Silver	0.0E+00	1.4E-02	1.4E-02	2.02	20.2	0.007	0.001
Thallium	0.0E+00	1.3E-02	1.3E-02	--	--	--	--
Vanadium	0.0E+00	6.6E-03	6.6E-03	0.344	0.413	0.019	0.016
Zinc	0.0E+00	2.0E+00	2.0E+00	66.1	66.5	0.03	0.03

Key:
-- = not available
BERA = baseline ecological risk assessment
EE-diet = estimated chemical exposure from diet
EE-sediment = estimated chemical exposure from incidental sediment ingestion
EE-total = total chemical exposure
EPC = exposure point concentration
HQ = hazard quotient
LOAEL = lowest observed adverse effect level
mg/kg = milligrams per kilogram
mg/kg/day = milligrams per kilogram per day
NOAEL = no observed adverse effect level
Grey shading = HQ > 1.0

Note:
a. All TAL inorganic analytes except major elements and nutrients (see Section 7.3.1)

Table 7-11a Mink Exposure Estimates and Hazard Quotients, Red Devil Mine Site BERA Supplement for Kuskokwim River Assessment Area: Site BSAFs and TTFs Used to Estimate Dieatry Exposure.

Analyte[a]	EE-sediment (mg/kg/d)	EE-diet (mg/kg/d)	EE-total (mg/kg/d)	NOAEL (mg/kg/d)	LOAEL (mg/kg/d)	HQ-NOAEL	HQ-LOAEL
Metals							
Antimony	0.0E+00	5.5E-03	5.5E-03	0.059	0.59	0.09	0.009
Arsenic	0.0E+00	5.8E-03	5.8E-03	1.04	1.66	0.006	0.003
Barium	0.0E+00	1.5E-02	1.5E-02	51.8	121	0.0003	0.0001
Beryllium	0.0E+00	2.4E-04	2.4E-04	0.532	--	0.0005	--
Cadmium	0.0E+00	3.3E-02	3.3E-02	0.77	1	0.043	0.033
Chromium	0.0E+00	2.8E-03	2.8E-03	9.24	--	0.0003	--
Cobalt	0.0E+00	4.2E-01	4.2E-01	7.33	10.9	0.057	0.039
Copper	0.0E+00	5.8E-02	5.8E-02	5.6	5.79	0.010	0.010
Lead	0.0E+00	2.7E-04	2.7E-04	4.7	5	0.0001	0.0001
Manganese	0.0E+00	2.0E-01	2.0E-01	51.5	65	0.004	0.003
Mercury	0.0E+00	3.3E-03	3.3E-03	13.2	--	0.0002	--
Methylmercury	0.0E+00	3.4E-06	3.4E-06	0.032	0.16	0.0001	0.00002
Nickel	0.0E+00	4.4E-03	4.4E-03	1.7	2.71	0.003	0.002
Selenium	0.0E+00	1.3E-01	1.3E-01	0.143	0.145	0.94	0.93
Silver	0.0E+00	3.8E-03	3.8E-03	6.02	60.2	0.001	0.0001
Thallium	0.0E+00	3.4E-03	3.4E-03	0.0074	0.074	0.46	0.046
Vanadium	0.0E+00	2.7E-03	2.7E-03	4.16	5.11	0.001	0.001
Zinc	0.0E+00	1.7E+00	1.7E+00	75.4	75.9	0.022	0.022

Key:
-- = not available
BERA = baseline ecological risk assessment
EE-diet = estimated chemical exposure from diet
EE-sediment = estimated chemical exposure from incidental sediment ingestion
EE-total = total chemical exposure
HQ = hazard quotient
mg/kg/day = milligrams per kilogram per day
NOAEL = no observed adverse effect level
Grey shading = HQ > 1.0

Note:
a. All TAL inorganic analytes except major elements and nutrients (see Section 7.3.1)

Table 7-11b Mink Exposure Estimates and Hazard Quotients, Red Devil Mine Site BERA Supplement for Kuskokwim River Assessment Area: Background BSAFs and TTFs Used to Estimate Dieatry Exposure.

Analyte[a]	EE-sediment (mg/kg/d)	EE-diet (mg/kg/d)	EE-total (mg/kg/d)	NOAEL (mg/kg/d)	LOAEL (mg/kg/d)	HQ-NOAEL	HQ-LOAEL
Metals							
Antimony	0.0E+00	4.3E-02	4.3E-02	0.059	0.59	0.72	0.072
Arsenic	0.0E+00	3.3E-02	3.3E-02	1.04	1.66	0.031	0.020
Barium	0.0E+00	5.5E-03	5.5E-03	51.8	121	0.0001	0.0000
Beryllium	0.0E+00	2.0E-04	2.0E-04	0.532	--	0.0004	--
Cadmium	0.0E+00	6.6E-02	6.6E-02	0.77	1	0.086	0.066
Chromium	0.0E+00	3.2E-03	3.2E-03	9.24	--	0.0003	--
Cobalt	0.0E+00	1.3E+00	1.3E+00	7.33	10.9	0.18	0.12
Copper	0.0E+00	2.1E-01	2.1E-01	5.6	5.79	0.037	0.036
Lead	0.0E+00	1.7E-03	1.7E-03	4.7	5	0.0004	0.0003
Manganese	0.0E+00	4.5E-01	4.5E-01	51.5	65	0.009	0.007
Mercury	0.0E+00	1.4E-01	1.4E-01	13.2	--	0.0106	--
Methylmercury	0.0E+00	8.6E-04	8.6E-04	0.032	0.16	0.027	0.005
Nickel	0.0E+00	5.1E-03	5.1E-03	1.7	2.71	0.003	0.002
Selenium	0.0E+00	3.1E-01	3.1E-01	0.143	0.145	2.1	2.1
Silver	0.0E+00	1.2E-02	1.2E-02	6.02	60.2	0.002	0.0002
Thallium	0.0E+00	1.1E-02	1.1E-02	0.0074	0.074	1.4	0.14
Vanadium	0.0E+00	5.4E-03	5.4E-03	4.16	5.11	0.001	0.001
Zinc	0.0E+00	1.7E+00	1.7E+00	75.4	75.9	0.02	0.02

Key:
-- = not available
BERA = baseline ecological risk assessment
EE-diet = estimated chemical exposure from diet
EE-sediment = estimated chemical exposure from incidental sediment ingestion
EE-total = total chemical exposure
EPC = exposure point concentration
HQ = hazard quotient
LOAEL = lowest observed adverse effect level
mg/kg/day = milligrams per kilogram per day
NOAEL = no observed adverse effect level
Grey shading = HQ > 1.0

Note:
a. All TAL inorganic analytes except major elements and nutrients (see Section 7.3.1)

Table 7-12 Toxicity Reference Values for Birds and Mammals.

Analyte	Wildlife Class	NOAEL (mg/kg-day)	Critical Effect	LOAEL (mg/kg-day)	Critical Effect	Reference and Comments
Metals						
Antimony	Birds	na	na	na	na	na
	Mammals	0.059	Reproduction	0.59	Reproduction	EPA (2005h). Highest bounded NOAEL (0.059 mg/kg-d) for growth or reproduction below lowest bounded LOAEL (0.59 mg/kg-d) for growth or reproduction from 20 laboratory toxicity studies.
Arsenic	Birds	2.24	Reproduction	3.55	Growth	EPA(2005a). Lowest NOAEL for growth, reproduction, or survival from nine laboratory toxicity studies. Lowest LOAEL for growth, reproduction, or survival greater than selected NOAEL.
	Mammals	1.04	Growth	1.66	Growth	EPA (2005a). Highest bounded NOAEL for growth, reproduction, or survival less than lowest bounded LOAEL for growth, reproduction, or survival from 62 laboratory toxicity studies.
Barium	Birds	20.8	Survival	41.7	Survival	Sample et al. (1996).
	Mammals	51.8	Reproduction, growth, and survival	121	Growth and survival	EPA (2005b). Geometric mean NOAEL for growth, reproduction, and survival from 12 laboratory toxicity studies. Lowest bounded LOAEL for reproduction, growth, or survival greater than geometric mean NOAEL.
Beryllium	Birds	na	na	na	na	na
	Mammals	0.532	Survival	na	na	EPA (2005c). Lowest NOAEL for growth, reproduction, or survival from four laboratory toxicity studies.
Cadmium	Birds	1.47	Reproduction, growth, and survival	2.37	Reproduction	EPA (2005d). Geometric mean NOAEL for growth, reproduction, and survival from 49 laboratory toxicity studies. Lowest bounded LOAEL for growth, reproduction, or survival greater than geometric mean NOAEL.
	Mammals	0.77	Growth	1	Growth	EPA (2005d). Highest bounded NOAEL (0.77 mg/kg-d) for reproduction, growth, or survival less than the lowest bounded LOAEL (1.0 mg/kg-d) from 141 laboratory toxicity studies.
Chromium	Birds	2.66	Reproduction, growth, and survival	2.78	Survival	EPA (2008f). Geometric mean NOAEL for growth, reproduction, and survival from 17 laboratory toxicity studies. Lowest bounded LOAEL for reproduction, growth, or survival greater than geometric mean NOAEL.
	Mammals	9.24	Reproduction and growth	na	na	EPA (2008f). Geometric mean NOAEL for reproduction and growth from 10 studies with trivalent chromium.
Cobalt	Birds	7.61	Growth	7.8	Growth	EPA (2005e). Geometric mean NOAEL for growth from 10 toxicity studies. Lowest bounded LOAEL for growth or reproduction greater than geometric mean NOAEL.
	Mammals	7.33	Reproduction and Growth	10.9	Reproduction	EPA (2005e). Geometric mean NOAEL for reproduction and growth based on 21 laboratory toxicity studies. Lowest bounded LOAEL for growth or reproduction greater than geometric mean NOAEL.
Copper	Birds	4.05	Reproduction	4.68	Growth	EPA (2007a). Highest bounded NOAEL for reproduction, growth, or survival (4.05 mg/kg-day) lower than the lowest bounded LOAEL for reproduction, growth, or survival (4.68 mg/kg-day).
	Mammals	5.6	Reproduction	6.79	Growth	EPA (2007a). Highest bounded NOAEL for reproduction, growth, or survival (5.6 mg/kg-day) lower than the lowest bounded LOAEL for reproduction, growth, or survival (6.79 mg/kg-day).
Lead	Birds	1.63	Reproduction	1.94	Reproduction	EPA (2005f). Highest bounded NOAEL (1.63 mg/kg-d) for growth, reproduction, or survival lower than the lowest bounded LOAEL (1.94 mg/kg-d) for growth, reproduction, or survival based on 57 laboratory toxicity studies.
	Mammals	4.7	Growth	5	Growth	EPA (2005f). Highest bounded NOAEL (4.7 mg/kg-d) for growth, reproduction, or survival lower than the lowest bounded LOAEL (5 mg/kg-d) for growth, reproduction, or survival based on 220 laboratory toxicity studies.
Manganese	Birds	179	Reproduction and Growth	348	Growth	EPA (2007b). Geometric mean NOAEL for reproduction and growth. Lowest bounded LOAEL for reproduction or growth greater than geometric mean NOAEL.
	Mammals	51.5	Reproduction and Growth	65	Growth	EPA (2007b). Geometric mean NOAEL for reproduction and growth. Lowest bounded LOAEL for reproduction or growth greater than geometric mean NOAEL.
Mercury	Birds	0.45	Reproduction	0.9	Reproduction	Sample et al. (1996).
	Mammals	13.2	Reproduction and survival	na	na	Sample et al. (1996).
Methylmercury	Birds	0.068	Reproduction	0.37	Reproduction	CH2MHILL (2000).
	Mammals	0.032	Reproduction	0.16	Reproduction	CH2MHILL (2000).
Nickel	Birds	6.71	Growth and survival	11.5	Growth	EPA (2007c). Geometric mean NOAEL for reproduction and growth. Lowest bounded LOAEL for reproduction or growth greater than geometric mean NOAEL.
	Mammals	1.7	Reproduction	2.71	Reproduction	EPA (2007c). Highest bounded NOAEL for reproduction, growth, or survival below lowest bounded LOAEL for reproduction, growth, or survival.
Selenium	Birds	0.291	Survival	0.368	Reproduction	EPA (2007d). Highest bounded NOAEL for reproduction, growth, or survival below lowest bounded LOAEL for reproduction, growth, or survival.
	Mammals	0.143	Growth	0.145	Reproduction	EPA (2007d). Highest bounded NOAEL for reproduction, growth, or survival below lowest bounded LOAEL for reproduction, growth, or survival.
Silver	Birds	2.02	Growth	20.2	Growth	EPA (2006a). Lowest LOAEL for reproduction or growth divided by 10.
	Mammals	6.02	Growth	60.2	Growth	EPA (2006a). Lowest LOAEL for reproduction or growth divided by 10.
Thallium	Birds	NA	NA	NA	NA	NA
	Mammals	0.0074	Reproduction	0.074	Reproduction	Sample et al. (1996).
Vanadium	Birds	0.344	Growth	0.413	Reproduction	EPA (2005g). Highest bounded NOAEL (0.344 mg/kg-d) for growth, reproduction, or survival less than lowest bounded LOAEL (0.413 mg/kg-d) for reproduction, growth, or survival based on 94 laboratory toxicity studies.
	Mammals	4.16	Reproduction and growth	5.11	Growth	EPA (2005g). Highest bounded NOAEL (4.16 mg/kg-d) for growth or reproduction less than lowest bounded LOAEL (5.11 mg/kg-d) for growth, reproduction, or survival based on 94 laboratory toxicity studies.
Zinc	Birds	66.1	Reproduction and Growth	66.5	Reproduction	EPA (2007e). Geometric mean NOAEL for reproduction and growth. Lowest bounded LOAEL for reproduction or growth greater than geometric mean NOAEL.
	Mammals	75.4	Reproduction and Growth	75.9	Reproduction	EPA (2007e). Geometric mean NOAEL for reproduction and growth. Lowest bounded LOAEL for reproduction or growth greater than geometric mean NOAEL.

Key:
LOAEL = lowest observed adverse effect level
mg/kg/day = milligrams per kilogram per day
na = not available
NOAEL = no observed adverse effect level
TRV = toxicity reference value

Table 7-13 Survival and Growth Results for *Hyalella azteca* 28-day Sediment Toxicity Tests.

Sample Location	Sample Location Description	Sample Number	Survival (%) (Mean ± SD)	Growth (mg) (average dry wt/amphipod) (Mean ± SD)	Biomass (mg) (Mean ± SD dry weight of survivors)
--	Lab control	Control	93.8 ± 9.2	0.26 ± 0.05	2.39 ± 0.45
KR082	Upstream reference	15KR082SD	81.3 ± 15.5[§]	0.26 ± 0.06	2.10 ± 0.67
KR083	Upstream reference	15KR0823D	96.3 ± 5.2	0.25 ± 0.04	2.41 ± 0.47
KR084	Downstream from RDC delta	15KR084SD	92.5 ± 10.4	0.24 ± 0.02	2.21 ± 0.31
KR085	Downstream from RDC delta	15KR085SD	92.5 ± 8.9	0.28 ± 0.04	2.55 ± 0.28
KR087	Downstream from RDC delta	15KR087SD	90.0 ± 14.1	0.23 ± 0.05	2.09 ± 0.51
KR088	Downstream from RDC delta	15KR088SD	88.8 ± 12.5	0.28 ± 0.03	2.47 ± 0.36
KR089	Downstream from RDC delta	15KR089SD	61.3 ± 17.3*[‡§†]	0.23 ± 0.03	1.38 ± 0.43*[‡§†]
KR090	Downstream from RDC delta	15KR090SD	92.5 ± 17.5	0.22 ± 0.04	2.04 ± 0.53
KR091	Downstream from RDC delta	15KR091SD	61.3 ± 12.5*[‡§†]	0.24 ± 0.04	1.44 ± 0.18*[‡§†]
KR092	Downstream from RDC delta	15KR092SD	90.0 ± 12.0	0.23 ± 0.02	2.04 ± 0.33
KR093	Downstream from RDC delta	15KR093SD	70.0 ± 26.2*[§†]	0.20 ± 0.03*[‡§†]	1.36 ± 0.44*[‡§†]
KR099	Other side of KR, downstream from delta	15KR099SD	90.0 ± 10.7	0.28 ± 0.04	2.45 ± 0.26

Notes:

* Significant difference from control sediment ($p<0.05$)

[‡] Significant difference from reference sediment 15KR082SD ($p<0.05$)

[§] Significant difference from reference sediment 15KR083SD ($p<0.05$)

[†] Significant difference from pooled data for reference samples 15KR082SD and 15KR083SD ($p<0.05$)

Key:

mg = milligram

RDC = Red Devil Creek

SD = standard deviation

Site sample that differs from reference samples or lab control (see Notes)

Table 7-14 Pearson Correlations and Significance Levels Between *Hyalella* Survival and Constituents in Kuskokwim River Sediment Samples Collected in Fall 2015.

Constituent	*Hyalella* Survival		Significant Relationship ($p < 0.05$)
	Correlation (R)[a]	Probability (*p*)[a]	
Principal Site Contaminants			
Antimony	0.2846	0.3700	No
Antimony	0.2821	0.3743	No
Mercury	0.2415	0.4496	No
Methylmercury	0.6759	0.1405	No
Physical Parameters			
Medium Sand (%)	-0.6835	0.0143	Yes
Clay	-0.5865	0.0450	Yes
TOC	-0.8718	0.0002	Yes
Major Elements			
Iron	-0.7323	0.0068	Yes
Magnesium	-0.8189	0.0011	Yes
Other Metals			
Cadmium	-0.6942	0.0122	Yes
Cobalt	-0.6647	0.0184	Yes
Copper	-0.5864	0.0451	Yes
Manganese	-0.7713	0.0033	Yes
Nickel	-0.6718	0.0167	Yes
Selenium	-0.8279	0.0009	Yes
Silver	-0.7253	0.0076	Yes
Vanadium	-0.6982	0.0116	Yes
Zinc	-0.5835	0.0464	Yes

Note:

a = Based on 10 site samples and two upstream reference samples.

Table 7-15 Spearman Correlations and Significance Levels Between *Hyalella* Survival and Constituents in Kuskokwim River Sediment Samples Collected in Fall 2015.

Constituent	*Hyalella* Survival		Significant Relationship ($p < 0.05$)
	Correlation (R)[a]	Probability (*p*)[a]	
Principal Site Contaminants			
Antimony	0.2451	0.4425	No
Arsenic	0.2451	0.4425	No
Mercury	0.1847	0.5654	No
Methylmercury	0.6323	0.1779	No
Physical Parameters			
Medium Sand (%)	-0.6004	0.0390	Yes
Silt	-0.6075	0.0361	Yes
Clay	-0.6549	0.0208	Yes
TOC	-0.5517	0.0630	Yes
Major Elements			
Iron	-0.6691	0.0173	Yes
Magnesium	-0.5914	0.0428	Yes
Sodium	0.7207	0.0082	Yes
Other Metals			
Cadmium	-0.8101	0.0014	Yes
Cobalt	-0.6540	0.0211	Yes
Copper	-0.5720	0.0520	Yes
Manganese	-0.6289	0.0285	Yes
Nickel	-0.6780	0.0154	Yes
Selenium	-0.8506	0.0005	Yes
Silver	-0.6994	0.0114	Yes
Vanadium	-0.6977	0.0116	Yes
Zinc	-0.6952	0.0121	Yes

Note:

a = Based on 10 site samples and two upstream reference samples.

Table 7-16 Comparison of Metals Concentrations in 2015 Kuskokwim River Sediment Samples Showing Reduced Growth of *Hyalella* with Sediment Screening Levels and Reference Concentrations

Analyte[a,b]	Units	Sample ID[b]						BERA Screening Level	2015 Reference Sample Range[c]
		15KR089SD		15KR091SD		15KR093SD			
		Result		Result		Result			
Cadmium	mg/Kg	0.39		0.46		0.43		3.5	0.12 - 0.47
Cobalt	mg/Kg	19		15		12		50	6.9 - 15
Copper	mg/Kg	46	J+	58		30		197	16 - 50
Iron	mg/Kg	**66000**		**41000**		20000		21200	15000 - **29000**
Manganese	mg/Kg	**3800**		**1800**		420		460	380 - **1200**
Nickel	mg/Kg	**55**	J+	**56**		**40**		36	20 - **51**
Selenium	mg/Kg	2.9		2		2.8		5	0.69 - 1.9
Silver	mg/Kg	0.2		0.15		0.093	J	1.7	0.008 - 0.14
Thallium	mg/Kg	0.066	UJ	0.076	J	0.069	J	0.24	ND - 0.098
Vanadium	mg/Kg	40	J+	38		29		57	22 - 33
Zinc	mg/Kg	100	J+	100		82		315	41 - 110
Hyalella Survival	%	61.3		61.3		70		--	81 - 96
Hyalella Growth	mg	0.23		0.24		0.2		--	0.25 - 0.26
Gravel	%	30.3		41.1		31.7		--	60.9 - 76.5
Coarse sand	%	17.5		11.5		16.2		--	13 - 14.7
Medium Sand	%	16.4		14.9		19.9		--	5.1 - 6.1
Fine Sand	%	11.6		9		12.5		--	3.5 - 10.6
Silt	%	19.5		19.3		15.7		--	0.1 - 8.3
Clay	%	4.6		4.2		4.1		--	0.1- 1.1
TOC	%	1.7		1.7		0.9		--	0.76 - 0.87

Key:

-- (double dash) = not applicable

BERA = Baseline Ecological Risk Assessment

Value = Exceeds BERA screening level

Value = Exceeds BERA screening level and range for reference samples

Notes:

a = Metals that were sigificantly negatively correlated with survival in Tables 7-14 and 7-15 are listed.

b = See Table 7-17 for comparison of all metals in all toxicity testing samples with screening levels.

c = Range for samples 15KR082SD and 15KR083SD

Table 7-17 Mean SQG Quotients for Kuskokwim River Sediment Samples Used in 28-day *Hyalella* Toxicity Test, Red Devil Mine Site BERA Supplement.

Analyte[a]	Units	Sediment Screening Levels	Sample Number, Result, and Hazard Quotient											
			15KR082SD[b]		15KR083SD[b]		15KR084SD		15KR085SD		15KR087SD		15KR088SD	
			Result	HQ	Result	HQ	Result	HQ	Result	HQ	Result	HQ	Result	HQ
Antimony	mg/Kg	2.9	0.79	0.27	0.27	0.09	920	317.24	3100	1068.97	40	13.79	100	34.48
Arsenic	mg/Kg	17	9.8	0.58	6.9	0.41	510	30.00	2100	123.53	40	2.35	230	13.53
Barium	mg/Kg	48	150	3.13	61	1.27	120	2.50	520	10.83	120	2.50	82	1.71
Beryllium	mg/Kg	0.36	0.45	1.25	0.2	0.56	0.29	0.81	0.64	1.78	0.44	1.22	0.58	1.61
Cadmium	mg/Kg	3.5	0.47	0.13	0.12	0.03	0.18	0.05	0.34	0.10	0.2	0.06	0.35	0.10
Chromium	mg/Kg	90	29	0.32	14	0.16	19	0.21	35	0.39	23	0.26	17	0.19
Cobalt	mg/Kg	50	15	0.30	6.9	0.14	8	0.16	15	0.30	8.8	0.18	15	0.30
Copper	mg/Kg	197	50	0.25	16	0.08	19	0.10	51	0.26	17	0.09	45	0.23
Iron	mg/Kg	21200	29000	1.37	15000	0.71	19000	0.90	27000	1.27	16000	0.75	37000	1.75
Lead	mg/Kg	91.3	12	0.13	2.7	0.03	6.7	0.07	11	0.12	6	0.07	9.8	0.11
Manganese	mg/Kg	460	1200	2.61	380	0.83	350	0.76	580	1.26	470	1.02	590	1.28
Mercury	mg/Kg	0.49	0.098 J	0.20	0.016 J	0.03	31	63.27	310	632.65	2.9	5.92	9.9	20.20
Nickel	mg/Kg	36	51	1.42	20	0.56	27	0.75	55	1.53	28	0.78	41	1.14
Selenium	mg/Kg	5	1.9	0.38	0.69	0.14	0.88	0.18	1.7	0.34	1.2	0.24	1.6	0.32
Silver	mg/Kg	1.7	0.14	0.08	0.0078 J	0.00	0.038 J	0.02	0.15	0.09	0.049	0.03	0.098 J	0.06
Thallium	mg/Kg	0.24	0.098 J	0.41	0.056 U	0.23	0.12 J	0.50	0.33	1.38	0.099	0.41	0.086 J	0.36
Vanadium	mg/Kg	57	33	0.58	22	0.39	23	0.40	29	0.51	31	0.54	29	0.51
Zinc	mg/Kg	315	110	0.35	41	0.13	54	0.17	85	0.27	71	0.23	93	0.30
Hyalella Survival	%	--	81.3	--	96.3	--	92.5	--	92.5	--	90	--	88.8	--
Hyalella Growth	mg	--	0.26	--	0.25	--	0.24	--	0.28	--	0.23	--	0.28	--
Hyalella Biomass	mg	--	2.10		2.41		2.21		2.55		2.09		2.47	
Mean SQG Quotient	**unitless**		**-**	**0.76**	**-**	**0.32**		**23.23**		**102.53**		**1.69**		**4.34**

Analyte[a]	Units	Sample Number, Result, and Hazard Quotient											
		15KR089SD		15KR090SD		15KR091SD		15KR092SD		15KR093SD		15KR099SD	
		Result	HQ	Result	HQ	Result	HQ	Result	HQ	Result	HQ	Result	HQ
Antimony	mg/Kg	19 J+	6.55	75	25.86	16	5.52	30	10.34	3.8	1.31	0.51	0.18
Arsenic	mg/Kg	31 J+	1.82	57	3.35	24	1.41	47	2.76	16	0.94	8.4	0.49
Barium	mg/Kg	110 J+	2.29	100	2.08	92	1.92	140	2.92	57	1.19	70	1.46
Beryllium	mg/Kg	0.59	1.64	0.33	0.92	0.46	1.28	0.44	1.22	0.32	0.89	0.25	0.69
Cadmium	mg/Kg	0.39	0.11	0.26	0.07	0.46	0.13	0.38	0.11	0.43	0.12	0.14 J	0.04
Chromium	mg/Kg	27 J+	0.30	20	0.22	23	0.26	26	0.29	18	0.20	17	0.19
Cobalt	mg/Kg	19	0.38	10	0.20	15	0.30	12	0.24	12	0.24	6.7	0.13
Copper	mg/Kg	46 J+	0.23	26	0.13	58	0.29	28	0.14	30	0.15	12	0.06
Iron	mg/Kg	66000	3.11	20000	0.94	41000	1.93	22000	1.04	20000	0.94	12000	0.57
Lead	mg/Kg	10	0.11	7.1	0.08	11	0.12	9.8	0.11	7	0.08	4.6	0.05
Manganese	mg/Kg	3800	8.26	510	1.11	1800	3.91	570	1.24	420	0.91	180	0.39
Mercury	mg/Kg	2.1	4.29	5.1	10.41	1.3	2.65	0.41	0.84	2	4.08	0.011 J	0.02
Nickel	mg/Kg	55 J+	1.53	31	0.86	56	1.56	38	1.06	40	1.11	22	0.61
Selenium	mg/Kg	2.9	0.58	1.2	0.24	2	0.40	1.8	0.36	2.8	0.56	0.89	0.18
Silver	mg/Kg	0.2	0.12	0.062	0.04	0.15	0.09	0.089 J	0.05	0.093 J	0.05	0.051 J	0.03
Thallium	mg/Kg	0.066 UJ	0.28	0.094	0.39	0.076 J	0.32	0.12 J	0.50	0.069 J	0.29	0.082 U	0.34
Vanadium	mg/Kg	40 J+	0.70	30	0.53	38	0.67	37	0.65	29	0.51	24	0.42
Zinc	mg/Kg	100 J+	0.32	85	0.27	100	0.32	90	0.29	82	0.26	52	0.17
Hyalella Survival	%	61.3	--	92.5	--	61.3	--	90	--	70	--	90	--
Hyalella Growth	mg	0.23	--	0.22	--	0.24	--	0.23	--	0.20	--	0.28	--
Hyalella Biomass	mg	1.38		2.04		1.44		2.04		1.36		2.45	
Mean SQG Quotient	**unitless**		**1.81**		**2.65**		**1.28**		**1.34**		**0.77**		**0.33**

Key:

-- = not applicable or available
BERA = Baseline Ecological Risk Assessment
Gray shading = Statistically different from one or both reference samples (p < .05) (see Table 7-13).
HQ = Hazard Quotient = (sample result / screening level) (unitless)
SQG = Sediment Quality Guideline

Note:

a = All TAL inorganic analytes except major elements and nutrients (see Section 7.3.1)

b = Upstream reference sample

Table 7-18 Risk Characterization for Benthic Macroinvertebrates in Kuskokwim River Assessment Area Based on Comparing Modeled Metals Concentrations in Benthic Macroinvertebrates With Tissue Screening Concentrations.

Analyte[a]	Site-Specific Benthic Macroinvertebrate TSC (mg/kg wet)[b]	Site BSAFs Used		Background BSAFs Used	
		Modeled Benthic Macroinvertebrate EPC (mg/kg wet)[c]	HQ[e]	Modeled Benthic Macroinvertebrate EPC (mg/kg wet)[d]	HQ[e]
Antimony	33	0.41	0.01	8.98	0.27
Arsenic	823	3.3	0.004	10.3	0.01
Barium	42	0.37	0.009	1.28	0.03
Beryllium	2.4	0.002	0.001	0.004	0.002
Cadmium	5.1	0.47	0.092	3.97	0.78
Chromium	266	0.066	0.0002	0.329	0.001
Cobalt	-- (f)	-- (f)	--	-- (f)	--
Copper	368	7.18	0.020	31.71	0.09
Lead	17	0.037	0.002	0.298	0.02
Manganese	196	15.7	0.080	66.0	0.3
Mercury	1.6	0.34	0.2	6.66	4.2
Methylmercury	1	0.00002	0.00002	0.00446	0.004
Nickel	91	0.49	0.005	0.99	0.01
Selenium	81	2.5	0.031	3.1	0.04
Silver	-- (f)	-- (f)	--	-- (f)	--
Thallium	-- (f)	-- (f)	--	-- (f)	--
Vanadium	171	0.095	0.001	0.446	0.003
Zinc	17588	27.2	0.002	33.0	0.002

Key:
-- not available or not applicable.
BCF = bioconcentration factor
EPC = exposure point concentration
HQ = hazard quotient
TSC = tissue screening concentration
Shading = HQ > 1.

Notes:
a. All TAL inorganic analytes except major elements and nutrients (see Section 7.3.1)
b. Developed from site-specific water-to-benthos BCFs and water quality criteria (see Appendix P).
c. From Table 7-6a.
d. From Table 7-6b.
e. Hazard quotient (EPC / screening level)
f. Not analyzed in benthic macroinvertebrates.

Table 7-19 Risk Characterization for Forage Fish Based on Comparing Modeled Whole-Body Concentrations with Tissue Screening Concentations for Effects on Fish, Red Devil Mine Site BERA Supplement for Kuskokwim River Assessment Area.

Parameter	Fish TSC (mg/kg wet)		Site BSAFs and TTFs Used		Background BSAFs and TTFs	
	Value	Source	Modeled Fish Tissue Concentration (mg/kg wet) [a]	HQ[c]	Modeled Fish Tissue Concentration (mg/kg wet) [b]	HQ[c]
Antimony	8.4	Site Specific Value from Final BERA Table 6-49.	0.04	0.005	0.31	0.037
Arsenic	50	Site Specific Value from Final BERA Table 6-49.	0.04	0.001	0.24	0.005
Barium	20.6	Site Specific Value from Final BERA Table 6-49.	0.11	0.005	0.04	0.002
Beryllium	--	--	0.002	--	0.001	--
Cadmium	1.10	Site Specific Value (see Appendix K).	0.240	0.22	0.48	0.44
Chromium	38	Site Specific Value from Final BERA Table 6-49.	0.021	0.001	0.024	0.001
Copper	50	Site Specific Value (see Appendix K).	0.42	0.008	1.53	0.031
Lead	1.1	Site Specific Value (see Appendix K).	0.002	0.002	0.013	0.012
Manganese	61	Site Specific Value from Final BERA Table 6-49.	1.44	0.024	3.31	0.055
Mercury	0.58	Site Specific Value from Final BERA Table 6-49.	0.02	0.042	1.0	1.8
Methylmercury	0.3 - 0.7	Sandheinrich and Weiner 2011.	0.00002	0.0001	0.0063	0.02
Nickel	5.3	Site Specific Value (see Appendix K).	0.032	0.006	0.038	0.007
Selenium	39	Site Specific Value from Final BERA Table 6-49.	0.99	0.025	2.24	0.057
Vanadium	13.2	Site Specific Value from Final BERA Table 6-49.	0.02	0.001	0.04	0.003
Zinc	11,577	Site Specific Value from Final BERA Table 6-49.	12.15	0.001	12.12	0.001

Notes:

a. From Table 7-7a.

b. From Table 7-7b.

c. HQ = (modeled fish tissue concentration) / TSC

Key:

-- (dash) = not available

BSAF = Biota Sediment Accumulation Factor

HQ = Hazard quotient

mg/kg = milligrams per kilogram

TSC = Tissue Screening Concentration

TTF = Trophic Transfer Factor

Table 7-20 Calculation of Weighted Benthic Macroinvertebrate (Benthos) Tissue Concentration for Mercury and Calculation of Mercury Exposure and Risk for Common Snipe with Weighted Benthos Tissue Concentration

Parameter	Units	Value: Near RDM Area	Value: Downriver Area	Remark
Calculation of Weighted Benthic Macroinvertebrate (Benthos) Tissue Exposure Point Concentration (EPC)				
Sediment EPC	mg/kg	261	2.1	From Table 7-3 (95% UCLs)
BSAF	unitless	0.008	0.155	From Tables 7-6a (Site) and Table 7-6b (Background).
Benthos Tissue EPC	mg/kg	2.09	0.33	Sediment EPC x BSAF.
Weighted Benthos Tissue EPC	mg/kg	0.60		(2.09 mg/kg x [0.65 mi. / 4.11 mi.]) + (0.33 mg/kg x [3.46 mi. / 4.11 mi.]). See Section 7.3.1.2.
Snipe Exposure Factors				
Body weight	kg	0.116		From Table 7-4.
Food Ingestion Rate (IR-Food)	kg/d wet	0.047		From Table 7-4.
Site Use Factor (SUF)	unitless	1		From Table 7-4. 100% site use assumed.
Exposure Duration (ED)	unitless	0.33		From Table 7-4.
Avian Toxicity Reference Values				
Chronic NOAEL	mg/kg/d	0.45		From Table 7-12.
Chronic LOAEL	mg/kg/d	0.9		From Table 7-12.
Snipe Exposure and Risk Calculation				
Diet	%	100% Benthos		From Table 7-4.
Weighted Benthos Tissue EPC	mg/kg	0.60		From above.
EE-Diet	mg/kg/d	0.081		((Weighted Benthos Tissue EPC x IR-Food) / BW) x SUF X ED
EE-Sediment	mg/kg/d	0.20		From Table 7-9b.
EE-Total	mg/kg/d	0.281		EE-Diet + EE-Sediment
HQ-NOAEL	unitless	0.62		EE-Total / NOAEL. HQ < 1; no risk expected.
HQ-LOAEL	unitless	0.31		EE-Total / LOAEL. HQ < 1; no risk expected.

Key:

BSAF = biota sediment accumulation factor
BW = body weight
ED = exposure duration
EE-Diet = estimated exposure from diet
EE-sed = estimated exposure from sediment
EE-total = total estimated exposure
EPC = exposure point concentrations
HQ = hazard quotient
IR-Food = Food ingestion rate
LOAEL = lowest observed adverse effect level
NOAEL = no observed adverse effect level
SUF = site use factor

Table 7-21 Calculation of Weighted Benthic Macroinvertebrate (Benthos) Tissue Concentration for Mercury and Calculation of Mercury Exposure and Risk for Benthic Macroinvertebrates

Parameter	Units	Value		Remark
		Near RDM Area	Downriver Area	
Calculation of Weighted Benthic Macroinvertebrate (Benthos) Tissue Exposure Point Concentration (EPC)				
Sediment EPC	mg/kg	261	2.1	From Table 7-3 (95% UCLs)
BSAF	unitless	0.008	0.155	From Tables 7-6a (Site) and Table 7-6b (Background).
Benthos Tissue EPC	mg/kg	2.09	0.33	Sediment EPC x BSAF.
Weighted Benthos Tissue EPC	mg/kg	0.60		(2.09 mg/kg x [0.65 mi. / 4.11 mi.]) + (0.33 mg/kg x [3.46 mi. / 4.11 mi.]). See Section 7.3.1.2.
Benthos Tissue Screening Concentration (TSC)				
Site-Specific TSC	mg/kg/d	1.6		From Table 7-18.
Benthic Macroinvertebrate Risk Calculation				
Hazard Quotient (HQ)	unitless	0.38		(Weighted Benthos Tissue EPC / site-specific TSC). HQ < 1; no risk expected.

Key:

BSAF = biota sediment accumulation factor

EPC = exposure point concentration

HQ = hazard quotient

TSC = tissue screening concentration

Table 7-22 Calculation of Weighted Forage Fish Tissue Concentration for Mercury and Calculation of Mercury Risk to Forage Fish with Weighted Forage Fish Tissue Concentration

Parameter	Units	Value		Remark
		Near RDM Area	Downriver Area	
Calculation of Weighted Forage Fish Tissue Concentration				
Sediment EPC	mg/kg	48	2.1	From Table 7-2 (95% UCLs).
BSAF	unitless	0.008	0.155	From Tables 7-6a (Site) and Table 7-6b (Background).
TTF	unitless	0.66	1.45	From Tables 7-7a (Site) and Table 7-7b (Background).
Forage Fish Tissue EPC	mg/kg	0.25	0.47	Sediment EPC x BSAF x TTF.
Weighted Forage Fish Tissue EPC	mg/kg	0.46		(0.25 mg/kg x [8.24 ha. / 156.2 ha.]) + (0.47 mg/kg x [147.96 ha. / 156.2 ha.]). See Section 7.3.1.1.
Fish Tissue Screening Concentration (TSC)				
Site-Specific TSC	mg/kg/d	0.58		From Table 7-19.
Forage Fish Risk Calculation				
Hazard Quotient (HQ)	unitless	0.79		(Weighted Forage Fish EPC / site-specific TSC). HQ < 1; no risk expected.

Key:

BSAF = biota sediment accumulation factor

EPC = exposure point concentration

HQ = hazard quotient

TTF = trophic transfer factor

TSC = tissue screening concentration

Table 7-23 Comparison of Mercury Hazard Quotients for Three Receptors Calculated with Tissue Concentrations Modeled with BSAFs and TTFs Developed from Red Devil Creek Data, Reference Creek Data, and Both Red Devil Creek and Reference Creek Data

Receptor[a]	Tissue Type	HQ		Modeled Mercury Tissue Concentration (mg/kg)	Basis for Modeled Mercury Tissue Concentration
		Value[b]	Source		
Common Snipe[c]	Benthic Macroinvertebrate Tissue	0.27	Table 7-9a	0.34	Red Devil Creek BSAF (0.008) (see Table 7-6a).
		1.2	Table 7-9b	6.7	Reference creek BSAF (0.155) (see Table 7-6b).
		0.31	Table 7-20	0.6	Weighted using both Red Devil Creek and Reference Creek BSAFs (see Table 7-20).
Benthic Macroinvertebrates	Benthic Macroinvertebrate Tissue	0.20	Table 7-18	0.34	Red Devil Creek BSAF (0.008) (see Table 7-6a).
		4.2	Table 7-18	6.7	Reference creek BSAF (0.155) (see Table 7-6b).
		0.38	Table 7-21	0.6	Weighted using both Red Devil Creek and Reference Creek BSAFs (see Table 7-21).
Forage Fish	Forage Fish Tissue	0.042	Table 7-19	0.02	Red Devil Creek BSAF (0.008) and TTF (0.66) (see Table 7-7a).
		1.8	Table 7-19	1.0	Reference creek BSAF (0.155) and TTF (1.45) (see Table 7-7b).
		0.79	Table 7-22	0.46	Weighted using Red Devil Creek and Reference Creek BSAFs and TTFs (see Table 7-22).

Key:

BSAF = biota sediment accumulation factor

HQ = hazard quotient

Shading = HQ > 1

TTF = trophic transfer factor

Note:

a = For the receptors listed, a potential mercury risk (HQ < 1) was predicted when BSAFs and TTFs developed from reference-creek data were used to model bioaccumulation, but not when BSAFs and TTFs developed from Red Devil Creek data were used to model bioaccumulation. No mercury risk is predicted when bioaccumulation is modeled using both Red Devil Creek and reference creek BSAFs and TTFs.

b = LOAEL-based HQ for common snipe. For benthic macroinvertebrates and forage fish, the HQ is based on comparing the modeled mercury tissue concentration with a tissue screening concentration.

c = Common snipe assumed to feed on benthic macroinvertebrates in near-shore sediment.

Table 7-24 Summary of Potential Risks by Assessment Endpoint, Red Devil Mine Site BERA Supplement for Kuskokwim River Assessment Area.

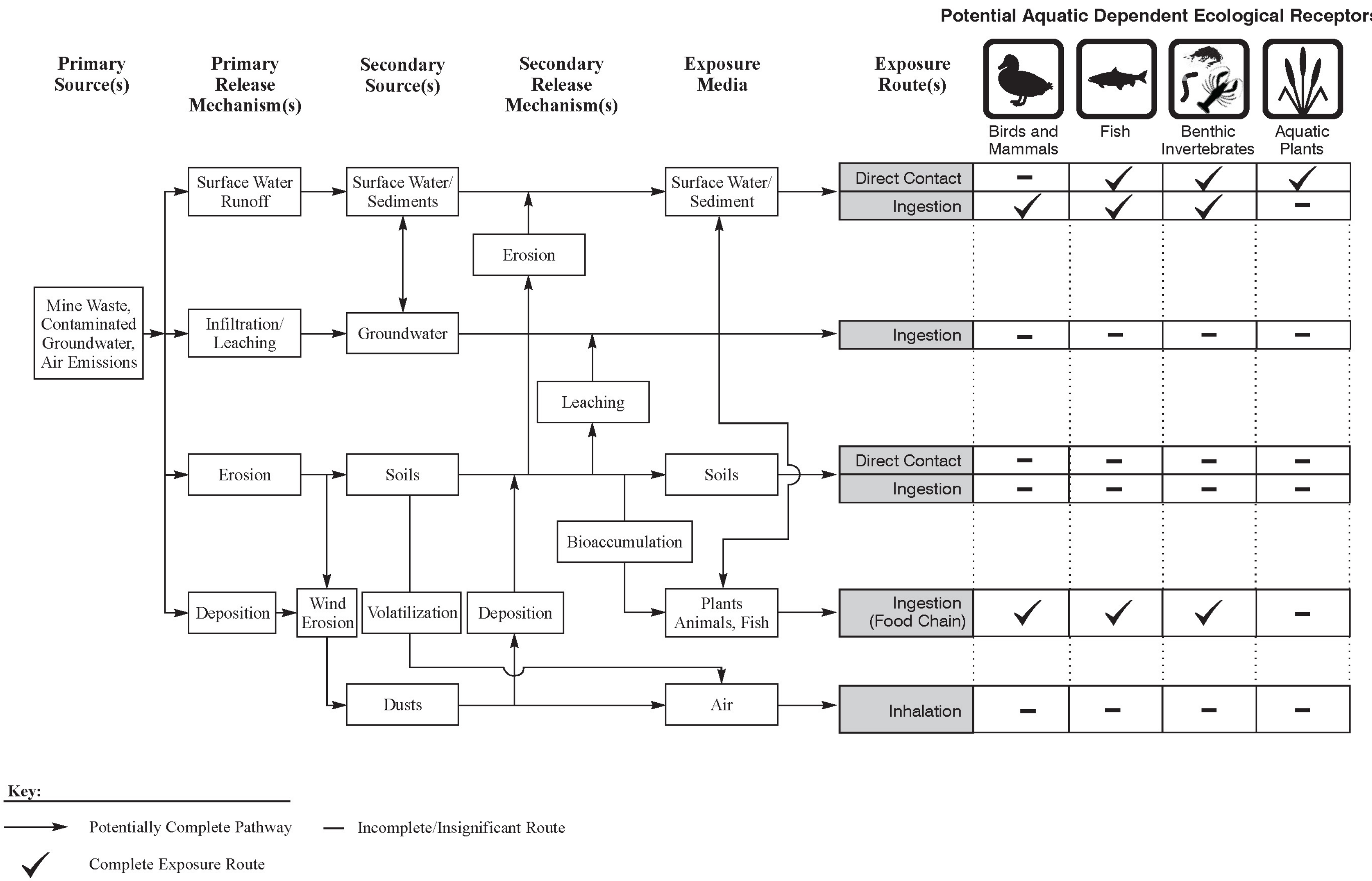
Assessment Endpoint	Model Species	Measure	Basis for Exposure and Risk Estimate	Contaminant of Potential Concern (HQ > 1)[a]	Remarks
Wildlife Population Level Endpoints					
Aquatic Dependent Herbivorous Birds	Green Winged Teal	Estimated exposure compared with TRV	Site BSAFs	None (Table 7-8a).	
			Background BSAFs	None (Table 7-8b).	
			Kuskokwim River Periphyton	Vanadium (HQ 8, Table 7-8c)	Vanadium risk from background.
Aquatic Dependent Invertivorous Birds	Common Snipe	Estimated exposure compared with TRV	Site BSAFs	None (Table7-9a).	
			Background BSAFs	Mercury (HQ 1.2), Selenium (HQ 1.1) (Table 7-9b).	Selenium risk from background. Mercury risk overestimated by factor of 4 when using background BSAF for entire assessment area.
Aquatic Dependent Piscivorous Birds	Belted Kingfisher	Estimated exposure compared with TRV	Site BSAFs and TTFs	None (Table 7-10a).	
			Background BSAFs and TTFs	Selenium (HQ 1, Table 7-10b)	Selenium risk from background.
Aquatic Dependent Piscivorous Mammals	Mink	Estimated exposure compared with TRV	Site BSAFs and TTFs	None (Table 7-11a).	
			Background BSAFs and TTFs	Selenium (HQ 1.2, Table 7-11b).	Selenium risk from background.
Community Level Endpoints					
Benthic Macroinvertebrates	Community present	Toxicity Testing	Survival, growth, and biomass differences between site and reference samples.	Uncertain. Low to moderate effects on survival and biomass in three samples may be due to sediment texture, TOC, iron, manganese, and/or nickel (Tables 7-13 to 7-16).	
		Modeled tissue levels compared with TSCs	Site BSAFs	None (Table 7-18).	
			Background BSAFs	Mercury (HQ 4.2, Table 7-18).	Mercury risk overestimated by factor of 4 when using background BSAF for entire assessment area.
		Screening level comparisons	Total metals concentrations in sediment	Antimony, arsenic, mercury, and other metals exceeded screening levels, but the exceedances were not associated with adverse effects in sediment toxicity tests, likely due to limited contaminant bioavailability (Table 7-17).	
Forage Fish	Community present	Modeled tissue levels compared with TSCs	Site BSAFs	None (Table 7-19).	
			Background BSAFs	Mercury (HQ 1.8, Table 7-19).	Mercury risk overestimated by factor of 2 when using background BSAF for entire assessment area.

Key:

BSAF = Biota sediment accumulation factor
HQ = hazard quotient
LOAEL = Lowest observed adverse effect level
TSC = Tissue screening concentrations
TTF = Trophic transfer factor

Note:

a = LOAEL-based HQ listed for wildlife.



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RED DEVIL MINE
RI SUPPLEMENT

Figure 7-1
ECOLOGICAL CONCEPTUAL SITE MODEL FOR KUSKOKWIM RIVER RISK EVALUATION

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8 Summary and Conclusions

This chapter presents a summary and conclusions of the RI Supplement. The RI Supplement was performed to augment existing data for soil, groundwater, surface water, and Kuskokwim River sediment and biota presented in the final RI report (E & E 2014). The objectives of the supplemental RI activities are generally to address data gaps identified during the development of the FS (E & E 2016), identify possible changes to site conditions resulting from the NTCRA, and support the development of site-wide remedial alternatives at the RDM. Additionally, sediment toxicity testing was conducted on Kuskokwim River sediment to evaluate potential impacts to benthos near the RDM, and data on total mercury and methylmercury measured in Kuskokwim River periphyton and fish were used to evaluate methylmercury bioaccumulation in the Kuskokwim River food chain near the RDM. A summary of the RI and other pertinent studies is presented in Chapter 2 of the RI Supplement Work Plan (E & E 2015). A detailed discussion of the data gaps and data quality objectives of the RI Supplement is presented in Chapter 3 of the RI Supplement Work Plan. Objectives of the supplemental RI activities also are briefly summarized in Chapters 2 through 5 of this report.

This chapter also presents a summary and conclusions of the Risk Assessment Supplement for the Kuskokwim River in the area of the RDM. The results of the Risk Assessment Supplement will be used, along with other lines of evidence, to support risk-management decisions for site-related contaminants in the Kuskokwim River near the RDM (see Chapter 9).

8.1 Soil Investigation

The RI Supplement soil characterization activities were designed to address data gaps associated with subsurface soil and bedrock. The soil characterization was performed to gather the types of additional information identified in Section 3.3 of the RI Supplement Work Plan (E & E 2015). The supplemental RI soil characterization was designed to meet the following objectives:

- Assess lithological and mineralogical characteristics of subsurface soils and bedrock.
- Identify mine waste types and soil types.
- Determine thickness and inorganic element concentrations of tailings/waste rock where present.
- Determine concentrations of inorganic elements in tailings/waste rock where present.

- Identify and determine the thickness of types of native soil/alluvium.
- Determine concentrations of inorganic elements in soil/alluvium below tailings/waste rock from the base of tailings/waste rock to the top of bedrock to assess impacts on native soil/alluvium from deposition of inorganic elements leached from tailings/waste rock.
- Determine depth of bedrock.
- Visually assess whether the bedrock is naturally mineralized.
- Determine the presence, depth, and thickness of saturated interval(s).

Soil characterization included installing additional soil borings at the site, consisting of:

- Seven soil borings in the Main Processing Area;
- Three soil borings in the Red Devil Creek Area; and
- Four soil borings in the Surface Mined Area that were converted to monitoring wells.

It is anticipated that data collected as part of the RI Supplement soil investigation will be used, in conjunction with the RI results, to refine the estimates of depth and volume of material to be remediated through action proposed in the FS.

The RI Supplement soil characterization built upon the results of the RI, and employed a similar approach to that used in the RI to identify types of mine wastes and native soils, and to attempt to identify naturally mineralized soils and soils impacted by contamination. Field lithological and mineralogical observations were used, in conjunction with XRF field screening data and laboratory analytical results, to identify mine waste and soil types and their thicknesses. The identification and augmented delineation of mine waste and soil types are detailed in Section 2.2.4.

The RI Supplement bedrock characterization results are detailed in Section 2.2.5. An important objective of the bedrock characterization was to identify and characterize localized zones of naturally mineralized bedrock. Naturally mineralized bedrock was identified using visually observable lithological and mineralogical observations and XRF field screening data. Mineralized zones associated with the underground mine workings were targeted during the borehole/monitoring well installation in the Surface Mined Area to provide information to evaluate the impacts of natural mineralization on groundwater quality. The occurrence of groundwater in soil and bedrock boreholes is presented in Section 2.2.6. Information on depths of bedrock mineralization was used in conjunction with information gathered during drilling regarding the occurrence of groundwater to inform well construction decisions of newly installed monitoring wells in the Surface Mined Area. Results of the groundwater well installation are detailed in Chapter 3 and briefly summarized in Section 8.2.

8.2 Groundwater Investigation

The RI Supplement groundwater characterization activities were designed to address data gaps associated with groundwater in the Main Processing Area, the Red Devil Creek downstream alluvial area, and the Surface Mined Area. Additional groundwater characterization was performed to gather the types of additional information identified in Section 3.3 of the RI Supplement Work Plan (E & E 2015). The supplemental RI groundwater characterization was designed to meet the following objectives:

- Assess groundwater occurrence, depth, and quality in the Surface Mined Area to better understand impacts of naturally mineralized bedrock and underground mine workings on groundwater flow paths and inorganic element concentrations.
- Assess groundwater occurrence, depth, and quality in the portions of the RDM affected by the 2014 NTCRA construction.
- Provide additional data on groundwater conditions in the area downgradient of Monofill #2.
- Assess groundwater concentrations of SVOCs, DRO, GRO, and BTEX in selected wells located within and upgradient of part of the Main Processing Area.
- Provide additional information on baseline groundwater conditions at the site.

It is anticipated that data collected as part of the RI Supplement groundwater investigation will be used, in conjunction with the RI results, to support the development of site-wide remedial alternatives for the RDM. Although the wells installed in the Surface Mined Area are intended primarily to assess the potential influence of natural mineralization and mine workings on groundwater conditions upgradient of the Main Processing Area, the resulting data may also be useful for characterizing groundwater conditions downgradient of the proposed on-site repository considered as part of the FS.

RI Supplement groundwater characterization activities included installation of new monitoring wells and sampling of new and existing wells. Four new monitoring wells were installed in the Surface Mined Area. Details of well installation are provided in Section 3.1.1. Surveying of new wells, water level measurement, and groundwater sampling are described in Sections 3.1.2 through 3.1.4.

Results of the RI Supplement groundwater characterization are detailed in Section 3.2 and briefly summarized below.

8.2.1 Surface Mined Area

New monitoring wells MW39, MW40, MW42, and MW43 were installed in the Surface Mined Area to provide additional information on groundwater conditions in the Surface Mined Area in the vicinity (laterally and vertically) of the underground mine workings. Detailed information on the well installation is presented in Section 3.2.1.

RI Supplement groundwater elevation results (detailed in Section 3.2.2) show that the depths to groundwater in the new Surface Mined Area wells were substantially greater than in other nearby wells installed in bedrock further away from the mine workings. The water level measurement results demonstrate that the mine workings provide a highly transmissive hydraulic connection between the area of the wells and the creek that serves to depress the water table in portions of the Surface Mined Area where the mine workings lie below the water table but above the nearby base level of Red Devil Creek. The results support the conclusion that the interconnected mine workings provide a preferential flow pathway of groundwater in areas drained by the mine workings from the Surface Mined Area to shallow depths below Red Devil Creek. The results also support the conclusion that much of the groundwater within the Red Devil Creek valley, including groundwater in the Main Processing Area and the area downstream of the Main Processing Area, emerges into Red Devil Creek and enters the Kuskokwim River as surface water rather than via groundwater flow.

New Surface Mined Area monitoring wells were installed with screened intervals in or near zones of natural sub-ore grade mineralization associated with the underground mine workings, and hydraulically upgradient of the underground mine workings. Groundwater sample results (detailed in Section 3.2.3.1) from the wells, therefore, provide information useful for assessing the impacts on groundwater quality of the natural mineralization present in bedrock close to, but hydraulically upgradient of, the mine workings. RI Supplement groundwater sample results from the newly installed wells contained concentrations of total antimony and arsenic ranging up to 250 µg/L and 610 µg/L, respectively. Dissolved mercury concentrations in those samples ranged as high as 48.2 ng/L. These concentrations are significantly higher than observed previously in the groundwater samples collected elsewhere in the Surface Mined Area from wells not installed in close proximity to the underground mine workings. These results demonstrate that the groundwater that flows into the underground mine workings network is impacted by the natural sub-ore grade mineralization associated with the Red Devil ore zones. Based on groundwater and stream elevation data, much of this impacted groundwater is expected to migrate via the underground mine workings network and emerge in Red Devil Creek along gaining reaches within the Main Processing Area where components of the mine workings system approach the surface.

8.2.2 Area of NTCRA Regrading

Groundwater quality in the vicinity of the 2014 NTCRA regrading and stream realignment (detailed in Section 3.2.3.2) was evaluated by sampling selected wells installed during the RI. Sampling results for total antimony, total arsenic, total mercury, and dissolved mercury were compared to previous sampling results from the selected wells. No obvious trends in concentrations or changes in concentration of these analytes that could be positively attributed to the NTCRA regrading have been noted to date.

An upward gradient was observed in the MW27/MW28 well pair consistent with the upward gradient observed during the RI and 2012 baseline monitoring events (see Section 3.2.2). An upward gradient in the vicinity of wells MW27 and MW28 is consistent with the previous interpretation that groundwater in that part of the Main Processing Area emerges into Red Devil Creek. A downward gradient was observed in the MW16/MW17 well pair, consistent with the direction observed during all except one of the previous monitoring events for that well pair. The downward gradient appears to be localized and may be attributable to losing conditions in that area. Localized losing conditions in this area are consistent with the pre-NTCRA conditions interpreted along Red Devil Creek in that part of the Main Processing Area during the RI and 2012 baseline monitoring events.

8.2.3 Area Downgradient of Monofill #2

Groundwater was sampled from wells MW09 and MW10 to provide additional data on groundwater conditions in the area downgradient of Monofill #2 (see Section 3.2.3.3). The 2015 sampling results for total antimony, total arsenic, total mercury, and dissolved mercury were compared to previous sampling results. No obvious trends in concentrations have been noted to date.

8.2.4 Organic Compounds in the Main Processing

Groundwater samples collected from wells MW19 and MW22 were analyzed for SVOCs, DRO, GRO, and BTEX (see Section 3.2.3.4). Several SVOCs were detected in one or more samples at concentrations below federal drinking water MCL and/or Alaska groundwater cleanup levels (18 AAC 75.345 Table C), if applicable. DRO was not detected in the samples from MW19, but was detected in samples from MW22 at concentrations below the Alaska groundwater cleanup level (1.5 mg/L). GRO was detected only in the sample collected from MW19 at a concentration below the Alaska groundwater cleanup level (2.2 mg/L). The only BTEX compound detected was toluene, which was detected below the MCL and Alaska groundwater cleanup level (1.0 mg/L).

8.2.5 Baseline Monitoring

Groundwater monitoring was performed at selected wells to address specific objectives associated with various site features and geographic areas, discussed in Sections 3.3.1 to 3.3.4 and 8.2.1 to 8.2.4. In addition to those specific objectives, groundwater monitoring data was collected from those and other wells to augment existing information on baseline groundwater conditions at the RDM. The other wells are distributed across the RDM. For these wells, the 2015 sampling results for total antimony, total arsenic, total mercury, and dissolved mercury were compared to previous sampling results. No obvious trends in concentrations were noted.

In general, groundwater elevations at most of the wells across the RDM during the spring and fall 2015 monitoring events were lower than during previous groundwater monitoring events at the RDM at similar times of the year. During the spring and fall 2015 groundwater monitoring events, as observed during the RI and 2012 baseline monitoring events, groundwater at the site generally flowed toward Red Devil Creek, with groundwater elevations generally mimicking topography over much of the site. An important exception to this general observation are the groundwater elevations in the Surface Mined Area (see Sections 3.3.1 and 8.2.1).

8.3 Surface Water Investigation

The RI Supplement surface water characterization activities were designed to address data gaps associated with surface water in Red Devil Creek and a seep located on the northwest bank of the creek. Additional surface water characterization was performed to gather the types of additional information identified in Section 3.3 of the RI Supplement Work Plan (E & E 2015). The supplemental RI surface water characterization was designed to meet the following objectives:

- Assess potential impacts on surface water quality and flow rate by flow of groundwater that is impacted by naturally mineralized bedrock and underground mine workings in the Surface Mined Area.
- Assess groundwater quality and flow rate in the area affected by the 2014 NTCRA construction.
- Provide additional information on baseline surface water conditions at the site.

Results of surface water characterization are detailed in Section 4.2 and briefly summarized below.

8.3.1 Stream Discharge

Estimated Red Devil Creek surface water discharge ranged from 1.3 to 1.9 cubic feet per second on June 19, 2015, and from 0.48 to 0.81 cubic feet per second on September 2, 2015. Stream discharge generally increased from upstream to downstream, consistent with overall gaining conditions and the conclusion that groundwater in the Main Processing Area and part of the Surface Mined Area emerges as surface water in the creek. The estimated discharge rates during both the spring and fall 2015 monitoring events were substantially lower than during all previous monitoring events. Such lower discharge is consistent with the comparatively lower groundwater elevations observed during the spring and fall 2015 groundwater monitoring.

8.3.2 Stream Water Quality

Surface water results for spring and fall 2015 sampling indicate generally increasing total and dissolved antimony, arsenic, and mercury concentrations along Red Devil Creek moving downstream through the Main Processing Area. Overall, the trends of increasing concentrations along Red Devil Creek are similar to those documented in the RI and 2012 baseline monitoring events, although the magnitudes varied. The spring 2015 concentrations in Red Devil Creek were generally lower than concentrations seen in previous sampling events. This may be attributable to lower groundwater elevations observed in spring 2015. The fall 2015 concentrations of antimony and arsenic in Red Devil Creek and the seep were generally lower than concentrations seen in previous sampling events. As suggested for the spring 2015 sample results, this may be attributable to lower groundwater elevations observed in spring 2015. The total and dissolved mercury results did not exhibit an obvious trend relative to previous results. No obvious trends that could be attributed to the 2014 NTCRA regrading have been noted to date.

8.3.3 Stream Water Contaminant Transport

The RI Supplement results and RI results show that transport of contaminants in surface water is occurring presently at the RDM. Contaminant loading (e.g., antimony, arsenic, mercury, and methylmercury) along Red Devil Creek as it flows through the Main Processing Area is attributable to groundwater migration into the stream along gaining reaches and erosion and entrainment of particulates. Groundwater emerges to surface water as baseflow within the Main Processing Area as well as at a seep located adjacent to the creek in the Main Processing Area.

Sources of inorganics in groundwater include leaching from mine wastes, as well as naturally mineralized bedrock and native soils. Based on results of the Surface Mined Area groundwater evaluation (see Sections 3.3.1 and 8.2.1), groundwater flow in portions of the Surface Mined Area is controlled by the system of interconnected underground mine workings. The mine workings provide a preferential flow pathway of groundwater in areas drained by the mine workings from the Surface Mined Area to shallow depths below Red Devil Creek. The results also support the conclusion that much of the groundwater within the Red Devil Creek valley, including groundwater in the Main Processing Area and the area downstream of the Main Processing Area, emerges into Red Devil Creek and enters the Kuskokwim River as surface water rather than via groundwater flow. The groundwater investigation results also demonstrate that the groundwater that flows into the underground mine workings network is impacted by the natural sub-ore grade mineralization associated with the Red Devil ore zones, and that much of this groundwater emerges into Red Devil Creek within the Main Processing Area and is a source of impacts to Red Devil Creek.

Surface water loading along the creek also is attributable to entrainment of contaminants within or adsorbed to particulates and dissolution/desorption of contaminants from bed and suspended sediment. The 2014 NTCRA was undertaken to address the active erosion of tailings/waste rock along Red Devil Creek and transport of those materials to the Kuskokwim River.

Additional data collected during the spring and fall 2015 monitoring show trends in total and dissolved antimony and arsenic concentrations, as well as turbidity and total suspended solids that are similar to trends observed during the RI and 2012 baseline monitoring. Total concentrations of antimony and arsenic were typically only slightly higher than the dissolved concentrations at each sample location throughout most of Red Devil Creek. Field measurements of turbidity and laboratory analysis of total suspended solids indicate low turbidity and total suspended solids concentrations at the times of sampling. Dissolved phase transport was concluded to be the dominant transport mechanism at the times of sampling for the RI and 2012 baseline monitoring events. Results of the 2015 monitoring further support this conclusion.

During the RI and 2012 baseline monitoring events, total concentrations of mercury were up to more than an order of magnitude higher than the dissolved concentrations at each surface water sample location within and downstream of the Main Processing Area. This was interpreted (see final RI report Section 5.6.2.1) to indicate that mercury transport in surface water in Red Devil Creek included substantial transport by particulate phases that are larger than 0.45 micrometers (the pore size of the filters used to collect the dissolved phase aliquots) at the time of sampling. It also was concluded in the final RI that particulate (e.g., colloidal) transport of mercury occurs in groundwater at the RDM (see final RI report Section 5.4.4). These conclusions are supported by several related lines of evidence discussed in final RI report Sections 5.3.1, 5.4.1, 5.4.4, 5.6.1, and 5.6.2. Additional groundwater and surface water data collected in 2015 show similar trends, providing further support for the conclusion that groundwater and surface water transport of mercury at the RDM includes substantial transport as particulates, including mobile colloids.

8.4 Kuskokwim River Investigations

The RI Supplement Kuskokwim River investigations were designed to address data gaps associated with sediment in the Kuskokwim River near and downriver of Red Devil Creek. The investigations are complemented with results of BLM studies addressing Kuskokwim River biota. Result were used to assess contaminant transport into and between media in Red Devil Creek, the Kuskokwim River, and other contaminant source areas.

Additional sediment characterization was performed to gather the types of additional information identified in Section 3.3 of the RI Supplement Work Plan (E & E 2015). The supplemental RI sediment characterization was designed to meet the following objectives:

- Assess the cross-river and downriver extents of contamination in Kuskokwim River sediment.
- Assess the turbidity of Kuskokwim River water.
- Assess the toxicity of sediments to benthic macroinvertebrates.
- Assess the potential for methylation and bioaccumulation of mercury.

Data collected to meet these objectives, in conjunction with data collected during the RI, BLM Kuskokwim River investigations, supplemental human health risk assessment (see Chapter 6), and ecological risk assessment (see Chapter 7), will be used to inform site-wide remedial decision making.

8.4.1 Cross-River and Downriver Extent of Sediment Contamination

As part of the RI Supplement, sediment sampling and analysis for total inorganic elements was performed to assess the cross-river and downriver extents of contamination in Kuskokwim River sediment. Concentrations of total antimony, arsenic, and mercury decrease with distance away from the riverbank near the RDM, and with distance downriver from the Red Devil Creek delta. Increases in concentrations of total antimony, arsenic, and mercury above background levels at the Red Devil Creek delta (e.g., sample KR084) into the Kuskokwim River are considered to be due to inputs from the RDM area.

Concentrations of antimony, arsenic, and mercury generally decrease with distance downriver from the Red Devil Creek delta area. Concentrations generally decrease to values near background levels for total antimony, arsenic, and mercury in the most downriver samples. The general trends toward decreasing concentrations downriver change to less regular patterns farther downriver. Slight increases in concentrations at a location approximately 1 kilometer, and a more pronounced increase in concentrations approximately 4.4 kilometers downriver, from the Red Devil Creek delta are likely attributable to other sources of these metals (see Sections 5.4.2 and 8.4.2).

8.4.2 Mineral Occurrences near Red Devil Mine

The RDM lies within a mineralized region (e.g., Miller et al. 1989) with locally naturally elevated concentrations of antimony, arsenic, mercury, and other metals in the environment, including sediment in the Kuskokwim River and some of its tributaries. Available information on mineral occurrences in the region are presented in Section 5.4.2. As noted in Section 5.4.2, several mineral occurrences are documented in the McCally Creek drainage, which drains into the Kuskokwim River approximately 1 kilometer downriver of the Red Devil Creek delta. Drainage associated with other mineral occurrences, including the Alice and Bessie claim group (formerly known as the Parks prospect), which is located near the northeast bank of the river, empty into the Kuskokwim River further downriver. It is likely that increases in total antimony, arsenic, and mercury concentrations in Kuskokwim River sediment at locations KR096 and KR103 are attributable, in part, to inputs from these other mineral occurrences.

8.4.3 Methylmercury in Sediment

Methylmercury was detected in eight of the 14 RI Supplement sediment samples at concentrations ranging up to 0.788 ng/g (estimated). Concentrations in three of the samples were greater than the RI background level (0.49 ng/g). Methylmercury was detected in RI samples from 2010 to 2012 in closer proximity to the RDM at concentrations ranging from 0.15 to 3.73 ng/g. The methylmercury concentration in 14 of 26 of the 2010 to 2012 samples exceeded the recommended RI background level of 0.49 ng/g. Concentrations of methylmercury in the RI and RI Supplement Kuskokwim River sediment samples are generally low compared with the national average for rivers (1.6 ng/g; Scudder 2009). These results are consistent with the observation that the environmental conditions of the Kuskokwim River near the RDM generally are not conducive to mercury methylation. Methylmercury levels in Kuskokwim River sediment are not significantly correlated with TOC when all available samples (including upriver reference samples) are considered.

8.4.4 Sediment Toxicity

A 28-day growth and survival test with *Hyalella azteca* (freshwater amphipod) was conducted with sediment from 10 locations in the Kuskokwim River downstream from the Red Devil Creek delta and from two upstream reference locations. The test results are presented and discussed in the BERA Supplement (Chapter 7) and used to evaluate potential risks to the benthic macroinvertebrate community in the Kuskokwim River near the RDM.

8.4.5 Kuskokwim River Periphyton

In 2014, the BLM collected periphyton samples from the near-shore environment of the Kuskokwim River at 13 locations downstream from the Red Devil Creek delta and 13 locations upstream form the Red Devil Creek delta. Sampling methods are discussed in the BLM Field Operations Plan (BLM 2014). The samples were analyzed for metals, methylmercury, inorganic arsenic, and percent solids. The following results are noteworthy:

- Antimony, arsenic, and mercury were elevated in periphyton samples collected downstream from the Red Devil Creek delta compared with upstream samples. The greatest difference was for mercury, which was about 20 times greater on average in periphyton samples collected downstream from the Red Devil Creek delta compared with upstream samples. In contrast, the average difference in total arsenic levels between downstream and upstream periphyton samples was 20%. Inorganic arsenic was not elevated in samples collected downstream from the Red Devil Creek delta.
- Methylmercury was not detected in the periphyton samples. Hence, despite the fact the total mercury levels were elevated in periphyton samples collected downstream from the Red Devil Creek delta, there is no indication that this pattern of total mercury contamination resulted in greater methylmercury levels at the base of the benthic food web.

8.4.6 Kuskokwim River Fish

Between 2011 and 2014, the BLM Alaska State Office, in cooperation with the USFWS and Alaska Department of Fish and Game, measured mercury concentrations in small muscle biopsies from northern pike and burbot equipped with radio transmitters, and related the concentrations to fish location and movements in the middle Kuskokwim River region. The study design and methods are described in Matz et al. (2017). Matz et al. (2017) divided the mainstream Kuskokwim River and major tributaries within the study area into eight watersheds or reaches for their investigation. The following results are noteworthy:

- Total mercury levels in pike and burbot from the Kuskokwim River reach that includes the RDM were among the lowest measured in the study.
- Only about 10% of burbot and 40% of pike captured in the Kuskokwim River reach that includes the RDM remained in that river reach. Low fidelity of burbot and pike to this reach has the effect of reducing their exposure to mercury and other contaminants from the RDM.
- Low fidelity of pike to the Kuskokwim River reach near the RDM likely is due to the physical and biological characteristics of the reach. The reach is characterized by strong current, high turbidity, linear shorelines, and low density of shoreline wetlands. These characteristics make the reach unattractive to pike.
- The greatest total mercury levels in pike were found in the Takotna, Holitna, and George River watersheds. All three watersheds have extensive areas of oxbows with abundant wetland habitat, ideal habitat for pike and other fish, and important sites for mercury methylation.
- Across the study area, mercury levels in pike increased with fish length and age, as would be expected for a bioaccumulative contaminant.
- Matz et al. (2017) found no relationship between pike total mercury levels and the number of mercury-containing mines or mercury-containing occurrences and prospects in a given watershed. This result led them to suggest that other factors, such as wetland area (a measure of watershed methylation potential), should be further investigated to understand controls on mercury levels in game fish from the middle Kuskokwim River region.

8.5 Kuskokwim River Human Health Risk Assessment

The HHRA Supplement was performed to address data gaps associated with Kuskokwim River that were not addressed as part of the baseline HHRA presented in the final RI. Since the final RI report was completed, substantial additional data were collected by E & E and the BLM (see Chapter 5) from the Kuskokwim River near the RDM and from the middle Kuskokwim River region in general. The HHRA Supplement is presented in Chapter 6. The results of the HHRA Supplement and BERA Supplement (Chapter 7) will be used, along with other lines of evidence (see Chapter 9), to support risk management decisions for site-related contaminants in the Kuskokwim River near the RDM.

The HHRA Supplement approach and results are briefly summarized below.

The HHRA Supplement was performed specifically to assess the risks and hazards from potential exposure to COPCs through direct contact and incidental ingestion of sediment, and consumption of fish from the Middle Kuskokwim River region as described in the *Proposed Technical Approach for the Kuskokwim River Risk Assessment Supplement* (BLM 2017). Additional results from sediment sampling (see Chapter 5) and BLM fish tissue sampling (Matz et al. 2017; see

Section 5.4.6) were used to help understand potential risks to human receptors that use the Kuskokwim River near and downstream from the RDM.

Section 6.1 presents background information. The portion of the baseline HHRA pertaining to the Kuskokwim River is discussed in Section 6.1.1, and the Middle Kuskokwim River Investigations are detailed in Section 6.1.2. The approach used to develop the HHRA Supplement is detailed in Section 6.1.3, and the risk assessment area is defined in Section 6.1.4. For direct exposure to sediment, the HHRA Supplement is limited to the area of the Kuskokwim River for which RI and RI Supplement sediment sample results indicate elevated levels of total antimony, arsenic, and mercury that are likely attributable to the RDM. A regional assessment of consumption of subsistence fish was conducted in the HHRA Supplement and addresses subsistence fish caught from watersheds within the middle Kuskokwim River area.

Section 6.2 presents the exposure assessment, performed to quantify potential exposures of human populations that could result from contact with COPCs from the RDM site.

Section 6.3 presents the toxicity assessment, performed to compile information on the nature of the adverse health effects of COPCs and to provide an estimate of the dose-response relationship for each COPC selected (i.e., determine the relationship between the extent of exposure and the likelihood and/or severity of adverse effects.

Section 6.4 presents the results of the risk characterization, the final component of the risk assessment process, which integrates the findings of the exposure assessment and toxicity assessment by quantitative estimation of human health risks. Results of the risk characterization are summarized in the following paragraphs.

Noncancer hazards and excess cancer risk from potential exposure to COPCs in Kuskokwim River sediments are presented on a site-related basis. Noncancer hazards from exposure to Kuskokwim River sediment near the RDM site, including the downriver portion, do not exceed acceptable hazards as defined by EPA and ADEC. Cancer risks from exposure to Kuskokwim River sediment for all receptors are within the acceptable EPA cancer risk range. For residents and recreational/ subsistence users, the cancer risk is slightly above the ADEC acceptable risk standard, but when the outlier results are removed, the cancer risks are within acceptable cancer risk range for both ADEC and EPA. Localized background sediment levels contribute approximately 3% to the overall site cancer risk from direct exposure to sediment and approximately 7% to the overall noncarcinogenic hazard from this pathway.

Noncancer hazards and excess cancer risk from potential exposure to COPCs in fish tissue are presented on a regional basis. Potential exposure to methylmercury and arsenic in muscle samples from fish collected from the middle Kuskokwim

River region resulted in cancer risk levels above both ADEC and EPA cancer risk and noncancer hazards above ADEC or EPA standards. The cancer risks are primarily driven by arsenic in northern pike and whitefish. The noncancer hazards are primarily driven by methylmercury in northern pike, and arsenic and methylmercury in whitefish.

An uncertainty analysis was performed to evaluate uncertainty associated with environmental sampling and analysis, EPCs, exposure assessment, toxicity assessment, and risk characterization. Results of the uncertainty analysis are detailed in Section 6.5.

8.6 Kuskokwim River Ecological Risk Assessment

The BERA Supplement was performed to address data gaps associated with Kuskokwim River that were not addressed as part of the BERA presented in the final RI. Since the final RI report was completed, substantial additional data were collected by E & E and the BLM (see Chapter 5) from the Kuskokwim River near the RDM and from the middle Kuskokwim River region in general. The BERA Supplement is presented in Chapter 7. The results of the BERA Supplement and HHRA Supplement (Chapter 6) will be used, along with other lines of evidence (see Chapter 9), to support risk management decisions for site-related contaminants in the Kuskokwim River near the RDM.

The BERA Supplement approach and results are briefly summarized below.

The BERA Supplement was performed specifically to help understand potential risks to aquatic-dependent receptors that use the Kuskokwim River near and downstream from the RDM, as described in the *Proposed Technical Approach for the Kuskokwim River Risk Assessment Supplement* (BLM 2017). The BERA supplement is focused on aquatic-dependent receptors that may use the Kuskokwim River near the RDM, including benthos, fish, and wildlife.

Section 7.1 presents background information. Section 7.2 presents a discussion of problem formulation. Section 7.3 presents the exposure assessment, including a description of the sediment data that were used in the assessment, how contaminant levels in wildlife food items were modeled from sediment, and how exposure was estimated. Section 7.4 presents the ecological effects assessment. Section 7.5 presents the risk characterization. Section 7.6 presents the uncertainty analysis. Section 7.7 presents a summary of potential risks. Potential risks are briefly summarized below.

Overall, the BERA supplement for the Kuskokwim River assessment area identified only marginal risks to the assessment endpoints evaluated when conservative approaches were used to model bioaccumulation. The following points are noteworthy:

- When using site BSAFs and TTFs to model food-chain bioaccumulation, no risks were predicted for herbivorous birds (represented by the green-winged teal), invertivorous birds (represented but the common snipe), piscivorous birds (represented by the belted kingfisher), piscivorous mammals (represented by the mink), forage fish (represented by the slimy sculpin), and benthic macroinvertebrates.

- Because BSAFs often increase with decreasing contaminant concentrations in sediment, BSAFs and TTFs based on data from reference creeks in the middle Kuskokwim River region also were used to model bioaccumulation. When background BSAFs and TTFs were used to model bioaccumulation, marginal potential risks were predicted for invertivorous birds from mercury and selenium, piscivorous birds from selenium, piscivorous mammals from selenium, benthic macroinvertebrates from mercury, and forage fish from mercury. However, it is noted that selenium risks to the snipe, kingfisher, and mink are from background. Further, using only background BSAFs and TTFs to model bioaccumulation likely overestimates risk in the Kuskokwim River assessment area by a factor of two to four.
- By assuming that aquatic-dependent herbivorous birds (green-winged teal) feed only on periphyton from the Kuskokwim River, a potential risk was identified from vanadium. However, vanadium risks are from background.
- Sediment toxicity testing was the strongest line of evidence used to evaluate potential impacts to the benthic macroinvertebrate community in the Kuskokwim River near the RDM. Low to moderate effects on survival, growth, and/or biomass were identified in 3 of 10 site samples, but there was no relationship between these effects and sediment concentrations of antimony, arsenic, mercury, and/or methylmercury, the principal site-related contaminants. Instead, the effects appeared to be the result of differences in sediment texture and/or TOC content between the site and reference samples, and/or the result of non-site-related metals (iron, manganese, and nickel) that appear to be naturally elevated in Kuskokwim River sediment.

9 Weight of Evidence Discussion for Potential Risks Associated with Kuskokwim River Fish and Sediments

This chapter provides a framework for the discussion of a number of factors that are critical to understanding site-specific and regional risk at the RDM and the Kuskokwim River. Specifically, this chapter:

1) Discusses the basis for using a weight-of-evidence (WOE) approach for characterizing human health risk from fish ingestion;
2) Summarizes the risk results from the HHRA and BERA Supplements;
3) Presents two fundamental questions regarding the influence of the RDM on potential risks associated with Kuskokwim River fish consumption;
4) Identifies and describes lines-of-evidence (LOE) relevant to the primary questions associated with Kuskokwim River fish consumption risk;
5) Provides answers to the primary questions based on the WOE of the multiple LOE that were evaluated for fish ingestion from the Kuskokwim River; and
6) Identifies and describes LOE relevant to sediment risks from the Kuskokwim River.

The principal objective of this WOE evaluation is to consider all relevant data in addressing important risk questions regarding the RDM site and provide direction to risk managers. By combining the results of multiple LOE relevant to a specific risk questions, it may be possible to reach conclusions that could not be achieved with any single LOE. This chapter summarizes LOE that have been described in detail elsewhere in this RI Supplement and presents the findings of the WOE evaluation.

9.1 Basis for Using a WOE Approach in Risk Characterization

The EPA Risk Characterization Handbook (EPA 2000b) states that a goal of risk characterization is to communicate the key findings of the assessment through a transparent process that results in a product that is clear, consistent, and reasonable. Risk characterization is a process that integrates the likelihood of risk and the strengths and limitations of the assessment. Although arriving at a risk number (e.g., HQ and/or cancer risk probability) is part of risk characterization, a full description of the strengths and weaknesses of the assessment is essential to risk characterization (EPA 2000b). When additional relevant data are available, multiple LOE can be integrated with the results of a risk assessment to develop a WOE approach to site risks that can aid risk managers in decision making at contaminated sites.

The phrase "weight of evidence" is used by EPA and other scientific bodies to describe the strength of the scientific inferences that can be drawn from a given body of evidence (NRC 2009). Risk assessors often use WOE approaches to integrate multiple LOE to reach risk conclusions (Linkov et al. 2009). WOE methods can be either qualitative or quantitative and may include listing of evidence, best professional judgment, logic, indexing, and quantification, among other methods (Linkov et al. 2009). For example, EPA uses WOE approaches to evaluate carcinogenicity (EPA 1986, 2005j) and in ecological risk assessment (EPA 1998).

Although the WOE concept is formally described primarily in ecological risk assessment guidance (EPA 1998), the concept is equally applicable to human health risk assessment. Examining multiple LOE provides a process and framework for reaching conclusions that take all relevant information into account, thereby increasing confidence in the conclusions of the assessment (EPA 1998). EPA guidance indicates that it is important that risk assessors provide a thorough representation of all LOE developed in the assessment rather than simply reducing the interpretation and description of potential risks to numeric calculations and results (EPA 1998).

Given the large data set assembled for the RDM RI and RI Supplement and the challenges in distinguishing between site-specific and regional factors that may contribute to risk, the development of a WOE evaluation is considered to be appropriate for this risk characterization.

9.2 Brief Summary of Risk Results from BERA and HHRA Supplements

9.2.1 BERA Supplement Risk Summary

The BERA supplement for the Kuskokwim River assessment area identified minimal potential risks to aquatic-dependent wildlife (teal, snipe, kingfisher, and mink), forage fish, and benthic macroinvertebrates when background BSAFs and TTFs were used to model bioaccumulation (see Section 7.7). However, further evaluation of these risks indicated that they were the result of high background exposures (see Section 7.5.4) or overly conservative modeling (see Section 7.6). When using site BSAFs and TTFs to model bioaccumulation, no risks were predicted for aquatic-dependent wildlife, forage fish, and benthic macroinvertebrates. Sediment toxicity testing results also support the conclusion that site-related contaminants are not affecting the benthic community in the Kuskokwim River near the RDM site.

9.2.2 HHRA Supplement Risk Summary

The HHRA Supplement for the Kuskokwim River assessment area indicated that direct exposure (incidental ingestion and dermal exposure) to Kuskokwim River sediment near the RDM site, including the downriver portion, do not exceed acceptable noncancer hazards as defined by EPA and ADEC. Cancer risks from exposure to Kuskokwim River sediment for all receptors are within the acceptable EPA excess cancer risk range of 1 in 10,000 to 1 in 1,000,000. For residents and recreational/subsistence users, the excess cancer risk is slightly above the ADEC standard of 1 in 100,000, but when the outlier results are removed the cancer risks are within an acceptable cancer risk range for both ADEC and EPA. Arsenic is the only substance associated with carcinogenic risk at the site.

For consumption of subsistence fish, the majority of the cancer risk is associated with arsenic levels in the tissue of whitefish, with lower levels of risk associated with consumption of northern pike and burbot. The primary non-carcinogen was methylmercury, with roughly equal hazards for whitefish and northern pike. This risk is attributed to regional contaminant exposure (i.e., exposure throughout the whole middle Kuskokwim River watershed), and not exposure exclusively to the RDM.

Whitefish are anadromous, and the pike are primarily associated with the tributaries and not the Kuskokwim River near RDM. There is no clear linkage between RDM and elevated risks associated with subsistence fish consumption. Modeled subsistence fish concentrations of arsenic, antimony and mercury, based on sediment and site BSAFs and TTFs, were lower than the actual concentrations in fish from the Kuskokwim River (see Table 6-27a). It should be emphasized that the majority of fish ingestion risk comes from consumption of whitefish, which are anadromous and move between the Kuskokwim River and its delta. Pike and burbot, while important subsistence species, account for a relatively small percentage of the fish ingestion risk from arsenic (see Tables 6-17 and 6-19).

9.3 Primary Questions Regarding Influence of RDM on Potential Risks Associated with Kuskokwim River Fish Consumption

The HHRA Supplement identified cancer risks and noncancer hazards for people consuming subsistence fish from the Kuskokwim River. However, the HHRA also presented data that several species of these fish were potentially exposed to multiple sources of mercury and arsenic within the Kuskokwim River watershed in addition to RDM. A primary finding of Matz et al. (2017) is that several important subsistence fish are either highly mobile (burbot) or prefer to stay in tributary waterways (pike), which consequently both minimizes the time spent near RDM and allows for exposure to other sources.

Previous sections of this RI Supplement discussed fish data collection efforts in the Kuskokwim River and approaches used to distinguish between site-related risk and broader regional risk issues. Due to the widespread distribution of mercury mineralization in the region and the mobile nature of the subsistence fish species, it is critical to distinguish between site-related impacts and regional impacts. To better distinguish between regional and site-specific risk issues regarding mercury and arsenic in the Kuskokwim River, two primary questions have been developed for this WOE evaluation. These questions are:

- Question 1: Are releases of mercury from RDM a primary contributor to elevated levels of methylmercury in upper trophic level, subsistence fish in the middle reach of the Kuskokwim River?
- Question 2: To what extent are the potential risks associated with exposure to metals, specifically methylmercury and arsenic, in fish from the middle reach of the Kuskokwim River, attributable to RDM versus other sources?

Answers to these questions are presented at the end of this chapter following a review of the important LOE in the sections below.

9.4 LOE Relevant to Answering the Primary Questions Associated with Kuskokwim River Fish Consumption

To address the questions posed above, a WOE evaluation was developed to consider multiple LOE relevant to understanding human exposure to methylmercury and arsenic in fish. The WOE evaluation combines the results of the risk assessment with additional LOE presented elsewhere in the RI and RI Supplement. As noted above, a principal objective of this WOE evaluation is to consider all relevant data in addressing the primary questions and provide critical information to risk managers. Each individual LOE is considered independently in regards to Kuskokwim River risk, and the LOE are considered collectively as part of the overall WOE evaluation. In addition to the results of the risk assessment supplements (see Section 8.2), the other LOE fall into four groups: (1) site characteristics; (2) contaminant bioavailability; (3) fish movement and local fishing patterns; and (4) effects of recent and planned remediation on potential exposure and risk. These LOE are shown graphically in Figure 8-1 and are summarized below.

The LOE related to RDM and Kuskokwim River characteristics are:

- Kuskokwim River Characteristics near the RDM;
- Regional and Local Background Issues; and
- Kuskokwim River Sediment Data.

The LOE related to contaminant bioavailability are:

- Sediment Toxicity Tests;
- Periphyton Data;
- Bioaccumulation Factors; and
- Mercury SSE Results.

The LOE related to fish movement and local fishing practices are:

- Telemetry Data;
- Fish Tissue Data; and
- Local Fishing Patterns.

The LOE related to recent and planned remediation on site risks are:

- Previous removal action efforts; and
- Planned future remedial actions.

9.4.1 RDM and Kuskokwim River Characteristics

- The middle reach of the Kuskokwim River (including areas both above and below RDM) runs through a mineralized region, portions of which are rich in mercury ore as well as non-ore minerals, including arsenic-bearing minerals. Sources of arsenic and mercury to the Kuskokwim River include natural weathering of mineralized bedrock and disturbance of mineralized areas at abandoned mines, including the RDM, and other mineral occurrences in the watershed (see Sections 5.4.1 and 5.4.2). The footprint of Kuskokwim River sediment impacts attributable to the RDM is small compared to the middle Kuskokwim River region (see Figure 6-2). In addition, atmospheric deposition of mercury to the watershed is a source of mercury.

- The Kuskokwim River within the area of sediment impacts associated with the RDM is characterized by linear shorelines, strong current, high turbidity, a predominantly coarse-grained bottom with little fine-grained sediment, and few or no shoreline wetlands. In general, this stretch of the river provides poor habitat for foraging, nesting, or maturation of young fish. It appears to function more as a travel corridor for fish moving up or down the river or to various tributaries.

- The environmental conditions of the Kuskokwim River within the area of sediment impacts associated with the RDM are not favorable to mercury methylation. Further, as discussed in Section 8.4.2, only a small fraction of total mercury in sediment is in a form that would most likely be subject to microbial methylation in the environment.

- Hence, despite generally high levels of total mercury in Kuskokwim River sediment near RDM, methylmercury levels in Kuskokwim River sediment samples collected near RDM typically were low. For example, methylmercury was detected in 2015 samples collected downriver from RDM at concentrations greater than the RI background concentration (0.49 ng/g) in sediment from only 3 of 14 locations, and below the national average for rivers (1.6 ng/g; Scudder 2009) in all samples. For the samples collected in close proximity to the RDM in 2010 to 2012, methylmercury was detected at concentrations above the national average in only 4 of 26 samples, with a maximum concentration of 3.73 ng/g.

9.4.2 Contaminant Bioavailability

- As part of the BERA supplemental, 28-day laboratory toxicity tests with Kuskokwim River sediments were conducted with the amphipod *Hyalella azteca*. Seven of ten samples collected from Red Devil Creek delta or downstream from the delta showed no differences in survival, growth, or biomass compared with upstream reference samples. The remaining three samples showed a moderate reduction in amphipod survival (10 to 30%) and biomass (30 to 40%) compared with upstream reference samples. While this LOE is not directly linked to human health effects, it nonetheless indicates that site sediments have minimal direct toxicity to aquatic organisms despite containing high levels of total mercury, arsenic, and other metals. These results suggest that the bioavailability of site-related metals in Kuskokwim River sediments is limited, which has implications for human exposure to site-related metals.

- Periphyton samples from the Kuskokwim River were analyzed to determine if methylmercury was present in organisms at the base of the benthic food web. None of the periphyton samples collected near the RDM had detectable levels of methylmercury. Again, although this LOE is not directly linked with human health effects, it does suggest that methylmercury production in Kuskokwim River sediment near and downstream from the RDM is minimal, which has implications for human exposure to methylmercury.

- Mercury SSE results for sediment samples collected downstream from the Red Devil Creek delta show that only a small fraction (typically less than 1%) of total mercury in sediment is in forms potentially subject to methylation. Because the total mercury concentration was high in some site samples, the absolute concentration of bioavailable mercury was high even though only a small fraction was bioavailable. Nonetheless, methylmercury levels in Kuskokwim River sediment near the RDM typically were low because conditions near the site are not favorable for mercury methylation. Hence, most mercury in Kuskokwim River sediment downstream from the Red Devil Creek delta is in a form that would not be expected to adversely impact people or the environment, a finding that is consistent with the low levels of methylmercury in sediment and periphyton, and limited sediment toxicity.

- Biota sediment accumulation factors (BSAFs) based on data from the RDM site are lower than BSAFs based on data from reference creeks in the middle Kuskokwim River area. This result suggests that the bioavailability of mercury, arsenic, and other metals at the RDM site is lower than in reference areas, which should function to limit exposure of people and wildlife to site-related metals in sediment near the RDM.

9.4.3 Fish Movement and Local Fishing Practices

- The telemetry studies showed that comparatively few pike were resident in the Kuskokwim River near the RDM. Rather, most were found in areas with better pike habitat, including the George and Holitna Rivers. In contrast with pike, burbot were found to be highly migratory and travelled widely in the Kuskokwim River. Both species spent significant amounts of time in other portions of the Kuskokwim River watershed. Therefore, mercury levels in their tissues are more reflective of exposure to mercury from those areas. No data were collected regarding the movement of whitefish but whitefish travel over long distances. Sheefish, the whitefish primarily consumed, are anadromous in the region (Matz et al. 2017).

- The highest methylmercury levels were found in resident pike from large tributary rivers with abundant wetland habitat, including the George and Holitna Rivers. On the other hand, pike captured in the Kuskokwim River near the RDM had the lowest tissue levels. Burbot had lower and less variable methylmercury levels than did pike. The tissue data are consistent with results of the telemetry study and habitat information. Collectively, the tissue data, telemetry results, and habitat information indicate that pike do not prefer the reach of the Kuskokwim River near the RDM, but reside primarily in areas with better pike habitat, including the George and Holitna Rivers and Kuskokwim River upstream from Sleetmute during the winter months. Therefore, their tissue methylmercury levels reflect exposure in those areas.

- Information on local fishing practices provided by residents of Red Devil Village and other nearby villages indicates that they fish for pike in the large tributaries of the Kuskokwim River, such as the George and Holitna Rivers, not in the Kuskokwim River near the RDM.

9.4.4 Recent and Planned Removal Actions

- During its operational period, the RDM directly discharged tailings and mining waste into Red Devil Creek and the Kuskokwim River, contributing to elevated mercury and arsenic levels in sediments in the creek's delta. In 2014, the BLM took action in Red Devil Creek that has greatly reduced the potential for tailings to move from the site into the Kuskokwim River.

- There are future plans for a remedial action that includes excavation and removal of the tailings in the Main Processing Area and downstream Red Devil Creek alluvial area. This action is expected to include much of the material in the Red Devil Creek delta, further reducing exposure of human and ecological receptors to site-related contaminants (including arsenic and mercury) in the Kuskokwim River near the RDM.

9.5 Answers to Primary Questions Regarding Fish Consumption Risks Based on WOE

In a dynamic setting like the Kuskokwim River, there are a number of variables at play that impact data collection and interpretation. This WOE evaluation was developed specifically to look at the questions previously stated using all the information available. The intent of a WOE evaluation is to include all relevant data in the decision-making process, letting the preponderance of evidence play the primary role in the site outcome.

Based on this WOE evaluation, the overall evidence supports the conclusion that, although the RDM has contributed mercury and arsenic to the Kuskokwim River, the mercury and arsenic levels measured in pike, burbot and whitefish reflect primarily regional exposure and there is no demonstrable RDM-specific increase in fish consumption risk. The mercury and arsenic levels measured in fish from the middle reach of the Kuskokwim and its tributaries are consistent with state-wide levels reported by ADEC (2017a and 2017b), suggesting that regional levels of mercury and arsenic in the Kuskokwim are not appreciably different than those across the state.

Based on full consideration of the multiple LOE included in this evaluation, the risk questions raised above can be answered as follows:

- Question 1: Are releases of mercury from RDM a primary contributor to elevated levels of methylmercury in upper trophic level, subsistence fish in the middle reach of the Kuskokwim River?

- Answer: Although the RDM has been shown to be a source of total mercury to the river, the cumulative evidence does not indicate that the RDM is contributing significantly to methylmercury levels in subsistence fish from the middle Kuskokwim River region.

- Question 2: To what extent are the potential risks associated with exposure to metals, specifically methylmercury and arsenic, in fish from the middle reach of the Kuskokwim River attributable to RDM versus other sources?

    - Answer: Methylmercury and arsenic levels in fish that live primarily in upgradient tributaries, or that range widely in the Kuskokwim River, are comparable to those collected from the river near RDM. Furthermore, the fish of interest do not spend much time near RDM due to poor habitat; hence, their tissue levels reflect bioaccumulation from the locations where they live and eat (i.e., the large tributaries for pike and the entire middle and lower Kuskokwim River for burbot). These results suggest that RDM, while a historical source of contaminant input to the river, is not contributing significantly to risks associated with exposure to methylmercury and arsenic in subsistence fish.

9.6 Discussion and WOE for Human Health Risks Associated with Exposure to Sediments in the Kuskokwim River

This section discusses the LOE associated with direct human exposure to sediments in the Kuskokwim River. Noncancer hazards from exposure to inorganic compounds in Kuskokwim River sediment near the RDM site, including the downriver portion, are at levels considered acceptable by EPA and ADEC. Cancer risks from exposure to inorganic contaminants in Kuskokwim River sediment for all receptors are within the acceptable EPA cancer risk range. For residents and recreational/subsistence users, the cancer risk is slightly above the ADEC acceptable cancer risk level. Arsenic is the only carcinogenic contaminant in sediment at the site.

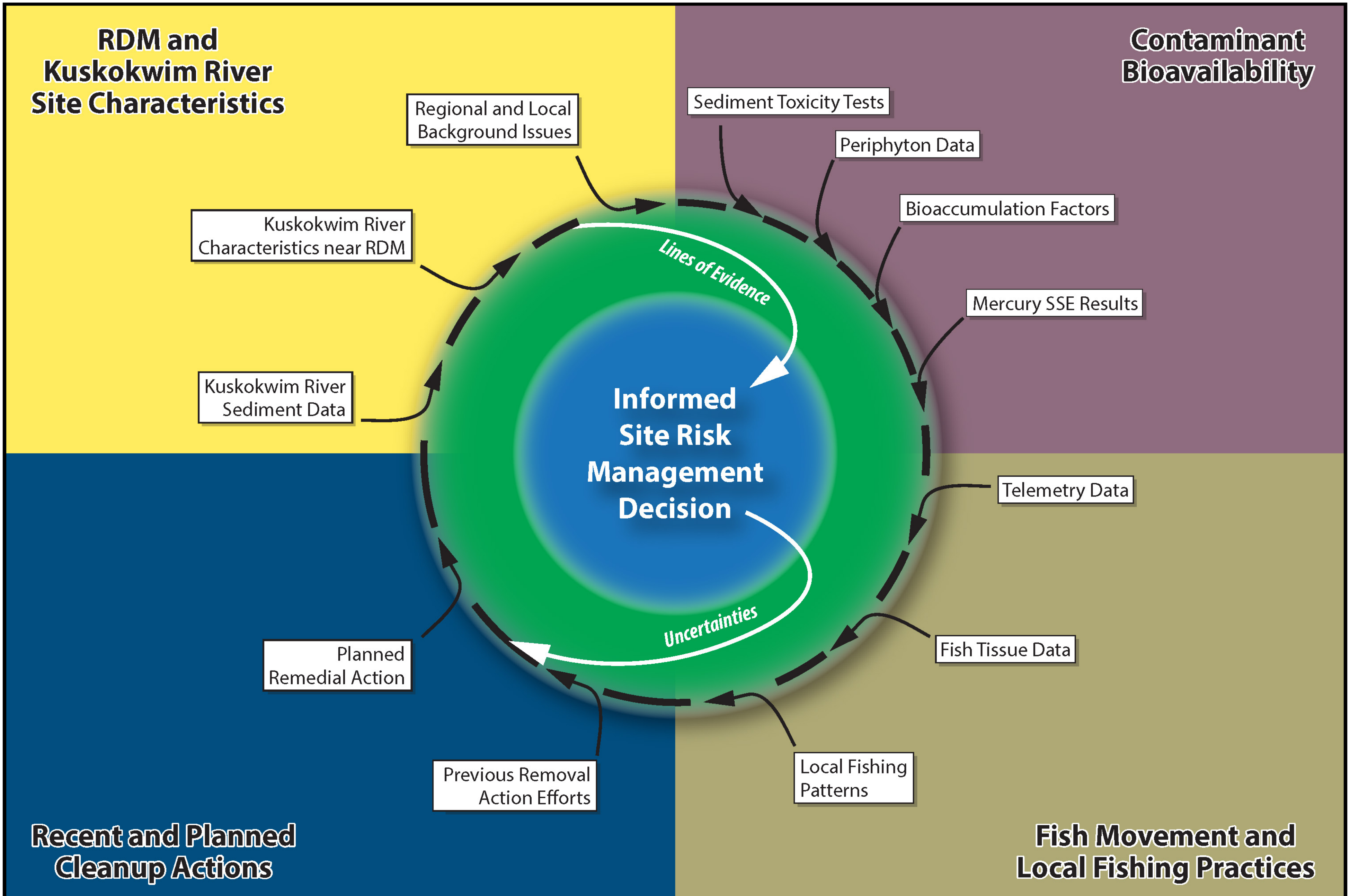
As noted in Section 8.4.4, there are plans for a future remedial action that include excavation and removal of the tailings in the Main Processing Area and downstream Red Devil Creek alluvial area, including much of the material in the Red Devil Creek delta. Many of the high concentration sediment samples for arsenic and mercury were collected in the delta directly offshore from the RDM. Remediation and removal of the mine waste at the Red Devil Creek delta is expected to reduce the risk estimates, since it will lower the concentrations of arsenic and mercury that a person may be exposed to via direct exposure. Given the modest exceedance of ADECs cancer risk level, BLM anticipates that future remedial efforts will remove sufficient waste material to reduce risks to below ADEC standards.

An additional LOE relates to site activity levels assumed to occur at the delta in the HHRA Supplement. As discussed above, the Kuskokwim River near RDM does not provide attractive habitat for burbot and northern pike. Information from residents in the Red Devil Village area indicates that people are more likely to fish for pike in the tributaries and for burbot during the winter months, and do not spend significant time fishing from the shore near the RDM. Other than near-shore fishing, there are few reasons for an individual to routinely come into contact with Kuskokwim River sediments. There are no residences located within the RDM; therefore, individuals would have to specifically visit this location. There is a locked gate that blocks the trail to the RDM area, further limiting access. Having established that fishing is not productive and the RDM area lacks road access and boat docks, people would likely not return to the same spot repeatedly.

According to local residents of Red Devil Village (Talaia-Murray 2017), drift-netting from a boat, in which the net does not come in contact with the shore, is the typical method of fishing in the area. Other shore activities include dressing fish at the shore and embarking/disembarking from boats on the shore. This would result in limited exposure to sediment along the shore of the Kuskokwim River. Although the true exposure is not known, based on the type of activities and range of ingestion rates, the adult and child incidental ingestion rate used in this HHRA Supplement likely overestimates risks and hazards at the site.

As discussed in Section 6.5.3, there is uncertainty associated with the procedures used to estimate direct exposure to sediment. Available information on the dermal absorption of chemicals from sediment is limited. Quantitative estimates of sediment incidental ingestion or the amount of time spent exposed to sediment along the shores of the Kuskokwim River do not exist; consequently, conservative estimates based on soil exposure were used. In addition, the amount of time people engage in activities where they may be exposed to sediment is not known and, therefore, had to be estimated based on professional judgment and discussions with local residents.

Overall, several LOE suggest that potential risks from sediment exposure are unlikely to be a genuine concern near the RDM currently or in the future. First, the amount of assumed sediment exposure likely was overestimated for reasons discussed above (i.e., the Kuskokwim River near RDM is not a productive area for shoreline fishing, and access to the area is restricted). Second, future risks after site remediation are expected to be even lower due to the planned removal of much of the tailings material from Red Devil Creek delta.



RED DEVIL MINE Red Devil, Alaska	Figure 9-1 Lines of Evidence Relevant to Kuskokwim River Risk Characterization

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A Data Review Memoranda

A Data Review Memoranda

B Summary of Soil Boring Data

B Summary of Soil Boring Data

C Sediment Toxicity Testing Report

C Sediment Toxicity Testing Report

D HHRA ProUCL Input and Output Files

D HHRA ProUCL Input and Output Files

E

Sediment Exposure Point Concentrations

E Sediment Exposure Point Concentrations

F

Sediment and Benthic Macroinvertebrate Metals Data for Red Devil Creek and Reference Creeks and Biota Sediment Accumulation Factors

G

Slimy Sculpin Metals Data for Red Devil Creek Used to Develop Benthos-to-Sculpin Trophic Transfer Factors

G Slimy Sculpin Metals Data for Red Devil Creek Used to Develop Benthos-to-Sculpin Trophic Transfer Factors

H

Red Devil Creek Benthic Macroinvertebrate Metals Data Used to Develop Trophic Transfer Factors

H Red Devil Creek Benthic Macroinvertebrate Metals Data Used to Develop Trophic Transfer Factors

I

Development of Benthos-to-Sculpin Trophic Transfer Factors

I Development of Benthos-to-Sculpin Trophic Transfer Factors

J

Pond Plant (Horsetail) and Pond Sediment Metals Data for Site and Background Ponds and Sediment to Plant Uptake Factors

J Pond Plant (Horsetail) and Pond Sediment Metals Data for Site and Background Ponds and Sediment to Plant Uptake Factors

K

Periphyton Metals Data and EPCs for Kuskokwim River Assessment Area

K Periphyton Metals Data and EPCs for Kuskokwim River Assessment Area

L

Reference Creek Benthic Macroinvertebrate Metals Data Used to Develop Background Trophic Transfer Factors

L Reference Creek Benthic Macroinvertebrate Metals Data Used to Develop Background Trophic Transfer Factors

M

Slimy Sculpin Metals Data for Reference Creeks Used to Develop Background Benthos-to-Sculpin Trophic Transfer Factors

M Slimy Sculpin Metals Data for Reference Creeks Used to Develop Background Benthos-to-Sculpin Trophic Transfer Factors

N

Development of Background Benthos-to-Sculpin Trophic Transfer Factors

N Development of Background Benthos-to-Sculpin Trophic Transfer Factors

O

Site-Specific Fish Tissue Screening Concentrations

O Site-Specific Fish Tissue Screening Concentrations

P

Site-Specific Tissue Screening Concentrations for Benthic Macroinvertebrates

P Site-Specific Tissue Screening Concentrations for Benthic Macroinvertebrates