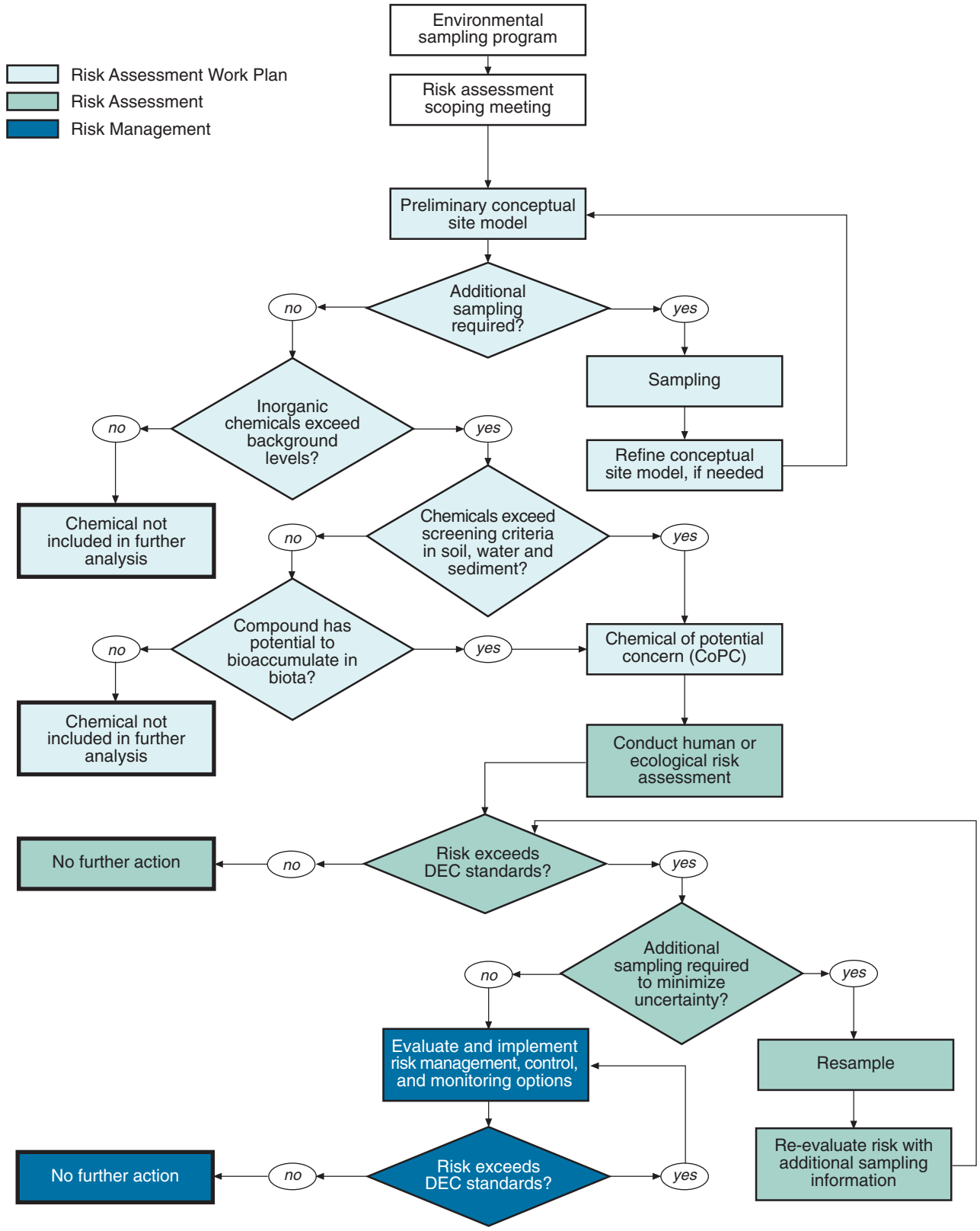
Figures



Source: Adapted from DEC et al. (2002)

Figure 1-1. Decision making framework for evaluating risk to human health and ecological receptors

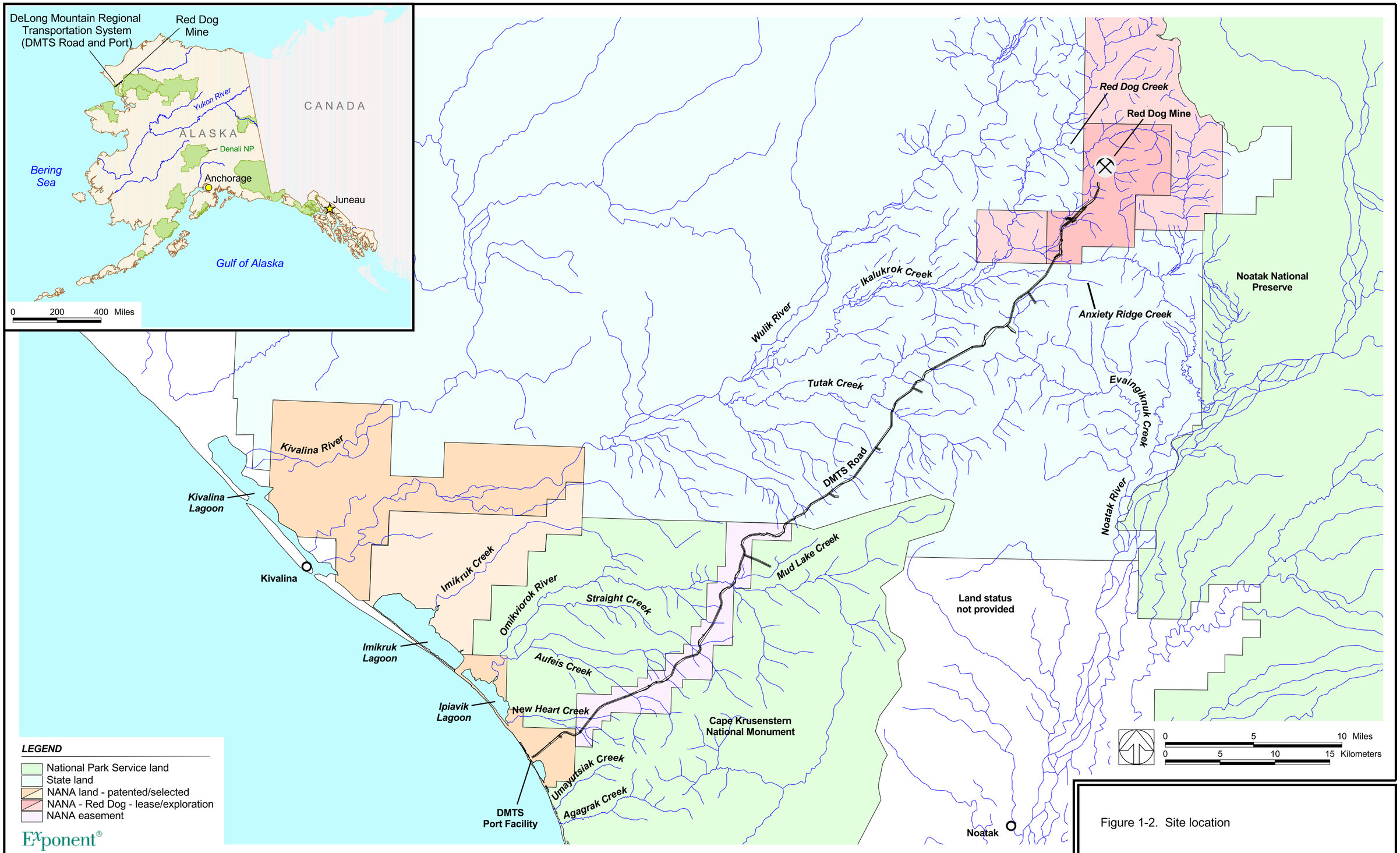
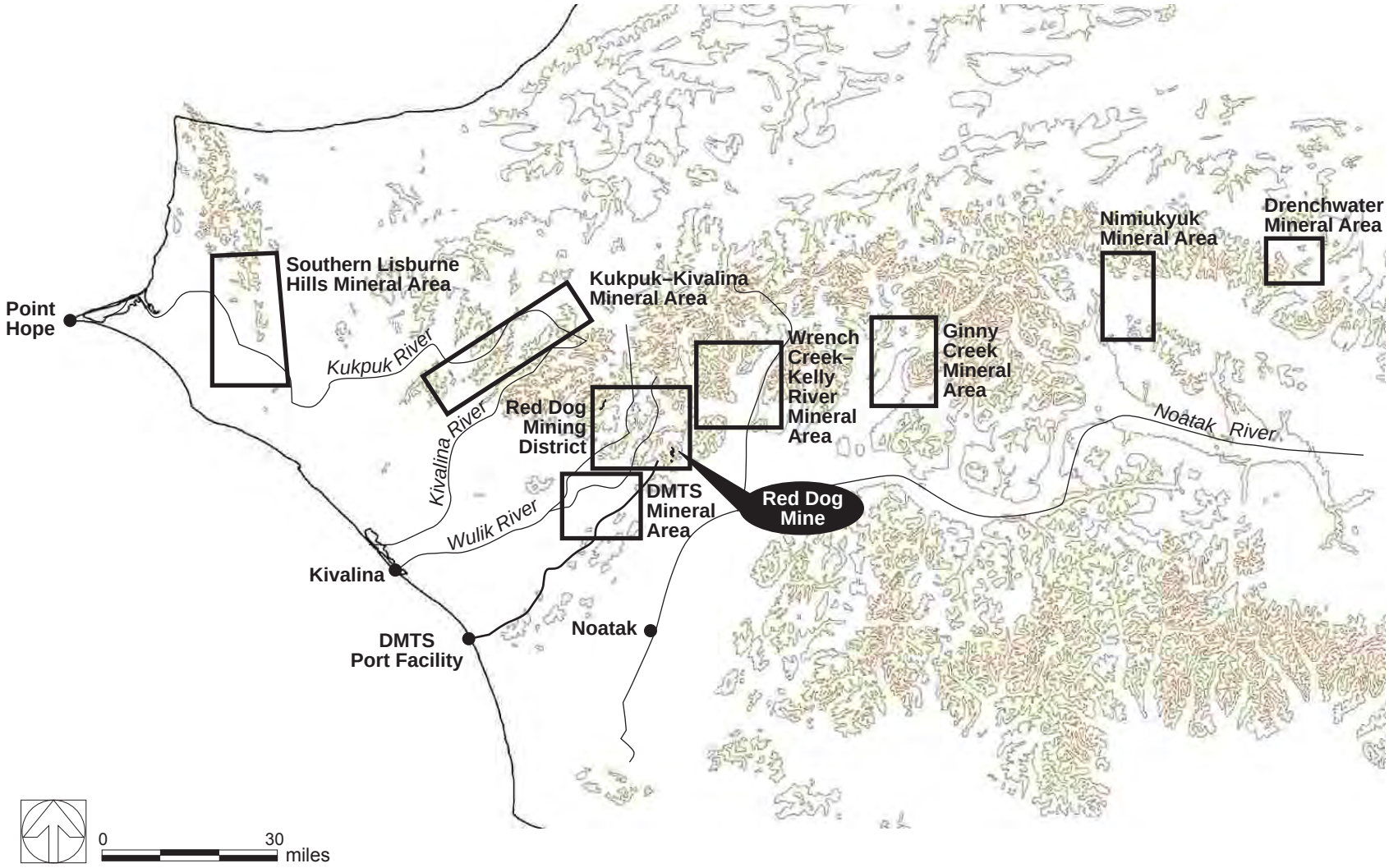


Figure 1-2. Site location



Source: Adapted from Teck Cominco (2002)

Figure 1-3. Areas of zinc, lead, and barite mineralization in the western Brooks Range, Alaska

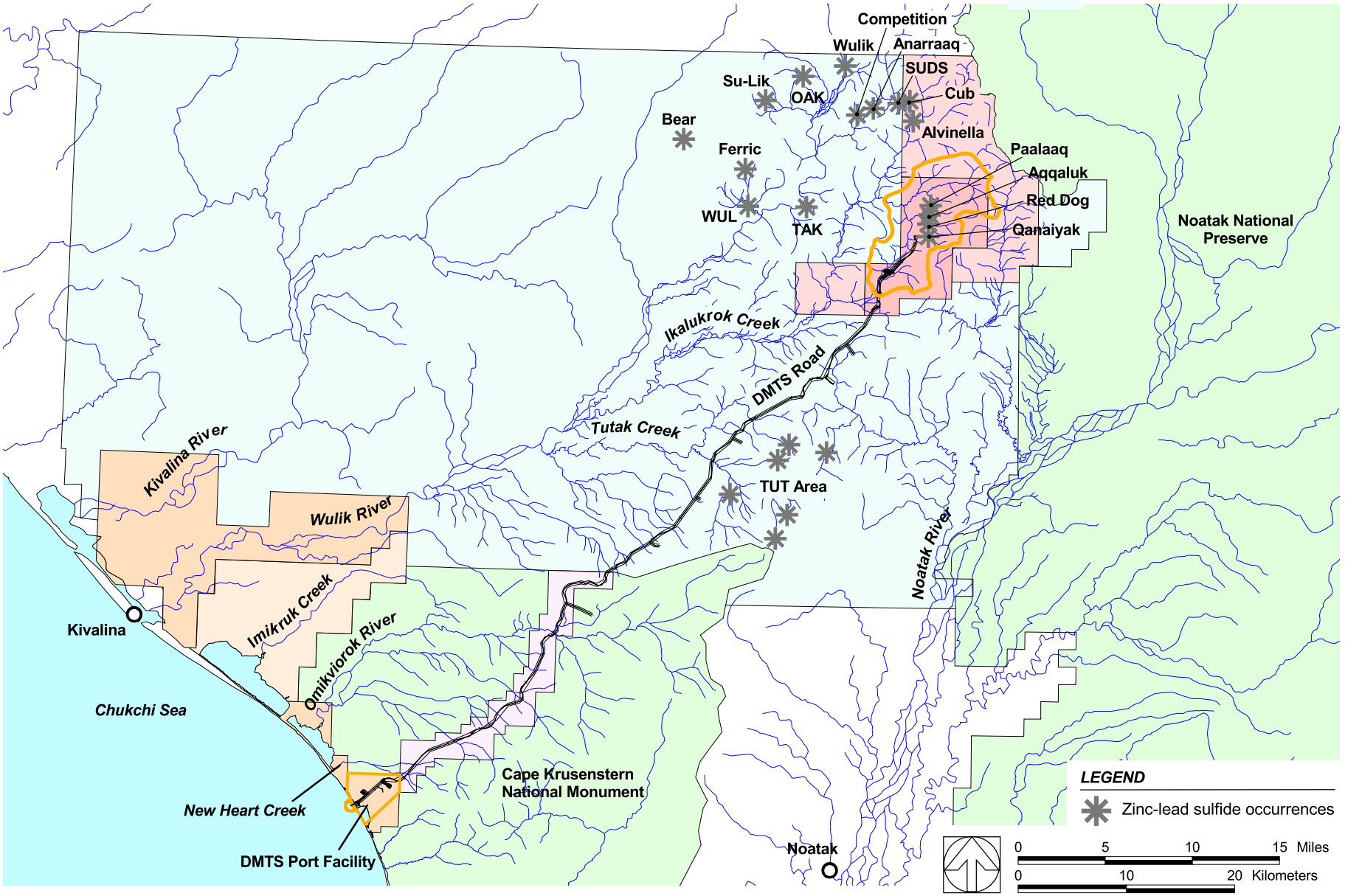


Figure 1-4. Mineralization map for the Red Dog mining district

Exponent®

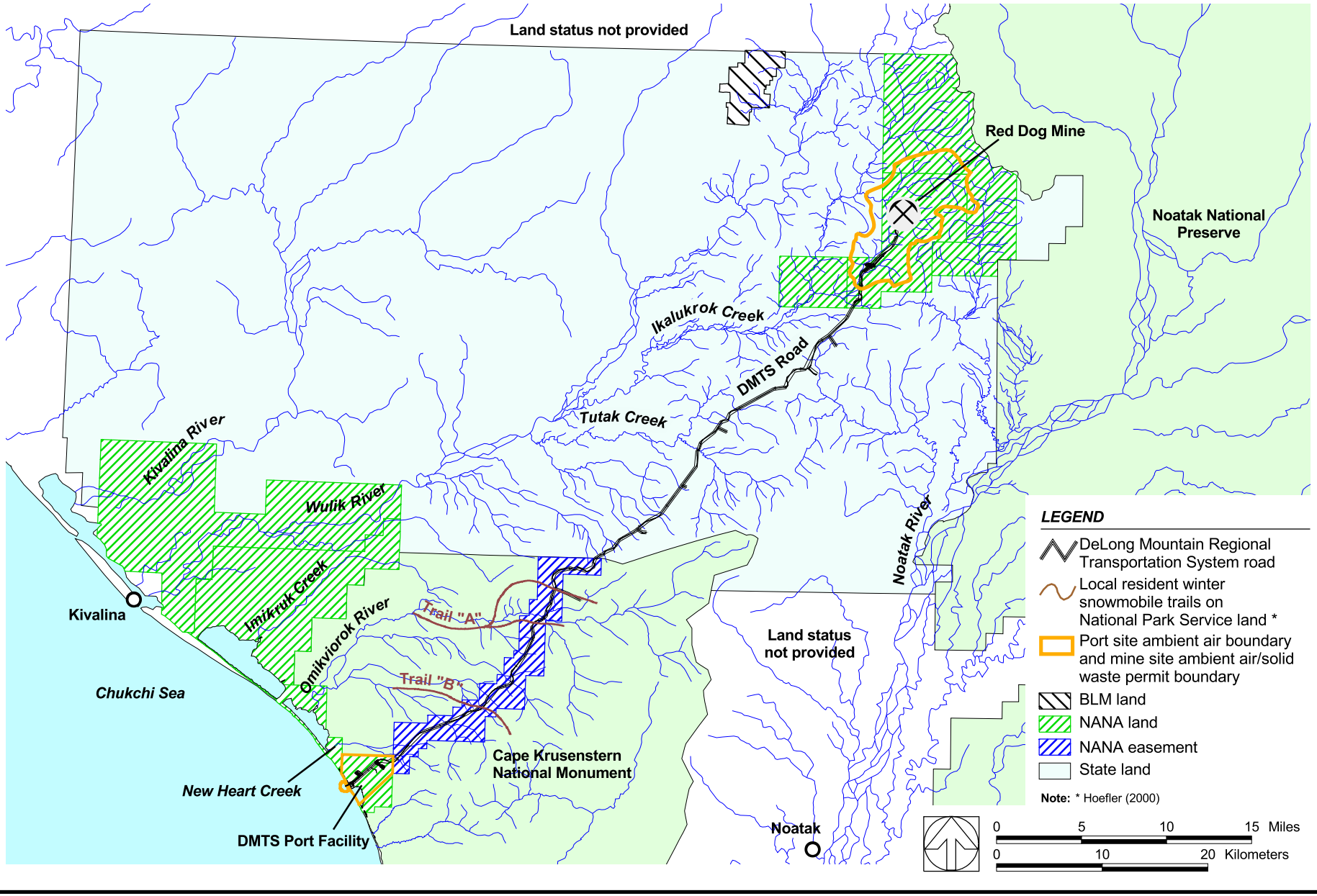
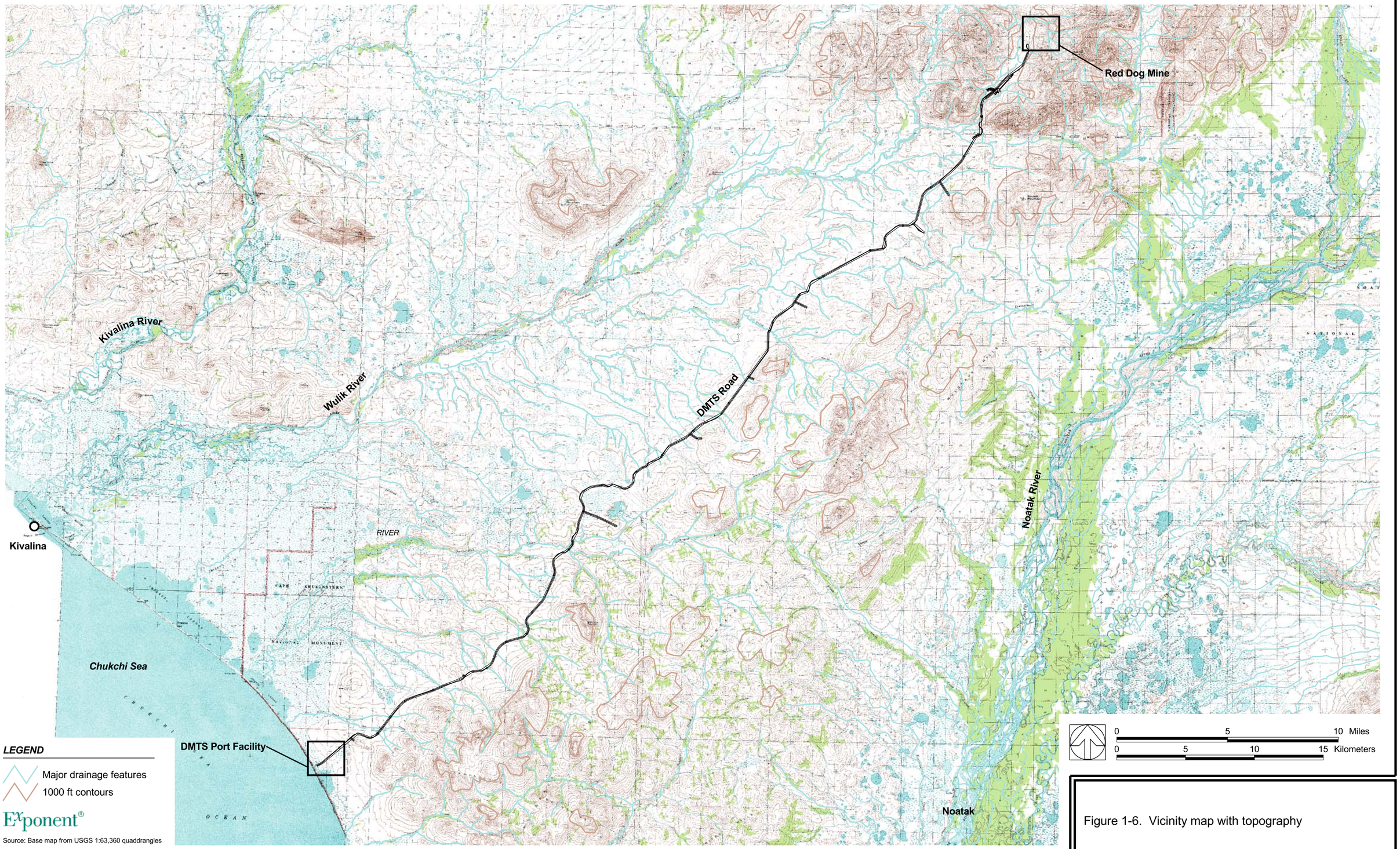


Figure 1-5. Land ownership and use map

Exponent®



LEGEND

Major drainage features

1000 ft contours

Exponent®

Source: Base map from USGS 1:63,360 quaddrangles

Figure 1-6. Vicinity map with topography

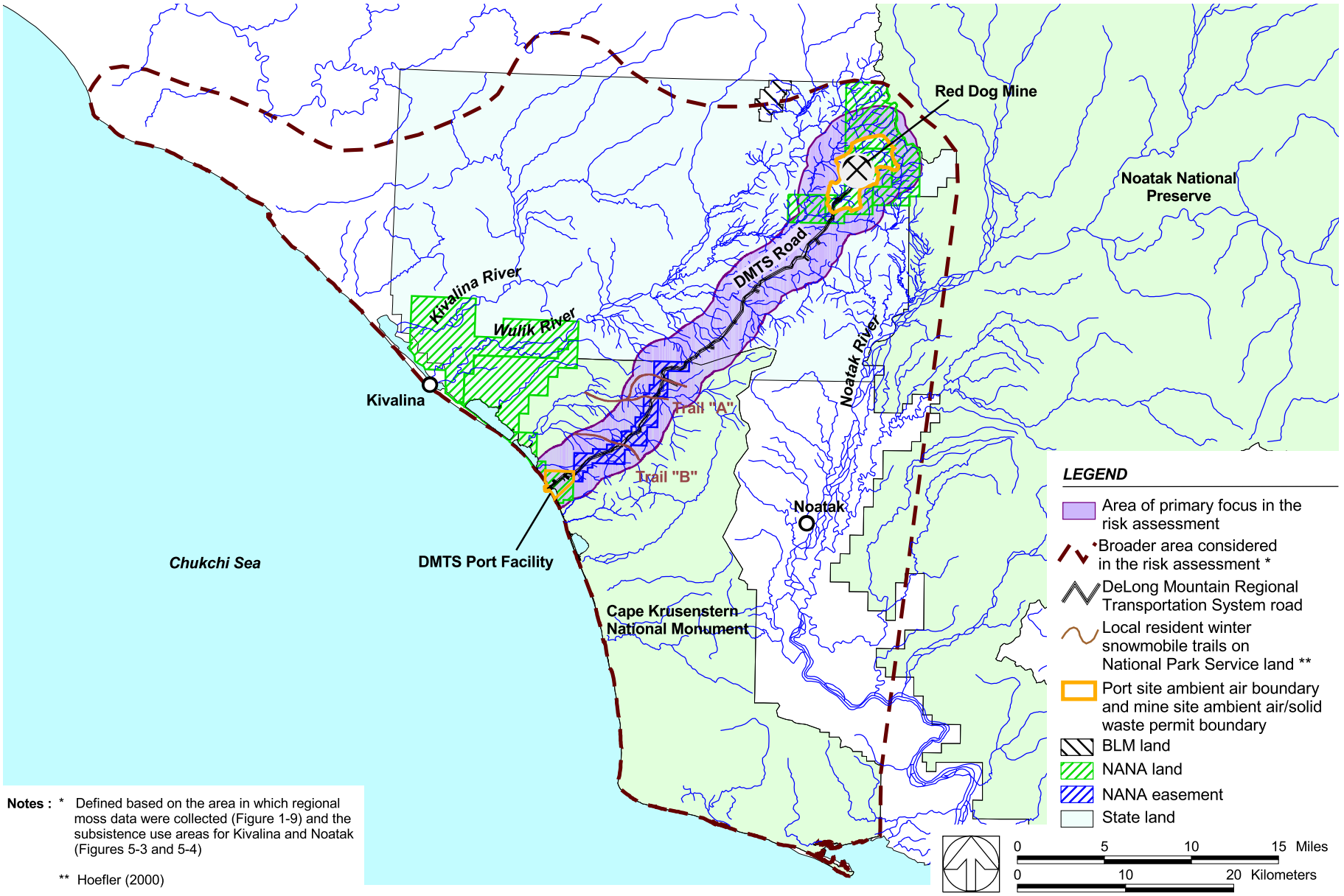
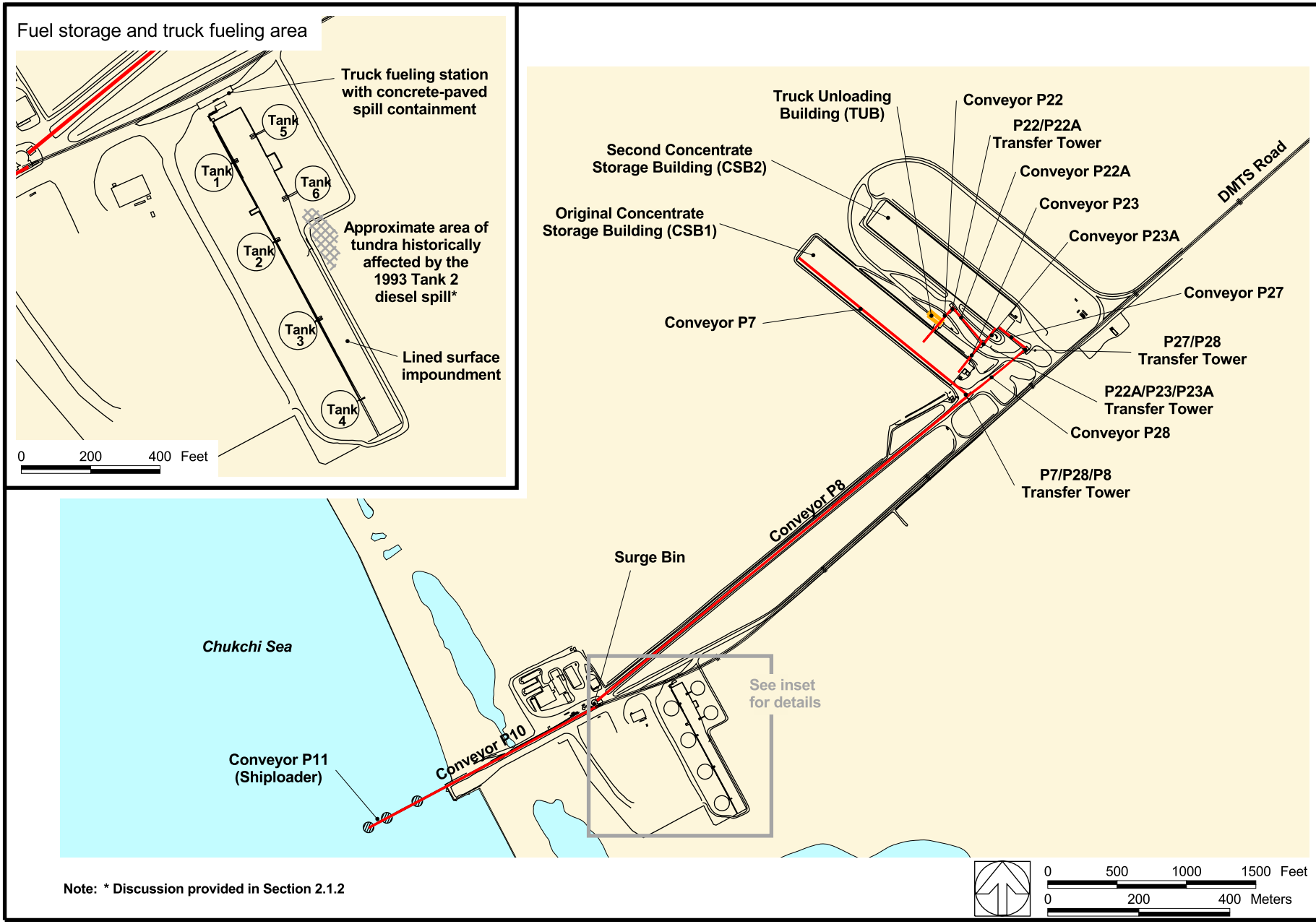


Figure 1-7. Risk assessment study areas and subsistance use areas

Exponent®



Note: * Discussion provided in Section 2.1.2

Figure 1-8. Port site storage and conveyance features map

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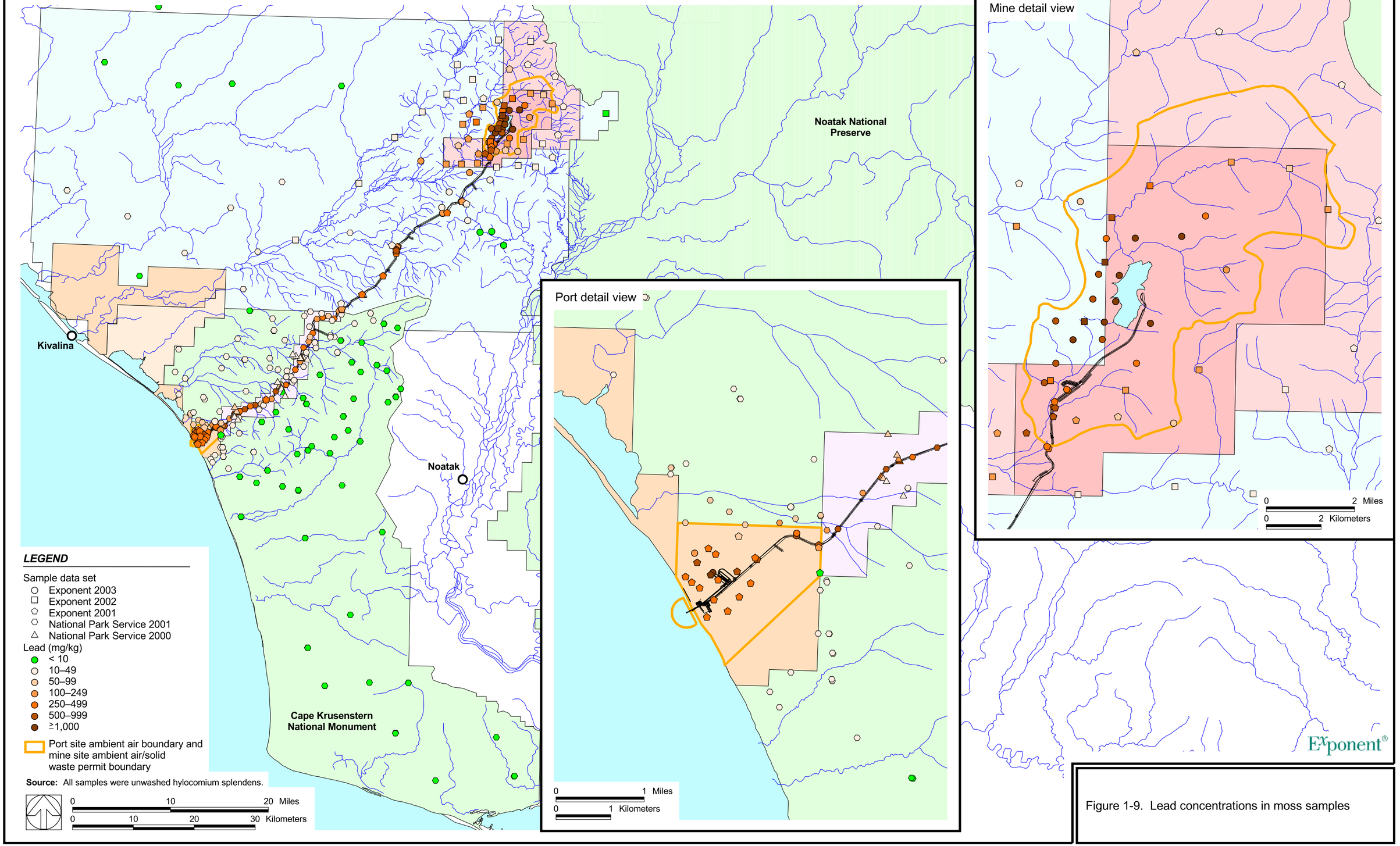
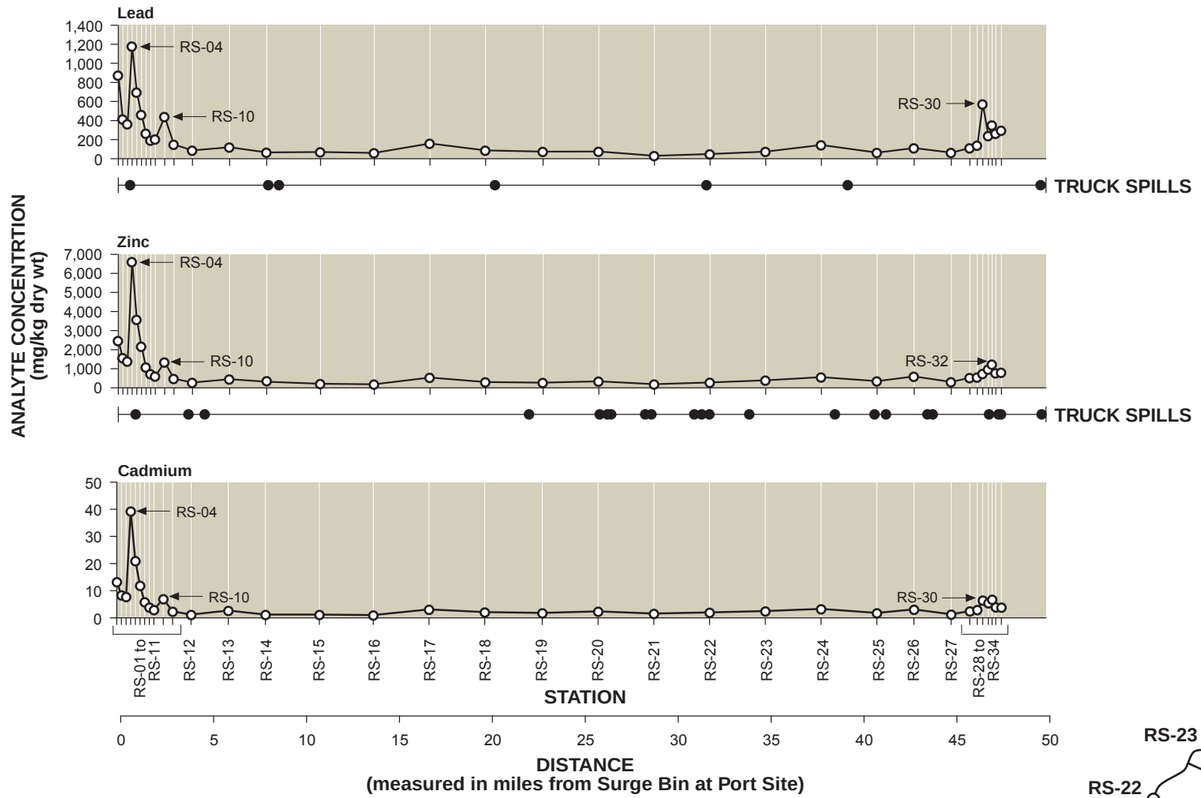
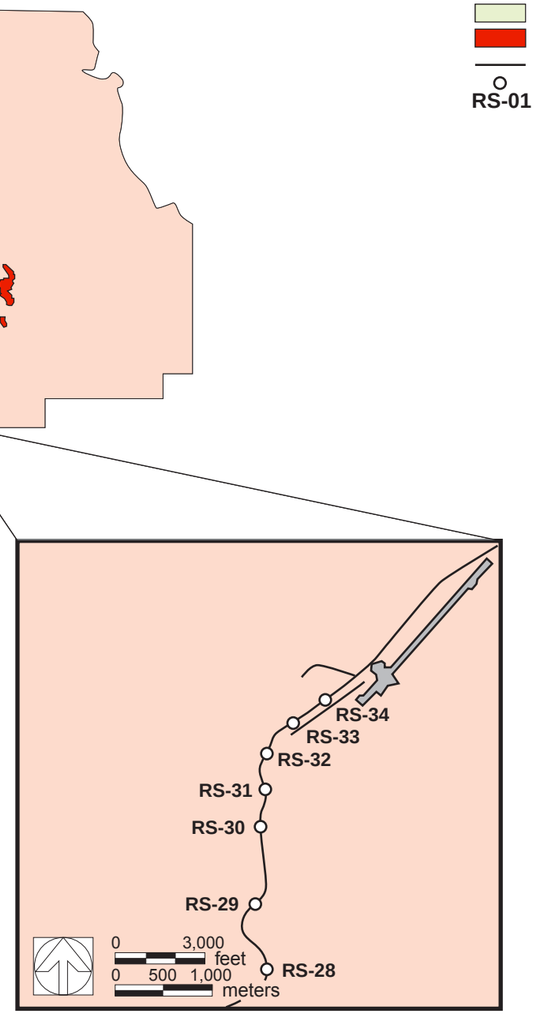


Figure 1-9. Lead concentrations in moss samples





LEGEND

- Red Dog lease/exploration site
- NANA patented/selected land
- State land
- Park land
- Mine area
- Haul road
- RS-01 Station number and location

Figure 1-10. Road surface concentrations for lead, zinc, and cadmium

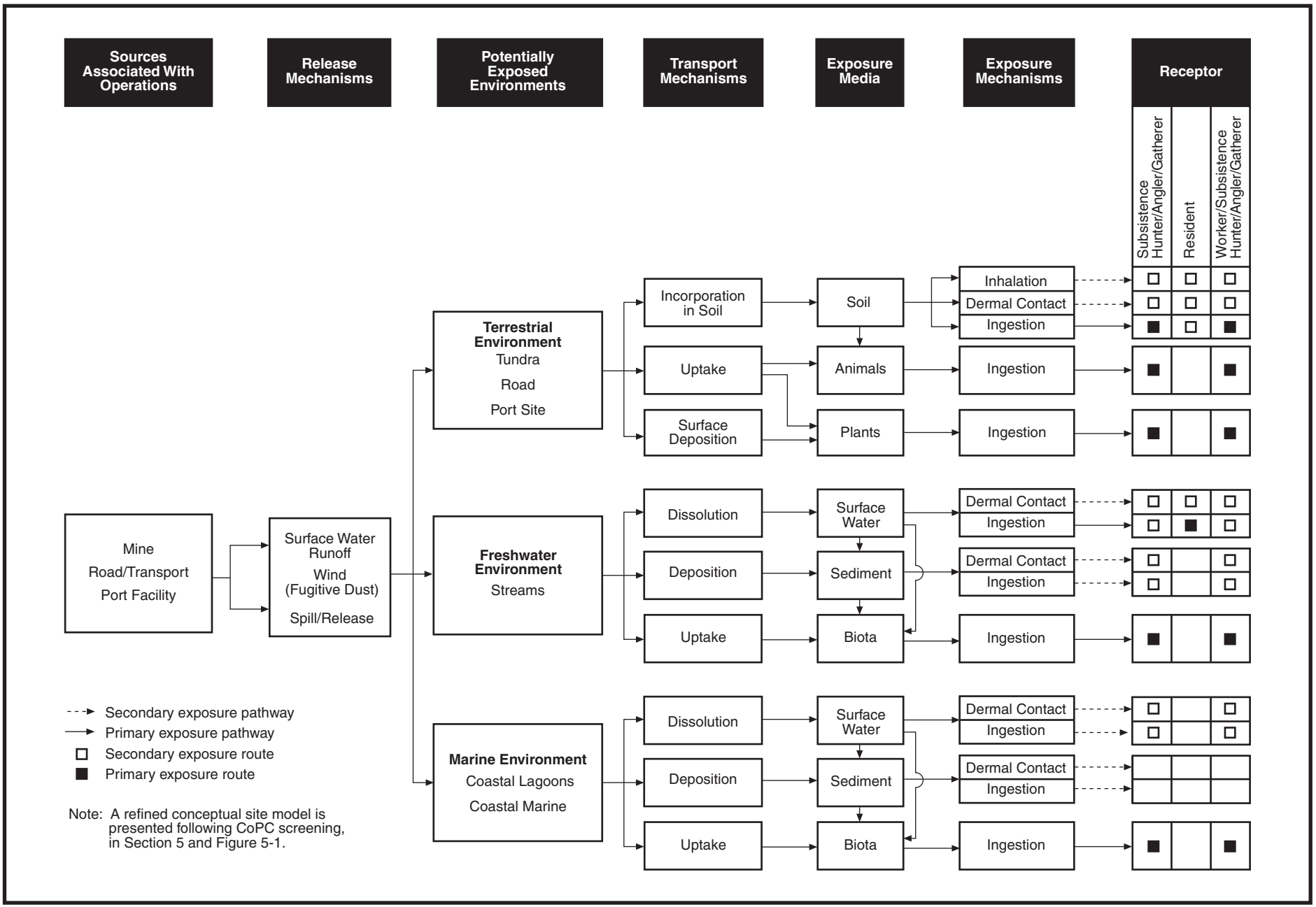


Figure 2-1. Preliminary conceptual site model for the DMTS human health risk assessment

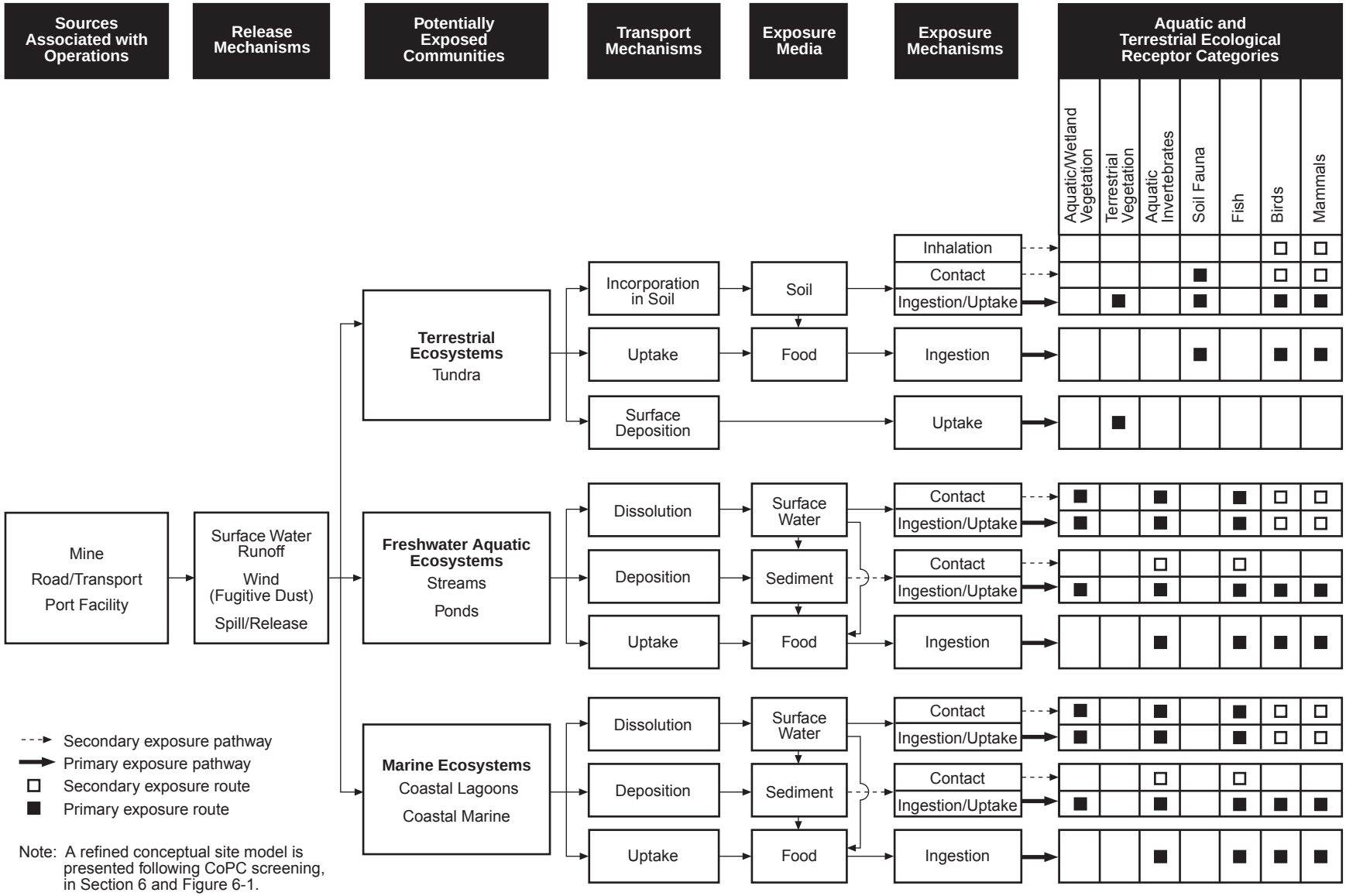


Figure 2-2. Preliminary conceptual site model for the DMTS ecological risk assessment

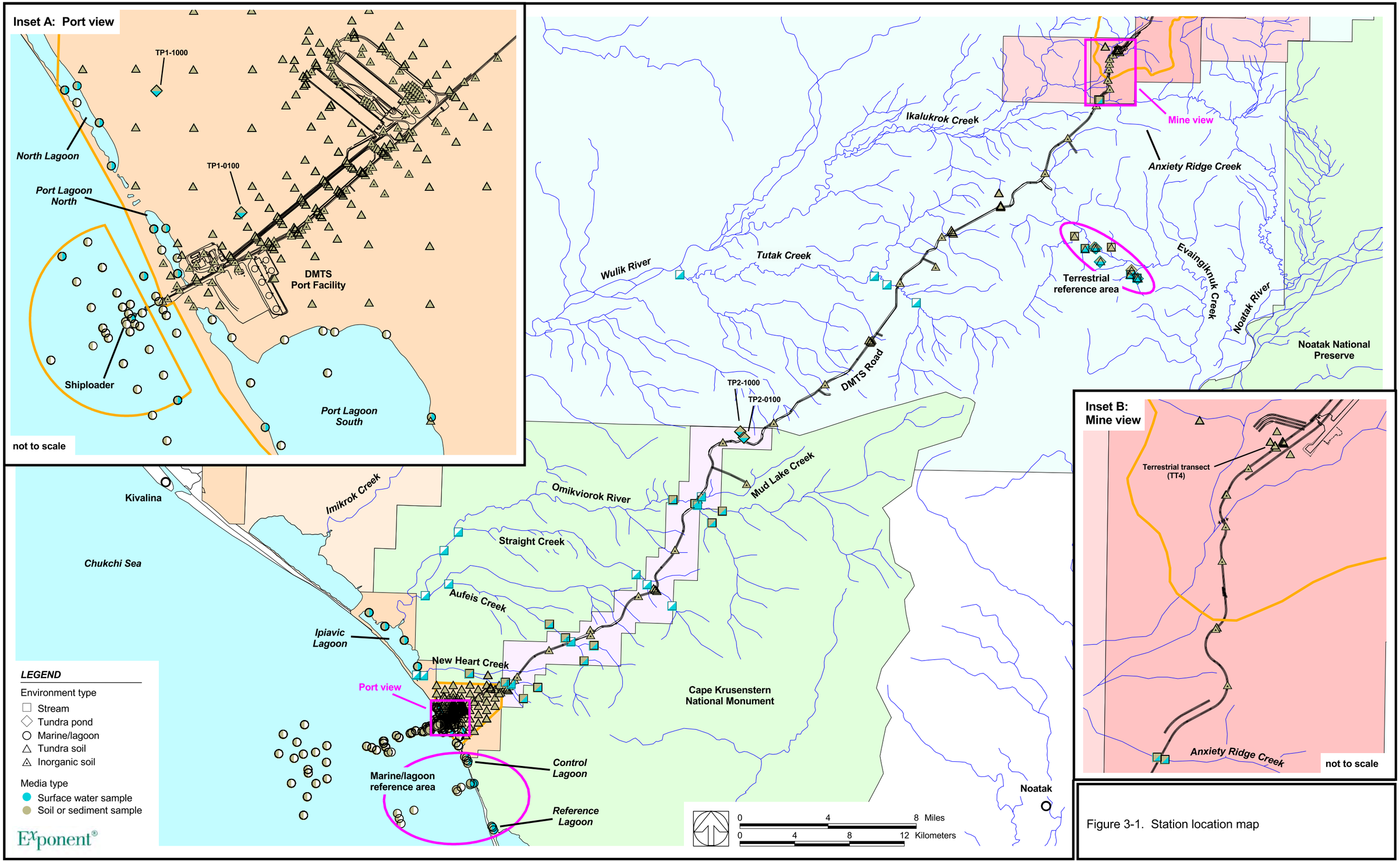


Figure 3-1. Station location map

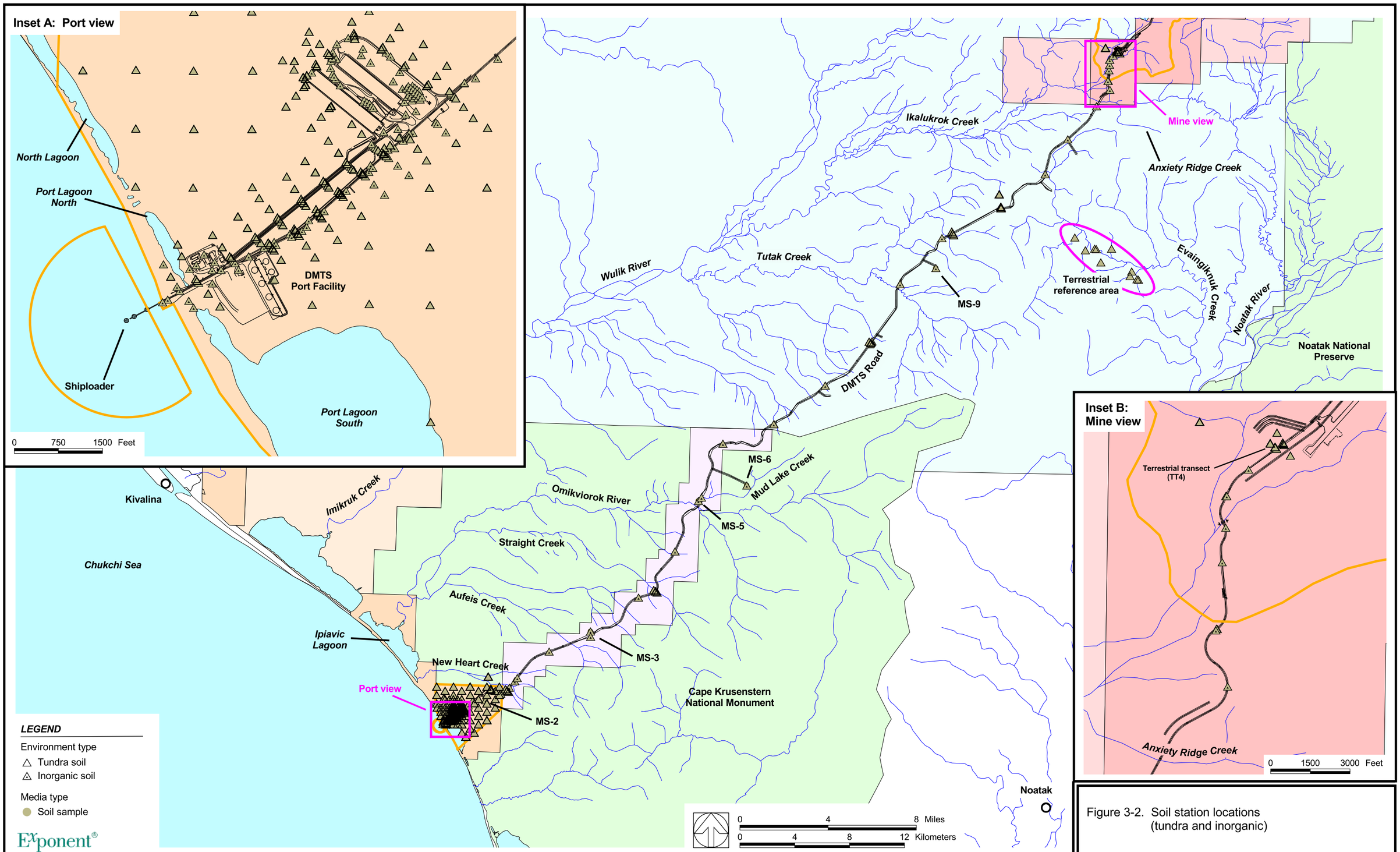


Figure 3-2. Soil station locations (tundra and inorganic)

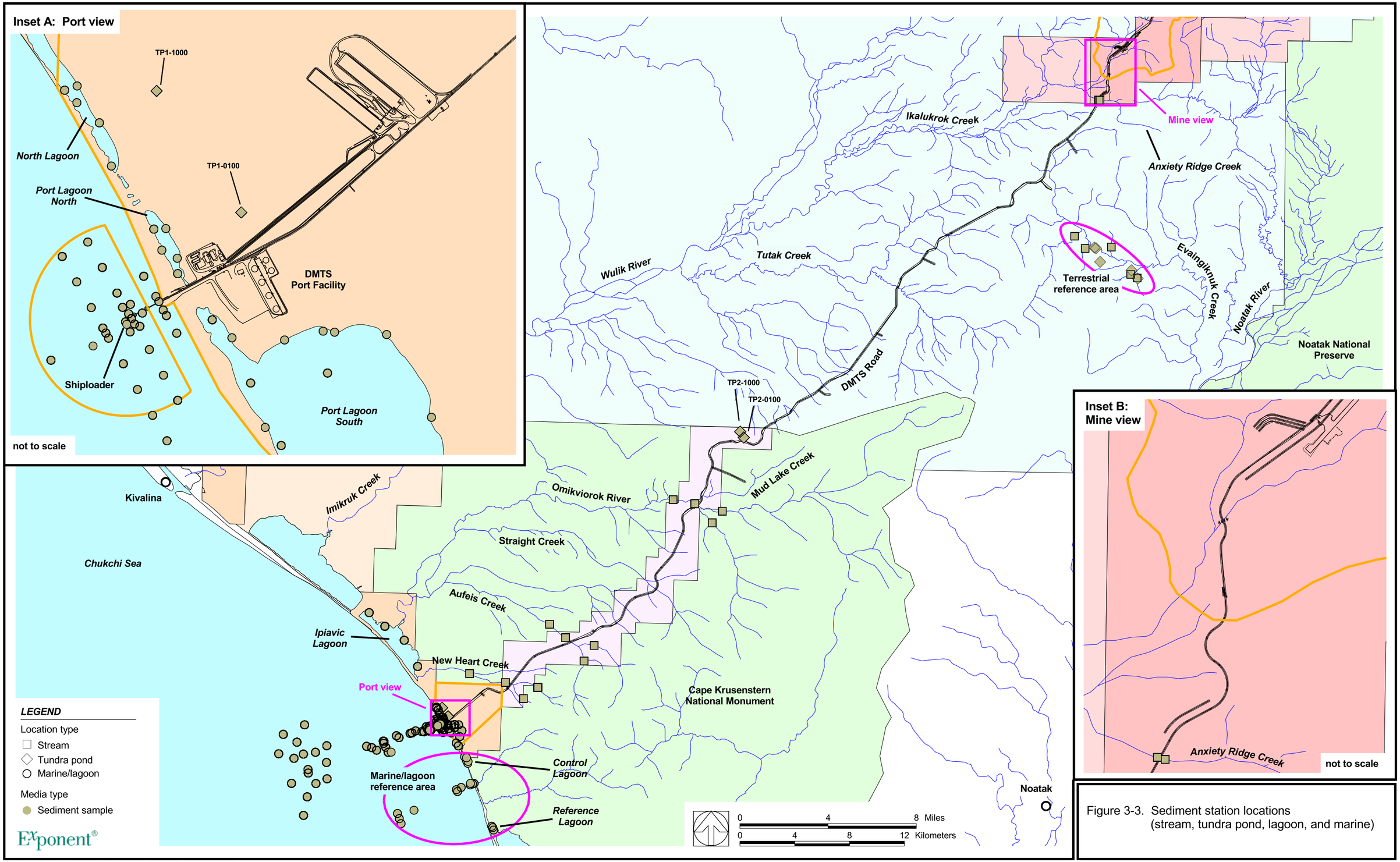


Figure 3-3. Sediment station locations (stream, tundra pond, lagoon, and marine)

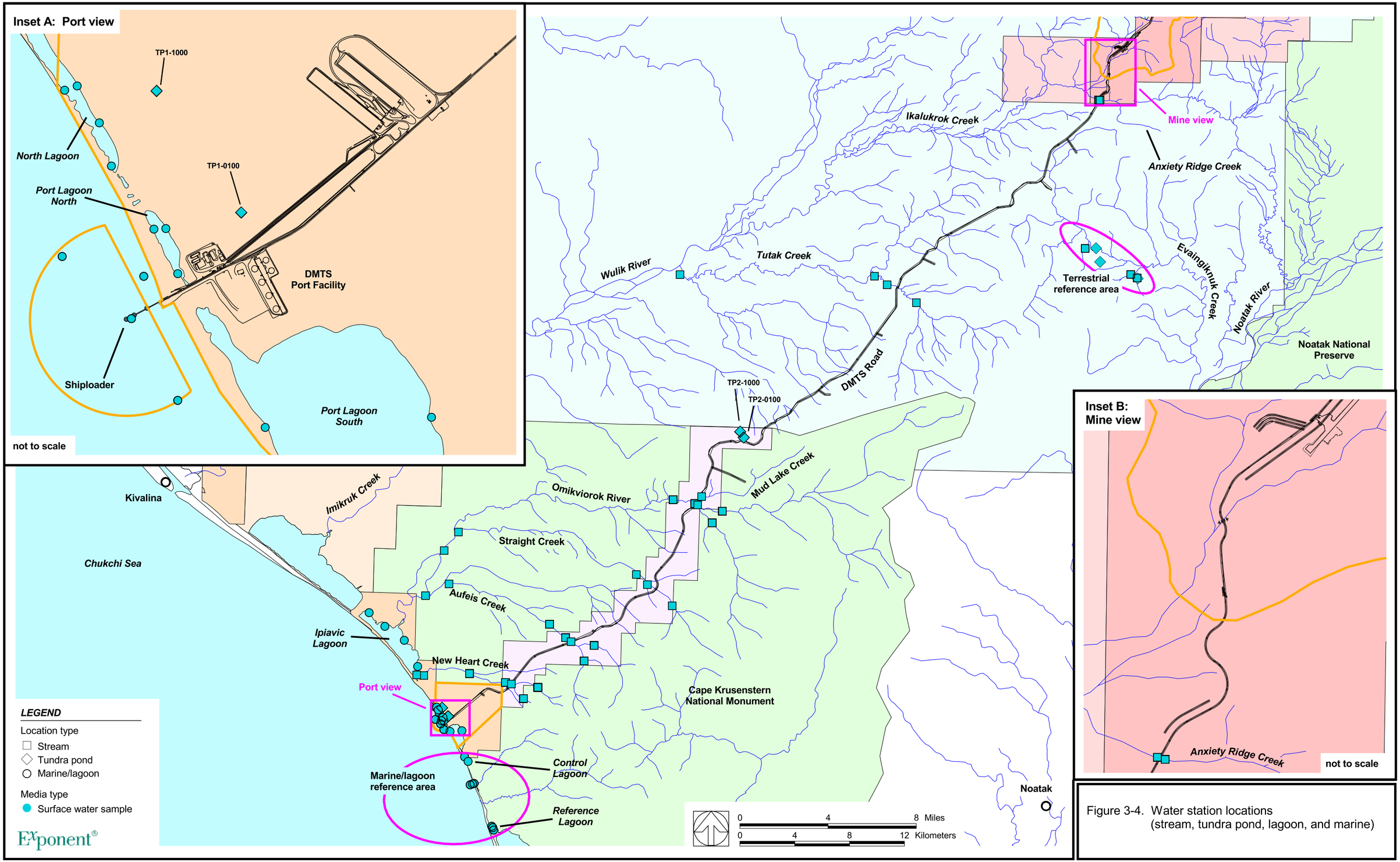


Figure 3-4. Water station locations (stream, tundra pond, lagoon, and marine)

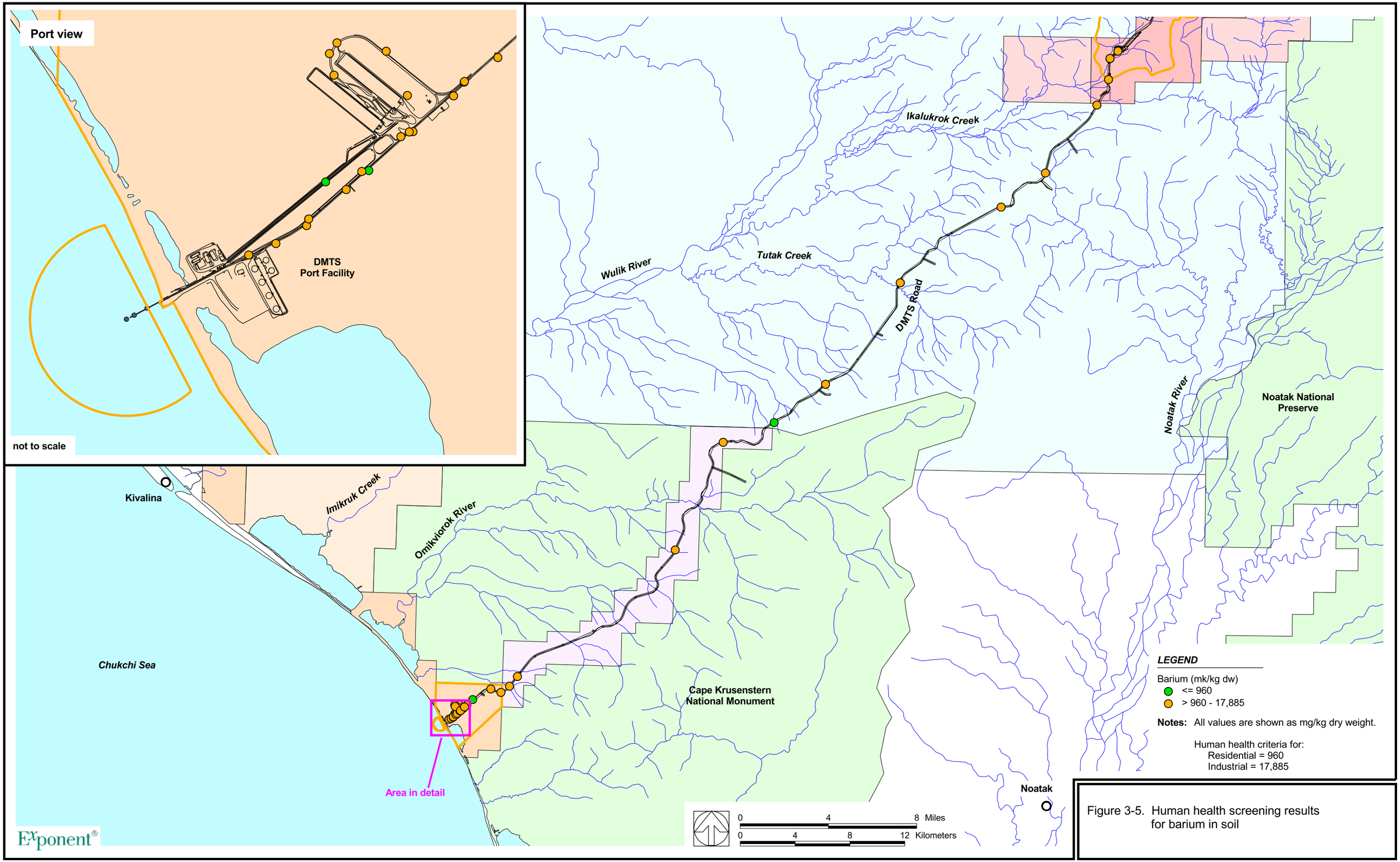


Figure 3-5. Human health screening results for barium in soil

8601997.001 2400/2500 | Jan 13, 2004 | HH Ba view | Fig 3-05 HH Ba layout | j:/red_dog/projects/ecological_1003.apr

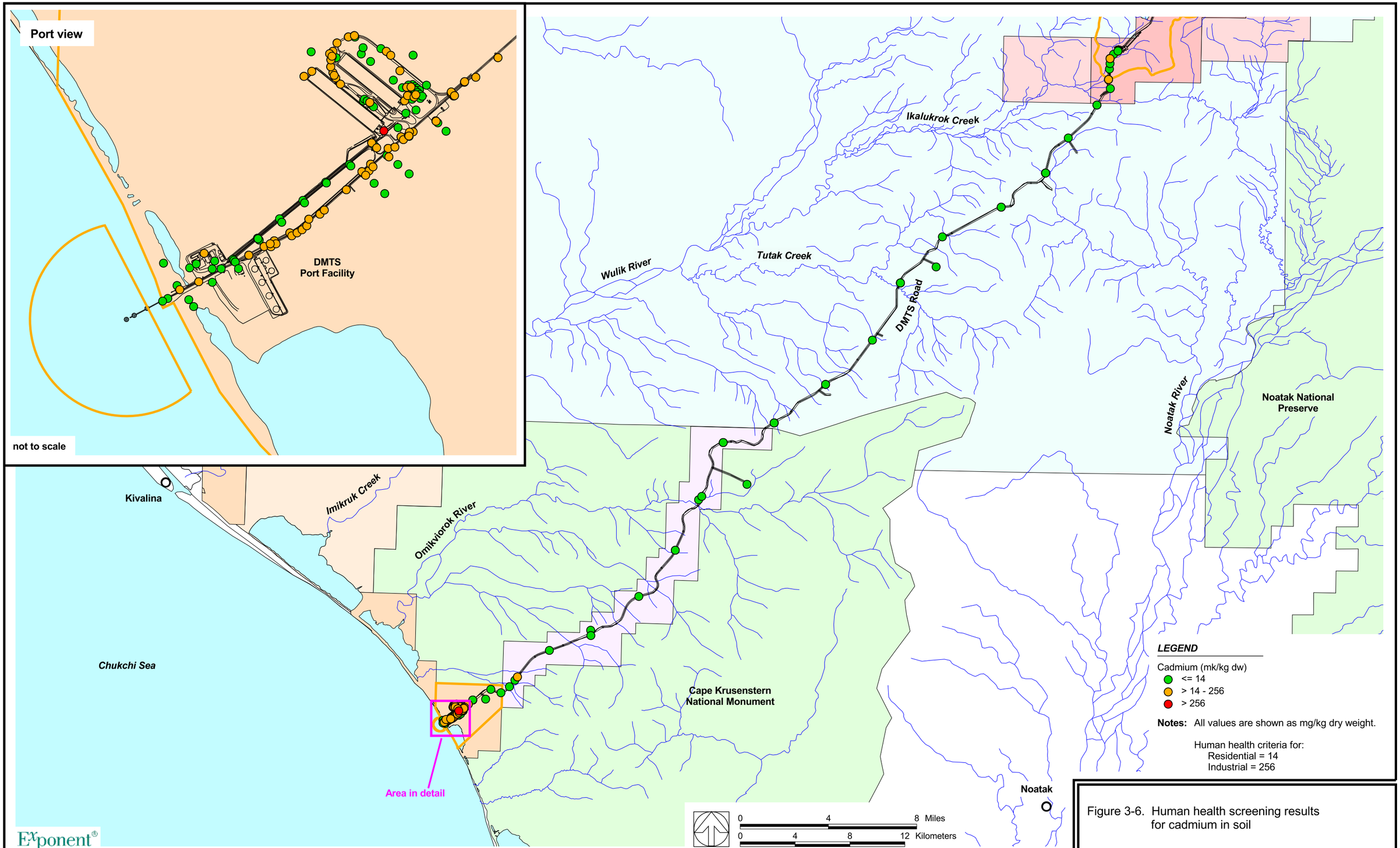


Figure 3-6. Human health screening results for cadmium in soil

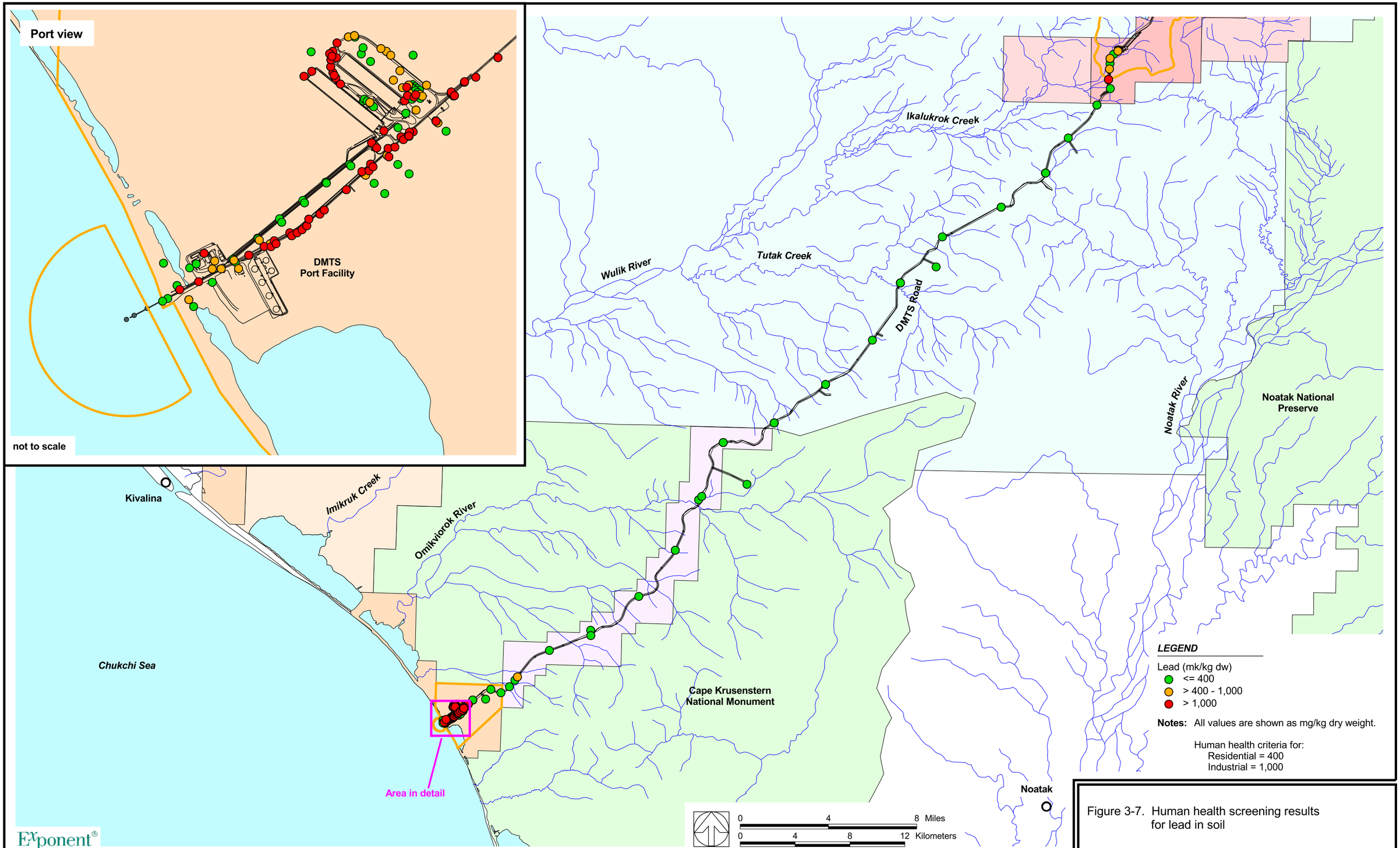


Figure 3-7. Human health screening results for lead in soil

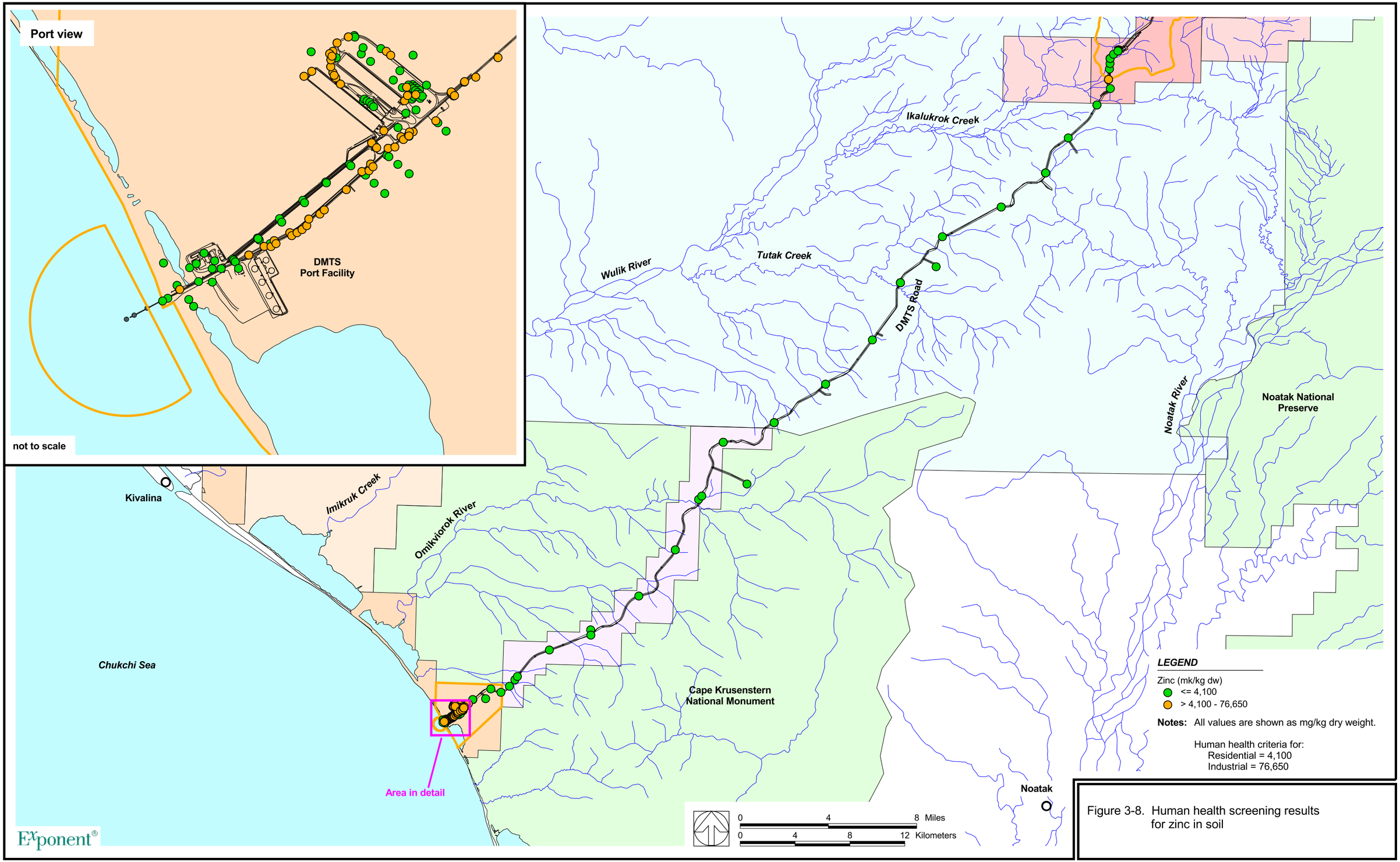


Figure 3-8. Human health screening results for zinc in soil

8601997.001 2400/2500 | Jan 13, 2004 | HH Zn view | Fig 3-08 HH Zn layout | j:/red_dog/projects/ecological_1003.apr

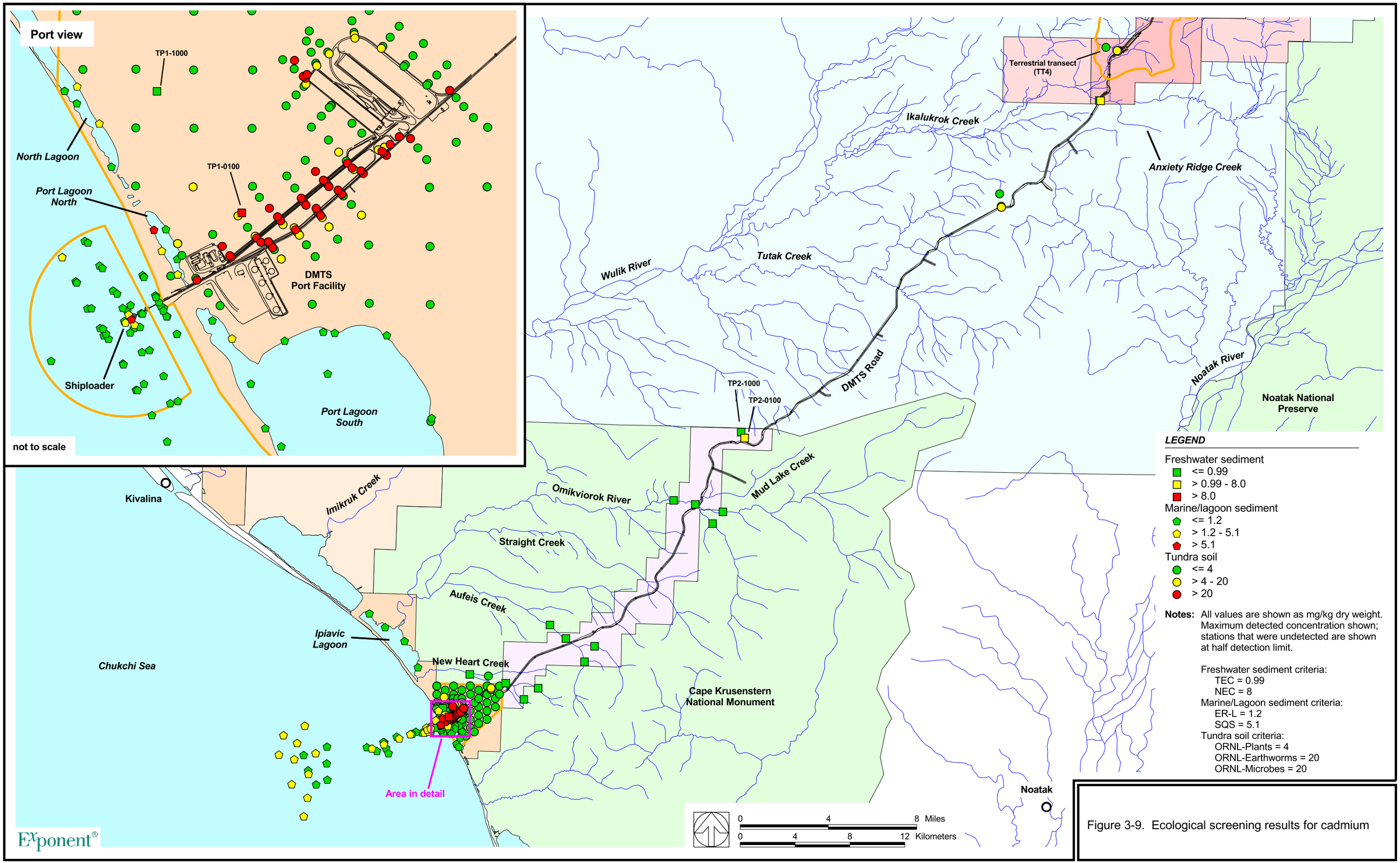


Figure 3-9. Ecological screening results for cadmium

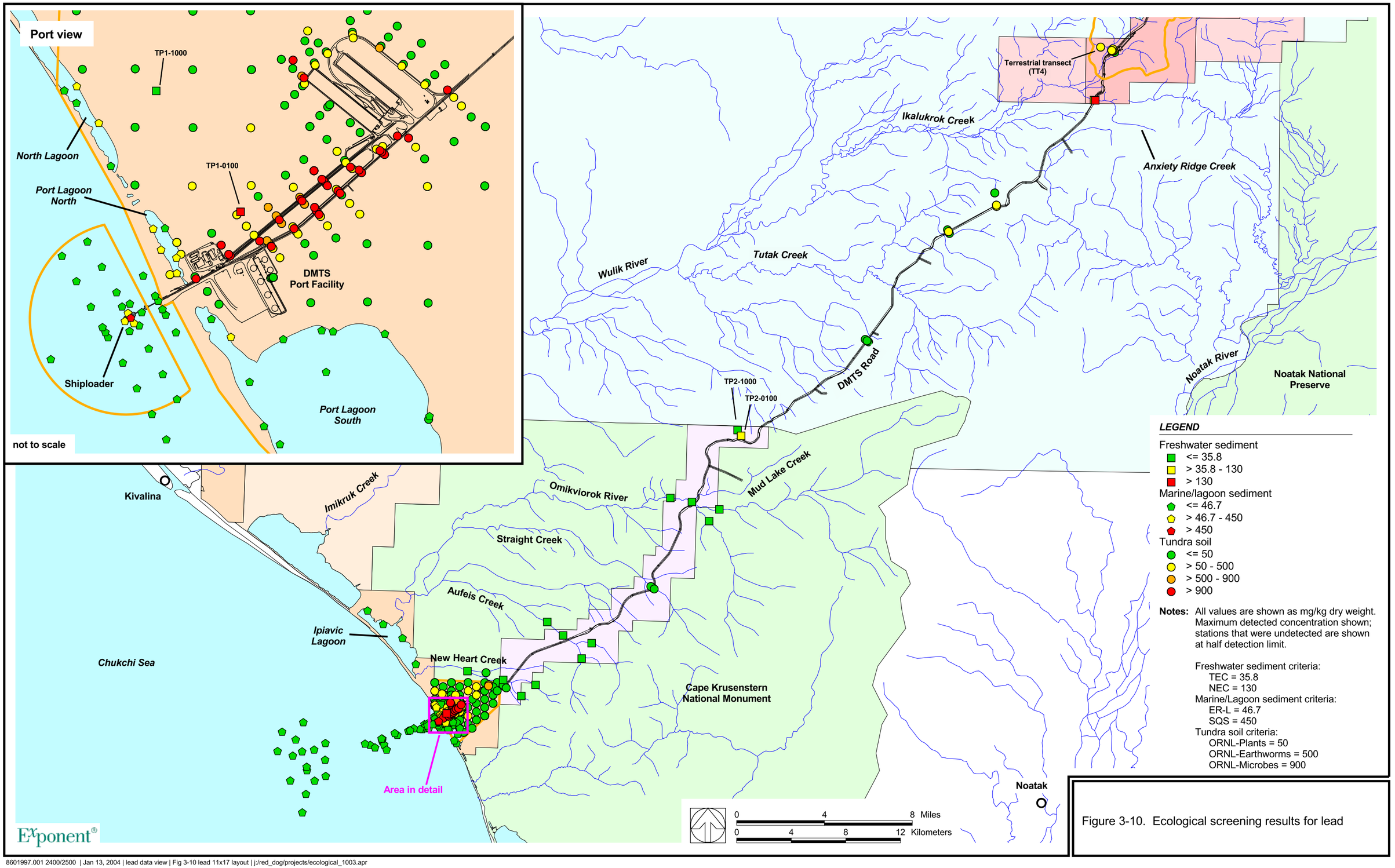


Figure 3-10. Ecological screening results for lead

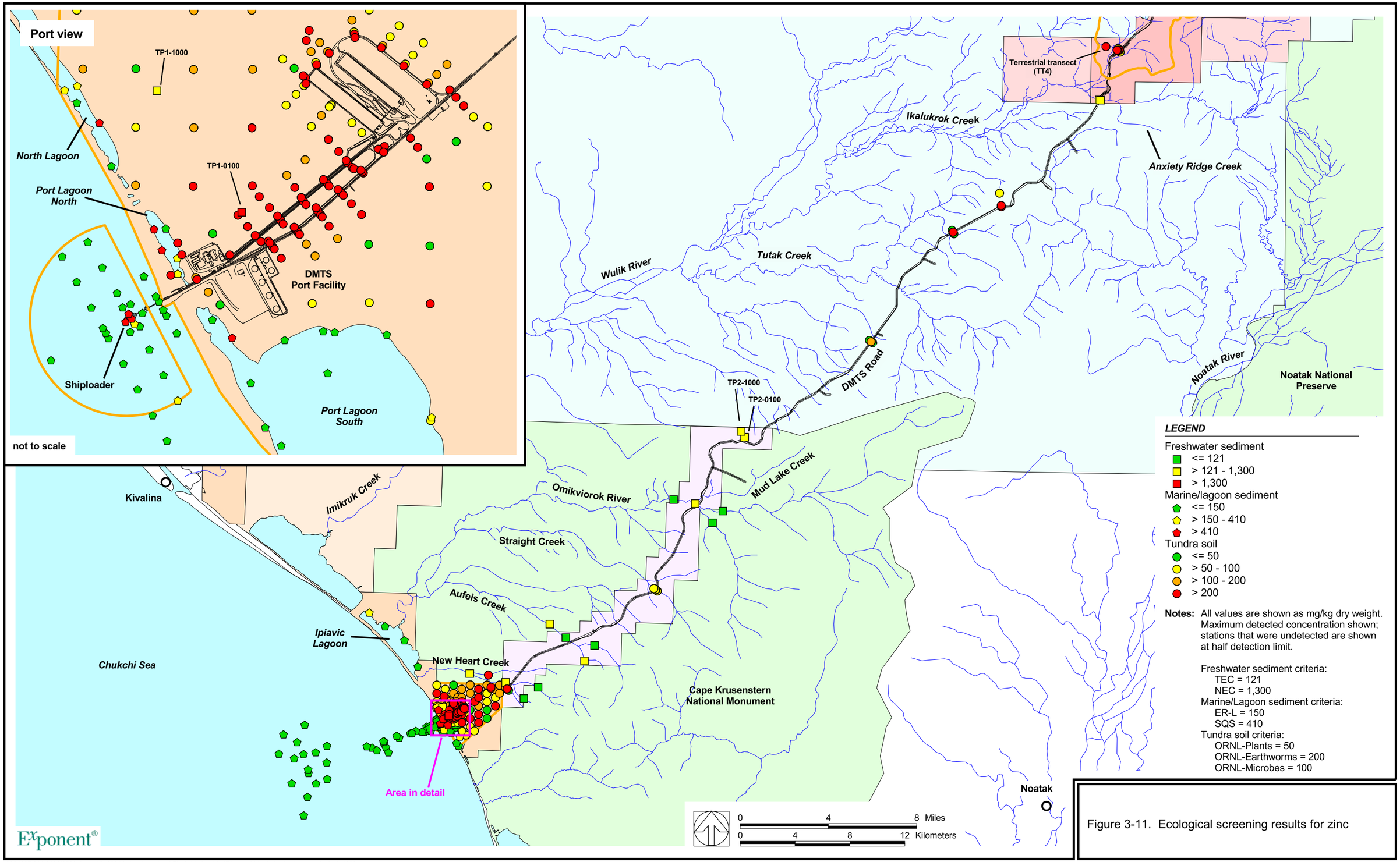


Figure 3-11. Ecological screening results for zinc

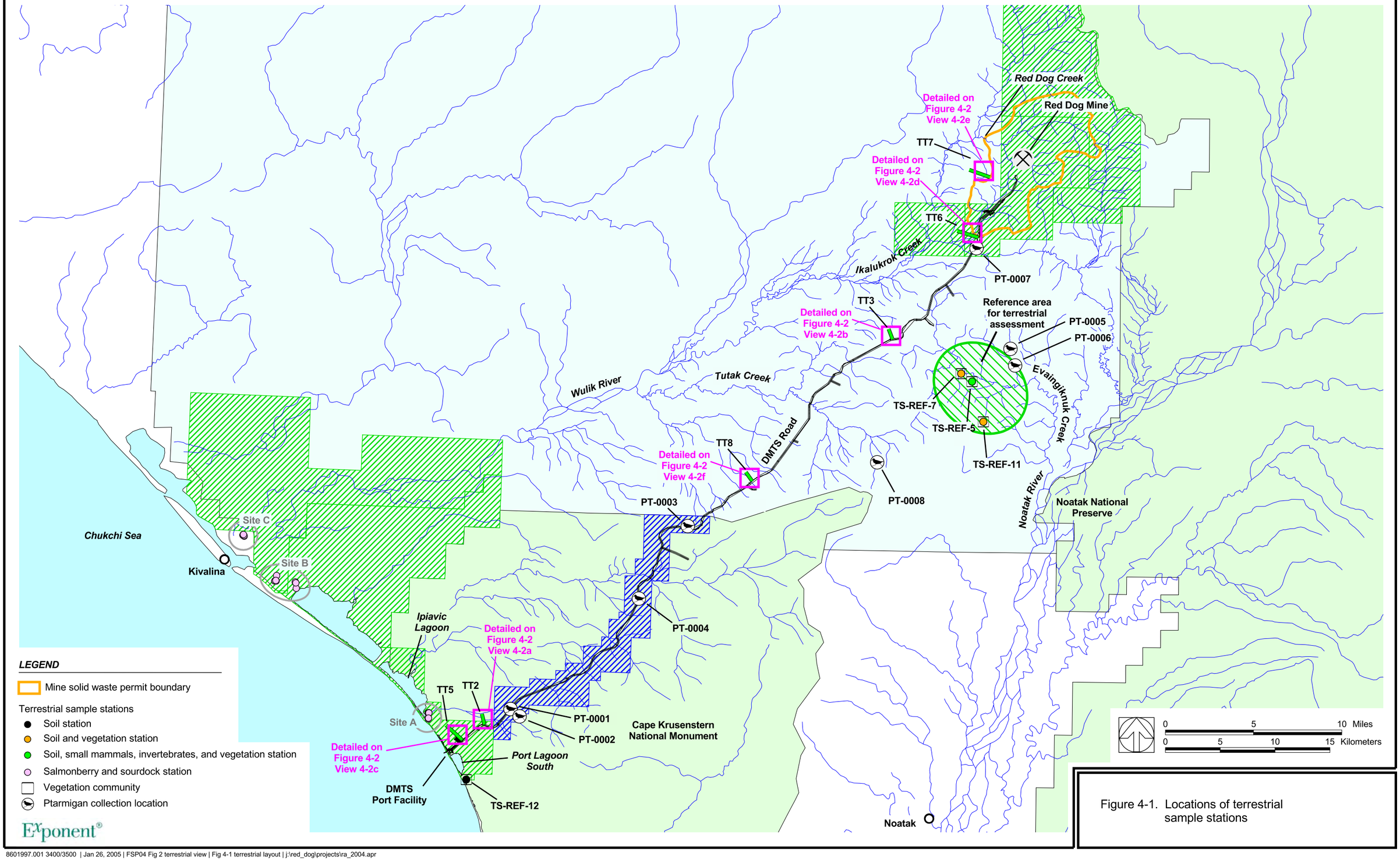
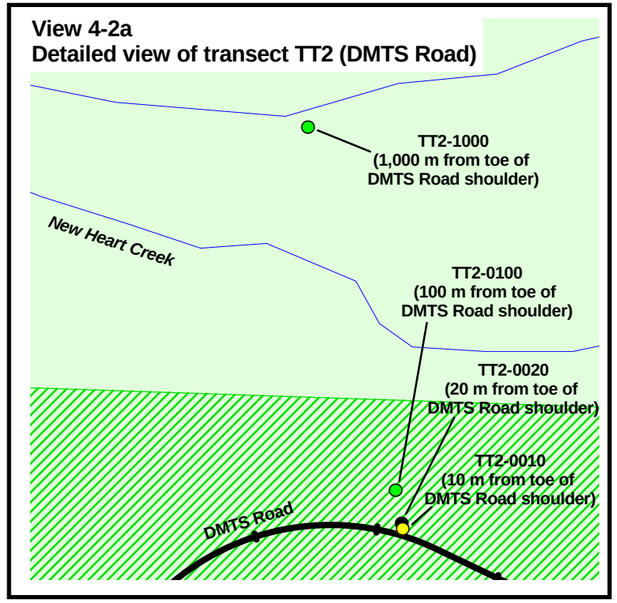
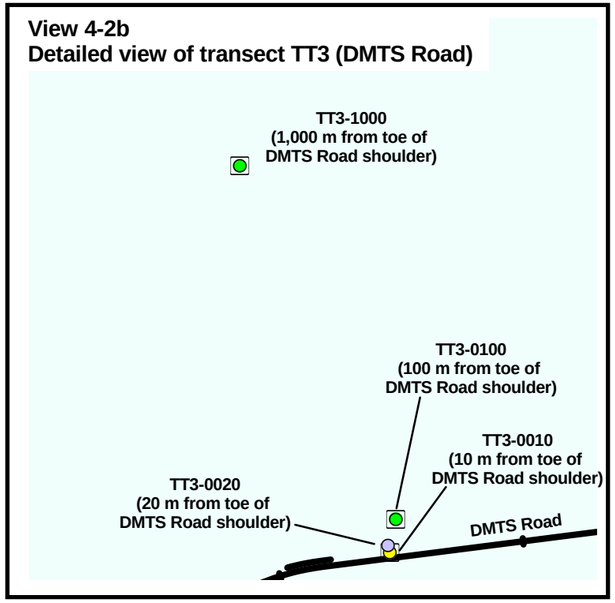
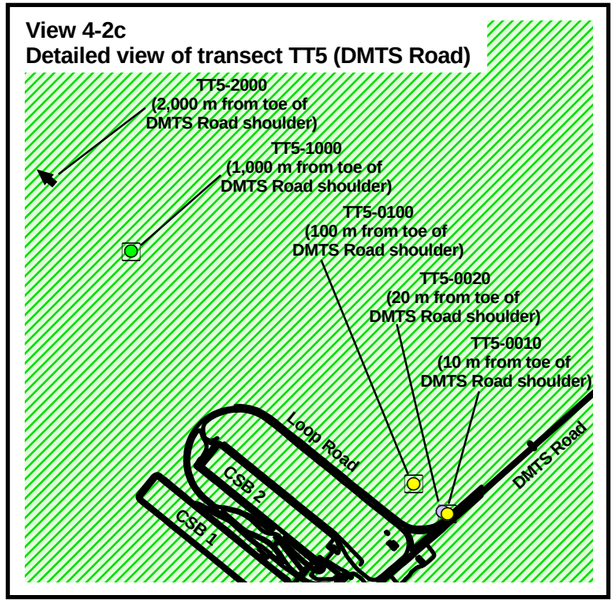
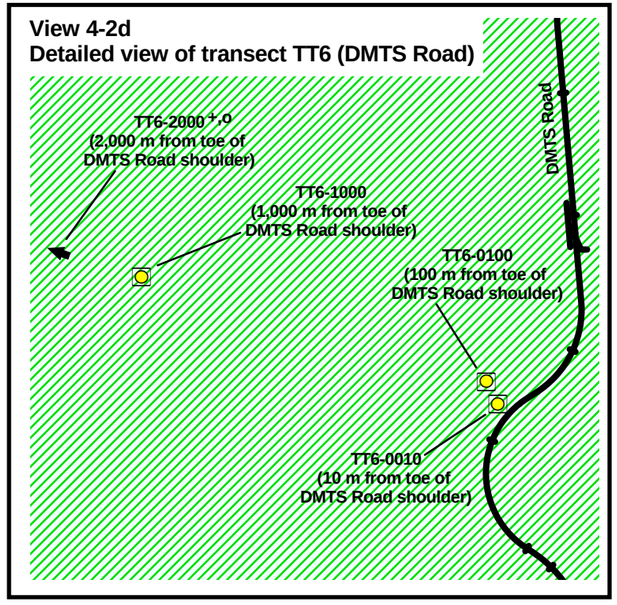


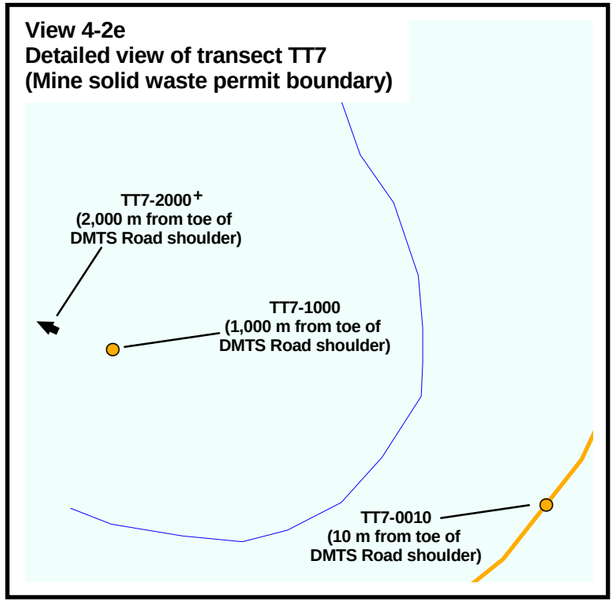
Figure 4-1. Locations of terrestrial sample stations

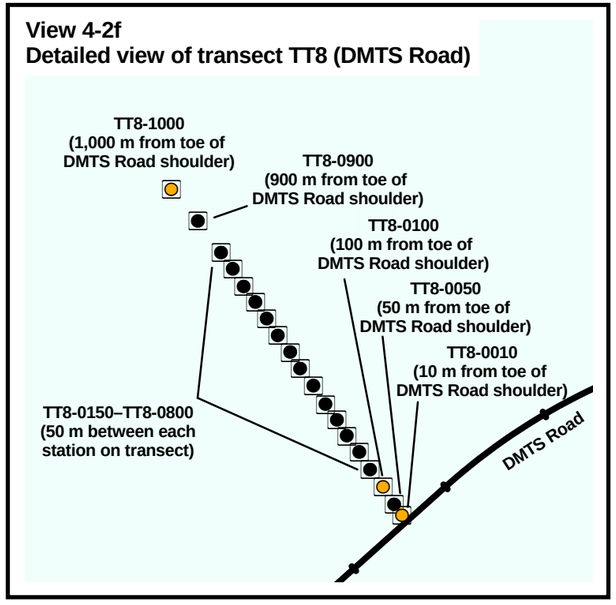












LEGEND

- Mine solid waste permit boundary

Terrestrial sample stations

- Soil station
- Soil and vegetation station
- Soil, invertebrates, and vegetation station
- Soil, small mammals, invertebrates, and vegetation station
- Soil and small mammals
- Vegetation community

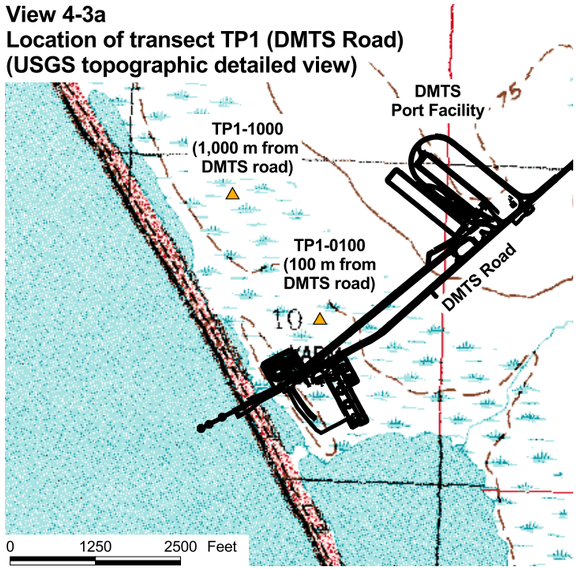
Notes: + No small mammals or invertebrates collected at this station
o No vegetation community analysis at this station

0 1000 2000 3000 Feet
0 500 1000 Meters

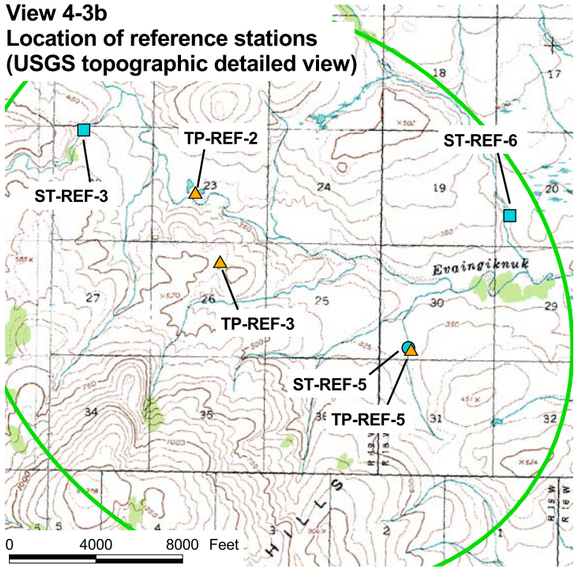
Figure 4-2. Detailed views of locations of terrestrial sample stations

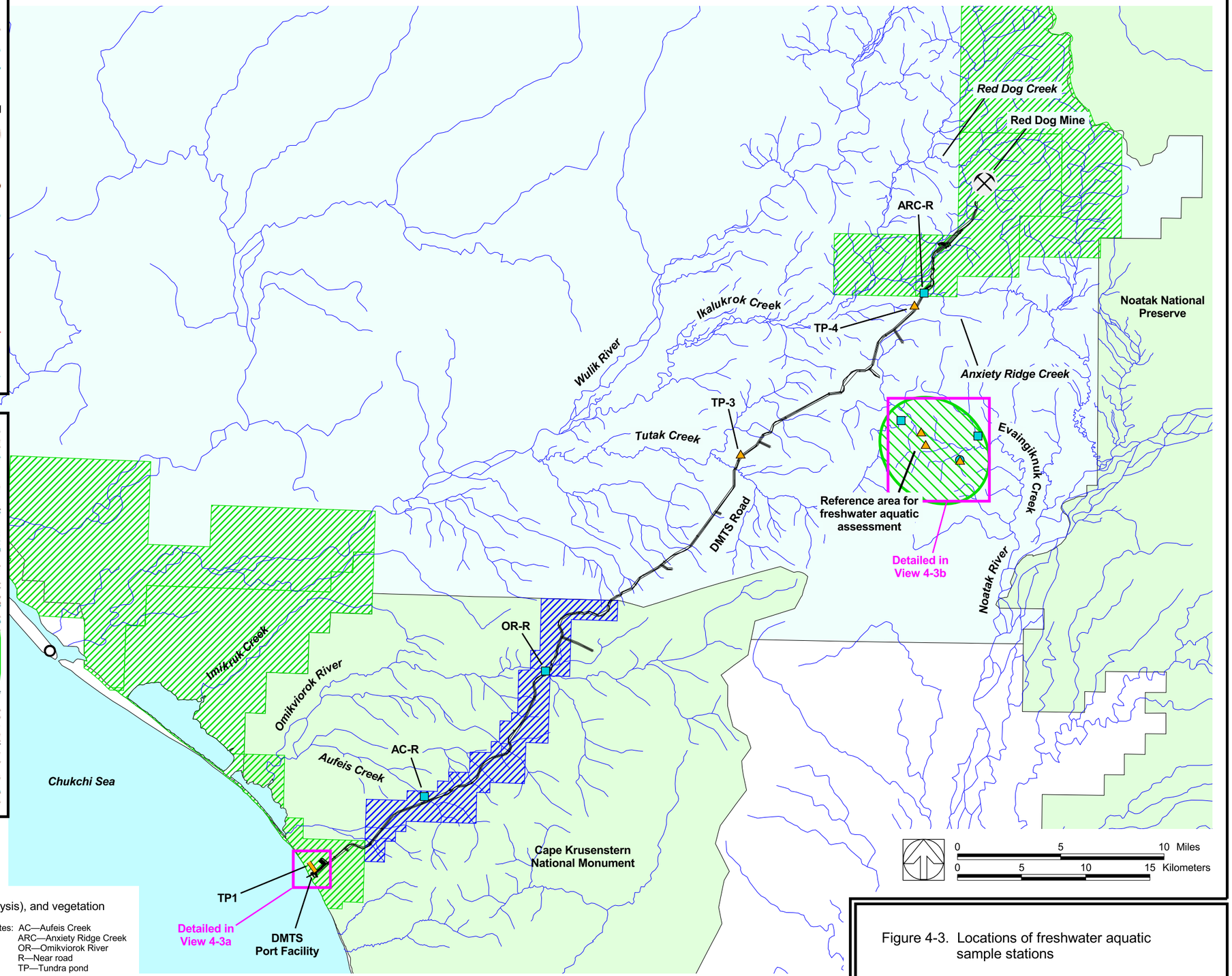
Exponent®

View 4-3a
Location of transect TP1 (DMTS Road)
(USGS topographic detailed view)



View 4-3b
Location of reference stations
(USGS topographic detailed view)





LEGEND

Stream station
- Aquatic invertebrates (community analysis), and vegetation
- Sediment, aquatic invertebrates (tissue chemistry and community analysis), and vegetation

Tundra pond station
- Tundra soil and vegetation

Notes: AC—Aufeis Creek
ARC—Anxiety Ridge Creek
OR—Omikviorok River
R—Near road
TP—Tundra pond

Figure 4-3. Locations of freshwater aquatic sample stations

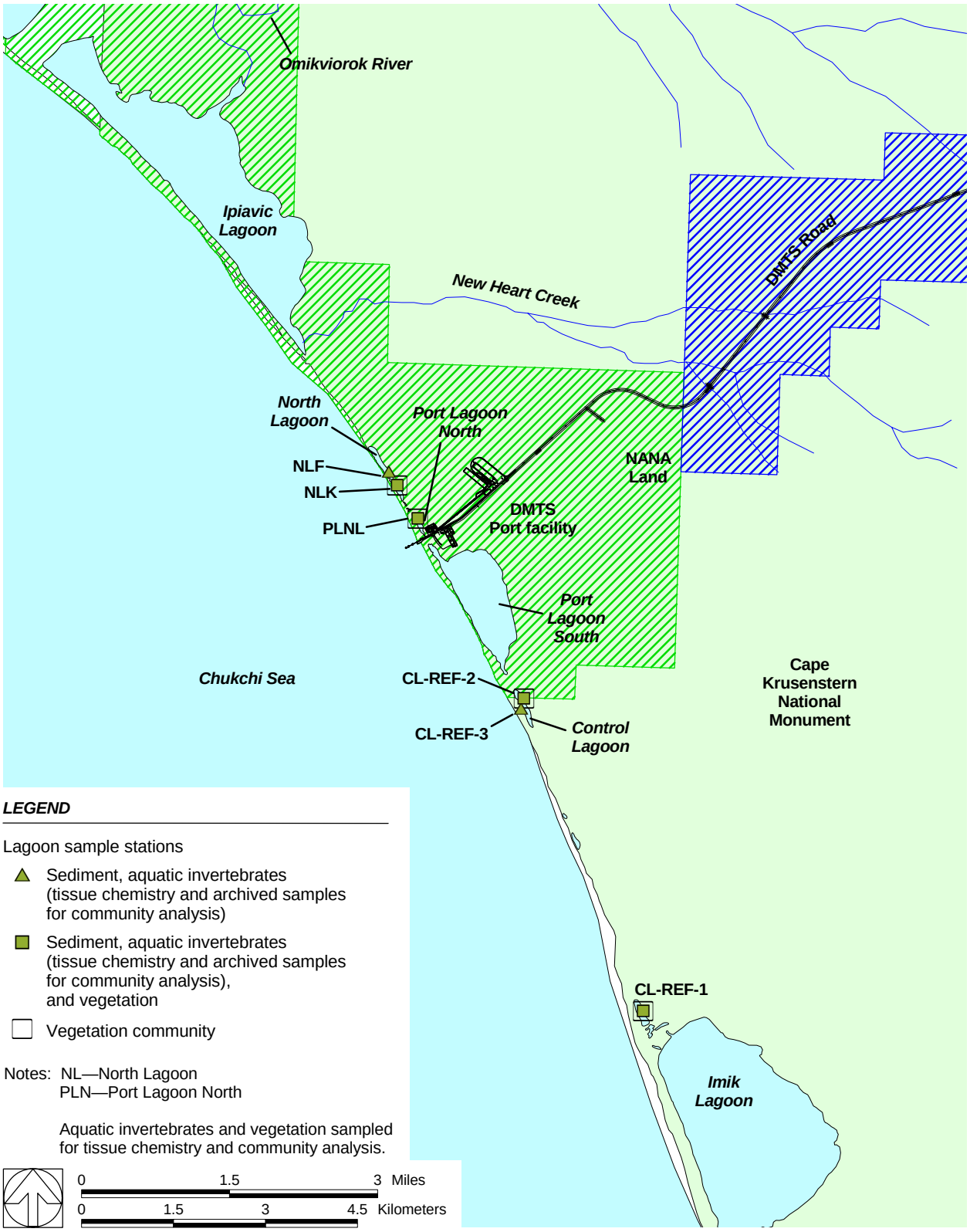


Figure 4-4. Locations of coastal lagoon sample stations

Exponent®

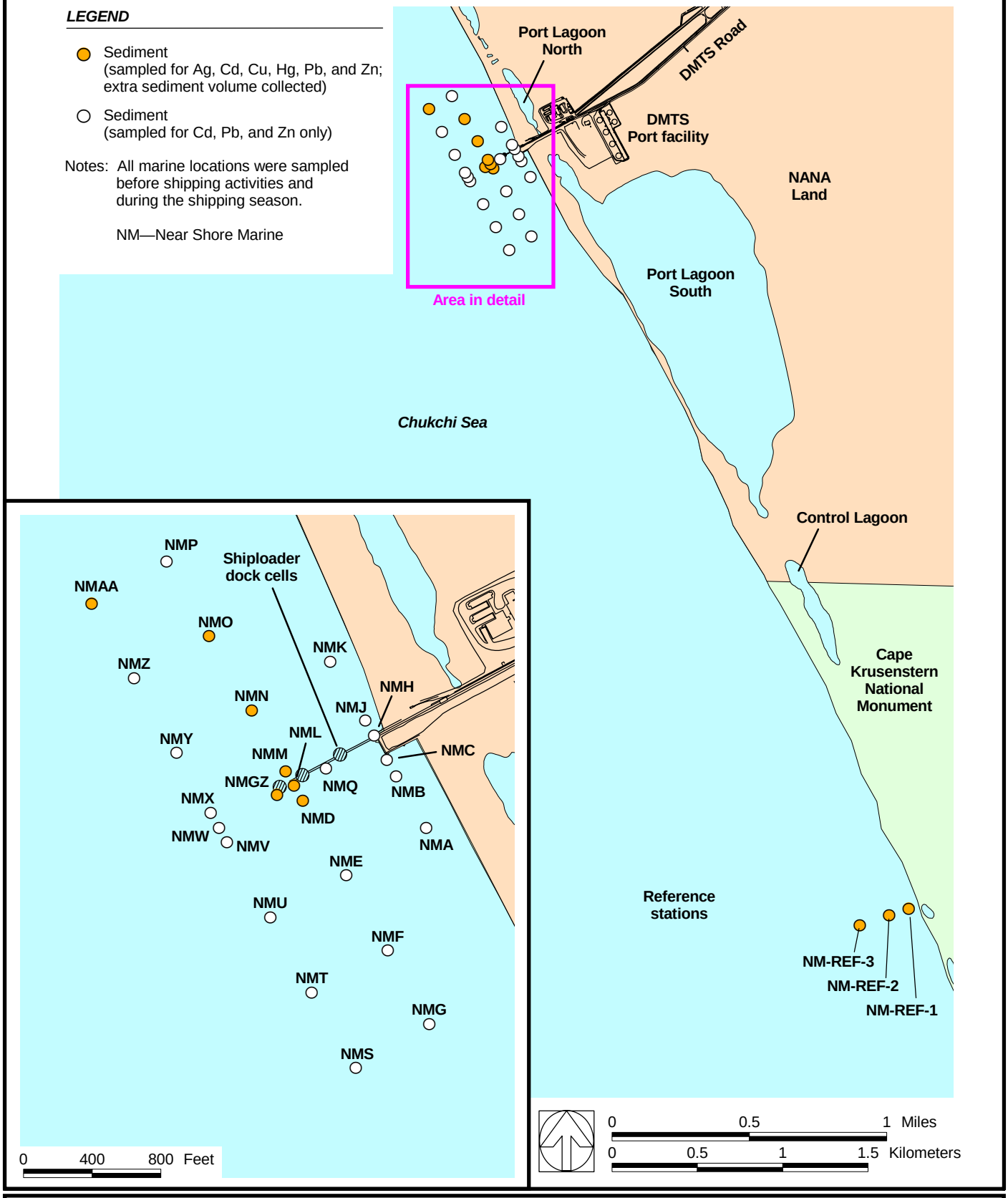


Figure 4-5. Locations of marine sediment sample stations

Exponent®

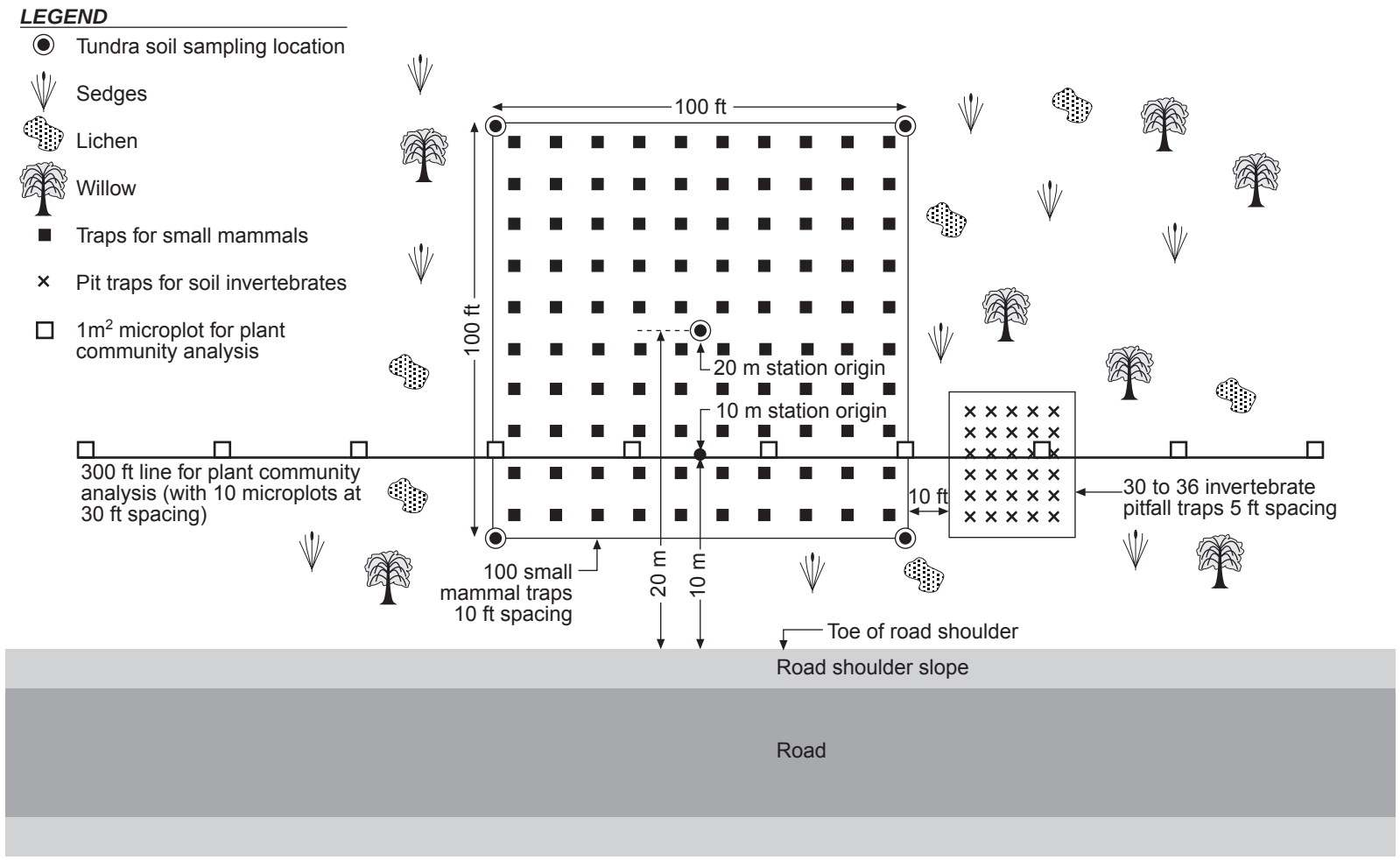


Figure 4-6. Schematic layout of typical 10 m and 20 m terrestrial transect station

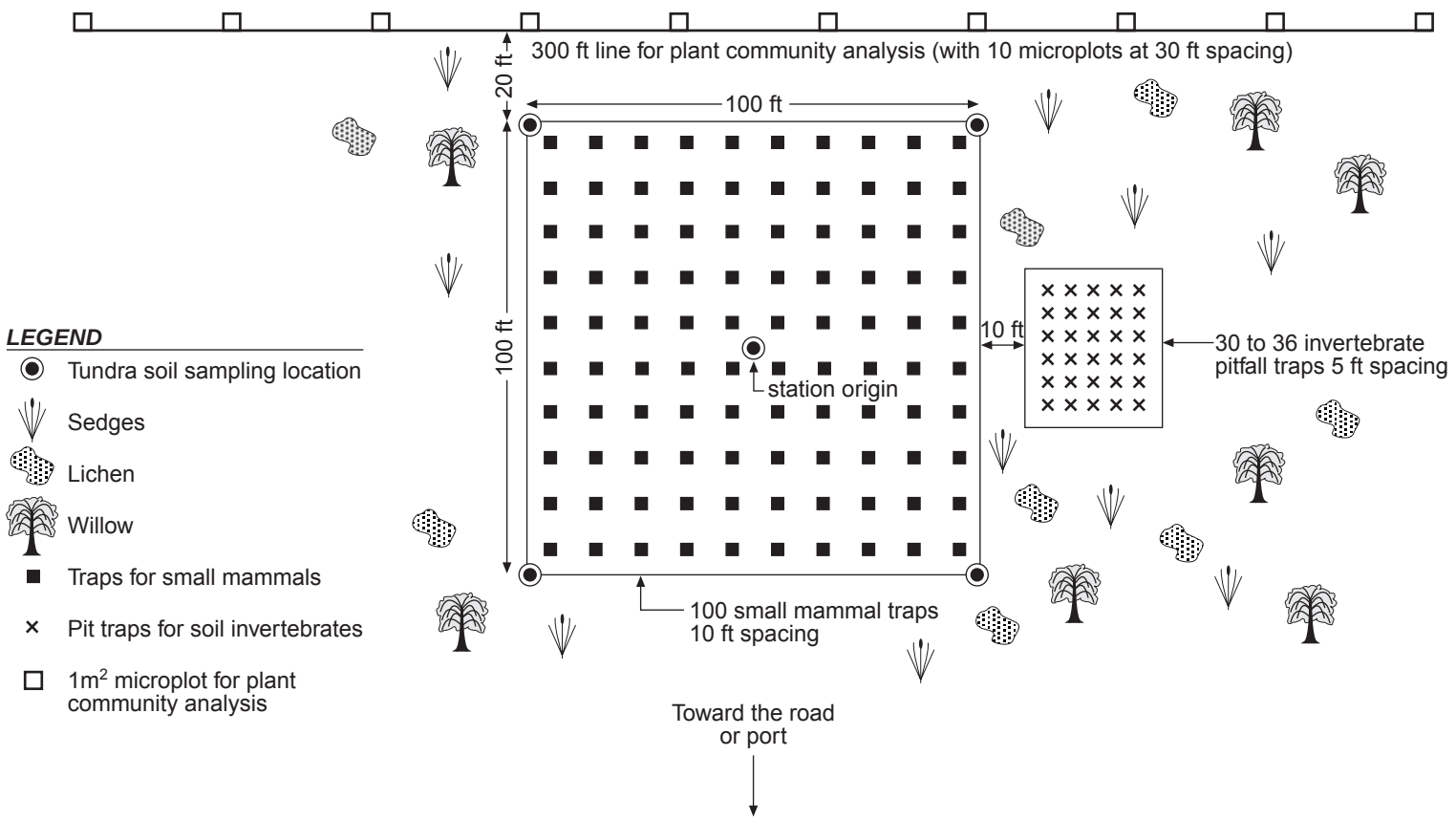
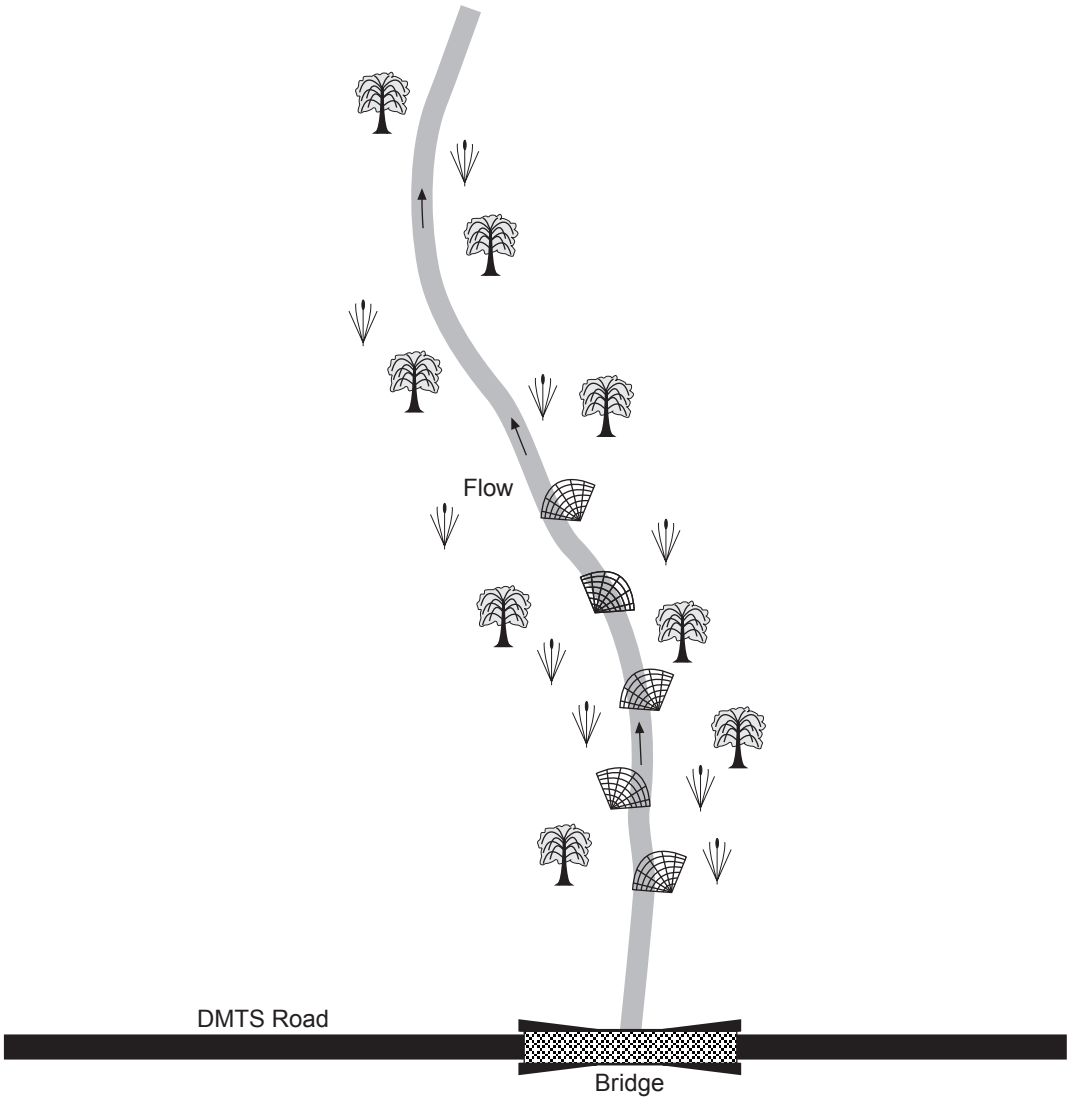


Figure 4-7. Schematic layout of typical 100 m, 1,000 m, and 2,000 m terrestrial transect station



LEGEND

Drift nets

Sedges

Willow

Note: The typical range of stream reach length between the road edge and the last net is 150–300 ft.

Figure 4-8. Schematic layout of typical stream station

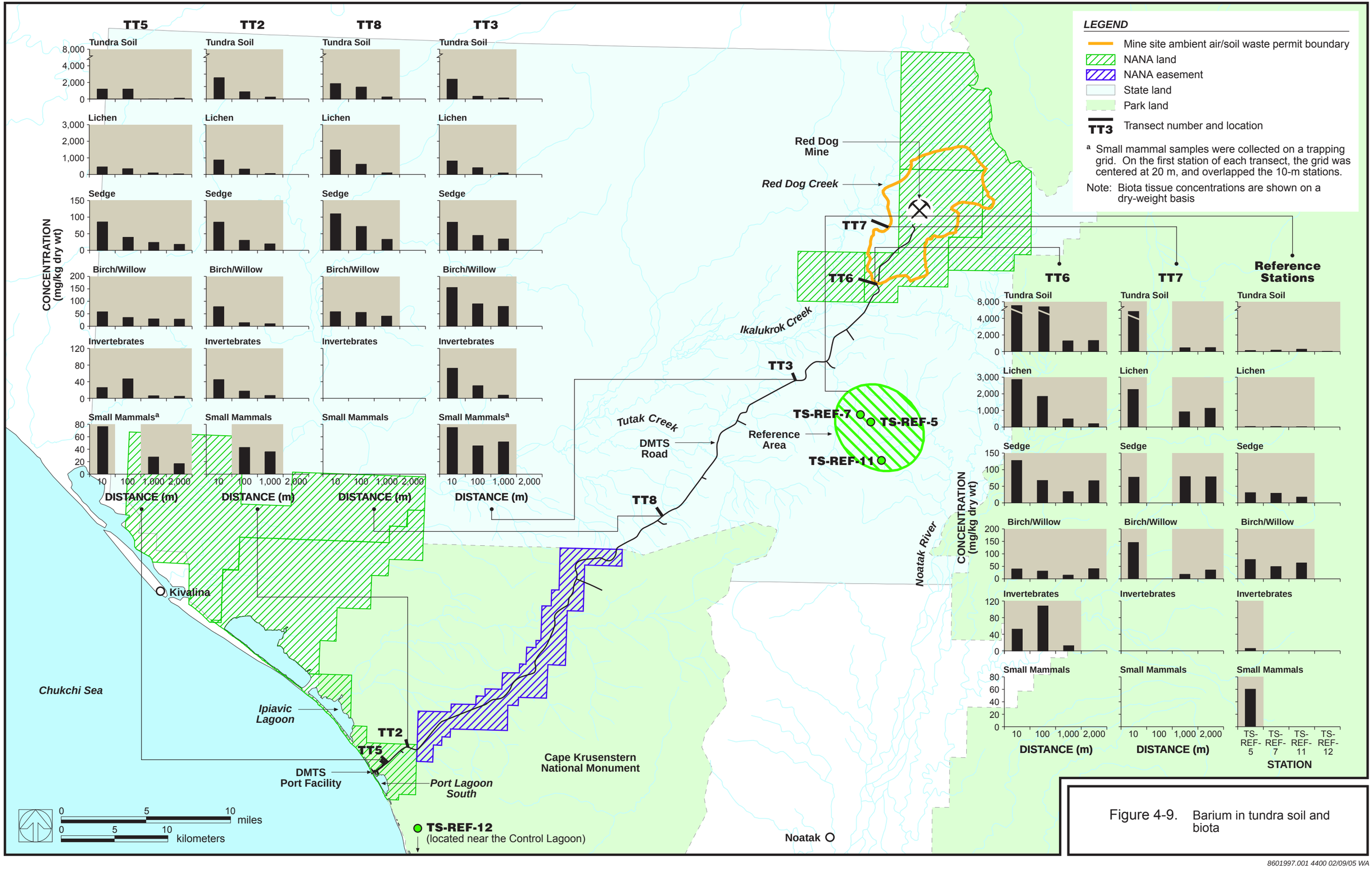


Figure 4-9. Barium in tundra soil and biota

8601997.001 4400 02/09/05 WA

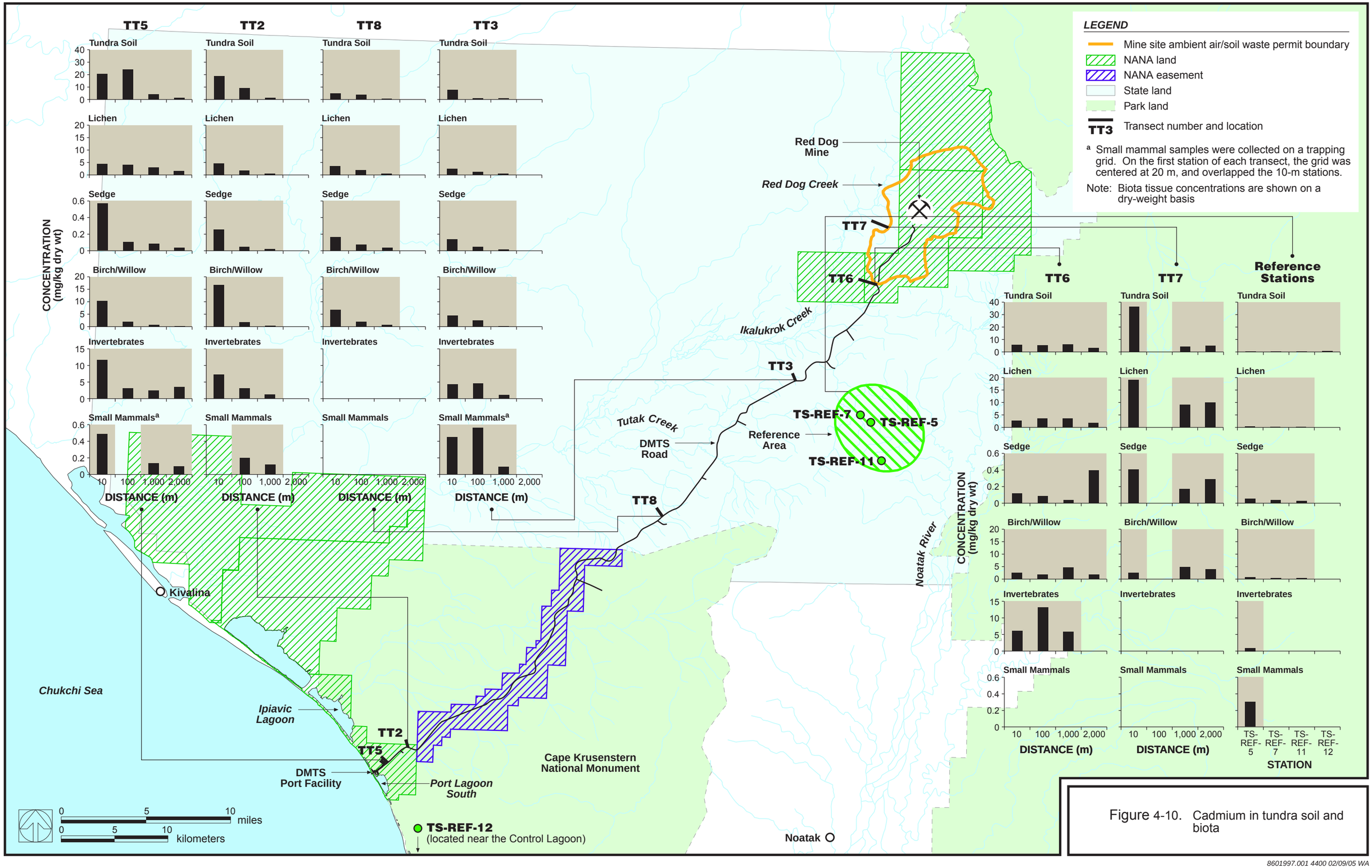


Figure 4-10. Cadmium in tundra soil and biota

8601997.001 4400 02/09/05 WA

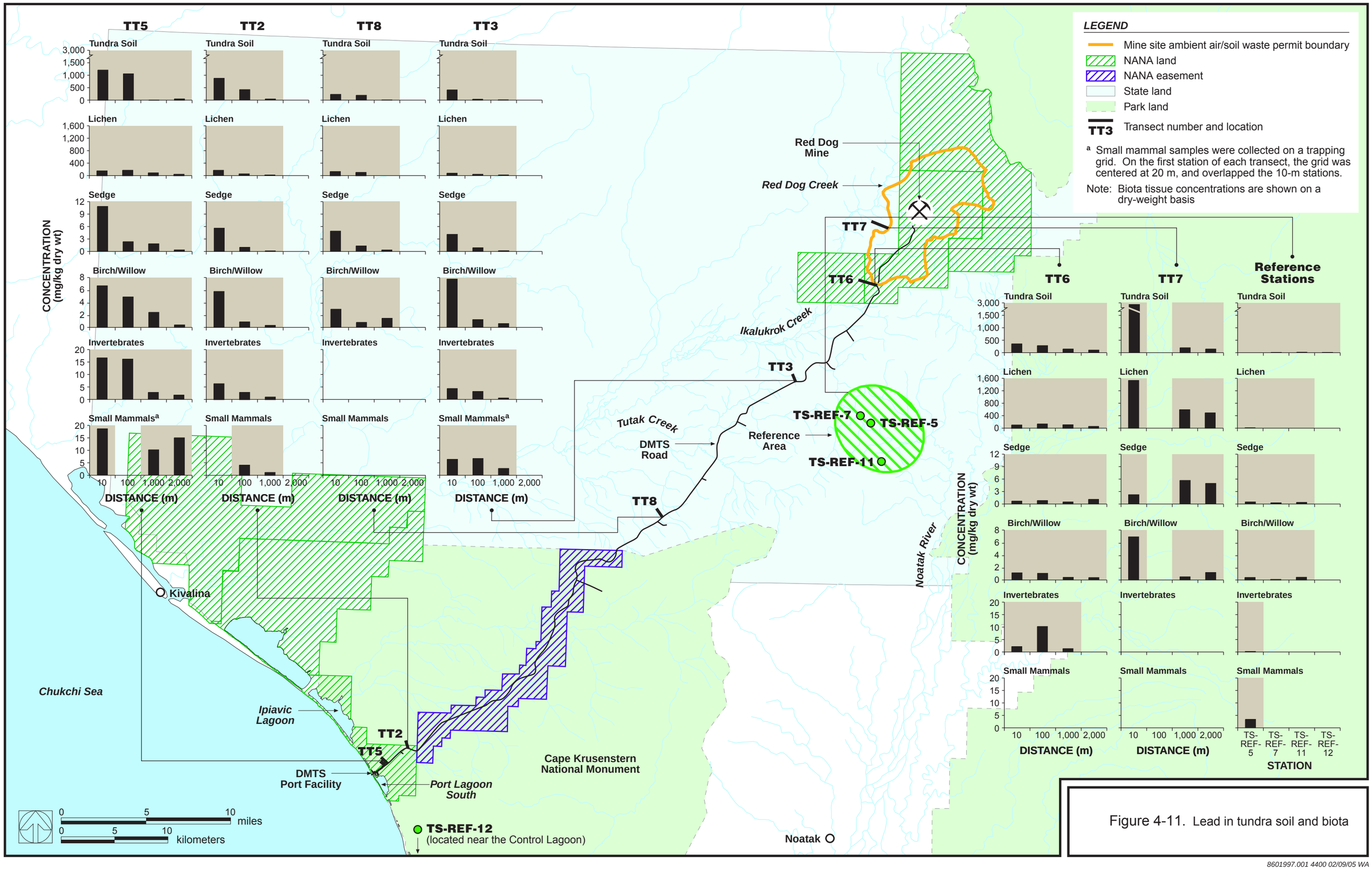


Figure 4-11. Lead in tundra soil and biota

8601997.001 4400 02/09/05 WA

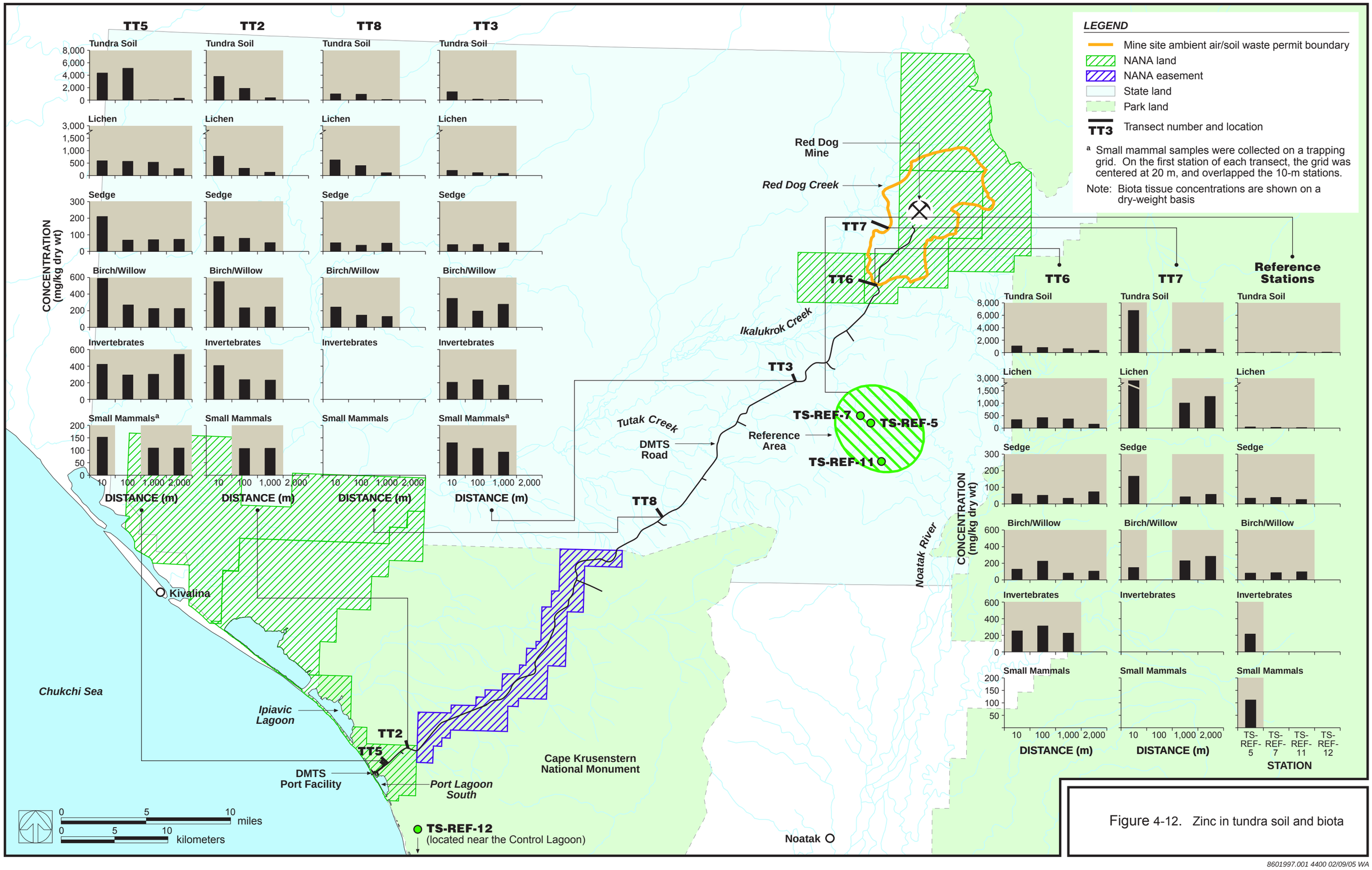
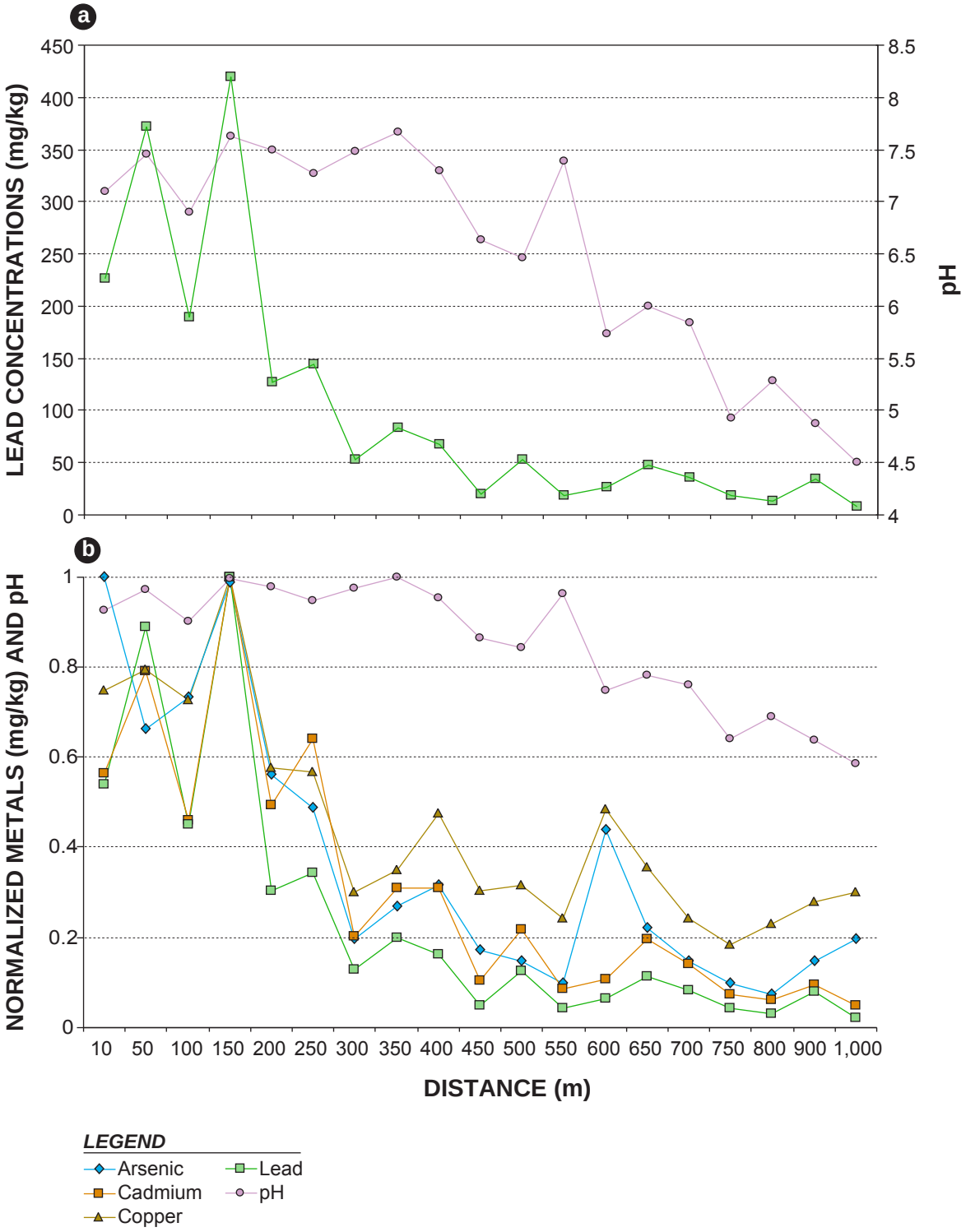


Figure 4-12. Zinc in tundra soil and biota

8601997.001 4400 02/09/05 WA



Note: In order to display values on a single plot, metals and pH were normalized by dividing all values for a given metal or pH by the largest value, such that the maximum is 1.0.

Figure 4-13. Concentrations as a function of distance from the road (Transect TT8) a) pH and lead; b) normalized metals and pH

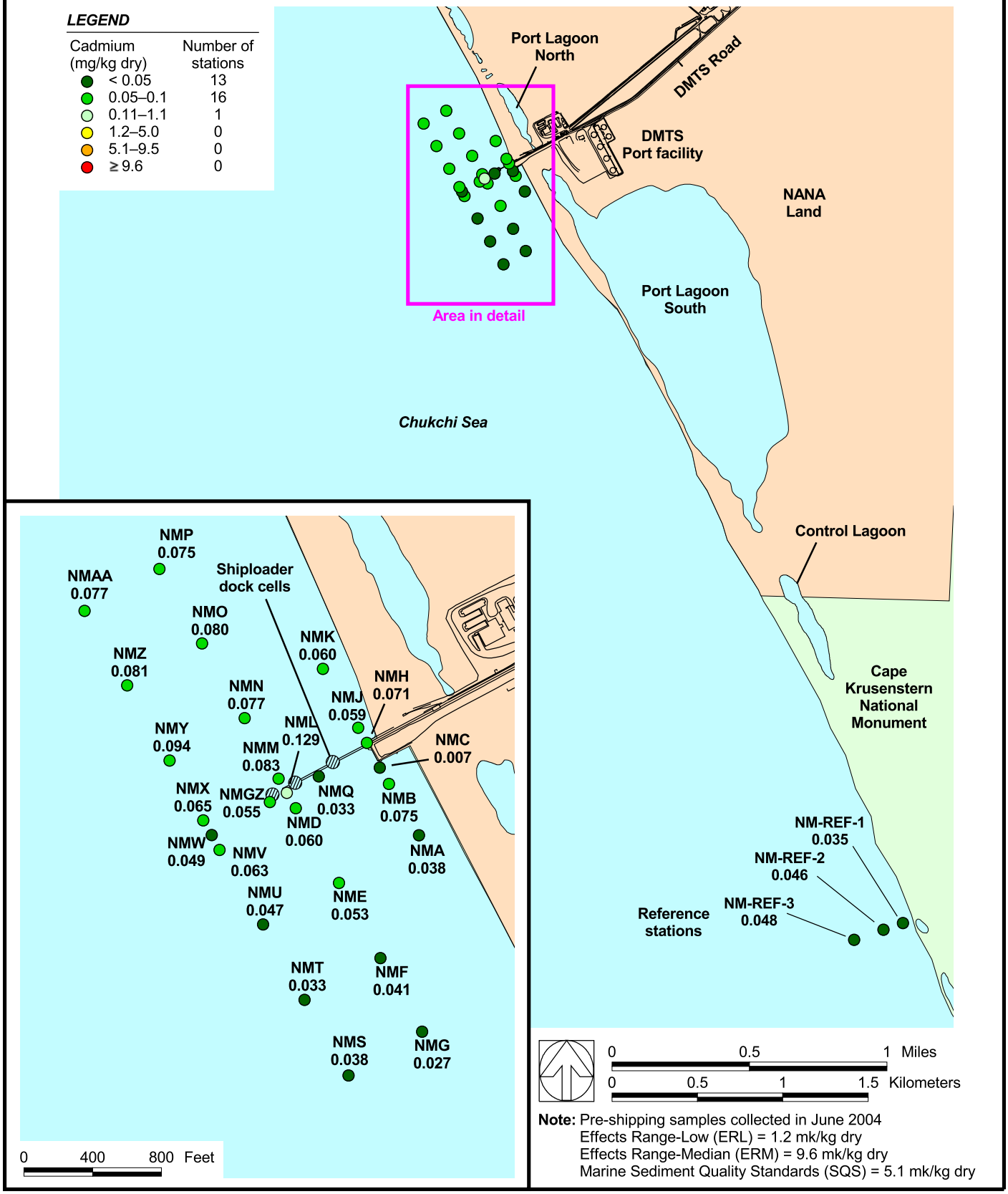


Figure 4-14. 2004 pre-shipping cadmium concentration (mg/kg dry)

Exponent®

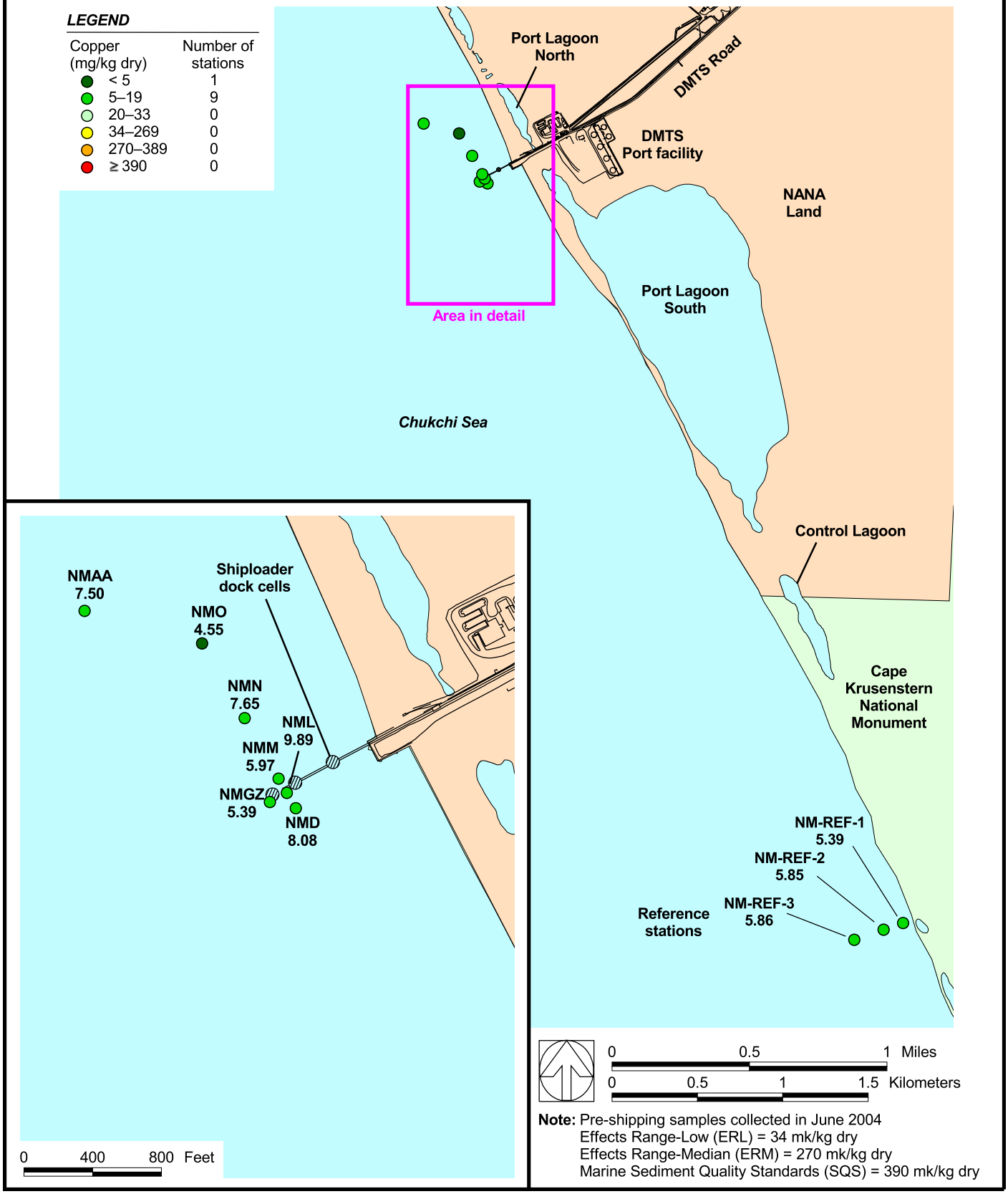


Figure 4-15. 2004 pre-shipping copper concentration (mg/kg dry)

Exponent®

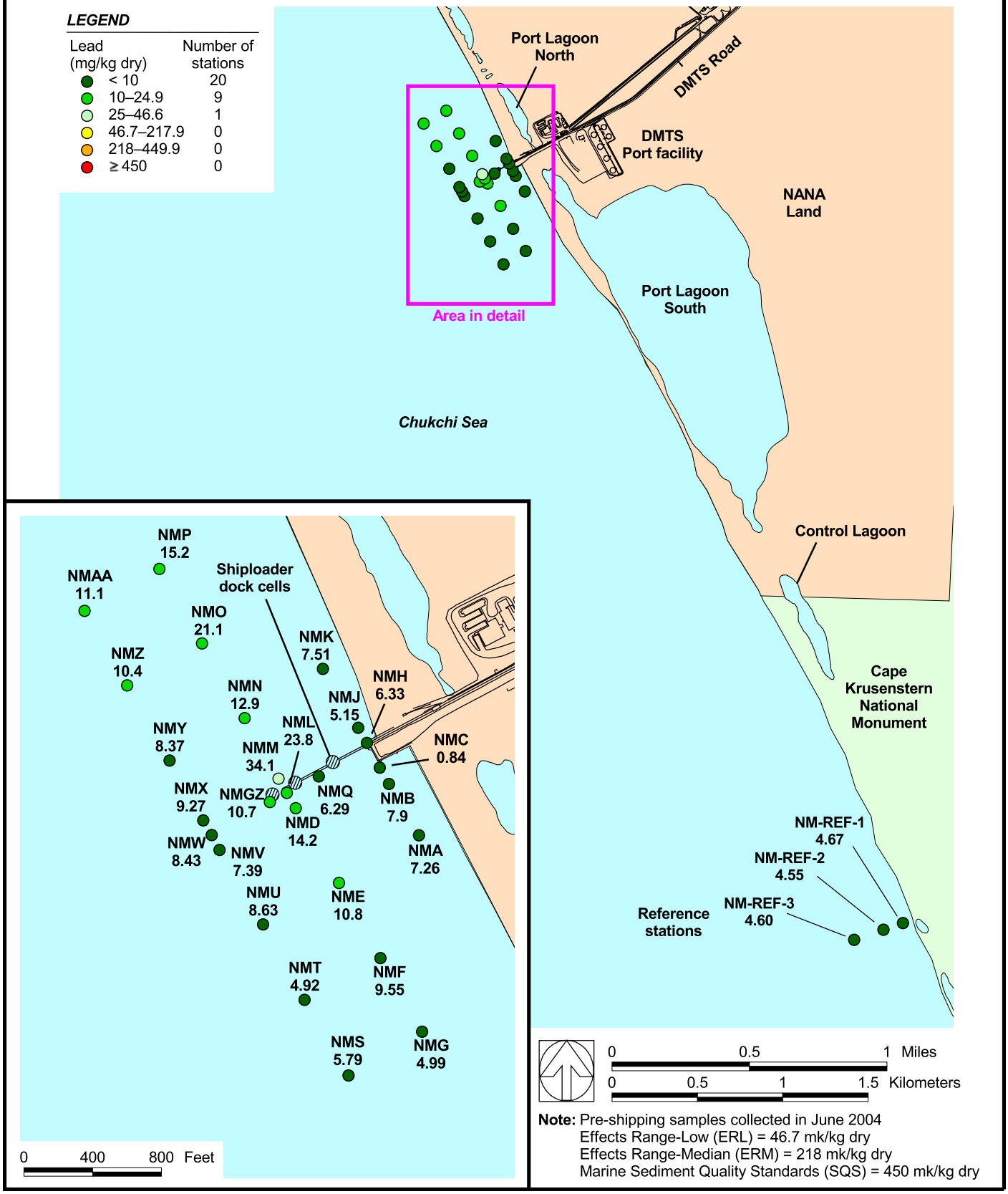


Figure 4-16. 2004 pre-shipping lead concentration (mg/kg dry)

Exponent®

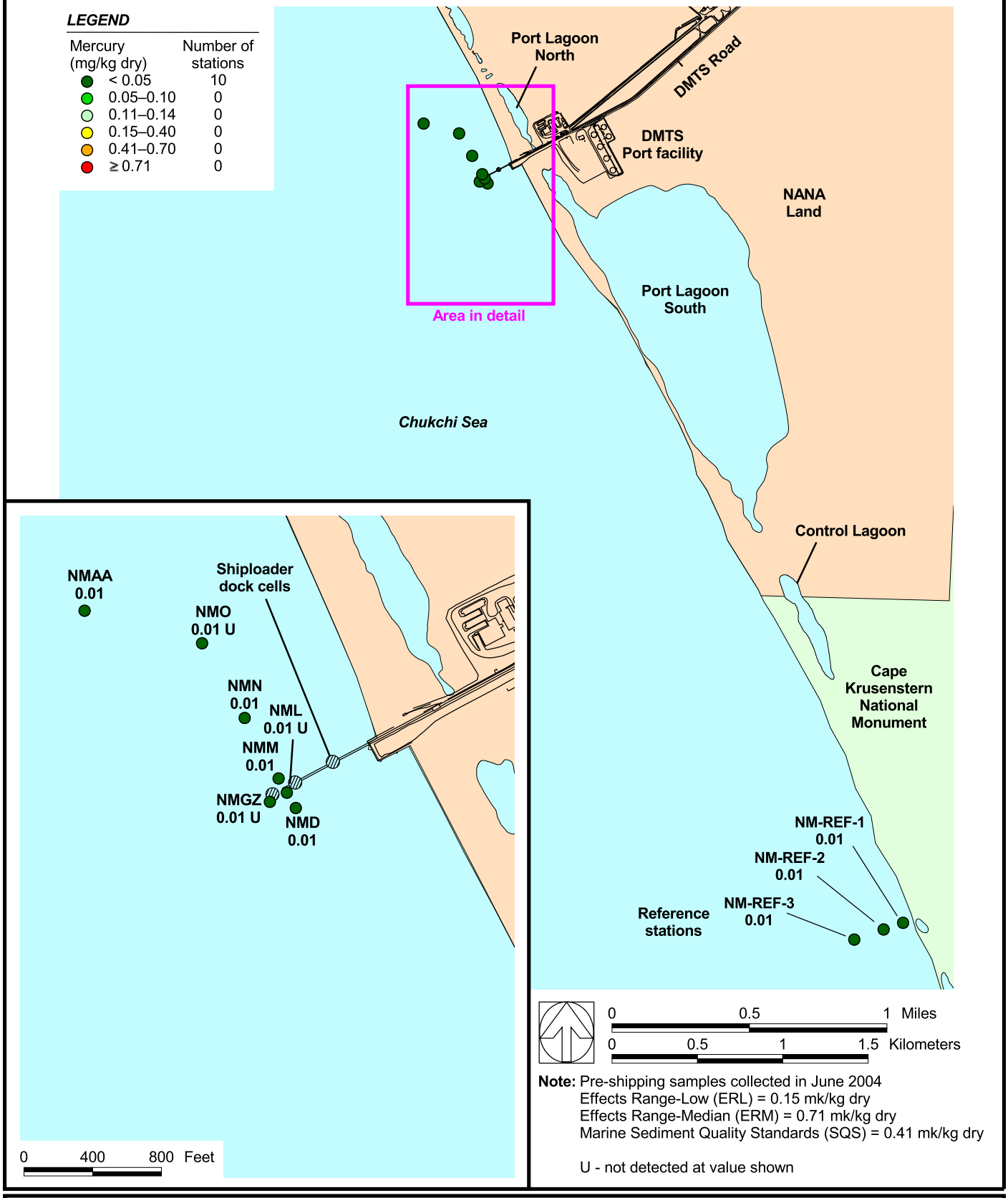


Figure 4-17. 2004 pre-shipping mercury concentration (mg/kg dry)

Exponent®

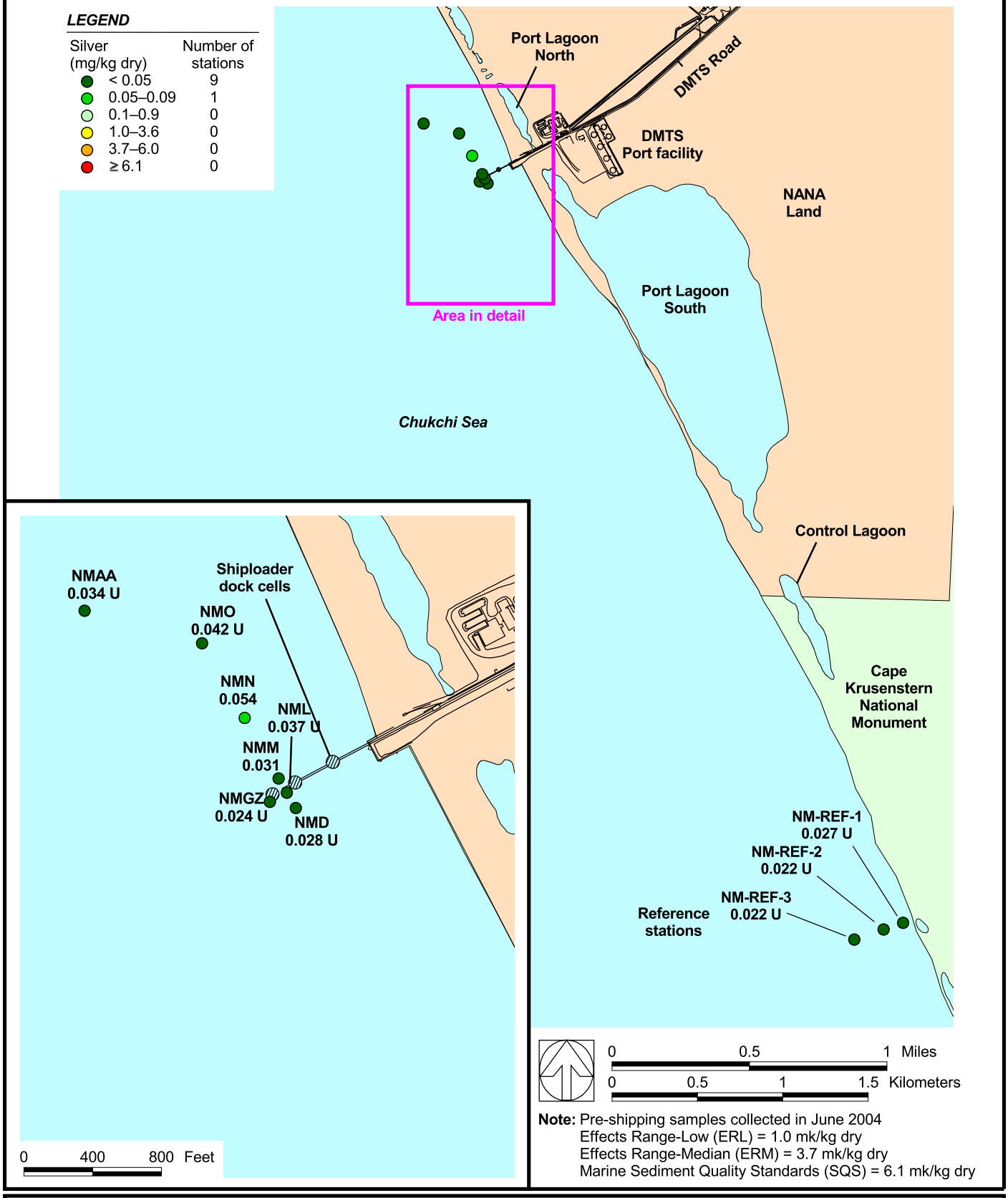


Figure 4-18. 2004 pre-shipping silver concentration (mg/kg dry)

Exponent®

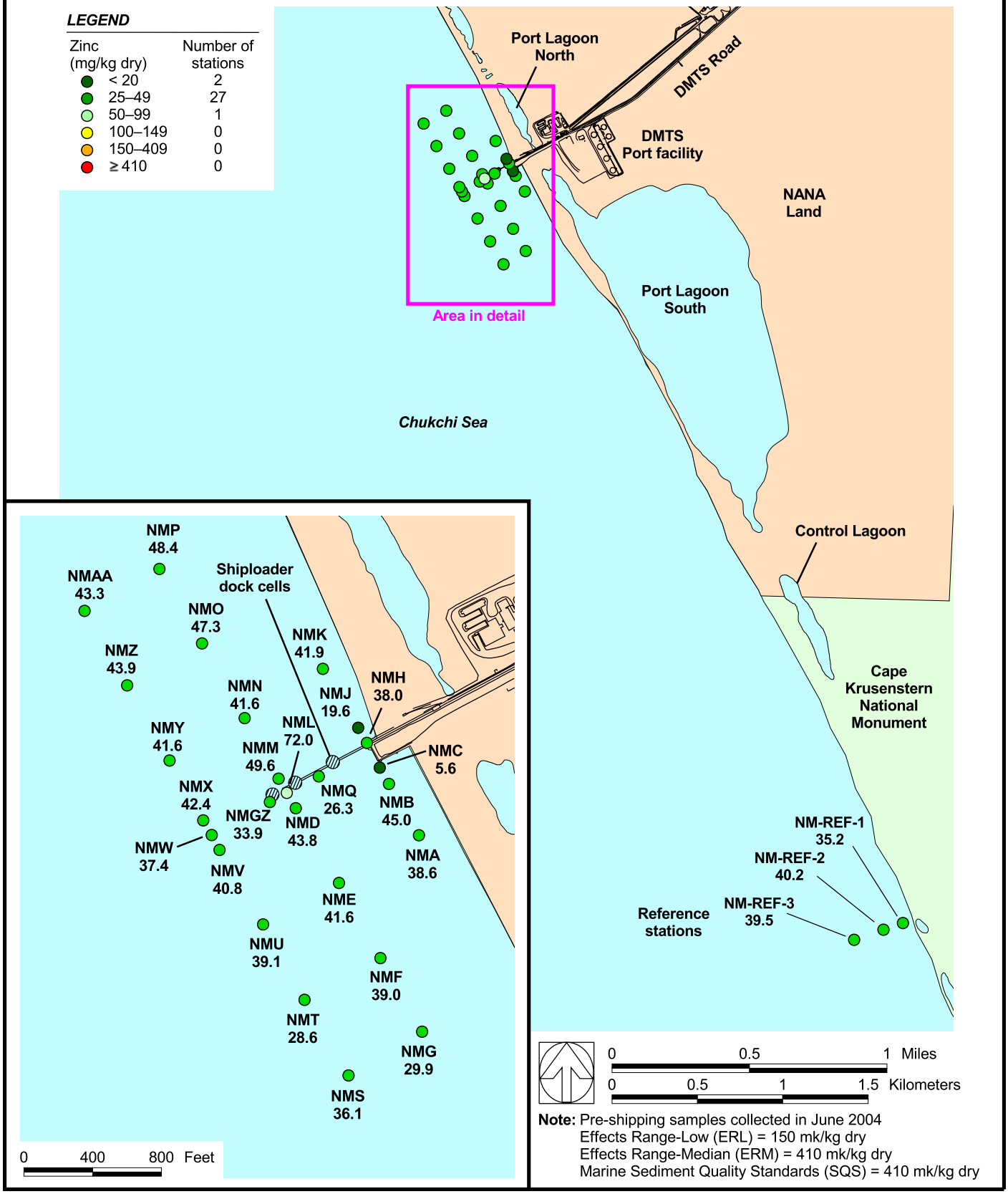


Figure 4-19. 2004 pre-shipping zinc concentration (mg/kg dry)

Exponent®

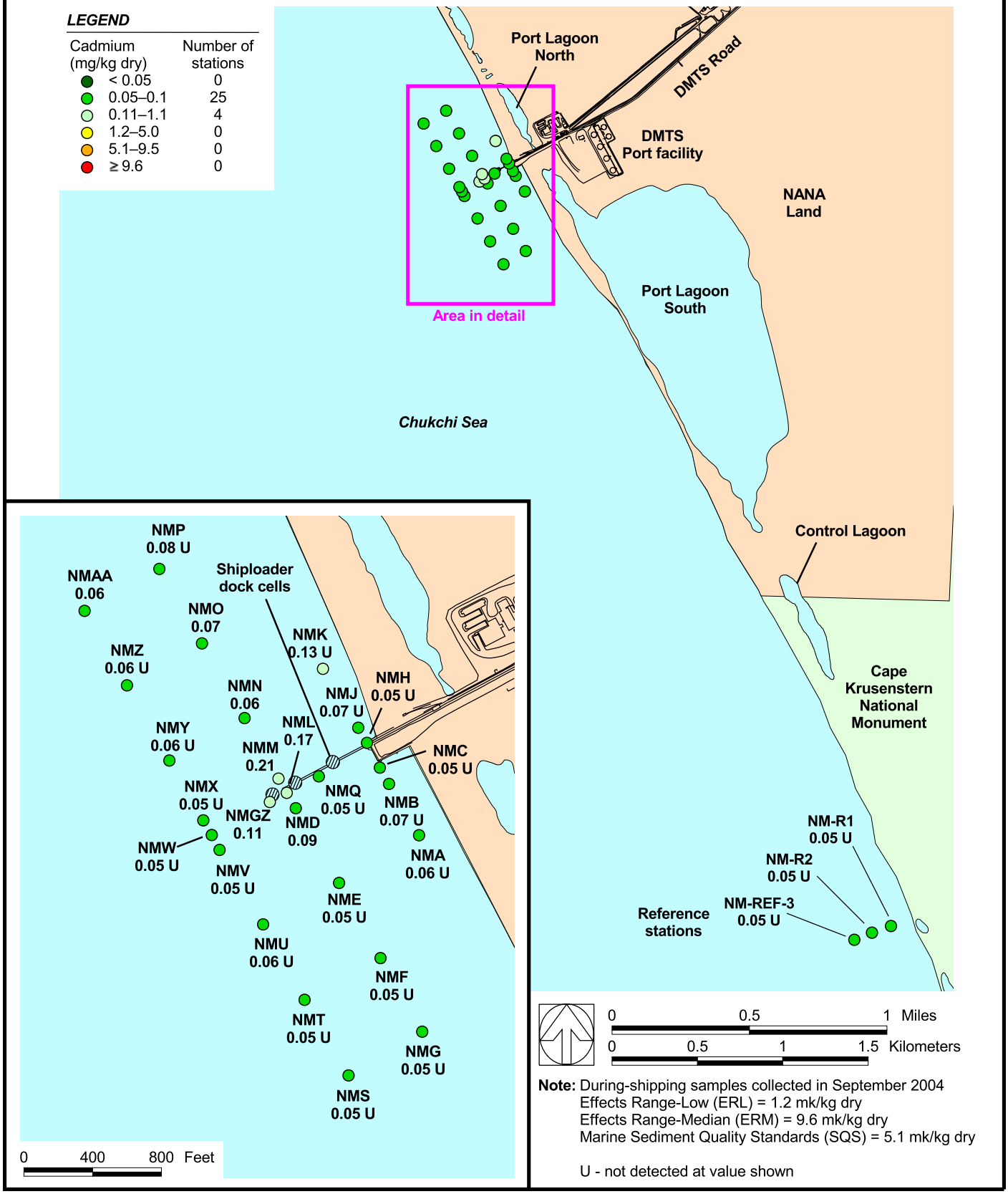


Figure 4-20. 2004 during-shipping cadmium concentration (mg/kg dry)

Exponent®

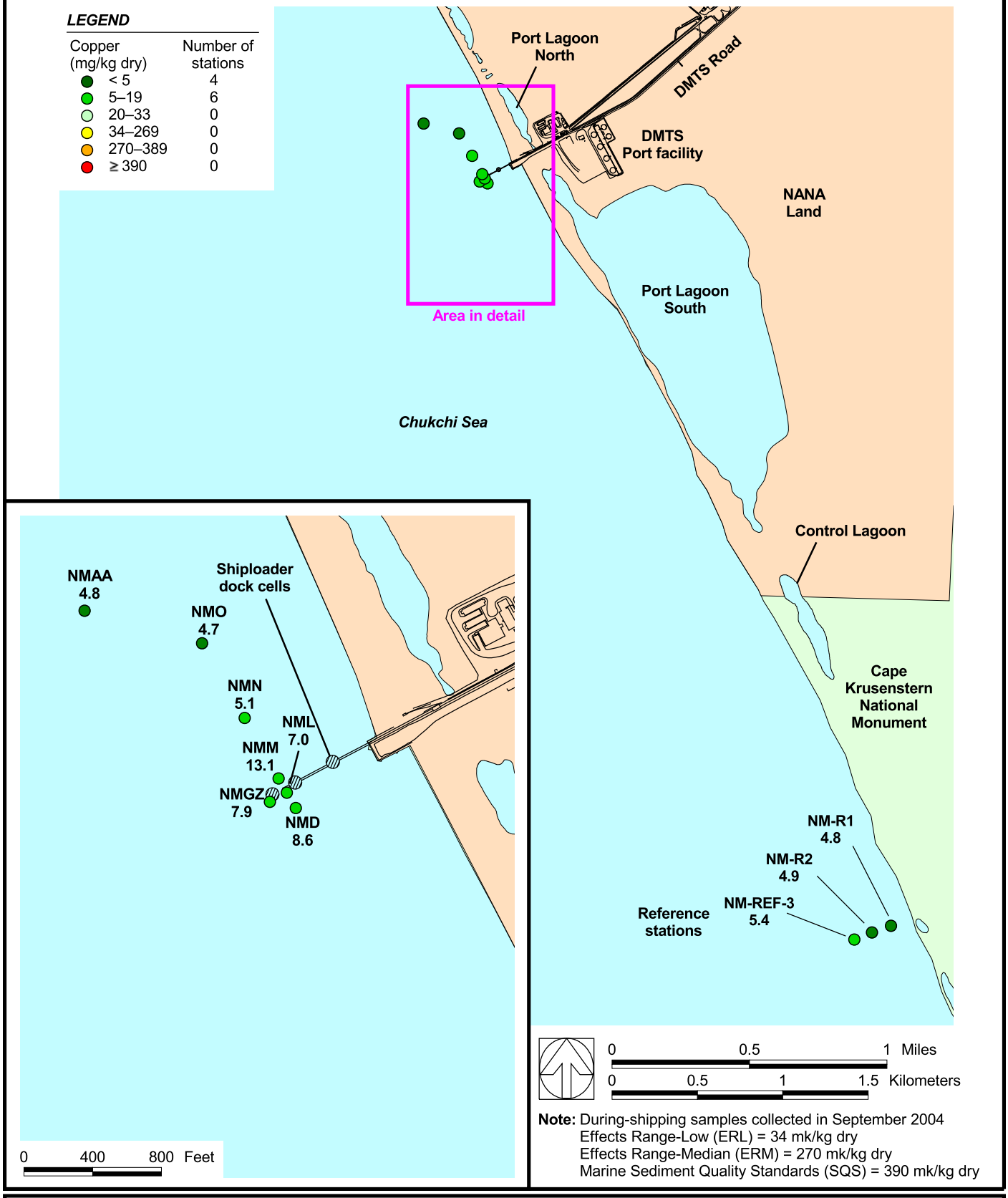


Figure 4-21. 2004 during-shipping copper concentration (mg/kg dry)

Exponent®

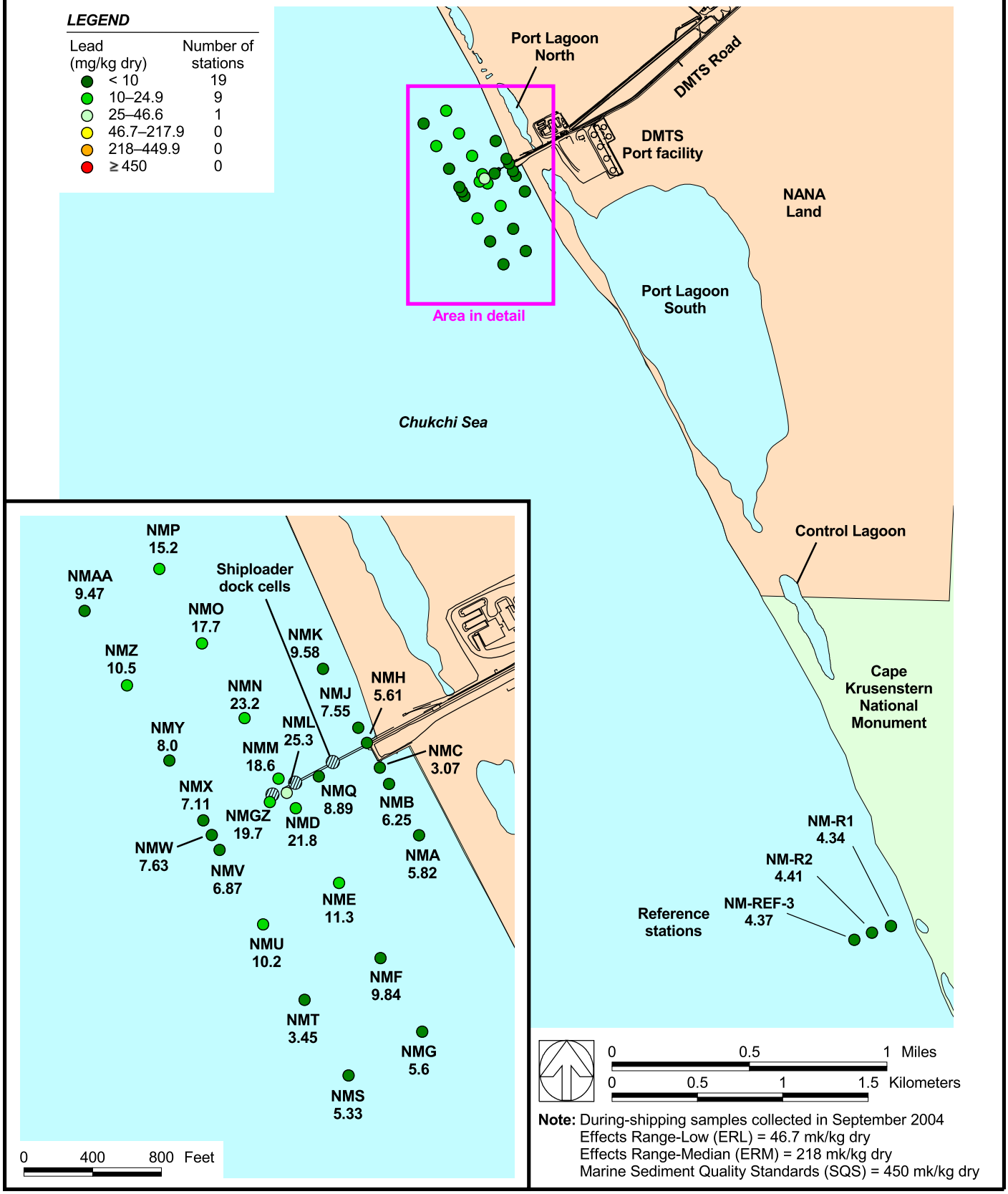


Figure 4-22. 2004 during-shipping lead concentration (mg/kg dry)

Exponent®

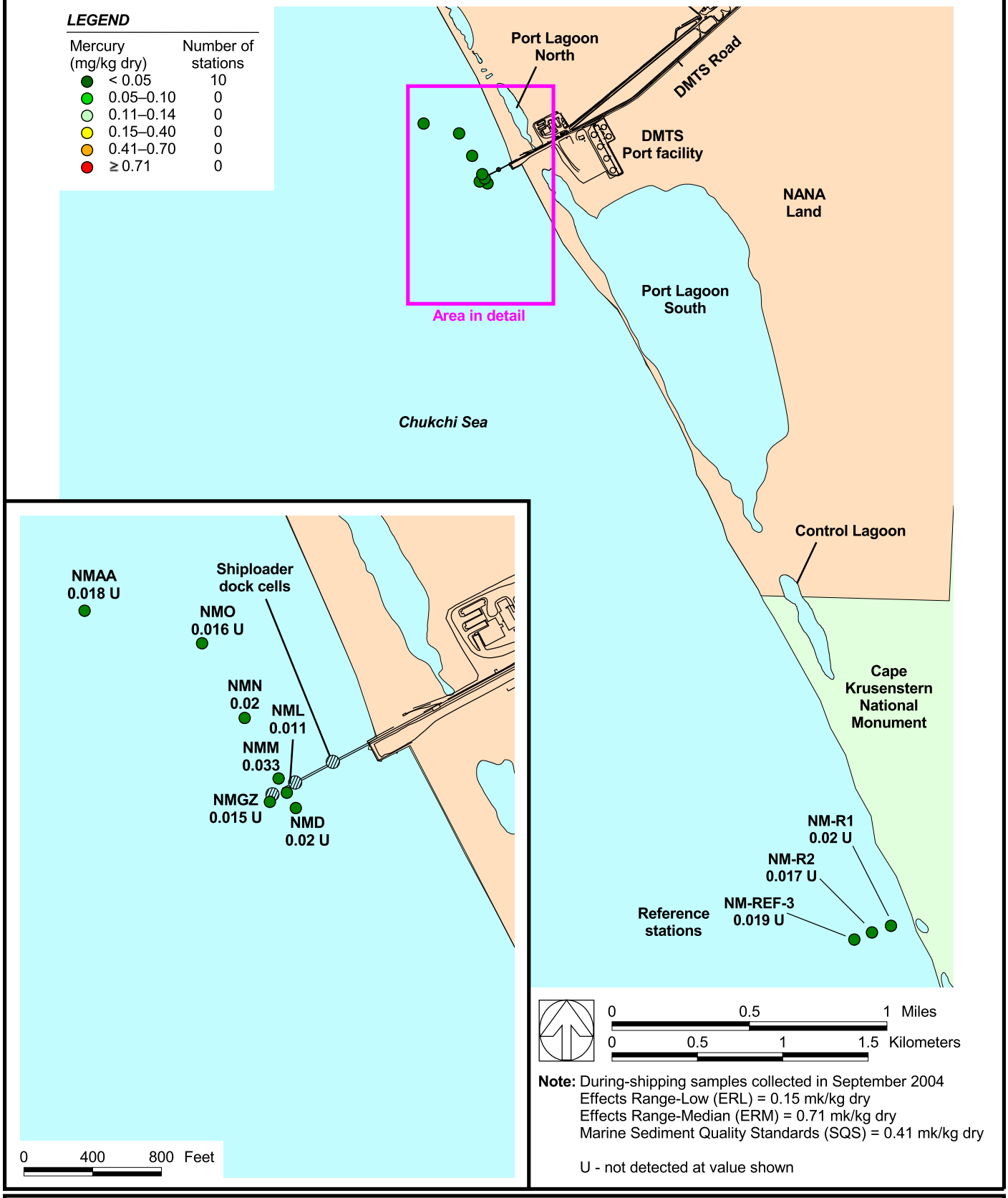


Figure 4-23. 2004 during-shipping mercury concentration (mg/kg dry)

Exponent®

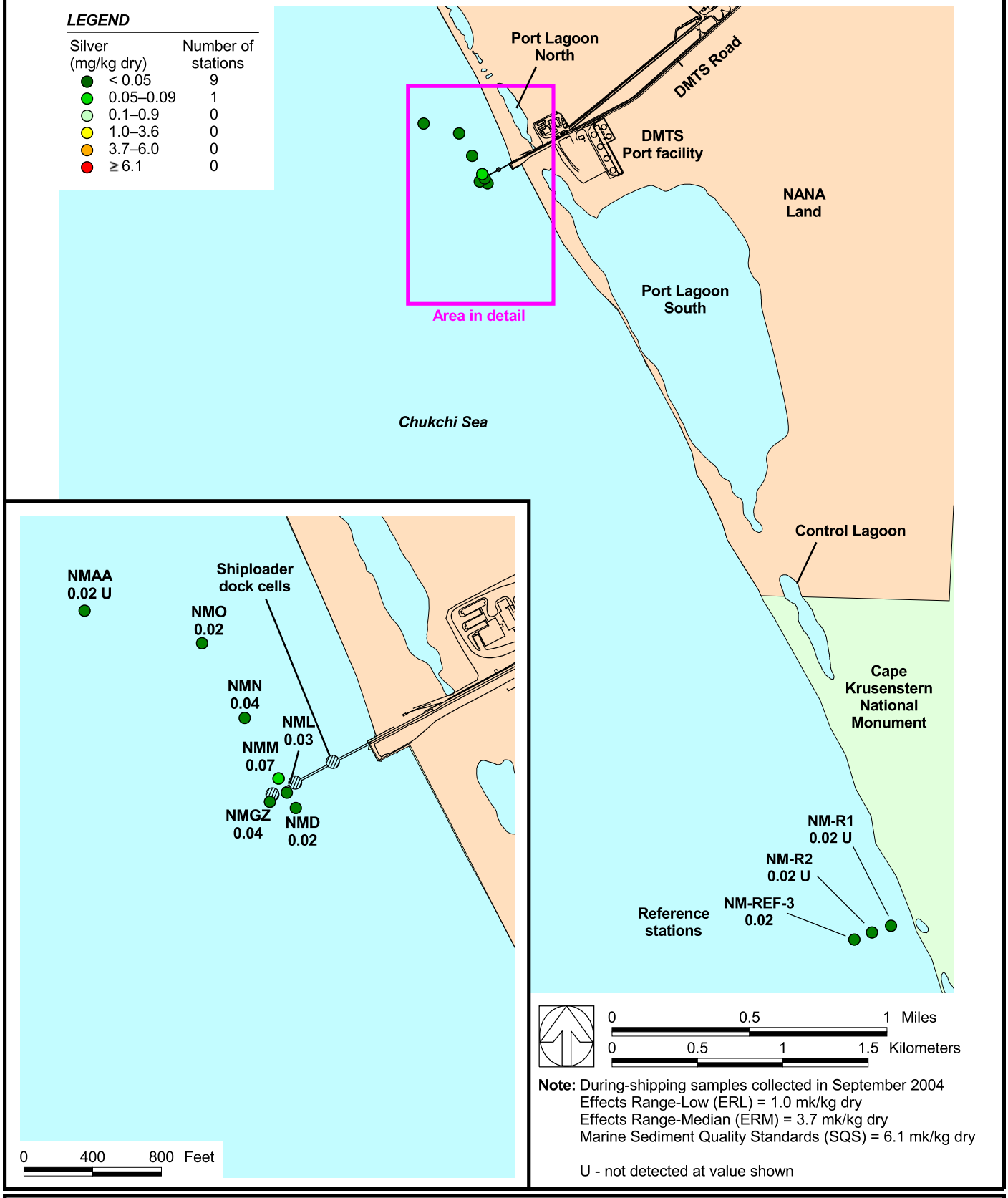


Figure 4-24. 2004 during-shipping silver concentration (mg/kg dry)

Exponent®

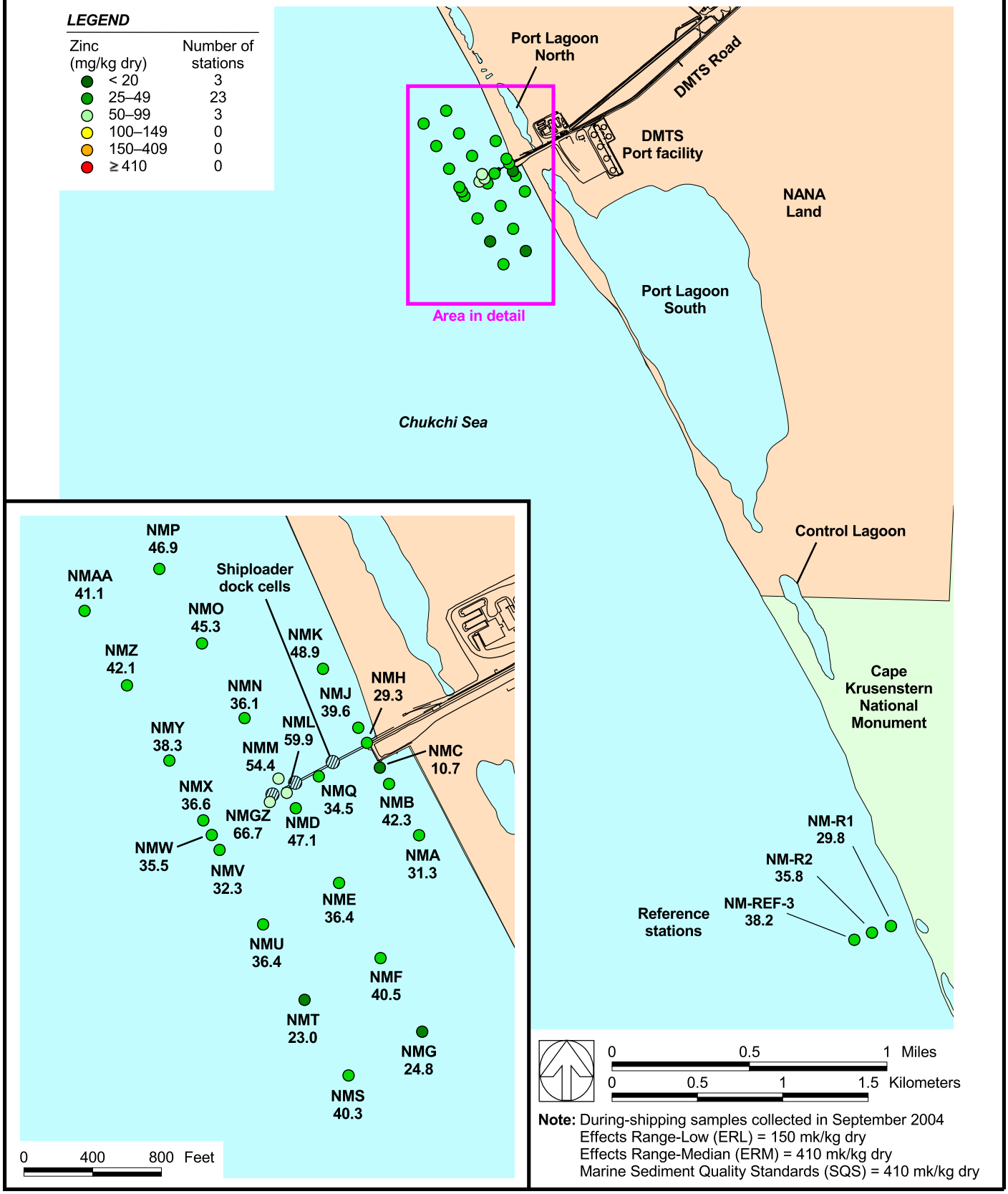


Figure 4-25. 2004 during-shipping zinc concentration (mg/kg dry)

Exponent®

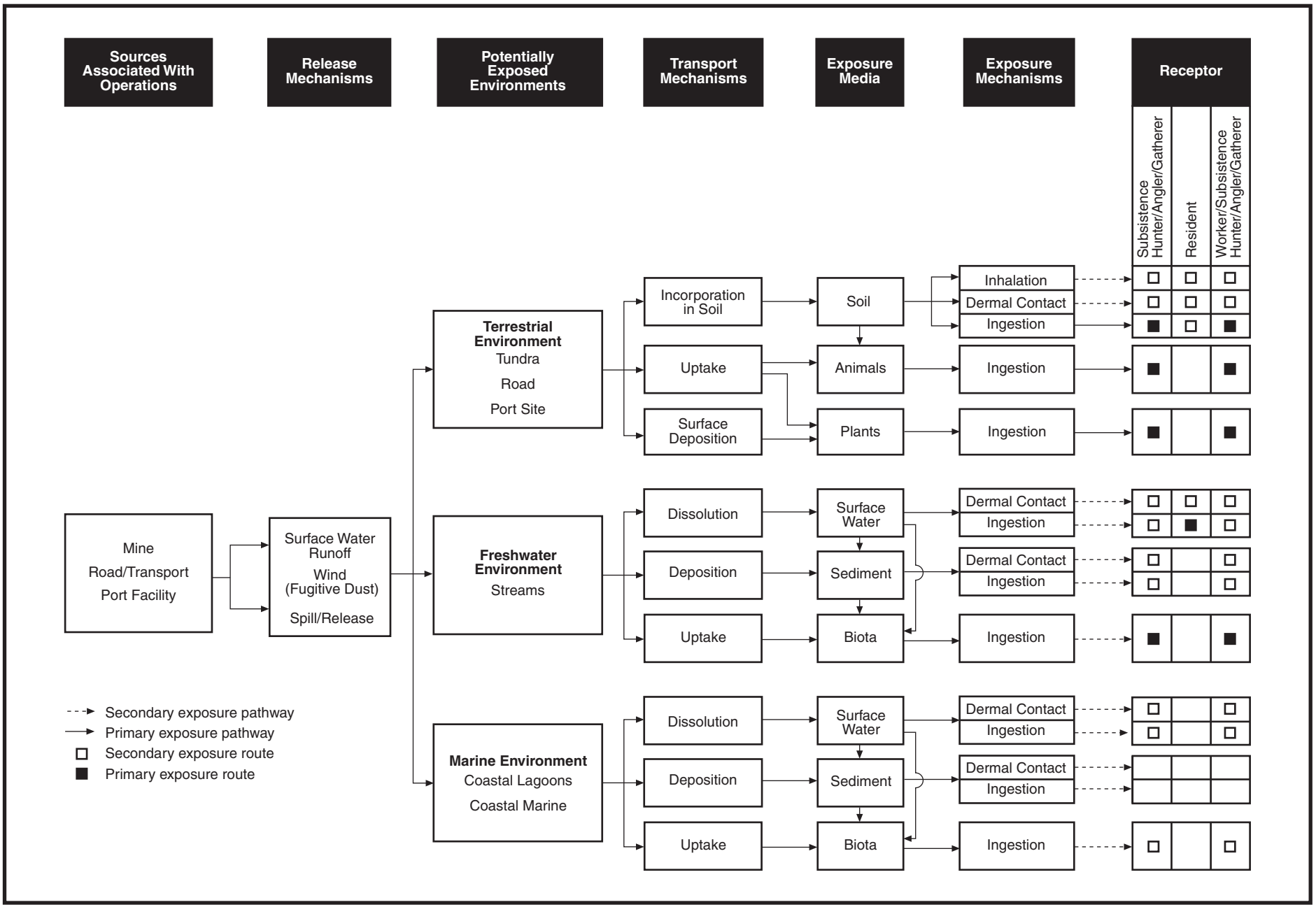


Figure 5-1. Refined conceptual site model for the DMTS human health risk assessment

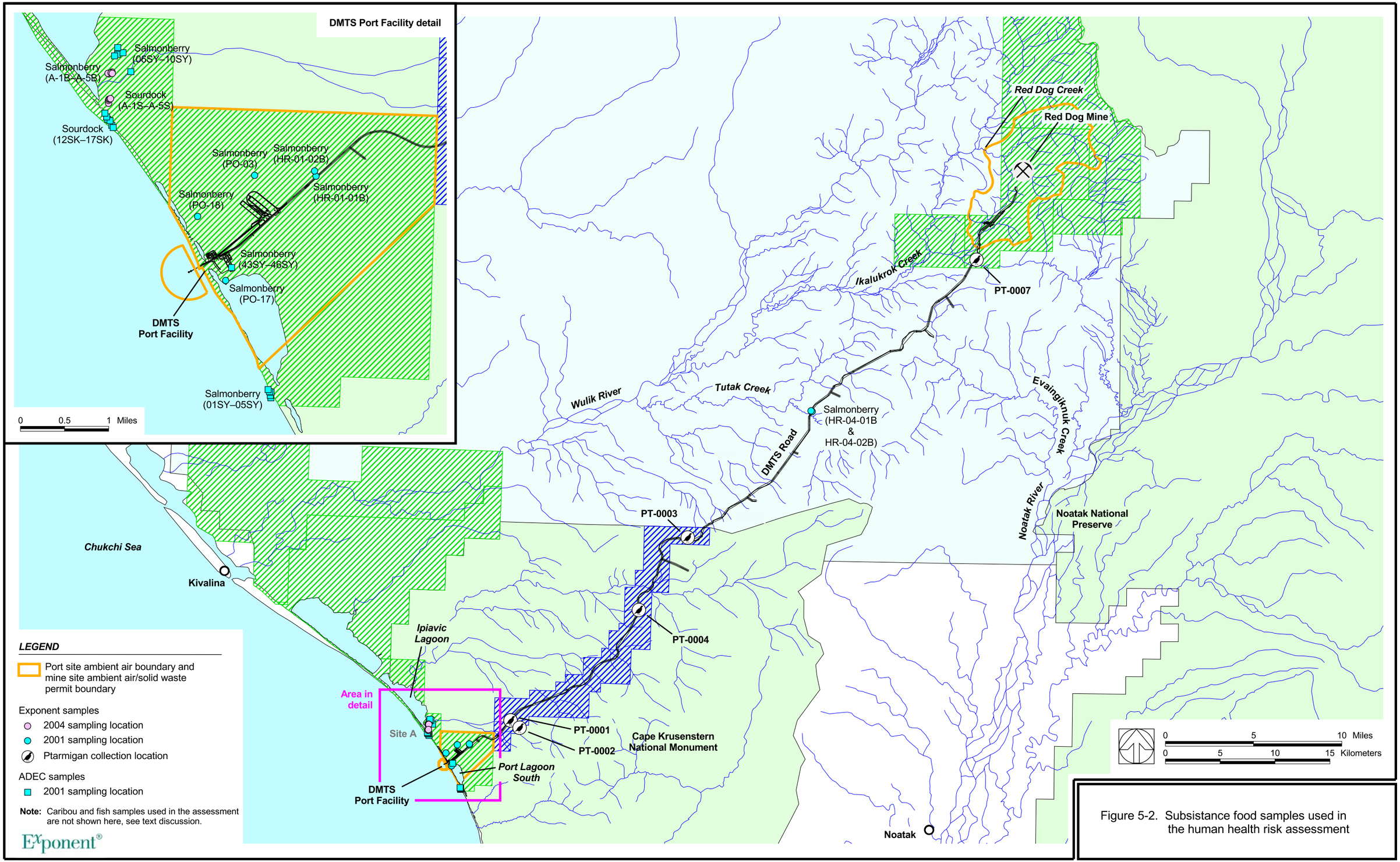
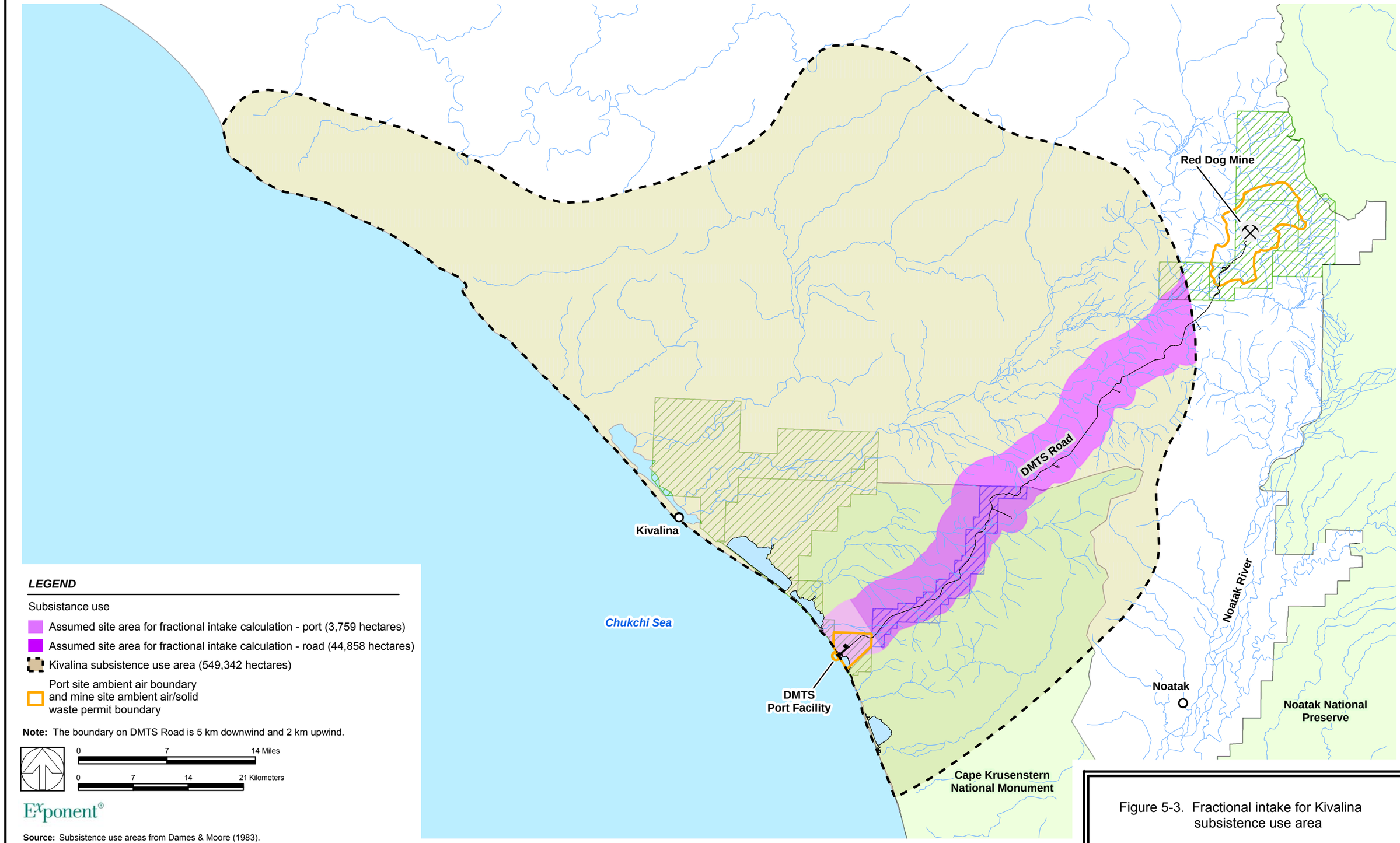


Figure 5-2. Subsistance food samples used in the human health risk assessment



LEGEND

Subsistance use

- Assumed site area for fractional intake calculation - port (3,759 hectares)
- Assumed site area for fractional intake calculation - road (44,858 hectares)
- Kivalina subsistence use area (549,342 hectares)
- Port site ambient air boundary and mine site ambient air/solid waste permit boundary

Note: The boundary on DMTS Road is 5 km downwind and 2 km upwind.

0 7 14 Miles

0 7 14 21 Kilometers

Exponent®

Source: Subsistence use areas from Dames & Moore (1983).

Figure 5-3. Fractional intake for Kivalina subsistence use area

8601997.001 3500 | January 04, 2005 | J:\Red_Dog\projects\Kivalina_subsistence_area.mxd

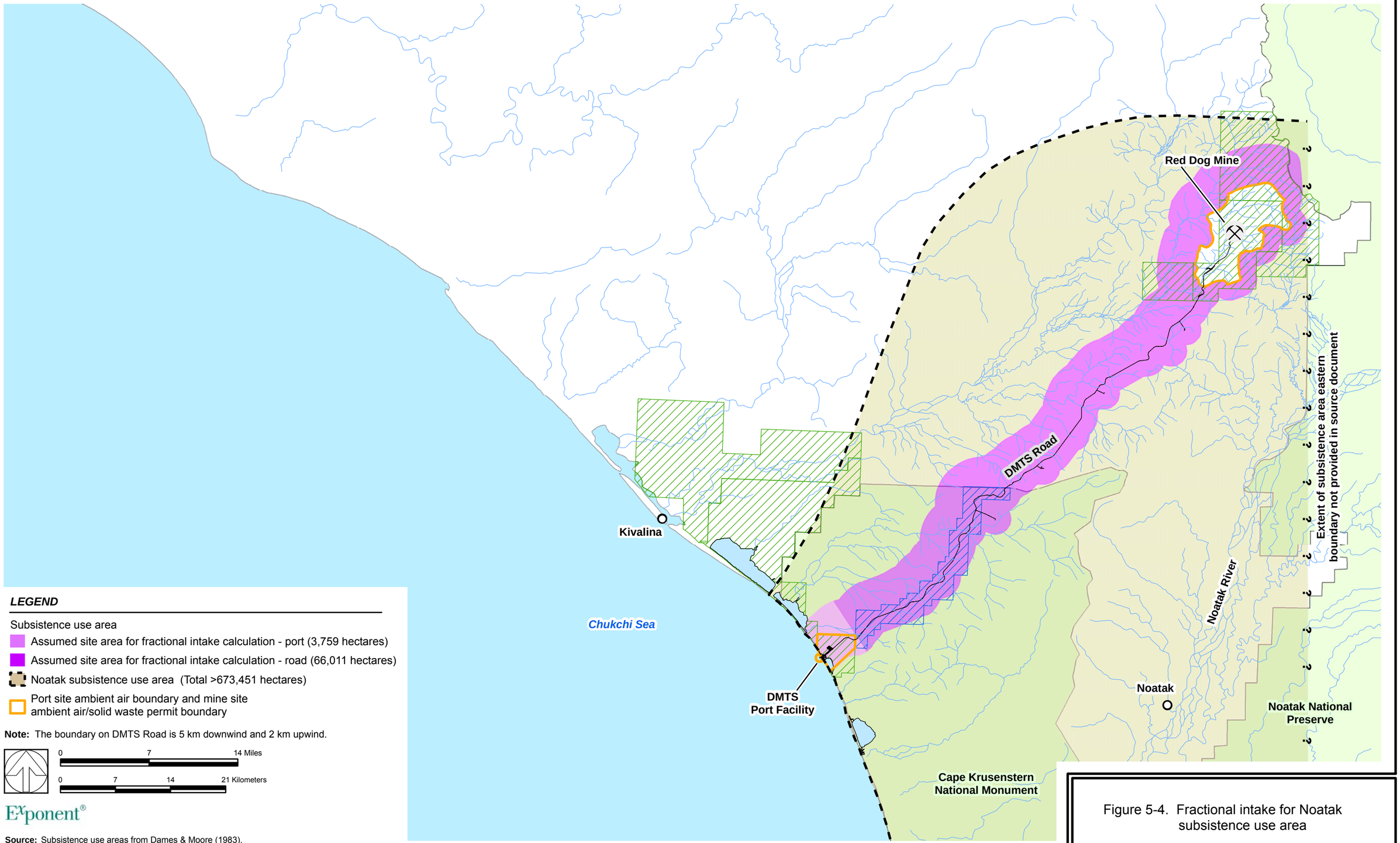
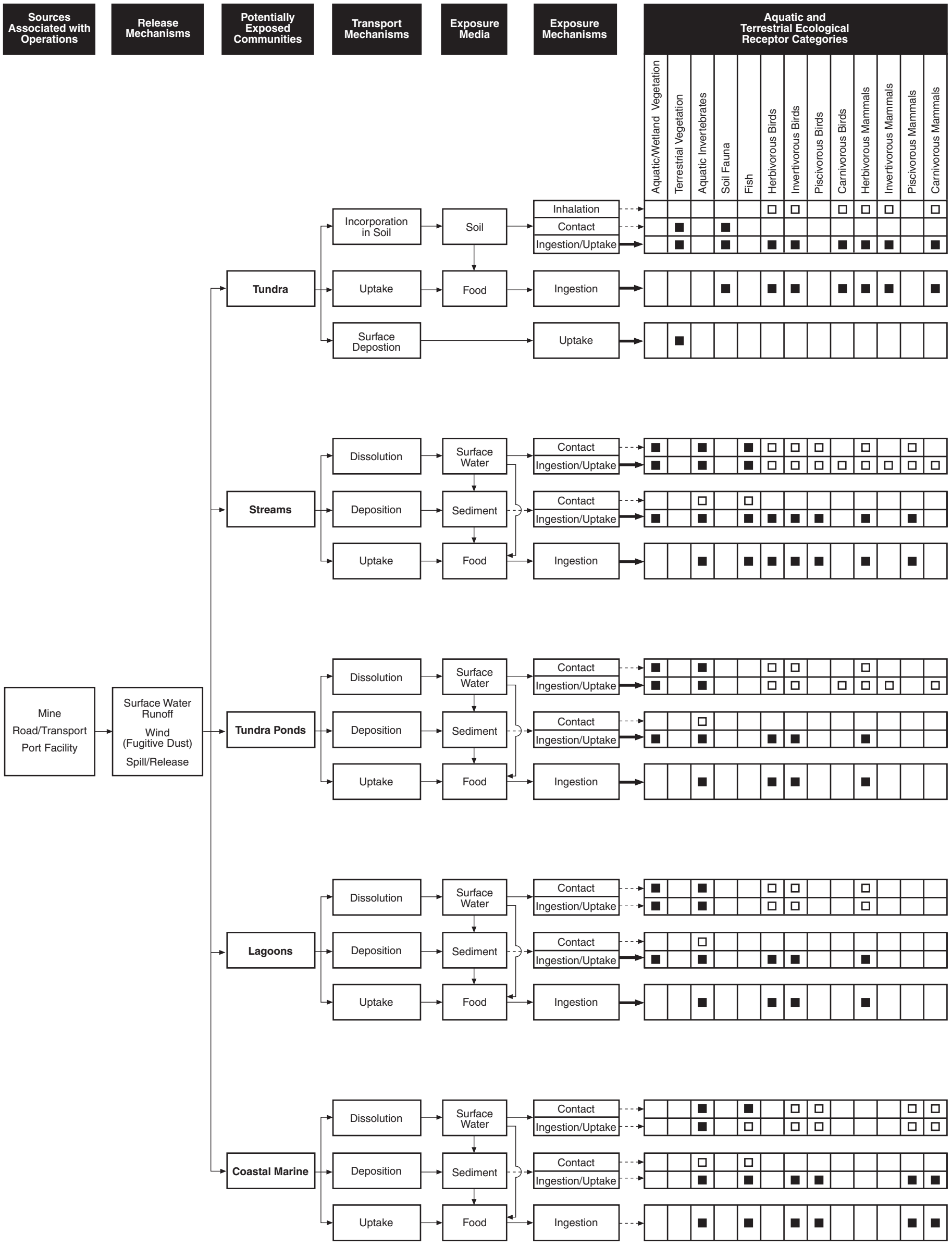


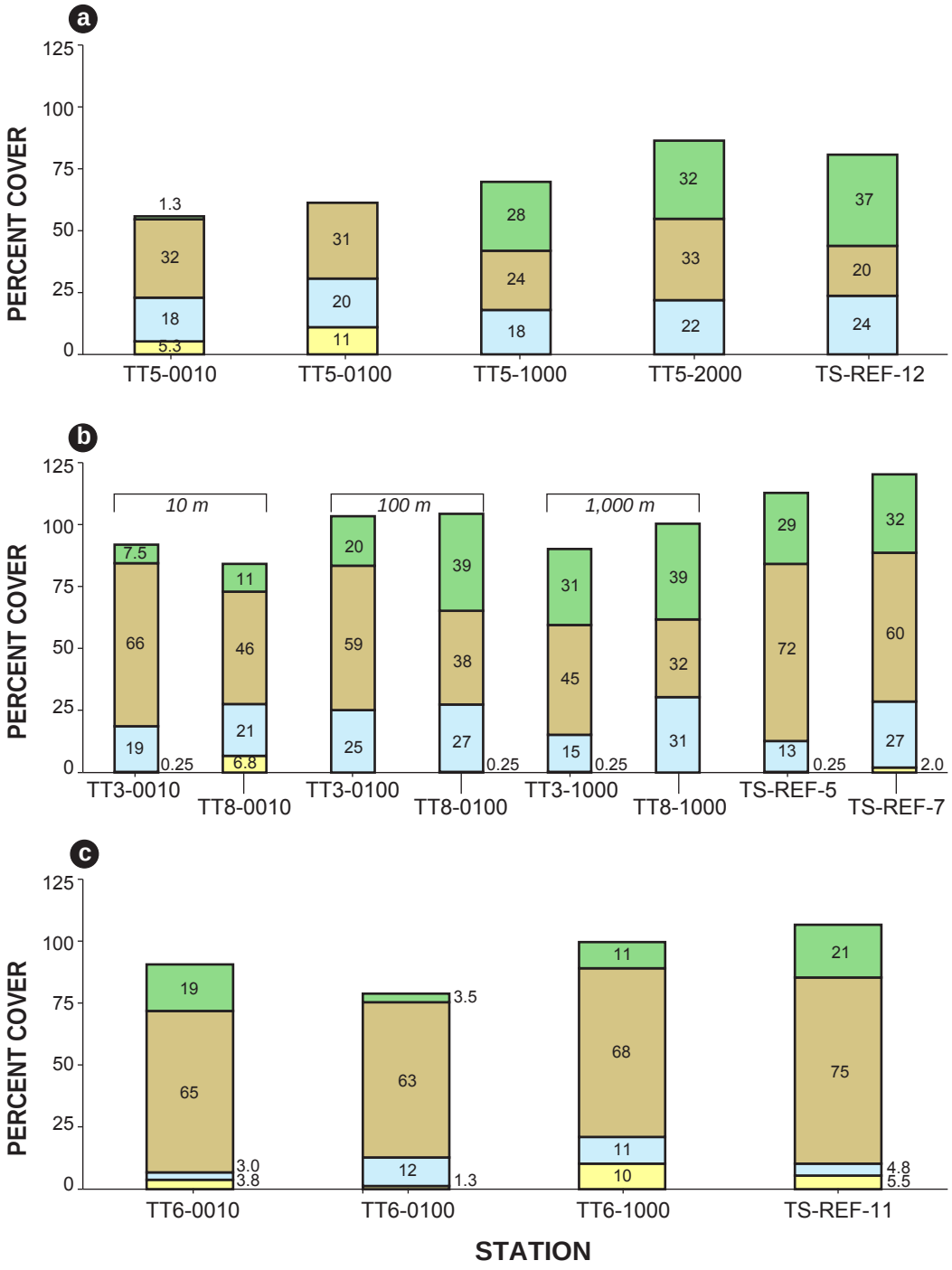
Figure 5-4. Fractional intake for Noatak subsistence use area

8601997.001 3500 | January 04, 2005 | J:\Red_Dog\projects\Noatak_subsistence_area.mxd



Notes: Fish were not present in the tundra pond and lagoon communities, therefore no complete exposure pathway to fish or fish-eating wildlife is documented in the conceptual site model for these habitats.
Aquatic vegetation was not present in the coastal marine offshore community, therefore no complete exposure pathway is documented in the conceptual site model for aquatic vegetation, or herbivorous wildlife in this habitat.

Figure 6-1. Refined conceptual site model for the DMTS ecological risk assessment



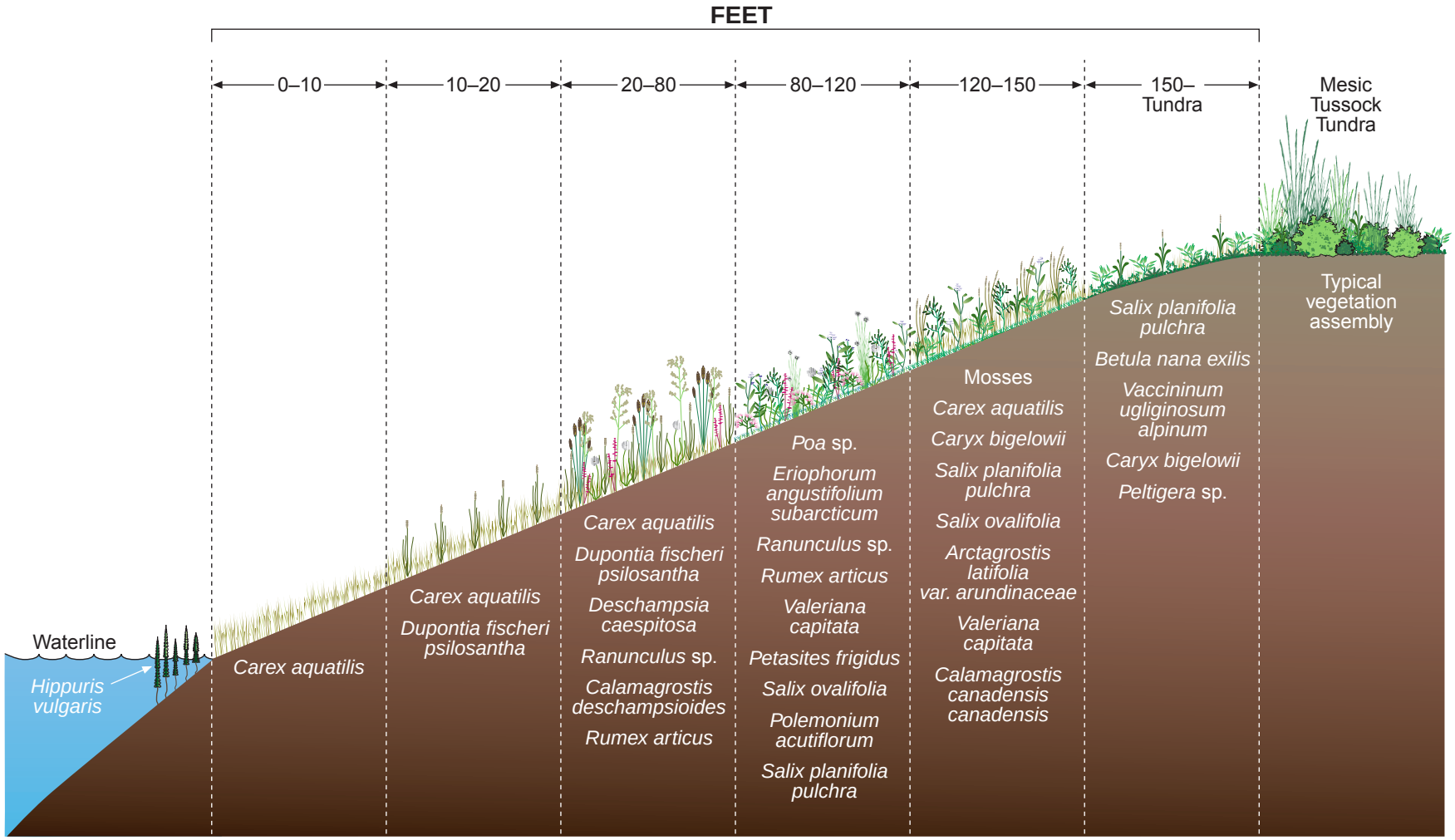
Note:

Covers represent average microplot (1-m^2) cover percentages of vascular plant groups derived by summing average species' covers.

Cover classes were used to estimate species' canopy covers, and consequently total vascular cover may exceed 100 percent.

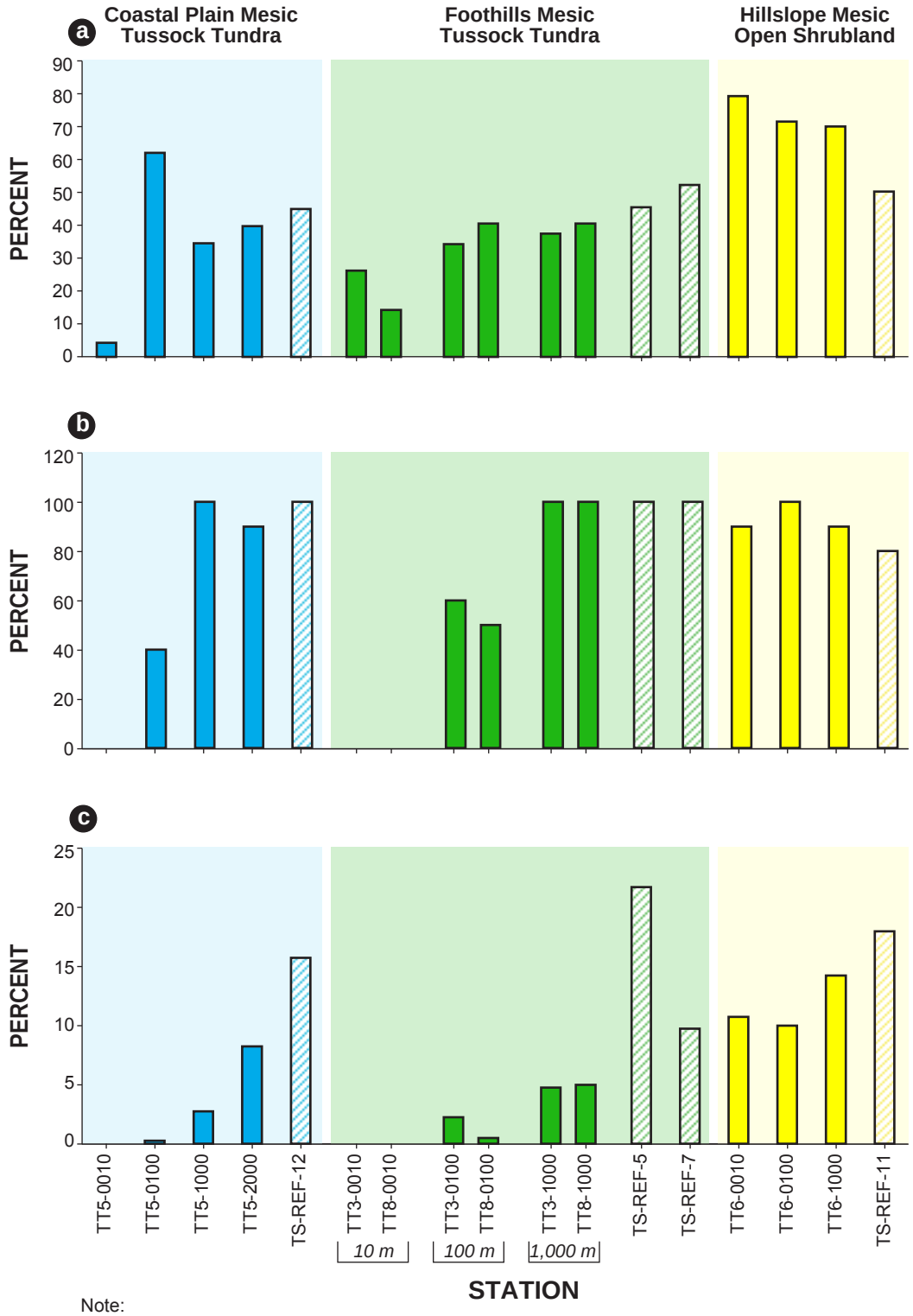
Species cover estimates excluded any plant area that was shaded by a taller canopy.

Figure 6-2. Vascular plant canopy composition of terrestrial vegetation communities along the DMTS road a) coastal plain mesic tussock tundra; b) foothills mesic tussock tundra; c) hillslope mesic open shrubland



Notes: Not to Scale.
Species listed in order of prevalence.
Profile is based on the plant community on the inland side of the north lagoon (station NLK).

Figure 6-3. Representative example of coastal lagoon vegetation profile



Note:

Covers represent average microplot (1-m^2) cover percentages, including areas shaded by a taller canopy.

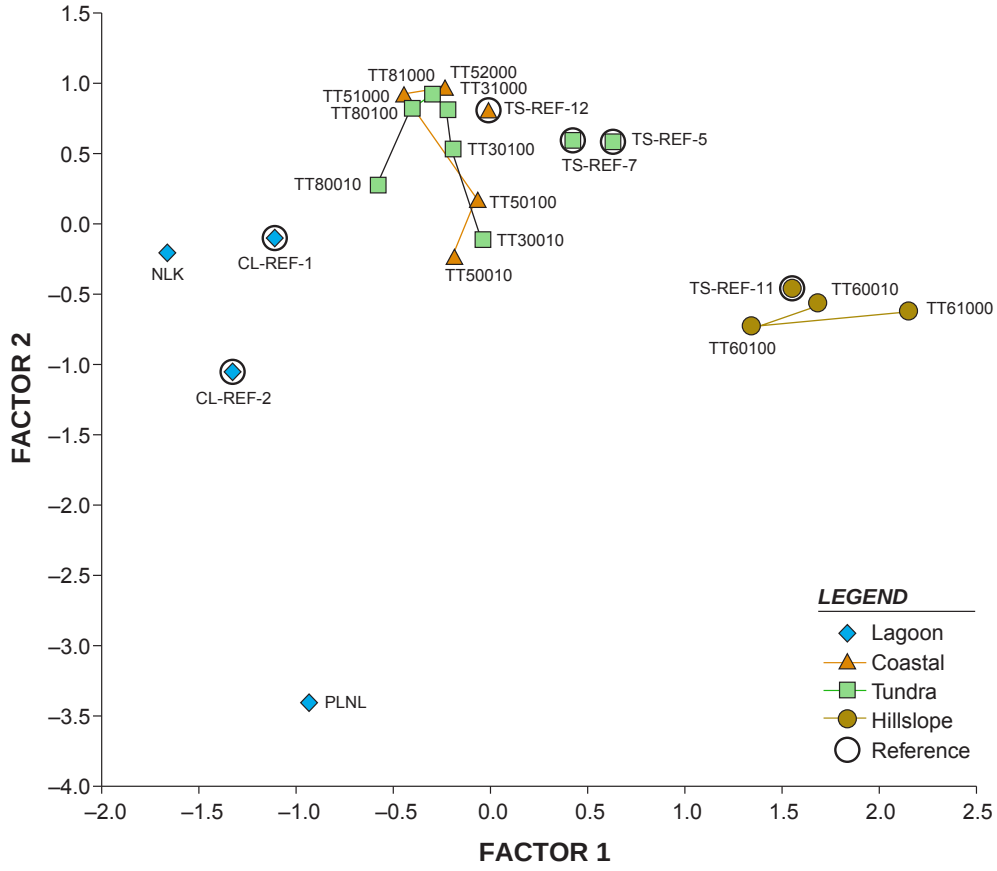
Lichen frequency is the percentage of 1-m^2 microplots that contained lichens.

Moss frequency was 90–100 percent at all stations (not shown)

Hatched bars = Reference stations

Solid bars = Site stations

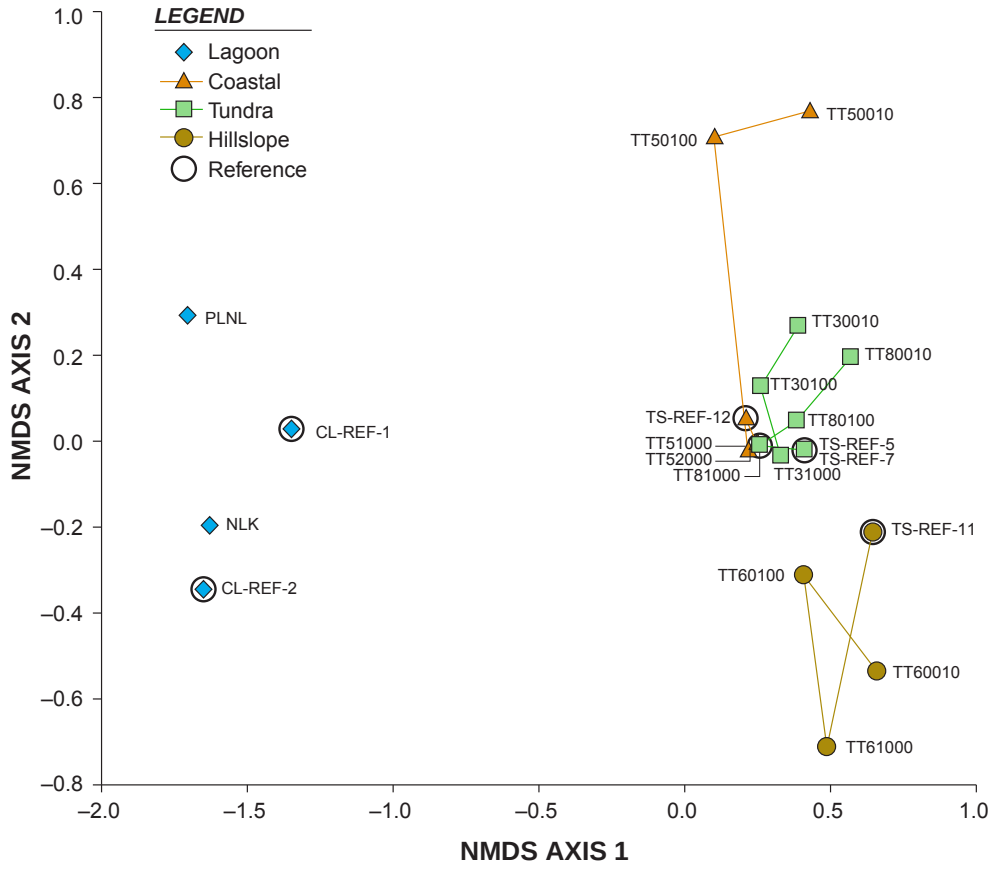
Figure 6-4. Average percent cover and frequency of mosses and lichens in microplots at terrestrial survey stations a) moss cover; b) lichen frequency; c) lichen cover



Coefficients for standardized factor scores after rotation

	Factor 1	Factor 2
Richness	**0.279**	–0.140
Deciduous shrubs	**0.236**	–0.016
Lichen	**0.213**	–0.031
Moss	**0.178**	–0.006
Diversity	0.137	0.134
Forbs	0.044	**–0.252**
Evergreen shrubs	–0.016	**0.200**
Unvegetated	–0.026	**–0.216**
Evenness	–0.063	**0.272**
Litter	–0.170	**0.247**
Graminoids	**–0.225**	0.062
Eigenvalue	3.622	3.490
Variance	32.9%	31.7%
Total variance	32.9%	64.7%
Before rotation:		
Eigenvalue	4.816	2.297
Variance	43.8%	20.9%
Total variance	43.8%	64.7%

Figure 6-5. Factors 1 and 2 from principal component analysis of high-level vegetation community variables with Varimax rotation



Coefficients of NMDS axes

		Axis 1	Axis 2
Deciduous Shrubs	*Salix planifolia pulchra*	0.725	0.360
	Salix lanata richardsonii	0.646	–1.452
	Salix polaris	0.562	1.870
	Vaccinium uliginosum alpinum	0.556	–0.209
	Betula nana exilis	0.535	–0.052
	Rubus chamaemorus	0.440	0.252
	Salix ovalifolia	0.336	0.321
Evergreen Shrubs	*Arctostaphylos alpina*	0.878	–1.284
	Empitrum nigrum hermaphorditum	0.552	–0.136
	Ledum palustre decumbens	0.456	0.020
	Vaccinium vitis-idaea minus	0.418	–0.064
	Andromeda polifolia	0.418	0.309
Forbs	*Pyrola grandiflora*	0.800	–1.426
	Equisetum arvense	0.730	–1.161
	Arnica lessingii lessingii	0.684	0.080
	Saussurea angustifolia	0.670	–1.663
	Pedicularis labradorica	0.658	–0.731
	Polygonum bistorta plumosum	0.644	–1.710
	Saxifraga punctata	0.644	–1.710
	Petasites frigidus or hyperboreus	0.528	0.838
	Polemonium acutiflorum	0.195	1.751
	Valeriana capitata	0.174	1.418
	Stellaria laeta	0.121	1.727
	Stellaria crassifolia	–2.190	–0.267
	Hippuris vulgaris	–2.278	0.664

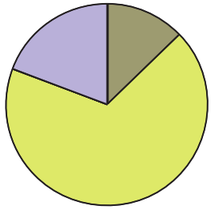
		Axis 1	Axis 2
Graminoids	*Carex microchaeta*	0.875	–1.153
	Festuca altaica	0.827	–1.212
	Poa sp.	0.765	–1.104
	Arctagrostis latifolia var. latifolia	0.757	–0.612
	Caryx bigelowii	0.596	–0.200
	Eriophorum vaginatum	0.406	0.236
	Poa lanata	0.379	1.810
	Arctagrostis latifolia var. arundinaceae	0.268	1.774
	Eriophorum angustifolium subarcticum	-0.869	0.549
	Arctophila fulva	–1.919	0.108
	Carex aquatilis	–1.931	–0.524
	Deschampsia caespitosa	–2.156	–0.327
	Dupontia fischeri psilosantha	–2.156	–0.295
	Calamagrostis deschampsioides	–2.236	–0.663
Lichen		0.504	–0.424
Moss		0.136	–0.217
Litter	Broadleaf litter	0.364	0.044
	Dry blades	–0.023	0.214
	Detritus/fines	–2.142	–0.283
	Littoral matter	–2.224	–0.495
Unvegetated	Road gravel	0.629	1.020
	Bare ground	0.562	0.859
	Rock	–0.994	–0.584
	Water	–1.498	0.583
	Sand/gravel	–2.240	–0.716

Stress = 6.736

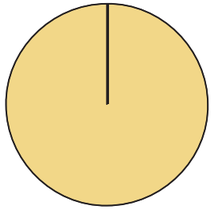
Figure 6-6. Axes 1 and 2 from nonmetric multidimensional scaling analysis of vegetation species percent cover data

TT5

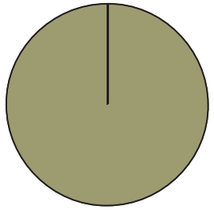
Station TT5-0010
Sample SI0006



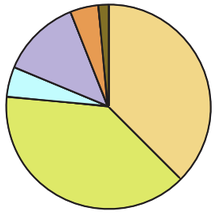
Station TT5-0010
Sample SI0005



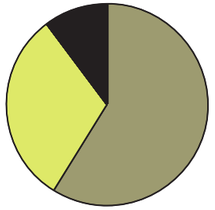
Station TT5-0100
Sample SI0009



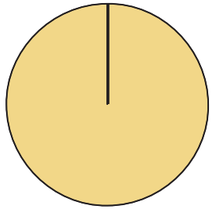
Station TT5-0100
Sample SI0010



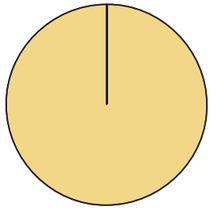
Station TT5-1000
Sample SI0004



Station TT5-1000
Sample SI0002-D

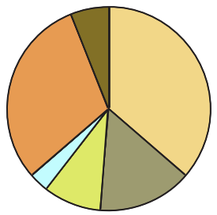


Station TT5-2000,
Sample SI0001

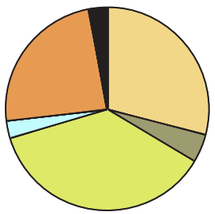


TT2

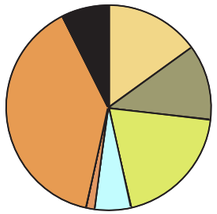
Station TT2-0010
Sample SI0011



Station TT2-0100
Sample SI0007

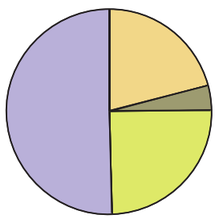


Station TT2-1000
Sample SI0008

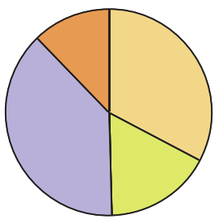


TT3

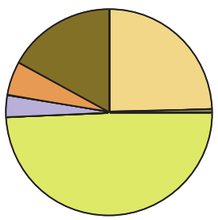
Station TT3-0010
Sample SI0014



Station TT3-0100
Sample SI0015

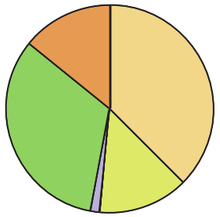


Station TT3-1000
Sample SI0016

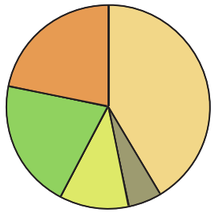


TT6

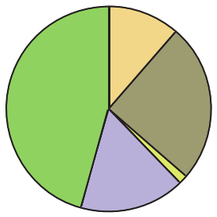
Station TT6-0010
Sample SI0017



Station TT6-0100
Sample SI0013

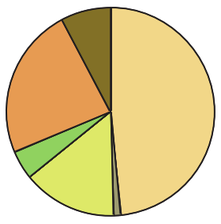


Station TT6-1000
Sample SI0012



Reference Station

Station TS-REF-5
Sample SI0018

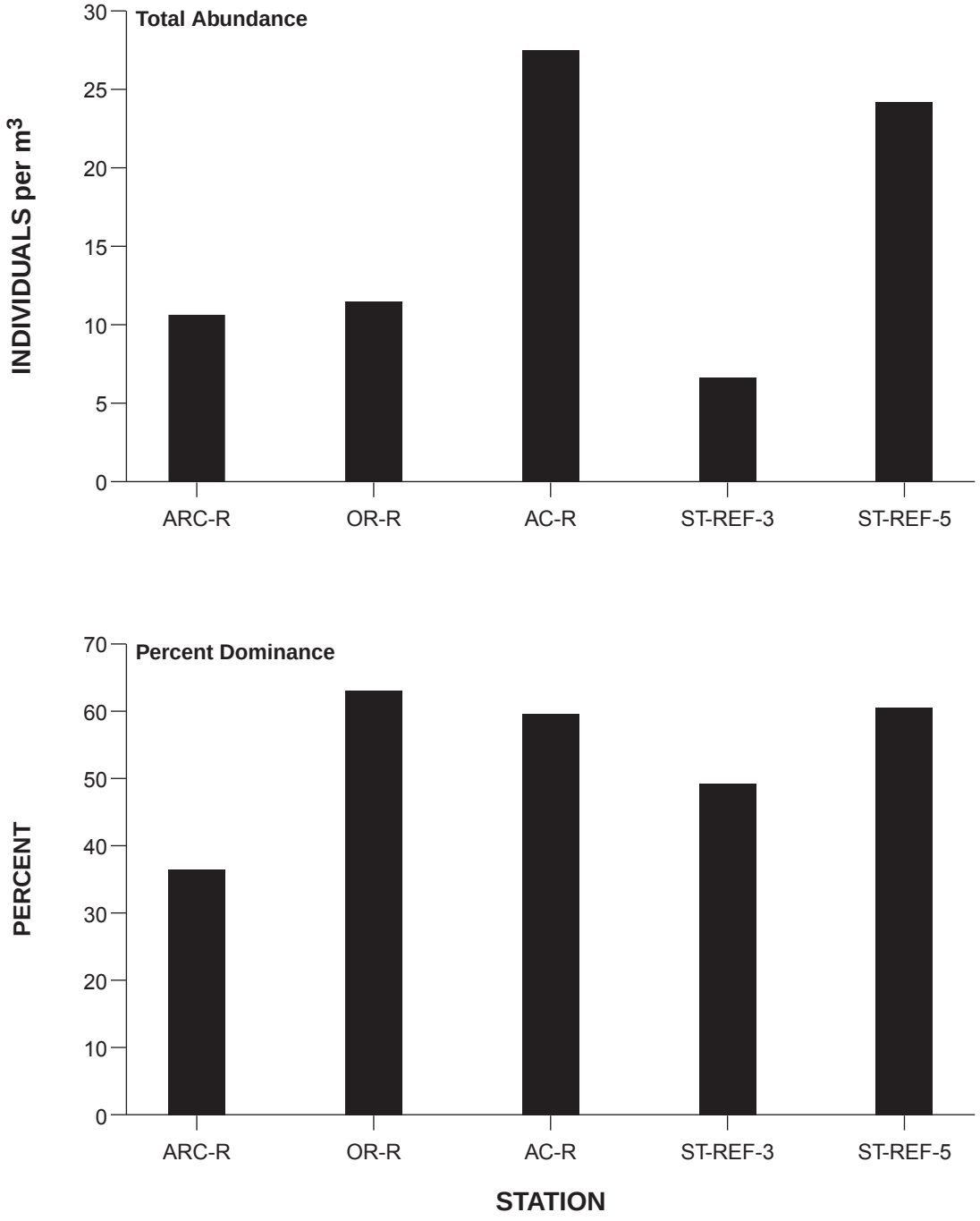


LEGEND

Percent by wet weight:

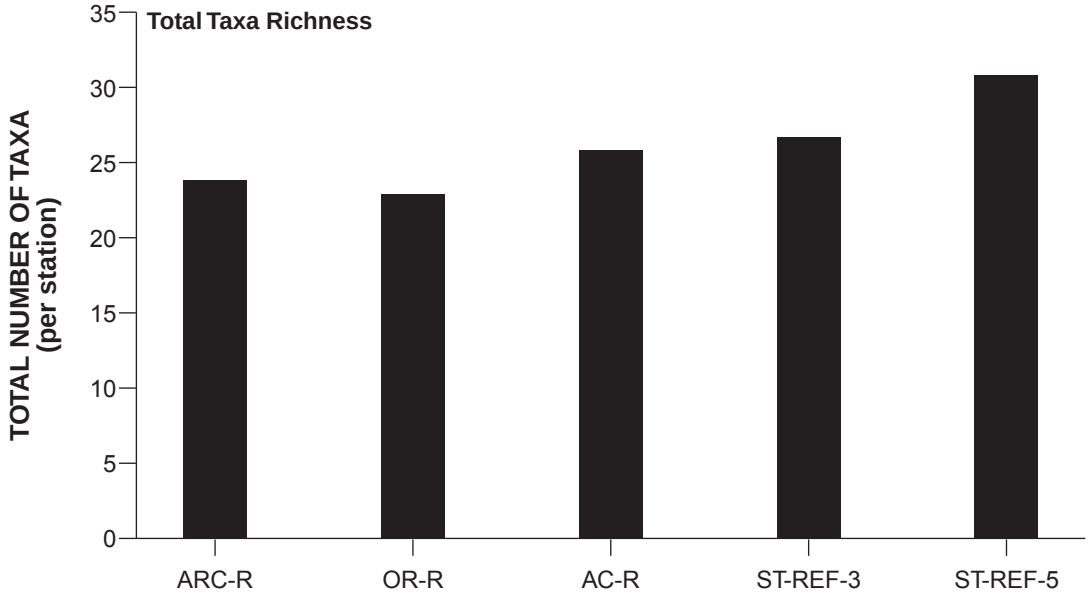
- Spiders
- Flying insects
- Crane flies
- Grasshoppers
- Beetles
- Caterpillars
- Slugs
- Moths
- Snails
- Other

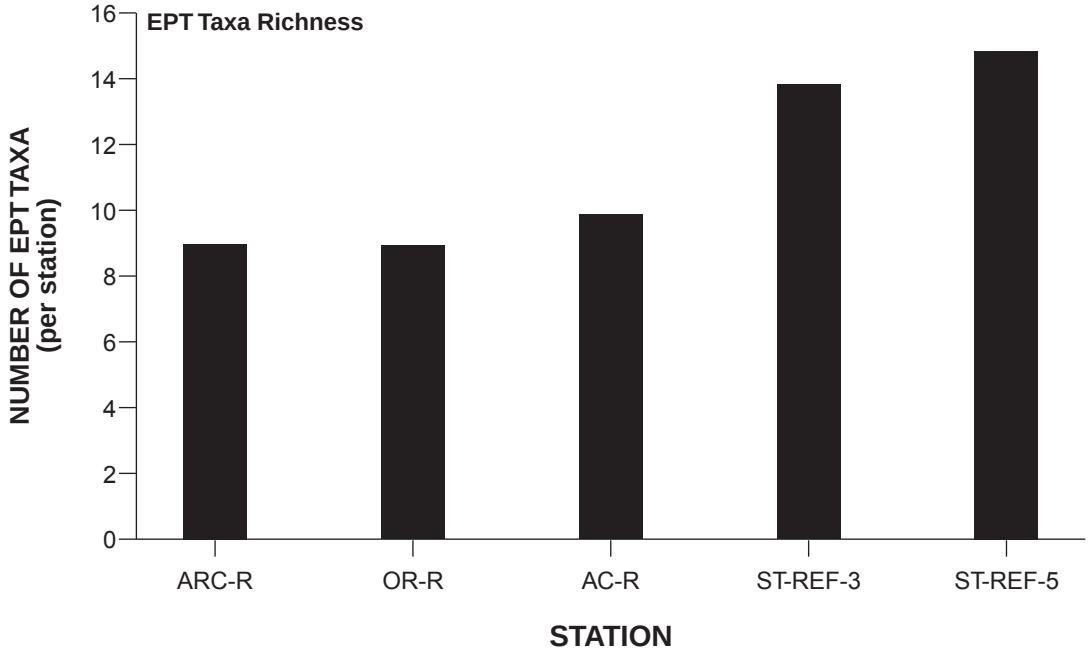
Figure 6-7. Composition of tundra soil invertebrate samples



Note: Percent dominance = Percent of total abundance accounted for by the most abundant taxon

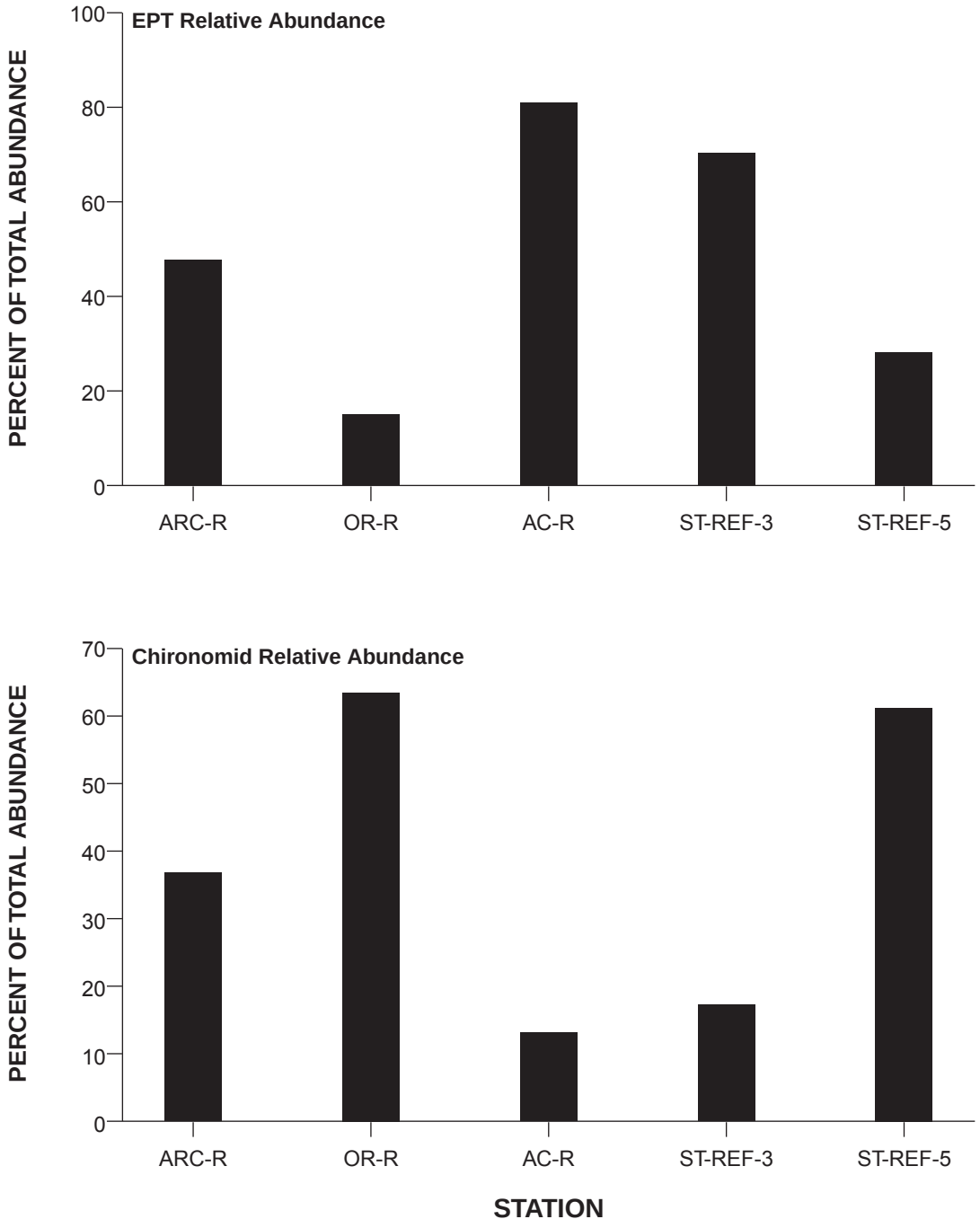
Figure 6-8. Comparison of total abundance and percent dominance between site and reference stations





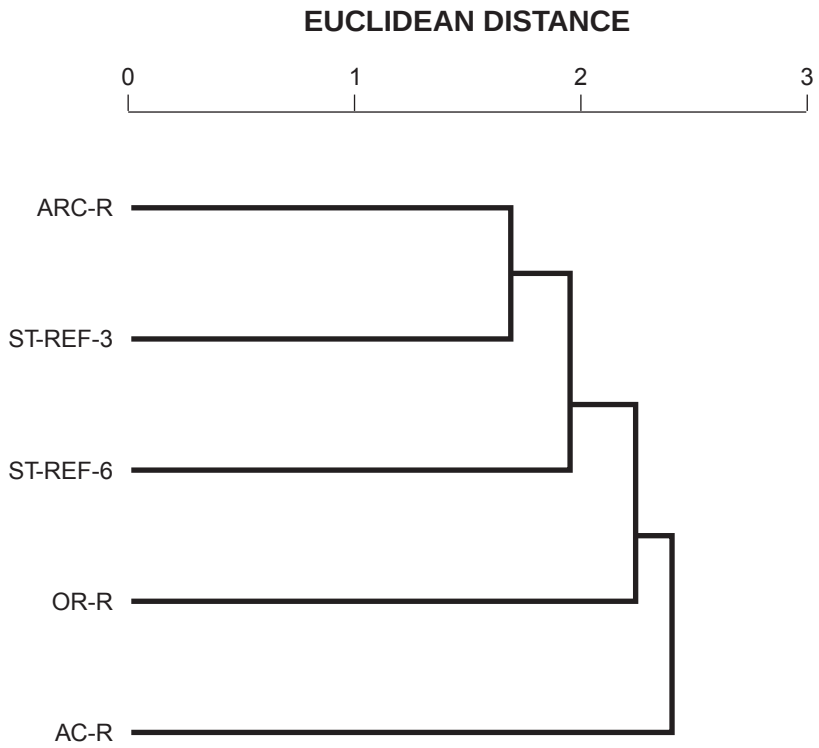
Note: EPT = Ephemeroptera, Plecoptera, and Trichoptera

Figure 6-9. Comparison of total and EPT taxa richness between site and reference stations



Note: EPT = Ephemeroptera, Plecoptera, and Trichoptera

Figure 6-10. Comparison of relative abundances of EPT taxa and chironomids between site and reference stations



Note: Classification analysis was based on the Bray-Curtis similarity index applied to log-transformed abundances of benthic macroinvertebrate taxa from each station

Figure 6-11. Results of classification analysis of benthic macroinvertebrate drift assemblages

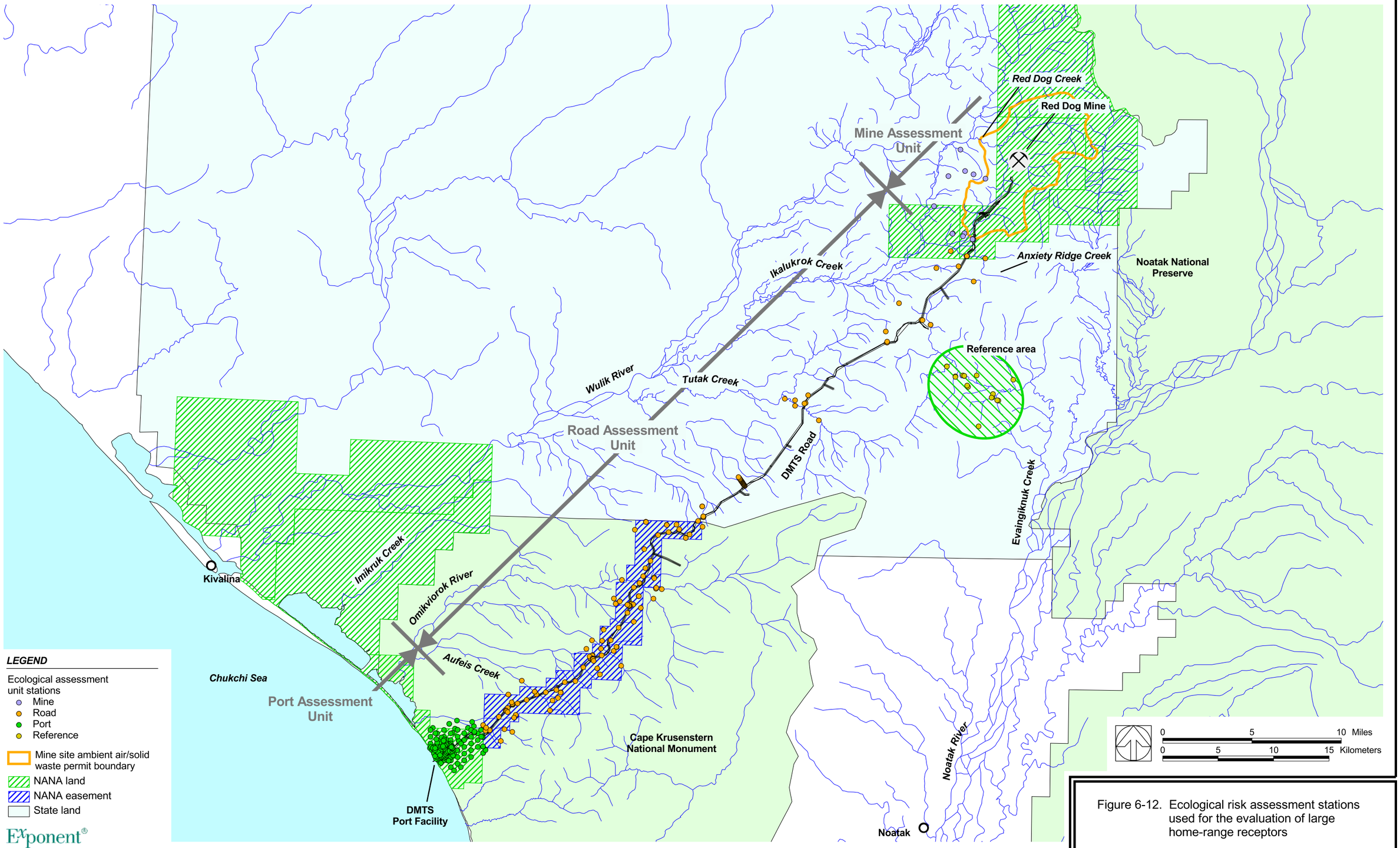


Figure 6-12. Ecological risk assessment stations used for the evaluation of large home-range receptors

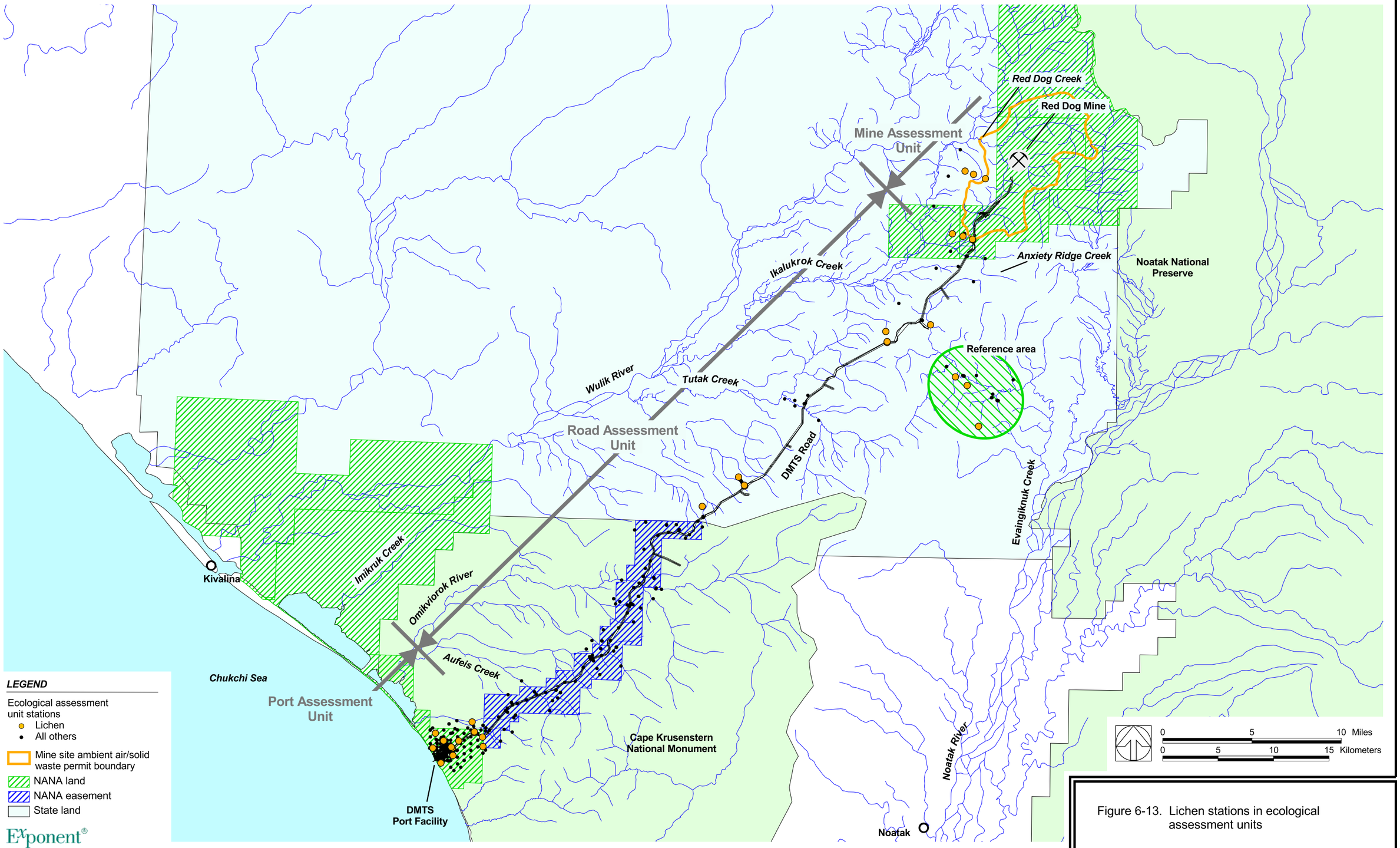


Figure 6-13. Lichen stations in ecological assessment units

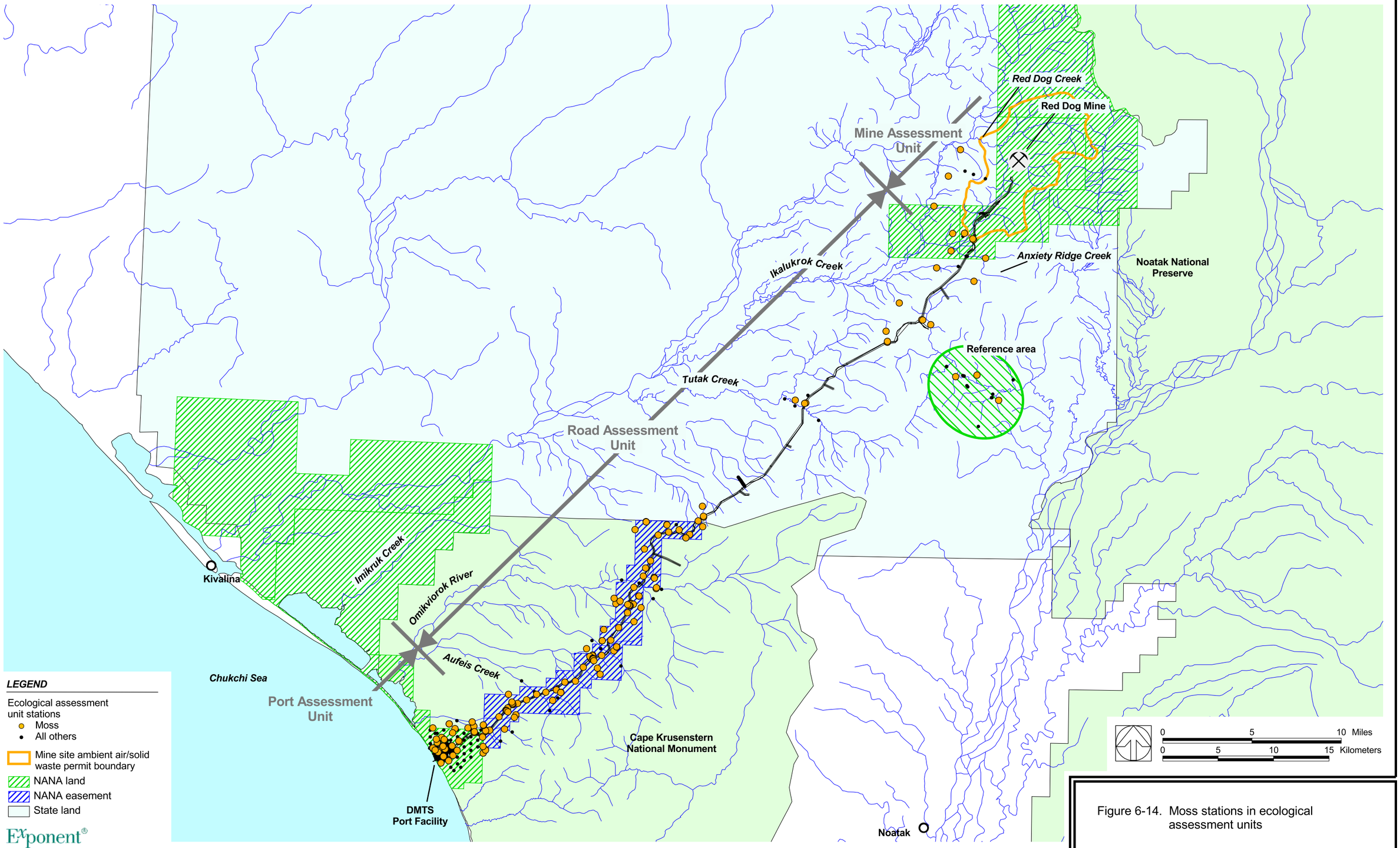


Figure 6-14. Moss stations in ecological assessment units

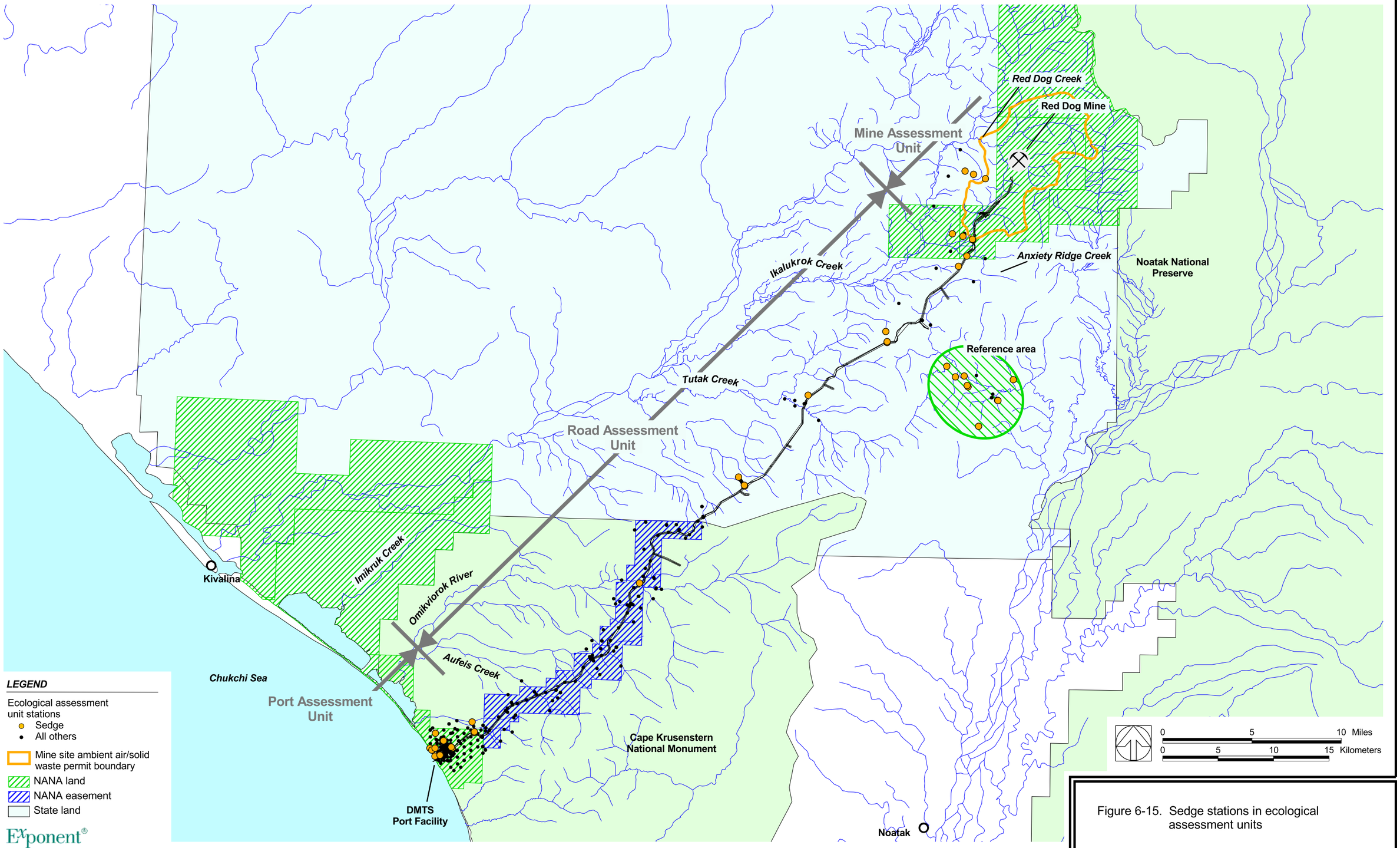


Figure 6-15. Sedge stations in ecological assessment units

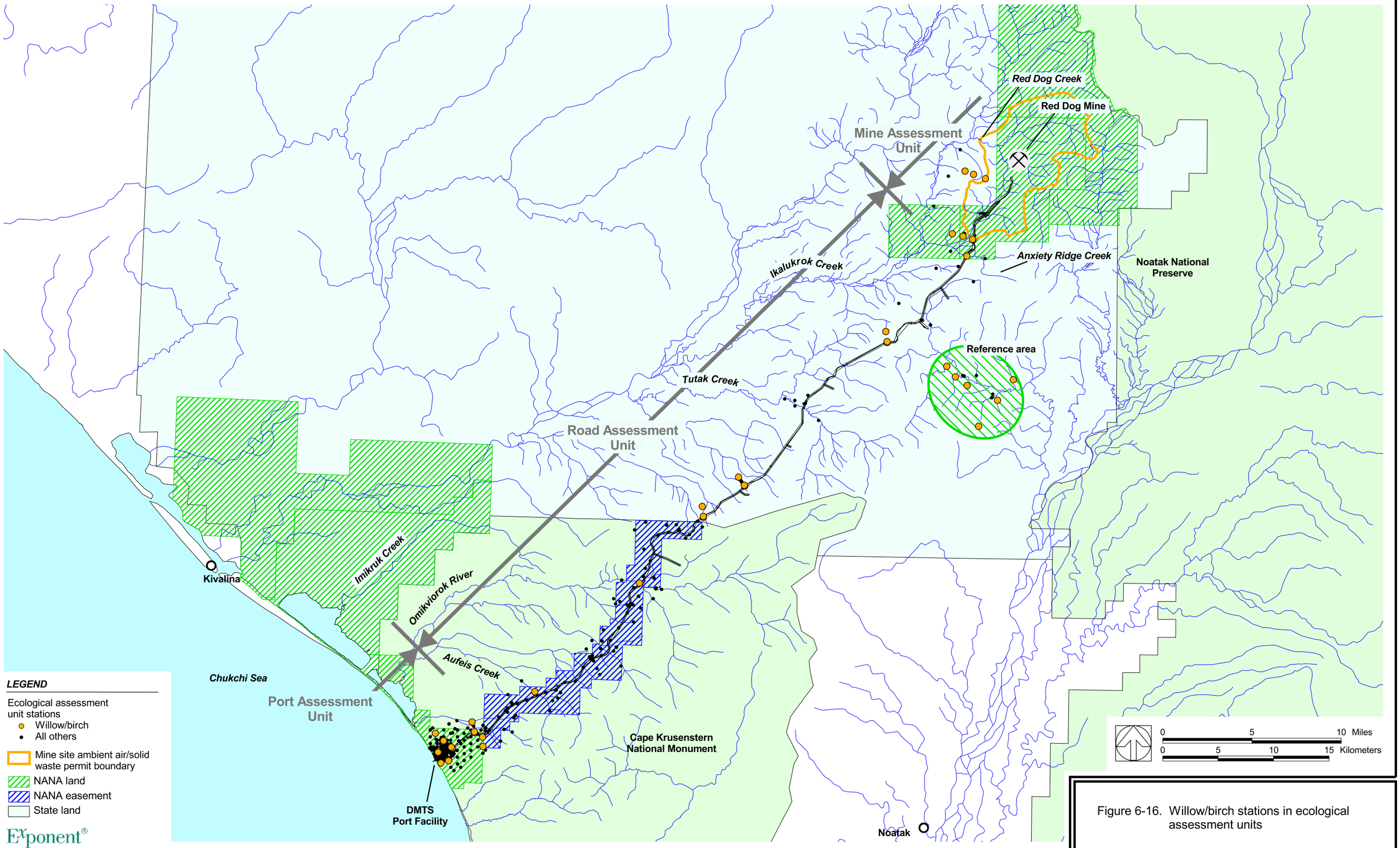


Figure 6-16. Willow/birch stations in ecological assessment units

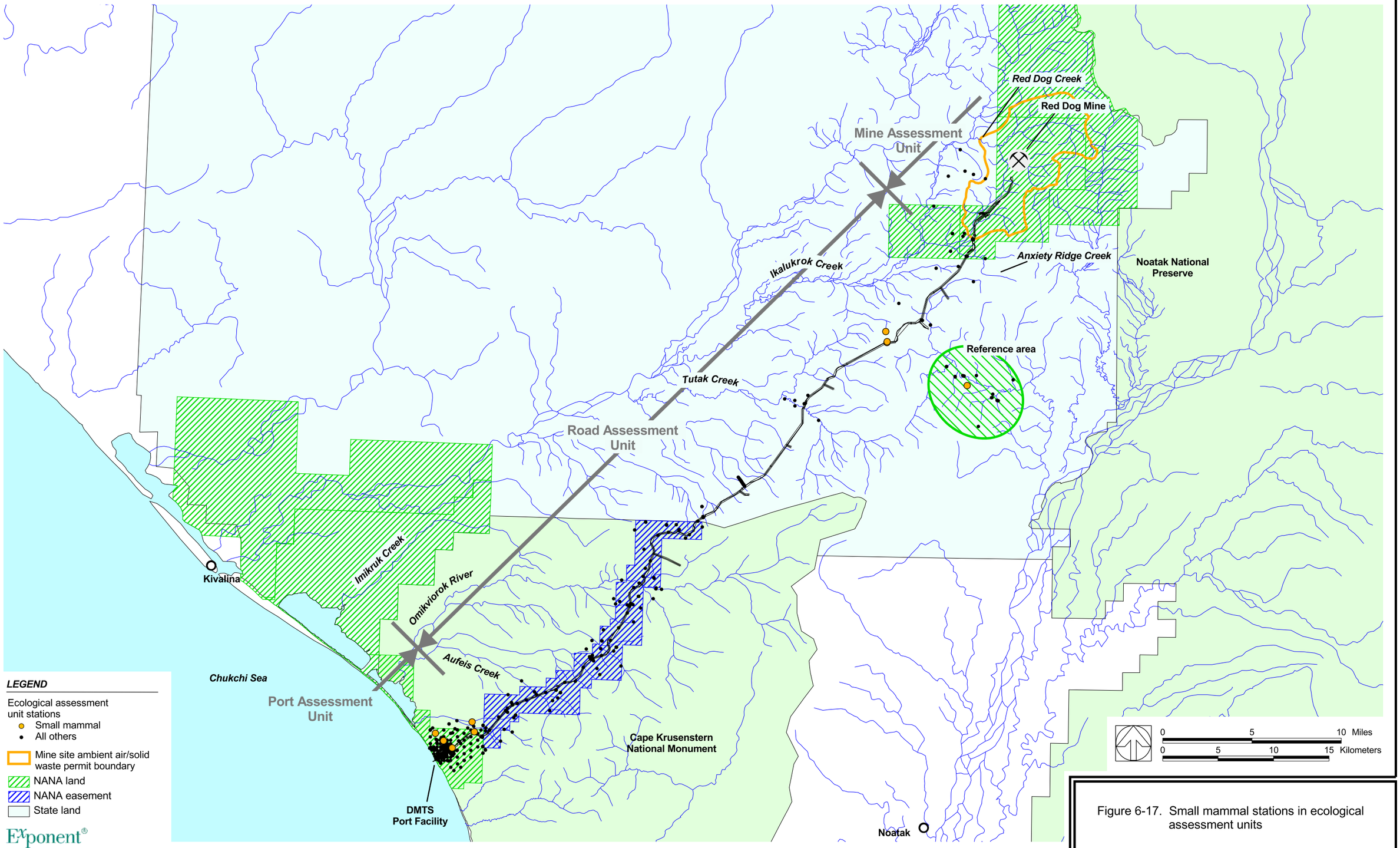


Figure 6-17. Small mammal stations in ecological assessment units

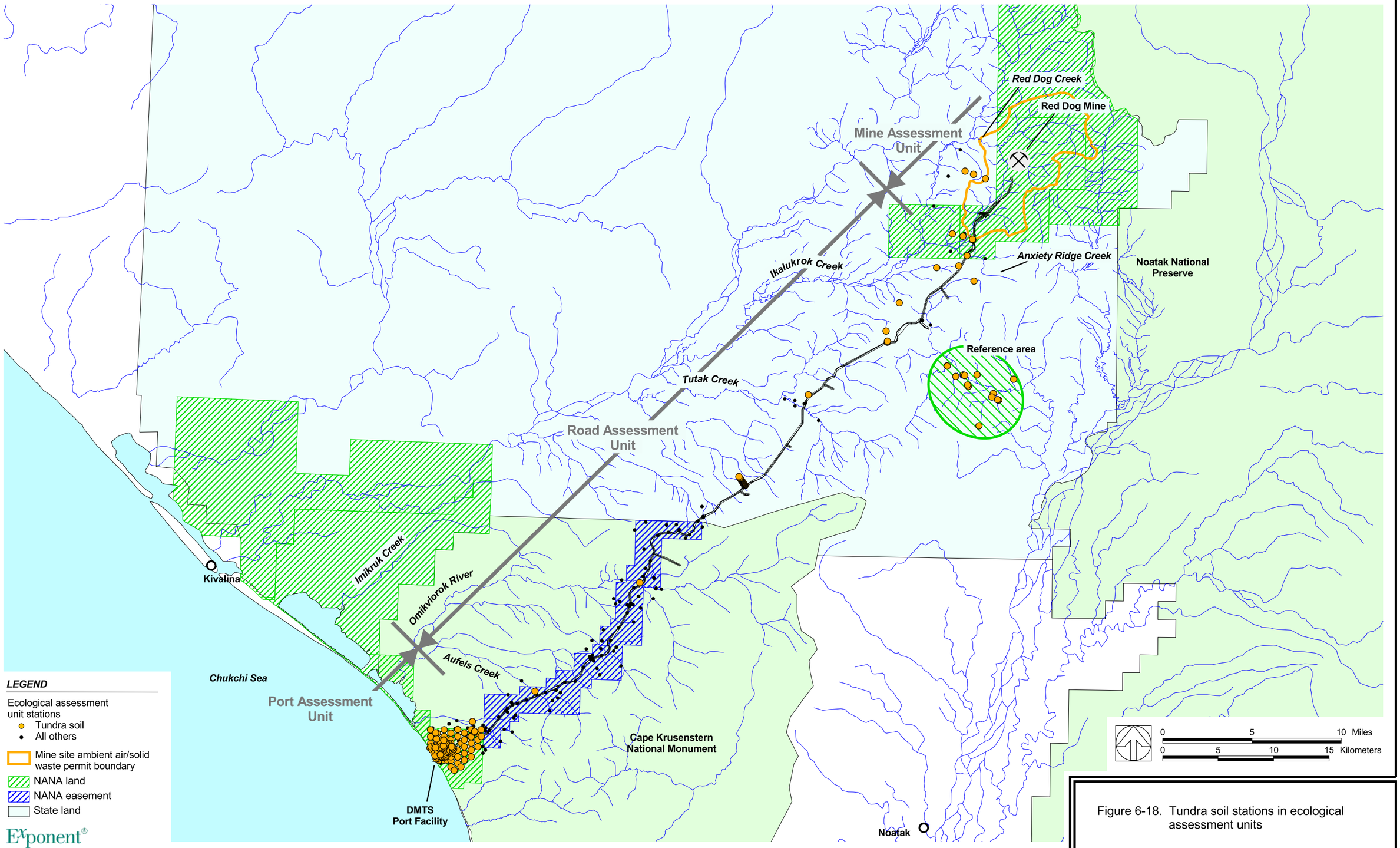


Figure 6-18. Tundra soil stations in ecological assessment units

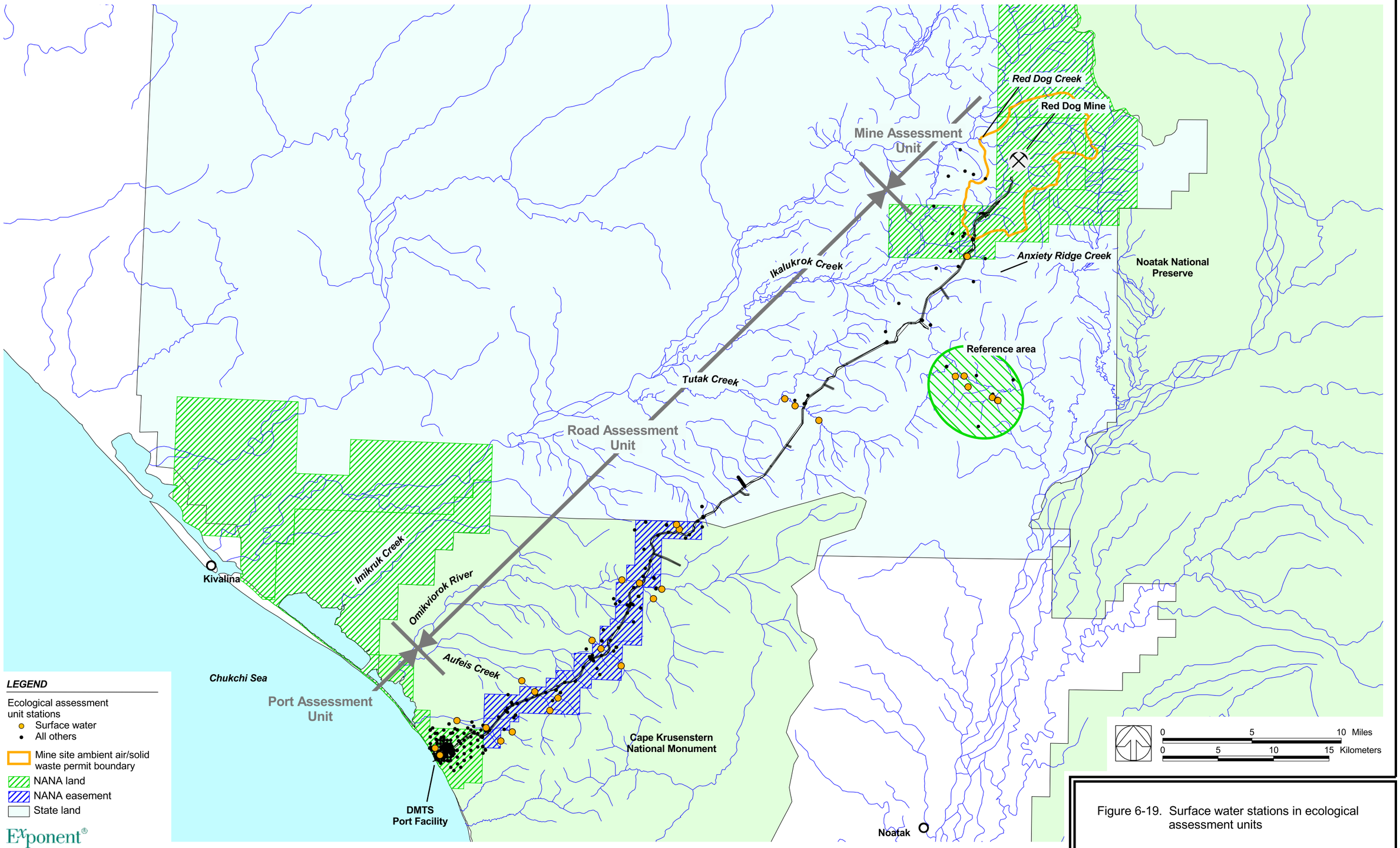
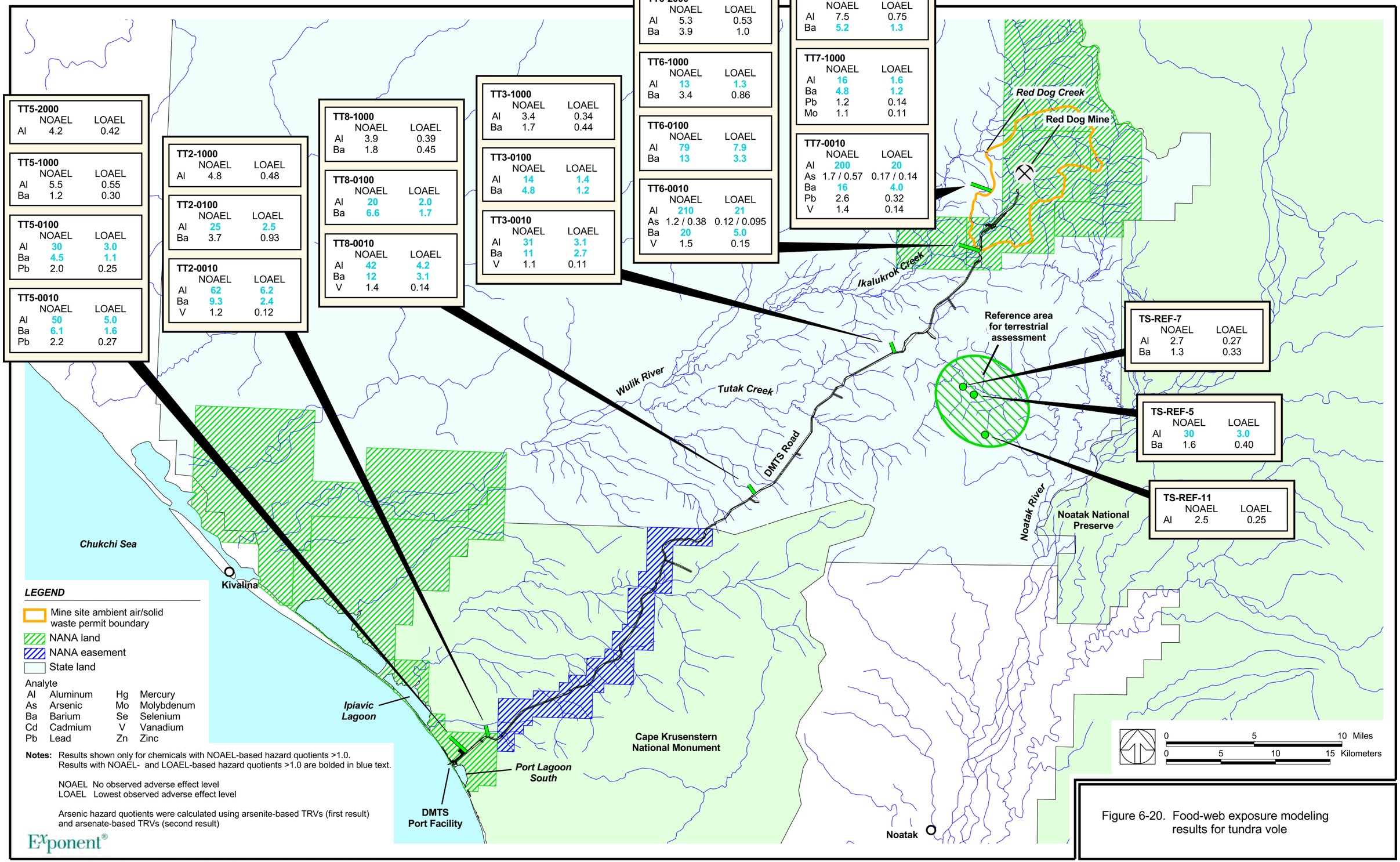


Figure 6-19. Surface water stations in ecological assessment units



Notes: Results shown only for chemicals with NOAEL-based hazard quotients >1.0.
Results with NOAEL- and LOAEL-based hazard quotients >1.0 are bolded in blue text.

NOAEL No observed adverse effect level
LOAEL Lowest observed adverse effect level

Arsenic hazard quotients were calculated using arsenite-based TRVs (first result) and arsenate-based TRVs (second result)

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Figure 6-20. Food-web exposure modeling results for tundra vole

TT5-2000

	NOAEL	LOAEL
Al	7.3	0.73
Cd	1.2	0.12
Hg	1.4	0.29
Se	1.5	0.90
Zn	1.1	0.55

TT5-1000

	NOAEL	LOAEL
Al	8.2	0.82
Hg	1.7	0.34
Se	1.3	0.77

TT5-0100

	NOAEL	LOAEL
Al	**39**	**3.9**
As	1.1 / 0.36	0.11 / 0.091
Ba	**7.0**	**1.8**
Cd	1.4	0.14
Pb	2.1	0.26
Hg	1.3	0.26
V	1.3	0.13
Zn	1.1	0.57

TT5-0010

	NOAEL	LOAEL
Al	**79**	**7.9**
As	1.5 / 0.50	0.15 / 0.13
Ba	**5.7**	**1.4**
Cd	4.1	0.41
Pb	2.4	0.29
Hg	2.4	0.49
Se	1.7	1.0
V	1.6	0.16
Zn	1.3	0.65

TT2-1000

	NOAEL	LOAEL
Al	6.6	0.66
Hg	1.1	0.22
Se	1.5	0.90

TT2-0100

	NOAEL	LOAEL
Al	**36**	**3.6**
Ba	4.1	1.0
Cd	1.2	0.12
Hg	1.2	0.24
Se	1.1	0.64
V	1.2	0.12

TT2-0010

	NOAEL	LOAEL
Al	**88**	**8.8**
As	1.3 / 0.41	0.13 / 0.10
Ba	**9.8**	**2.5**
Cd	2.6	0.26
Pb	1.4	0.17
Hg	1.3	0.27
V	1.6	0.16
Zn	1.2	0.59

TT3-1000

	NOAEL	LOAEL
Al	5.4	0.54

TT3-0100

	NOAEL	LOAEL
Al	**27**	**2.7**
Ba	**4.2**	**1.1**
Cd	1.5	0.15
Hg	2.5	0.49

TT3-0010

	NOAEL	LOAEL
Al	**50**	**5.0**
As	1.3 / 0.43	0.13 / 0.11
Ba	**12**	**3.1**
Cd	1.5	0.15
Hg	2.3	0.45
V	1.9	0.19

TT6-1000

	NOAEL	LOAEL
Al	5.9	0.59
Ba	**5.1**	**1.3**
Cd	2.0	0.20
Mo	1.2	0.12
V	1.6	0.16

TT6-0100

	NOAEL	LOAEL
Al	**27**	**2.7**
Ba	**28**	**7.2**
Cd	4.3	0.43
Hg	1.3	0.27

TT6-0010

	NOAEL	LOAEL
Al	**34**	**3.4**
As	1.5 / 0.49	0.15 / 0.12
Ba	**27**	**6.8**
Cd	2.0	0.20
V	1.9	0.19

TS-REF-5

	NOAEL	LOAEL
Al	**100**	**10**
Ba	1.6	0.42
Se	1.1	0.66
V	1.3	0.13

Red Dog Creek
Red Dog Mine
TT7
Ikalukrok Creek
Reference area for terrestrial assessment
Wulik River
Tutak Creek
TS-REF-7
TS-REF-11
TT8
DMTS Road
Noatak River
Noatak National Preserve
Chukchi Sea
Kivalina
Ipiavic Lagoon
Cape Krusenstern National Monument
Port Lagoon South
DMTS Port Facility
Noatak

LEGEND

- Mine site ambient air/solid waste permit boundary
- NANA land
- NANA easement
- State land

Analyte

Al	Aluminum	Hg	Mercury
As	Arsenic	Mo	Molybdenum
Ba	Barium	Se	Selenium
Cd	Cadmium	V	Vanadium
Pb	Lead	Zn	Zinc

Notes: Results shown only for chemicals with NOAEL-based hazard quotients >1.0.
Results with NOAEL- and LOAEL-based hazard quotients >1.0 are bolded in blue text.

NOAEL No observed adverse effect level
LOAEL Lowest observed adverse effect level

Arsenic hazard quotients were calculated using arsenite-based TRVs (first result) and arsenate-based TRVs (second result)

0 5 10 Miles
0 5 10 15 Kilometers

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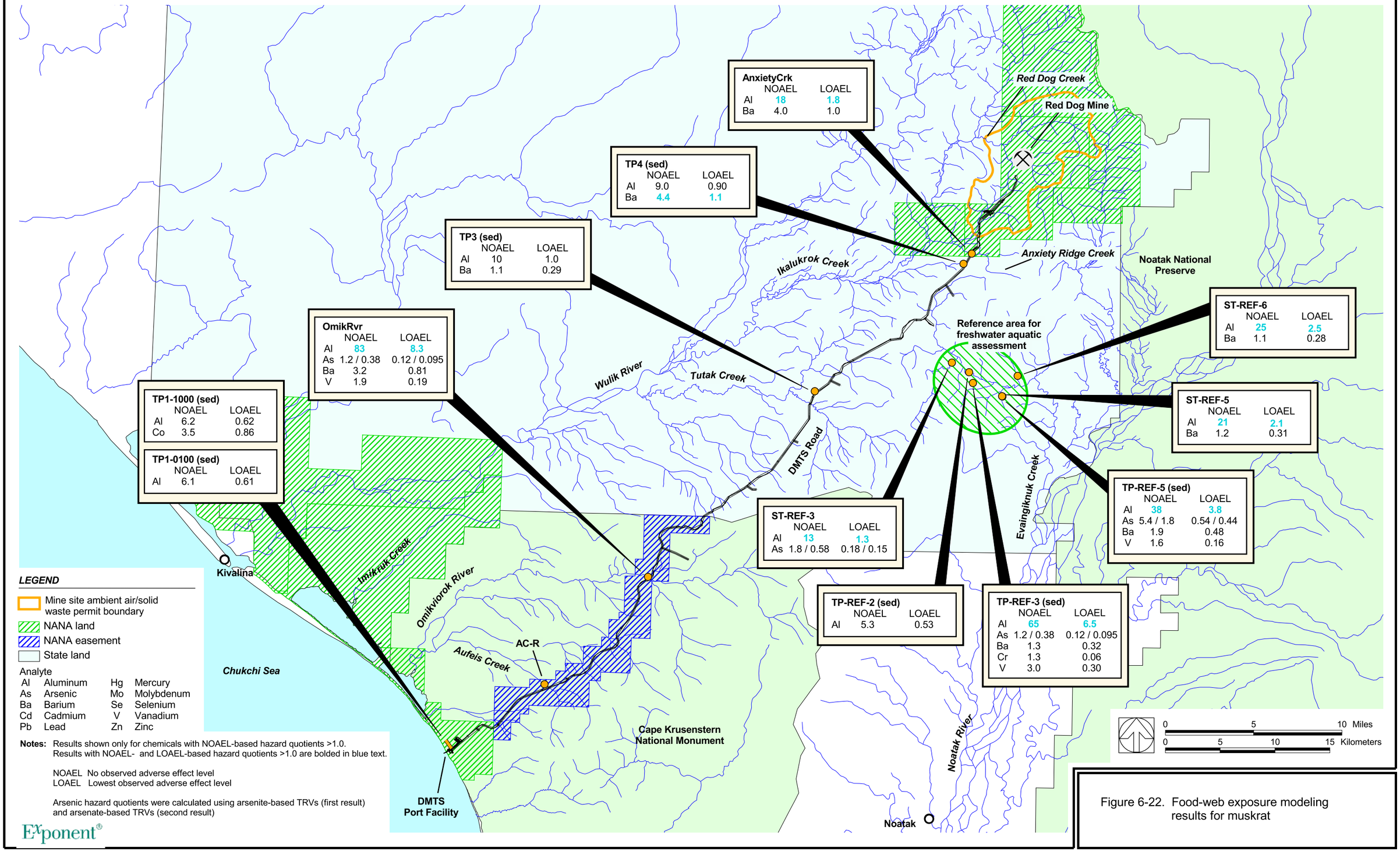
Figure 6-21. Food-web exposure modeling results for tundra shrew



Notes: Results shown only for chemicals with NOAEL-based hazard quotients >1.0.
Results with NOAEL- and LOAEL-based hazard quotients >1.0 are bolded in blue text.

NOAEL No observed adverse effect level
LOAEL Lowest observed adverse effect level

Arsenic hazard quotients were calculated using arsenite-based TRVs (first result) and arsenate-based TRVs (second result)

Figure 6-22. Food-web exposure modeling results for muskrat

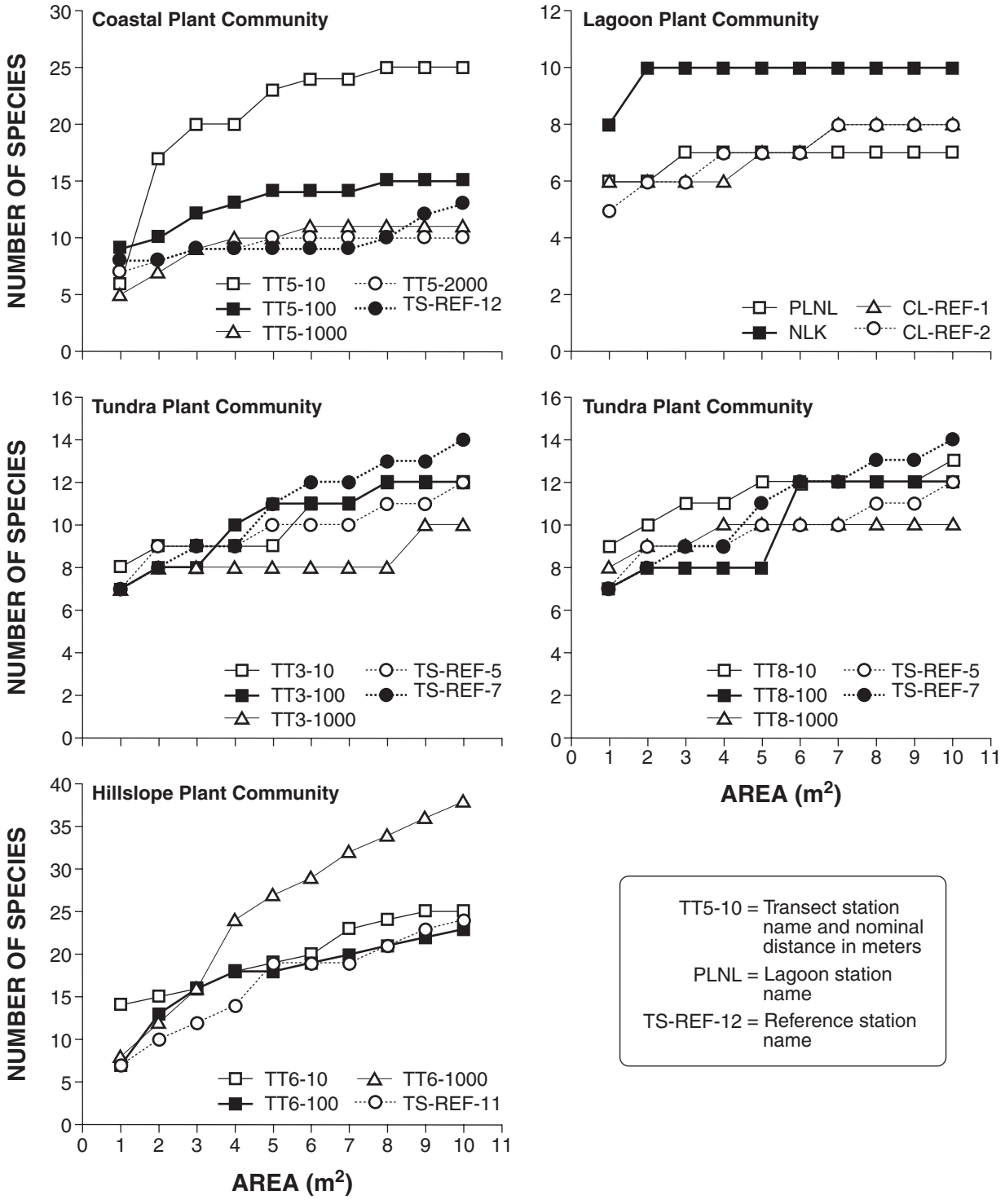


Figure 6-23. Species area curves for plant community surveys