

# **Meteorological Monitoring for the Pebble Project**



**November 2007**

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# Introduction

- **Baseline Meteorological Monitoring Program**
- **Objectives – Collect Meteorological Data to Support:**
  - Air Quality Permit Application
  - Other Environmental Studies
  - Engineering Design (water balance, etc.)
- **PSD vs. non-PSD**
  - PSD (Prevention of Significant Deterioration) stations will collect data in accordance with all EPA PSD requirements
  - Non-PSD stations are operated primarily to obtain precipitation and evaporation measurements and will collect data in accordance with most EPA PSD requirements.



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# **Meteorological Station Nomenclature**

- **Pebble 1 Station (mill site, PSD )**
- **Pebble 2 station (formerly tsf site, decommissioned)**
- **Pebble 3 station**
- **Pebble 4 station (tailings storage facility site, PSD )**
- **Pebble 5 station (PSD)**
- **Pebble 5A station**
- **Pebble 6 station (PSD)**
- **Williamsport (PSD)**
- **North Head (PSD)**
- **Pebble Port (port site, PSD)**



# Meteorological Monitoring Timeline

- **Installation of Pebble 1 and Pebble 2 as non-PSD stations**
  - *October 6 through 10, 2004.*
  - *October 21 through 26, 2004.*
- **Pebble 1 converted to PSD Station**
  - *June 11, 2005*
- **Pebble 2 Moved and Reestablished as Pebble 3**
  - *November 19, 2005*
- **Pebble 4 PSD Station Installation Completed**
  - *June 11, 2006*
- **Installation of Pebble Port PSD station**
  - *June 21, 2005*
- **Pebble 1 and Pebble Port First Annual PSD Monitoring Period**
  - *August 1, 2005 to July 31, 2006*



# Meteorological Monitoring Timeline

- **Pebble 1 and Pebble Port Second Annual PSD Monitoring Period, and Pebble 4 First Annual PSD Monitoring Period**
  - *August 1, 2006 to July 31, 2007*
- **Installation of Pebble 5 and Pebble 5A stations**
  - *June 13, 2007 to July 1, 2007*
- **Installation of Williamsport station**
  - *July 9, 2007 to July 22, 2007*
- **Installation of Pebble 6 station**
  - *July 27, 2007 to August 4, 2007*
- **Installation of North Head station**
  - *September 21, 2007 to September 28, 2007*

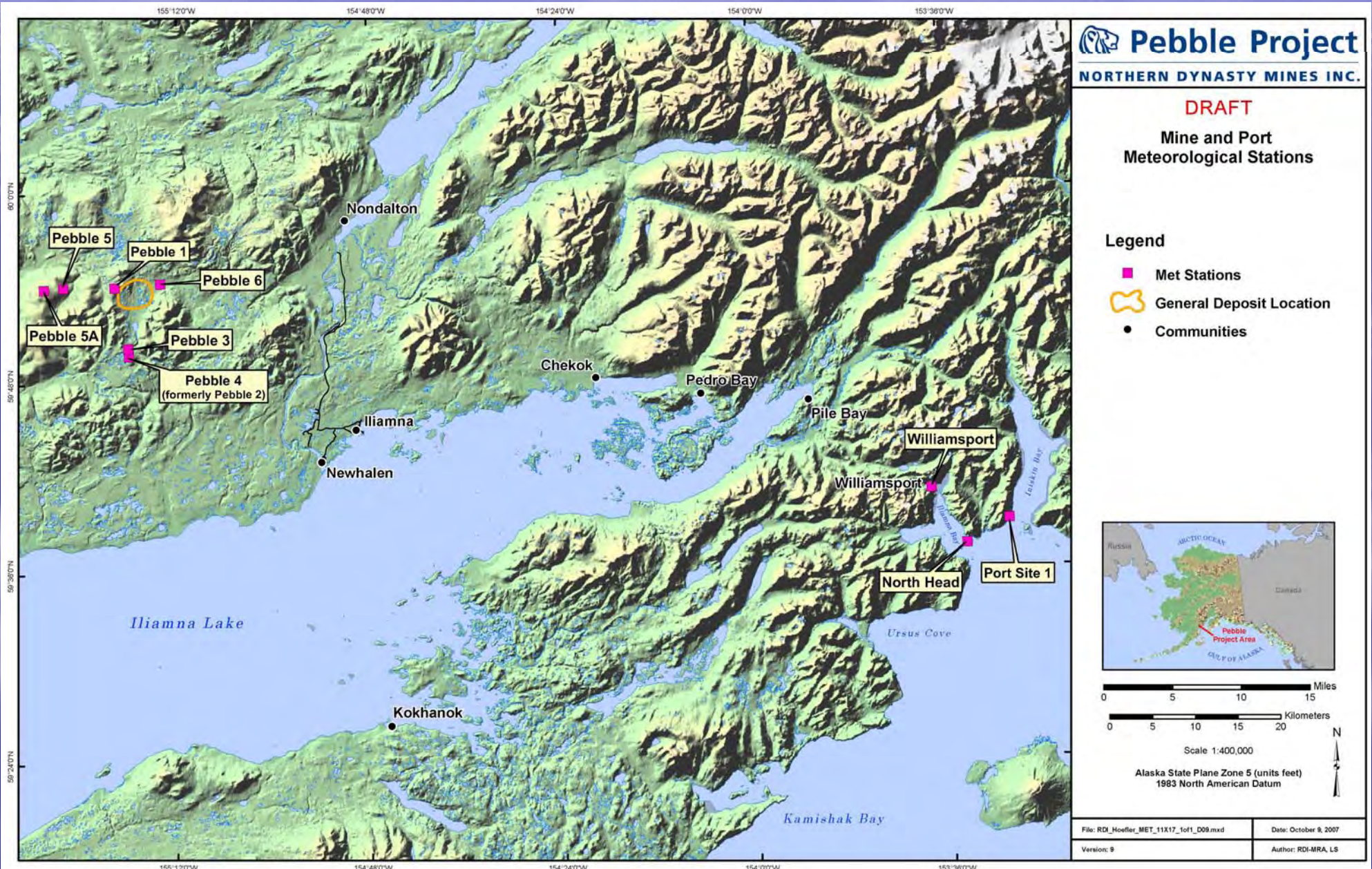




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# Meteorological Station Location Map



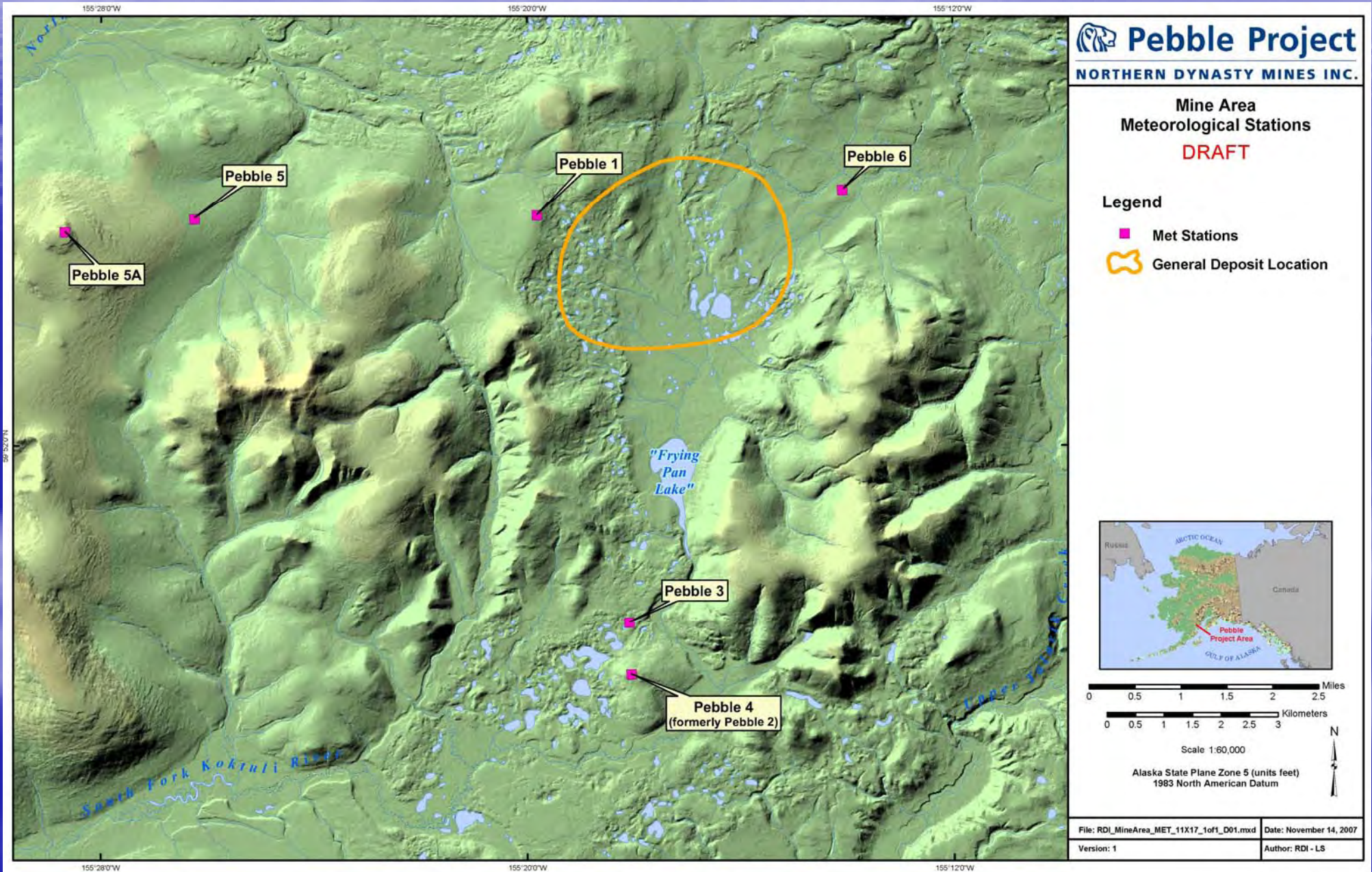




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# Mine Area Meteorological Station Location Map



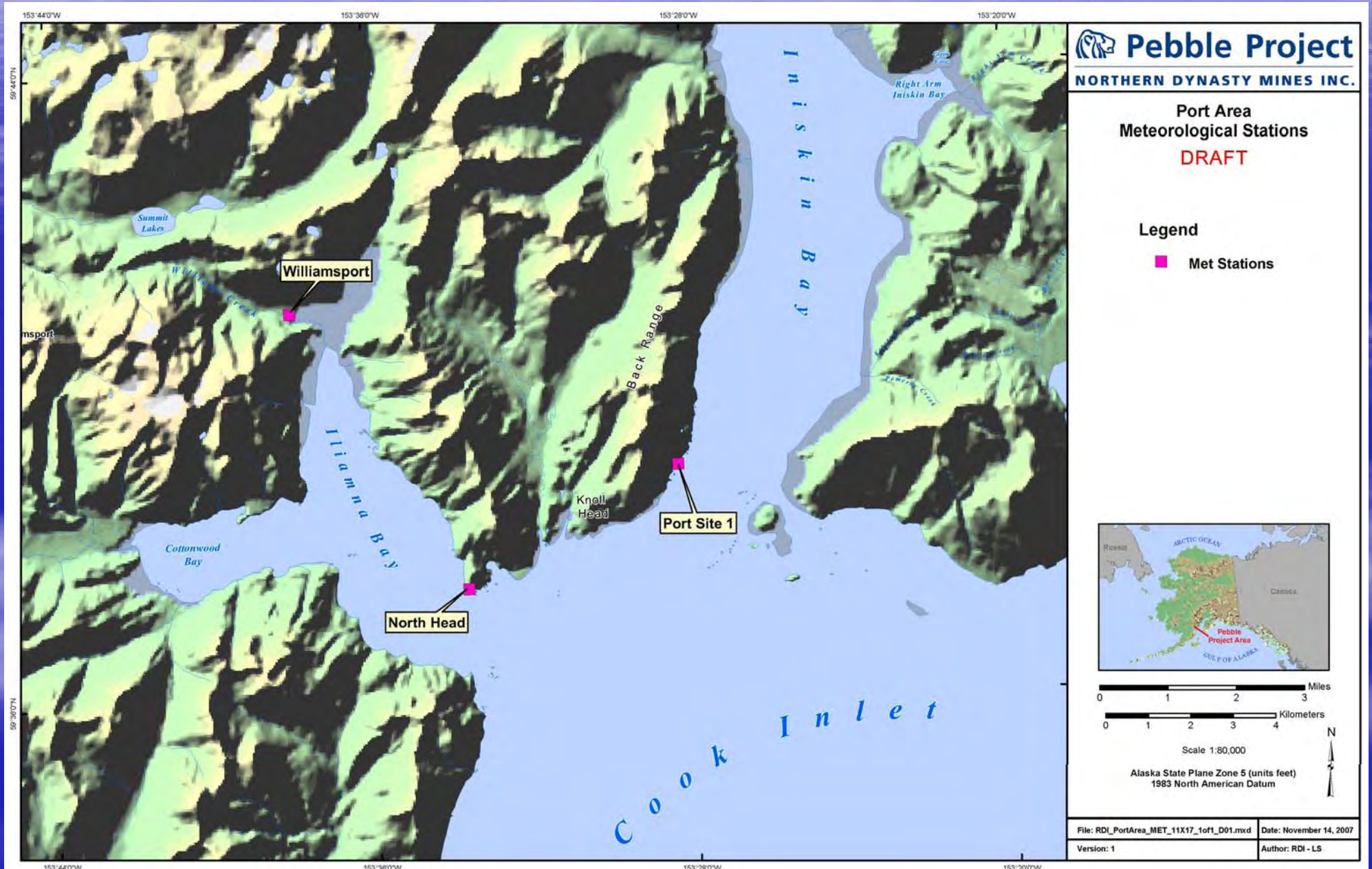




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# Port Area Meteorological Station Location Map









# **Meteorological Monitoring Significant Data Gaps**

- **Air temperature 1/1/2005 – 1/28/2005 (Pebble 1 and 2)**
- **Precipitation 2/21/2005 – 3/29/2005 (Pebble 1 and 2)**
- **Air temperature 6/18/2005 – 7/21/2005 (Pebble 1)**
- **Air temperature 5/11/2005 – 10/8/2005 (Pebble 2)**
- **Precipitation 10/24/2005 – 11/3/2005 (Pebble 1 and 2)**
- **Precipitation 10/9/2005 – 10/18/2005 (Pebble 2)**
- **Air temperature 7/25/2005 – 8/4/2005 (Pebble Port)**
- **Temperature difference 1/17/2007 – 9/2/2007 (Pebble 1)**





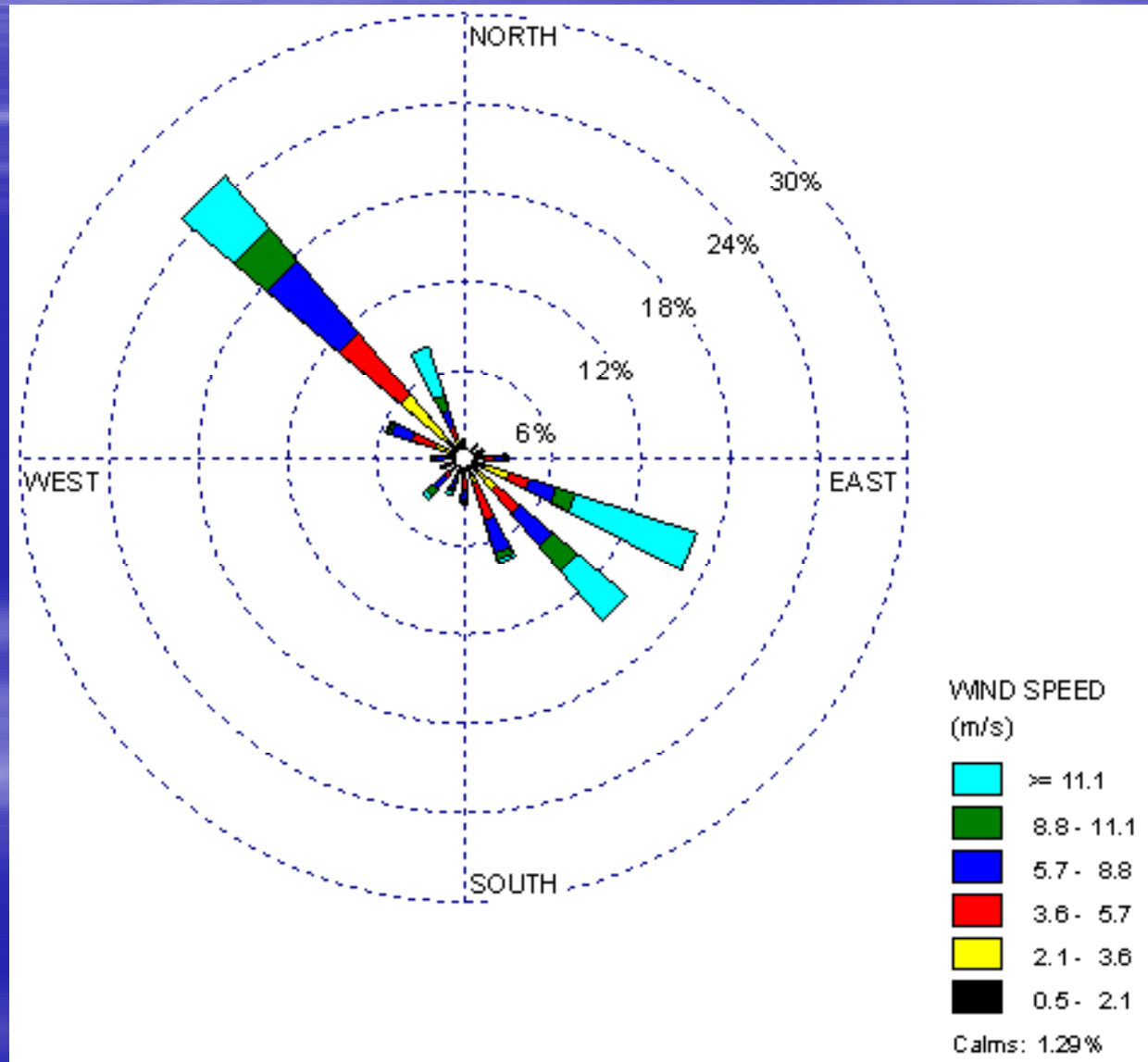
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# Pebble 1 Station

## Wind Rose

(Pebble 1 or Mill Site)





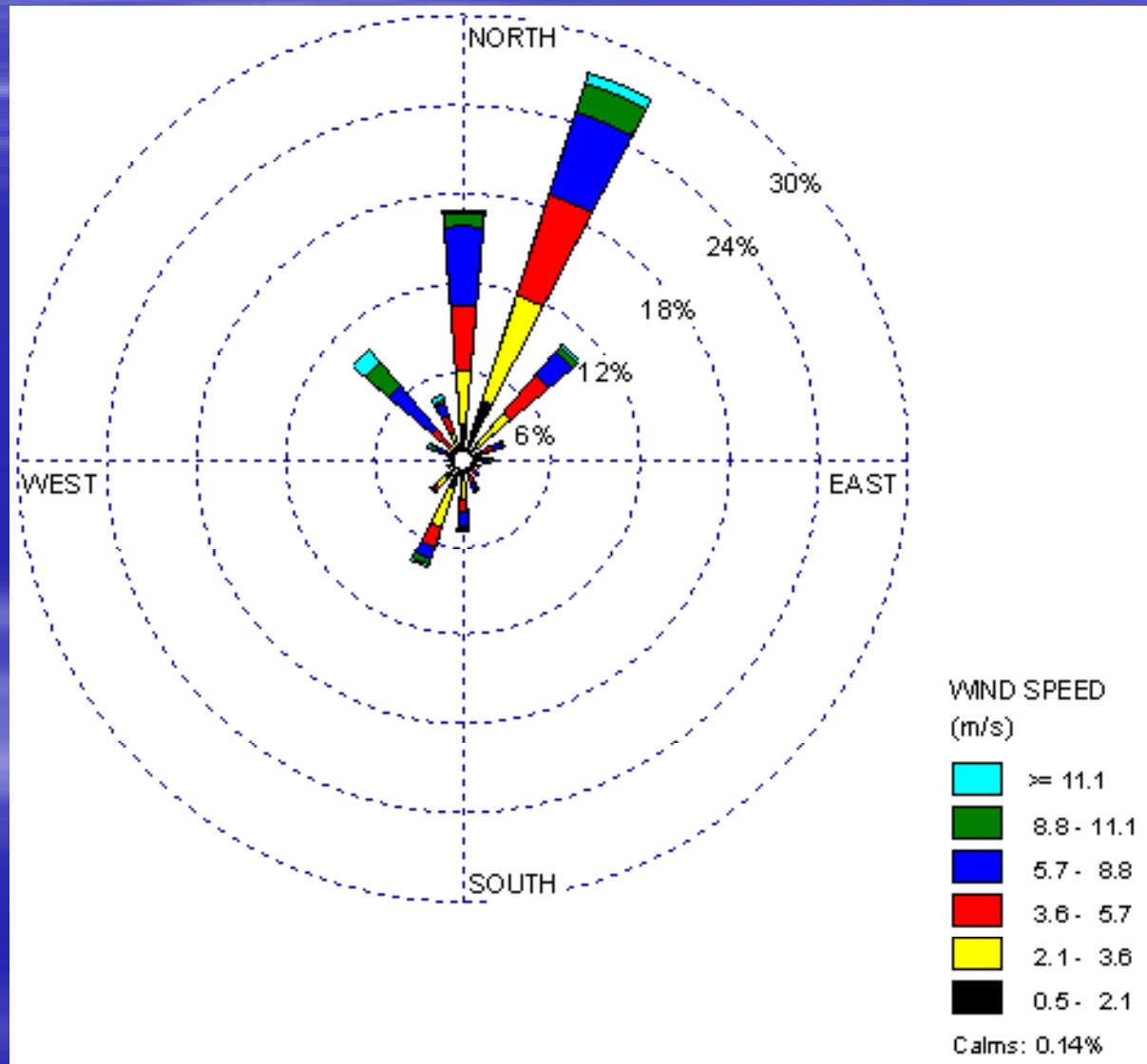
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# Pebble Port Station

## Wind Rose

(Pebble Port or Port Site)







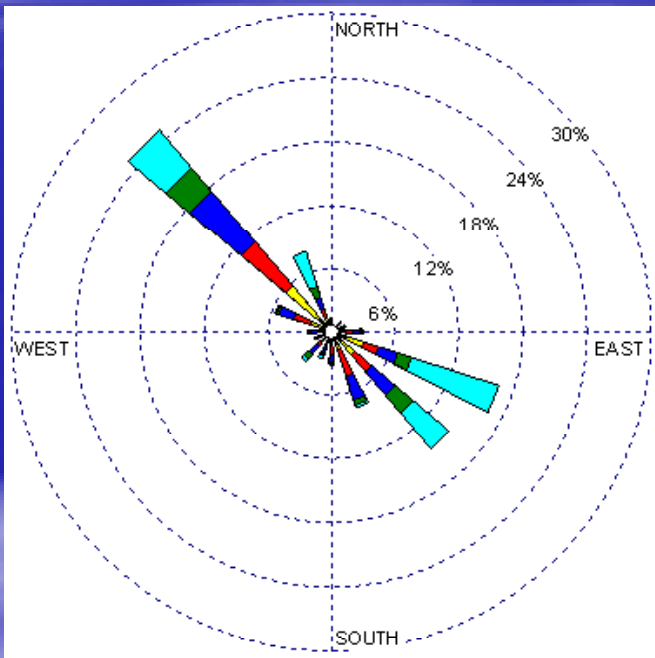
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# Pebble Area Wind Roses

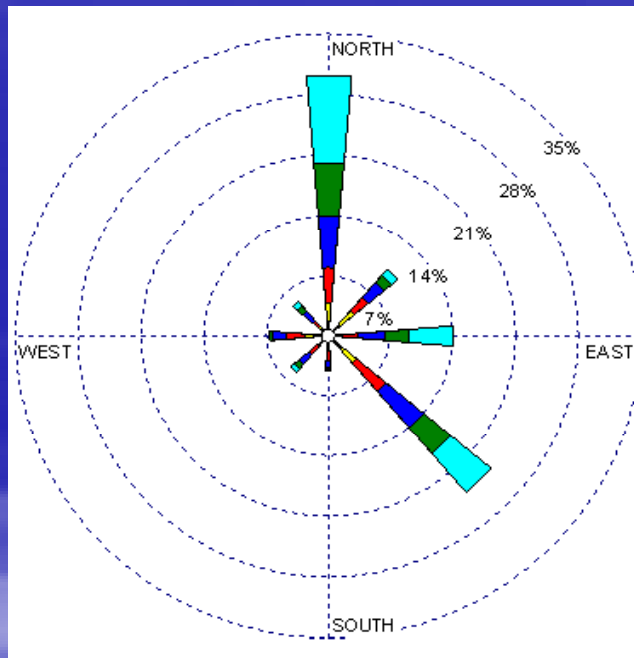
## Pebble 1 (Mill site)

August 2005 – July 2007



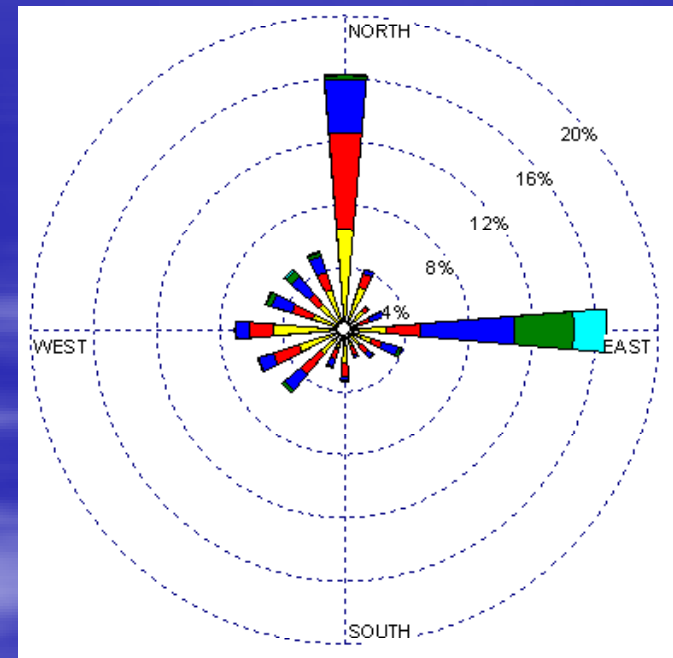
## Pebble 4 (TSF site)

August 2006 – July 2007



## Iliamna Airport (NWS ASOS)

August 2005 – July 2007





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# Wind Speeds (monthly mean; m/s)

## Pebble Project Monthly Average Wind Speed (m/s)

Year	Month	Pebble 1	Pebble 3	Pebble 4	Iliamna	Pebble Port
2006	January	6.9	4.8	-	4.2	5.5
	February	12.1	6.4	-	6.6	6.4
	March	8.0	5.0	-	4.6	5.1
	April	8.0	5.0	-	5.0	5.0
	May	7.3	4.4	-	4.6	3.9
	June	7.7	4.3	-	4.5	3.3
	July	6.0	3.8	6.0	4.1	3.9
	August	5.8	3.6	5.9	3.7	3.9
	September	7.2	3.7	6.6	3.9	4.2
	October	8.9	5.2	9.1	5.6	4.9
	November	10.7	7.9	12.7	5.6	5.3
	December	7.3	6.3	9.1	5.0	6.1
2007	January	10.5	6.6	10.8	5.3	6.9
	February	8.0	4.9	8.0	3.2	4.3
	March	11.3	7.6	11.9	3.8	5.7
	April	8.9	5.5	8.5	3.8	5.4
	May	5.8	3.3	5.4	2.6	3.7
	June	6.3	3.8	6.4	2.6	3.3
	July	4.7	2.8	4.5	2.3	3.0





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# Wind Speeds

(maximum hourly average;

## Pebble Project Maximum Hourly Average Wind Speed (m/s)

Year	Month	Pebble 1	Pebble 3	Pebble 4	Iliamna	Pebble Port
2006	January	26.8	17.5	-	11.6	20.4
	February	30.9	17.2	-	17.4	16.3
	March	31.9	15.6	-	16.1	16.2
	April	23.2	17.0	-	13.4	14.8
	May	24.9	14.6	-	13.4	11.5
	June	26.1	14.8	-	11.6	10.9
	July	18.7	10.2	16.5	10.3	16.0
	August	19.2	9.2	16.6	6.7	13.6
	September	24.7	12.5	23.6	12.1	11.9
	October	28.2	13.6	26.3	12.5	14.2
	November	30.7	21.1	34.9	14.3	15.1
	December	26.8	17.0	24.5	10.7	18.4
2007	January	40.0	17.2	31.3	11.6	16.6
	February	30.2	16.2	26.7	10.7	13.6
	March	29.0	22.3	37.6	10.3	16.5
	April	30.3	22.7	30.0	12.1	14.3
	May	18.0	9.1	17.2	7.2	11.1
	June	18.7	11.6	19.4	6.7	11.5
	July	12.9	7.5	11.5	7.6	13.4



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# Air Temperature (monthly average; degrees C)

## Pebble Project Monthly Average Temperature (deg. C)

<u>Year</u>	<u>Month</u>	<u>Pebble 1</u>	<u>Pebble 3</u>	<u>Pebble 4</u>	<u>Iliamna</u>	<u>Pebble Port</u>
<b>2006</b>	<b>January</b>	<b>-16.1</b>	<b>-15.3</b>	<b>-</b>	<b>-15.1</b>	<b>-7.5</b>
	<b>February</b>	<b>-7.6</b>	<b>-6.7</b>	<b>-</b>	<b>-5.3</b>	<b>-2.7</b>
	<b>March</b>	<b>-8.9</b>	<b>-7.9</b>	<b>-</b>	<b>-7.4</b>	<b>-3.1</b>
	<b>April</b>	<b>-4.2</b>	<b>-2.5</b>	<b>-</b>	<b>-1.2</b>	<b>1.2</b>
	<b>May</b>	<b>4.8</b>	<b>6.0</b>	<b>-</b>	<b>7.2</b>	<b>7.5</b>
	<b>June</b>	<b>8.3</b>	<b>9.2</b>	<b>-</b>	<b>10.4</b>	<b>10.2</b>
	<b>July</b>	<b>10.6</b>	<b>11.4</b>	<b>11.0</b>	<b>12.5</b>	<b>12.5</b>
	<b>August</b>	<b>9.0</b>	<b>9.9</b>	<b>12.5</b>	<b>11.3</b>	<b>12.5</b>
	<b>September</b>	<b>7.1</b>	<b>7.9</b>	<b>10.1</b>	<b>9.5</b>	<b>10.1</b>
	<b>October</b>	<b>1.1</b>	<b>2.2</b>	<b>5.7</b>	<b>4.4</b>	<b>5.7</b>
	<b>November</b>	<b>-13.4</b>	<b>-12.0</b>	<b>-4.7</b>	<b>-8.8</b>	<b>-4.7</b>
	<b>December</b>	<b>-10.0</b>	<b>-9.1</b>	<b>-3.3</b>	<b>-8.2</b>	<b>-3.3</b>
<b>2007</b>	<b>January</b>	<b>-12.2</b>	<b>-11.2</b>	<b>-5.9</b>	<b>-10.8</b>	<b>-5.9</b>
	<b>February</b>	<b>-7.6</b>	<b>-6.7</b>	<b>-2.5</b>	<b>-5.2</b>	<b>-2.5</b>
	<b>March</b>	<b>-17.5</b>	<b>-16.1</b>	<b>-9.2</b>	<b>-14.1</b>	<b>-9.2</b>
	<b>April</b>	<b>0.6</b>	<b>1.4</b>	<b>4.1</b>	<b>2.6</b>	<b>4.1</b>
	<b>May</b>	<b>4.0</b>	<b>4.8</b>	<b>6.9</b>	<b>5.9</b>	<b>6.9</b>
	<b>June</b>	<b>8.4</b>	<b>9.5</b>	<b>10.5</b>	<b>10.7</b>	<b>10.5</b>
	<b>July</b>	<b>11.1</b>	<b>12.0</b>	<b>12.4</b>	<b>13.4</b>	<b>12.4</b>



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# Air Temperature (Minimum; degrees C)

## Pebble Project Minimum Hourly Average Temperature (deg. C)

Year	Month	Pebble 1	Pebble 3	Pebble 4	Iliamna	Pebble Port
2006	January	-35.3	-33.4	-	-32.2	-24.1
	February	-31.6	-29.9	-	-30.6	-19.5
	March	-23.8	-22.7	-	-22.2	-12.9
	April	-16.4	-14.4	-	-15.0	-5.6
	May	-7.2	-11.0	-	-6.1	-1.5
	June	-0.1	0.8	-	1.7	4.5
	July	5.7	3.8	5.5	7.2	8.0
	August	4.1	1.0	4.3	8.9	7.2
	September	-2.3	-5.6	-1.1	3.3	-1.6
	October	0.0	-10.2	2.5	-4.4	0.0
	November	-24.3	-22.6	-23.2	-18.3	-13.0
	December	-21.9	-25.3	-21.0	-19.4	-13.3
2007	January	-33.8	-31.0	-31.1	-28.9	-21.3
	February	-23.3	-21.4	-21.9	-16.7	-13.4
	March	-28.9	-27.2	-27.9	-20.0	-17.1
	April	-5.1	-11.0	-4.5	-6.7	-2.5
	May	-1.9	-4.5	-0.8	2.2	0.9
	June	1.1	-0.2	1.7	6.7	5.4
	July	6.1	2.5	6.4	9.4	7.7





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# Air Temperature (Maximum; degrees C)

## Pebble Project Maximum Hourly Average Temperature (deg. C)

<b>Year</b>	<b>Month</b>	<b>Pebble 1</b>	<b>Pebble 3</b>	<b>Pebble 4</b>	<b>Iliamna</b>	<b>Pebble Port</b>
<b>2006</b>	<b>January</b>	<b>1.3</b>	<b>1.8</b>	<b>-</b>	<b>2.8</b>	<b>5.2</b>
	<b>February</b>	<b>1.4</b>	<b>2.7</b>	<b>-</b>	<b>5.0</b>	<b>6.3</b>
	<b>March</b>	<b>0.0</b>	<b>5.6</b>	<b>-</b>	<b>4.4</b>	<b>2.3</b>
	<b>April</b>	<b>1.8</b>	<b>8.2</b>	<b>-</b>	<b>8.3</b>	<b>7.6</b>
	<b>May</b>	<b>23.0</b>	<b>24.3</b>	<b>-</b>	<b>26.7</b>	<b>17.7</b>
	<b>June</b>	<b>19.3</b>	<b>20.8</b>	<b>-</b>	<b>20.6</b>	<b>19.3</b>
	<b>July</b>	<b>22.4</b>	<b>22.9</b>	<b>24.3</b>	<b>23.3</b>	<b>21.9</b>
	<b>August</b>	<b>16.8</b>	<b>17.5</b>	<b>16.8</b>	<b>15.0</b>	<b>20.3</b>
	<b>September</b>	<b>15.8</b>	<b>17.3</b>	<b>17.0</b>	<b>12.2</b>	<b>17.0</b>
	<b>October</b>	<b>10.6</b>	<b>11.8</b>	<b>11.2</b>	<b>9.4</b>	<b>12.5</b>
	<b>November</b>	<b>-0.8</b>	<b>0.6</b>	<b>-0.3</b>	<b>1.1</b>	<b>2.9</b>
	<b>December</b>	<b>1.3</b>	<b>2.7</b>	<b>2.2</b>	<b>2.8</b>	<b>5.1</b>
<b>2007</b>	<b>January</b>	<b>5.4</b>	<b>6.1</b>	<b>5.4</b>	<b>5.0</b>	<b>8.6</b>
	<b>February</b>	<b>6.4</b>	<b>6.6</b>	<b>5.5</b>	<b>4.4</b>	<b>10.4</b>
	<b>March</b>	<b>-0.1</b>	<b>6.9</b>	<b>1.7</b>	<b>-5.6</b>	<b>1.1</b>
	<b>April</b>	<b>9.2</b>	<b>9.2</b>	<b>9.9</b>	<b>7.2</b>	<b>10.5</b>
	<b>May</b>	<b>12.2</b>	<b>13.6</b>	<b>11.7</b>	<b>8.9</b>	<b>14.5</b>
	<b>June</b>	<b>21.8</b>	<b>23.4</b>	<b>22.5</b>	<b>20.0</b>	<b>25.2</b>
	<b>July</b>	<b>21.4</b>	<b>23.2</b>	<b>22.6</b>	<b>18.9</b>	<b>20.1</b>



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# Precipitation (monthly totals; mm)

## Pebble Project Monthly Total Precipitation (mm)

<b>Year</b>	<b>Month</b>	<b>Pebble 1</b>	<b>Pebble 3</b>	<b>Pebble 4</b>	<b>Iliamna</b>
<b>2006</b>	<b>January</b>	<b>9.1</b>	<b>1.8</b>	<b>-</b>	<b>81.0</b>
	<b>February</b>	<b>135.4</b>	<b>43.7</b>	<b>-</b>	<b>89.7</b>
	<b>March</b>	<b>69.8</b>	<b>32.8</b>	<b>-</b>	<b>83.1</b>
	<b>April</b>	<b>51.3</b>	<b>19.1</b>	<b>-</b>	<b>44.5</b>
	<b>May</b>	<b>21.8</b>	<b>13.0</b>	<b>-</b>	<b>15.7</b>
	<b>June</b>	<b>81.3</b>	<b>57.9</b>	<b>-</b>	<b>80.3</b>
	<b>July</b>	<b>19.8</b>	<b>27.2</b>	<b>-</b>	<b>34.8</b>
	<b>August</b>	<b>213.6</b>	<b>223.5</b>	<b>224.4</b>	<b>196.1</b>
	<b>September</b>	<b>132.3</b>	<b>178.8</b>	<b>135.0</b>	<b>5.6</b>
	<b>October</b>	<b>176.5</b>	<b>168.1</b>	<b>150.0</b>	<b>4.6</b>
	<b>November</b>	<b>30.5</b>	<b>9.4</b>	<b>0.4</b>	<b>1.3</b>
	<b>December</b>	<b>67.3</b>	<b>34.3</b>	<b>16.8</b>	<b>0.0</b>
<b>2007</b>	<b>January</b>	<b>38.6</b>	<b>29.2</b>	<b>34.6</b>	<b>0.0</b>
	<b>February</b>	<b>9.7</b>	<b>11.2</b>	<b>5.2</b>	<b>0.0</b>
	<b>March</b>	<b>27.9</b>	<b>13.2</b>	<b>5.6</b>	<b>0.0</b>
	<b>April</b>	<b>46.0</b>	<b>35.1</b>	<b>30.8</b>	<b>1.0</b>
	<b>May</b>	<b>20.3</b>	<b>17.8</b>	<b>16.4</b>	<b>0.0</b>
	<b>June</b>	<b>56.4</b>	<b>61.0</b>	<b>59.0</b>	<b>41.9</b>
	<b>July</b>	<b>60.5</b>	<b>58.9</b>	<b>59.2</b>	<b>67.3</b>



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# Precipitation

## (Max Daily Precipitation; mm)

### Pebble Project Maximum Daily Precipitation (mm)

Year	Month	Pebble 1	Pebble 3	Pebble 4	Iliamna
2006	January	2.3	1.3	-	10.2
	February	17.8	16.5	-	9.1
	March	21.1	17.8	-	20.1
	April	9.1	6.1	-	11.2
	May	5.8	5.6	-	4.6
	June	16.3	14.7	-	13.7
	July	9.1	6.4	9.4	7.9
	August	18.3	27.2	5.8	42.7
	September	4.8	17.3	5.0	1.0
	October	8.1	6.9	6.2	2.3
	November	2.5	1.3	0.2	1.3
	December	3.3	1.5	3.2	0.0
2007	January	4.3	6.4	3.6	0.0
	February	0.8	5.1	2.6	0.0
	March	1.5	1.0	1.2	0.0
	April	1.5	2.5	3.0	1.0
	May	1.3	1.0	1.8	0.0
	June	2.8	3.0	3.4	27.4
	July	5.6	6.4	5.6	18.5





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# Evaporation (monthly totals; mm)

## Pebble Project Monthly Total Pan Evaporation (mm)

<b>Year</b>	<b>Month</b>	<b>Pebble 1</b>	<b>Pebble 3</b>	<b>Pebble 4</b>
<b>2006</b>	<b>January</b>	-	-	-
	<b>February</b>	-	-	-
	<b>March</b>	-	-	-
	<b>April</b>	-	-	-
	<b>May</b>	<b>88.1</b>	-	<b>104.7</b>
	<b>June</b>	<b>69.8</b>	-	<b>81.2</b>
	<b>July</b>	<b>70.4</b>	-	<b>75.1</b>
	<b>August</b>	<b>17.8</b>	-	<b>20.5</b>
	<b>September</b>	<b>16.5</b>	-	<b>25.3</b>
	<b>October</b>	-	-	-
	<b>November</b>	-	-	-
	<b>December</b>	-	-	-
<b>2007</b>	<b>January</b>	-	-	-
	<b>February</b>	-	-	-
	<b>March</b>	-	-	-
	<b>April</b>	-	-	-
	<b>May</b>	<b>56.4</b>	<b>98.1</b>	<b>63.6</b>
	<b>June</b>	<b>71.5</b>	<b>61.4</b>	<b>92.5</b>
	<b>July</b>	<b>48.3</b>	<b>95.8</b>	<b>65.8</b>



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# Extreme Observations for Station Records [Metric Units]

	Pebble 1 (Mill Site)	Pebble 3	Pebble 4 (TSF PSD)	Pebble 5	Pebble 5A	Pebble 6	Williamspo rt	North Head	Pebble Port (Port Site)
<b>Maximum Hourly Wind Speed (m/s)</b>	40.0	22.7	37.6	20.8	35.7	16.7	13.2	24.6	20.4
<b>Maximum Wind Gust (m/s)</b>	59.2	57.9	61.3	30.4	50.6	50.9	38.0	39.7	39.5
<b>Maximum Hourly Air Temperature (deg. C)</b>	23.6	24.3	24.3	22.6	22.2	23.4	22.8	12.6	25.2
<b>Minimum Hourly Air Temperature (deg. C)</b>	-35.5	-33.4	-31.1	-9.8	-9.6	-14.7	-6.6	-1.3	-24.1
<b>Maximum Daily Precipitation (mm)</b>	30.6	27.2	9.4	38.9	-	37.6	-	-	-
<b>Maximum Monthly Evaporation (summer only, mm)</b>	107.8	98.1	104.7	144.4	-	120.9	-	-	-



**Pebble Project**

**NORTHERN DYNASTY MINES INC.**

# Extreme Observations for Station Records [English Units]

	Pebble 1 (Mill Site)	Pebble 3	Pebble 4 (TSF PSD)	Pebble 5	Pebble 5A	Pebble 6	Williamspo rt	North Head	Pebble Port (Port Site)
<b>Maximum Hourly Wind Speed (mph)</b>	89.5	50.8	84.1	46.5	79.8	37.4	29.5	55.0	45.6
<b>Maximum Wind Gust (mph)</b>	132.4	129.5	137.1	68.0	113.2	113.9	85.0	88.8	88.3
<b>Maximum Hourly Air Temperature (deg. F)</b>	74.5	75.7	75.7	72.7	72.0	74.1	73.0	54.7	77.4
<b>Minimum Hourly Air Temperature (deg. F)</b>	-31.9	-28.1	-24.0	14.4	14.7	5.5	20.1	29.7	-11.4
<b>Maximum Daily Precipitation (in)</b>	1.2	1.1	0.4	1.5	-	1.5	-	-	-
<b>Maximum Monthly Evaporation (summer only, in)</b>	4.2	3.9	4.1	5.7	-	4.7	-	-	-





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# 2008 Monitoring Plans

- Continue monitoring at all stations





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