

Appendix E Dust Deposition Data Analysis

Dust deposition gauge monitoring was implemented by the Esperance Port Authority (EsPA) in November 1995, as a requirement of the port's environmental licence. Initially, analysis for nickel and haematite was required. Analysis of total deposited dust commenced in August 2003. In November 2004, the requirement to analyse for lead and nickel was added; and in November 2006 the requirement to analyse for haematite was altered to iron.

The gauges were placed in nine locations within the Esperance Port and throughout the Esperance township. The location of the gauges is shown in **Figure E- 1** below. The gauges measured total dust deposition over one-month periods ($\text{g/m}^2/\text{month}$) and were operational one month in every three (February, May, August and November). Due to changes in monitors and the species requiring analysis, the results available are not consistent across sites. **Table E- 1** below details the monitoring data available.

- **Table E- 1 Data Availability for the nine dust deposition gauges**

	Data Available								
	DG1	DG3	DG4	DG5	DG6	DG7	DG8	DG9	DG10
Total Dust	11/2003 - 8/2007	11/2003 - 08/2007	11/2003 - 08/2007	11/2003 - 08/2007	11/2003 - 08/2007	11/2004 - 08/2007	05/2005 - 08/2007	05/2005 - 08/2007	05/2005 - 08/2007
Nickel	2/1996 - 8/2007	11/1996 - 8/2007	11/1995 - 8/2007	11/1995 - 08/2007	02/1998 - 08/2007	11/2004 - 08/2007	05/2005 - 08/2007	05/2005 - 08/2007	05/2005 - 08/2007
Iron	11/2003 - 08/2007	11/2003 - 08/2007	11/2003 - 08/2007	11/2003 - 08/2007	11/2003 - 08/2007	11/2003 - 08/2007	05/2005 - 08/2007	05/2005 - 08/2007	05/2005 - 08/2007
Sulfur	11/2004 - 08/2007	11/2004 - 08/2007	11/2004 - 08/2007	11/2004 - 08/2007	11/2004 - 08/2007	11/2004 - 08/2007	11/2005 - 08/2007	11/2005 - 08/2007	11/2005 - 08/2007
Lead	11/2004 - 08/2007	11/2004 - 08/2007	11/2004 - 08/2007	11/2004 - 08/2007	11/2004 - 08/2007	11/2004 - 08/2007	05/2005 - 08/2007	05/2005 - 08/2007	05/2005 - 08/2007

As dust deposition data was gathered over monthly monitoring periods, the results have been interpreted incorporating analysis of the prevailing winds during the month under discussion. This provides an indication of the direction from which a majority of dust was likely to have originated during the month. Due to the variation in results for deposition of the different species analysed, not all figures are presented on a consistent scale. To assist in interpretation of the data, **Table E- 2** details the scales utilised.



■ **Table E- 2 Scales used in figures for analysis of dust deposition**

	Figure Scales	
	Gauges 1 – 8	Gauges 9 and 10 (peak)
Total dust deposition	0 - 18g/m ² /month	0 - 35g/m ² /month
Sulfur deposition		
Iron deposition	0 - 0.8g/m ² /month	0 - 35g/m ² /month
Nickel deposition	0 - 0.07g/m ² /month	0 - 1.6 g/m ² /month
Lead deposition		

As shown on **Figure E- 1**, gauges 9 and 10 were located within the port area. As such they are considered to be measuring peak dust deposition and the results from these sites have been separated from those of the other gauges.

The wind speed and direction within the port premises may be influenced by the size and location of the storage sheds. This leads to complex meteorological conditions that are likely to have a significant influence on the dust deposition at gauges 9 and 10. These two peak gauges may also be influenced by the fact that iron ore received at the port is contained in open rakes. Dust from these operations may reach gauges 9 and 10 in certain meteorological conditions.

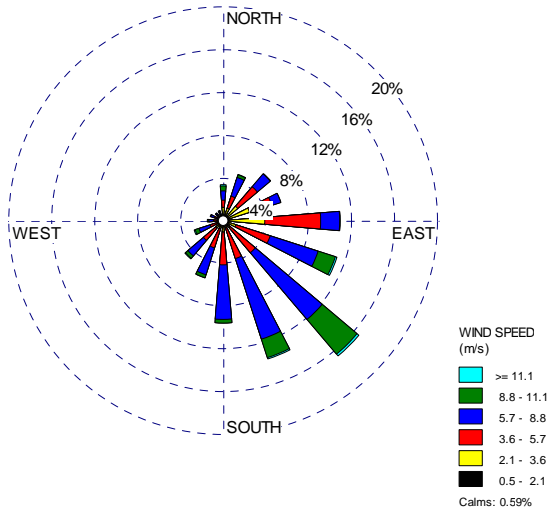
Total dust deposited has been compared with the criterion of a total allowable maximum deposition of 4g/m²/month. This criterion applies only to total dust and hence has not been used for the other species, for which there are no deposition criteria.



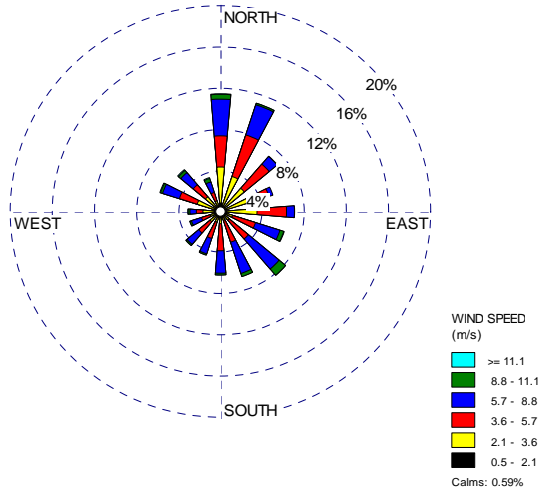
■ **Figure E- 1 Location of dust deposition monitors.**

E.1 Location of Deposition Gauges and Potential Seasonal Meteorological Influences

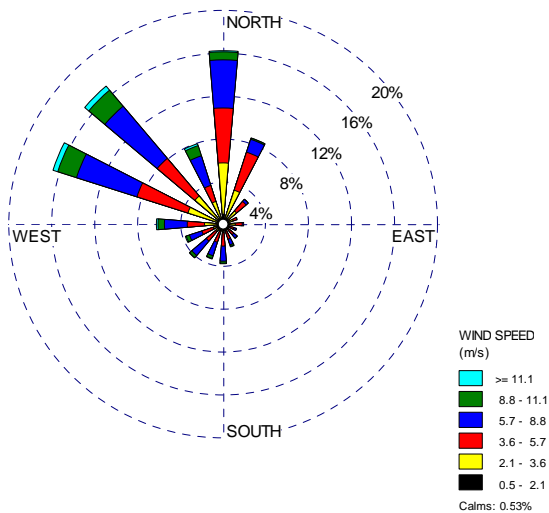
Dust deposition gauges 1, 4, 5, and 7 are located north-west of the port at locations near the coast and further inland. As such, it would be expected that dust from the port would have the greatest potential to impact these gauges during south-easterly and easterly winds. As shown in **Figure E- 2**, the summer seasonal wind rose for Esperance illustrates the dominance of south-easterly and easterly winds over this season. In contrast, the winter wind rose (**Figure E- 4**) shows a predominance of north-westerly and westerly winds. Hence dust originating from port activities would not be expected to impact these gauges during the winter months. Over spring (**Figure E- 5**) and autumn (**Figure E- 3**) the wind patterns are more variable, with contribution from the east and south-east. As such there is the potential for gauges 1, 4, 5 and 7 to be impacted by dust from the port over these two seasons.



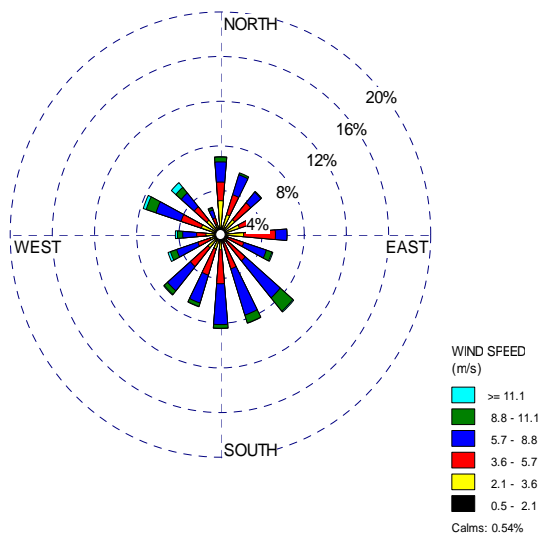
■ Figure E- 2 Summer wind rose



■ Figure E- 3 Autumn wind rose



■ Figure E- 4 Winter wind rose



■ Figure E- 5 Spring wind rose

Deposition gauge 3 is located west-south-west of the port, and therefore has the potential to be impacted by dust from the port when winds originate from the east and north-east. The seasonal



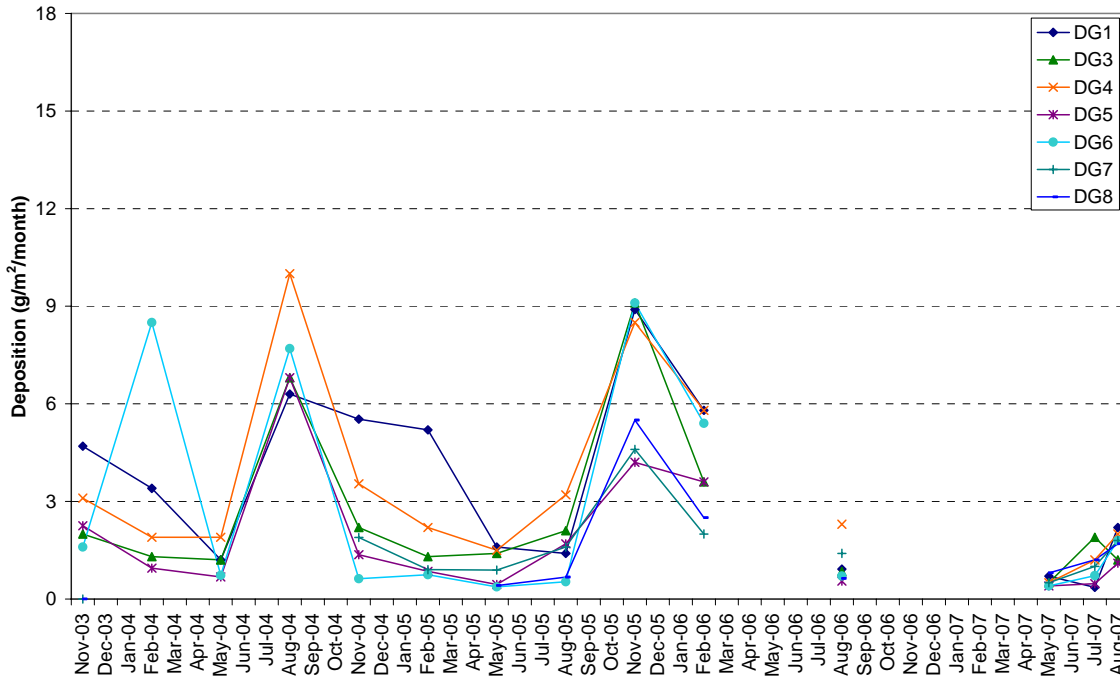
wind rose figures show that easterly winds are a feature of summer (**Figure E- 2**) and, to a lesser extent, spring (**Figure E- 5**), whilst north-easterly winds comprise a small component of winds across all the seasons. Deposition gauge 6 is located to the south-west of the port. As such this site would be expected to be influenced by winds coming from a north-easterly direction. The seasonal wind roses show that in Esperance this wind direction is most common over autumn (**Figure E- 3**), and to a lesser extent over winter (**Figure E- 4**).

Deposition gauge 8 is situated west of the port and therefore has the potential to be impacted by dust from the port during easterly winds, and possibly north-easterly and south-easterly winds. The seasonal wind roses show that easterly winds are most prevalent during summer (**Figure E- 2**), with a lesser contribution in spring and autumn.

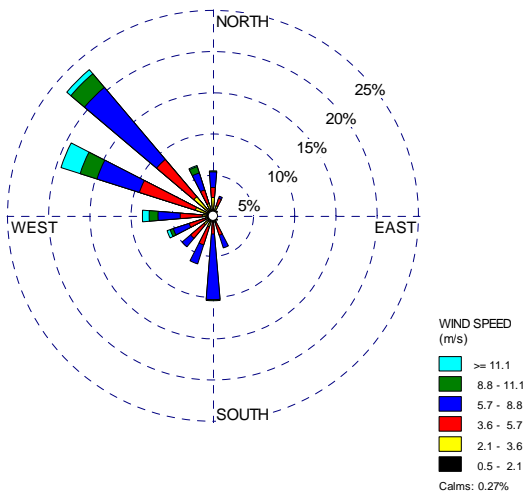
As stated earlier, gauges 9 and 10 are considered to be measuring peak dust deposition and as a consequence would be expected to be impacted by dust from the port at all times when material is being loaded.

E.2 Total dust deposited

The concentration of total dust deposited over each month period at each gauge is presented in **Figure E- 6**. This figure shows a clear trend of peaks at all gauges in August 2004 (late winter) and November 2005 (late spring). Analysis of the wind rose for August 2004 (**Figure E- 7**) shows that the dominant winds were from the north-westerly and west-north-westerly directions. Considering the position of all gauges, under these prevailing winds deposition of dust from the Esperance Port would be limited. As such, it is likely that much of the dust deposited during this month originated from other sources.



■ Figure E- 6 Total dust deposited (g/m²/month)

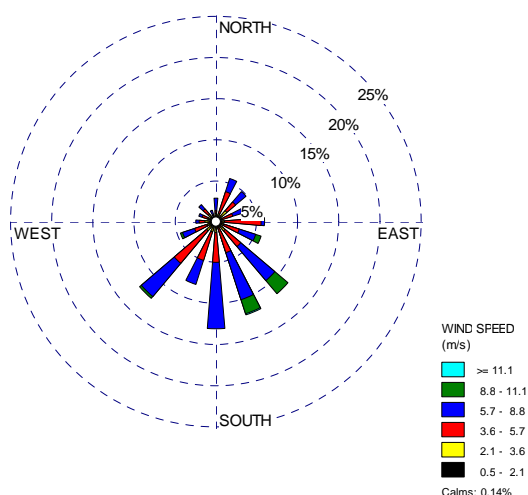


■ Figure E- 7 August 2004 wind rose



All total dust deposition levels recorded in August 2004 were above the criteria of a total allowable maximum of 4g/m²/month. However, as already stated, the dominant winds experienced during this month would not have carried dust from the port to the gauges, therefore only a portion of the dust deposited may have been attributable to port operations.

The wind rose for November 2005, as presented in **Figure E- 8**, shows that the dominant wind directions ranged from south-easterly to south-westerly. South-easterly winds would have the potential to carry dust from the port to gauges 1, 4, 7 and 5. The maximum concentration of 9.1g/m²/month was recorded at both gauges 3 and 6. Gauge 3 had the potential to be influenced by dust from the port, mainly due to its proximity to the operations. This gauge is located on a hill, so may also be subject to complex meteorological conditions. Gauge 6 would have the potential to be impacted by dust from the port under north-easterly wind conditions; as such it is unlikely this peak can be attributed to operations at the port.

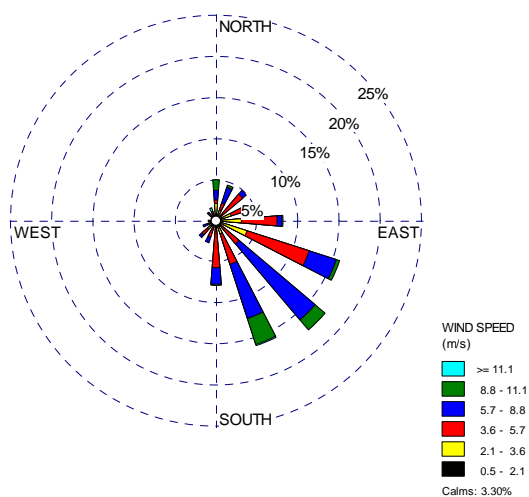


■ **Figure E- 8 November 2005 wind rose**

All total dust deposition levels recorded in November 2005 were above the criteria of a total allowable maximum of 4g/m²/month.

Another peak dust deposition concentration of interest from **Figure E- 6** occurred at gauge 6 in February 2004 (late summer). The deposition measured during this month (8.5g/m²/month) exceeded the deposition assessment criteria. Analysis of the prevailing winds over this month (**Figure E- 9**) shows a dominance of winds from the south-east. Given the position of gauge 6, it is unlikely that this peak was highly influenced by activities at the port.

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■ **Figure E- 9 February 2004 wind rose**

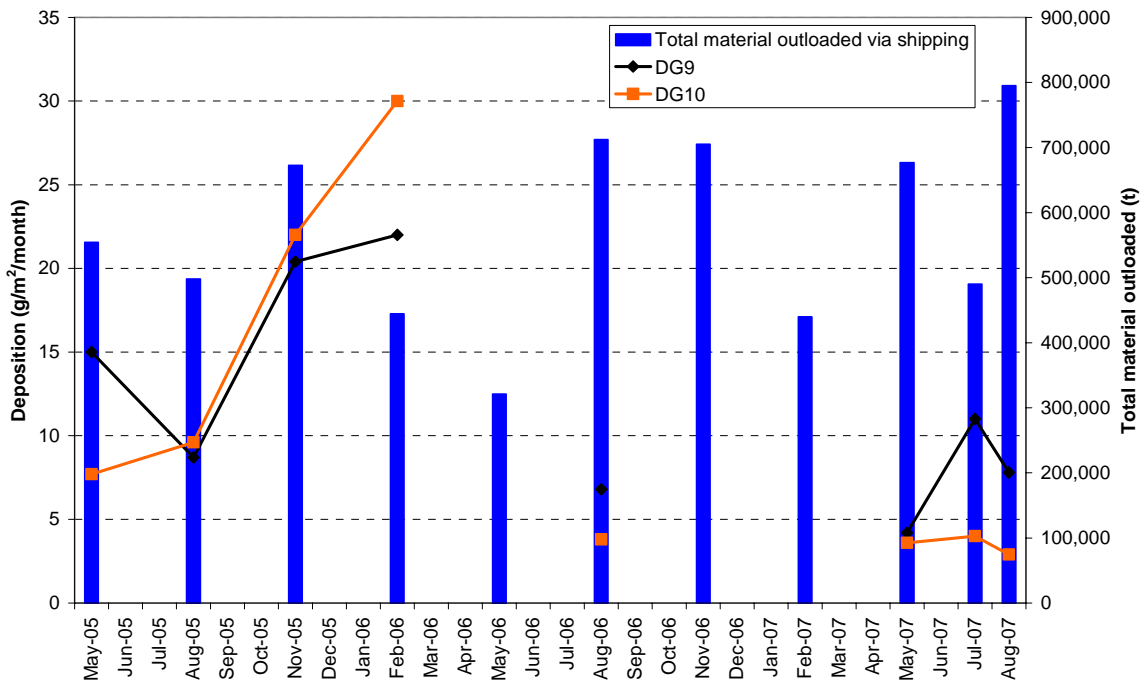
E.2.1 Peak Sites

Figure E- 10 presents the total dust deposited at the peak sites (gauges 9 and 10), along with the total material throughput (consisting of nickel, iron, sulfur and lead) at the port. It is difficult to make any conclusions from this due to gaps in the deposition data.

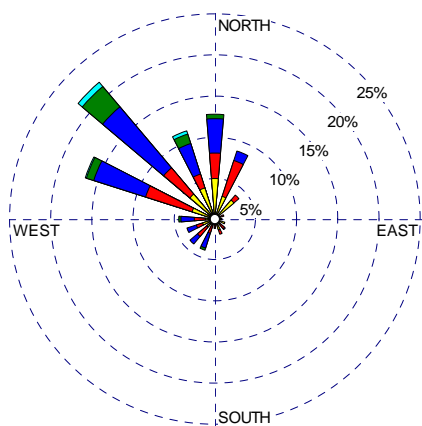
Maximum throughput at the port occurred in August 2007, but this does not correlate with the maximum total dust deposition recorded. **Figure E- 11** presents the wind rose for August 2007 and shows that the dominant winds were from the north-west. It is unlikely that loading activities at the port would influence deposited dust levels under these wind conditions at gauges 9 and 10.

Maximum deposition at the peak stations occurred in February 2006, a month where winds were predominantly from the south-east (**Figure E- 12**). Under these conditions it would be expected that dust from the port would be carried to gauges 9 and 10.

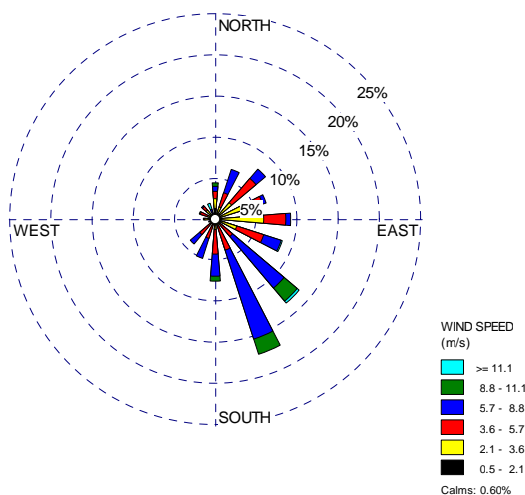
Although all measured dust deposition levels at gauges 9 and 10 exceeded the NSW assessment criteria of $4\text{g}/\text{m}^2/\text{month}$, the measurements were taken within the boundary of an industrial facility and hence the criteria does not apply.



■ Figure E- 10 Total dust deposited ($g/m^2/month$) at the peak sites compared with total throughput at the port.



■ Figure E- 11 August 2007 wind rose

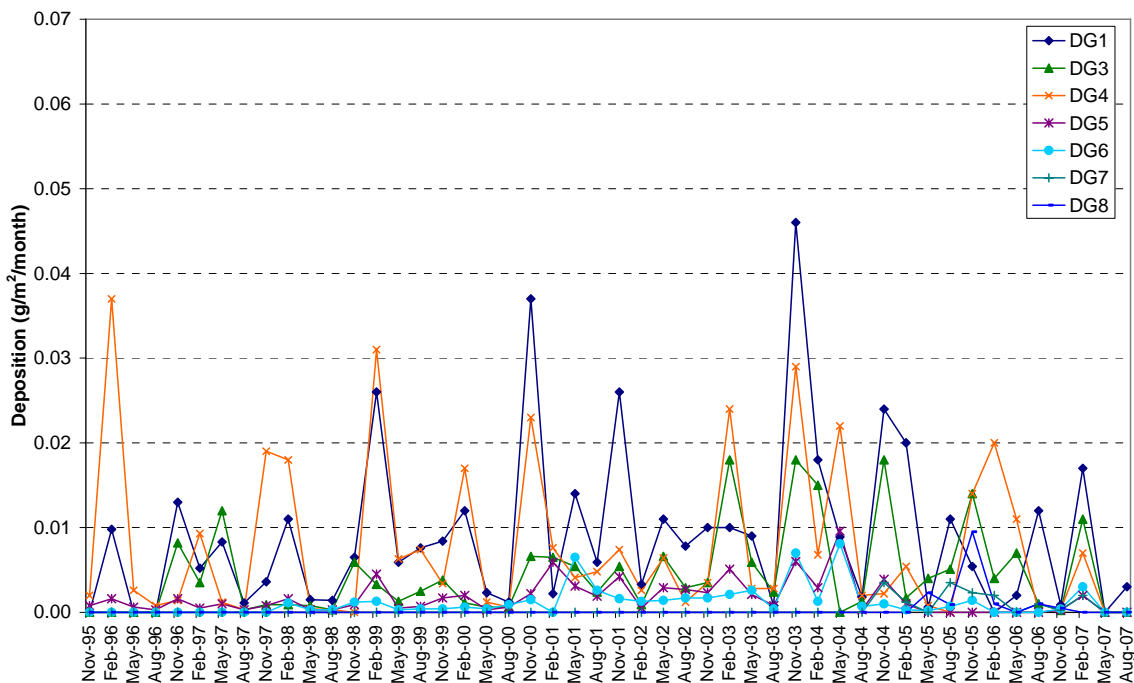


■ Figure E- 12 February 2006 wind rose

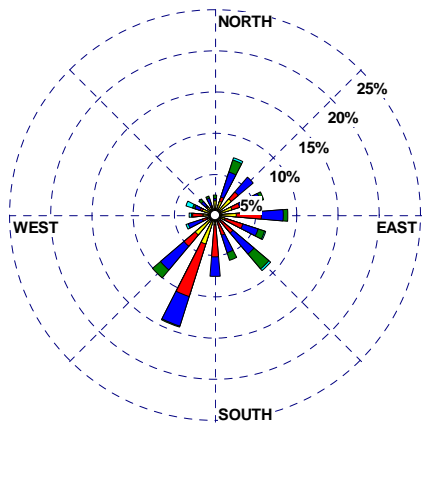


E.3 Nickel deposition

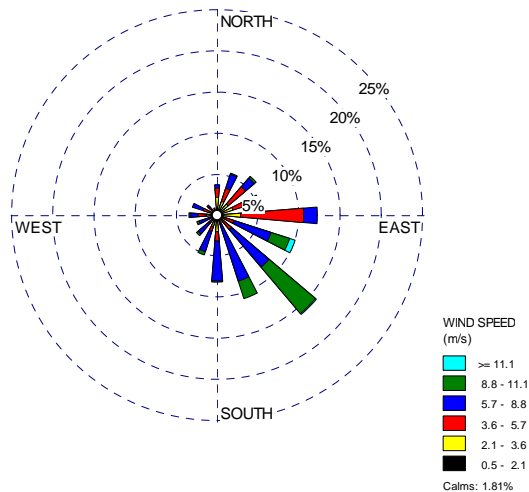
The concentration of total nickel deposited at each gauge over each monthly period is presented in **Figure E- 13** below. This figure shows a pattern in peaks at deposition gauge 1 in November (early summer) of 1996, 2000, 2001, 2003 and 2004. Analysis of the wind patterns from these months (**Figure E- 14** to **Figure E- 18**) shows winds were predominantly from the south-easterly direction. Given the position of gauge 1, there is the potential for this site to be influenced by dust from the port under south-easterly winds. Gauge 5, which is located further inland to the north-west of gauge 1, did not experience the same magnitude of peaks as gauge 1, indicating that the dust was not transported inland.



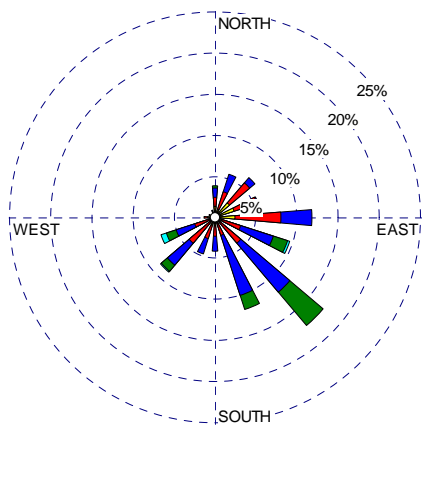
■ **Figure E- 13 Deposited nickel (g/m²/month)**



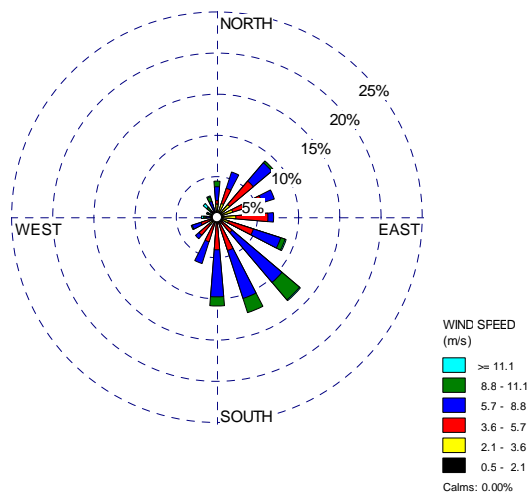
■ Figure E- 14 November 1996 wind rose



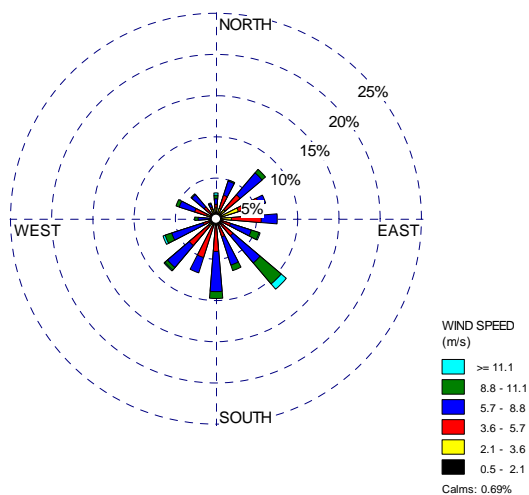
■ Figure E- 15 November 2000 wind rose



■ Figure E- 16 November 2001 wind rose



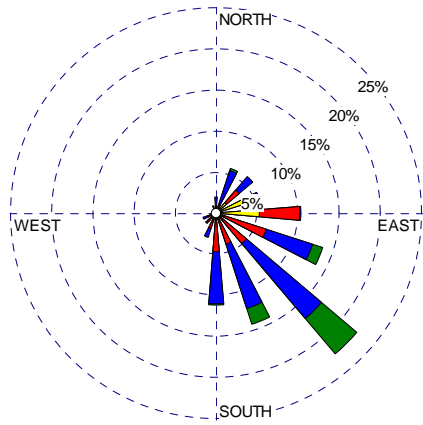
■ Figure E- 17 November 2003 wind rose



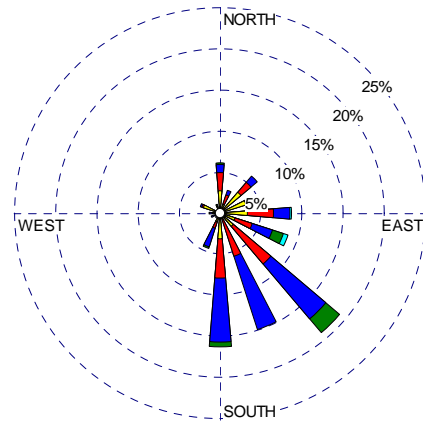
■ **Figure E- 18 November 2004 wind rose**

Figure E- 13 also shows a pattern of peaks in nickel concentrations at gauge 4 during February (late summer) of 1996, 1998, 1999, 2000, 2003 and 2006. Winds during these months, as presented in **Figure E- 19** to **Figure E- 24**, are predominantly from a south-easterly direction with some more southerly and easterly components also making a contribution. As deposition gauge 4 is situated north-west of the port, south-easterly winds would have the potential to carry dust from the port to this gauge. This also confirms the prediction that gauge 4 would be likely to experience dust from the port during summer conditions.

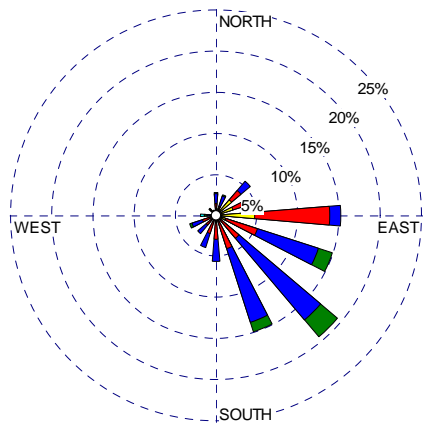
Deposition gauge 7, which is located slightly north-west of gauge 4, did not experience the same magnitude of peaks as gauge 4. Considering its position, gauge 7 would be expected to experience dust impact from the port under the same conditions as gauge 4. However, this did not occur, indicating that the dust was not transported further inland.



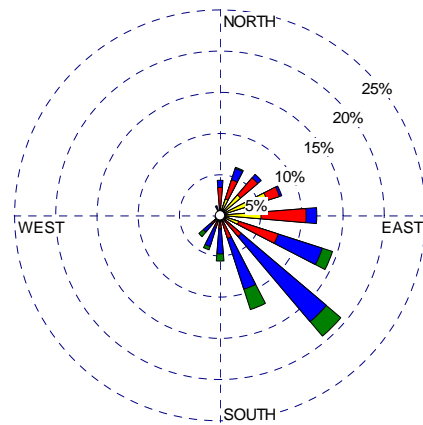
■ Figure E- 19 February 1996 wind rose



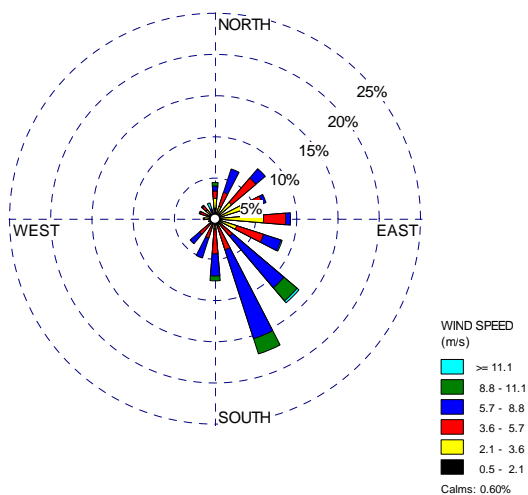
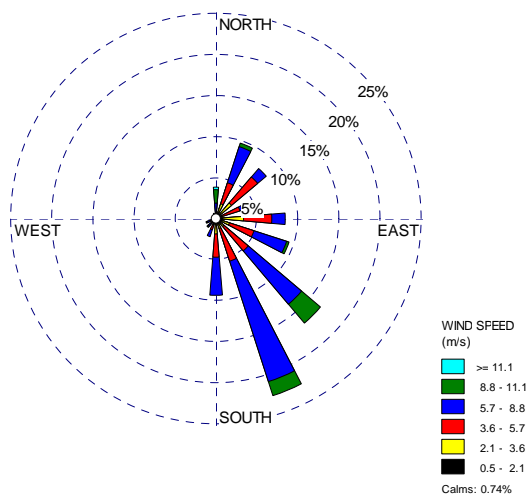
■ Figure E- 20 February 1998 wind rose



■ Figure E- 21 February 1999 wind rose



■ Figure E- 22 February 2000 wind rose

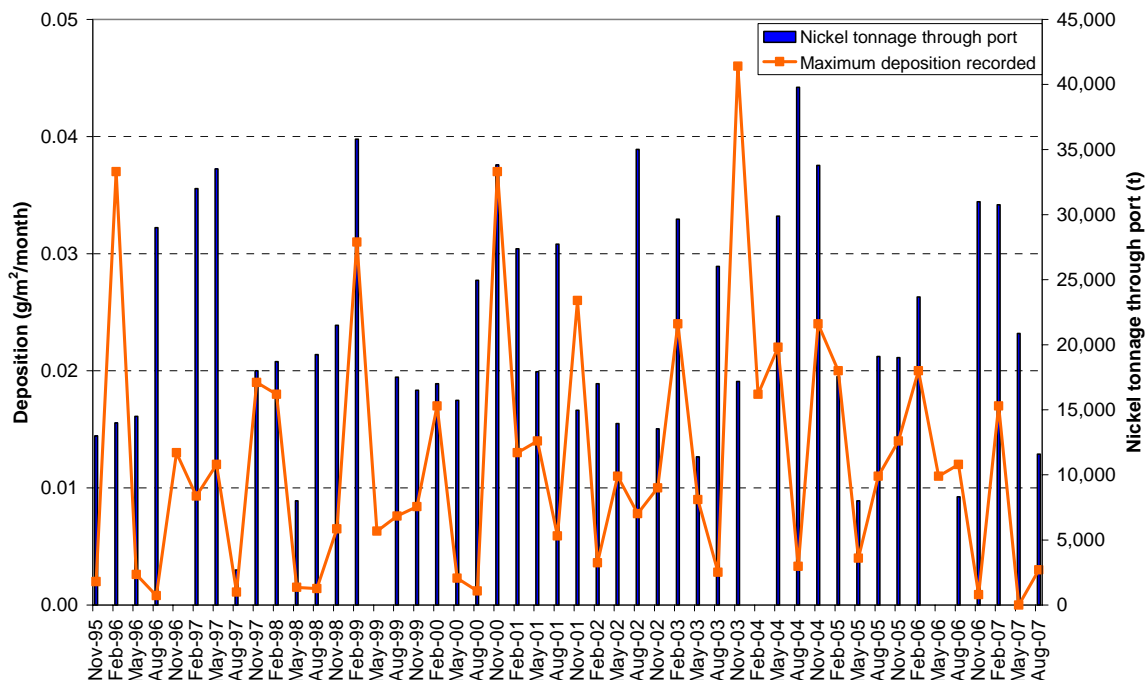


■ **Figure E- 23 February 2003 wind rose**

■ **Figure E- 24 February 2006 wind rose**

When the maximum recorded concentrations of nickel deposition are compared with the tonnage of nickel moving through the port (**Figure E- 25**), it can be seen that there are occasions when a higher tonnage corresponds to increased deposition (for example February 1999 and November 2000). Equally, there are occasions when this is not the case (for example August 1996 and August 2003). As such, no firm conclusions can be made on the impact of tonnage through the port on deposited nickel.

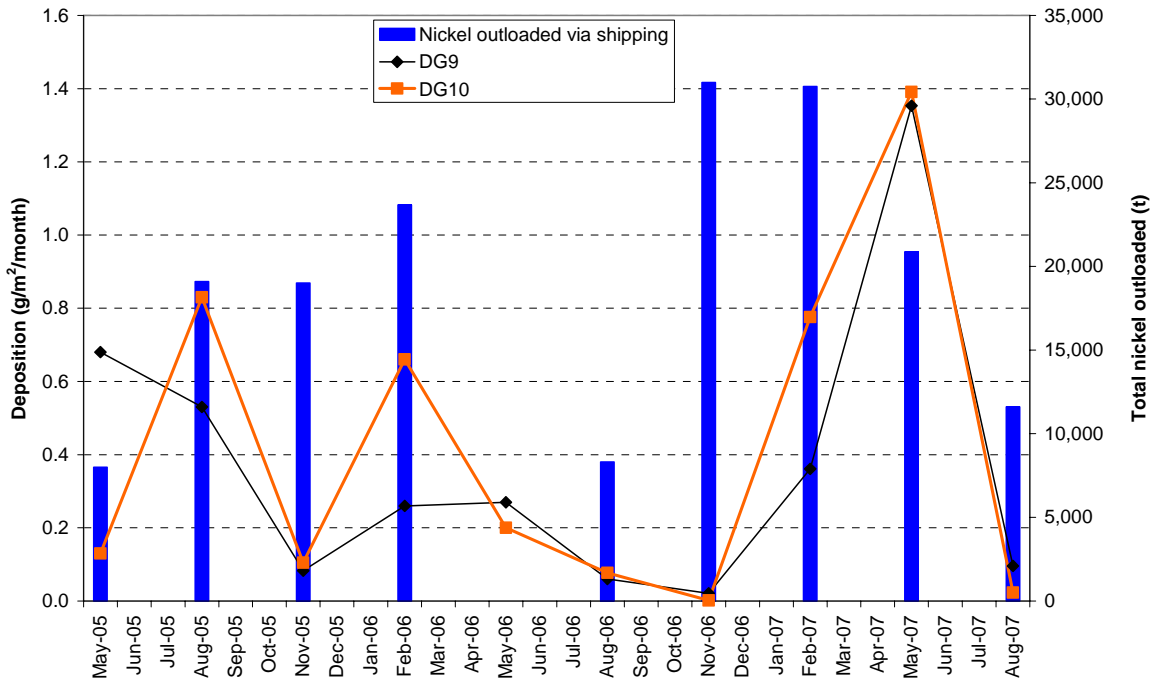
The maximum nickel throughput which occurred in August 2004 does not correspond with the maximum deposition concentration, which occurred in November 2003 at gauge 1. Analysis of the wind rose for August 2004 (**Figure E- 7**) shows that winds were predominantly from the north-west; hence no sites would be expected to be significantly influenced by dust from the port during this month. In contrast, the wind rose for November 2003 (**Figure E- 17**) shows a dominance of south-easterly winds. This is consistent with the summer wind patterns that were predicted to influence the transport of dust from the port at a number of the gauges, including gauge 1. As such deposition concentrations measured during this month may have been influenced by dust originating from the port.



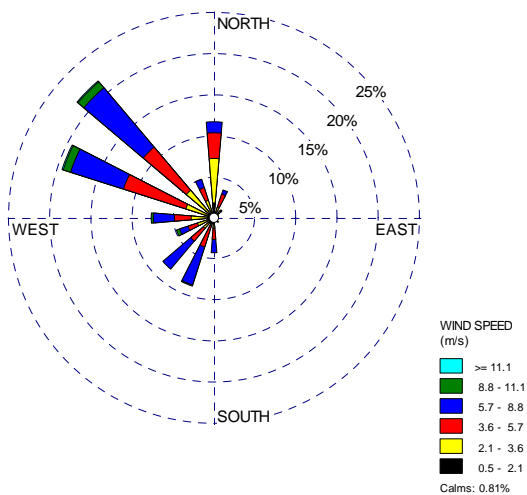
■ Figure E- 25 Nickel tonnage through the port compared with maximum nickel deposition concentrations.

E.3.1 Peak Sites

Deposition of nickel recorded at the peak sites (gauges 9 and 10) is presented in **Figure E- 26**, along with the total throughput of nickel at the port. This figure shows that highest concentrations at gauges 9 and 10 were recorded in May 2007, a time which does not correspond with highest nickel throughput at the port. Wind patterns for May 2007 are presented in **Figure E- 27**, which shows that winds were predominantly from the north-west. However, meteorological conditions within the port are highly variable and as such conclusions cannot be made based solely on the predominant winds.



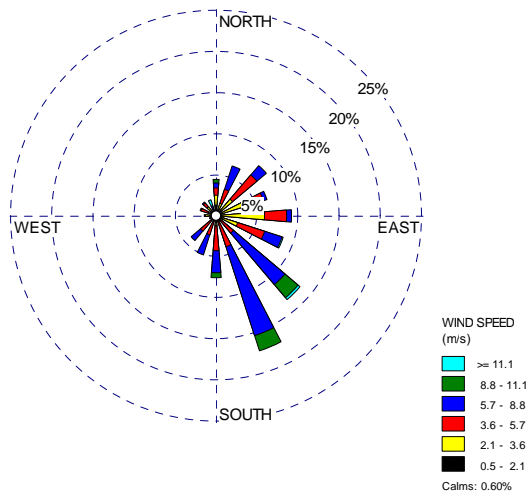
■ Figure E- 26 Total nickel deposited (g/m²/month) at the peak sites compared with total nickel throughput at the port



■ Figure E- 27 May 2007 wind rose

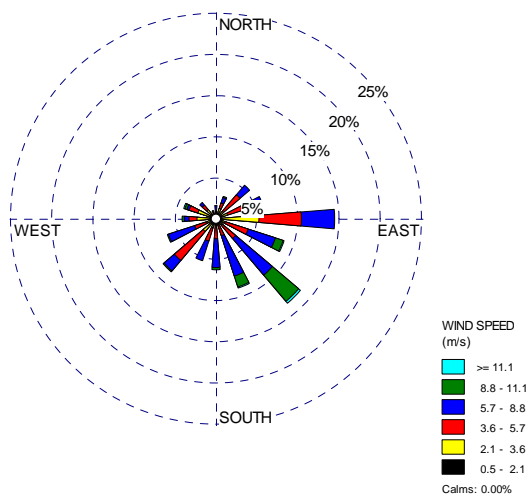


Other high deposition values were recorded in February 2006 and February 2007. The wind roses for these months (**Figure E- 12** and **Figure E- 28**) show that the dominant wind direction is south-easterly. This indicates that dust from the port may have contributed to the high concentrations at gauges 9 and 10.



■ **Figure E- 28 February 2007 wind rose**

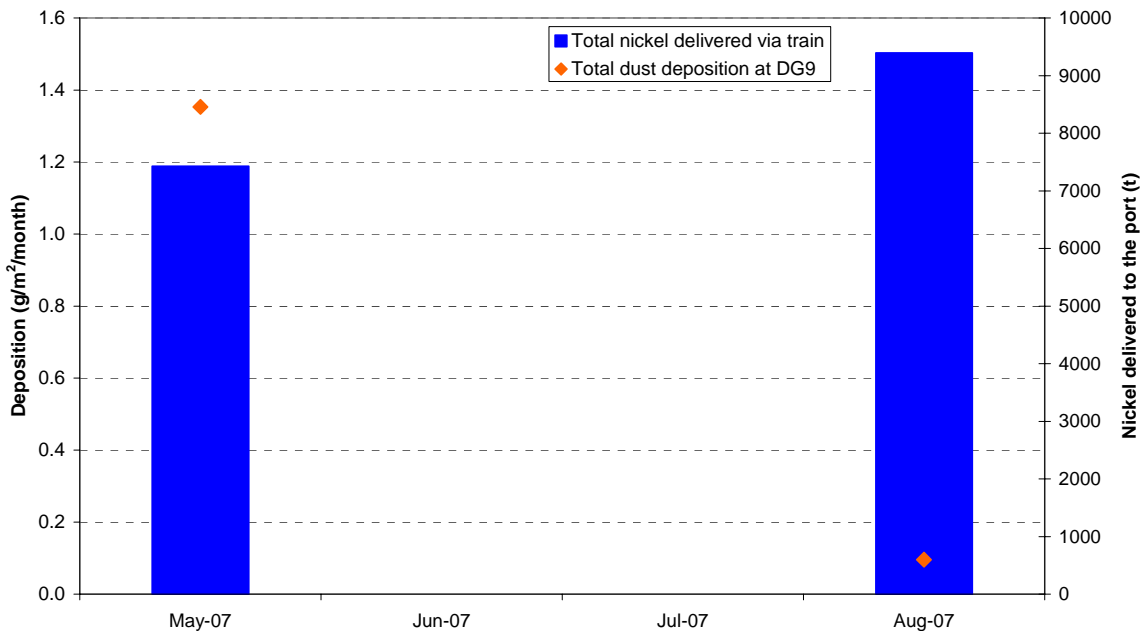
The lowest nickel deposition concentrations were recorded in November 2006, which also corresponds with the greatest nickel throughput at the port. Dominant winds in this month originated from the east (**Figure E- 29**) and hence would have the potential to carry nickel dust from the port to gauges 9 and 10. The fact that the deposition concentrations from this month are so low raises questions as to the validity of the results. November 2006 coincided with the use of a new laboratory for analysis and additionally, the laboratory reported results in mg/L rather than g/m²/month. These results were converted to g/m²/month using rainfall data for November 2006 (EsPA 2007).



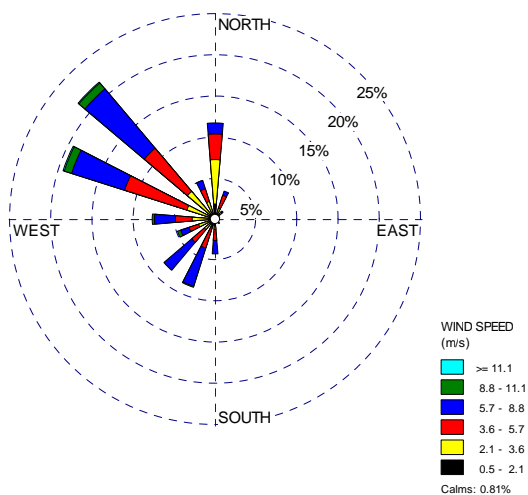
■ **Figure E- 29 November 2006 wind rose**

Comparison between nickel deposition at gauge 9 and the total tonnage of nickel delivered by train to the port (**Figure E- 30**) shows that an increase in the total nickel delivered does not necessarily correspond to an increase in nickel deposition. Gauge 9 was chosen for comparison as it is located close to the rail line and nickel storage shed. Maximum deposition was recorded during May 2007. The wind rose from this month, presented in **Figure E- 31**, shows that the predominant wind direction was from the north-west. With winds from this direction it is difficult to determine a primary source of the dust.

The highest tonnage of nickel delivered to the port was in August 2007. Winds during this month were also predominantly from the north-west (**Figure E- 11**). Again, with the wind blowing from this direction it is difficult to determine the primary source of dust.



■ Figure E- 30 Nickel deposition at gauge 9 compared with the nickel delivered to the port by train

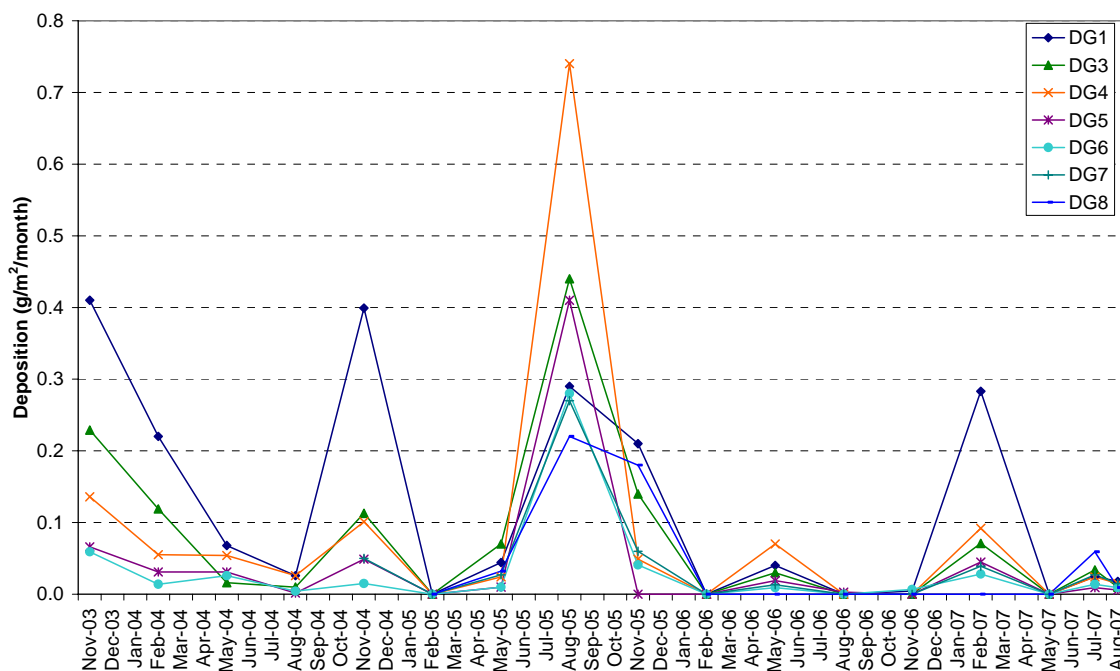


■ Figure E- 31 May 2007 wind rose

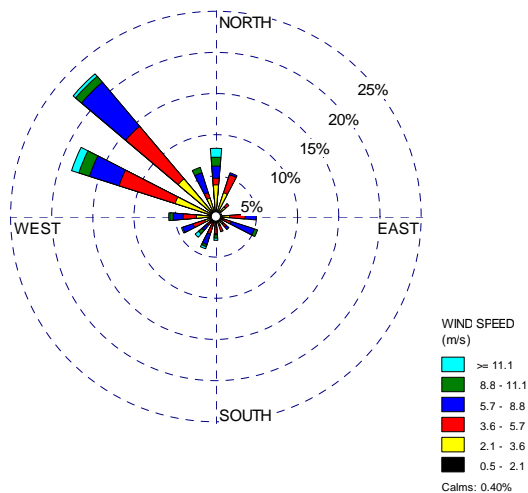


E.4 Iron deposition

Figure E- 32 presents deposited iron concentrations at each gauge and also the total iron throughput at the port for the corresponding month. The maximum deposited iron concentration was $0.7\text{g/m}^2/\text{month}$, recorded at deposition gauge 4 in August 2005. The graph shows a trend of increased iron deposition at gauges 1, 3, 4, 5, 7 and 8 in August 2005. Analysis of wind patterns over this month (Figure E- 33) reveals the predominant winds were from the north-west. Given the location of gauges 1, 3, 4, 5, 7 and 8 (Figure E- 1) the increased iron deposition over this month cannot be attributed to the port as it is situated south-east of these gauges.

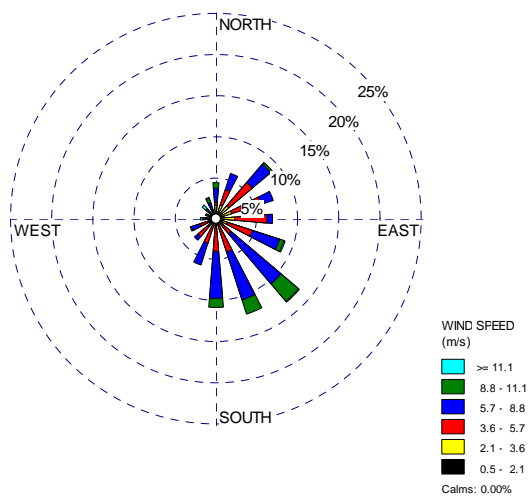


■ Figure E- 32 Deposited iron ($\text{g/m}^2/\text{month}$)

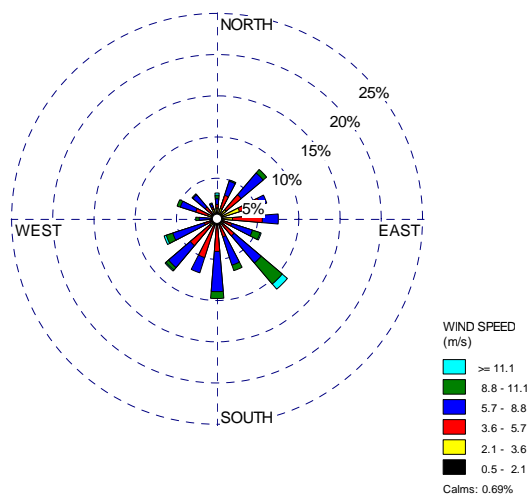


■ **Figure E- 33 August 2005 wind rose**

Figure E- 32 also shows higher iron deposition concentrations at deposition gauges 1, 3, 4 and 5 in November 2003 and 2004. Analysis of the winds over these months (**Figure E- 34** and **Figure E- 35**) shows that winds were predominantly from the south-east, with contribution also from winds originating from the north-east. South-easterly winds would have the potential to carry dust from the port to these gauges, however north-easterly winds would only be expected to potentially affect gauge 3.

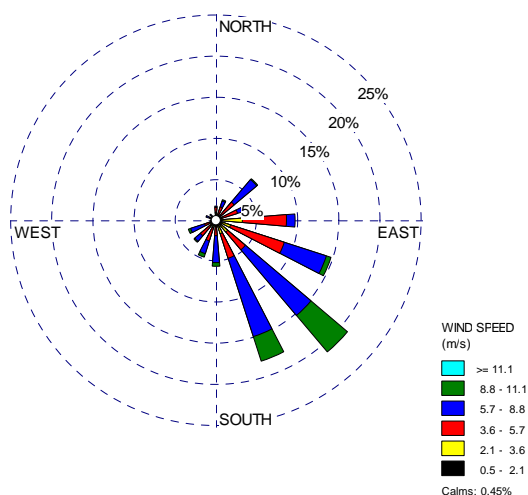


■ **Figure E- 34 November 2003 wind rose**



■ **Figure E- 35 November 2004 wind rose**

A lesser peak can also be seen for gauges 1, 3, 4, 5, 7, and 8 in February 2007. Winds in this month were predominantly south-easterly (**Figure E- 36**) and hence would have had the potential to carry dust from the port to these gauges.

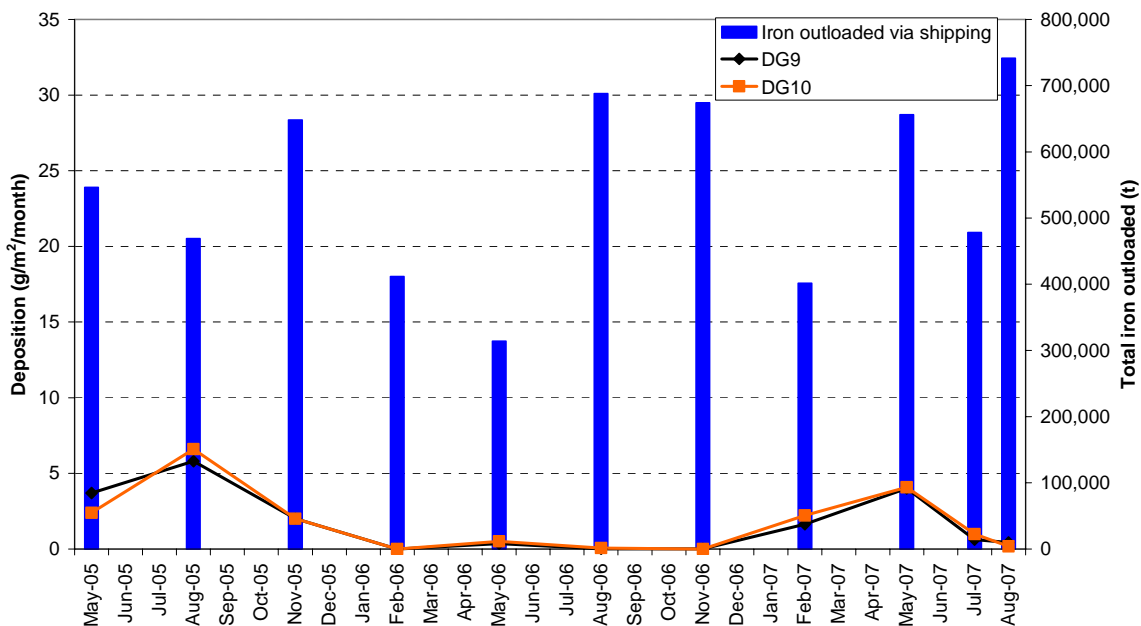


■ **Figure E- 36 February 2007 wind rose**

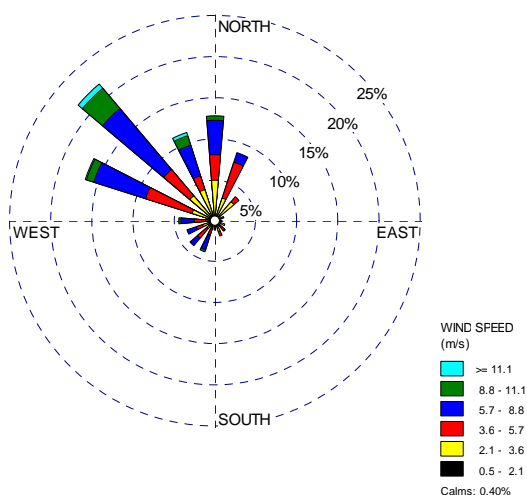
E.4.1 Peak Sites

Deposition of iron recorded at the peak sites (gauges 9 and 10) is presented in **Figure E- 37** below, along with the total throughput of iron at the port. Maximum deposition at both gauges was recorded in August 2005. As shown in the graph, this does not correspond with maximum iron throughput at the port. Analysis of the wind rose for August 2005 (**Figure E- 33**) shows that the prevailing winds were north-westerly, suggesting loading of iron into ships may not have been a contributing factor to iron deposition, but that transport of material to the port may have been.

Maximum iron throughput at the port occurred in August 2007, but the corresponding iron deposition did not reflect this peak. Similar to August 2005, winds in this month were dominated by those from the north-west (**Figure E- 38**) and as such would not be expected to carry dust from the port to gauges 9 and 10.



■ Figure E- 37 Total iron deposited (g/m²/month) at the peak sites compared with total iron throughput at the port.



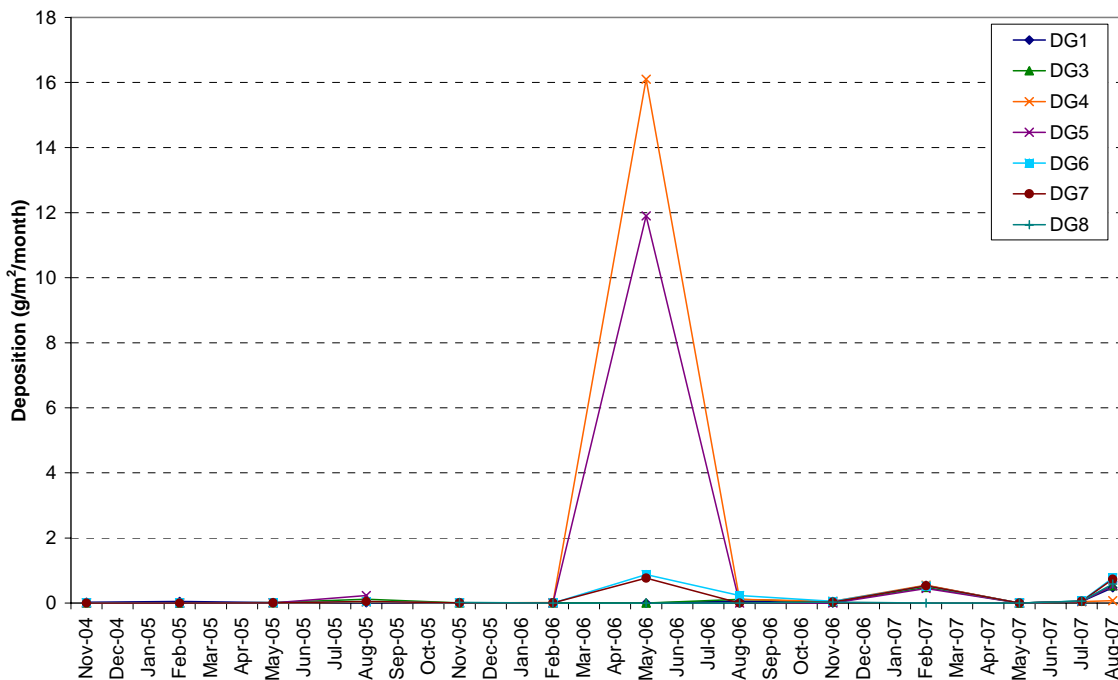
■ Figure E- 38 August 2007 wind rose



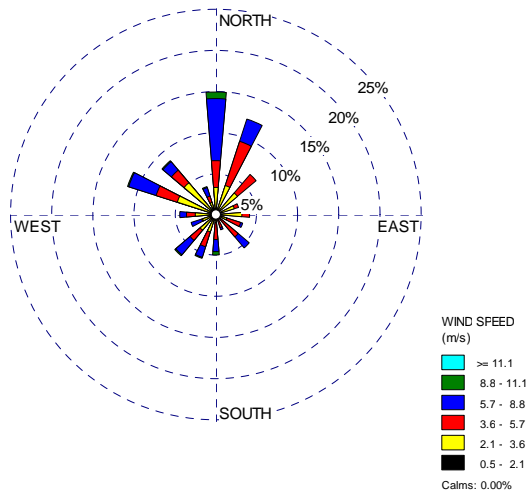
E.5 Sulfur deposition

The maximum deposited sulfur concentration of 16.1g/m²/month was recorded at deposition gauge 4 in May 2006 (Figure E- 39). During this month there is a clear trend of increased sulfur deposition at gauges 4, 5, 6 and 7. The wind rose for this month (Figure E- 40) shows that northerly, north-easterly and north-westerly winds were dominant. Of these, only the north-easterly winds would have had the potential to carry sulfur dust from the port and only to gauge 6.

Given the magnitude of the increase in sulfur concentration and the fact that gauges 1, 3 and 8 did not experience the same increase, it is likely that this data is erroneous. This is possibly due to a sampling, handling or laboratory contamination error.



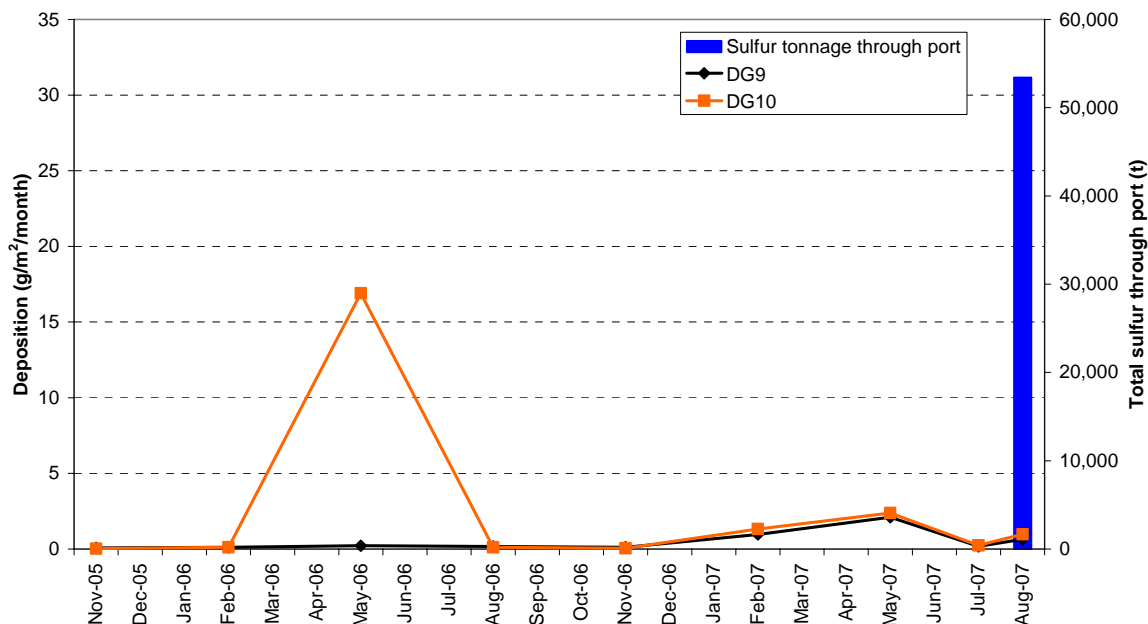
■ Figure E- 39 Deposited sulfur (g/m²/month)



■ **Figure E- 40 May 2006 wind rose**

E.5.1 Peak Sites

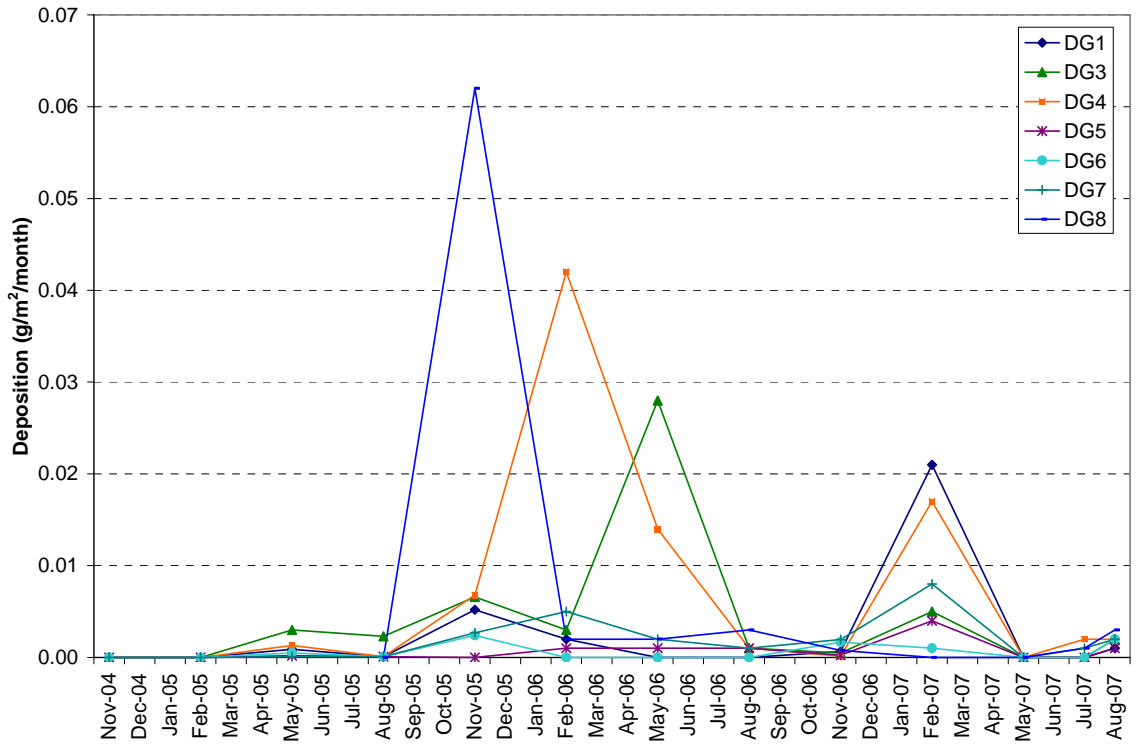
Deposition of sulfur recorded at the peak sites (gauges 9 and 10) is presented in **Figure E- 41** below, along with the total throughput of sulfur at the port. Sulfur throughput only corresponded with deployment of the deposition gauges in August 2007; hence a limited interpretation of the data is possible. The maximum deposited sulfur concentration was in May 2006, which corresponds with maximums recorded at other gauges (**Figure E- 39**). The wind rose for this month (**Figure E- 40**) shows that northerly, north-easterly and north-westerly winds were dominant. Winds from the north and north-east would have the potential to carry dust from the port to gauge 10, however as no sulfur was outloaded at the port in this month the source cannot be determined. Again there was potentially a sampling, handling or laboratory contamination error.



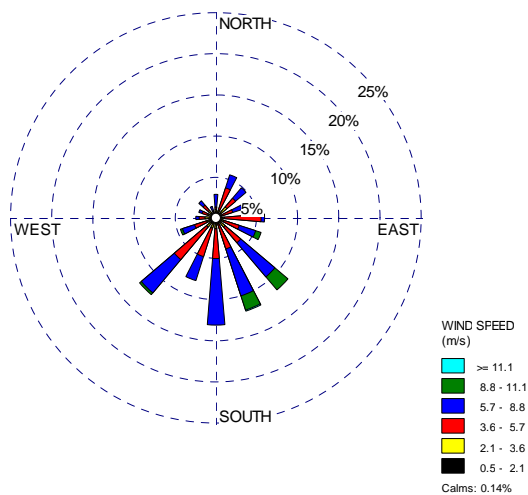
■ **Figure E- 41 Total sulfur deposited (g/m²/month) at the peak sites compared with total sulfur throughput at the port (t).**

E.6 Lead deposition

The concentrations of deposited lead recorded are presented in **Figure E- 42**. This figure shows that trends in peaks across the gauges are less apparent than or the other species analysed. The maximum concentration was recorded at deposition gauge 8 in November 2005 (0.062g/m²/month). Predominant winds during this month ranged from south-easterly to south-westerly (**Figure E- 43**). There is a possibility that south-easterly winds could carry dust from the port to gauge 8. This peak was not reflected in lead deposition at gauge 3, which is also east of the port but closer to the port than gauge 8. However, gauge three is located on a hill, which would influence the movement of wind and therefore the deposition of dust.



■ Figure E- 42 Deposited lead (g/m²/month)

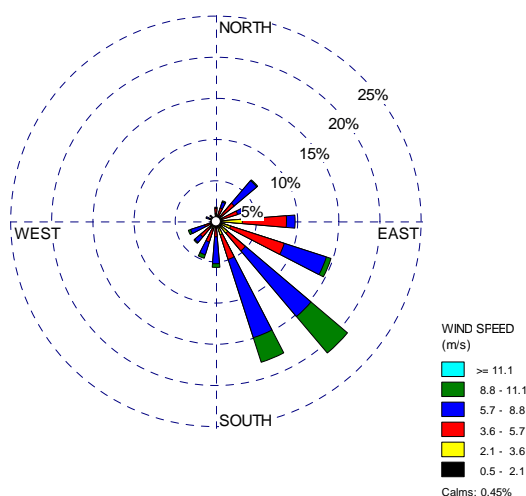


■ Figure E- 43 November 2005 wind rose

Figure E- 42 also shows increased lead deposition at gauge 4 in February 2006. Winds during this month were predominantly south-easterly (**Figure E- 12**) and would therefore have the potential to carry lead dust from the port to this gauge.

Gauge 3 experienced an increase in lead deposition in May 2006 (**Figure E- 42**). Analysis of the wind rose for this month (**Figure E- 40**) reveals the winds were predominantly northerly and north-easterly. Given the location of gauge 3 (**Figure E- 1**), there is the potential that lead dust was transported from the port to this gauge.

Another lesser peak in deposited lead concentrations was experienced in February 2007 at gauges 1, 3, 4, 5 and 7 (**Figure E- 42**). This month experienced predominantly south-easterly winds, as shown in **Figure E- 44**. These winds would have the potential to carry dust from the port to all the above gauges.



■ **Figure E- 44 February 2007 wind rose**

E.6.1 Peak Sites

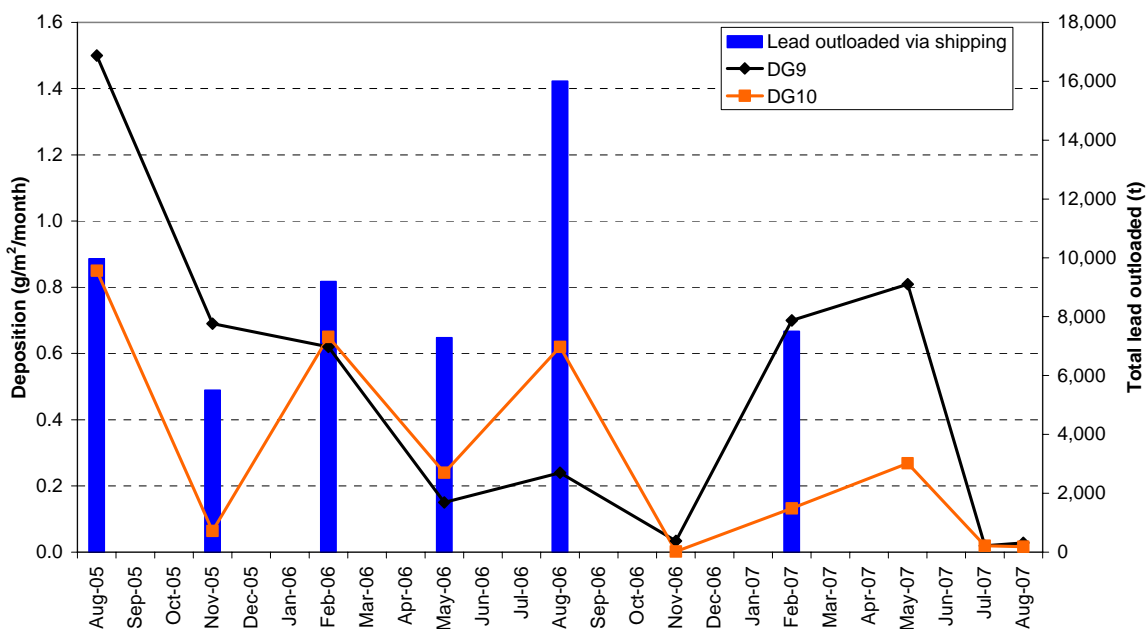
Deposition of lead recorded at the peak sites (gauges 9 and 10) is presented in **Figure E- 45** below, along with the total throughput of lead at the port. This figure shows that the highest throughput in August 2006 does not correspond with the highest lead deposition. Winds in August 2006 were dominated by those from the north-west, as shown in **Figure E- 46**. As stated previously, winds from this direction would not be expected to carry dust from the port to gauges 9 and 10. However,

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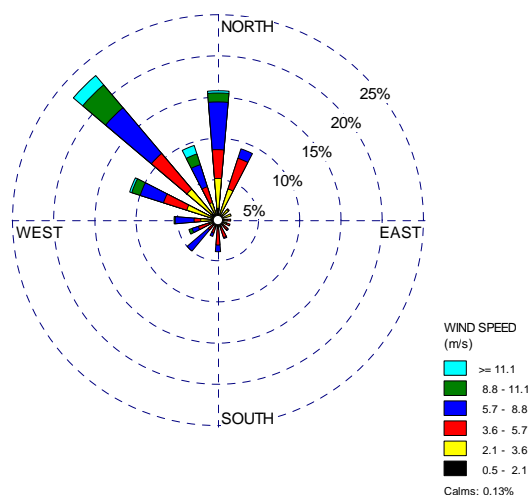


the complex meteorological conditions resulting from the locations of storage sheds on site, along with re-suspension of lead dust through vehicle activity, could potentially have influenced lead deposition at these gauges.

Maximum lead depositions were recorded at both gauges in August 2005. Analysis of the wind rose for August 2005 (**Figure E- 33**) shows that the prevailing winds were north-westerly, suggesting loading of lead into ships may not have been a contributing factor to lead deposition. Again there is the potential for the lead deposition to be affected by complex meteorological conditions and vehicle activity.



■ **Figure E- 45 Total lead deposited (g/m²/month) at the peak sites compared with total lead throughput at the port (t).**



■ **Figure E- 46 February 2007 wind rose**

E.7 Conclusions and Seasonal Trends

The following conclusions can be drawn from the data analysis:

- For both total dust and nickel, peaks in deposition concentrations were seasonal in nature, occurring mainly in late spring (November) and late summer (February) across the years of sampling.
- Peaks in deposition which were observed to occur during late winter (August) of various years could not be attributed to the port, indicating that background sources have an equivalent potential to contribute to dust deposition as the port under certain meteorological conditions.
- Highest concentrations of total dust and nickel deposition were consistently recorded at deposition gauges 1 and 4. These gauges were the nearest to the port in a north-westerly direction. On most occasions, similar peaks were not concurrently recorded at the gauges also north west of the port but further inland (gauges 5 and 7). This indicates that dust which may have originated from the port was primarily deposited close to the port and was not transported inland.
- Analysis of deposition concentrations and the tonnage of material out loaded via shipping at the port revealed that wind direction primarily affects dust deposition, not the amount of material being handled.
- Exceedances of the maximum allowable increase in deposited dust of $4\text{g}/\text{m}^2/\text{month}$ were observed. Some of these were recorded when the prevailing winds indicated the dust was not



likely to have originated from the port. Exceedances were also recorded when the prevailing winds indicated that the dust may have originated from Port activity.

- The deposition data used in this analysis was from sampling conducted only once every three months. This data is insufficient to make an adequate analysis of dust deposition and how it is affected by port activities and meteorological conditions. Sampling on a monthly basis is required before any further conclusions can be made.

E.8 References

EsPA – See Esperance Port Authority

Esperance Port Authority 2007. *Annual environmental Monitoring Report – Dust Gauge Deposition Monitoring at Esperance September 2007-August 2007, Doc. No: 07-05.*