The Cost of Red Dawn to the NSW Economy[1].

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Abstract

On September 23, 2009 much of New South Wales awoke to a strange phenomenon, a huge cloud of red dust, "Red Dawn" the name given by the media to the event. This dust was sourced from the far west and northwest of the state and the Lake Eyre basin, and was lifted by a concurrence of weather events including strong frontal winds, that brought the effects of the dry winter of 2009 in central Australia to the city of Sydney and north-eastern New South Wales. Dust density caused disruptions to transport networks, and to commercial and domestic activities. These activities and disruptions imposed costs to the economy of the state and, based on data from primary and secondary sources and information from previous research in Australia and overseas, an estimate was made as to the costs of the dust storm on the economy. This estimate is $425 million with the major component imposed on households due to cleaning premises and cars, and other associated costs. The impacts on commercial activity varied across sectors, with construction and retail/services sectors incurring costs due to loss of production and productivity, and cleaning, totalling approximately $44 million. The transport sector suffered losses in the region of $10 million. Further losses in productivity and production across all other sectors of the economy through absenteeism imposed a further cost of $7.5 million dollars. Contrary to previous research the impacts on health and emergency services were negligible. Some benefits were also generated by the dust storm. One of which was the deposition of soil and soil nutrients on land used for production, this led to an estimated benefit to the economy of approximately $1.1 million. A benefit that was not measured was that of nutrient deposition on the ocean and the subsequent increase in algal blooms and increases in fish stocks.

Introduction

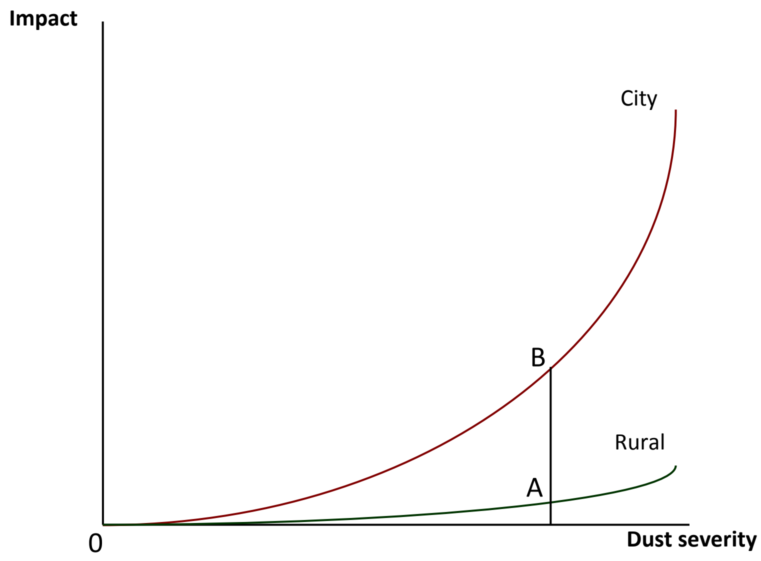
Two types of damage are caused by wind erosion of soil, on-site and off-site. On-site damage is impairment to the area directly affected by the wind, i.e. removal of the soil from the surface leading to scalding of the site. The removal of the surface soil by the wind also takes soil nutrients as well as soil organic matter and soil carbon. Also, included in the on-site damage category is the damage to infrastructure within that area, such as fencing, roads, or water supply points. Off-site damage is caused by the dust[3] cloud limiting activities that would be "normal" without the dust in the wind and the deposition of dust from the erosion event on downwind sites. Examples of off-site damage include: closure of transport infrastructure such as roads, rail, water, or airports due to low visibility or accidents caused

[3] In the current study any reference to dust implies dust caused by wind erosion and carried off-site.

by low visibility; damage to utility systems, such as electricity lines or transformers; building damage, such as dust build up on or within buildings, or the blasting of exposed surfaces of buildings; the health impacts on downwind populations, particularly those in the population with respiratory and cardio-pulmonary problems; and reduction in productivity of land downwind (Hansen and Libecap 2004, Huszar and Piper 1994, Miri et al., 2009, Williams and Young 1999).

Wind erosion and dust storms also have several positive effects downwind of the onsite damage. These benefits are soil and soil nutrient deposition on land and on water. Deposited dust contributes to soil build up in downwind regions. The dust also carries nutrients, such as nitrogen or phosphorus, and organic carbon that are positive contributors to soil health and nutrition (Cattle et al., 2009, Raupach, McTainsh and Leys 1994). These soil nutrients can also be used by various micro-organisms in the oceans, such as phytoplankton (Boyd et al., 2004), leading to increased fish stocks, and other soil components contribute to marine sediments (Hesse and McTainsh 2003).

Figure 1: Impact of dust storms on different populations or regions.



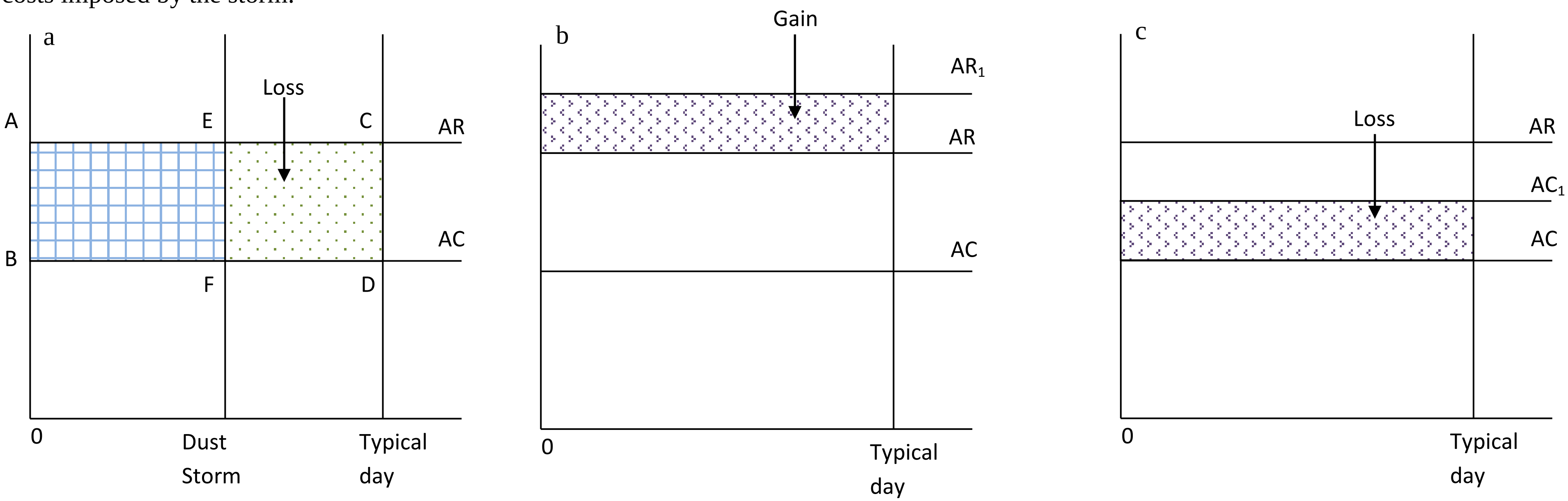
The impact of dust events as noted by several authors, such as Ai and Polenske (2008) and Huszar and Piper (1986) is to some extent determined by the number of people affected or the location of significant damage or interruptions to economic infrastructure, such as transport facilities or construction sites. Ai and Polenske (2008) suggest that the impacts of dust storms in China are higher in cities, due to the large populations and the level of infrastructure and economic activity in these areas, when compared to rural regions where population and infrastructure levels are lower. This type of effect would also be observed in Australia, as noted below Sydney airport was closed and construction activity reduced due to lower visibility and safety issues. Limited anecdotal reports from regional areas did not indicate a significant impact, other than inconvenience, in these areas. One way to illustrate this type of effect is shown in Figure 1. The severity of the dust storm may be similar, but due to lower populations and levels of infrastructure and economic activity, the impact in regional areas (A) could be lower than that in cities (B).

Economic Impacts of Dust Events

The socio-economic impacts of dust events are widespread across all sectors of the community. Previous research, in countries other than Australia, has focussed on off-site impacts of dust events. Huszar and Piper (1986) in one of the first studies on the costs of off-site impacts of dust determined that the major off-site impact of dust erosion was on households, principally due to interior cleaning and domestic landscaping renovation. One major factor Huszar and Piper (1986) did not gather information on in their cost analysis was the health impacts of dust storms. Saxton (1995) discusses the many respiratory effects of dust inhalation and the potential diseases caused by inhalation of particulate matter in dust storms, particularly PM_{10} particles (i.e. particles with a size less than 10 μm). Williams and Young (1999), in one of the first studies of the costs of dust in Australia, included the health costs of dust storms in South Australia and concluded that a major cost of dust in South Australia was caused by adverse health effects, particularly on the portion of the population that suffered from respiratory diseases, especially asthma sufferers. The health costs were the most significant contributor to the overall costs of dust storms, followed by household costs but these only constituted 13% of the costs of off-site erosion. Saxton (1995) and Williams and Young (1999) mention motor vehicle accidents or include the costs to society of these types of events, but do not include an analysis of the attendance at these events of emergency services. Miri et al. (2009) estimated the impact on the economy of a series of severe dust storms in south-eastern Iran over a period of 4 years and included in their analysis costs for school closures and removal of sand accumulations in residential areas. Many other studies of the off-site costs of dust have not considered effects on other sectors of the economy such as transport, construction, or emergency services.

During and consequent to a dust storm various types of economic impacts are experienced by businesses and households, the different impacts are presented in Figure 2. In some cases business revenue is impacted as fewer customers purchase goods or services on the day of the

Figure 2: Types of losses and gains due to dust storm on businesses and households. Panel a) represents the loss in sales, Panel b) represents the gain in revenue on the day of the storm or the day following the storm due to increased demand for services, and Panel c) represents increased costs imposed by the storm.



storm and anecdotal reports after the September 23, 2009 indicate this was the effect felt by businesses such as coffee shop owners (Walters and White 2009). This type of effect is shown in Panel a), where on a typical day average revenue is at point C and costs incurred to generate that revenue are at D. However, on the day of the dust storm revenue is reduced to point E, but there is also a concurrent reduction in variable costs to F. This imposes a profit loss of area CDFE on the business.

Panel b) is an example of the additional revenue that may be gained on days after the storm by businesses, as consumers who were restricted in their activities due to the dust storm, resume normal activities and attempt to regain the lost opportunities due to the storm. An example of this type of effect would be taxi drivers, who had reduced revenue on the day of the storm but travellers attempting to complete journeys on subsequent days lead to an increase in taxi travel. Another example of this type of effect could be shoppers who delayed purchases on the day of the storm, but purchased their goods on the days after the storm. One point to note here is that the losses incurred on the day of the storm may be offset by the gains in revenue after the storm; in this case it is simply a deferral in income rather than a loss in income.

Finally, Panel c) demonstrates an increase in cost with no change to revenue. This could occur in several situations. For example, airlines that have flights cancelled typically provide passengers hotel rooms and or meal vouchers, thus incurring additional costs. Also, households incur extra cleaning costs as houses, cars, and surfaces surrounding houses need to be cleaned to remove dust, without any subsequent increase in income.

The Dust Storm of September 23, 2009.

The dust storm that affected much of north-eastern Australia on September 23, 2009 was due to the coincidence of several climatic factors. A hot dry winter, particularly in the source area of western New South Wales and north-eastern South Australian led to a landscape that had low to no vegetation cover. A deep low pressure system over south-eastern Australia caused strong winds. The lack of vegetative cover left the soil surface prone to wind erosion, from even the lightest breeze. The deep low and associated cold fronts generated winds of up to 100km/h, with directions varying from north-westerly to westerly. It was these westerly winds picking up the dust in the source area that created the dust storm covering the eastern seaboard of Australia (Leys et al., 2011).

Dust covered much of north-eastern Australia. The major dust plume was approximately 1,500 km long from slightly south of Sydney to northern Queensland. In New South Wales the major areas affected by dust were north of a line running approximately from Broken Hill to Albion Park, near Wollongong. However, there were also reports of some dust in Wagga Wagga in the south of New South Wales. Depending on the location the dust event lasted anywhere from 1 to 6 hours, with Sydney in the upper end of the storm's duration. The concentration of dust in the plume varied along the length of the plume, but concentrations were highest in the southern end of the plume, i.e. in the Sydney and Newcastle areas.

The major off-site impact of the storm was the amount of dust transported and or deposited along the path of the fronts. Estimates of the amount of soil transported by the storm suggest that a maximum of 71,000 t/hour of dust was transported off the coast of New South Wales between Albion Park and Newcastle, with a total dust loss into the Pacific Ocean/Tasman Sea in the region of 300,000 tonnes across the same part of the coast. Overall, total soil loss from the storm has been predicted to be over 2,000,000 tonnes (Leys et al., 2011). This loss does not take into account dust and particulates deposited on land in the front's path. For a full analysis of the meteorological, climate and physical components of the dust storm of September 23, 2009 see Leys et al., 2011.

Cost analysis of impacts.

Calculation of the economic damage and costs caused by wind erosion or dust storms can be difficult, particularly for the off-site costs. It is hard to identify all off-site effects of the dust event and how these affect individual households, businesses, or government units within the economy (Huszar and Piper 1986), therefore estimates based on the best information are used.

The cost analysis was based on data provided by those primarily affected by the dust storm i.e. emergency services or the airlines, or derived from previous studies in Australia and overseas. In the analysis below several assumptions are made regarding the population and number of households in Sydney and New South Wales. These assumptions are based on Australian Bureau of Statistics data and put the number of households at 2,718,172 and population at 7,068,287 in September 2009 (ABS 2010a, b). Also, the proportion of the New South Wales population in the Sydney Statistical Division (SSD) was derived from the ABS census data for the 2001[4] census (ABS 2009) and updated as per the previous information. Using this method the proportion of the population of New South Wales in the Sydney Statistical Division is approximately 63%. Included in the cost analysis is the impact on households and businesses outside the SSD. Given the approximate path of the dust plume, it

[4] Census 2001 data was used to estimate the population of the SSD as later census publications did not report populations in the SSD but in individual Local Government Areas (LGA) or other statistical divisions.

was assumed the areas north of a line running approximately from Broken Hill to Bathurst then to Newcastle were also affected but not to the same extent as the SSD, therefore costs were reduced by a factor of 50%, as this segment of the state represents a further 25% of the population.

1. <u>Transport Effects</u>

Air Transport

One of the major effects on transport services due to the dust storm of September 23, 2009 was the closure of Sydney Airport and the subsequent need for airlines to divert, delay or cancel flights. The costs of these effects are: the extra costs of fuel and labour required to align passengers and aeroplanes to their correct destination and schedules; fixed costs incurred simply by aircraft not generating income; the need to accommodate and cater for passengers whose flights are delayed or cancelled; and the loss in profits.

Flight information was received from several airlines with respect to the number of flight cancellations, diversions, delays, and an estimate of the number of passengers accommodated due to these flight problems. All airlines were affected to varying degrees by the dust cloud, with QANTAS (including QANTAS Link) and Virgin Blue (now Virgin Australia) impacted most, simply due to the volume of flights by these two airlines. In total over 700 flights were impacted by the dust, most flights were delayed with a relatively low number of cancelations; however some international flights were diverted to Melbourne or Brisbane. Special dispensations were also issued by Infrastructure Australia for several flights to land after the Sydney airport curfew came into effect due to the storm delaying departures and because of air traffic control holding requirements caused by the dust (Infrastructure Australia, 2009). The airlines that responded also mentioned that as public companies they could not provide specific cost information as it has not been provided to shareholders or the stock market, thus breaking corporations law.

Previous research by Williams and Young (1999) provided cost estimates that were used in the current research. Williams and Young (1999) provided three estimates of costs for aircraft diversions $31,500, $63,000, and $15,000, representing median, high and low costs of extra flying time, and a once off cost of $20,154 for on-ground costs. These costs were updated using Australian Consumer Price Index data (ABARES 2010), and were used to represent domestic jet, international jet, and domestic commuter costs, respectively. The on-ground costs represented the fixed costs of aircraft operation and, in the case of a cancellation, were used as the cost of a cancelled flight. In the case of a delay the on-ground costs were multiplied by a factor of 0.25 to represent the costs associated with moving aircraft, holding aircraft outside of a gate or a delay in getting to a gate, and other associated ground costs. Based on these data the cost of the dust storm to the airline industry was approximately $8.2 million

Road and Water Transport

Given that Sydney relies on road and water transport the effects on these two methods of travel also need to be considered. Road transport could be affected in several ways due to the dust storm. The first is simply a reduction in travelling speed due to lower visibility. This reduction in speed increases the total travelling time and costs for drivers, passengers, and road-based public transport such as buses. One of the major road impacts was the closure of the M5 tunnel in south-western Sydney due to extremely high particulate concentrations in the tunnel. Again this increased the travel time of commuters from the southwest of Sydney. Poor visibility also reduced the capacity of captains of waterborne craft to navigate Sydney Harbour and the Parramatta River; ferry services were suspended for most of the 23rd of September. Another transport related effect was the closure of the Port of Botany for 3 hours due to the dust and wind generated by the storm (Collyer, 2009).

Travel time delays or increased travel time were calculated using road travel and congestion information from the Bureau of Transport and Regional Economics (BTRE 2007). Given that it is difficult to estimate the difference in travel times in clear days against the low visibility due to the dust storm and other factors, such as the closure of the M5 tunnel, several different travel time costs are estimated. The RTA (2010) reported that the average travel speed in peak hour in Sydney is 31 km/h in morning peak and 43 km/h in the afternoon peak, BTRE (2007) estimated that the cost of travel delays was $9 per hour per traveller. In the current study it is assumed that travel speed was reduced to either 30 or 35 km/h, and the travel delay cost, after adjustment for inflation is $10.19 per hour per traveller. It was estimated that approximately 25 per cent of Sydney's population undertakes a trip on any given week day (ABS 2010c). Taking into account the total travel distance from BTRE (2007) and population, the average trip is approximately 28 km (ABS 2010c). This yielded total travel delay costs for car drivers, passengers and bus passengers of $3.4 and $1.5 million dollars for travel speeds of 30 and 35 km/h, respectively. One point here is that given the number of workers absent on the day of the dust storm, there may have not been any traffic delays in some parts of the Sydney region, thus these costs are at the upper end of the estimates, and there may indeed have been no difference in travel times and hence, no costs incurred.

The impact on public transport varied depending on the mode of transport. For example, buses delayed due to poor visibility are included in the travel time analysis discussed above, but ferries were cancelled due to poor visibility on Sydney Harbour and associated waterways. In the case of Sydney Ferries 114 ferries were cancelled on September 23 (Sydney Ferries 2010). One of the problems with estimating the costs imposed on some public transport services, such as buses and ferries, is that many travellers hold periodical tickets, i.e. weekly tickets, thus these passengers do not pay on the day of travel when using the mode of transport for which they hold tickets. For this reasons it was not possible to estimate a cost of the dust storm to Sydney Ferries as they have already received much of the revenue for the day in advance, and may have had some cost savings due to inputs, such as fuel, not used.

The Port of Botany was closed for three hours during the storm due to both the wind and dust generated by the storm. However, it was not possible to estimate the cost of this closure for two reasons. The first is that it was a relatively short period of time, and the second is that estimating a cost of delay for loading/unloading shipping and associated transport was found to be extremely difficult. Hence, this is a cost that may need to be considered in later analyses.

2. Health Effects

Williams and Young (1999) identified the major cost of dust storms was to human health, particularly that segment of the population prone to respiratory distress or asthma attacks. This cost is an aggregated cost based on the direct and indirect effects of the respiratory distress caused. Direct costs are those costs associated with treatment of the disease, such as medication, professional services, and perhaps hospitalisation if needed. The indirect costs are those costs incurred by people not directly affected by illness. These costs would include the loss of productivity by the person affected, as they may not be able to perform tasks as efficiently as if they were not ill. Carers of those who suffer, such as parents of children affected, may need time off their own work to care for the child, and therefore incur some costs themselves, i.e. loss of income, or their employer may incur losses in productivity due to absentee workers.

Reports from the NSW Bureau of Health Information (BHI 2011) indicate that in the week of the dust storm there was no difference in hospital emergency room attendance when compared to 2008 and 2010. However, this does not indicate that respiratory problems did not affect certain groups within the population, i.e. asthma patients, it merely indicates that these patients may have treated themselves or that if a problem did arise they did not seek emergency department treatment. This is contrary to some media reports on the day that indicated increased calls to emergency services and hospital emergency room attendances (see for example Saminathar and Johnson 2009). However, other media reports indicated that there were few to no increased attendances at hospitals for patients presenting with respiratory problems (Ramachandran 2009). Media reports indicating no change in attendances are supported in the research arena. Several studies in Australia and the USA have shown that in some cases increasing rural dust does not lead to increased hospital admissions (Rutherford et al., 2003, Schwartz et al., 1999). One cost not included in the analysis of health issues is that of absenteeism for carers of those who did not attend hospital but were otherwise unable to attend school or leave the home; this cost is included in a subsequent section

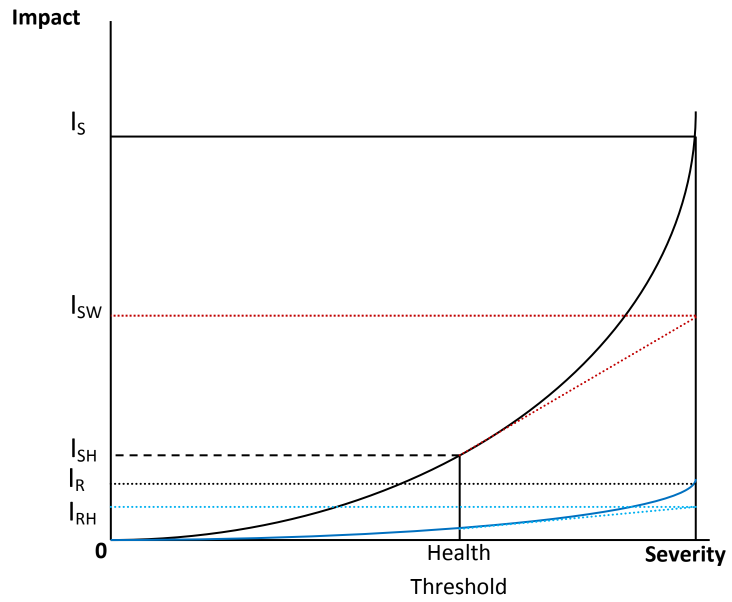
One potential reason for minimal impact of the dust storm on health could be the proactive role the Department of Health and the then Department of Environment took with respect to air quality monitoring and issuance of health alerts due to poor air quality. On the day of the dust storm Health Alert SMS and emails were sent to subscribers to the health alert system advising of a high pollution level event. Alerts were sent beginning at 2.00 am through to 9.00 am on the morning of the storm (S. Quigley, pers comm. 2011), thus those at risk could make individual decisions regarding the impact of the dust level on their health.

The reduction in impact of these warnings is illustrated in Figure 3. The health threshold is the level of dust severity at which warnings are issued. In the case where no warnings are issued the impact in the city is shown as I_S but if warnings are issued the impact curve changes shape and the impact after the warnings is reduced to I_{SW}. The change in shape is due to the response of that proportion of the population that would suffer the most from atmospheric dust. This proportion will change their behaviour and reduce the net impact, not completely, of the health effects of the dust. This figure also illustrates the differences in impacts in regional and metropolitan areas. The difference in impact in the regional areas is shown as the difference between I_R and I_{RH}, which is smaller than the difference in I_S and I_{SW}.

3. <u>Commercial Activity</u>

The impacts on commercial activity of disruptions due to the dust storm fall into two broad categories; falls in revenues due to shoppers not purchasing during the dust event, and a slow down or stoppage of some commercial activity such as construction due to occupational health and safety issues related to breathing, visibility, and slipperiness of work surfaces. In the case of shopping purchases the major effect would be on discretional expenditures, such as coffee shop purchases, as many discretional purchases may not be undertaken on other days. The impacts on non-discretional expenditure, i.e. essential purchases, such as food, may be large on the day of the event, but much of the reduced expenditure would be recovered in subsequent days.

Figure 3: The reduction in impact due to health warnings.



Commercial activity costs are separated into two categories; retail/service activities, including retail sales and cleaning costs after the dust event; and construction activity. Huszar and Piper (1986) surveyed businesses to ascertain the costs incurred by them in the event of dust storms. In the current study we utilised the estimates of business costs of Huszar and Piper (1986) and extrapolated them for the Sydney dust storm. The estimates of Huszar and Piper (1986) were divided by the population of New Mexico to give a cost per head of population, this value was then corrected for inflation and exchange rate effects using ABARES (2011) \$A/\$US exchange rates and US inflation rates data. However, the estimates of Huszar and Piper (1986) are based on a series of events over a six month period. To account for this and the severity of the September 23 event, the estimates of Huszar and Piper (1986) were halved. Using this method resulted in an estimation of costs to businesses in the SSD of \$34.7 million, and to businesses outside the SSD of \$6.9 million. These costs capture the loss in revenue from lower retail and service sales, costs of cleaning premises, and losses in productivity due to the dust reducing activity such as transport and outside work. These two values equate to approximately 21% of the daily retail turnover.

Estimation of construction sector costs is a novel cost to include in dust erosion research, hence a method is not provided by previous research. However, after discussions with the

Master Builders Association of NSW it was proposed to use data reported by the Australian Bureau of Statistics (ABS 2011a) measuring the value of construction activity and make an estimate of the percentage of construction worksites closed down on September 23, 2009. The data put the total value of construction, private and public in the September quarter 2009 at $4,315,011,000 and assuming 80 working days per quarter yielded a daily value of construction of approximately $54 million. There are two main problems with determining the cost of lost production. The first is how many sites were closed on the day of the dust storm and the location of construction sites throughout the affected area and the second is how to treat the loss in value. The loss in value in construction is due to the delay in the overall project as well as costs that are incurred whether construction is undertaken or not. Furthermore, some construction projects may have penalties associated with completion times. The delay in construction can be reduced if workers work overtime to complete the work not undertaken due to the storm, thus imposing on the firm additional labour costs. In this analysis we measure the loss or delay in construction work with two costs, one is the opportunity cost of money and the second is a penalty cost, which includes additional costs, such as overtime, as well as the penalty costs of delayed completion. Opportunity cost of money or the discount rate is set at 7%, the cost of borrowed capital plus a risk premium (ABARES 2010). An additional 3% is added onto this value to account for penalties and additional costs, thus the cost of construction delays is set at 10% of the value of construction not undertaken on the day of the storm. It is further assumed that the delays impose further delays throughout the construction year.

In this study we assumed that construction activity is in proportion to population, therefore 63% of construction activity took place in the SSD, and we assumed different levels of reduction in activity in this region 75%, 50% or 25%. Reductions of 25% or 50% were assumed to occur in the other affected region of the state. It is important to remember that the cost of construction losses is not the loss in construction value on the day of the storm, as this value is recovered as the project must be completed, but the costs associated with investment opportunities, and additional labour and associated costs. Using the above data for costs of construction delays a range of estimates from $1.1 to $3.2 million were derived as shown in Table 1. Given that we have assumed a discount rate and penalty rate total of 10% tests of the sensitivity of these estimates were undertaken and these tests showed that for every 1% difference in the discount/penalty rate the estimates changed by 10%.

Table 1: Cost of delays in construction based on various reduction rates in construction activity in different regions of New South Wales.

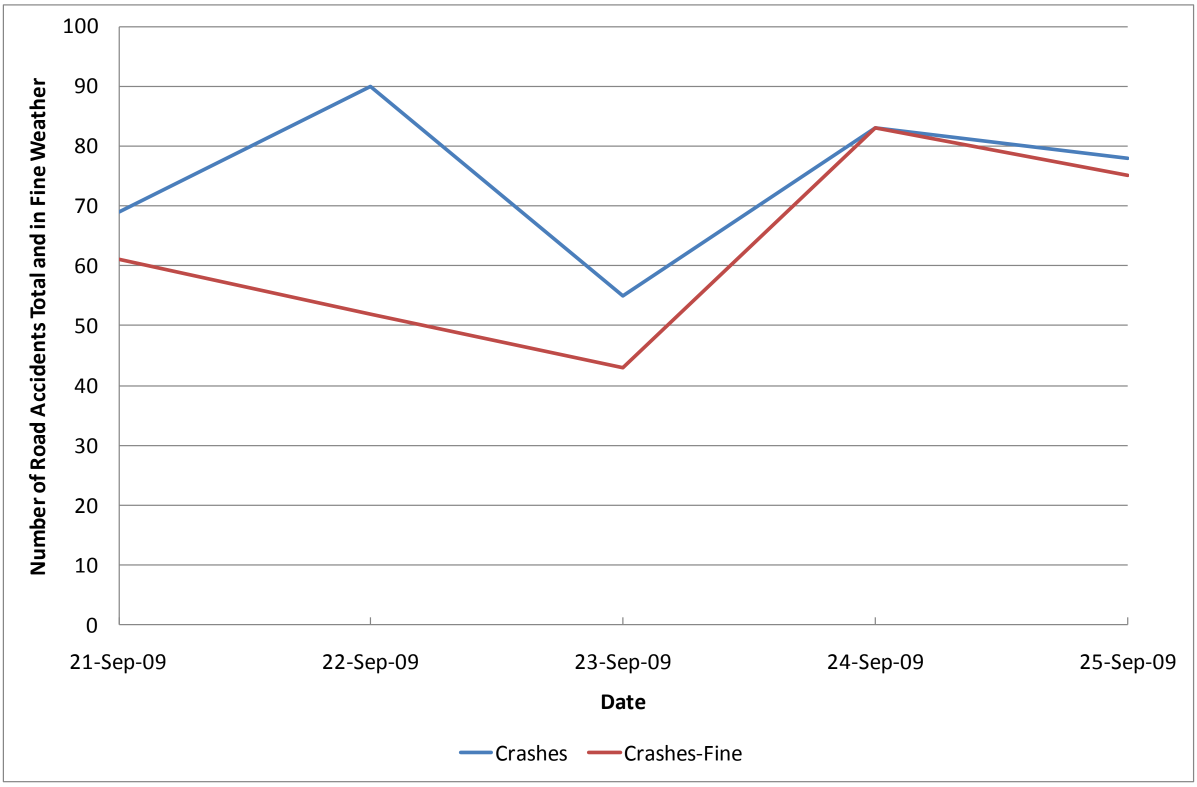
	Reduction Rate in Construction Activity (%)		
	Sydney	Northern NSW	Costs
Scenario 1	75	50	$3,226,036
Scenario 2	50	50	$2,375,169
Scenario 3	25	25	$1,187,585

4. Emergency Services

A factor not mentioned in previous research is that of false fire alarms due to the dust in the atmosphere. Although there no direct impact of the false alarm the fire brigade is required to attend any fire alarms, false or real, thus potentially incurring costs. NSW Fire and Rescue Service reported a substantial increase in the number of false fire alarms on the day of the storm (pers. comm. NSW Fire and Rescue). On the day of the storm NSW Fire and Rescue responded to 493 false alarms that were categorised as due to the extreme weather conditions and a further 41 that were classified as suspected malfunctions. In comparison in 2007 and 2010 Fire and Rescue had no weather-related false alarms and only 1 in 2008. Taking the difference between false alarm callouts on 23 September 2008 and 2009 showed that there were 504 more callouts in 2009 than in 2008. Discussions with NSW Fire and Rescue Service indicated that the Service does not estimate the costs of unit operations on a per response basis, as the costs of operating units are based on service requirements not response requirements, i.e. costs per unit per station. However, NSW Fire and Rescue does impose a charge for activation of a fire alarm where activation is avoidable, the Service does not charge for alarms activated when activation is beyond the control of the owner, such as in storms. The fee charged for a false alarm is $750. It could be reasonably assumed that part of the fee is for cost recovery, i.e. labour and other variable costs incurred with appliance operation, and that part of the fee is a penalty. In this study, as no information is available as to the division of the $750 between these two components, it is assumed that 50% of the fee was operational cost and the other penalty. This division yields a cost per alarm of $375 and a total cost of $189,000. The assumption made regarding the division of the fee has little impact on the overall cost of the dust storm, as the false alarm costs are minimal when compared to other costs incurred due to the storm.

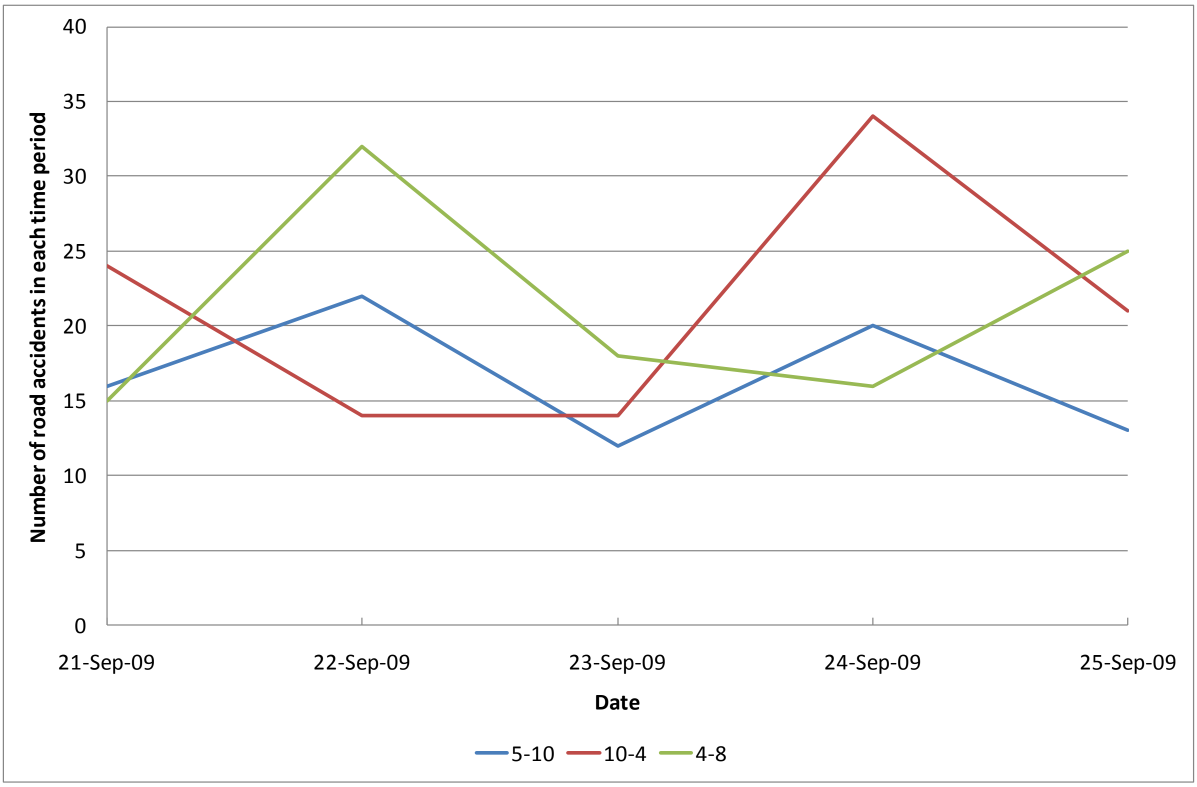
Previous research on dust storms has indicated that motor vehicle accidents can also be attributed to dust storms (Saxton, 1995, Williams and Young 1999). Crash report data were obtained from the Roads and Traffic Authority (RTA) of New South Wales for the week of 21 – 25 September 2009. This data is summarised in Figure 4 and shows that on the day of the dust storm the number of crashes was the lowest of the week and that most of the crashes on that day occurred in fine weather, i.e. no accidents were reported in fog or mist. This figure shows that the lower visibility caused by the dust storm did not increase the number of road accidents, relative to other days in the week. This may be due to one of two factors. The first being that drivers were driving at lower speeds and taking more care due to the poor visibility, or secondly that there were less vehicles on the roads as many drivers chose to remain at home, this may be the case particularly for parents driving children to school as schools reported increased absenteeism (Ting, 2009).

Figure 4: Number of road accidents in total (Crashes) and of those accidents in fine weather or clear visibility (Crashes - Fine) on September 21 - 25, 2009.



Further to the road accident data is the timing of accidents, the lowest visibility on the day of the dust storm was in the morning and during the middle of the day. Breaking the crash data into three periods, morning peak, midday to mid-afternoon, and afternoon peak, as shown in Figure 5, demonstrates that the low visibility period in the morning did not lead to increased road accidents. This lower road accident data, coupled with the health data presented earlier, allows us to imply that the services of the NSW Ambulance Service or Police Service did not increase markedly due to the dust storm and therefore no costs are included for either of those two services in the total costs to the economy.

Figure 5: Road crash data at three times, 5am to 10am (5-10), 10am to 4 pm (10-4), and 4pm to 8pm (4-8) for the week of September 21 - 25, 2009.



5. Cleaning

Cleaning costs due to dust storms can be substantial. Huszar and Piper (1986) determined that one of the most significant off-site costs of dust erosion was domestic cleaning. Other cleaning costs are incurred by commercial operations and possibly utilities. Williams and Young (1999) determined that electricity utilities in South Australia were required to clean transformers and lines after dust storms to ensure power leakages were minimised.

Cleaning costs are separated into three categories, domestic, commercial, and utility providers. Commercial cleaning costs are included in the costs discussed in section 3 above, however municipal cleaning is estimated separately. Based on data supplied, most municipalities either did not incur significant additional costs to clean up after the dust storm or incurred costs that were not directly measurable. The municipalities reported that cleaning after the dust event was undertaken by crews that would have otherwise been employed on other tasks, therefore the costs incurred are due to later completion times of other projects, or that cleaning was completed in the normal course of regular cleaning cycles. Information from several councils indicated that some specific cleaning costs were incurred, mostly for higher profile locations, but the costs averaged approximately $2000 per council. In this case we assumed that all councils incurred some minor costs of cleaning and used the average of $2000 across all municipalities affected, 101, yielding a total cost of $202,000.

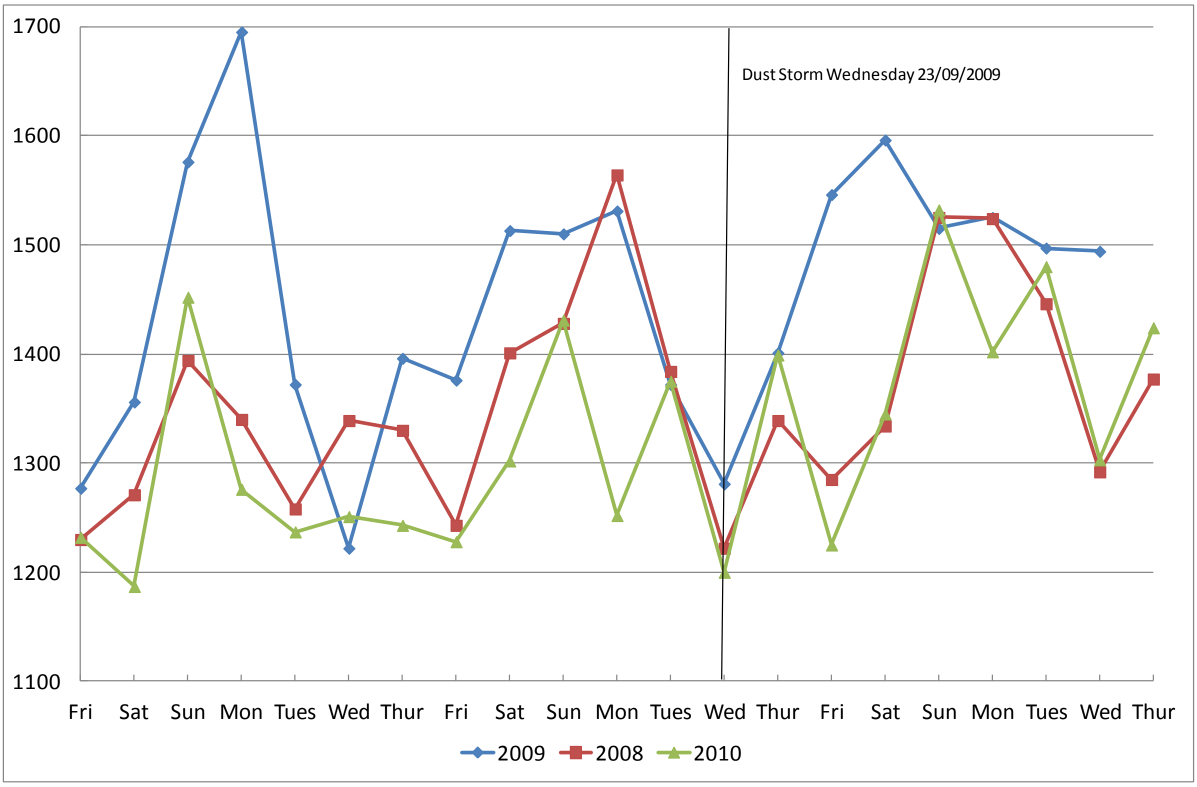
Based on reports there were no cleaning charges incurred by utilities beyond "normal" maintenance cleaning. There was one media report of several underground miners trapped in a mine at Broken Hill due to a power failure caused by electrical towers being knocked over by the storm, however the timing of this event was after the main dust storm had passed Broken Hill (Louthean, 2009).

Domestic costs are estimated utilising the approach of Huszar and Piper (1986) and the inflation and exchange rate corrections as suggested by Williams and Young (1999). One difference between the costs estimated in this study and those of Huszar and Piper (1986) and Williams and Young (1999) is that the dust storm of 23 September 2009 was a once off event, whereas the estimates of the other two research analyses were average annual costs, and in the case of Huszar and Piper (1986) the dust erosion covered the period November 1983 to May 1984. These authors also included costs of landscaping damage and loss of recreational activities, in the current study these costs are not included in the estimate of costs to households, given the once off event and that the event occurred on a working day.

One estimate for cleaning costs in the current study the adjusted costs of Huszar and Piper (1986) were halved, as a comparison individual components of costs of cleaning, i.e. labour, car washing, domestic cleaning, and laundry, in the Sydney metropolitan area were estimated. When compared to the 50% of Huszar and Piper (1986) estimates the difference was marginal, therefore the costs reported in this study for cleaning are 50% of values generated from the Huszar and Piper (1986) analysis. Using these estimates for domestic cleaning costs per person yielded a value of $115 per household. These costs include cleaning and laundry, car repairs, i.e. new air filters, and water for washing down, as well as a cost of labour for sweeping and other cleaning activities. Multiplying this value by the number of households in the SSD generated a cost of $196.5 million, and an additional cost to non-SSD NSW households of $58.3 million. A further cost of cleaning was estimated for households in Queensland as the dust cloud passed over much of the populous regions of that state. This cost was based on the same basic data as for New South Wales and the number of households affected was approximately 1.2 million, yielding a cost of $104 million.

On the day after the dust storm water restrictions in Sydney region were relaxed to allow households and businesses to clean and wash down surfaces etc (Costa, 2009). The relaxation of these rules on water use is demonstrated in Figure 6, on the Thursday and Friday following the dust storm daily water use increased by an average of 260 Ml and 280 Ml above the average use for 2008 and 2010 (SCA various dates). In 2009 water for domestic use was valued at $1.87/kl; thus additional water use cost users approximately $1 million or approximately $0.60 per household. This value is captured in the above cost per household of $115.

Figure 6: Daily water usage from Sydney Catchment Authority for the second, third and fourth weeks of September to allow for daily comparisons.



6. Other costs.

Another potential cost is an increase in school absenteeism as parents kept children home due to concerns regarding the health effects of the dust in the atmosphere. Coupled with children remaining at home would be an increase in parent absenteeism from places of employment.

6.1 Absenteeism

Media reports for the day suggested absentee rates of 25% higher than the average of 4% (Hohenboken 2009). Due to the uncertainty as to the number of workers absent on a particular day, estimating a cost requires assumptions to be made based on average attendance and the costs of work absenteeism. Making these assumptions based on workforce size (ABS 2011b) and the cost of absenteeism (Direct Health Solutions 2010) provided an estimate of the cost of absenteeism on the day of the dust storm.

Direct Health Solutions (2010) using survey data estimated that average absenteeism is approximately 4% of the workforce on any one day. The survey also estimated the cost of absenteeism as $379 per day. This is the cost to the employer of lost productivity, not the cost to the employer of leave expenses; these are already costed into the employer's costs of production. Given that the level of absenteeism is uncertain, and that some absenteeism costs have been captured in the loss in value of construction, the costs for three levels of absenteeism are estimated, 4.5%, 5% and 6%. These three values represent the lowest, most likely and highest levels of absenteeism and the costs associated with these levels of absenteeism are presented in Table 2 below. Also, included in the absenteeism costs are the costs of carer absenteeism for health related issues.

Table 2: Absenteeism rates and the costs of absenteeism.

	Median	Lowest	Highest
Absenteeism Rate	5%	4.5%	6%
Base Absenteeism Rate	4%	4%	4%
Difference	1%	0.5%	2%
Additional Workers Absent	26354	9036	60992
Total Absenteeism Cost	$7,500,000	$2,500,000	$17,300,000

6.2 Other costs not included

Another cost not considered in this study, but one that has been estimated in other studies, is the loss in value of agricultural production due to dust deposition on crops, particularly horticultural crops. Ai and Polenske (2008) estimated a loss of $US27 million in agricultural production in the Beijing region after one particular dust storm; however, much of this loss was due to reductions in yields of high value horticultural crops due to particulate deposition. In the current study there are no estimates in loss in production of agricultural crops, and it would be necessary to conduct a survey of businesses that may have been affected by the dust storm to gain an indication as to the losses incurred by these businesses.

7. Soil Loss and Loss of Agricultural Productive Capacity.

The significant on-site cost of the dust storm is the loss of topsoil and the subsequent reduction in productive capacity of the area from which the dust originated. Further on-site costs incurred by land owners could include repairs or reconstruction of farm infrastructure such as fences, water facilities, and repairs to roads or tracks. Additional costs could also be incurred by stock owners either for fodder to replace that which was destroyed by the dust storm or for the sale of stock necessary due to the loss in feed or the inability to control stock due to fences being destroyed.

Given the areas from which the dust originated it is not possible to directly calculate the on-site costs of the dust storm. However, Huszar and Piper (1986) suggest that an approximation of the on-site costs of wind erosion can be obtained from the off-site costs. In this study we use a value of 2% of the costs of household cleaning as the basis for determining on-site costs. Therefore, the estimated on-site costs are approximately $7 million. This cost includes immediate costs incurred by agricultural producers in the dust affected areas, such as fodder for stock, replacement of damaged infrastructure, and stock losses, as well as long term damage and loss in income caused by the wind erosion. These types of losses are difficult to estimate as the amount of soil removed and the associated nutrients, i.e. nitrogen and soil carbon, take many years to replace to a level similar to that prior to the erosion event, and the level of productivity of the area over this period would be lower (Leys, 2002), subsequently producers would have income levels less than that before the event. Also, it is assumed in the costs estimated that producers in the rangelands would not replace the lost nutrients with fertiliser as most rangeland operations simply do not apply fertilisers across their holdings due to the scale and cost of the operation. It could be reasonably assumed that the non-replacement of fertiliser depends on the productivity of the land affected. As noted above the rangelands affected have relatively low productivity when compared to regions to the east with high inherent levels of fertility and productivity. In the case of these higher productive regions it would be reasonable to assume that producers would indeed replace soil fertility losses associated with dust storms.

8. Potential Benefits of Dust Storm

There were several benefits generated by the dust storm, however measuring some of these may be extremely difficult. The first benefit, which may not appear as a benefit to some, is the deposition of nutrient-laden soil on land in the path of the dust storm. This deposition does have a benefit to those receiving the soil and nutrients. Leys (2002) reports values of 0.0034 $g/m^2/d$ of total nitrogen and 0.0008 $g/m^2/d$ of total phosphorus deposited after a wind erosion event. Assuming these values hold for the levels of nitrogen and phosphorus deposited on land, 25% of New South Wales land mass had some nutrients deposited, and using 2009 values for agricultural fertilisers, the value of nutrient deposition is approximately $1.1 million.

The second benefit which is extremely difficult to measure is that of the value of the nutrient-laden soil to sea life. The nutrients in the dust, particularly iron, when deposited on the ocean, provide additional nutrients for phytoplankton growth, leading to increased feedstock for other sea life (Cropp et al., 2005). This increase in feed and other sea life may increase fish stocks, but the time horizon for this benefit is again difficult to determine. The challenges in estimating the benefit of the dust deposition in the oceans are: firstly determining the iron and other nutrient content of the dust; converting these nutrients into changes in phytoplankton growth rates; and finally estimating the changes in the dynamics of fish populations and subsequent harvesting of these potentially increased fish populations. These challenges are beyond the scope of the current study, but are an interesting area of future study.

Summary of cost analysis

A summary of the costs and benefits from the analysis presented above is contained in Table 3. This table shows that the total costs to the economy of the dust storm of 23 September 2009 was approximately $425 million, with more than half of the cost incurred by households for cleaning and associated activities. However, commercial activities were also affected significantly with transport, construction and retail/service sectors suffering total costs of over $43 million. In the case of commercial and construction sectors, these are costs incurred in loss of business, cleaning, loss in construction time, and other direct costs due to the dust storm. In the case of the transport sectors the costs were due to cancellations, diversions and delays, as well as catering for passengers affected by these factors. One significant cost not considered in previous research is the cost of absenteeism of employees, and in this study this is over $7.5 million, this cost is the measure of the loss in production and productivity sustained by employers due to employees being absent and does not include the employee-related costs, i.e. leave pay. Two costs that are not included in this study that others have included are health and motor vehicle accidents. Although previous research has included these costs, the data collected for this study indicated that there were no significant increases in emergency room attendances, in the case of people with respiratory conditions such as asthma, or in the case of motor vehicle accidents. In the case of car crashes the data indicated a drop in the number of accidents on the day of the dust storm.

Table 3: Summary of costs to economy of September 23, 2009 dust storm (Values may not be exact due to rounding).

Activity	Source/Location	Cost
Cleaning		
Household	Sydney SD	$196,500,000
	Other	$58,300,000
	Qld	$104,300,000
Municipal		$202,000
Transport		
	Road	$1,500,000
	Air	$8,200,000
Construction	Scenario 1	$2,400,000
Commercial		$41,600,000
Absenteeism	Median	$7,500,000
Emergency Services		
Fire and Rescue		$189,000
Nutrient Deposition		-$2,400,000
Net Off Site Costs		**$418,360,000**
On-Site Costs Adjustment		2% of domestic cleaning
On-Site Costs		$7,200,000
Net Total Costs		**$425,600,000**

Many other costs were incurred by the economy due to the dust storm, but some of these are difficult to estimate. For example, municipal cleaning costs appear relatively small compared to domestic or commercial losses, however, much of the municipal costs were absorbed into council operating costs, and cleaning after the storm was either done in the normal cleaning cycle of the council or led to the delay of other operational tasks. Other costs reported in the media included the inability of school students to undertake various school-related activities, such as school excursions or sporting carnivals. Whilst some of these costs would have been included in the estimated costs to the commercial sector of the economy, valuing the loss of opportunities to students and staff is extremely difficult.

Given the uncertainty with some cost estimations a range of total costs is also provided in Table 5. This range shows that the cost of the dust storm to the New South Wales economy was in the range of $419-438 million, and is influenced mostly by the domestic costs of cleaning. It must also be remembered that the costs estimated in this study are for the New South Wales economy and the costs of cleaning in Queensland, however other sectors in the Queensland economy were affected in a similar way to northern New South Wales, but not to the same degree as areas in the southern part of the plume such as Sydney and Newcastle.

Table 4: Range of total costs to the economy of the dust storm of September 23, 2009.

	Base	High	Low
Total Costs	$425,600,000	$438,100,000	$419,400,000

Concluding Remarks

In this study we have attempted to estimate the costs and benefits of the "Red Dawn" dust storm of September 23, 2009. This dust event caused the closure of Sydney airport and led to disruptions of other transport services, as well as a reduction in construction and other commercial activities. Coupled with these interruptions, households were also impacted through the need to clean up after the event and also through the need for some carers to remain at home due to health and other perceived risks on the day. All of these factors combined to impose a significant cost on the economy of New South Wales, as economic activity was limited by the physical aspects of the storm. Given the nature of the storm and the period that has elapsed since the event, the scope for retrieving information from some sectors of the economy is limited. Also, the type of information required for a completely accurate estimation, such as a complete cost breakdown in sectors such as the construction, retail, or service industries, is not available due to the structure of the industry and disparate businesses operating within these segments. Some businesses or sectors of the economy, i.e. public companies, are governed by rules that preclude the release of some data or information that has not been provided to shareholders; hence estimations based on previous research may not be as accurate as desirable. Overall, we believe we have provided an estimate of the costs and benefits of the dust event of September 23, 2009 that is based on sound evidence and assumptions.

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