Accident benefits of sealing unsealed roads
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J. Minchington and P. Bradshaw
Beca Infrastructure Ltd, Wellington

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PO Box 2840, Waterloo Quay, Wellington, New Zealand
Telephone 64-4 931 8700; Facsimile 64-4 931 8701
Email: *research@landtransport.govt.nz*
Website: *www.landtransport.govt.nz*

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Beca Infrastructure Ltd, PO Box 3942, Wellington

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An important note for the reader

Land Transport New Zealand is a Crown entity established under the Land Transport New Zealand Amendment Act 2004. The objective of Land Transport New Zealand is to allocate resources in a way that contributes to an integrated, safe, responsive and sustainable land transport system. Each year, Land Transport New Zealand invests a portion of its funds on research that contributes to this objective.

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Glossary

AADT	Annual average daily traffic: the total volume of traffic passing a roadside observation location over the period of a calendar year, divided by the number of days in that year.
Accident rate	A unit measure of the number of accidents occurring at a site considering its length and traffic volume (10^6*accidents/year/vehicle-km).
CAS	Crash Analysis System, an interactive database of reported crashes in New Zealand created by the New Zealand Ministry of Transport.
Jittered plot	A visual graphic to illustrate the scatter of data points.
Outlier	Infrequent and anomalous observation.
PEM	Land Transport NZ's *Project evaluation manual* presents the procedures for the economic evaluation of projects eligible for the National Land Transport Programme.
RCA	Road controlling authority.
Regression to the mean	The tendency of the sample mean of a random variable to tend towards the true mean as the sample size increases (Land Transport NZ 2005).
T-test	A statistical test used to compare the mean of a sample to a known number.

Contents

Executive summary 7
Abstract 9

1. **Introduction** 10
   - 1.1 Objective 10
   - 1.2 Background 10
   - 1.3 Statistical method 11
   - 1.4 Pilot study 11
2. **Method** 13
   - 2.1 Data collection 13
   - 2.2 Route classification and site grouping 13
3. **Data analysis** 15
   - 3.1 Safety benefits/disbenefits 15
   - 3.2 Background trend 16
4. **Results** 17
5. **Discussion** 19
6. **Conclusions and recommendations** 21
7. **References** 22

Appendices

A. **Study sites.** These are Excel files located at www.landtransport.govt.nz/research/reports/index.html

B. **Study accidents.** These are Excel files located at www.landtransport.govt.nz/research/reports/index.html

C. **PEM terrain classification tables** 24

D. **Jittered plots** 25

E. **Regression analysis** 29

Executive summary

The objective of this study was twofold: First, to determine if there were benefits or disbenefits associated with sealing unsealed roads. Second, if this was proven, to then determine a procedure for calculating the accident benefits (or disbenefits) associated with sealing unsealed roads. The accident benefits (or disbenefits) have been evaluated based on a terrain classification (flat, rolling, hilly or mountainous) and the location of a road (North Island or South Island).

The authors of this report were unable to locate any other published studies investigating the benefits or disbenefits of sealing unsealed roads. Several reports, however, commented on accidents on unsealed roads and suggested that seal extensions encouraged higher speeds, thereby increasing the accident rate. These reports did not refer to any quantitative research (Henning et al. 2005, Clark et al. 2005). There has been research carried out regarding safety on rural roads, but this was not specific to sealing unsealed roads (ACRS 2004, McLean et al. 2000).

The research was split into two stages. A pilot study was undertaken to determine whether there was sufficient data available to enable the accident benefits or disbenefits of sealing a road to be calculated with a desirable level of confidence. The analysis of the entire data set (all terrains and locations) for the pilot study indicated an increase of approximately 0.1 accidents/year/vehicle-km after sealing. A similar conclusion could be made for the specific terrain classification and locations, 'South Island roads' and 'flat'. The pilot study data set did not include enough sites to achieve conclusive results for North Island roads or for terrain classifications other than South Island or flat sites.

For the detailed study, all North Island district councils thought to have unsealed roads were contacted and asked for information regarding seal extensions conducted between 1994 and 2001. Half of the councils returned the required information, which was then combined with the pilot study information. Accident data was collected from the Ministry of Transport's Crash Analysis System (CAS) for both injury and non-injury accidents for a period of at least four years before and after the seal extensions were carried out (1990–2005). Each site was categorised according to its horizontal and vertical alignment based on Table A10.5 of the *Project evaluation manual* (PEM). At least 68 sites were collected for each terrain classification (flat, rolling, hilly and mountainous) as suggested by the statistical requirements found during the pilot study.

The safety benefit has been considered as the 'after minus before' difference in accident rate (accidents/year/vehicle-km). The sites were analysed by each of the four terrain classifications and then given an overall analysis. Flat sites were split into North and South Island sites, due to the large quantity of information for this terrain classification. The analysis was conducted by testing the data set's difference from zero using a t-test. To assess the background trend (i.e. the accident rate at untreated sites), the accident rates were determined for all unsealed and sealed years at all sites.

The site groupings that were tested and the conclusions reached from the statistical analysis are outlined below in Table E.1.

Table E.1 Outcome of the statistical analysis.

Classification	Sites	Mean difference	95% confidence interval	Conclusion
Overall (all road lengths)	393	0.0840	-0.268, 0.436	No statistical change in the accident rate
North Island flat	80	-0.0253	-0.530, 0.479	No statistical change in the accident rate
South Island flat	98	1.006	0.401, 1.611	Statistical evidence of an increase in the accident rate
All flat	178	0.542	0.311, 0.773	Statistical evidence of an increase in the accident rate
Rolling	65	-0.0295	-0.362, 0.303	No statistical change in the accident rate
Hilly	91	-0.721	-1.956, 0.514	No statistical change in the accident rate
Mountainous	59	0.0686	-0.316, 0.453	No statistical change in the accident rate

The statistical analyses also revealed large outliers in some of the data sets, which are shown below in Table E.2.

Table E.2 Outlier sites.

Site ID	Site name	Accident change
69	Anso Road	Decrease
277	Jew Road	Decrease
391	Wimbledon Road	Decrease
522	Tauwhareparae Road	Increase
2015	Upland Road	Increase
2204	Inland Road	Decrease
2210	Otahuna Road	Increase
2216	Robinsons Road	Increase
2292	Heywards Road	Increase

Overall, the research concludes that there is no statistically significant benefit or disbenefit associated with sealing unsealed roads.

The key recommendations arising from this research are to carry out site specific before and after studies on:

- the sites listed in Table E.2 to determine whether a common hazard exists that causes the identified outliers, other than seal presence
- a proportion of the South Island flat sites to determine why these sites show a 'statistical increase' in accidents.

Abstract

Research was carried out between 2005 and 2006 to determine if there were benefits or disbenefits associated with sealing unsealed roads, and if so, to determine a procedure for calculating the accident savings (or costs). Road data and seal extension site information were obtained from various district councils in New Zealand and combined with the Ministry of Transport's accident data to give accident rates before and after sealing.

No statistically significant change in the accident rate was found following the sealing of roads. To determine any regression to the mean effects, a background trend analysis was conducted and found no significant overall change in the accident rate during the period 1990–2005.

The research concludes that there is no statistical benefit or disbenefit associated with sealing unsealed roads and recommends that site specific before and after studies are conducted into the study outliers and a portion of flat South Island sites.

1. Introduction

1.1 Objective

The objective of this study was twofold: First, to determine if there were benefits or disbenefits associated with sealing unsealed roads. Second, if this was proven, to then determine a procedure for calculating the accident benefits (or disbenefits) associated with sealing unsealed roads. The accident benefits (or disbenefits) have been evaluated based on a terrain classification (flat, rolling, hilly or mountainous) and the location of a road (North Island or South Island).

1.2 Background

A significant proportion of New Zealand's road network is currently unsealed. Approximately 33,000 kilometres of the total 93,000 kilometres or 35% of all roads in New Zealand are unsealed (Land Transport NZ 2006b). These roads range from main roads to access roads and traverse flat to mountainous terrain.

The authors of this report were unable to locate any other published studies investigating the benefits or disbenefits of sealing unsealed roads. Several reports, however, commented on accidents on unsealed roads and suggested that seal extensions increased speeds, thereby increasing the accident rate. The reports did not refer to any quantitative research (Henning et al. 2005, Clark et al. 2005). There has been research carried out with regard to safety on rural roads but this was not specific to sealing unsealed roads (ACRS 2004, McLean et al. 2000).

The Australian College of Road Safety (ACRS) found that unsealed shoulders were a frequent cause of accidents on rural roads and noted an increasing number of fatalities occurring on these roads (ACRS 2004). This may indicate that unsealed portions of roads are a contributing factor to accidents. Increasing numbers of fatalities on rural roads indicates the importance of this area for investigation.

The Road Accident Research Unit at Adelaide University undertook a rural in-depth crash investigation study. They found that most rural accidents occurred on two-lane sealed roads, with 58% of the accidents occurring on straight roads and two-thirds being non-intersection accidents (McLean 2001). Adelaide University's research suggests that the terrain of the road influences the accident rate with straighter roads leading to more accidents. As the majority of the accidents in the study did not occur at intersections, they could have been due solely to the road or a driver and not involved interaction between drivers.

1.3 Statistical method

The investigation undertaken for this report relied heavily on the statistical method and accuracy of the collected data. However, data can be subject to bias and errors depending on the method used to collect it. Austroads (2004) suggests the accuracy of accident data can be affected by:

- systematic reporting bias
- random reporting bias
- subjective bias
- reporting errors
- coding errors
- location errors
- discontinuity over time
- delays
- masked or hidden problem.

This study addressed issues of bias by using a random sampling method.

The New Zealand Police record accidents on a standard reporting form, which includes a crash diagram. The diagram helps confirm specifics about the accident. However, the current study did not require accurate information of what happens in a crash, thereby avoiding the inclusion of many reporting, coding and location errors which may be made during the collection and input of police accident reports.

The study assumes that similar reporting errors occurred across New Zealand and occurred similarly over the 16 years of the study. Errors due to the wrong location of a sealing or accident site were assumed to be minimal. This assumption was critical and had a large effect on the study as few accidents had occurred on a site that had undergone sealing.

1.4 Pilot study

A pilot study was undertaken to determine whether there was sufficient data available to enable the accident benefits or disbenefits of sealing a road to be calculated with a desirable level of confidence. This was done by collecting accident data on a sample set of routes that had been sealed between 1994 and 2001. These sites were not randomly chosen, but were already known to the researchers.

Annual average daily traffic (AADT) for before and after sealing was estimated to be the same for all sites in the pilot study. For this reason the AADT was not used in the calculation of accident benefits.

The analysis of the entire data set indicated an increase of approximately 0.1 accidents/year/kilometre after sealing. A similar conclusion could be made for South Island roads and for the flat terrain classification. The data set did not include enough sites to achieve conclusive results for North Island roads or other terrain classifications. The pilot study determined that at least 68 sites were required for a 90% confidence level in a change of 0.1 in the accident rate.

2. Method

2.1 Data collection

All North Island district councils thought to have unsealed roads (37) were contacted and asked for information regarding unsealed roads sealed between 1994 and 2001. The councils were asked to provide each road's location, length, width, date sealed, pavement type, total deviation angle, before and after traffic volumes, alignment changes, or barriers installed. Approximately half of the councils returned the required information which was then combined with the pilot study information. The list of councils that contributed to this study is shown in Table 2.1 and a complete list of sites that were sealed is contained in Appendix A (available at www.landtransport.govt.nz/research/reports/index.html).

Table 2.1 District councils that contributed to this study.

Pilot study	New
Ashburton	Far North
Kaikoura	Kaipara
Selwyn	Otorohanga
Waimakariri	Waitomo
Western Bay of Plenty	Waipa
	Waikato
	Opotiki
	Central Hawkes Bay
	Taupo
	New Plymouth

Accident data was collected from the Ministry of Transport's Crash Analysis System (CAS) for both injury and non-injury accidents for a period of at least four years before and after the seal extensions were carried out (1990–2005). A table of the accidents relating to the seal extension sites is included in Appendix B (available at www.landtransport.govt.nz/research/reports/index.html).

2.2 Route classification and site grouping

Each site was categorised according to its horizontal and vertical alignment based on Table A10.5 of the PEM. At least 68 sites were collected for each terrain classification (flat, rolling, hilly and mountainous) to return statistically significant results as suggested by the pilot study. This provided enough data to predict accident benefits or disbenefits to at least a 90% confidence level for a change of 0.1 in the accident rate.

The PEM specifies that a site may be divided into four categories of horizontal and vertical terrain. The vertical categories are: 0-20, 20-40, 45-60 and above 60 metres of total vertical rise or fall. The horizontal categories were determined by Table A10.6 of the PEM which specifies the four categories as: less than 1.0, 1.0-3.0, 3.0-6.0, and more than 6.0 curves per kilometre. Table A10.5 of the PEM specifies which terrain classification a site belongs to according to the site's horizontal and vertical terrain. A copy of these tables is included in Appendix C.

Prior to classification, an analysis of the road's geometry had to be completed. The total number of curves for each of the sites was counted to classify each site.

The initial intention was to further subdivide the groups into sites where additional works such as seal widening or realignment were carried out at the same time as the seal extensions (in order to isolate the effects of these factors). Unfortunately the data provided by the local authorities was not sufficient to make this possible. It should be noted that this data would only have been useful when developing crash prediction models to determine safety benefits or disbenefits for inclusion in the PEM. The research determined that no benefit or disbenefit was proved and so this work was not required.

The number of sites found for each terrain and location classification is shown in Table 2.2 below:

Table 2.2 The number of sealed sites used in this study by terrain classification.

Classification	Sites
North Island flat	80
South Island flat	98
Rolling	65
Hilly	91
Mountainous	59
Total	**393**

3. Data analysis

3.1 Safety benefits/disbenefits

The accident rate was calculated for each seal extension site before and after sealing. The accident rate in this report refers to the number of accidents at a given site that have occurred every million vehicle kilometres travelled per year (10^6*accidents/year/vehicle-km). The accident rate takes into consideration the length and traffic volume of the site.

For some sites the limited accuracy of traffic volume data hindered the accurate calculation of the accident rate. Ideally for the calculation of the accident rate, an AADT for a site before and after it was sealed was required. The traffic volume data provided by the councils, which was used in this study, was a daily count, AADT, or an estimate of the AADT.

The AADT for each site before and after sealing was not available for 85% of the sites, in which case it was assumed during analysis that the traffic volume did not change. The assumption of no change in traffic volume was based on the fact that most of the sites were backcountry, farming roads or side roads with low traffic volumes. The sites with before and after volumes had an average of 17% increase in traffic after sealing, which was a small change compared with the accident rate, and had little effect on the determination of accident benefits.

A sensitivity analysis was conducted on the traffic volume data to assess the effect that including before-sealing volume data might have on the results. Most of the volumes provided by councils were recent (after sealing) traffic volumes. At sites where no volume data before sealing was gathered, before volumes were estimated by using a 2.5% arithmetic traffic growth as specified by the PEM. The average increase in traffic volume for the sensitivity analysis after sealing was 17%.

The AADT estimates were sourced from council database systems. For 90% of the sites the AADT was less than 260, which indicated that most sites were low-volume roads and therefore not a priority for councils to gain accurate counts. The estimates may have been based on counts from adjoining roads or traffic generation models. The large data set used for this study was expected to compensate for the lack of actual count data.

For the purposes of this study the safety benefit or disbenefit was considered the ‘after minus before’ difference in the accident rate.

A statistical analysis of the safety benefits or disbenefits for each terrain classification and for the entire study set was carried out. Due to the abundance of data for the flat sites, these were analysed separately as North and South Island sites, as well as together. The analysis was conducted by testing a data set’s difference from zero using a t-test.

The t-test was conducted by assessing whether a 95% confidence interval around each data set's mean was entirely positive or negative. The 95% confidence interval used was: the data set's mean plus or minus the t value for n-1 degrees of freedom and the 0.975th percentile multiplied by the data set's standard deviation divided by the square root of the sample size.

Jittered dotplots of the data indicated that the parent distribution was approximately normal, but zero inflated, thereby reducing the degrees of freedom used in the t-test. This resulted in a test that was more likely to indicate a difference if one existed.

For the t-test to be valid, the most important condition (of independence and normality of observations) was that the observations be drawn independently. As the observations used in this research were for each site (after minus before difference in mean accidents per unit exposure) it was reasonable to expect the observations would be independent from site to site (Saville & Wood 2002 and 2005).

Due to the natural pairing of the data (accidents at the sites were measured before and after treatment) a matched pair analysis was used. As the aim of this research was to detect a change in the accident rate, an ample number of sites were used (473 changes in total). The mean number of accidents per unit exposure (before or after) was a sufficient statistic for the Poisson parameter.

A minimum of four years of accident data either side of the site seal date was used to minimise the effect of variation in accident rate from year to year (thereby decreasing the importance of the regression to the mean effect). Section A6.2.3 of the PEM requires a minimum of three years of accident records to measure safety effects for a major alteration to the road environment. A maximum of 12 years was used to avoid the effects of other trends and environment changes that could influence the result, such as volume or road condition.

3.2 Background trend

The PEM states that since 1985 there has been a downward trend in reported accidents. This type of background trend will mask an increase in accidents due to sealing and hence needs to be assessed. If a trend were found in the data set it would be used to adjust the accident rate before and after sealing.

To assess the background trend (i.e. the accident rate at untreated sites), the average accident rate for all years at all sites was calculated. The average accident rate for a year, instead of the total accident rate, was used for this calculation to take into consideration sites with a zero accident rate, and thereby avoid bias to sites where accidents had occurred. Comparing the simple linear regression R-squared value for the trend to the 95% confidence R-squared value tested the significance of the trend.

4. Results

The overall results of the statistical analysis indicated no change in the accident rate after a road was sealed. However, there was an increase in the accident rate for the 'all flat' data set, due solely to an increase in accidents on South Island flat sites.

The site groupings that were tested and the conclusions reached from the statistical analysis are outlined below in Table 4.1. The mean difference represents the mean difference in accident rate (after minus before sealing) for each classification. The confidence interval is the range in which the true mean of the accident rate difference is thought to lie with 95% confidence.

A jittered plot, which illustrates the data spread for each classification group is included in Appendix D.

Table 4.1 Outcome of the statistical analysis.

Classification	Sites	Mean difference	95% confidence interval	Conclusion
Overall (all road lengths)	393	0.0849	-0.267, 0.436	No statistical change in the accident rate
North Island flat	80	-0.0253	-0.530, 0.479	No statistical change in the accident rate
South Island flat	98	1.006	0.401, 1.611	Statistical evidence of an increase in the accident rate
All flat	178	0.542	0.312, 0.773	Statistical evidence of an increase in the accident rate
Rolling	65	-0.0295	-0.362, 0.303	No statistical change in the accident rate
Hilly	91	-0.718	-1.951, 0.515	No statistical change in the accident rate
Mountainous	59	0.0686	-0.316, 0.453	No statistical change in the accident rate

The statistical analyses also revealed outliers in some of the data sets. These may represent locations where conditions exist that could significantly affect the safety of drivers on the road once it had been sealed. These sites are listed below in Table 4.2.

Robinsons Road, which is the extreme outlier, was trimmed from the flat terrain classification. This led to a similar statistical result for the classification, therefore the other identified outliers were retained in each classification analysis.

Table 4.2 Outlier sites.

Site ID	Site name	Accident change
69	Anso Road	Decrease
277	Jew Road	Decrease
391	Wimbledon Road	Decrease
522	Tauwhareparae Road	Increase
2015	Upland Road	Increase
2204	Inland Road	Decrease
2210	Otahuna Road	Increase
2216	Robinsons Road	Increase
2292	Heywards Road	Increase

The background trend analysis revealed that there was no statistically significant trend. A regression analysis confirmed there was no significant linear trend over time to a 95% confidence level, as the R^2 of the trend (0.0185) was much less than the 95% confident R^2 value (0.310). A copy of the regression analysis is included in Appendix E.

The statistical analysis of the sensitivity analysis (t-test) and the conclusions reached are outlined below in Table 4.3. The 'all flat' classification is now indicating no statistically significant change in the accident rate.

Table 4.3 Outcome of the sensitivity analysis.

Classification	Sites	Mean difference	95% confidence interval	Sensitivity conclusion
Overall (all road lengths)	393	-0.154	-0.588, 0.280	No change in conclusion
North Island flat	80	-0.214	-0.872, 0.444	No change in conclusion
South Island flat	98	0.679	0.0518, 1.306	No change in conclusion
All flat	178	0.278	-0.178, 0.733	Sensitivity analysis indicates no statistical evidence of a change in the accident rate
Rolling	65	-0.109	-0.475, 0.256	No change in conclusion
Hilly	91	-1.118	-2.731, 0.495	No change in conclusion
Mountainous	59	-0.0189	-0.449, 0.411	No change in conclusion

5. Discussion

The statistical analysis revealed that there was no statistical evidence of an increase in accidents for the surveyed sites. South Island flat sites heavily governed the pilot study and were a significant factor in the pilot study's outcome. Also, the pilot study only investigated sites that were known to the researchers at the time, which could have led to a site bias.

The sensitivity analysis of the traffic volume data, in which before-sealing traffic volumes were estimated by a 2.5% arithmetic growth, indicated little change to the original conclusions. This reaffirmed that the accident rate didn't change significantly for sealed sites. More accurate traffic volume data would have increased the accuracy of this research, but would not have changed the outcome.

The terrain classification process illuminated three factors that may have affected the clarity of the research result.

First, a site's terrain classification was based on the number of curves in the site. No account was taken of the road terrain either side of the site and the effect that this may have had on the site's accident rate (for instance, no consideration of a curve being out of context with the surrounding environment was taken into consideration). A short length of straight road in an overall rolling or hilly road terrain commonly found in the North Island and a length of straight road on a long and flat road commonly found in the South Island would both be classified as 'flat' sites. Also, sites incorporating curves that were out of context from the overall terrain of a road were not recognised. This may have led to inappropriate classification of sites and may clarify why South Island flat sites gave a different result.

Second, a significant number of North Island unsealed roads that were sealed during the period of the study were 'no exit' or dead-end roads. These roads may have different speed and travel characteristics than say, a connecting road. Traffic on a dead-end road will most likely not travel the entire length of the road and hence not travel as fast as on a connecting road. This may lead to a significantly lower accident rate than on a connecting road, hence masking any change in the accident rate.

Third, no account was taken of the road's place in a roading hierarchy. Arterial roads (e.g. some South Island sites used in this study) may have different characteristics than a local road. An arterial could expect to have a higher percentage of drivers unfamiliar with the road, higher speeds and better alignment than a local road. This may affect the accident rate and so to neglect it could mask the true change in the accident rate after sealing.

The South Island flat sites data set was found to have statistical evidence of an increase in the accident rate, which in turn affected the flat sites data set for the whole country. The reason that the South Island data set showed an increase in the accident rate is not immediately clear. A site-specific before/after study for the South Island flat sites may be required to determine whether there was any common factor causing the increase in accidents other than the seal extension. It is recommended that a study of this type be undertaken.

The fact that there was no background trend in the accident rate is contrary to national trends (for all roads). The lack of a background trend may be a result of the low number of accidents. It may also be due to the different nature of drivers on rural roads, with a bias toward familiar road users. The trend in this study was analysed from data spanning 16 years (1990–2005) and encompassed 274 accident events. It was, therefore, considered sufficient to illustrate any background trend.

Most of the site data sets experienced outliers, as listed in Table 4.2. These outliers did not have a statistically significant effect on the outcome of the analysis but represented marked increases and decreases in the accident rate and indicated sites where sealing had greatly affected the accident rate. These changes to the accident rate may have been due to road design measures such as alignment changes, barriers, or a lack of either. The outliers could just be an anomaly due to ‘regression to the mean’. They should be further investigated to determine whether there were any significant secondary effects occurring at these sites. This could be combined with a study of South Island flat sites. An outcome of such a study would provide useful information for the PEM and for safety auditors to take into consideration in upgrade projects.

6. Conclusions and recommendations

The research concludes that there is no statistical benefit or disbenefit associated with sealing unsealed roads and recommends that:

- Chapter 4 SP4: Seal Extensions, of the *Economic Evaluation Manual* (Land Transport NZ 2006a) is retained in its current form
- site specific before and after studies are carried out on the outlier sites listed in Table 4.2 to determine whether a common hazard exists that may be exacerbating the number of accidents following sealing
- site specific before and after studies are carried out on a proportion of the South Island flat sites to determine why these sites show a statistical increase in accidents after sealing.

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Appendix A: Study sites

Appendix B: Study accidents

These appendices can be found on
www.landtransport.govt.nz/research/reports/index.html

Appendix C: PEM terrain classification tables

Page A10-15

can be obtained from profile drawings or highway information sheets. Alternatively, this profile and curve data can be obtained from RAMM data.

Table A10.5 Combined Terrain Classification

Vertical Terrain (rise and fall)	Horizontal Terrain (degrees/km): Straight (0-50)	Curved (50-150)	Winding (150-300)	Tortuous (>300)
Flat (0-20)	Flat	Rolling	Hilly	Mountainous
Rolling (20-45)	Flat	Rolling	Hilly	Mountainous
Hilly (45-60)	Rolling	Hilly	Hilly	Mountainous
Mountainous (>60)	Rolling	Hilly	Mountainous	Mountainous

Step c) **Determine percentage of road with passing sight distance** (%PSD), for each sub-section. The %PSD is the proportion of the section that has visibility greater than 450m. This can be calculated using RAMM (gradient and horizontal curvature) data.

In the absence of RAMM data, each sub-section can be classified according to terrain type, based on average gradient and curvature. Terrain type sectioning can then be converted to percentage passing sight distance using Table A10.6.

Table A10.6 Terrain Relationship To Passing Sight Distance

Measure	**Horizontal Terrain**			
	Straight	**Curved**	**Windy**	**Tortuous**
Curvature, degrees per km	0-50	50-150	150-300	>300
Number of curves per km	<1.0	1.0 – 3.0	3.0 – 6.0	>6.0
Average % passing sight distance	**35**	**15**	**10**	**5**
Percentage of road length with:				
- less than 25% sight distance	45	85	95	98
- 25 to 50% sight distance	30	15	5	2
- 50 to 75% sight distance	15	-	-	-
- over 75% sight distance	-	-	-	-

Note that this second method is not as accurate and may not be sufficient in situations where the benefits are sensitive to %PSD, especially where traffic volumes are higher.

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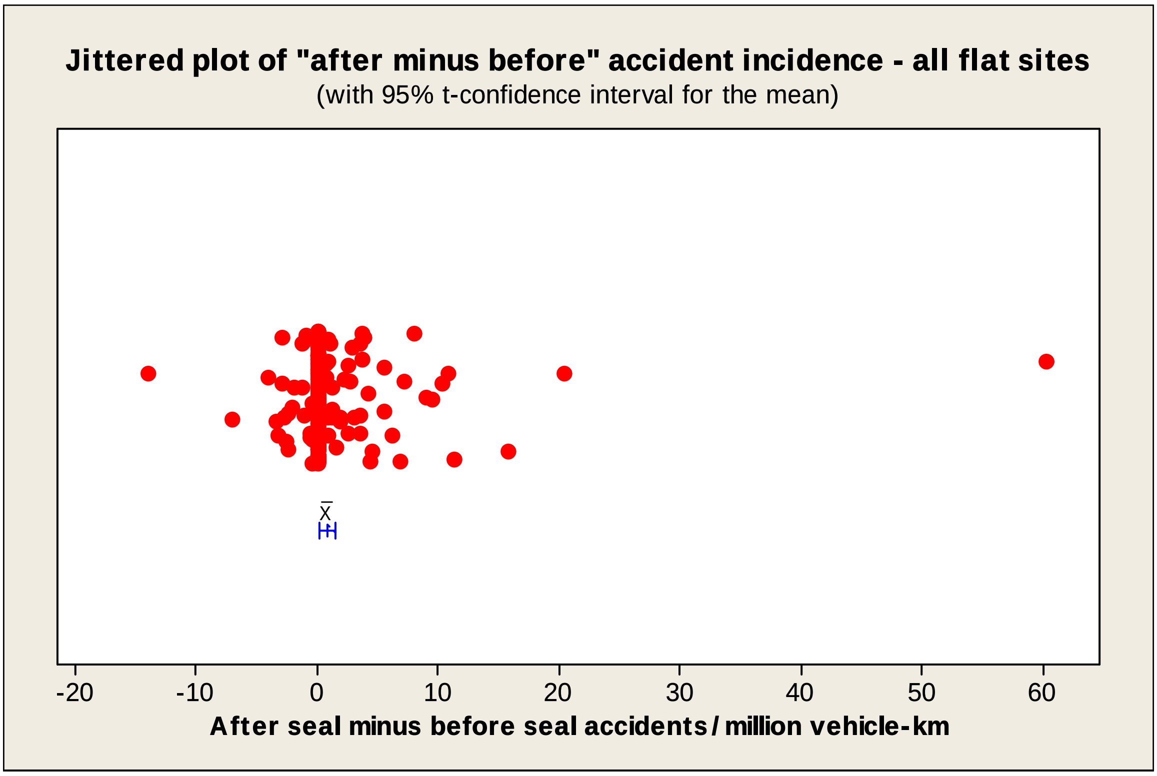
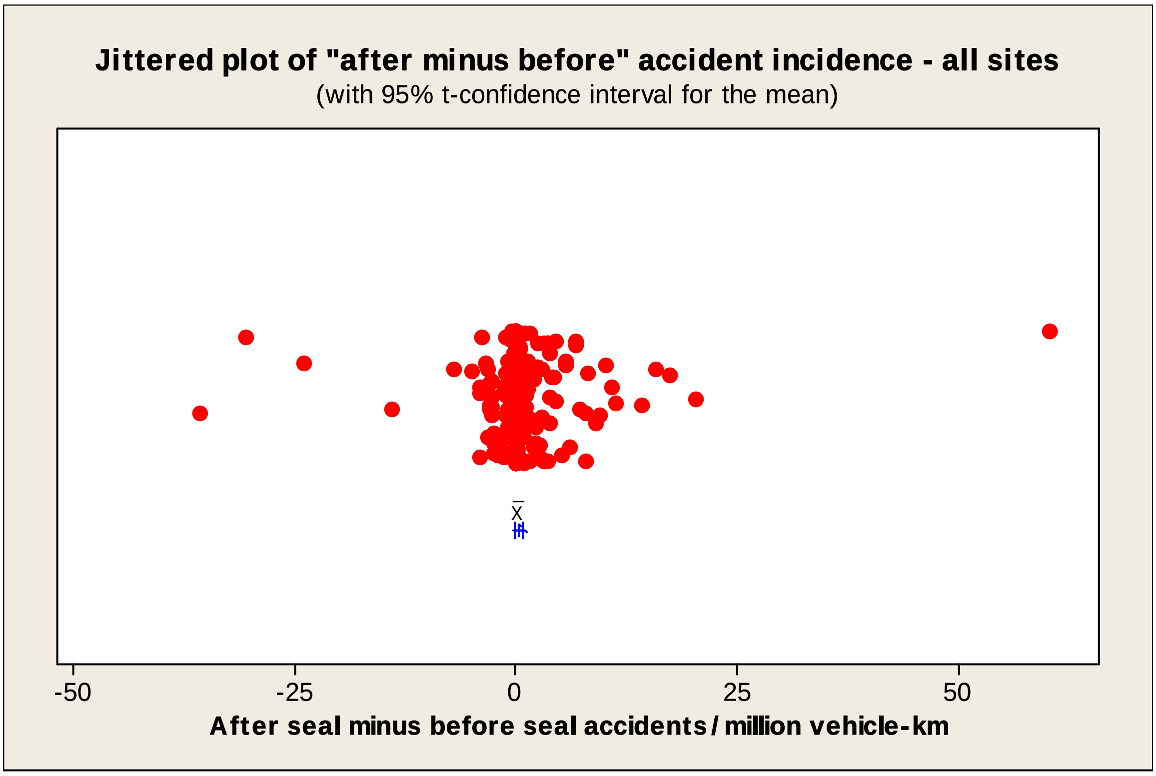
Manual Number: PFM2 Effective 1 October 2005

Appendix D: Jittered plots

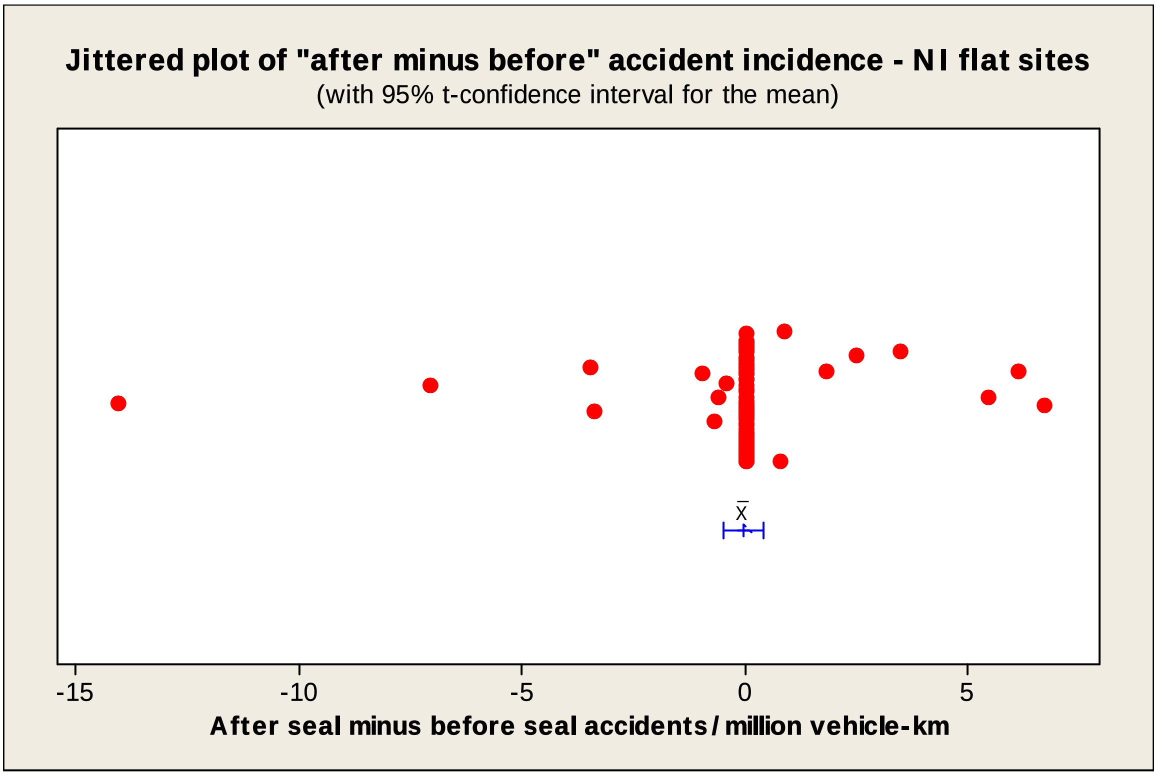
Overall (all road lengths)



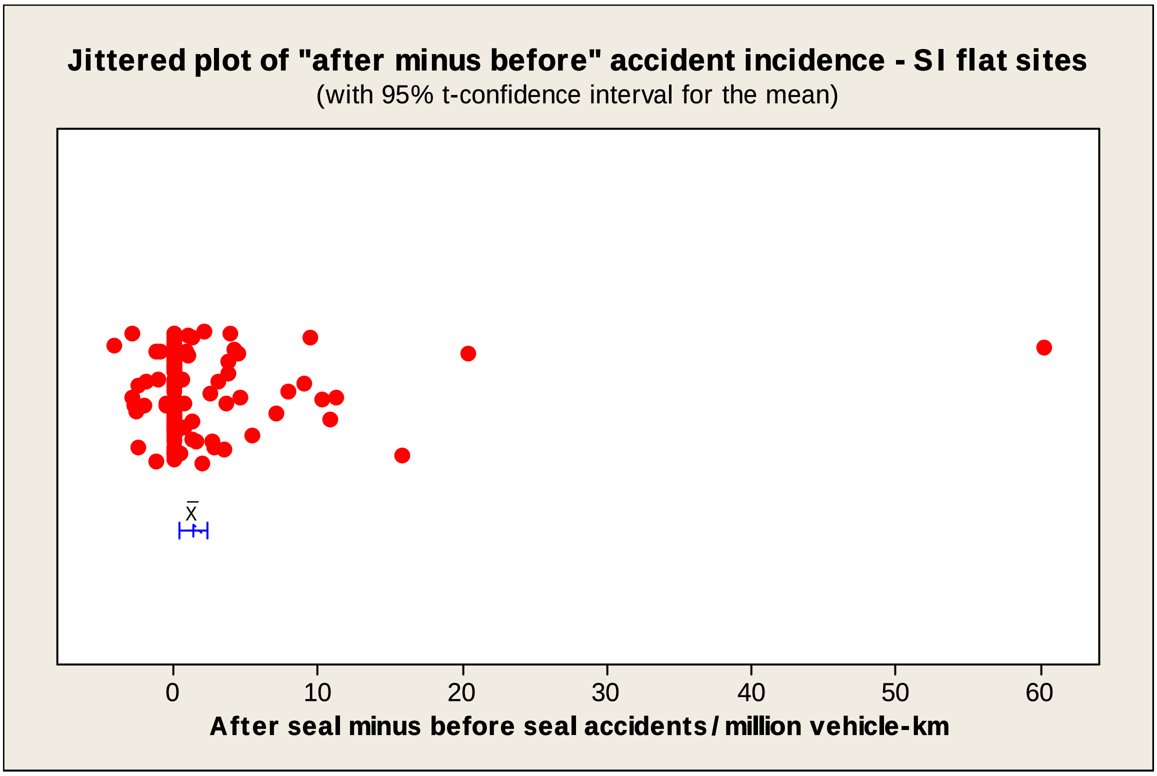
All flat sites



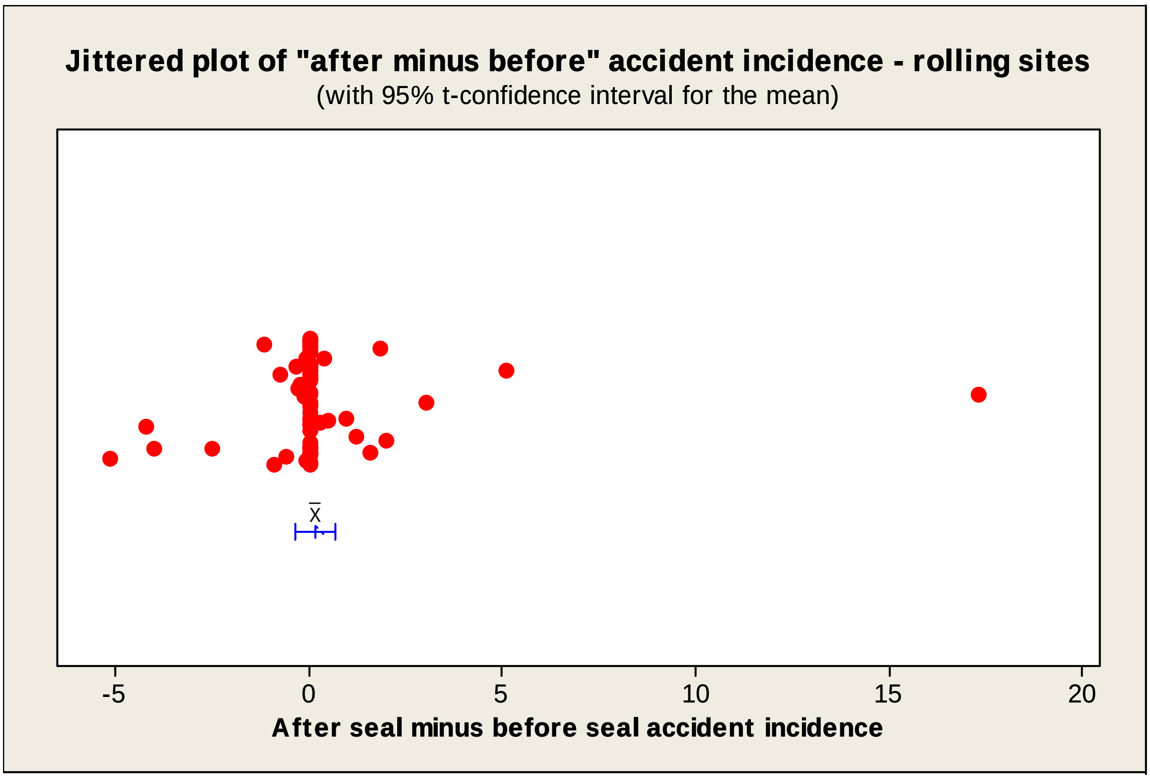
North Island flat sites



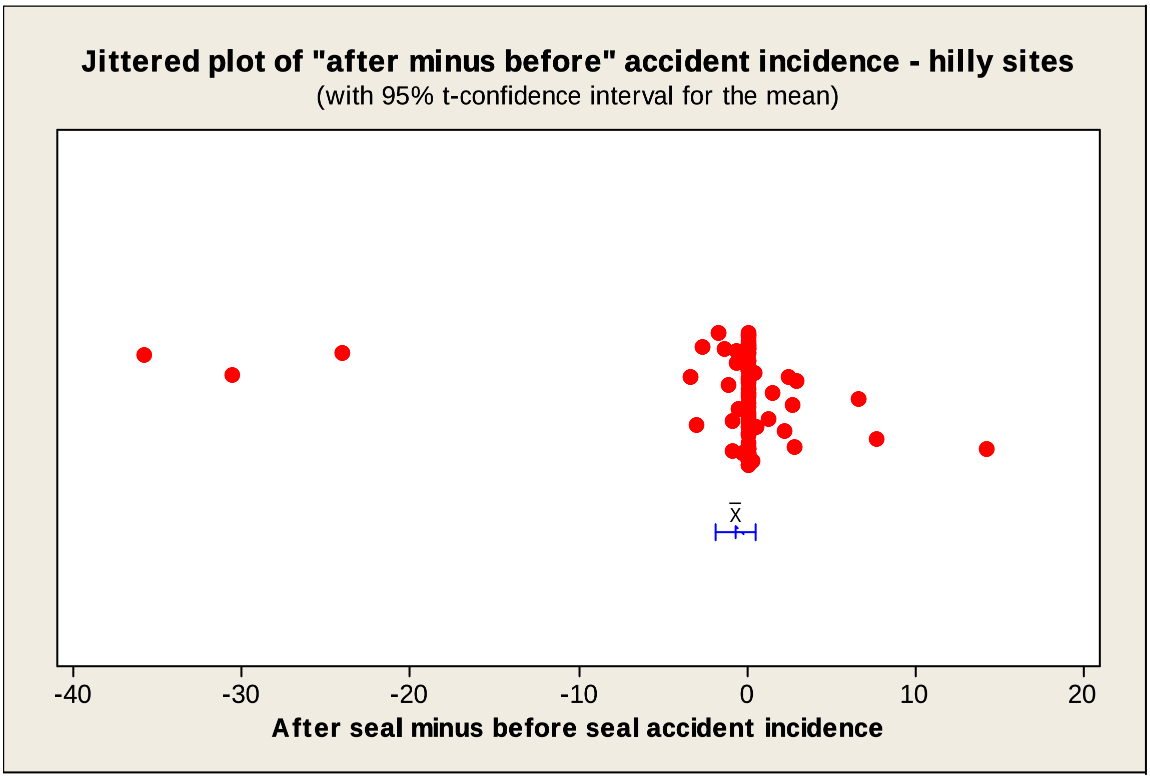
South Island flat sites



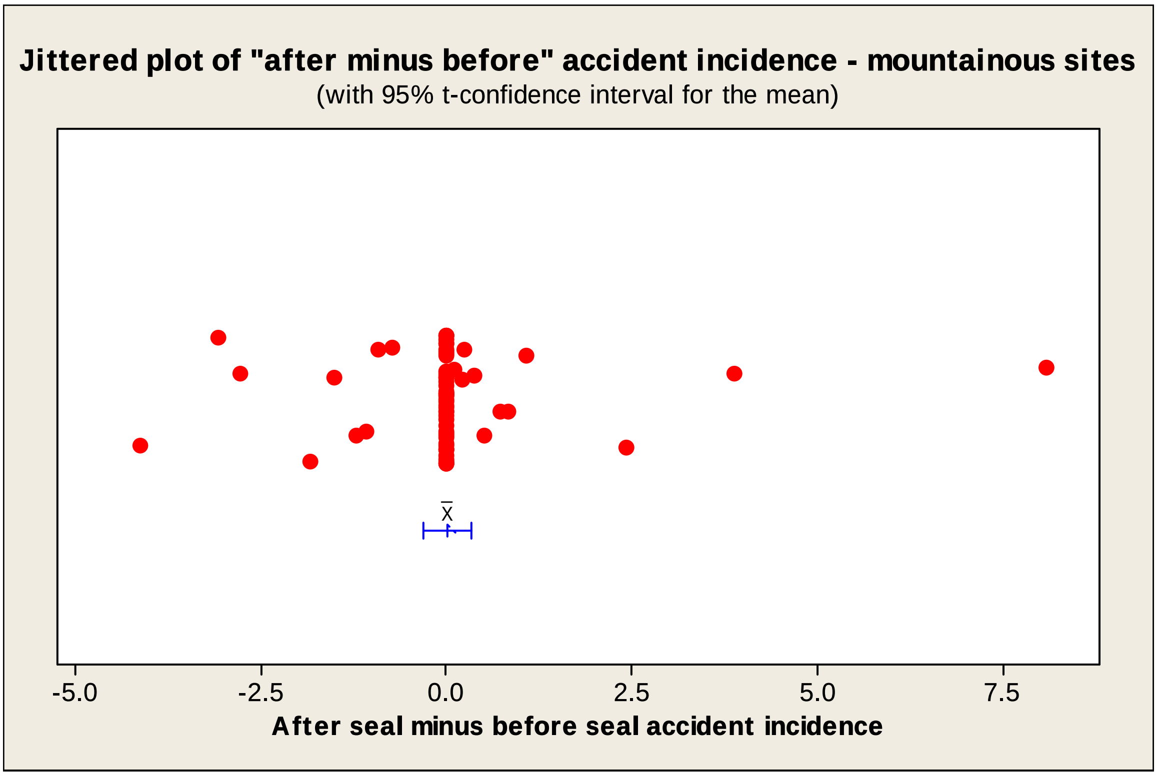
Rolling sites



Hilly sites

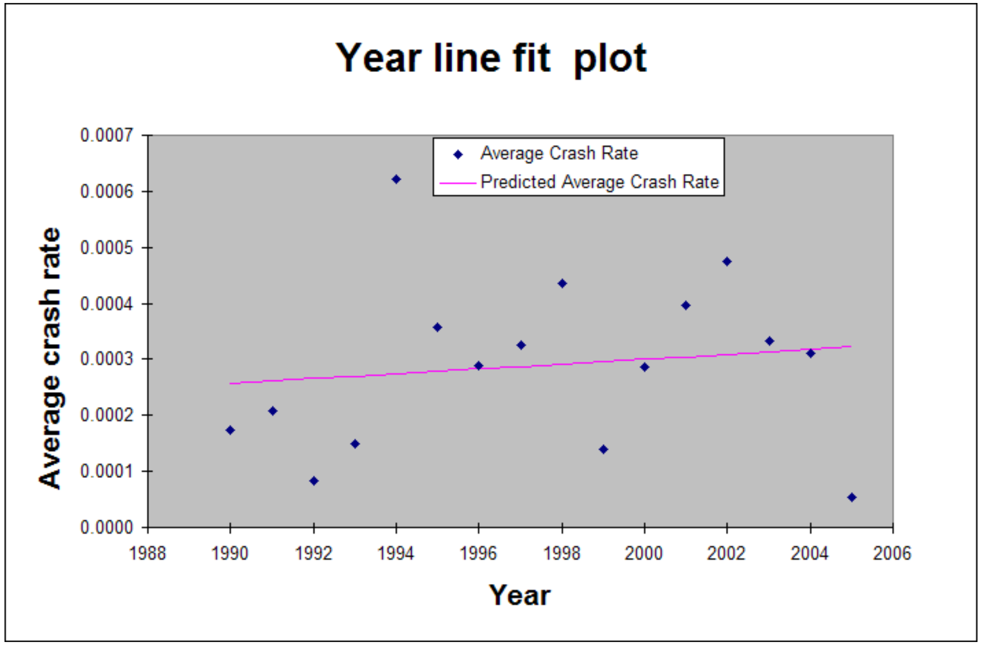


Mountainous sites



1. Appendix E: Regression analysis

Year	Average crash rate
1990	0.0001727557
1991	0.0002087069
1992	0.0000829920
1993	0.0001495483
1994	0.0006208205
1995	0.0003564315
1996	0.0002878336
1997	0.0003244350
1998	0.0004360819
1999	0.0001389595
2000	0.0002867894
2001	0.0003956468
2002	0.0004753789
2003	0.0003333357
2004	0.0003102712
2005	0.0000527772



SUMMARY OUTPUT

Regression statistics		*95% Confidence*
Multiple R	0.1358325	0.557
R Square	0.018450468	0.310249
Adjusted R Square	-0.051660213	
Standard Error	0.000155802	
Observations	16	

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	6.3881E-09	6.3881E-09	0.263162014	0.615954828
Residual	14	3.39842E-07	2.42744E-08		
Total	15	3.4623E-07			

	Coefficients	*Standard error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*
Intercept	-0.008368766	0.016878074	-0.495836565	0.627702579	-0.044568668	0.027831135	-0.044568668
Year	4.33458E-06	8.44958E-06	0.512993191	0.615954828	-1.3788E-05	2.24571E-05	-1.3788E-05