Birth outcomes and selected cancers in populations living near landfill sites

Report to the Department of Health

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1 Summary

Background

Excess risks of certain congenital anomalies, low birth weight and still birth near landfill have been reported (Vrijheid, 2000). Recently, a European study of 21 hazardous waste sites, including 10 from the UK, reported excess risks within 3 km for all congenital anomalies combined, cardiac and neural tube defects (significant relative risks ranging from 1.33 to 1.86), and a non-significant three-fold risk of gastroschisis, based on 12 cases (Dolk *et al.*, 1998). One further UK study, near the Nant-y-Gwyddon landfill in Wales, also reported an excess risk of gastroschisis on the basis of four cases (Fielder *et al.*, 2000).

A number of studies have also suggested associations between residence near landfills containing hazardous waste and excess risk of cancer, although no consistent pattern has emerged (Vrijheid, 2000).

Because of these concerns, we undertook a national study to examine risk of adverse birth outcomes and selected cancers near landfill sites, using data on all known sites in Great Britain.

Classification of populations near landfill sites

A comprehensive database of landfill sites was compiled in a geographical information system from data provided by the national regulatory agencies. For England and Wales, four data sets were used: a set compiled by WRc Ltd from public records and direct contact with waste regulators and landfill operators; two data sets (Merseyside and Staffordshire) compiled by the Environment Agency from their regional offices; and a database of currently licensed sites, held by the Environment Agency. For Scotland, the Scottish Environment Protection Agency provided data sets containing all known, licensed sites (as of 1995), and sites currently paying licence fees.

The data content and completeness of these various data sets varied greatly. The majority of sites included were those licensed under the Control of Pollution Act 1974, but some long predated licensing (the earliest listed sites opened in 1900 and closed in 1913). Grid co-ordinates were missing for many sites, and often rounded to the nearest 1000 metres or more; many site names were non-specific or incomplete, and data on waste amounts and types were incomplete, especially for older sites.

The data sets were therefore first compared and merged on the basis of the site references and other data fields, as appropriate. After removal of 222 duplicates, the combined data set comprised 19,294 sites. These were intersected with district boundaries, buffered to 500 metres to allow for generalisation errors or sites which lie in more than one district. In this way, 412 mislocated sites were found and returned for checking by the data providers. Of these, 98 could not be corrected and were removed, leaving a total of 19,196 sites (17,746 in England and Wales and 1,450 in Scotland). The operating dates of these 19,196 sites were defined on the basis of dates of first/last waste input (where available) or issue/surrender of licence (otherwise). Waste type was classified into three broad categories: special (i.e. hazardous) as defined by the Special Wastes Regulations

1996, non-special and unknown. No attempt was made to classify sites in terms of their size because of the incompleteness of the available data and because size can vary greatly over time as sites evolve. The reported surface area ranged from 0.05 ha to over 500 ha (median 1.6 ha).

The resulting database was intersected with approximately 1.6 million postcodes in Great Britain, using a rule-based decision tree. Errors in both data sets need to be recognised. Landfill sites are represented by a point (the position of the gateway or the centroid of the boundary polygon) which cannot accurately represent the complex and changing area of the sites. Postcodes provide only an approximation of place of residence, to an accuracy of 10-100 metres in urban areas but a kilometre or more in rural areas. For these reasons, a radius of 2 km was used to define proximity to landfill sites (coinciding with recent assessment of the likely limit of dispersal; WHO, 2000); because of the inaccuracies and spatial resolution of the data, further sub-divisions nearer the sites, for example to examine for 'dose-response' effects with distance, were not considered meaningful.

The area within 2 km of landfill sites included 80% of the national population. During classification, 25% of the population were excluded because they lived near the 9,631 landfill sites which closed before 1982, opened after 1997, or for which key data were missing or incomplete. The remaining 9,565 landfill sites comprised 774 licensed to receive special waste and 7,803 non-special waste, while 988 were classified as 'unknown'. Postcodes outside the 2 km zones around all landfill sites in all years were classified into the reference area (20% of population).

Although the special sites themselves are subject to stricter management measures and design standards than other sites, they may in some cases handle only very small quantities of special wastes, while some hazardous wastes (e.g. asbestos) may have been disposed of, unreported, in other sites. Landfill sites tend to be located in old mineral or other excavations, they may be on old (industrial or contaminated) land, and many lie close to existing industrial activities. There is therefore the potential for exposure to environmental contamination from other sources. Further details of methods to allocate populations to landfill sites and their limitations are given in an accompanying Technical Report by Briggs, *et al.* (2001).

Health and denominator data

Main outcome measures were all congenital anomalies combined, neural tube defects, cardiovascular defects, hypospadias and epispadias, abdominal wall defects (including surgical corrections for gastroschisis and exomphalos), still births, and prevalence of low ($< 2,500g$) and very low ($< 1,500g$) birth weight. Cancer outcomes were: bladder, brain, hepatobiliary, childhood and adult leukaemia.

We used several national post-coded registers held by the UK Small Area Health Statistics Unit: i) the National Congenital Anomaly System in England and Wales, 1983-1998 together with ii) data on terminations, 1992-1998, performed for "grounds E" of the 1967 Abortions Act, to improve ascertainment of certain anomalies, especially neural tube defects; iii) congenital anomaly data (including terminations) for Scotland, 1988-1994; iv) hospital discharge data for England (Hospital Episode Statistics) and Scotland (Scottish

Hospital In-Patient Statistics), 1993-1998 (reliable data for Wales were not available); v) national births and vi) stillbirths data, 1983-1998. A deprivation score was obtained by assigning postcodes to tertiles of the national distribution of the Carstairs' deprivation index (Carstairs and Morris, 1991) based on 1991 census statistics at Enumeration District (ED) level.

Statistical methods

Risks for the population within 2 km of landfill relative to the reference population were calculated using indirect standardisation. Model predictions from Poisson regression of data from the reference area were used to obtain estimates of the reference rates which were more stable than those based on stratification. The regression function included combinations of the following categorical covariates: year of birth, administrative region, sex (low/very low birth weight and still birth only), age (cancers and leukaemia only) and deprivation (tertile of the Carstairs' index), using a descending stepwise selection procedure to identify models, starting from the fullest model including all possible interactions. For abdominal wall defects, maternal age (available 1986-1998 for England and Wales only) was added. Because of the smaller numbers of cases among the hospital admissions outcomes, no modelling was done and we present unadjusted and deprivation-adjusted results only.

To the extent that our model assumptions fail to hold (for example, because of data anomalies, unmeasured confounding or sampling variability in the rates) some degree of over-dispersion and a widening of the confidence intervals are to be expected. We therefore calculated 99% (rather than 95%) confidence intervals around the relative risk estimates and stress estimation of relative risks rather than significance testing.

We tested sensitivity of our results by using an alternative model for each outcome that included additionally the most significant term excluded at the last step. We also included urban/rural status and examined risks for rural areas only, and for low and very low birth weight (where there were sufficient data); we also examined sensitivity to use of quintiles (rather than tertiles) of the Carstairs' index.

The main analysis identified at outset was for all landfill sites (special, non-special, and 'unknown') combined. Main results are for the combined period during operation and after closure. Subsidiary analyses examined risks separately for special and non-special waste sites, and in the period before and after opening for the 5,260 landfill sites with available data.

Results

The area within 2 km of the 9,565 landfill sites that were operating at some time during the study period, tended to be more urban and more deprived than that beyond 2 km (reference area): 34% (versus 23%) of the population were in the most deprived tertile. Special waste sites tended to be concentrated in more industrialised areas, with slightly higher deprivation than non-special sites (36% versus 34% of population respectively (in 1997) in the most deprived tertile of Carstairs' score). Compared with the reference area,

the area within 2 km also had a higher proportion of births to mothers under 20 years of age (7.7% versus 6.1%); and among women aged 15-44, it included (1991 census) a higher proportion of women of Indian, Pakistani or Bangladeshi origin (4.8% versus 3.2%) and a lower proportion of black women (2.0% versus 3.4%).

With adjustment for potential confounders, relative risks within 2 km of landfill (all waste types) were 1.01 (99% CI 1.01-1.02) for all anomalies combined, 1.05 (1.01-1.09) for neural tube defects, 0.96 (0.93-0.99) for cardiovascular defects, 1.07 (1.04-1.10) for hypospadias and epispadias and 1.08 (1.01-1.15) for abdominal wall defects. Relative risk for surgical correction of gastroschisis and exomphalos was 1.19 (1.05-1.34); there was no excess risk for surgical correction of hypospadias and epispadias. Relative risks for low and very low birth weight were 1.05 (1.05-1.06) and 1.04 (1.03-1.05) respectively, with no excess risk of still birth. For the congenital anomalies register and terminations data, risks above one around special waste sites were found for all outcomes, ranging from 1.03 (0.86-1.25) for abdominal wall defects to 1.11 (1.03-1.21) for both cardiovascular defects and hypospadias and epispadias. Where a landfill opened during the study period, risks above one for congenital anomalies (except neural tube and cardiovascular defects) were found in the period before opening (especially hospital admissions for abdominal wall defects, relative risk 2.26; 1.23-4.15).

For the cancers, a relative risk of 1.04 for bladder cancer and 1.05 for hepatobiliary cancer in the models with deprivation excluded reduced to 1.01 (1.00–1.02) and 1.00 (098–1.03) respectively once deprivation was added. No excess risk was found for the other cancers, nor was there excess risk of any cancers near the subset of special landfill sites. The results were relatively robust to the models used in the sensitivity analysis.

Discussion

This is by far the largest study to report on the possible association between residence near landfill and health outcomes. By including all landfill sites in the country, we avoided the possibility of bias from selective reporting, and statistical power was maximised, reducing the play of chance. However, problems with data quality (including levels of ascertainment for congenital anomalies), other potential biases and confounding could have led to spurious associations. For example, while the births and stillbirths data are well recorded, the National Congenital Anomaly System in England and Wales is known to be incomplete (Working Group, 1995). Although such under-ascertainment would only bias our results if it were differential with respect to distance from landfill, (and we had no reason to suspect such bias) nonetheless differences of the order detected in our study could be explainable by variable reporting.

To the extent that the Carstairs' index (measured at the level of Enumeration District) may incompletely account for individual-level characteristics associated with risk of congenital anomaly, such as smoking (Wasserman *et al.*, 1996), drug use (Torfs *et al.*, 1994) and infections during pregnancy (Lynberg *et al.*, 1994) (which may themselves be distributed differentially with respect to landfill sites) then there is also the possibility that residual confounding, i.e., from non-landfill factors, may explain the results.

In conclusion, we found small excess risks of congenital anomalies and low and very low

birth weight in populations living near landfill sites, but no excess of cancers. Currently, no causal mechanisms are available to explain these findings, and alternative explanations including data artefacts and residual confounding by socio-demographic or other variables are possible. The apparent excess risks of congenital anomalies before landfill opened lend some support to the latter interpretation, although further studies to help differentiate between the various possibilities are required.

2 Introduction

The UK Small Area Health Statistics Unit (SAHSU) is an independent unit, funded by government, for the analysis of health statistics in relation to sources of environmental pollution. As part of its programme, it has been commissioned to carry out a study of health effects near landfill sites in Great Britain, following reports (to date inconclusive) of excess risks of certain congenital anomalies and cancers associated with residence near landfill sites (see Vrijheid, 2000). The primary objectives of the SAHSU study were to test the hypotheses that living near a landfill site (regardless of waste type deposited) operating at some time during the study period is associated with excess risks of giving birth to a child with a congenital anomaly (and a number of specific anomalies), stillbirths, low birthweight or very low birthweight. The secondary objective was to test the hypothesis that living near a landfill site (regardless of waste type deposited) operating at some time during the study period is associated with an excess risk of certain cancers. Subsidiary analyses examined the above hypotheses for sub-groups of these landfills: sites classified as containing or receiving 'special' (hazardous) waste, sites classified as containing or receiving 'non-special' waste (i.e. only wastes not classified as 'special'). To aid interpretation, data have been analysed i) with and without indicators of socio-economic status, to assess potential confounding by deprivation; and, where appropriate, ii) for rural populations only, to examine the effect of rural-urban differences in the potentially 'exposed' and reference populations and, iii) for periods before and after site opening, during operation and after site closure, to examine for differences in risk estimates during different periods of site operation.

The remainder of this report discusses the health and covariate data, the analysis and constraints thereof and gives details of the results of the study. Section 3 covers the health and covariate data. Section 4 summarises the analyses and Section 5 sets out the method used to model the reference rates. Sections 6 and 7, give the results for the analyses of the birth outcomes and cancer outcomes, respectively. A Technical Annex describes in detail the landfill data (Briggs *et al.*, 2001).

3 Data

3.1 Landfill data

Distance from landfill sites was used as a surrogate for potential exposure. We defined potentially 'exposed' areas as being within $2km$ of a landfill site (see Briggs *et al.*, 2001); higher spatial resolution was considered infeasible because of concerns about accuracy and spatial resolution of the data. A recent WHO report suggests that any potential exposure from landfill sites is likely to be limited to $1km$ from the site by the air pathway, and $2km$ by the water pathway (WHO, 2000).

The subset of sites chosen for analysis, again defined in Briggs *et al.* 2001, and on which this report concentrates, were classified according to their opening status (by year) and waste type accepted. Waste sites are referred to here as 'special', 'non-special' and 'all site types'. The 'all site types' group also includes the 'unknown'-classed sites, but is

dominated by the non-special sites. The status of a group of sites is referred to as 'operating only', 'closed only', or, the union of those sets, as 'operating and closed'. Note that populations within $2km$ of sites closed before the beginning of the study period do not contribute to these analyses. Unless qualified, we use 'study area' to mean the area within $2km$ of sites, accepting any type of waste, either operating or closed.

3.2 Health outcomes and data sources

Primary case endpoints are:

- all congenital malformations (ICD9 740-759; ICD10 Q00-Q99)
- neural tube defects (ICD9 740.0-740.2, 741.0-741.9, 742.0; ICD10 Q00.0-Q00.2, Q05.0-Q05.9, Q01.0-Q01.9)
- cardiovascular defects (ICD9 745.0-747.9; ICD10 Q20.0-Q28.9)
- hypospadias and epispadias (ICD9 752.6; ICD10 Q54.0-Q54.9, Q64.0)
- hospital admissions for surgical corrections of hypospadias and epispadias (M731, M732)
- abdominal wall defects (ICD9 756.7; ICD10 Q79.2-Q79.4)
- hospital admissions for surgical correction of gastroschisis and exomphalos (T281)
- stillbirths
- low birthweight ($< 2500g$) and very low birthweight ($< 1500g$)

Secondary case endpoints are:

- leukaemia (ICD9 204-208; ICD10 C91-C95 excluding C91.4) in children age 0-14 years and in adults (15+ years)
- bladder cancer (ICD9 188, 236.7; ICD10 C67, D41.4)
- brain cancer (ICD9 191-192, 225, 237.5, 237.6, 237.9; ICD10 C70-C72, D32, D33, D43)
- hepatobiliary cancer (ICD9 155-156; ICD10 C22-C24)

The health outcome data used in England and Wales (E&W) and Scotland (S) are as follows:

- Congenital anomalies registrations 1983–1998 (E&W), 1988–1994 (S)
- Ground E terminations ("where there is a substantial risk that if the child were born it would suffer from such physical or mental abnormality as to be seriously handicapped"), 1992–1998 (E&W), 1988–1994 (S)

- Birth registrations, 1983-1998 (E&W, S)
- Hospital discharge data for England (Hospital Episodes Statistics - HES), Scotland (Scottish Hospital In-Patient Statistics - SHIPS), 1993-1998
- Cancer registrations, 1987–1997 (E&S), 1987–1994 (W) except for leukaemia in children where we have used 1983–1997 (E&S), 1983–1994 (W)

3.3 Potential confounders

The following are potential confounders available from data sources within SAHSU.

3.3.1 Region and year

These potentially important covariates are available on all SAHSU data bases. Figure 1 shows the administrative (census) regions in England, Wales and Scotland. We use them as proxies for the different data providers/registers in the study, which may have different rates of case ascertainment, for example.

3.3.2 Socio-economic deprivation

The potentially confounding effects of socio-economic deprivation are addressed via the use of the Carstairs' deprivation score (Carstairs and Morris, 1991), based on 1991 census data, categorised into tertiles, derived at the ED level and assigned to the post-code. The first tertile refers to the least deprived and the third tertile to the most deprived. Throughout the analysis, results are provided both with and without adjustment for deprivation.

3.3.3 Urban-rural status

We obtained a measure of urban status using population density from the 1991 census and used a cut-off of 1000 people per square kilometre.

3.3.4 Maternal age

This report considers the group of anomalies classified as abdominal wall defects, which includes gastroschisis and exomphalos. There is evidence that gastroschisis is more prevalent in young mothers, see Torfs *et al.* (1994), and Rankin *et al.* (1999), although the latter state that the prevalence of exomphalos is highest in 35-39 year old mothers. Of the 1043 abdominal wall defects considered by Tan *et al.* (1996), 52% were classified as gastroschisis and 42% as exomphalos.

Maternal age is available on the terminations data and the congenital anomalies data base (England and Wales only). On the births data base (England, Wales and Scotland), we have maternal age for the years 1985–1998. However, 1985 data appear patchy, so

we use it from 1986. Maternal age is not, however, available from the Scottish congenital anomalies data base. We have therefore used maternal age as an additional covariate for abdominal wall defects with a study time span of 1986–1998 in England and Wales only. In Section 6.2 we also look at the relationship between maternal age and other potential confounders, based on the births data, for which Scotland *is* included.

3.3.5 Gestational age

This covariate is important for interpretation of the birthweight analyses but is only available for Scotland. We examined the distribution of births with respect to gestational age and classification into study and reference area within Scotland.

3.3.6 Maternal ethnicity

We obtained information at ward level on ethnicity of women between the ages of 15 and 44 from the 1991 census. We examined the distribution of women with respect to ethnicity and classification into study and reference area.

3.4 Birth outcomes

The relevant exposure window for the birth outcomes is the pregnancy period, with different periods of gestation being important for different outcomes. Since the landfill data only permitted yearly resolution, we assigned the year before birth as the period of potential exposure.

3.4.1 Congenital anomalies

The anomaly outcomes are counts of all anomalies, neural tube defects (NTDs), cardiovascular defects, hypospadias (including epispadias) and abdominal wall defects (1983–1998, England and Wales; 1988–1994, Scotland). Data issues include over-reporting of anomalies in Scotland, under-reporting of anomalies in England and Wales and the so-called 'minor exclusions' rule change. Prior to 1990 all malformations, however minor, were notifiable to OPCS. In January 1990 an exclusion list of minor malformations was introduced based on EUROCAT definitions. As a result, between 1989 and 1990 the number of congenital malformation notifications received by the OPCS fell by 34% (from 12,464 to 8,202). There was a further fall (around 900 notifications) between 1990 and 1991 related to the rule change (OPCS, 1991).

When calculating reference rates for these outcomes, available covariates are year of birth, region, deprivation, urban-rural status and maternal age (limited as noted above).

3.4.2 Hospital admissions data

Since some of the registers, from which the congenital anomalies data set is derived, may have poor rates of detection, we have also used cases obtained from data on hospital admissions (discharges), both on admission and on surgical correction, using the operation codes.

We used HES data for England and Scotland (SHIPS) for 1993–1998. We do not use equivalent data for Wales (PEDW) because of concerns about the completeness of that data set. There is a varying delay between date of birth and date of operation. For surgical corrections for gastroschisis and exomphalos, operations take place within the first year of life in most cases so we use birth years 1993 - 1997 inclusive. This means that a baby born on the last day of 1997 is captured in the 1998 data if operated on within the first year of life. Taking hospital admissions for abdominal wall defects in the first year of life, also gives data on births between 1993 and 1997. For hypospadias and epispadias, operations appear over a longer period since birth. We take those operations within the first three years of life (age < 3) which limits our data to births falling in the years 1993, 1994 and 1995.

Cases were obtained from multiple episodes by removing duplicates based on date of birth, sex and post-code. Then cases were removed if their age at admission or year of birth did not fall within the limits given above. Potential sources of error here are the removal of multiple births (twins, triplets etc.) and double counting of children who have changed post-codes, either through migration or a change in post-code for administrative reasons.

Naturally, most of the surgical corrections for gastroschisis and exomphalos appeared in the hospital admissions for abdominal wall defects (96%) whereas the surgical data accounted for approximately 23% of the hospital admission data for these outcomes.

The denominator data for the hospital admission data are all live births within the birth years given above. For hypospadias and epispadias, only live male births were used.

3.4.3 Terminations data

Screening for anomalies results in up to 80% of NTD affected conceptions being terminated, see Richards, *et al.* (1999) and ONS (1999). The availability and efficacy of screening is likely to vary geographically. To address these problems we have obtained data on termination of pregnancies (TOPs) from 1992–1998 for England and Wales and 1988–1994 for Scotland. These are included using post-code with date of termination in place of date of birth. However, the terminations data do not have information on the sex of the foetus, so analyses including the TOPs data have not been adjusted for sex.

The denominator for the anomaly outcomes therefore includes all live births, stillbirths and TOPs. Note that we have data only on those pregnancies terminated on grounds E, i.e. “where there is a substantial risk that if the child were born it would suffer from such physical or mental abnormality as to be seriously handicapped”.

Table 1 shows the number of cases, in the reference area, obtained from the terminations

data base, compared with the total number of cases in that area. Note that the percentage shown is only intended to indicate the relative importance of including the termination data depending on the outcome in question and that *the total number of cases is from a larger number of years than the terminated cases*. In particular, it cannot be used and does not seek to comment on the efficacy of any screening programmes for anomalies. The number of terminations included by study area are shown in Table 2. These tables show the relative unimportance of including the termination data in the analysis of hypospadias and hence this analysis does not include terminations data. As a result, we are able to use only male births (live and still) as the denominator data for this outcome.

Endpoint	Terminated cases	Total	%
All anomalies	2208	34325	6.4
NTD	518	1140	45.4
Cardiovascular defects	192	2716	7.1
Hypospadias and epispadias	2	2485	0.1
Abdominal wall defects	60	448	13.4

Table 1: Terminations by endpoint in the reference area.

Endpoint	**Terminated cases**	
	$< 2km$	Reference area
All anomalies	5778	2208
NTD	1487	518
Cardiovascular defects	535	192
Hypospadias and epispadias	1	2
Abdominal wall defects	156	60

Table 2: Terminations by endpoint in the study and reference areas.

3.4.4 Stillbirth and birthweight outcomes

The birth outcomes are stillbirth, low birthweight ($< 2500g$) and very low birthweight ($< 1500g$), for 1983–1998 (England, Wales and Scotland).

When calculating standard rates for these outcomes, available covariates are calendar year, region, sex, urban-rural status and deprivation. We also have gestational age for Scotland only.

The denominator data for the birthweight outcomes are all live births. The denominator data for the stillbirth cases are all live and still births. See Tables 21 and 22 for the numbers of stillbirths in the reference area and study area, respectively.

3.5 Cancer outcomes

The cancer outcomes are hepatobiliary cancer, bladder cancer, brain cancer (1987–1997, England and Scotland; 1987–1994, Wales), adult leukaemia (1987–1997, England and Scotland; 1987–1994, Wales) and childhood leukaemia (1983–1997, England and Scotland; 1983–1994, Wales). The date of diagnosis is used as the date of incidence. It is well known that there is a latency period between first exposure and the detection of cancer for most carcinogens. Latency periods are usually not well defined, but are likely to be in the order of several years for leukaemia (shorter for childhood leukaemia), and probably even longer for most solid tumours. For mainly pragmatic reasons, we chose a one year (minimum) latency time for childhood leukaemia and a five year (minimum) latency period for the other cancers for the purpose of this study, though recognising these are quite short. Thus the exposure period was 'lagged' one or five years to take this into account.

For the solid tumour data and adult leukaemia, we use ages 15 and over and 0–14 years for childhood leukaemia.

When calculating standard rates for these outcomes available covariates are year, region, age, sex, urban-rural status and deprivation. The age bands for the solid tumour cancers and adult leukaemia are 15–44, 45–64 and 65 and over. For childhood leukaemia they are 0–4, 5–9, 10–14.

The denominator data for the cancer outcomes are the population data from census. Population counts have been apportioned down to post-code level, by age-sex profile, see Section 5.3 of Briggs *et al.*, 2001. Note that the resulting values are not whole numbers and hence have been reported rounded to the nearest whole number.

Base data on outcomes and populations were reduced to case and denominator data by removing incomplete data and by restricting analyses to the years covered by the available health data, allowing for the lag periods as above.

4 Analyses

The following gives a synopsis of the analyses that were undertaken.

Data summaries

- Tables of population and case counts
- Plots/tables of crude rates by year, deprivation etc.

Descriptive Characteristics of the study population compared with the reference population:

- Socio-economic/urban description
- Sex-ratio (birthweight data) in the study and reference areas
- Maternal age (1986–1998) in the study and reference areas (England and Wales only)

- Maternal ethnicity in the study and reference areas
- Gestational age, in Scotland, in the study and reference areas.

Calculation of reference rates We use a Poisson log-linear model for the reference area data to determine a parsimonious model for the rates. The fitted values from this model are then used as the reference rates in the study. See Section 5 for details.

Main analysis All landfills, accepting any type of waste, either operating or closed, during operation only and after closure only:

- Congenital anomalies (registry and hospital data)
- Stillbirth
- Low birthweight and very low birthweight.

Secondary analysis All landfills, accepting any type of waste, either operating or closed, during operation only and after closure only:

- Brain cancer
- Hepatobiliary cancer
- Bladder cancer
- Childhood leukaemia (ages 0-14)
- Adult leukaemia (ages ≥ 15).

Subsidiary analyses As for the birth and cancer objectives but using certain subsets of the data:

- 'Special' and 'non-special' waste sites separately
- Populations within $2km$ of a site where a landfill opens later in the study period (birth outcomes only).

Other

- Repeat using only rural populations
- Include maternal age as a covariate for abdominal wall defects (England & Wales)
- Explore sensitivity of results to chosen models for the reference rates.

5 Modelling of the reference rates

Examination of the geographical distribution of the landfill sites indicated that around 80% of live births in the UK occur at postcodes within $2km$ of a landfill site. The familiar scenario of a small study area lying within a relatively much larger reference area does, therefore, not hold in this case and hence the use of national reference rates is not appropriate. This has implications for the statistical analysis as the usual 'reference rates', after stratification by known confounders, would not be estimated with the negligible error

normally associated with such studies. Even so, the reference area includes over 2 million births over the study period.

The main analysis in the study tests the null hypothesis that there is no difference in risk between the study area and reference area (with respect to all landfill sites), even after adjusting for known (and available) confounders. Subsidiary analyses look at special and non-special sites separately.

As noted above, the usual approach to studies such as these is to stratify on all known confounders and evaluate expected numbers in the study area using rates derived from the reference area. Choice of stratification is usually made as fine as possible to capture the true form of the relationship, whilst keeping the cells large enough to estimate the reference rates with good precision. The problem here is that the reference population, is smaller than that in the study area, so that many of the cells in the ideally adopted stratification would have small numbers or even be empty. Hence we required a method for reducing the number of cells, or estimating the expected numbers some other way.

The most-deprived part of the reference population was particularly problematic, so we used tertiles of deprivation rather than the usual quintiles. We examined the relationship between the potential confounders and disease rates within the reference populations to determine a parsimonious covariate model. This was done using Poisson regression for all outcomes as follows: Consider data in the reference area only with three covariates, region, time period and deprivation, denoted by R, T and D respectively, then the number of cases in the ijkth stratum of those variables is denoted y_{ijk} and the population therein by N_{ijk}, where $i = 1, \ldots, I, j = 1, \ldots, J$ and $k = 1, \ldots, K$. Assuming the population are known constants, we model the probability of disease in that stratum as p_{ijk}, using the following Poisson model:

$$y_{ijk} \sim \text{Poisson}(\mu_{ijk} = N_{ijk} \times p_{ijk})$$

with

$$\begin{aligned} \log p_{ijk} &= \alpha_0 + \alpha_i^R + \alpha_j^T + \alpha_k^D \\ &+ \alpha_{ij}^{RT} + \alpha_{ik}^{RD} + \alpha_{jk}^{TD} \\ &+ \alpha_{ijk}^{RTD} \end{aligned}$$

and the constraints $\alpha_1^R = \alpha_1^T = \alpha_1^D = \alpha_{11}^{RT} = \alpha_{11}^{RD} = \alpha_{11}^{TD} = \alpha_{111}^{RTD} = 0$.

Deviance differences can be used to decide on a parsimonious sub-model of the saturated model above. The parameters from this model (and hence functions of them) are more precisely estimated than traditional reference rates as long as a model with less parameters than the saturated model is chosen. The saturated model has $I \times J \times K$ parameters. For example, where there are 10 regions, 16 years and 3 deprivation categories, the saturated model has 480 parameters and if only the main effect parameters are important, we need only 27 parameters. The fitted values from this model are then used as the reference rates for the main part of the study.

By using this approach we were able to obtain an estimate of the association between the potential confounders and the health outcomes in the reference area which were independent of landfill; applying these rates in the 'study' area, therefore gave an estimate

of the 'landfill' association having adjusted for these variables. We also considered as an alternative modelling the disease rates for the entire population (study and reference areas) as a whole and including a (0,1) variable (reference/landfill) to estimate risks associated with landfill, but rejected this idea because of possible bias in the risk estimates. For example, the 'regional' effect estimated by the model would now include data from both the 'study' and reference areas (and predominantly the 'study' area because of the distribution of population between the two areas), so that if landfill associated with high risk tended to be located in particular regions, then adjustment for region might inappropriately remove some of the 'landfill' effect.

However, to the extent that our model assumptions fail to hold (for example, because of data anomalies, unmeasured confounding or sampling variability in the rates) some degree of over-dispersion and a widening of the confidence intervals is to be expected. To guard against over-interpretation, we calculated Poisson 99% (rather than 95%) confidence intervals around the relative risk estimates, assuming a common relative risk for all landfill sites, but note that this does not necessarily ensure that all the variability has been captured. We therefore emphasise estimation of relative risks rather than statistical testing and do not calculate an overall significance level. We note that the primary hypotheses are those concerning the birth outcomes but acknowledge that multiple hypotheses are involved.

6 Analysis: birth outcomes

6.1 Relationships between confounders, study/reference areas and outcomes

Compared with the study area, we can classify the reference area as being less deprived, more rural, having fewer younger mothers and having less early and very early births.

In looking for potential confounders amongst our possible covariates, we note that in order for a covariate to be a confounder, it must satisfy two relationships - to be associated both with the exposure (in this case, proximity to landfill) and the outcome of interest. In the following sections we attempt to examine these and other relationships.

In the following section, we look at the denominator for the anomalies outcomes (except hypospadias and epispadias which use male births), labelled 'total births'. This number is made up of live births, still births and terminations in England and Wales (1983–1998) and Scotland (1988–1994), unless stated otherwise. Terminations data are included 1992–1998 for England and Wales and 1988–1994 for Scotland. Note that tabulations of 'total births' by exposure category include those postcodes where a deprivation tertile could not be assigned. These data are not included in the calculation of rates or used for modelling, or used in calculating the relative risks.

6.1.1 Region and year

Figure 1 shows the ten administrative (census) regions referred to in this report. Figures 2 and 3 show the raw rates of the birth outcomes by region and year, respectively. The relative over-reporting of anomalies in Scotland compared with the other regions is clearly shown (Figure 2). The plots of all anomalies and cardiovascular defects against year (Figure 3) also clearly show the effect of including the Scottish data (1988–1994) and the terminations data in England and Wales (1992–1998). This increase masks the decrease resulting from the 'minor anomaly' rule change in 1989/1990. The vertical bars indicate approximate 95% confidence intervals.

Table 4 shows the total number of births by exposure category and region, where 'exposure' is defined as to an operating or closed site accepting any waste type. A chi-squared test of independence between rows and columns was rejected ($p < 10^{-4}$).

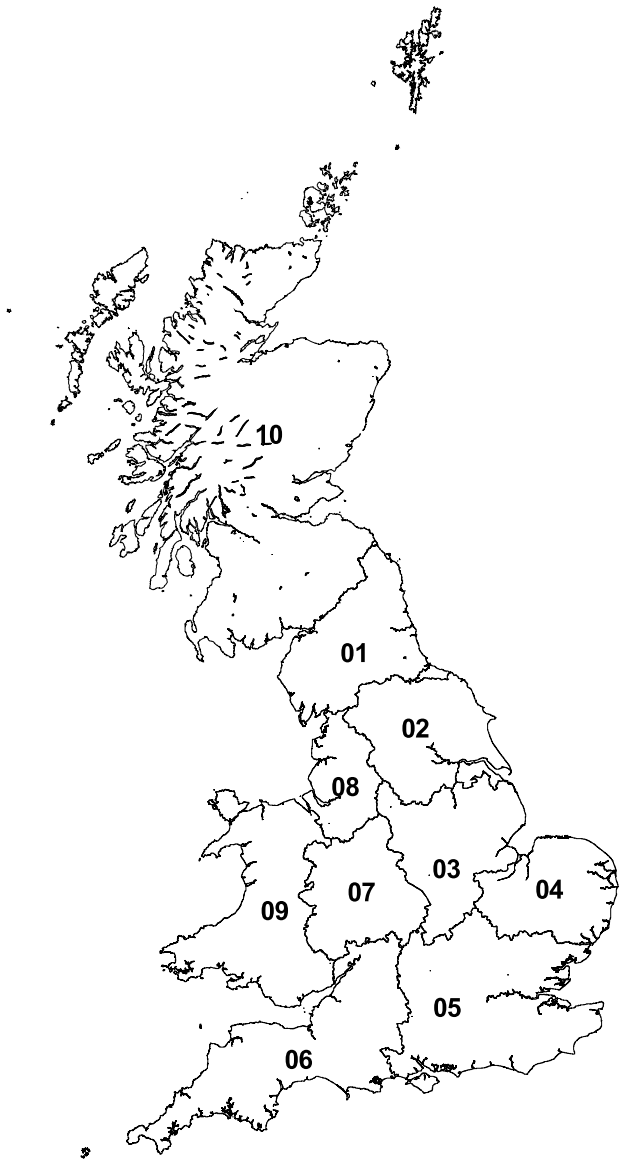

Figure 1: UK 1991 census regions.

ID	Region name	ID	Region name
01	North East	06	South West
02	Yorkshire	07	West Midlands
03	East Midlands	08	North West
04	East Anglia	09	Wales
05	South East	10	Scotland

Table 3: UK regions.

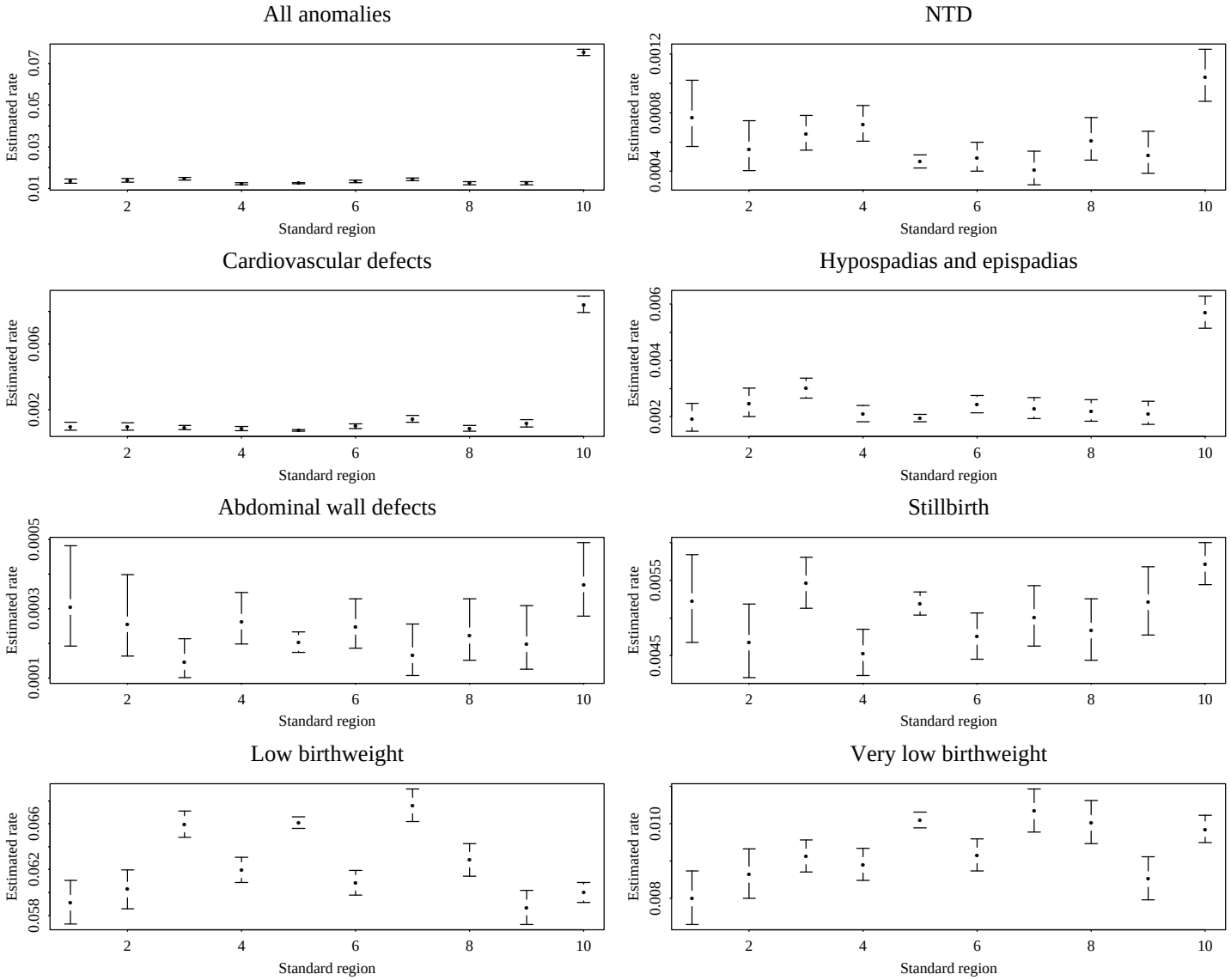

Figure 2: Crude rates of birth outcomes in the reference area, by administrative region. Anomaly rates (except hypospadias and epispadias) include terminations where available.

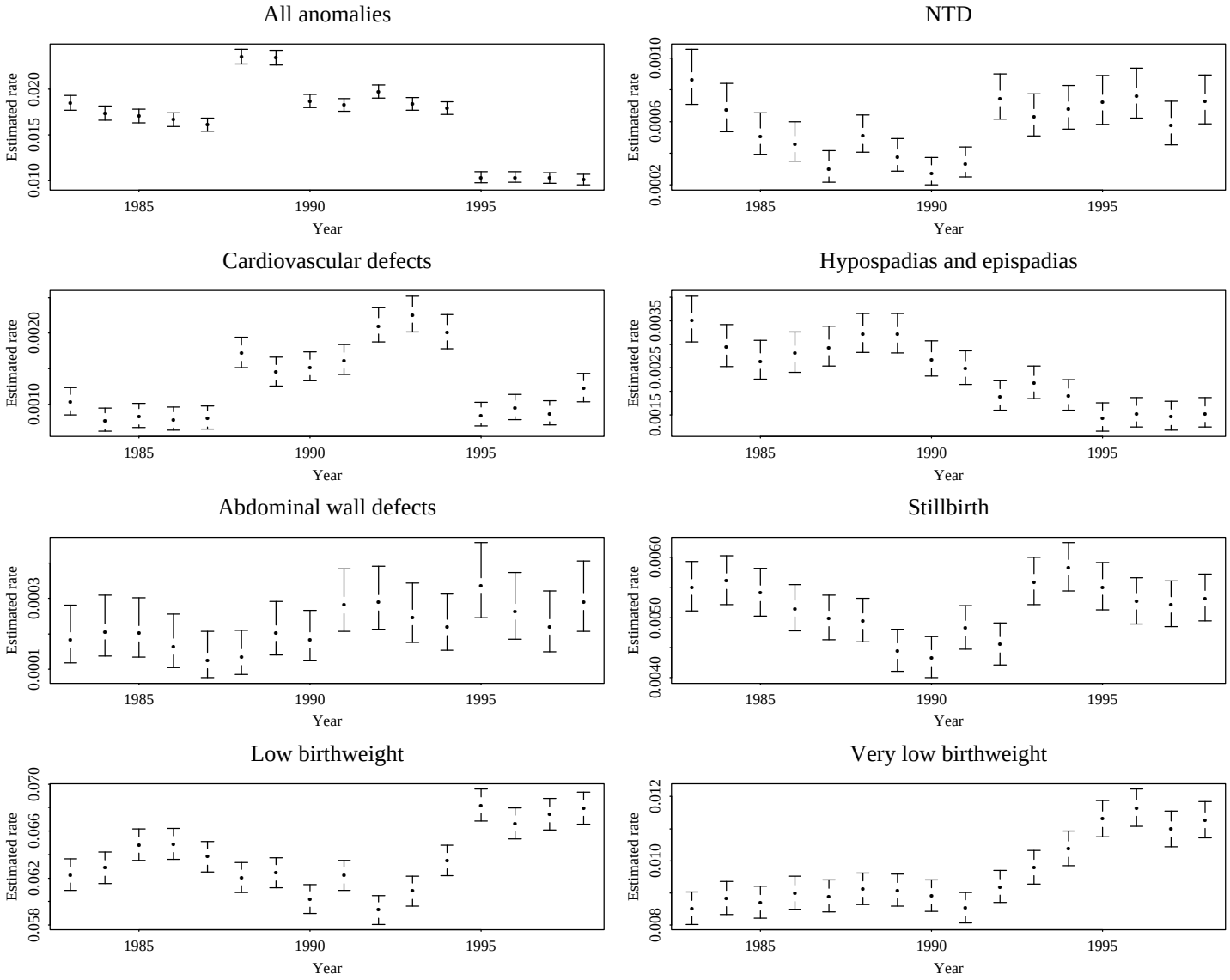

Figure 3: Crude rates of birth outcomes in the reference area, by year. Anomaly rates (except hypospadias and epispadias) include terminations where available.

Region	Exposure category			
	$< 2km$	%	Reference	%
1	447793	7.7	59077	2.9
2	814644	14	75428	3.7
3	503403	8.6	184627	9.1
4	108420	1.9	187115	9.2
5	1437120	24.6	874413	43.1
6	435647	7.5	190347	9.4
7	713460	12.2	120775	5.9
8	805756	13.8	112678	5.5
9	345085	5.9	96179	4.7
10	219555	3.8	129849	6.4
Total	5830883	100	2030488	100

Table 4: Total births by region and exposure category.

6.1.2 Deprivation

Table 5 shows the total number of births by exposure category and deprivation. In the study area, 26.4% of the births were to mothers in the most affluent tertile, 33.3% in the middle tertile and 40.2% in the most deprived tertile. In the reference area, these percentages were 40.1%, 31.7% and 28%. A chi-squared test of independence between rows and columns was rejected ($p < 10^{-4}$).

Deprivation tertile	Exposure category			
	$< 2km$	%	Reference	%
1	1542087	26.4	814017	40.1
2	1941093	33.3	644161	31.7
3	2342395	40.2	567896	28
Unavailable	5308	0.1	4414	0.2
Total	5830883	100	2030488	100

Table 5: Total births by deprivation tertile and exposure category.

We note that the study area tends to be more deprived than the reference area. For the equivalent table of population counts (person-years), see Tables 88 and 89.

Table 6 shows the rates of the birth outcomes in the reference region by deprivation tertile. Note that the hospital data outcomes are additionally denoted (SC) and (HA) for surgical correction and hospital admission, respectively.

Outcome	Deprivation tertile		
	1	2	3
Anomaly register data			
All anomalies	0.01606	0.01716	0.01796
NTD	0.00051	0.00062	0.00058
Cardiovascular defects	0.00117	0.00139	0.00153
Hypospadias and epispadias	0.00236	0.00241	0.00242
Abdominal wall defects	0.00018	0.00023	0.00026
Hospital data			
Hypospadias and epispadias (SC)	0.00259	0.00283	0.00265
Abdominal wall defects (HA)	0.00029	0.00035	0.00044
Gastroschisis and exomphalos (SC)	0.00016	0.00017	0.00026
Live and stillbirths			
Stillbirth	0.00441	0.00507	0.00623
Low birthweight	0.05403	0.06159	0.07913
Very low birthweight	0.008	0.00932	0.01219

Table 6: Rates in the reference area by deprivation tertile (1 = affluent, 3 = deprived).

6.1.3 Urban-rural status

Table 7 shows the total number of births by exposure category and urban-rural status. Data with invalid deprivation scores are included. In the study area, 17% of the births were to mothers resident in rural areas. In the reference area, this percentage was 31.3%. A chi-squared test of independence between rows and columns was rejected ($p < 10^{-4}$).

Urban-rural status	Exposure category			
	$< 2km$	%	Reference	%
Rural	989547	17	635780	31.3
Urban	4841336	83	1394708	68.7
Total	5830883	100	2030488	100

Table 7: Total births by urban-rural status and exposure category.

Table 8 shows the numbers of births, cases and the crude rate in the reference area by urban-rural status. The column headed p shows the (two-sided) p-value from a test of equal proportions of cases in the urban and rural areas.

Outcome	Rural			Urban			p
	Cases	Births	Rate	Cases	Births	Rate	
Anomaly register data							
All anomalies	10494	631458	0.01662	23831	1394616	0.01709	0.017
NTD	368	631458	0.00058	772	1394616	0.00055	0.435
Cardiovascular defects	875	631458	0.00139	1841	1394616	0.00132	0.245
Hypospadias and epispadias	768	323419	0.00237	1717	713901	0.00241	0.785
Abdominal wall defects	130	631458	0.00021	318	1394616	0.00023	0.352
Live and stillbirths							
Stillbirth	3236	673048	0.00481	7964	1504748	0.00529	< 0.001
Low birthweight	37002	669812	0.05524	100956	1496784	0.06745	< 0.001
Very low birthweight	5589	669812	0.00834	15269	1496784	0.0102	< 0.001

Table 8: Cases, births and crude rate, by outcome and urban-rural status in the reference area.

6.1.4 Sex

As we cannot adjust for sex in analyses involving the terminations data, it is important that the sex ratio in the study area is not different from that in the reference area. Table 9 shows the percentage of male births (amongst live and still births) by exposure category. The percentages in the first three rows are not significantly different from the reference area, as shown by the p-values given.

Exposure category	Percentage males	p value
all site types 0-2km	51.28766	0.99
Special 0-2km	51.34931	0.345
Non-special 0-2km	51.27442	0.737
Reference	51.28818	

Table 9: Percentage of male births by exposure category and (two-sided) p-value from testing against the reference area.

Table 10 shows the numbers of cases, births and the crude rate in the reference region by sex. Data available on the stillbirths and birthweight outcomes only. The column headed p shows the (two-sided) p-value from a test of equal proportions of cases amongst males and females.

Outcome	Males			Females			p
	Cases	Births	Rate	Cases	Births	Rate	
Live and stillbirths							
Stillbirth	5954	1116952	0.00533	5246	1060844	0.00495	< 0.001
Low birthweight	65298	1110998	0.05877	72660	1055598	0.06883	< 0.001
Very low birthweight	10686	1110998	0.00962	10172	1055598	0.00964	0.898

Table 10: Cases, births and crude rate, by sex for the stillbirth and birthweight data in the reference area.

6.1.5 Maternal age

Table 11 shows the total number of births by exposure category and maternal age. Events where maternal age was not recorded are not tabulated. In the study area, 7.73% of the births were to mothers under the age of 20 years. In the reference area, this percentage was 6.13%. A chi-squared test of independence between rows and columns was rejected ($p < 10^{-4}$).

Age in years	Exposure category			
	$< 2km$	%	Reference	%
< 20	394127	7.7	109297	6.1
≥ 20	4707556	92.3	1672390	93.9
Total	5101683	100	1781687	100

Table 11: Total births by maternal age and exposure category.

Recall that we can only adjust for maternal age in England and Wales (1986–1998) as maternal age is not recorded on the Scottish anomaly data. Therefore we tabulate the denominator for that analysis also.

Table 12 shows the total number of births by exposure category and maternal age (England and Wales, 1986–1998). Events where maternal age was not recorded are not tabulated. In the study area, 7.61% of the births were to mothers under the age of 20 years. In the reference area, this percentage was 5.94%.

Age in years	Exposure category			
	$< 2km$	%	Reference	%
< 20	358464	7.6	92069	5.9
≥ 20	4349498	92.4	1457370	94.1
Total	4707962	100	1549439	100

Table 12: Total births by maternal age and exposure category, not including births in Scotland.

Table 13 shows the numbers of cases, births and the crude rate in the reference region by maternal age group. Data available in England and Wales, 1986–1998 only. The column

headed p shows the (two-sided) p-value from a test of equal proportions of cases amongst younger and older mothers.

Outcome	< 20 **years**			≥ 20 **years**			p
	Cases	Births	Rate	Cases	Births	Rate	
Abdominal wall defects	62	92069	0.00067	268	1457370	0.00018	< 0.001

Table 13: Cases, births and crude rate, by maternal age group for the abdominal wall data in the reference area.

6.1.6 Maternal ethnicity

Table 14 shows the percentage of women aged between 15 and 44 in the study and reference area by ethnicity. Data are based on the 1991 census.

Ethnic group	**Exposure category**	
	$< 2km$	Reference
White	91.7	90.1
Indian, Pakistani, Bangladeshi	4.8	3.2
Black	2.0	3.4
Other	1.5	3.3

Table 14: Percentage of women aged between 15–44 years in different ethnic groups.

6.1.7 Gestational age

Table 15 shows the numbers of live births in Scotland, between 1983–1998, by exposure category and gestation. Births earlier than 32 weeks gestation are said to be very preterm and those earlier than 37 weeks are said to be preterm births. In the study area, 1.17% of the births were very preterm, 6.6% were preterm, and 93.4% occurred in the 37th week or later. In the reference area, these percentages were 1.09, 6.12 and 93.9 respectively. A chi-squared test of independence between rows and columns was rejected ($p < 10^{-4}$).

Gestation	**Exposure category**			
	$< 2km$	%	Reference	%
< 32 weeks	5401	1.2	3059	1.1
$32 \leq$ gestation < 37	24980	5.4	14147	5
≥ 37 weeks	429663	93.4	263783	93.9
Total	460044	100	280989	100

Table 15: Live births in Scotland, 1983–1998, by gestation and exposure category.

6.2 Relationships between potential confounders within the reference area

In this section we explore bivariate relationships between the covariates to be modelled within the reference region. Table 16 shows the number of total births in the reference

Maternal age (in years)	Urban-rural status			
	Rural	%	Urban	%
< 20	28403	5.1	80894	6.6
≥ 20	524255	94.9	1148135	93.4
Total	552658	100	1229029	100

Table 16: Total births, in the reference area, by urban-rural status and maternal age.

area by maternal age and urban-rural status. In rural areas, 5.14% of the births were to mothers under 20 years of age. In urban areas, this percentage is 6.58%.

Urban-rural status	Deprivation tertile					
	1	%	2	%	3	%
Rural	342752	48.7	174273	30.6	35633	7
Urban	361426	51.3	395126	69.4	472477	93
Total	704178	100	569399	100	508110	100

Table 17: Total births, in the reference area, by urban-rural status and deprivation tertile.

Table 17 shows the total number of births in the reference area by deprivation and urban-rural status. In the most affluent tertile, 48.7% of the births were to rural mothers. In the middle and most deprived tertiles, these percentages are 30.6% and 7.01%.

Maternal age (in years)	Deprivation tertile					
	1	%	2	%	3	%
< 20	29394	4.2	33687	5.9	46216	9.1
≥ 20	674784	95.8	535712	94.1	461894	90.9
Total	704178	100	569399	100	508110	100

Table 18: Total births, in the reference area, by deprivation tertile and maternal age.

Table 18 shows the total number of births in the reference area, by maternal age and deprivation tertile. In the most affluent tertile, 4.17% of the births were to mothers under 20 years of age. In the middle and most deprived tertiles, these percentages are 5.92% and 9.1%.

Table 19 shows the number of total births in the reference area by maternal age and region.

Region	Maternal age (years)					
	< 20	%	≥ 20	%	Total	%
1	3485	7.4	43908	92.6	47393	100
2	3864	6.4	56943	93.6	60807	100
3	10188	6.8	139173	93.2	149361	100
4	9276	6.1	143660	93.9	152936	100
5	36131	5	681759	95	717890	100
6	9013	5.8	146377	94.2	155390	100
7	6546	6.7	91082	93.3	97628	100
8	7215	8	83022	92	90237	100
9	6351	8.2	71446	91.8	77797	100
10	17228	7.4	215020	92.6	232248	100

Table 19: Total births, in the reference area, by region and maternal age.

6.3 Calculation of reference rates for the births analysis

The general strategy for covariate adjustment by modelling the observed data in the reference region is outlined in Section 5. Here we discuss the selection of covariates and their interactions into the linear predictor of that model.

In order to obtain a simple procedure applicable to all outcomes in the study, we fitted the fullest model possible and used that as the starting point in a step-wise model selection procedure. Where possible, the saturated model was used as the starting point. We began by using all possible covariates (year, region and sex) and including deprivation. Where deprivation did not appear in the stepwise-selected model, we forced its inclusion as a main effect.

For the deprivation-unadjusted model, we examined two methods (for the anomaly outcomes only): Firstly, by repeating the selection procedure without deprivation and secondly, by simply removing any terms involving deprivation. In all cases, the same model resulted and henceforth, the first method only was used, with the additional constraint that the two models differed only in terms of deprivation. Where the two models differed in another term, that term was added to the other model.

As a check on sensitivity of the relative risks to the results of the model selection procedure we also chose a single alternative model in each case. This took the form of the addition of a single term to the model. The term added was the next most significant term not already included in the model. Usually, but not always, this was the year-region interaction.

The all anomalies outcome was used to gain an idea of the potential upper limit model for the other anomaly outcomes and as expected, the rarer outcomes did not support so complex a model. Models were assessed informally using residual plots to look for systematic departures from the model and by comparing the predictions and their errors from the selected and 'alternative' models. The reference rates compared very favourably with those that would have been obtained from the normal stratification method, being more stable and having greater precision.

Table 20 shows the chosen models (and the number of parameters therein, n_p) for the birth outcomes. The top half of the table refers to the deprivation-unadjusted models and the lower half to the adjusted models. An intercept term is implicit in each model. These are our base models throughout and are denoted in table captions by 'using modelled rates', as in Sections 6.4.3, 6.4.6 and 6.4.7. All other models considered are for exploring the sensitivity of results to the model chosen. The last column of the table gives the additional term included to give the alternative model applied in Section 6.4.4. Note that for the all anomalies outcome, there was no additional term left to be added in the deprivation-unadjusted case.

Because of the smaller numbers of cases among some of the hospital admission outcomes, we chose to produce unadjusted results and deprivation-adjusted results only, and therefore no modelling (or sensitivity analysis) was carried out.

Outcome	Model	n_p	Alt
Deprivation unadjusted			
All anomalies	y + r + r:y*	151	NA
NTD	y + r	25	r:y
Cardiovascular	y + r	25	r:y
Hypospadias & epispadias	y + r	25	r:y
Abdominal wall	y + r	25	r:y
Stillbirth	y + r + s + r:s	35	r:y
Low birthweight	y + r + s	26	r:y
Very low birthweight	y + r	25	r:y
Deprivation adjusted			
All anomalies	d + y + r + r:d + r:y*	171	y:d
NTD	d + y + r	27	r:y
Cardiovascular	d + y + r + r:d	45	r:y
Hypospadias & epispadias	d† + y + r	27	r:y
Abdominal wall	d + y + r	27	r:y
Stillbirth	d + y + r + s + r:s	37	d:y
Low birthweight	d + y + r + s + r:d + d:s	48	r:y
Very low birthweight	d + y + r + r:d	45	d:y

Table 20: Models chosen by stepwise selection for the birth outcomes. Main effects are represented by the following terms: d, deprivation; y, year; r, region; s, sex. Interactions are denoted by ':'. † denotes outcomes where deprivation was not selected by the stepwise selection process, but was added as a main effect. The column headed n_p is the number of parameters in the chosen model. The final column shows terms added in the alternative model used in the sensitivity analysis. *The region-year interaction included 16 years for England and Wales but only 7 years for Scotland (1988-94).

6.4 Results

6.4.1 Rates in the study and reference areas

In the following tables, 'births' are comprised of livebirths, stillbirths and terminations for the anomaly register data (except hypospadias and epispadias), livebirths and stillbirths for the stillbirths outcome and livebirths only for the hospital admission (except hypospadias and epispadias) and birthweight outcomes. The denominator data for hypospadias

Outcome	Cases	Births	Rate
Anomaly register data			
All anomalies	34325	2026074	0.01694
NTD	1140	2026074	0.00056
Cardiovascular defects	2716	2026074	0.00134
Hypospadias and epispadias	2485	1037320	0.0024
Abdominal wall defects	448	2026074	0.00022
Hospital data			
Hypospadias and epispadias (SC)	536	199974	0.00268
Abdominal wall defects (HA)	227	646415	0.00035
Gastroschisis and exomphalos (SC)	126	646415	0.00019
Live and stillbirths			
Stillbirth	11200	2177796	0.00514
Low birthweight	137958	2166596	0.06367
Very low birthweight	20858	2166596	0.00963

Table 21: Cases, births and crude rate, by outcome in the reference area.

Outcome	Cases	Births	Rate
Anomaly register data			
All anomalies	90272	5825575	0.0155
NTD	3508	5825575	0.0006
Cardiovascular defects	6723	5825575	0.00115
Hypospadias and epispadias	7363	2983963	0.00247
Abdominal wall defects	1488	5825575	0.00026
Hospital data			
Hypospadias and epispadias (SC)	1503	585414	0.00257
Abdominal wall defects (HA)	755	1903892	0.0004
Gastroschisis and exomphalos (SC)	467	1903892	0.00025
Live and stillbirths			
Stillbirth	32271	6062700	0.00532
Low birthweight	422149	6030429	0.07
Very low birthweight	62191	6030429	0.01031

Table 22: Cases, births and crude rate, by outcome within 2km of all site types either currently operating or closed.

and epispadias from the anomaly register are male live and stillbirths only and for surgical corrections of hypospadias and epispadias the denominator data are male live births only.

The births, cases and raw rates for the birth outcomes are given in Table 21 for the reference area and in Table 22 for the study area within 2km of an operating or closed site of any waste type.

Outcome	Special sites			Non-special		
	Cases	Births	Rate	Cases	Births	Rate
Anomaly register data						
All anomalies	12594	803833	0.01567	71423	4517196	0.01581
NTD	495	803833	0.00062	2769	4517196	0.00061
Cardiovascular defects	998	803833	0.00124	5297	4517196	0.00117
Hypospadias and epispadias	1064	412201	0.00258	5743	2313135	0.00248
Abdominal wall defects	191	803833	0.00024	1166	4517196	0.00026
Hospital data						
Hypospadias and epispadias (SC)	177	67281	0.00263	1215	469149	0.00259
Abdominal wall defects (HA)	89	222179	0.0004	590	1522851	0.00039
Gastroschisis and exomphalos (SC)	51	222179	0.00023	371	1522851	0.00024
Live and stillbirths						
Stillbirth	4332	825456	0.00525	25260	4725120	0.00535
Low birthweight	57116	821124	0.06956	331351	4699860	0.0705
Very low birthweight	8400	821124	0.01023	48791	4699860	0.01038

Table 23: Cases, births and crude rate, by outcome within 2km of special and non-special sites either currently operating or closed.

Outcome	Cases	Births	Rate
Anomaly register data			
All anomalies	64972	3951062	0.01644
NTD	2453	3951062	0.00062
Cardiovascular defects	4572	3951062	0.00116
Hypospadias and epispadias	5434	2023910	0.00268
Abdominal wall defects	1006	3951062	0.00025
Hospital data			
Hypospadias and epispadias (SC)	824	324060	0.00254
Abdominal wall defects (HA)	391	957966	0.00041
Gastroschisis and exomphalos (SC)	253	957966	0.00026
Live and stillbirths			
Stillbirth	21968	4104936	0.00535
Low birthweight	284239	4082968	0.06962
Very low birthweight	40672	4082968	0.00996

Table 24: Cases, births and crude rate, by outcome within 2km of all site types currently operating.

Table 23 gives results for the study areas within 2km of an operating or closed site of special and non-special type separately.

Table 24 gives results for the study area within 2km of an operating site of any waste type.

Outcome	Cases	Births	Rate
Anomaly register data			
All anomalies	25300	1874513	0.0135
NTD	1055	1874513	0.00056
Cardiovascular defects	2151	1874513	0.00115
Hypospadias and epispadias	1929	960053	0.00201
Abdominal wall defects	482	1874513	0.00026
Hospital data			
Hypospadias and epispadias (SC)	679	261354	0.0026
Abdominal wall defects (HA)	364	945926	0.00038
Gastroschisis and exomphalos (SC)	214	945926	0.00023
Live and stillbirths			
Stillbirth	10303	1957764	0.00526
Low birthweight	137910	1947461	0.07082
Very low birthweight	21519	1947461	0.01105

Table 25: Cases, births and crude rate, by outcome within 2km of all site types after closure only.

Table 25 gives results for the study area within 2km of a closed site of any waste type.

6.4.2 Unadjusted relative risks

Outcome	Estimate	99%	CI
Anomaly register data			
All anomalies	0.915	0.907	0.923
NTD	1.07	1.025	1.118
Cardiovascular defects	0.861	0.834	0.888
Hypospadias and epispadias	1.03	1	1.061
Abdominal wall defects	1.155	1.081	1.235
Hospital data			
Hypospadias and epispadias (SC)	0.958	0.896	1.024
Abdominal wall defects (HA)	1.129	1.028	1.24
Gastroschisis and exomphalos (SC)	1.258	1.117	1.418
Live and stillbirths			
Stillbirth	1.035	1.02	1.05
Low birthweight	1.099	1.095	1.104
Very low birthweight	1.071	1.06	1.082

Table 26: Unadjusted relative risks and confidence intervals, by outcome in the study area.

Table 26 gives unadjusted relative risks and 99% confidence intervals.

6.4.3 All site types: operating and closed, operating only and closed only

Tables 27, ..., 30 give the relative risks (with confidence intervals) for the congenital anomalies data, hospital admissions data, stillbirth data and the birthweight data for all site types, either operating or closed, during operation only and after closure only. All these tables show results from the step-wise selected models shown in Table 20.

Considering the operating and closed sites together, the estimated relative risk for all anomalies combined, after adjusting for deprivation, is 1.01 (99% CI 1.005-1.023); there are small excess risks for NTDs, hypospadias and epispadias and abdominal wall defects, and risk is below one for cardiovascular defects. In the hospital admission outcomes, Table 28, we see an excess for abdominal wall admissions and surgical corrections of gastroschisis and exomphalos.

A 5% excess in stillbirths, Table 29, is removed by adjusting for deprivation. There are 5.1 and 3.6% excess risks for low and very low birthweight events after adjustment for deprivation, see Table 30.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
All anomalies						
Operating and closed	1.012	1.003	1.021	1.014	1.005	1.023
Operating only	1.022	1.011	1.032	1.023	1.013	1.034
Closed only	0.987	0.972	1.004	0.99	0.974	1.006
NTD						
Operating and closed	1.076	1.03	1.124	1.053	1.008	1.1
Operating only	1.129	1.071	1.189	1.103	1.047	1.162
Closed only	0.971	0.897	1.051	0.952	0.88	1.031
Cardiovascular defects						
Operating and closed	0.948	0.918	0.978	0.959	0.929	0.989
Operating only	0.96	0.924	0.997	0.975	0.938	1.013
Closed only	0.923	0.873	0.975	0.926	0.876	0.979
Hypospadias and epispadias						
Operating and closed	1.067	1.036	1.1	1.071	1.04	1.104
Operating only	1.082	1.044	1.12	1.086	1.048	1.124
Closed only	1.029	0.971	1.092	1.033	0.974	1.095
Abdominal wall defects						
Operating and closed	1.138	1.065	1.217	1.078	1.008	1.152
Operating only	1.176	1.085	1.276	1.111	1.024	1.205
Closed only	1.066	0.948	1.198	1.015	0.903	1.141

Table 27: Relative risks and confidence intervals for **all site types** using $\geq 2km$ rates for comparison. Using modelled rates. Data include terminations (except hypospadias and epispadias).

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
Hypospadias and epispadias (SC)						
Operating and closed	0.958	0.896	1.024	0.955	0.894	1.021
Operating only	0.949	0.867	1.038	0.946	0.865	1.035
Closed only	0.969	0.878	1.07	0.966	0.875	1.067
Abdominal wall defects (HA)						
Operating and closed	1.129	1.028	1.24	1.073	0.977	1.178
Operating only	1.162	1.02	1.324	1.103	0.968	1.256
Closed only	1.096	0.957	1.254	1.043	0.911	1.193
Gastroschisis and exomphalos (SC)						
Operating and closed	1.258	1.117	1.418	1.186	1.052	1.336
Operating only	1.355	1.152	1.593	1.274	1.084	1.498
Closed only	1.161	0.973	1.384	1.096	0.919	1.307

Table 28: Relative risks and confidence intervals for **all sites types** using $\geq 2km$ rates for comparison. Unadjusted unless stated otherwise.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
Stillbirth						
Operating and closed	1.049	1.034	1.064	1.003	0.989	1.018
Operating only	1.06	1.042	1.079	1.012	0.995	1.03
Closed only	1.026	1	1.053	0.985	0.96	1.01

Table 29: Relative risks and confidence intervals for **all site types** using $\geq 2km$ rates for comparison. Using modelled rates.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
Low birthweight						
Operating and closed	1.107	1.102	1.111	1.051	1.047	1.055
Operating only	1.109	1.104	1.115	1.051	1.046	1.056
Closed only	1.101	1.093	1.109	1.05	1.043	1.057
Very low birthweight						
Operating and closed	1.079	1.068	1.091	1.036	1.026	1.047
Operating only	1.075	1.061	1.089	1.032	1.019	1.045
Closed only	1.087	1.068	1.107	1.044	1.026	1.062

Table 30: Relative risks and confidence intervals for **all site types** using $\geq 2km$ rates for comparison. Using modelled rates.

6.4.4 Sensitivity to modelled reference rates

In order to assess the sensitivity of the 'all site types' results to the model used for estimation of the reference rates, we also looked at a single alternative model for each outcome. In most cases this involved adding the next most significant excluded term, and in general this was the interaction between year and region. See Table 20 for the terms included. These alternative results are given in Tables 31, . . . , 33 for the anomaly data and the stillbirth and birthweight data. No alternative model was available in the case of all anomalies (deprivation unadjusted). Results are robust to these model changes.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
All anomalies						
Operating and closed				1.014	1.005	1.023
Operating only				1.023	1.013	1.034
NTD						
Operating and closed	1.076	1.03	1.123	1.053	1.008	1.1
Operating only	1.127	1.07	1.188	1.102	1.046	1.161
Cardiovascular defects						
Operating and closed	0.949	0.919	0.979	0.96	0.93	0.99
Operating only	0.956	0.92	0.993	0.971	0.934	1.008
Hypospadias and epispadias						
Operating and closed	1.068	1.037	1.101	1.072	1.04	1.104
Operating only	1.085	1.048	1.124	1.089	1.052	1.128
Abdominal wall defects						
Operating and closed	1.141	1.067	1.22	1.08	1.01	1.154
Operating only	1.173	1.081	1.272	1.106	1.02	1.199

Table 31: Relative risks and confidence intervals for **all site types** using $\geq 2km$ rates for comparison. Using alternative rates. Data include terminations (except hypospadias and epispadias).

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
Stillbirth						
Operating and closed	1.05	1.035	1.065	1.003	0.989	1.017
Operating only	1.059	1.041	1.077	1.014	0.997	1.032

Table 32: Relative risks and confidence intervals for **all site types** using $\geq 2km$ rates for comparison. Using alternative rates.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
Low birthweight						
Operating and closed	1.107	1.102	1.111	1.051	1.047	1.055
Operating only	1.11	1.105	1.115	1.052	1.047	1.057
Very low birthweight						
Operating and closed	1.08	1.068	1.091	1.036	1.025	1.047
Operating only	1.077	1.064	1.091	1.033	1.02	1.046

Table 33: Relative risks and confidence intervals for **all site types** using $\geq 2km$ rates for comparison. Using alternative rates.

6.4.5 Urban-rural status as an additional confounder

Table 8 indicated that the raw rates for some of the birth outcomes were significantly different in the urban and rural groups, implying that urban-rural status may be a confounder. However, we noted in Table 17 that there was marked co-variation between urban-rural status and deprivation. We would therefore expect that much of the urban-rural effect would be captured by the adjustment for deprivation. As part of the sensitivity analysis we thus included the binary urban indicator in the pool of possible covariates for the step-wise selection procedure, again constraining the difference between the deprivation unadjusted and adjusted models. This has been done for the anomaly register outcomes, stillbirths and the birthweight outcomes. Table 34 shows the model selected in each case and Tables 35, 36 and 37 show the results. Results are not repeated where the selected model did not change from that shown in Table 20. Inclusion of the urban-rural covariate had only a marginal effect, especially on the deprivation-adjusted risk estimates.

Outcome	Model	n_p
Deprivation unadjusted		
All anomalies	y + r + u + r:y* + u:r	161
NTD	y + r	25
Cardiovascular defects	y + r + u + u:r	35
Hypospadias & epispadias	y + r + u†	26
Abdominal wall defects	y + r + u†	26
Stillbirth	y + r + s + u + r:s	36
Low birthweight	y + r + s + u + r:u	36
Very low birthweight	y + r + u + r:u	35
Deprivation adjusted		
All anomalies	d + y + r + u + r:d + r:y* + u:d + u:r	183
NTD	d + y + r	27
Cardiovascular defects	d + y + r + u + r:d + u:d + u:r	57
Hypospadias & epispadias	d + y + r + u + u:d	30
Abdominal wall defects	d + y + r + u + u:d	30
Stillbirth	d + y + r + s + r:s	37
Low birthweight	d + y + r + s + u + d:r + d:s + d:u	51
Very low birthweight	d + y + r + u + d:r + d:u + r:u†	57

Table 34: Models chosen by stepwise selection for the birth outcomes, including urban-rural status as an additional covariate in the pool of possible covariates. Main effects are represented by the following terms: d, deprivation; y, year; r, region; s, sex; u, urban-rural status. Interactions are denoted by ':'. † denotes term added to make the deprivation adjusted model comparable with the unadjusted model in all terms except deprivation. The column headed n_p is the number of parameters in the chosen model. *The region-year interaction included 16 years for England and Wales but only 7 years for Scotland (1988-94).

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
All anomalies						
Operating and closed	1.017	1.008	1.026	1.017	1.009	1.026
Operating only	1.028	1.018	1.038	1.028	1.018	1.038
NTD						
Operating and closed						
Operating only						
Cardiovascular defects						
Operating and closed	0.973	0.943	1.004	0.977	0.947	1.008
Operating only	0.985	0.948	1.024	0.993	0.956	1.031
Hypospadias and epispadias						
Operating and closed	1.058	1.027	1.09	1.06	1.029	1.092
Operating only	1.072	1.035	1.11	1.074	1.037	1.112
Abdominal wall defects						
Operating and closed	1.109	1.038	1.186	1.077	1.008	1.152
Operating only	1.146	1.057	1.243	1.11	1.023	1.204

Table 35: Relative risks and confidence intervals for **all site types** using $\geq 2km$ rates for comparison. Using modelled rates, allowing for urban-rural status. Data include terminations (except hypospadias and epispadias).

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
Stillbirth						
Operating and closed	1.033	1.018	1.047			
Operating only	1.043	1.025	1.062			

Table 36: Relative risks and confidence intervals for **all site types** using $\geq 2km$ rates for comparison. Using modelled rates, allowing for urban-rural status.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
Low birthweight						
Operating and closed	1.07	1.065	1.074	1.044	1.04	1.048
Operating only	1.072	1.067	1.077	1.045	1.04	1.05
Very low birthweight						
Operating and closed	1.051	1.041	1.062	1.031	1.021	1.042
Operating only	1.048	1.035	1.062	1.028	1.015	1.041

Table 37: Relative risks and confidence intervals for **all site types** using $\geq 2km$ rates for comparison. Using modelled rates, allowing for urban-rural status.

6.4.6 Sites which opened after 1982

In order to explore the risks of adverse birth outcomes before a landfill site had opened, in areas where subsequently a site did open, we analysed a sub-set of sites, which opened during the study period. We then performed the analyses for these sites before and after the opening, thus comparing birth outcomes in the same sites before and after opening. Tables in this section are with respect to all site types.

Outcome	Before opening			After opening		
	Cases	Births	Rate	Cases	Births	Rate
Anomaly register data						
All anomalies	7635	429160	0.01779	62132	4150320	0.01497
NTD	223	429160	0.00052	2509	4150320	0.0006
Cardiovascular defects	417	429160	0.00097	4477	4150320	0.00108
Hypospadias and epispadias	671	220227	0.00305	5064	2125477	0.00238
Abdominal wall defects	104	429160	0.00024	1060	4150320	0.00026
Hospital data						
Hypospadias and epispadias (SC)	38	9982	0.00381	1055	424271	0.00249
Abdominal wall defects (HA)	18	21282	0.00085	578	1384135	0.00042
Gastroschisis and exomphalos (SC)	6	21282	0.00028	359	1384135	0.00026
Live and stillbirths						
Stillbirth	2418	461776	0.00524	23176	4295686	0.0054
Low birthweight	29875	459358	0.06504	304376	4272510	0.07124
Very low birthweight	4096	459358	0.00892	44488	4272510	0.01041

Table 38: Cases, births and crude rate, by outcome and opening status.

Table 38 shows the numbers of births, cases and the crude rate in the study area by opening status. Note that the 'after opening' category is equivalent to the category denoted 'Operating and closed' in other tables.

Tables 39, . . . , 42 give the relative risk estimates. Modelled rates are based on the models shown in Table 20. Note that the smaller numbers of cases and births, in the 'before' group particularly, result in wider confidence intervals than for the main analysis.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
All anomalies						
Before opening	1.02	0.99	1.051	1.02	0.991	1.051
After opening	1.001	0.991	1.011	1.004	0.993	1.014
NTD						
Before opening	0.989	0.832	1.175	0.98	0.825	1.165
After opening	1.071	1.017	1.128	1.047	0.994	1.102
Cardiovascular defects						
Before opening	0.909	0.801	1.031	0.92	0.811	1.043
After opening	0.905	0.871	0.94	0.919	0.884	0.955
Hypospadias and epispadias						
Before opening	1.079	0.976	1.191	1.08	0.978	1.193
After opening	1.049	1.012	1.088	1.054	1.016	1.092
Abdominal wall defects						
Before opening	1.275	0.99	1.641	1.243	0.966	1.6
After opening	1.122	1.036	1.214	1.057	0.976	1.144

Table 39: Before and after **opening** analysis for a sub-set of sites that opened during the study period. Using modelled rates.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
Hypospadias and epispadias (SC)						
Before opening	1.42	0.935	2.157	1.423	0.937	2.161
After opening	0.928	0.857	1.004	0.926	0.855	1.002
Abdominal wall defects (HA)						
Before opening	2.408	1.312	4.42	2.26	1.232	4.148
After opening	1.189	1.068	1.324	1.124	1.01	1.251
Gastroschisis and exomphalos (SC)						
Before opening	1.446	0.505	4.14	1.33	0.465	3.806
After opening	1.331	1.161	1.524	1.243	1.085	1.424

Table 40: Before and after **opening** analysis for a sub-set of sites that opened during the study period. Unadjusted unless stated.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
Stillbirth						
Before opening	1.03	0.977	1.085	1.006	0.955	1.061
After opening	1.067	1.049	1.085	1.015	0.998	1.032

Table 41: Before and after **opening** analysis for a sub-set of sites that opened during the study period. Using modelled rates.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
Low birthweight						
Before opening	1.039	1.024	1.055	1.009	0.994	1.024
After opening	1.129	1.124	1.134	1.067	1.062	1.072
Very low birthweight						
Before opening	1.004	0.965	1.046	0.978	0.939	1.018
After opening	1.09	1.077	1.103	1.042	1.029	1.055

Table 42: Before and after **opening** analysis for a sub-set of sites that opened during the study period. Using modelled rates.

6.4.7 Sensitivity of the anomaly register results to Scotland

Since there are large differences in the raw rates of congenital anomalies in Scotland compared with England and Wales, we have looked at the results obtained by applying the selected models (shown in Table 20) to England and Wales data only.

Tables 43 and 44 show the cases, births and rates of congenital anomalies for England and Wales only in the reference area and the study area.

Outcome	Cases	Births	Rate
All anomalies	24577	1896371	0.01296
NTD	1005	1896371	0.00053
Cardiovascular defects	1621	1896371	0.00085
Hypospadias and epispadias	2108	971054	0.00217
Abdominal wall defects	400	1896371	0.00021

Table 43: Cases, births and crude rate, by outcome in the reference area, for 1983–1998, England and Wales only. Data include terminations (except hypospadias and epispadias).

Outcome	$0-2km$		
	Cases	Births	Rate
All waste			
All anomalies	74893	5606396	0.01336
NTD	3270	5606396	0.00058
Cardiovascular defects	5022	5606396	0.0009
Hypospadias and epispadias	6754	2871986	0.00235
Abdominal wall defects	1408	5606396	0.00025

Table 44: Cases, births and crude rate, by outcome in the study areas, for England and Wales only, 1983–1998. Data include terminations (except hypospadias and epispadias).

With the exception of NTD's (deprivation adjusted result), comparing Table 45 with 27 shows that the relative risks for England and Wales alone are slightly higher. Results by

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
All anomalies						
Operating and closed	1.029	1.02	1.039	1.031	1.021	1.041
Operating only	1.044	1.033	1.056	1.045	1.034	1.057
NTD						
Operating and closed	1.078	1.03	1.127	1.044	0.998	1.092
Operating only	1.132	1.072	1.195	1.095	1.038	1.156
Cardiovascular defects						
Operating and closed	0.96	0.925	0.995	0.987	0.951	1.023
Operating only	0.974	0.932	1.018	1.005	0.962	1.05
Hypospadias and epispadias						
Operating and closed	1.08	1.046	1.114	1.086	1.053	1.121
Operating only	1.102	1.063	1.143	1.109	1.069	1.15
Abdominal wall defects						
Operating and closed	1.152	1.075	1.234	1.098	1.025	1.176
Operating only	1.18	1.086	1.283	1.121	1.031	1.219

Table 45: Relative risks and confidence intervals for **all site types** using $\geq 2km$ rates for comparison, England and Wales only. Using step-wise chosen modelled rates. Data include terminations (except hypospadias and epispadias).

region (including Scotland) are given in Section 6.4.12. Using the alternative set of models gave similar results.

6.4.8 Sensitivity of the abdominal wall results in England and Wales (1986–1998) to maternal age

In this section we fit a sequence of models in order to compare the effects of adjusting (or not) for maternal age and deprivation. These results are not available for Scotland. In these analyses, region is not an important factor in the model.

The births, cases and raw rates for abdominal wall defects with valid maternal age are given in Table 46 for the reference area and for the study area. Since this is a rare outcome, we only give the figures for 'during operation and after closure' (all site types).

Exposure	Cases	Births	Rate
Reference	330	1549439	0.00021
Study	1203	4707962	0.00026

Table 46: Cases, births and crude rate of abdominal wall defects for 1986–1998, England and Wales (lagged by one year). Not available for Scotland. Only data with valid maternal age included.

The step-wise selected model results are given in Table 47, allowing year, region, depriva-

tion and maternal age as possible covariates. The selected models were m + y + m:y and m + y + d* + m:y (*deprivation term not selected, therefore added). Note that these results for the abdominal wall defects are not comparable with Table 27 as that table includes Scottish data, nor with Table 45, as that includes data from 1983 onwards.

Site status	**Deprivation unadjusted**			**Deprivation adjusted**		
	Estimate	99%	CI	Estimate	99%	CI
Abdominal Wall defects (EW)						
Operating and closed	1.133	1.052	1.22	1.116	1.037	1.203
Operating only	1.19	1.083	1.306	1.172	1.067	1.287

Table 47: Relative risks and confidence intervals for **all site types** using $\geq 2km$ rates for comparison. Adjusted for maternal age, using modelled rates. Not available for Scotland.

The alternative models additionally included region and the deprivation-year interaction in the deprivation-unadjusted and adjusted models, respectively. Table 48 shows the results.

Site status	**Deprivation unadjusted**			**Deprivation adjusted**		
	Estimate	99%	CI	Estimate	99%	CI
Abdominal Wall defects (EW)						
Operating and closed	1.147	1.065	1.236	1.115	1.035	1.201
Operating only	1.202	1.095	1.32	1.169	1.064	1.283

Table 48: Relative risks and confidence intervals for **all site types** using $\geq 2km$ rates for comparison. Adjusted for maternal age, using alternative model. Not available for Scotland.

In order to examine further the effect of maternal age on the relative risk estimates we fitted a sequence of models, shown in Table 49, adjusting always for year, then deprivation and maternal age separately and together. This sequence shows the effect of adjusting for maternal age (mage) and deprivation (depr) both independently and together in addition to a year effect. Hence, we see that adjusting for year only we estimate an 18.6% excess risk (Table 50: referring to the results for operating and closed sites), adjusting additionally for maternal age only, this decreases to 13.3% (Table 51) while adjusting additionally for deprivation only, it decreases to 15.1%. Adjusting for all three factors gives an estimated excess of 11.6%.

Note that repeating the above with the year-deprivation interaction term also included (where appropriate) gave similar results.

	Deprivation	
	Unadjusted	Adjusted
Table		
Table 50	year (13)	year + depr (15)
Table 51	year + mage + year:mage (26)	year + mage + depr + year:mage (28)

Table 49: Models fitted in the following two tables. Numbers in parentheses indicate the number of parameters in each model.

Site status	**Deprivation unadjusted**			**Deprivation adjusted**		
	Estimate	99%	CI	Estimate	99%	CI
Abdominal Wall defects (EW)						
Operating and closed	1.186	1.101	1.278	1.151	1.068	1.239
Operating only	1.249	1.137	1.371	1.21	1.102	1.329

Table 50: Relative risks and confidence intervals for **all site types** using $\geq 2km$ rates for comparison. Not available for Scotland.

Site status	**Deprivation unadjusted**			**Deprivation adjusted**		
	Estimate	99%	CI	Estimate	99%	CI
Abdominal Wall defects (EW)						
Operating and closed	1.133	1.052	1.22	1.116	1.037	1.203
Operating only	1.19	1.083	1.306	1.172	1.067	1.287

Table 51: Relative risks and confidence intervals for **all site types** using $\geq 2km$ rates for comparison, adjusted for maternal age. Not available for Scotland.

6.4.9 Sensitivity of the stillbirth and birthweight outcomes to deprivation classification

We have repeated the basic analyses for these three outcomes using quintiles of deprivation instead of tertiles. The deprivation unadjusted columns are repeated from before. Compared with the tertile analysis, differences are slight.

Site status	**Deprivation unadjusted**			**Deprivation adjusted**		
	Estimate	99%	CI	Estimate	99%	CI
Stillbirth						
Operating and closed	1.049	1.034	1.064	1.001	0.987	1.015
Operating only	1.06	1.042	1.079	1.01	0.992	1.027

Table 52: Relative risks and confidence intervals for **all site types** using $\geq 2km$ rates for comparison. Using modelled rates. Using deprivation **quintiles**.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
Low birthweight						
Operating and closed	1.107	1.102	1.111	1.049	1.045	1.053
Operating only	1.109	1.104	1.115	1.05	1.045	1.055
Very low birthweight						
Operating and closed	1.079	1.068	1.091	1.034	1.023	1.045
Operating only	1.075	1.061	1.089	1.03	1.017	1.044

Table 53: Relative risks and confidence intervals for **all site types** using $\geq 2km$ rates for comparison. Using modelled rates. Using deprivation **quintiles**.

6.4.10 Sensitivity to classification of Neural Tube Defects

This section looks at the sensitivity of the results to the inclusion of the 'Spina bifida occulta' codes (ICD9 756.1;ICD10 Q76.0) in the NTD data. In the study area there were 301 additional cases and 109 in the reference area. Table 54 shows the results and can be compared with the equivalent rows of Table 27. Substantive conclusions are unchanged.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
NTD and spina bifida occulta						
Operating and closed	1.07	1.026	1.115	1.048	1.005	1.093
Operating only	1.113	1.059	1.17	1.089	1.037	1.145

Table 54: Relative risks and confidence intervals for **all site types** using $\geq 2km$ rates for comparison. Using modelled rates. Data include terminations.

6.4.11 Anomaly register analysis using rural-only data

The reference area has a relatively high proportion of rural areas. In order to assess the sensitivity of the anomaly register results to the rurality of the reference area we have repeated the analysis for the anomaly outcomes, using data only from rural areas. The resulting reduction in the number of cases and births available inflates the confidence intervals.

Table 55 shows the cases, births and rate of anomalies in the rural-classified parts of the study and reference areas.

Table 56 shows the results from using the same model, shown in Table 20, chosen for the full data set.

The stepwise regression procedure was then repeated using the rural-only subset of the data and different models were sometimes chosen. These differences are shown in Ta-

Exposure category	Cases	Births	Rate
Study			
All anomalies	14656	984452	0.01489
NTD	551	984452	0.00056
Cardiovascular defects	1139	984452	0.00116
Hypospadias and epispadias	1114	505218	0.0022
Abdominal wall defects	233	984452	0.00024
Reference			
All anomalies	10494	631458	0.01662
NTD	368	631458	0.00058
Cardiovascular defects	875	631458	0.00139
Hypospadias and epispadias	768	323419	0.00237
Abdominal wall defects	130	631458	0.00021

Table 55: Cases, births and crude rate, by outcome for 1983–1998, England and Wales; 1988–1994 Scotland, (lagged by one year). 'Exposure' is to any waste type at any time. Data include terminations (except hypospadias and epispadias). Data from rural areas only.

Site status	**Deprivation unadjusted**			**Deprivation adjusted**		
	Estimate	99%	CI	Estimate	99%	CI
All anomalies						
Operating and closed	1.012	0.991	1.034	1.013	0.991	1.034
Operating only	1.02	0.995	1.046	1.021	0.996	1.046
NTD						
Operating and closed	1.016	0.91	1.134	0.987	0.885	1.102
Operating only	1.057	0.928	1.203	1.023	0.898	1.165
Cardiovascular defects						
Operating and closed	0.944	0.875	1.019	0.945	0.875	1.02
Operating only	0.971	0.888	1.062	0.973	0.889	1.064
Hypospadias and epispadias						
Operating and closed	1.045	0.967	1.128	1.012	0.936	1.093
Operating only	0.558	0.511	0.609	0.539	0.494	0.588
Abdominal wall defects						
Operating and closed	1.172	0.99	1.388	1.08	0.912	1.278
Operating only	1.118	0.91	1.373	1.022	0.832	1.255

Table 56: Relative risks and confidence intervals for **all site types** using $\geq 2km$ rates for comparison. Using the same model for the rates as chosen in the full data set. Data include terminations (except hypospadias and epispadias). Data from rural areas only.

ble 57. Table 58 shows the results from using the models selected from the rural data. Results are not repeated where the same model was selected.

	Deprivation	
	Unadjusted	Adjusted
Outcome		
All anomalies	no change	region:depr dropped
NTD	no change	no change
Cardiovascular	no change	region:depr dropped
Hypospadias & epispadias	no change	no change
Abdominal wall	main effect year dropped	main effect year dropped

Table 57: Difference in models fitted to the rural-only data compared with the model chosen based on the full data, shown in Table 20.

Site status	**Deprivation unadjusted**			**Deprivation adjusted**		
	Estimate	99%	CI	Estimate	99%	CI
All anomalies						
Operating and closed				1.014	0.992	1.035
Operating only				1.021	0.996	1.047
NTD						
Operating and closed						
Operating only						
Cardiovascular defects						
Operating and closed				0.955	0.885	1.031
Operating only				0.982	0.898	1.074
Hypospadias and epispadias						
Operating and closed						
Operating only						
Abdominal wall defects						
Operating and closed	1.178	0.995	1.394	1.084	0.916	1.283
Operating only	1.1	0.896	1.351	1.006	0.819	1.235

Table 58: Relative risks and confidence intervals for **all site types** using $\geq 2km$ rates for comparison. Models used for estimating reference rates are shown in Table 57. Using modelled rates. Data include terminations (except hypospadias and epispadias). Data from rural areas only.

A comparison of tables 56 and 58 indicates that the difference in chosen models is unlikely to account for the differences between the rural-only and the original results, so we may compare Tables 27 and 56. The largest differences are for NTD's and hypospadias and epispadias with smaller relative risks amongst the rural populations. The rural results are higher for abdominal wall defects. In all cases, the smaller data set means that the relative risks are estimated with less precision in the rural only data.

6.4.12 Anomaly register data by administrative region

In this section we look at the results by administrative (census) region for all congenital anomalies and each of the specific anomalies. Modelled rates are based on the models shown in Table 20. Table 3 lists the region names.

Region	$< 2km$			Reference			Relative Risk
	Cases	Births	Rate	Cases	Births	Rate	
1	6354	447026	0.01421	796	59001	0.01349	1.054
2	12209	814106	0.015	1031	74617	0.01382	1.085
3	8207	503133	0.01631	2700	183773	0.01469	1.11
4	1255	108256	0.01159	2297	186754	0.0123	0.943
5	17465	1436294	0.01216	10869	873424	0.01244	0.977
6	5359	435106	0.01232	2548	190069	0.01341	0.919
7	8659	713048	0.01214	1732	120350	0.01439	0.844
8	11062	804649	0.01375	1404	112273	0.01251	1.099
9	4323	344778	0.01254	1200	96110	0.01249	1.004
10	15379	219179	0.07017	9748	129703	0.07516	0.934

Table 59: All anomalies cases, births and rates by region and exposure category. Relative risks by region.

Region	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
All anomalies						
1	1.06	1.026	1.094	1.04	1.006	1.074
2	1.093	1.068	1.119	1.118	1.093	1.145
3	1.131	1.099	1.164	1.146	1.114	1.179
4	0.963	0.895	1.036	0.963	0.895	1.036
5	1.012	0.992	1.032	1.009	0.989	1.029
6	0.953	0.92	0.987	0.967	0.933	1.001
7	0.855	0.831	0.879	0.839	0.816	0.863
8	1.125	1.098	1.153	1.121	1.094	1.149
9	1.035	0.995	1.076	1.049	1.009	1.091
10	0.934	0.915	0.954	0.939	0.92	0.959

Table 60: Relative risks and confidence intervals for all anomalies by census region. Using modelled rates.

Region	$< 2km$			Reference			Relative Risk
	Cases	Births	Rate	Cases	Births	Rate	
1	336	447026	0.00075	45	59001	0.00076	0.985
2	489	814106	0.0006	41	74617	0.00055	1.093
3	275	503133	0.00055	120	183773	0.00065	0.837
4	75	108256	0.00069	134	186754	0.00072	0.966
5	708	1436294	0.00049	406	873424	0.00046	1.06
6	234	435106	0.00054	93	190069	0.00049	1.099
7	458	713048	0.00064	49	120350	0.00041	1.578
8	490	804649	0.00061	68	112273	0.00061	1.005
9	205	344778	0.00059	49	96110	0.00051	1.166
10	238	219179	0.00109	135	129703	0.00104	1.043

Table 61: NTD cases, births and rates by region and exposure category. Relative risks by region.

Region	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
NTD						
1	0.992	0.862	1.142	0.956	0.831	1.101
2	1.098	0.977	1.233	1.054	0.938	1.185
3	0.839	0.718	0.979	0.822	0.704	0.96
4	0.951	0.706	1.28	0.945	0.702	1.273
5	1.054	0.956	1.161	1.051	0.954	1.158
6	1.089	0.921	1.289	1.061	0.897	1.256
7	1.573	1.394	1.774	1.539	1.365	1.736
8	1.007	0.897	1.132	0.98	0.872	1.101
9	1.169	0.976	1.399	1.139	0.951	1.363
10	1.039	0.88	1.228	1.032	0.874	1.22

Table 62: Relative risks and confidence intervals for NTD's by census region. Using modelled rates.

Region	$< 2km$			Reference			Relative Risk
	Cases	Births	Rate	Cases	Births	Rate	
1	448	447026	0.001	55	59001	0.00093	1.075
2	991	814106	0.00122	70	74617	0.00094	1.298
3	475	503133	0.00094	161	183773	0.00088	1.078
4	86	108256	0.00079	155	186754	0.00083	0.957
5	1111	1436294	0.00077	626	873424	0.00072	1.079
6	407	435106	0.00094	182	190069	0.00096	0.977
7	457	713048	0.00064	170	120350	0.00141	0.454
8	575	804649	0.00071	93	112273	0.00083	0.863
9	472	344778	0.00137	109	96110	0.00113	1.207
10	1701	219179	0.00776	1095	129703	0.00844	0.919

Table 63: Cardiovascular defects cases, births and rates by region and exposure category. Relative risks by region.

Region	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
Cardiovascular defects						
1	1.076	0.952	1.215	1.059	0.938	1.196
2	1.298	1.196	1.409	1.535	1.415	1.666
3	1.076	0.956	1.211	1.056	0.938	1.188
4	0.944	0.715	1.246	0.949	0.719	1.253
5	1.071	0.991	1.157	1.066	0.987	1.152
6	0.969	0.853	1.101	0.943	0.83	1.072
7	0.453	0.401	0.51	0.504	0.447	0.569
8	0.86	0.773	0.958	0.821	0.737	0.914
9	1.201	1.067	1.352	1.152	1.023	1.297
10	0.918	0.862	0.977	0.889	0.835	0.946

Table 64: Relative risks and confidence intervals for cardiovascular defects by census region. Using modelled rates.

Region	$< 2km$			Reference			Relative Risk
	Cases	Births	Rate	Cases	Births	Rate	
1	570	229217	0.00249	58	30357	0.00191	1.302
2	1161	416683	0.00279	94	38201	0.00246	1.132
3	814	258029	0.00315	282	94220	0.00299	1.054
4	129	55372	0.00233	198	95230	0.00208	1.12
5	1343	735571	0.00183	870	446873	0.00195	0.938
6	463	223009	0.00208	236	97510	0.00242	0.858
7	779	365383	0.00213	141	61979	0.00227	0.937
8	1119	412278	0.00271	126	57511	0.00219	1.239
9	376	176444	0.00213	103	49173	0.00209	1.017
10	609	111977	0.00544	377	66266	0.00569	0.956

Table 65: Hypospadias and epispadias cases, births and rates by region and exposure category. Relative risks by region.

Region	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
Hypospadias and epispadias						
1	1.326	1.191	1.477	1.339	1.202	1.492
2	1.141	1.058	1.231	1.151	1.068	1.242
3	1.075	0.982	1.177	1.078	0.985	1.18
4	1.186	0.945	1.488	1.187	0.946	1.489
5	0.976	0.91	1.047	0.975	0.909	1.046
6	0.892	0.791	1.005	0.893	0.792	1.006
7	0.953	0.869	1.045	0.957	0.873	1.05
8	1.27	1.176	1.372	1.272	1.178	1.374
9	1.054	0.923	1.204	1.059	0.928	1.21
10	0.96	0.865	1.066	0.964	0.869	1.07

Table 66: Relative risks and confidence intervals for hypospadias and epispadias by census region. Using modelled rates.

Region	$< 2km$			Reference			Relative Risk
	Cases	Births	Rate	Cases	Births	Rate	
1	150	447026	0.00034	18	59001	0.00031	1.1
2	236	814106	0.00029	19	74617	0.00025	1.138
3	115	503133	0.00023	27	183773	0.00015	1.556
4	28	108256	0.00026	49	186754	0.00026	0.986
5	281	1436294	0.0002	176	873424	0.0002	0.971
6	133	435106	0.00031	47	190069	0.00025	1.236
7	145	713048	0.0002	20	120350	0.00017	1.224
8	241	804649	0.0003	25	112273	0.00022	1.345
9	79	344778	0.00023	19	96110	0.0002	1.159
10	80	219179	0.00036	48	129703	0.00037	0.986

Table 67: Abdominal wall defects cases, births and rates by region and exposure category. Relative risks by region.

Region	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
Abdominal wall defects						
1	1.091	0.884	1.347	0.971	0.787	1.198
2	1.136	0.961	1.343	1.012	0.856	1.197
3	1.538	1.21	1.956	1.472	1.158	1.872
4	0.951	0.584	1.547	0.94	0.578	1.529
5	0.949	0.814	1.107	0.95	0.815	1.108
6	1.206	0.965	1.508	1.166	0.933	1.458
7	1.212	0.978	1.501	1.14	0.921	1.412
8	1.327	1.125	1.567	1.273	1.079	1.503
9	1.14	0.853	1.523	1.065	0.797	1.423
10	0.984	0.738	1.312	0.943	0.707	1.258

Table 68: Relative risks and confidence intervals for abdominal wall defects by census region. Using modelled rates.

6.4.13 Special waste sites

Tables 69, ..., 72 give the relative risks (with confidence intervals) for each of the birth outcomes for residences near special waste sites, operating or closed and during operation only. Modelled rates are based on the models shown in Table 20.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
All anomalies						
Operating and closed	1.067	1.043	1.092	1.068	1.044	1.093
Operating only	1.083	1.056	1.111	1.085	1.057	1.113
NTD						
Operating and closed	1.098	0.978	1.233	1.07	0.953	1.201
Operating only	1.147	1.006	1.309	1.118	0.98	1.276
Cardiovascular defects						
Operating and closed	1.108	1.021	1.202	1.112	1.025	1.207
Operating only	1.201	1.097	1.314	1.201	1.097	1.314
Hypospadias and epispadias						
Operating and closed	1.111	1.027	1.202	1.114	1.03	1.206
Operating only	1.103	1.009	1.205	1.106	1.013	1.209
Abdominal wall defects						
Operating and closed	1.094	0.908	1.318	1.033	0.858	1.245
Operating only	1.014	0.808	1.272	0.958	0.764	1.202

Table 69: Relative risks and confidence intervals for **special waste sites** using $\geq 2km$ rates for comparison. Using modelled rates. Data include terminations (except hypospadias and epispadias).

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
Hypospadias and epispadias (SC)						
Operating and closed	0.981	0.809	1.191	0.977	0.805	1.186
Operating only	0.985	0.77	1.259	0.981	0.767	1.254
Abdominal wall defects (HA)						
Operating and closed	1.141	0.868	1.499	1.078	0.821	1.417
Operating only	1.088	0.75	1.578	1.035	0.714	1.502
Gastroschisis and exomphalos (SC)						
Operating and closed	1.178	0.821	1.689	1.105	0.77	1.584
Operating only	1.144	0.703	1.861	1.082	0.665	1.761

Table 70: Relative risks and confidence intervals for **special waste sites** using $\geq 2km$ rates for comparison. Unadjusted unless stated otherwise.Data are from the hospital episode database, England and Scotland only. Denominator for hypospadias and epispadias is live male births only.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
Stillbirth						
Operating and closed	1.039	0.999	1.08	0.993	0.955	1.032
Operating only	1.037	0.992	1.085	0.992	0.949	1.038

Table 71: Relative risks and confidence intervals for **special waste sites** using $\geq 2km$ rates for comparison. Using modelled rates.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
Low birthweight						
Operating and closed	1.106	1.094	1.118	1.049	1.038	1.06
Operating only	1.095	1.082	1.109	1.042	1.029	1.055
Very low birthweight						
Operating and closed	1.079	1.049	1.109	1.031	1.002	1.06
Operating only	1.065	1.03	1.1	1.021	0.988	1.056

Table 72: Relative risks and confidence intervals for **special waste sites** using $\geq 2km$ rates for comparison. Using modelled rates.

6.4.14 Non-special waste sites

Table 73 , . . . , 76 gives the relative risks (with confidence intervals) for the birth outcomes for non-special waste sites, either operating or closed and during operation only. Modelled rates are based on the models shown in Table 20.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
All anomalies						
Operating and closed	1.013	1.003	1.023	1.016	1.006	1.026
Operating only	1.02	1.009	1.032	1.023	1.011	1.035
NTD						
Operating and closed	1.087	1.035	1.141	1.064	1.013	1.117
Operating only	1.134	1.069	1.203	1.109	1.045	1.176
Cardiovascular defects						
Operating and closed	0.934	0.901	0.967	0.947	0.914	0.981
Operating only	0.925	0.885	0.966	0.944	0.903	0.986
Hypospadias and epispadias						
Operating and closed	1.067	1.031	1.104	1.071	1.035	1.108
Operating only	1.084	1.042	1.128	1.088	1.046	1.132
Abdominal wall defects						
Operating and closed	1.135	1.052	1.224	1.072	0.994	1.156
Operating only	1.19	1.086	1.304	1.121	1.023	1.228

Table 73: Relative risks and confidence intervals for **non-special waste sites** using $\geq 2km$ rates for comparison. Using modelled rates. Data include terminations (except hypospadias and epispadias).

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
Hypospadias and epispadias (SC)						
Operating and closed	0.966	0.897	1.04	0.964	0.895	1.037
Operating only	0.933	0.843	1.032	0.93	0.841	1.029
Abdominal wall defects (HA)						
Operating and closed	1.103	0.992	1.227	1.048	0.942	1.165
Operating only	1.13	0.974	1.31	1.07	0.923	1.241
Gastroschisis and exomphalos (SC)						
Operating and closed	1.25	1.093	1.429	1.176	1.029	1.344
Operating only	1.361	1.136	1.632	1.278	1.066	1.531

Table 74: Relative risks and confidence intervals for **non-special waste sites** using $\geq 2km$ rates for comparison. Unadjusted unless stated otherwise.Data are from the hospital episode database, England and Scotland only. Denominator for hypospadias and epispadias is live male births only.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
Stillbirth						
Operating and closed	1.052	1.035	1.07	1.004	0.988	1.02
Operating only	1.064	1.043	1.085	1.012	0.993	1.033

Table 75: Relative risks and confidence intervals for **non-special waste sites** using $\geq 2km$ rates for comparison. Using modelled rates.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
Low birthweight						
Operating and closed	1.116	1.111	1.121	1.057	1.052	1.062
Operating only	1.12	1.114	1.126	1.058	1.052	1.064
Very low birthweight						
Operating and closed	1.09	1.077	1.103	1.045	1.033	1.057
Operating only	1.087	1.071	1.102	1.041	1.026	1.057

Table 76: Relative risks and confidence intervals for **non-special waste sites** using $\geq 2km$ rates for comparison. Using modelled rates.

6.5 Summary of the main results by outcome

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
All site types						
Before opening	1.02	0.99	1.051	1.02	0.991	1.051
Operating and closed	1.012	1.003	1.021	1.014	1.005	1.023
Operating only	1.022	1.011	1.032	1.023	1.013	1.034
Closed only	0.987	0.972	1.004	0.99	0.974	1.006
After opening (post 1982 subset)	1.001	0.991	1.011	1.004	0.993	1.014
Special sites						
Operating and closed	1.067	1.043	1.092	1.068	1.044	1.093
Operating only	1.083	1.056	1.111	1.085	1.057	1.113
Non-special sites						
Operating and closed	1.013	1.003	1.023	1.016	1.006	1.026
Operating only	1.02	1.009	1.032	1.023	1.011	1.035

Table 77: Summary table of results for all anomalies. Using modelled rates.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
All site types						
Before opening	0.989	0.832	1.175	0.98	0.825	1.165
Operating and closed	1.076	1.03	1.124	1.053	1.008	1.1
Operating only	1.129	1.071	1.189	1.103	1.047	1.162
Closed only	0.971	0.897	1.051	0.952	0.88	1.031
After opening (post 1982 subset)	1.071	1.017	1.128	1.047	0.994	1.102
Special sites						
Operating and closed	1.098	0.978	1.233	1.07	0.953	1.201
Operating only	1.147	1.006	1.309	1.118	0.98	1.276
Non-special sites						
Operating and closed	1.087	1.035	1.141	1.064	1.013	1.117
Operating only	1.134	1.069	1.203	1.109	1.045	1.176

Table 78: Summary table of results for NTD's. Using modelled rates.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
All site types						
Before opening	0.909	0.801	1.031	0.92	0.811	1.043
Operating and closed	0.948	0.918	0.978	0.959	0.929	0.989
Operating only	0.96	0.924	0.997	0.975	0.938	1.013
Closed only	0.923	0.873	0.975	0.926	0.876	0.979
After opening (post 1982 subset)	0.905	0.871	0.94	0.919	0.884	0.955
Special sites						
Operating and closed	1.108	1.021	1.202	1.112	1.025	1.207
Operating only	1.201	1.097	1.314	1.201	1.097	1.314
Non-special sites						
Operating and closed	0.934	0.901	0.967	0.947	0.914	0.981
Operating only	0.925	0.885	0.966	0.944	0.903	0.986

Table 79: Summary table of results for cardiovascular defects. Using modelled rates.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
All site types						
Before opening	1.079	0.976	1.191	1.08	0.978	1.193
Operating and closed	1.067	1.036	1.1	1.071	1.04	1.104
Operating only	1.082	1.044	1.12	1.086	1.048	1.124
Closed only	1.029	0.971	1.092	1.033	0.974	1.095
After opening (post 1982 subset)	1.049	1.012	1.088	1.054	1.016	1.092
Special sites						
Operating and closed	1.111	1.027	1.202	1.114	1.03	1.206
Operating only	1.103	1.009	1.205	1.106	1.013	1.209
Non-special sites						
Operating and closed	1.067	1.031	1.104	1.071	1.035	1.108
Operating only	1.084	1.042	1.128	1.088	1.046	1.132

Table 80: Summary table of results for hypospadias and epispadias. Using modelled rates.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
All site types						
Before opening	1.275	0.99	1.641	1.243	0.966	1.6
Operating and closed	1.138	1.065	1.217	1.078	1.008	1.152
Operating only	1.176	1.085	1.276	1.111	1.024	1.205
Closed only	1.066	0.948	1.198	1.015	0.903	1.141
After opening (post 1982 subset)	1.122	1.036	1.214	1.057	0.976	1.144
Special sites						
Operating and closed	1.094	0.908	1.318	1.033	0.858	1.245
Operating only	1.014	0.808	1.272	0.958	0.764	1.202
Non-special sites						
Operating and closed	1.135	1.052	1.224	1.072	0.994	1.156
Operating only	1.19	1.086	1.304	1.121	1.023	1.228

Table 81: Summary table of results for abdominal wall defects. Using modelled rates.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
All site types						
Before opening	1.42	0.935	2.157	1.423	0.937	2.161
Operating and closed	0.958	0.896	1.024	0.955	0.894	1.021
Operating only	0.949	0.867	1.038	0.946	0.865	1.035
Closed only	0.969	0.878	1.07	0.966	0.875	1.067
After opening (post 1982 subset)	0.928	0.857	1.004	0.926	0.855	1.002
Special sites						
Operating and closed	0.981	0.809	1.191	0.977	0.805	1.186
Operating only	0.985	0.77	1.259	0.981	0.767	1.254
Non-special sites						
Operating and closed	0.966	0.897	1.04	0.964	0.895	1.037
Operating only	0.933	0.843	1.032	0.93	0.841	1.029

Table 82: Summary table of results for surgical corrections of hypospadias and epispadias. Using stratified rates.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
All site types						
Before opening	2.408	1.312	4.42	2.26	1.232	4.148
Operating and closed	1.129	1.028	1.24	1.073	0.977	1.178
Operating only	1.162	1.02	1.324	1.103	0.968	1.256
Closed only	1.096	0.957	1.254	1.043	0.911	1.193
After opening (post 1982 subset)	1.189	1.068	1.324	1.124	1.01	1.251
Special sites						
Operating and closed	1.141	0.868	1.499	1.078	0.821	1.417
Operating only	1.088	0.75	1.578	1.035	0.714	1.502
Non-special sites						
Operating and closed	1.103	0.992	1.227	1.048	0.942	1.165
Operating only	1.13	0.974	1.31	1.07	0.923	1.241

Table 83: Summary table of results for hospital admissions for abdominal wall defects. Using stratified rates.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
All site types						
Before opening	1.446	0.505	4.14	1.33	0.465	3.806
Operating and closed	1.258	1.117	1.418	1.186	1.052	1.336
Operating only	1.355	1.152	1.593	1.274	1.084	1.498
Closed only	1.161	0.973	1.384	1.096	0.919	1.307
After opening (post 1982 subset)	1.331	1.161	1.524	1.243	1.085	1.424
Special sites						
Operating and closed	1.178	0.821	1.689	1.105	0.77	1.584
Operating only	1.144	0.703	1.861	1.082	0.665	1.761
Non-special sites						
Operating and closed	1.25	1.093	1.429	1.176	1.029	1.344
Operating only	1.361	1.136	1.632	1.278	1.066	1.531

Table 84: Summary table of results for surgical corrections for gastroschisis and exomphalos. Using stratified rates.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
All site types						
Before opening	1.03	0.977	1.085	1.006	0.955	1.061
Operating and closed	1.049	1.034	1.064	1.003	0.989	1.018
Operating only	1.06	1.042	1.079	1.012	0.995	1.03
Closed only	1.026	1	1.053	0.985	0.96	1.01
After opening (post 1982 subset)	1.067	1.049	1.085	1.015	0.998	1.032
Special sites						
Operating and closed	1.039	0.999	1.08	0.993	0.955	1.032
Operating only	1.037	0.992	1.085	0.992	0.949	1.038
Non-special sites						
Operating and closed	1.052	1.035	1.07	1.004	0.988	1.02
Operating only	1.064	1.043	1.085	1.012	0.993	1.033

Table 85: Summary table of results for stillbirth. Using modelled rates.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
All site types						
Before opening	1.039	1.024	1.055	1.009	0.994	1.024
Operating and closed	1.107	1.102	1.111	1.051	1.047	1.055
Operating only	1.109	1.104	1.115	1.051	1.046	1.056
Closed only	1.101	1.093	1.109	1.05	1.043	1.057
After opening (post 1982 subset)	1.129	1.124	1.134	1.067	1.062	1.072
Special sites						
Operating and closed	1.106	1.094	1.118	1.049	1.038	1.06
Operating only	1.095	1.082	1.109	1.042	1.029	1.055
Non-special sites						
Operating and closed	1.116	1.111	1.121	1.057	1.052	1.062
Operating only	1.12	1.114	1.126	1.058	1.052	1.064

Table 86: Summary table of results for low birthweight. Using modelled rates.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
All site types						
Before opening	1.004	0.965	1.046	0.978	0.939	1.018
Operating and closed	1.079	1.068	1.091	1.036	1.026	1.047
Operating only	1.075	1.061	1.089	1.032	1.019	1.045
Closed only	1.087	1.068	1.107	1.044	1.026	1.062
After opening (post 1982 subset)	1.09	1.077	1.103	1.042	1.029	1.055
Special sites						
Operating and closed	1.079	1.049	1.109	1.031	1.002	1.06
Operating only	1.065	1.03	1.1	1.021	0.988	1.056
Non-special sites						
Operating and closed	1.09	1.077	1.103	1.045	1.033	1.057
Operating only	1.087	1.071	1.102	1.041	1.026	1.057

Table 87: Summary table of results for very low birthweight. Using modelled rates.

7 Analysis: cancer outcomes

Note that all 'populations' referred to below are person-years. Also recall that the population 'counts' are actually estimates and hence not integers but real numbers. Tables show rounded whole numbers only, but totals are rounded sums of the real numbers, hence some minor discrepancies occur.

7.1 Relationship between deprivation and exposure category

Deprivation tertile	Exposure category			
	$< 2km$	%	Reference	%
1	74993479	31.2	44988937	44.1
2	84072041	35	33427559	32.8
3	80950189	33.7	23424435	23
Unavailable	67943	0	100084	0.1
Total	240083653	100	101941014	100

Table 88: Solid cancer and adult leukaemia denominator by Carstairs' tertile and exposure category.

Table 88 shows the solid cancer and adult leukaemia denominator by exposure category and deprivation. Counts include ages 15+ in England and Scotland (1987–1997) and Wales (1987–1994). In the study area, 31.24% of the population is in the most affluent tertile, 35.02% in the middle tertile, 33.72% in the most deprived tertile and 0.0283% in the unclassified category. In the reference area, these percentages were 44.13%, 32.79%, 22.98% and 0.09818%.

Deprivation tertile	Exposure category			
	$< 2km$	%	Reference	%
1	24545260	29.7	13601204	43.7
2	26423496	32	9574354	30.8
3	31574720	38.2	7912408	25.4
Unavailable	18019	0	24930	0.1
Total	82561496	100	31112896	100

Table 89: Childhood leukaemia denominator by Carstairs' tertile and exposure category.

Table 89 shows the childhood leukaemia denominator by exposure category and deprivation. Counts include ages 0–14 in England and Scotland (1983–1997) and Wales (1983–1994). In the study area, 29.73% of the population is in the most affluent tertile, 32% in the middle tertile, 38.24% in the most deprived tertile and 0.02182% in the unclassified category. In the reference area, these percentages were 43.72%, 30.77%, 25.43% and 0.08013%.

Data where the deprivation tertile was unavailable were not included in later analyses.

7.2 Crude cancer rates by potential confounders in the reference areas

We give the crude cancer rates by potential confounders in the reference area as Figures 4, . . . , 8 for hepatobiliary cancer, bladder cancer, brain cancer, childhood leukaemia and adult leukaemia, respectively.

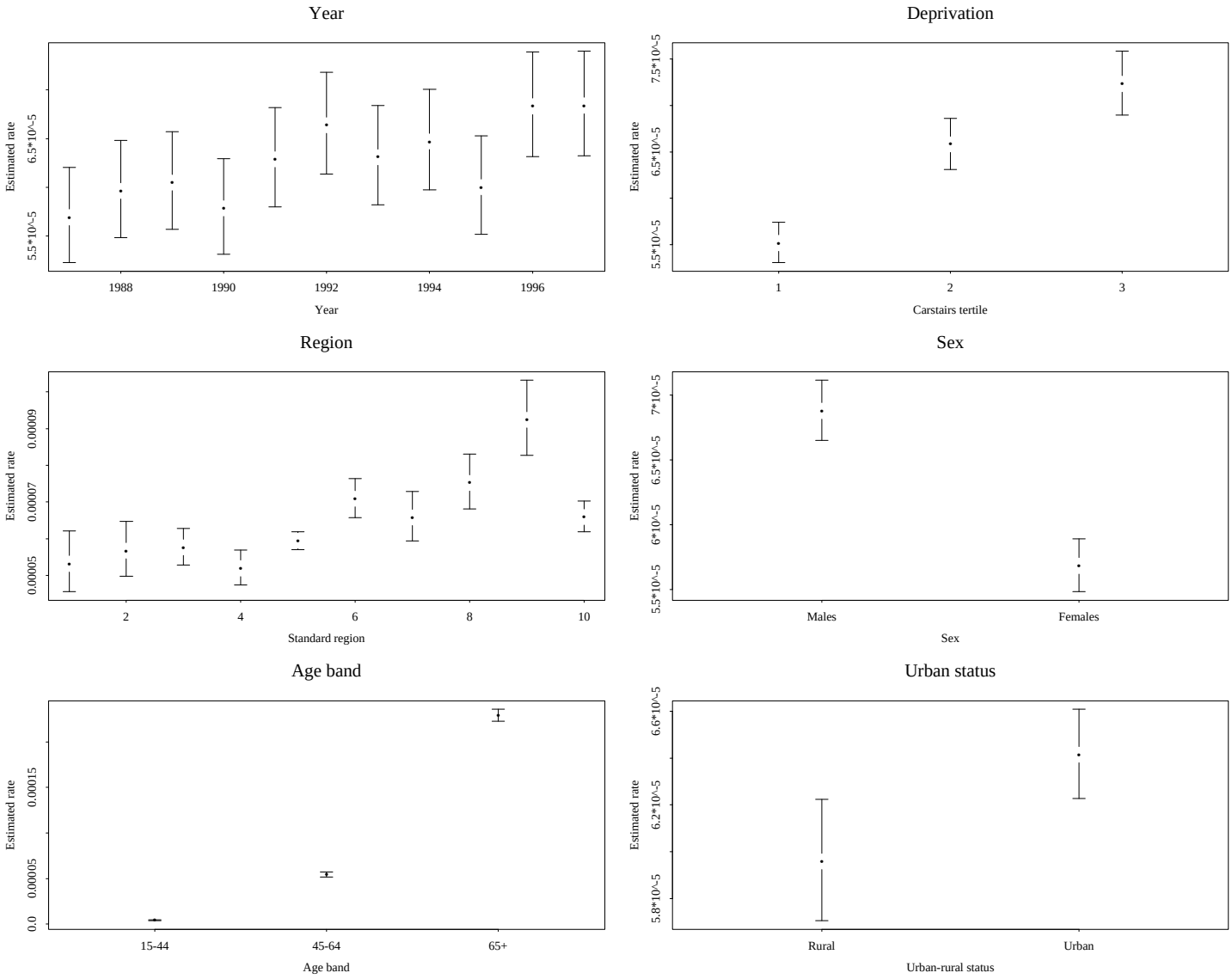

Figure 4: Crude rates of hepatobiliary cancer in the reference area.

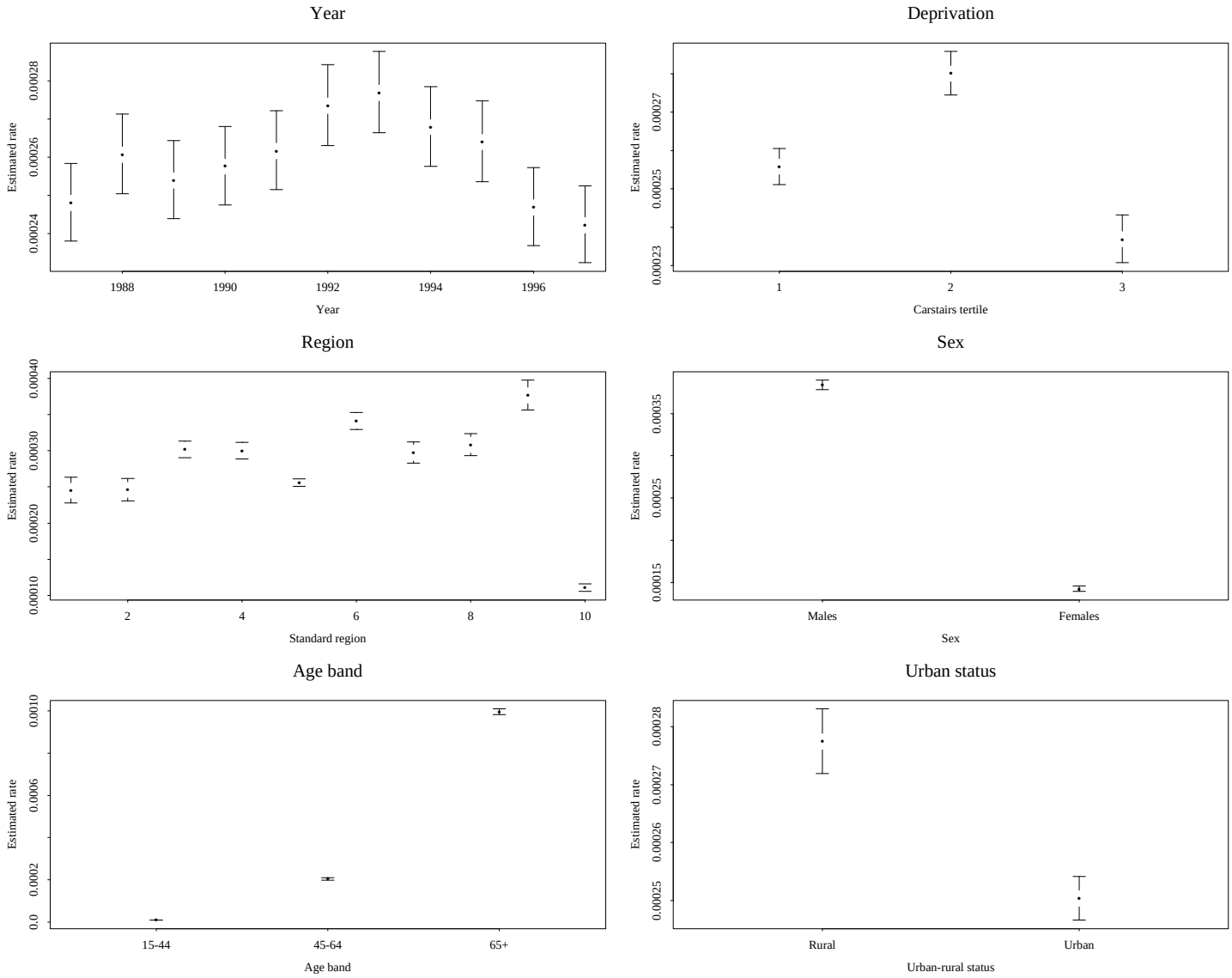

Figure 5: Crude rates of bladder cancer in the reference area.

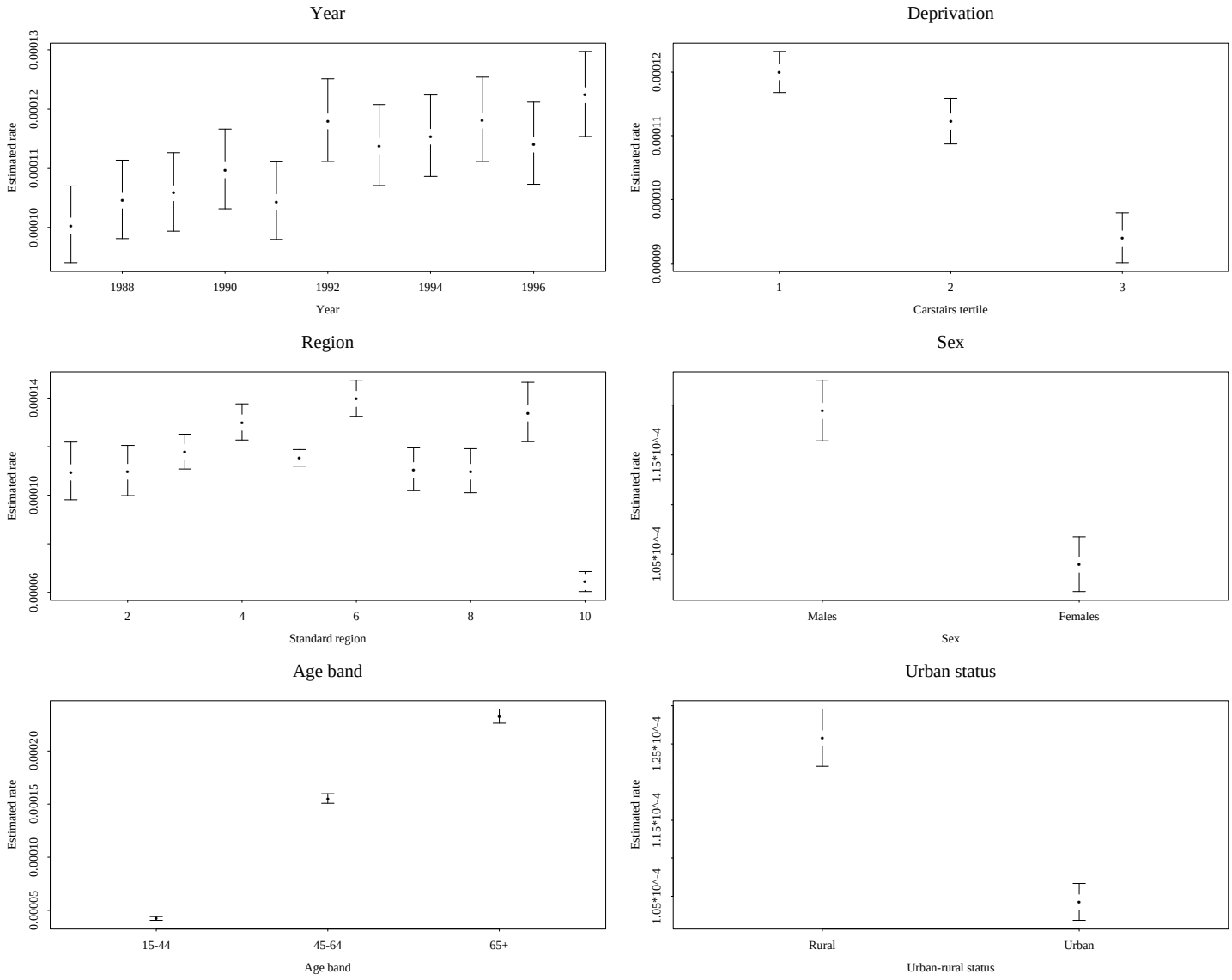

Figure 6: Crude rates of brain cancer in the reference area.

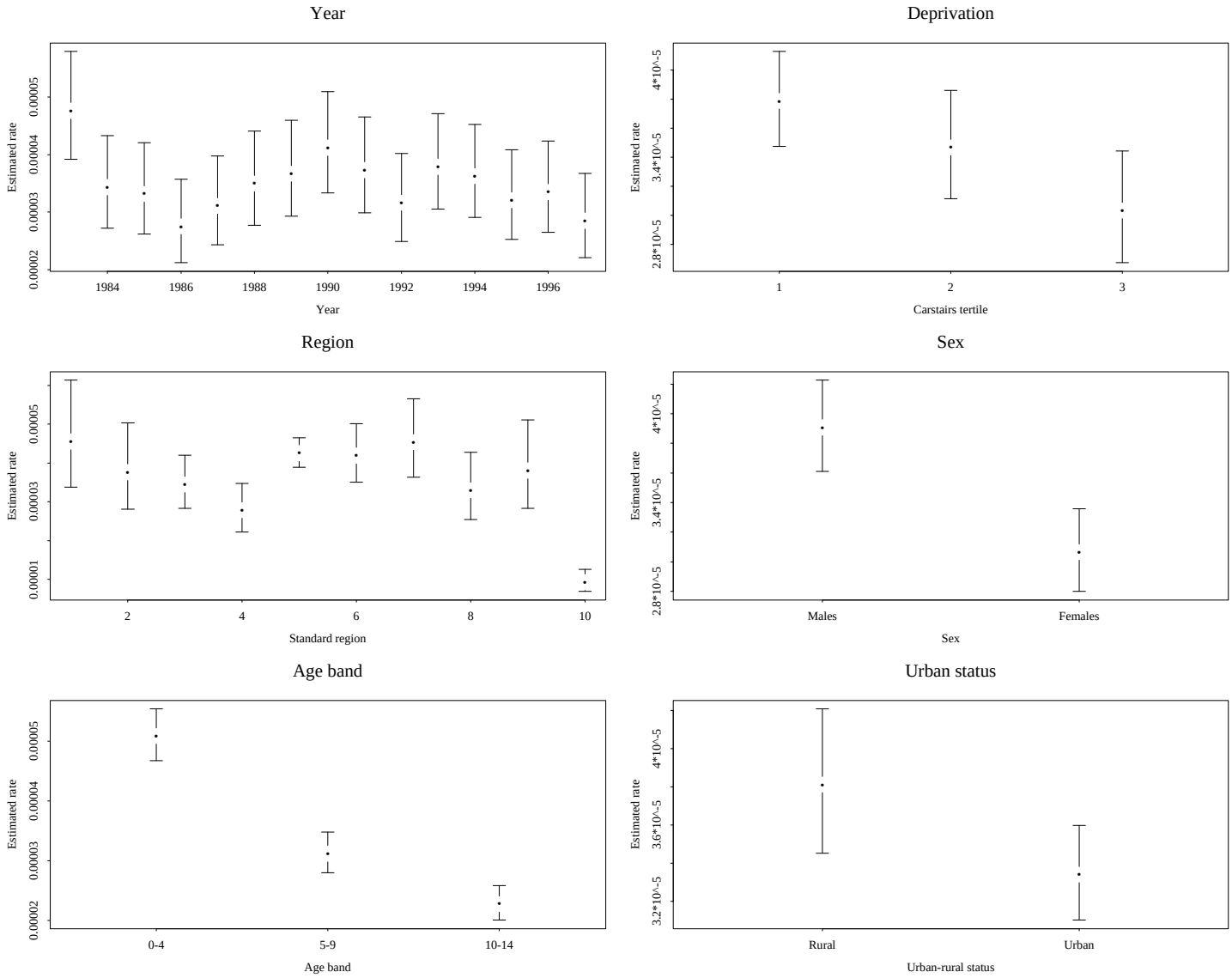

Figure 7: Crude rates of childhood leukaemia in the reference area.

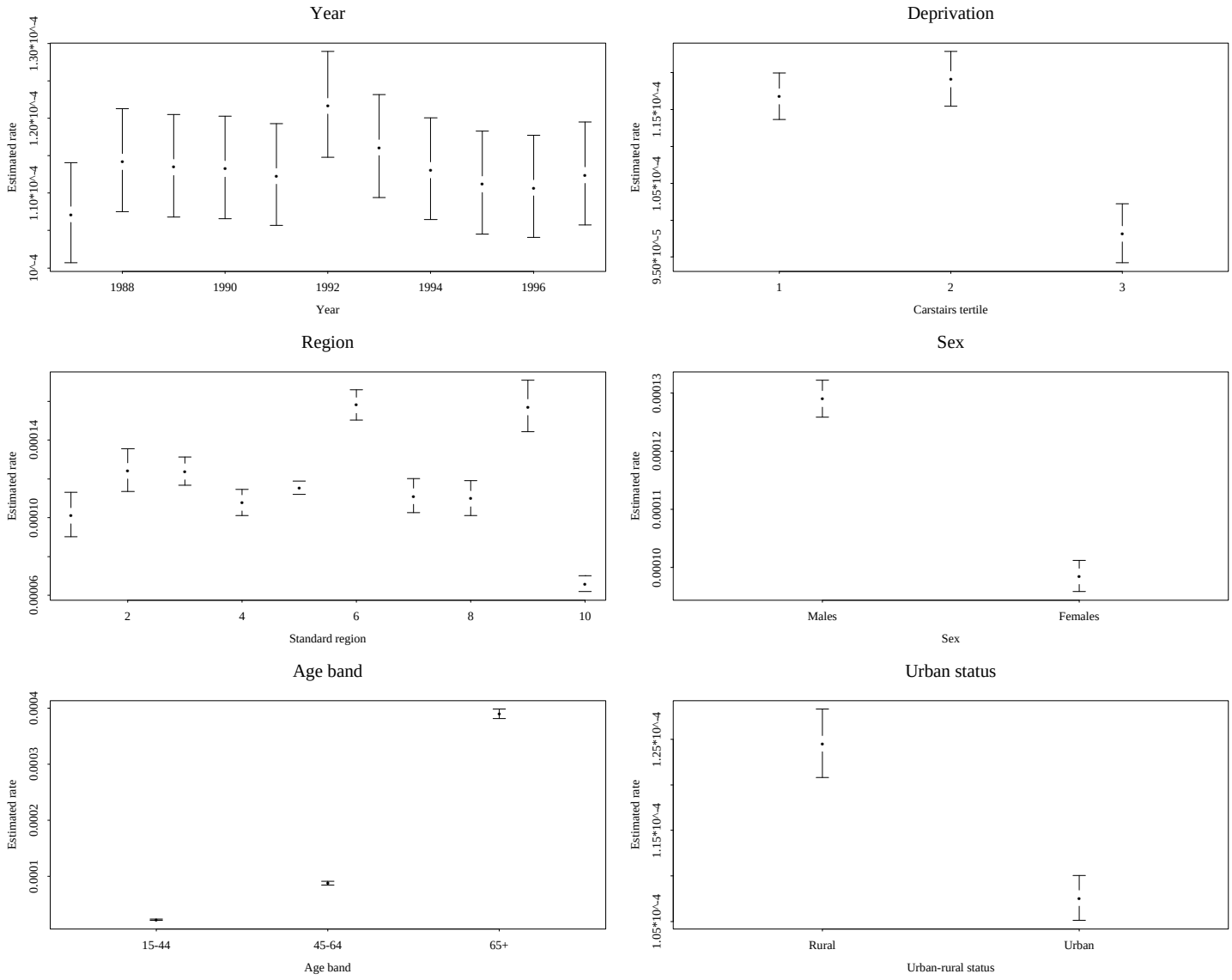

Figure 8: Crude rates of adult leukaemia in the reference area.

7.3 Calculation of reference rates for the cancer analysis

We followed a similar procedure as for the births analysis, adapted to be implemented more efficiently in the face of the greater number of covariates, (age and sex). We used the step-wise model selection routine as before, but starting from the main effects model. Deprivation adjusted and unadjusted models were constrained as before. Table 90 shows the selected models and number of parameters n_p. The top half of the table refers to the deprivation-unadjusted models and the lower half to the adjusted models. An intercept term is implicit in each model. These are our base models throughout and are denoted in table captions by 'using modelled rates', as in Sections 7.4.2, 7.4.5 and 7.4.6. All other models considered are for exploring the sensitivity of results to the model chosen. The last column of the table gives the additional term included to give the alternative model applied in Section 7.4.3.

Endpoint	Model	n_p	Alt
Deprivation unadjusted			
Hepatobiliary	y + r + a + s + r:s	32	a:r
Bladder	y + r + a + s + a:r + a:y + a:s + r:s	72	y:r
Brain	y + r + a + s + a:r + a:y + a:s + r:s	72	y:r
Childhood leukaemia	r + a + s	13	y
Adult leukaemia	r + a + s + a:s	15	y
Adjusted			
Hepatobiliary	d + y + r + a + s + a:d + r:s	38	a:r
Bladder	d + y + r + a + s + a:r + a:y + a:d + a:s + r:d + r:s†	96	y:r
Brain	d + y + r + a + s + a:r + a:s + a:y + r:s	74	y:r
Childhood leukaemia	d + r + a + s + d:s	17	y
Adult leukaemia	d* + r + a + s + a:s	17	y

Table 90: Models chosen by stepwise selection for the cancer outcomes. Main effects are represented by the following terms: d, deprivation; y, year; r, region; s, sex; a, age band. Interactions are denoted by ':'. * denotes endpoints where deprivation was not selected by the step-wise selection process, but was added as a main effect. † denotes term added to make the deprivation adjusted model comparable with the unadjusted model in all terms except deprivation. The column headed n_p is the number of parameters in the chosen model. The final column shows terms added in the alternative model used in the sensitivity analysis.

7.4 Results

7.4.1 Rates in the study and reference areas

The population, cases and raw rates for the cancer outcomes are given in Table 91 for the reference area and in Table 92 for the study area within 2km of an operating or closed site of any waste type.

Outcome	Cases	Population	Rate
Solid tumour cancers			
Hepatobiliary	6377	101840930	0.0000626
Bladder	26419	101840930	0.0002594
Brain	11350	101840930	0.0001114
Leukaemia			
Childhood leukaemia	1087	31087966	0.000035
Adult leukaemia	11533	101840930	0.0001132

Table 91: Cases, population and crude rate, by outcome in the reference area.

Outcome	Cases	Population	Rate
Solid tumour cancers			
Hepatobiliary	15396	240015710	0.0000641
Bladder	63367	240015710	0.000264
Brain	25452	240015710	0.000106
Leukaemia			
Childhood leukaemia	2886	82543477	0.000035
Adult leukaemia	26279	240015710	0.0001095

Table 92: Cases, population and crude rate, by outcome within 2km of all site types either currently operating or closed.

Table 93 gives results for the study areas within 2km of an operating or closed site of special and non-special type separately.

Outcome	Special sites			Non-special		
	Cases	Population	Rate	Cases	Population	Rate
Solid tumour cancers						
Hepatobiliary	2137	32877335	0.000065	11882	186257197	0.0000638
Bladder	8986	32877335	0.0002733	48623	186257197	0.0002611
Brain	3485	32877335	0.000106	19730	186257197	0.0001059
Leukaemia						
Childhood leukaemia	375	11209350	0.0000335	2232	64353882	0.0000347
Adult leukaemia	3621	32877335	0.0001101	20323	186257197	0.0001091

Table 93: Cases, population and crude rate, by outcome within 2km of special and non-special sites either currently operating or closed.

Table 94 gives results for the study area within 2km of an operating site of any waste type.

Outcome	Cases	Population	Rate
Solid tumour cancers			
Hepatobiliary	12015	188111619	0.0000639
Bladder	49926	188111619	0.0002654
Brain	19729	188111619	0.0001049
Leukaemia			
Childhood leukaemia	1984	57461434	0.0000345
Adult leukaemia	20544	188111619	0.0001092

Table 94: Cases, population and crude rate, by outcome within 2km of all site types currently operating.

Table 95 gives results for the study area within 2km of a closed site of any waste type.

Outcome	Cases	Population	Rate
Solid tumour cancers			
Hepatobiliary	3381	51904091	0.0000651
Bladder	13441	51904091	0.000259
Brain	5723	51904091	0.0001103
Leukaemia			
Childhood leukaemia	902	25082044	0.000036
Adult leukaemia	5735	51904091	0.0001105

Table 95: Cases, population and crude rate, by outcome within 2km of all site types after closure only.

7.4.2 All site types: operating and closed, operating only and closed only

Tables 96 ... 98 give the relative risks (with confidence intervals) for the cancer outcomes for the study areas within $2km$ of all site types, operating or closed and during operation only. Modelled rates are based on the models shown in Table 90.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
Hepatobiliary						
Operating and closed	1.052	1.03	1.074	1.004	0.983	1.025
Operating only	1.055	1.031	1.08	1.005	0.982	1.029
Closed only	1.039	0.994	1.086	0.998	0.955	1.043
Bladder						
Operating and closed	1.038	1.027	1.048	1.01	1	1.021
Operating only	1.044	1.032	1.056	1.015	1.003	1.027
Closed only	1.015	0.992	1.037	0.994	0.972	1.016
Brain						
Operating and closed	0.978	0.962	0.993	0.99	0.975	1.007
Operating only	0.976	0.958	0.994	0.989	0.971	1.008
Closed only	0.983	0.95	1.017	0.994	0.96	1.028

Table 96: Relative risks and confidence intervals for **all site types** using $\geq 2km$ rates for comparison. Using modelled rates.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
Childhood leukaemia						
Operating and closed	0.933	0.889	0.978	0.957	0.912	1.004
Operating only	0.925	0.873	0.98	0.95	0.896	1.006
Closed only	0.951	0.873	1.036	0.973	0.893	1.06

Table 97: Relative risks and confidence intervals for **all site types** using $\geq 2km$ rates for comparison. Using modelled rates.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
Adult leukaemia						
Operating and closed	0.988	0.973	1.004	0.992	0.976	1.008
Operating only	0.987	0.969	1.005	0.991	0.973	1.008
Closed only	0.994	0.961	1.029	0.997	0.964	1.032

Table 98: Relative risks and confidence intervals for **all site types** using $\geq 2km$ rates for comparison. Using modelled rates.

7.4.3 Sensitivity to modelled reference rates

Again, we looked at the results when compiled using a more complex model than that chosen by the stepwise procedure, see Table 90 for the added term. Results are robust to the additional term.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
Hepatobiliary						
Operating and closed	1.052	1.03	1.074	1.005	0.984	1.026
Operating only	1.056	1.031	1.081	1.007	0.983	1.031
Bladder						
Operating and closed	1.038	1.027	1.049	1.011	1	1.021
Operating only	1.044	1.033	1.057	1.015	1.004	1.027
Brain						
Operating and closed	0.978	0.962	0.994	0.991	0.975	1.007
Operating only	0.976	0.959	0.995	0.99	0.972	1.008

Table 99: Relative risks and confidence intervals for **all site types** using $\geq 2km$ rates for comparison. Using alternative rates.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
Childhood leukaemia						
Operating and closed	0.937	0.893	0.983	0.961	0.916	1.009
Operating only	0.918	0.866	0.972	0.943	0.89	0.999

Table 100: Relative risks and confidence intervals for **all site types** using $\geq 2km$ rates for comparison. Using alternative rates.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
Adult leukaemia						
Operating and closed	0.988	0.973	1.004	0.992	0.976	1.008
Operating only	0.986	0.969	1.004	0.99	0.972	1.008

Table 101: Relative risks and confidence intervals for **all site types** using $\geq 2km$ rates for comparison. Using alternative rates.

7.4.4 Urban-rural status as an additional confounder

We have also included the binary urban indicator in the pool of possible covariates for the step-wise selection procedure, again constraining the difference between the deprivation unadjusted and adjusted models. Table 102 shows the model selected in each case, with the number of parameters estimated, n_p, and Tables 103, 104 and 105 show the results.

Endpoint	Model	n_p
Deprivation unadjusted		
Hepatobiliary	y + r + a + s + u + r:s + a:u + s:u	36
Bladder	y + r + a + s + u + a:r + a:y + a:s + r:s + a:u + y:u	85
Brain	y + r + a + s + u + a:r + a:y + a:s + r:s	73
Childhood leukaemia	r + a + s + u + a:u	16
Adult leukaemia	r + a + s + u + a:s + r:u	25
Adjusted		
Hepatobiliary	d + y + r + a + s + u + a:d + r:s + s:u +a:u†	42
Bladder	d + y + r + a + s + u + a:r + a:y + a:d + d:u + a:s + a:u + d:r + u:y + r:s†	111
Brain	d + y + r + a + s + u + a:r + a:y + a:s + r:s	75
Childhood leukaemia	d* + r + a + s + u + a:u	18
Adult leukaemia	d* + r + a + s + u + a:s +r:u	27

Table 102: Models chosen by stepwise selection for the cancer outcomes when the urban status variable is included in the pool of possible covariates. Main effects are represented by the following terms: d, deprivation; y, year; r, region; s, sex; a, age band; u, urban status. Interactions are denoted by ':'. * denotes endpoints where deprivation was not selected by the step-wise selection process, but was added as a main effect. † denotes term added to make the deprivation adjusted model comparable with the unadjusted model in all terms except deprivation. The column headed n_p is the number of parameters in the chosen model.

Site status	**Deprivation unadjusted**			**Deprivation adjusted**		
	Estimate	99%	CI	Estimate	99%	CI
Hepatobiliary						
Operating and closed	1.017	0.996	1.038	0.992	0.972	1.013
Operating only	1.02	0.996	1.044	0.994	0.971	1.018
Bladder						
Operating and closed	1.022	1.012	1.033	1.005	0.995	1.016
Operating only	1.027	1.015	1.039	1.008	0.997	1.02
Brain						
Operating and closed	0.996	0.98	1.012	1.002	0.985	1.018
Operating only	0.995	0.977	1.013	1.001	0.982	1.019

Table 103: Relative risks and confidence intervals for **all site types** using $\geq 2km$ rates for comparison. Using modelled rates, including the urban-rural indicator.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
Childhood leukaemia						
Operating and closed	0.967	0.921	1.014	0.976	0.93	1.024
Operating only	0.959	0.905	1.016	0.969	0.914	1.026

Table 104: Relative risks and confidence intervals for **all site types** using $\geq 2km$ rates for comparison. Using modelled rates, including the urban-rural indicator.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
Adult leukaemia						
Operating and closed	0.995	0.979	1.01	0.996	0.98	1.012
Operating only	0.993	0.975	1.011	0.995	0.977	1.013

Table 105: Relative risks and confidence intervals for **all site types** using $\geq 2km$ rates for comparison. Using modelled rates, including the urban-rural indicator.

7.4.5 Special waste sites

Tables 106, . . . , 108 give the relative risks (with confidence intervals) for each of the cancer outcomes for exposure to special waste sites, operating or closed and during operation only. Modelled rates are based on the models shown in Table 90.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
Hepatobiliary						
Operating and closed	1.035	0.979	1.094	0.98	0.927	1.036
Operating only	1.027	0.967	1.091	0.974	0.917	1.035
Bladder						
Operating and closed	1.035	1.007	1.063	1	0.973	1.027
Operating only	1.03	1.001	1.061	0.996	0.967	1.026
Brain						
Operating and closed	0.972	0.931	1.016	0.988	0.945	1.032
Operating only	0.984	0.939	1.031	0.998	0.953	1.046

Table 106: Relative risks and confidence intervals for **special waste sites** using $\geq 2km$ rates for comparison. Using modelled rates.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
Childhood leukaemia						
Operating and closed	0.899	0.787	1.027	0.925	0.81	1.057
Operating only	0.922	0.794	1.071	0.948	0.816	1.101

Table 107: Relative risks and confidence intervals for **special waste sites** using $\geq 2km$ rates for comparison. Using modelled rates.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
Adult leukaemia						
Operating and closed	0.989	0.948	1.032	0.993	0.952	1.037
Operating only	0.993	0.949	1.04	0.997	0.952	1.044

Table 108: Relative risks and confidence intervals for **special waste sites** using $\geq 2km$ rates for comparison. Using modelled rates.

7.4.6 Non-special waste sites

Table 109 , . . . , 111 gives the relative risks (with confidence intervals) for the cancer outcomes for non-special waste sites, either operating or closed and during operation only. outcomes by exposure. Modelled rates are based on the models shown in Table 90.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
Hepatobiliary						
Operating and closed	1.056	1.032	1.082	1.007	0.984	1.031
Operating only	1.06	1.032	1.089	1.008	0.981	1.036
Bladder						
Operating and closed	1.042	1.03	1.054	1.015	1.003	1.027
Operating only	1.052	1.038	1.066	1.023	1.009	1.036
Brain						
Operating and closed	0.981	0.963	0.999	0.994	0.976	1.013
Operating only	0.978	0.958	0.999	0.992	0.971	1.013

Table 109: Relative risks and confidence intervals for **non-special waste sites** using $\geq 2km$ rates for comparison. Using modelled rates.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
Childhood leukaemia						
Operating and closed	0.928	0.879	0.98	0.954	0.903	1.007
Operating only	0.915	0.857	0.978	0.941	0.881	1.006

Table 110: Relative risks and confidence intervals for **non-special waste sites** using $\geq 2km$ rates for comparison. Using modelled rates.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
Adult leukaemia						
Operating and closed	0.987	0.97	1.005	0.991	0.973	1.009
Operating only	0.987	0.967	1.008	0.991	0.971	1.012

Table 111: Relative risks and confidence intervals for **non-special waste sites** using $\geq 2km$ rates for comparison. Using modelled rates.

7.5 Summary of the main results by outcome

Modelled rates are based on the models shown in Table 90.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
All site types						
Operating and closed	1.052	1.03	1.074	1.004	0.983	1.025
Operating only	1.055	1.031	1.08	1.005	0.982	1.029
Special sites						
Operating and closed	1.035	0.979	1.094	0.98	0.927	1.036
Operating only	1.027	0.967	1.091	0.974	0.917	1.035
Non-special sites						
Operating and closed	1.056	1.032	1.082	1.007	0.984	1.031
Operating only	1.06	1.032	1.089	1.008	0.981	1.036

Table 112: Summary table of results for hepatobiliary cancer. Using modelled rates.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
All site types						
Operating and closed	1.038	1.027	1.048	1.01	1	1.021
Operating only	1.044	1.032	1.056	1.015	1.003	1.027
Special sites						
Operating and closed	1.035	1.007	1.063	1	0.973	1.027
Operating only	1.03	1.001	1.061	0.996	0.967	1.026
Non-special sites						
Operating and closed	1.042	1.03	1.054	1.015	1.003	1.027
Operating only	1.052	1.038	1.066	1.023	1.009	1.036

Table 113: Summary table of results for bladder cancer. Using modelled rates.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
All site types						
Operating and closed	0.978	0.962	0.993	0.99	0.975	1.007
Operating only	0.976	0.958	0.994	0.989	0.971	1.008
Special sites						
Operating and closed	0.972	0.931	1.016	0.988	0.945	1.032
Operating only	0.984	0.939	1.031	0.998	0.953	1.046
Non-special sites						
Operating and closed	0.981	0.963	0.999	0.994	0.976	1.013
Operating only	0.978	0.958	0.999	0.992	0.971	1.013

Table 114: Summary table of results for brain cancer. Using modelled rates.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
All site types						
Operating and closed	0.933	0.889	0.978	0.957	0.912	1.004
Operating only	0.925	0.873	0.98	0.95	0.896	1.006
Special sites						
Operating and closed	0.899	0.787	1.027	0.925	0.81	1.057
Operating only	0.922	0.794	1.071	0.948	0.816	1.101
Non-special sites						
Operating and closed	0.928	0.879	0.98	0.954	0.903	1.007
Operating only	0.915	0.857	0.978	0.941	0.881	1.006

Table 115: Summary table of results for childhood leukaemia. Using modelled rates.

Site status	Deprivation unadjusted			Deprivation adjusted		
	Estimate	99%	CI	Estimate	99%	CI
All site types						
Operating and closed	0.988	0.973	1.004	0.992	0.976	1.008
Operating only	0.987	0.969	1.005	0.991	0.973	1.008
Special sites						
Operating and closed	0.989	0.948	1.032	0.993	0.952	1.037
Operating only	0.993	0.949	1.04	0.997	0.952	1.044
Non-special sites						
Operating and closed	0.987	0.97	1.005	0.991	0.973	1.009
Operating only	0.987	0.967	1.008	0.991	0.971	1.012

Table 116: Summary table of results for adult leukaemia. Using modelled rates.

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