WATER RESEARCH

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INTERIM REPORT

USAGE AND PERFORMANCE OF ASBESTOS CEMENT PRESSURE PIPE

DoE CONTRACT

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SUMMARY

I OBJECT

To report the first years work of a DoE contract to:

a) determine the length, size range and age distribution of asbestos cement pipe in use in the UK supply system for potable water.

b) assess the geographical distribution of asbestos cement pipe relative to conveyed water quality.

c) estimate the number of consumers receiving water which has been conveyed through asbestos cement.

d) determine the structural performance of asbestos cement pressure pipe for comparison with cast iron and uPVC.

e) identify environmental and service parameters which influence the failure frequency.

II REASON

Asbestos cement (AC) pipes contain approximately 11% by weight of asbestos fibres and are known to deteriorate in certain aggressive environments. To determine the scale of any potential degradation, data on the lengths and age profile of AC in use in the UK water supply system are required. The usage with respect to water quality and population will highlight those areas where deterioration and hence the potential for fibre release is likely to be most critical.

To identify whether asbestos cement pipe represents an acceptable option for mains laying or renewal, data on the engineering performance of AC in different environments are required. This will also enable comparison of its performance with alternative materials.

III CONCLUSIONS

i) Asbestos cement pipes form approximately 11% by length of the UK supply system for potable water with approximately 22% of the population receiving water which has, at some stage, been conveyed through AC. A more detailed breakdown was not undertaken for the purposes of this report.

ii) Approximately 18,500 kms of AC pipe have been laid in areas where a significant proportion of the conveyed water is potentially aggressive.

iii) A majority of the asbestos cement pipe was laid during the 1950's and 1960's. With the introduction of plastic pipes, use of AC for the small diameters has declined. However an increasing proportion of the AC pipe laid over recent years has been for large diameter mains where its materials and laying costs compare favourably with alternative pipe materials.

iv) The general failure rate of AC pipework is similar to that of both cast iron and uPVC. Therefore it can be considered as an alternative to each of these materials.

v) In the control area studied where the environments are not aggressive to AC the failure rate of AC increases linearly with age. The cause of this upward trend is unknown and may be affected by the external environment or changes in the materials properties. The overall failure rate however, remains below the National average.

vi) In aggressive environments, corrosion related failures have been reported after as little as 20 years service. Much AC is now 20 to 30 years old, which is the age when corrosion related failures are first seen. Based on the examination of failure records, it can therefore be anticipated that the number of corrosion related failures will increase over the next decade. The degradation of AC will be examined in part 2 of the current contract.

vii) No conclusion can be drawn on the effects of water quality on internal degradation of the pipes as the failure records do not include such data. These effects will be studied in the second phase of the contract.

viii) No comment can be made on the efficacy of bitumen seal coats as the presence or absence of such coatings was not generally recorded.

IV RECOMMENDATIONS

An understanding of the parameters controlling degradation of asbestos cement pipe is required to enable the potential rate of fibre release to be assessed. Examination of various age pipe samples exhumed from a variety of water qualities and environments will enable determination of the mechanism and rate of deterioration of asbestos cement pipe. Such an exercise is planned for part 2 of the contract.

V RESUME

A detailed survey of the Water Industry's records has enabled the length of asbestos cement pipe in use for water supply to be determined. Where available, diameter and age profiles of the system have been collated with an assessment of the population served.

Following a general survey of the Industry's mains laying and burst records, four areas which have used substantial quantities of asbestos cement pipe, and have maintained good records, were selected for a detailed examination of the material's performance. Of the four areas, three have predominantly soft waters which are generally aggressive to asbestos cement. The fourth was chosen as a control, with hard water and clay soils which are generally not aggressive to asbestos cement.

The overall failure rate for the four areas is 0.10 failures/kilometre year (fails/km yr) which broadly compares with previously reported rates of 0.14 fails/km yr for cast iron, and 0.139 fails/km yr for uPVC pipes laid in London.

The failure rate in a non-aggressive environment was found to increase linearly with age for both class B (7.5 bar rated) and class C (10 bar rated) pipe. In soft water aggressive environments, corrosion related failures have been recorded for pipes approximately 20 years old. The proportion of corrosion related failures increases with age.

1. INTRODUCTION

Asbestos cement (AC), potable water pressure pipes have been in service in the United Kingdom since the 1930's when production first started. Use of the material became widespread during the 1950's and 1960's particularly in the smaller diameter distribution main sizes. The introduction of uPVC pipes in the 1960's eroded this market as it was economically more attractive. The recent interest in asbestos in the environment has raised questions (Hansard 1983) on the use of asbestos cement for carrying potable waters, particularly with regard to its effect on water quality and the potential for fibres released by deteriorating pipework.

A recent study commissioned by the Department of the Environment (DoE) (Conway and Lacey 1984) has shown that asbestos cement pipes do contribute to asbestos levels in water in the distribution system, and suggests that the aggressiveness of the water, and the length and age of the pipes probably contribute to the concentration of fibres found.

Additionally AC is known to deteriorate, although the parameters controlling the rate of degradation, and their effect on pipe performance are not understood.

Hence the DoE have commissioned the Water Research centre (WRc) (for details see Appendix 3) to survey the Water Industry's records and to compile data on the use of AC to:

a) quantify the usage of AC pipe with respect to age and conveyed water quality.

b) assess the population served through AC mains.

c) determine the performance of AC pipe and the parameters which affect its deterioration and failure rate.

2. USAGE OF ASBESTOS CEMENT PIPE

2.1 Data Collection

i) Length

Various approaches were adopted in collating data from the Water Utilities depending on the quality and form of the records. Much of the data was derived directly from mains laying records or from distribution plans with the remainder relying either on estimates based on the known mains laying practice, or measurement of mains identified as AC by the Utilities staff. In those instances where complete material information was not available, only that which was positively identified as AC was measured. Hence the amount recorded represents a minimum length in the ground.

ii) Diameter

The diameters of the mains were generally identified on the plans or mains laying records. In some areas the data provided was limited to size ranges, often split between small diameter, distribution mains <6", and large diameter trunk mains, >6".

iii) Ages

When available most of the data gave only approximate age distributions for the pipe laid. However, accurate information was available from a limited number of areas, which has enabled the production of precise age profiles.

iv) Population served

An estimate of the population served through AC pipes was generally made by determining which towns and villages are supplied by AC trunk mains. The populations of these towns was obtained from recent census records generally held by the appropriate water undertaking. In some instances detailed numbers of consumers connected to AC distribution mains were available, but generally only for short lengths of pipe. Where no population figure was available, estimates were based on the proportion of distribution size mains which were AC, with an enhanced proportion for large diameter trunk mains. However, as many of the distribution systems are networked, and consumers may receive water from various sources, accurate population data is impossible to obtain.

v) **Water Quality**

Water quality data was obtained from a WRc data base which contains information on water hardness, alkalinity and pH. These were used to identify the areas where the conveyed water is potentially aggressive to AC.

2.2 Results

2.2.1 Length of Asbestos Cement Pipe

Data on the length of asbestos cement pipe in use has successfully been obtained from water utilities containing 98% of the UK water mains. Of the 347,669 kms of main in the ground (Water Services Yearbook 1984, 1985) over 37,500 kms, or approximately 11% of the system, is asbestos cement. Some 12.1 million people, or approximately 22% of the population receive water which has been conveyed through AC pipe. The data is summarised in Table 1, which also shows the breakdown in usage between the Water Authorities, Water Companies, Scottish Regional Councils and the Department of the Environment for Northern Ireland.

Table 2 presents a detailed breakdown of the usage and population served for each Water Authority, and for the Companies within each Authority's boundary.

A wide variation in AC pipe usage is evident between different Water Authority areas ranging from 3% in Thames Water area to 22% in Anglian. Within the Scottish Regional Councils (RC's) the variation is wider, from 3% in Central and Lothian RC's to 70% in the Western Isles Island Council. The data is presented graphically in Figures 1A and 1B and shows more clearly the pattern of usage around the country. There is a clear relationship between the use of AC mains and population density. Those areas with a low population density ie with large rural areas, have laid a relatively large proportion of mains in AC, whereas those with a high population density, ie containing large urban areas, have laid a small proportion of AC.

2.2.2 Diameters

Detailed data giving the length for each diameter of AC pipe laid was available for over 60% of the recorded AC pipe length. The remaining data generally contained lengths for two or more pipe sizes, and these were apportioned between diameters in the ratios obtained from the more detailed data. This allowed the total length of pipe of each diameter to be estimated. Figure 2 presents the proportions and lengths of pipe in several diameter bands and shows that over 80% of the AC mains laid are 6" or less in diameter, which generally relates to distribution main sizes.

Variations in the usage of the different diameters exist between the Water Authorities, the Scottish Regional Councils, and the Water Companies. Small diameter mains up to 3", account for a higher proportion of the AC laid in the Scottish Regional Councils than the Water Authorities, which in turn are higher than the Water Companies see figure 3. This trend also correlates with the population densities of the supply areas, those with a low population density using large proportions of small diameter mains.

2.2.3 Age profiles

The majority of the Water Undertakings provided approximate age data, but complete and accurate age data was available from only a limited number of Water Utilities which contained approximately 12% of the total length of asbestos cement mains. The detailed profile derived is consistent with the approximate data and can be considered representative of the national mains laying pattern as the data was compiled from Water Authority areas, Water Companies and Scottish Regional Councils. Additionally the diameter breakdown is similar to the total national usage.

From an initially low rate of laying of AC mains in the 1930's, use of the material gained in popularity, reaching a peak of 1250km/yr in the 1950's and 1960's see figure 4. The rate of mains laying has since continuously decreased to the current rate of approximately 200km/yr.

Figures 5 and 6 show the age distribution for the diameter ranges used. In figure 5 the age profile for the AC mains is presented in terms of the percentage of the total mains laid, and shows a gradual move away from laying small diameters, with the use of 3" and below reaching a maximum in the 1950's, 4" to 10" reaching a maximum in the 1960's and 12" and above reaching a maximum in the 1970's.

Presenting the age/diameter data as a proportion of the mains laid during each decade, figure 6 shows the trend towards the use of larger diameters. Until the 1950's over 50% of the asbestos cement mains laid were 3" or less in diameter, whereas in the 1980's this figure had fallen to 2%. Conversely the use of 12" and above has increased from none during the 1930's and 1940's, to 20% during the 1980's.

These trends in the mains laying can be attributed to several factors.

Manufacture of asbestos cement pipe started in the UK in the late 1920's, when it provided the only practical alternative to cast iron in the smaller diameters. With the lower cost, and the claimed chemical stability it proved an attractive material. The use of AC increased sharply during the 1940's and 1950's as the passing of the 1944 Rural Water Supplies Act placed an obligation on the Water Undertakings to supply water to communities, providing certain conditions were met.

The advent of uPVC in the 1960's provided a cheap alternative to cast iron and asbestos cement, and thus the market share of small diameter AC pipe dropped, and continued to decline during the 1970's and 1980's. However, polymeric materials are currently restricted to the smaller diameter mains while AC is available up to 900mm diameter. Thus AC still competes with ductile iron and alternative materials for larger diameter trunk mains.

2.2.4 Asbestos cement and corrosive environments

Asbestos cement pipes are known to deteriorate when conveying certain aggressive waters. (Buelow et al 1980, Kristiansen 1977, Millette etal 1984). Deterioration of AC is generally caused by either soft water leaching of the cementitious matrix, or by acid or sulphate attack. Various attempts have been made to classify the aggressiveness of water to AC, with the two most commonly used parameters being the Langelier Index (Langelier 1936) which is a measure of the level of carbonate saturation, and the AWWA Aggressiveness Index (AWWA 1977) which is a simplified Langelier Index (see Appendix 1).

As most water distribution systems are networked and often convey blended waters it has not been possible to relate AC mains directly to their conveyed water quality. Thus an arbitrary parameter was used defining areas with aggressive waters as those where most of the conveyed water was considered to be 'soft' (ie total hardness < 75mg/l). In these areas it can be anticipated that some internal deterioration of the AC mains is possible. The areas with the most aggressive water are in the north and the west, where the water is derived from moorland sources, or from areas of hard igneous and metamorphic rock (Figure 7). Within these areas of potentially aggressive water approximately 18,500km of asbestos cement pipes have been laid serving a population of approximately 5.5 million. This represents 48% of the asbestos cement mains, and 10% of the population of the UK.

2.3 Summary of mains laying data

i) Of the 347,669 kms of potable water mains, approximately 11% or 37,542 kms are asbestos cement.

ii) 22% or 12.1 million of the United Kingdom's population receives water which has been conveyed through AC.

iii) The users with the largest percentage of AC are those with a high proportion of rural areas containing a low population density

iv) Much of the AC laid during the 1950's and 1960's was for rural water supply, and hence was laid in the areas of low population density. Many of these areas coincide with regions with soft conveyed and groundwater which can be considered to be aggressive to AC. Thus approximately 50% of the asbestos cement mains laid may be deteriorating and these supply some 10% of the country's population.

3. PERFORMANCE OF ASBESTOS CEMENT MAINS

To assess the in-service performance of asbestos cement pipes, and to determine whether the presence of soft conveyed water and soft groundwaters cause structural deterioration of the pipe material, failure records have been examined from four areas identified as having laid large lengths of AC, and having maintained good mainslaying and burst records. (Thomas and De Rosa, 1985)

One of the areas selected considered AC mains to perform well. In this area both the conveyed water and the groundwater are hard, and the soils are generally cohesive clays.

The other three areas were selected as they have generally soft conveyed water and soft groundwaters, and have reported some deterioration of AC pipe.

Table 3 summarises the extent of the data available for each area, with a broad assessment of the conditions of use.

3.1 Area 1

3.3.1 Quality of Records

Detailed mainslaying records have been maintained over the whole period of asbestos cement usage, with accurate information recorded on the year laid, the diameter, and the class of pipe. Some limited information is available on the position in which the pipes have been laid, ie field, path, road, but the presence or absence of bitumen pipe coatings has not been recorded.

Burst records have been maintained since 1952, and the information recorded for each failure has generally been very detailed.

The only parameters unrecorded are the presence of a pipe coating, the operating pressure and the cause of failure.

The total hardness of the conveyed water in the area varies between 150 and 500mg/l $CaCO_3$, and most of the water has a hardness of 300mg/l $CaCO_3$. The soils are generally cohesive clays which are not chemically aggressive to AC, with a hard groundwater, producing a non aggressive external environment.

3.1.2 Analysis

Figure 8A shows the length of asbestos cement laid in Area 1, with a histogram of the percentage laid during each decade presented in figure 8B. Comparison with the National laying pattern of figure 4 shows a similar increase in use during the 1950's and 1960's with a subsequent decline in recent years. However, due to the satisfactory performance of AC in this area it continued to be used at a significant rate during the 1970's and 1980's, whereas the National usage declined more severely. There is a trend towards the use of larger diameter AC, as shown in figure 9, which is consistent with the National trend shown in figure 6.

In 1956 the use of class B asbestos cement pipe for water mains was discontinued, with class C pipe for the smaller diameters becoming standard.

The number of failures occurring on AC mains has increased since records started in 1952 (figure 10A). However, when the length in service is taken into account the trend is reversed, with a relatively constant, low failure rate since 1957 (figure 10B). Two peaks in the failure rate are evident in 1959 and 1976, which correspond to two hot summers with long dry periods. The influence of climatic conditions on the failure rate can be seen in figure 11, where the occurrence of failures through the year is presented. In this study area, over 60% of the failures have occurred during July, August and September when the soil moisture deficit is at a maximum. This results in shrinkage of the cohesive clay soils which are predominant within the area, and causes loading of the buried pipes. Additionally the drying of the clays reduces the attenuation of imposed traffic loads leading to higher loads transmitted to the pipes. The high incidence of ring fracture failures, and the large proportion of failures on small diameter mains, Table 4, are consistent with such external loading imposing bending stresses on the pipes. (Zeitlen JG and Kassiff GK 1959)

The apparent reduced failure rate after 1957 is coincident with the introduction of class C pipes, which having a thicker pipe wall, see Appendix 2, can withstand higher bending stresses. Indeed, when separate failure rates are calculated for each of the two classes of pipe, the class C pipes have an average failure rate an order of magnitude lower than the class B pipes; 0.026 failures/km yr compared with 0.264 failures/km yr respectively.

Two factors could distort the real difference, enhancing the apparent class C performance:

i) the larger diameter pipes, which have a higher bending moment resistance, account for an increasing proportion of the AC pipe laid. Thus different diameter distributions exist for class B and class C pipe, which could be expected to affect their overall failure rates.

ii) the class B pipes tend to be older, and thus could be expected to exhibit a higher failure rate.

To examine the effect of diameter, the failure rate for each size of pipe was calculated for both class B and class C pipes. The results plotted in figure 12 show that the failure rate decreases with increasing diameter, reflecting the increased resistance to beam loading. Comparison of the failure rate of a given diameter for each class of pipe, shows the failure rate for class C to be significantly lower than class B pipe.

Variations in the age profile of the two classes can be eliminated by considering the age of the pipes at failure, and relating to the length exposed. The resulting failure rates are plotted against age in figures 13 and 14 for class B and class C pipes respectively. Using the least squares method a best fit line has been determined, and a linear relationship was identified between failure rate and age for both classes of material.

The equations of the two best fit lines are:

for class B pipe $f = 0.0070a + 0.12$
for class C pipe $f = 0.0022a + 0.002$

where f = failure rate (No/km)
a = age (years)

Thus the predicted overall failure rate at 50 years is

0.47 failures/km yr for class B pipe
0.11 failures/km yr for class C pipe

A similar analysis has been performed on 4" pipe of each class, and it can be seen from figures 13a and 14a that the same linear relationship between failure rate and age exists. The failure rate for 4" class C AC pipe is lower than the failure rate for 4" class B AC pipe.

The predicted failure rates at 50 years being

0.46 failures/km yr for 4" class B AC pipe

0.12 failures/km yr for 4" class C AC pipe

There is however a substantial scatter evident at the larger ages due to the short lengths of pipe exposed for that time, see figures 13 and 14.

3.2 Area 2

3.2.1 Quality of Records

Although the only details available on mains laying were from distribution plans, and failure records have only been maintained since 1979, this area was included in the survey as it had reported problems with degradation of asbestos cement pipes. The limited data available precludes any accurate analysis of failure trends and relationships, but does enable comparison of failure rates with other areas.

The conveyed water is generally soft with total hardness values between 35 and 90 mg/l $CaCO_3$. Thus the conveyed waters are aggressive towards AC and some degradation of the pipe material can be anticipated. Sandy/gravel soils cover most of the region and enable rapid percolation of the soft groundwaters.

3.2.2 Analysis

Annual failure rates for area 2 have been calculated for pipes of >3" diameter, and are presented in figure 15, with the average non-accidental failure rate for the six years of records 0.10 failures/km yr. These failures have occurred fairly uniformly through the year (figure 11) suggesting the failures are not attributable either directly or indirectly to the climatic conditions. As accurate age data for laying of the mains is not readily available, the effect of age on failure rate cannot be analysed. However approximate ages at failure are available enabling general trends to be viewed in ten year age bands. Over 90% of the failures recorded on pipes 50 or more years old have been a attributed to corrosion (figure 16), with corrosion cited as the cause of failure on a few pipes which are less than 20 years old. It can be seen from figure 16 that the proportion of failures attributed to corrosion progressively increases with pipe age, and thus can be expected to become more prevalent.

The effect of diameter on failure rate is comparable to that seen in area 1 (figure 12) with the failure rate decreasing with increasing diameter. However, as the class of pipe has not been recorded, it is not possible to determine whether this lower failure rate is related to class or diameter.

A summary of the failure data together with the total mains laid is presented in Table 5, where the high incidence of longitudinal fractures and the high proportion of failures occurring in sand and gravel are prominent.

A longitudinal fracture is consistent with an effective over-pressurisation of the pipe, which may be caused by surge pressures, by loss of strength due to degradation of the pipe material or by a combination of these effects. This is confirmed by the cause of some 60% of the failures being attributed to either surge or corrosion.

3.3 Area 3

3.3.1 Quality of Records

Mainslaying records have been maintained since asbestos cement was first laid although the data on pipe ages is not precise. Various classes of pipe have been laid, but have not always been recorded.

Burst records have been maintained since 1972, and have recorded most information. However, the limited period covered by the records precludes an accurate analysis of failure trends.

The conveyed water is generally soft with the total hardness commonly less than 50ppm as $CaCO_3$. Much of the soil is sandy/gravel with some areas of peat and clay.

3.3.2 Analysis

Annual failure rates, excluding failures due to accidental damage, for the eleven years of records are presented in figure 17, with the average failure rate 0.026 failures/km yr. There is very little variation from this value with increasing age, although the cause and type of failure changes. In figure 18 the number of failures for each five year period is presented with the numbers of corrosion induced and longitudinal failures. In the early life of the pipes there are very few corrosion or longitudinal failures.

After approximately 15 years however corrosion induced failures become increasingly significant, with 35% of the failures of 25 - 30 year old pipe attributed to corrosion, and 75% recorded as longitudinal fractures. Thus the pipes are progressively deteriorating in the soft conveyed and groundwaters, but in this operating environment have a minimum life of 15 - 20 years before corrosion causes failure.

Figure 19 presents the failure rate for each diameter of AC pipe laid within this area. However, the small number of failures recorded may be masking any trends in the failure rate.

Table 6 presents a summary of the failure data and shows that the types of failure are evenly divided between long fractures, ring fractures and joints, indicating failure is not caused by a single mechanism.

Climatic conditions do not appear to significantly affect the failure rate, as the recorded failures have occurred relatively uniformly through the year (figure 11).

3.4 Area 4

3.4.1 Quality of Records

Detailed mainslaying records have been maintained since asbestos cement was first laid, and the pattern of use is similar to the National usage, with a majority of the AC laid during the 1950's and 1960's (figure 20). All the pipe laid in this area has been class C.

Burst records were initiated in 1971, and have been maintained in good detail since. Again the limited period precludes accurate analysis of failure trends.

The conveyed water is generally soft, with a total hardness of less than 50ppm as $CaCO_3$, and would thus be considered moderately aggressive to AC. Much of the soil in the area is sandy/gravel with limited areas of clay.

3.4.2 Analysis

During the 11 years of available burst records there have been 135 failures which are not attributed to accidental damage. This gives an average failure rate of 0.047 failures/km yr; the annual rates are plotted in figure 21. Analysis of the failure rate with respect to age shows a very high failure rate (0.95 fails/km yr) during the first year of service (figure 22). Of these failures 90% are ring fractures indicating the application of a bending load. When a cause of failure has been recorded 55% are attributed to subsidence and 41% to loading. Failures of this type early in the life of a pipeline may be caused by several factors, either individually, or in combination.

i) the use of contractors vehicles in development areas on unmade ground, thus severely overloading the buried pipes.

ii) general ground settlement

iii) poorly laid pipe

iv) poor quality pipe

After the first year the failure rate drops to a constant low level of 0.04 failures/km yr (figure 22).

Although most of the failures are ring fractures, Table 7, which are characteristic of beam loading, there does not appear to be the expected relationship between diameter and failure rate figure 19B. However, this may be due to the limited data available.

Few corrosion related failures have been reported despite the soft conveyed water, with few related longitudinal fractures.

There appears to be little effect of climatic conditions, with the failures fairly evenly distributed through the year (figure 11).

3.5 Comparison of the four areas examined

In each of the four areas selected, the mains laying pattern is broadly similar, with a majority of the asbestos cement pipe laid during the 1950's and 1960's. Much of the pipe in use is small diameter, although there is a trend away from the use of AC for small diameter mains.

Comparison of the failures in area 1 which was selected as its water and environments are non-aggressive with areas 2, 3 and 4, where soft water, aggressive environments exist shows several important factors.

i) The non-accidental failure rate of class C AC pipe in area 1 is comparable to that of areas 3 and 4, but is considerably lower than area 2 where the class of main is unknown.

ii) Class B pipes in area 1 have a significantly higher failure rate than the class C pipe, and higher than the overall failure rates of areas 2, 3 and 4.

iii) Area 2 shows a high incidence of corrosion related failures, which account for an increasing proportion of the total failures of older pipes.

iv) Ring fractures which are commonly caused by bending stresses are the predominant type of failure in area 1. Area 2 features a high incidence of longitudinal fractures which are consistent with an effective over-pressurisation of the pipe. Corrosion of the pipe wall may result in a longitudinal fracture as the pipe would lose its ability to withstand internal pressure.

v) The distribution of failures through the year is fairly random for areas 2, 3 and 4 where sandy/gravel soils commonly occur, whereas in area 1, with cohesive clay soils, most of the failures occur during the dry summer months.

This is also reflected in the high failure rate of area 1 during years with hot dry summers.

vi) Although no degradation of the material is reported in area 1, the failure rate increases linearly with age for both class B and class C pipe, suggesting either deterioration of the material properties is occurring or the influence of external factors increases.

vii) In areas 2 and 3 which have aggressive waters, the proportion of failures attributed to corrosion increases with age, with corrosion related failures first occurring at around 20 years. Longitudinal failures which are commonly associated with corrosion follow a similar trend although at a higher rate. Area 4 however, which has a similarly aggressive conveyed water has recorded very few corrosion related failures.

viii) For the four areas examined, the overall non-accidental failure rate of AC is 0.10 failures/km yr, with the highest rate 0.11/km yr. This compares with 0.139 fails/km yr for non-accidental failures of 3" and 4" uPVC mains and 0.14 fails/km yr for cast iron mains in London (Critchley and Habershon 1981).

4. RELATIONSHIP BETWEEN FAILURE DATA AND MAINSLAYING

In the four areas selected for analysis of failure data a majority of the AC mains were laid during the 1950's and 1960's and in later years an increasing proportion of the AC laid has been for larger diameter mains. Thus the mainslaying pattern is similar to the national pattern of use suggesting that the failure trends of each area may be related to other comparable environments without undue distortion due to different age and diameter profiles. However as no information is available on the position of laying variations in the failure rates may occur due to different surface usage.

Analysis of the failure records from Area 1 shows the failure rate to increase linearly with age. The relationship has been determined to be:

$$F = 0.00697A + 0.122 \text{ for class B pipes}$$
$$F = 0.00217A + 0.00225 \text{ for class C pipe}$$

where F = failure rate failures/km yr

A = age years

The reason for this trend is not known, but assuming that it continues, according to the relationships shown above, then at 50 years a failure rate of 0.47 failures/km yr can be anticipated for class B pipe and 0.11 failures/km yr for class C pipe. Or alternatively the national average failure rate of 0.22 failure/km yr (Lackington 1983) will be reached after:

14 years service for class B pipe
100 years service for class C pipe

In areas 2, 3 and 4 (with more aggressive environments of soft conveyed and groundwater) the information on ages was not accurate enough to allow a trend analysis. However, an increasing proportion of the failures after about 20 years service are attributed to corrosion. The cause of the corrosion and whether internal or external corrosion, a combination of the two or some other parameter control the failure rate is currently unknown. 50% of the AC has been laid in soft water areas and Nationally the majority of the AC pipe was laid during the 1950's and 1960's and is thus 15 to 35 years old. With corrosion a time dependent phenomenon and with corrosion related failures reported from about 20 years it is anticipated that corrosion will become an increasing cause of failure, unless steps can be taken to prevent or minimise any further deterioration.

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TABLE 1 - USE OF ASBESTOS CEMENT FOR WATER MAINS

	Population Density	Length of Mains Total*	AC	AC	Population Total*	Served via AC	Served via AC
	/km2	kms	kms	%	000's	000's	%
Water Authorities	357	219,255	22,043	10	37,071	7,444	20
Companies Water	451	68,166	6,884	10	12,508	3,404	27
Scottish Regional Councils	67	42,267	6,624	16	5,020	1,184	24
DoE Northern Ireland	110	17,981	1,991	11	1,562	116	7
TOTAL		347,669	37,542	11	56,161	12,148	22

* Data from references
Water Services Yearbook 1985
Water Services Yearbook 1984
Water Authorities Association 1984
Strathclyde RC Private Communications

TABLE 2 - NATIONAL USAGE OF ASBESTOS CEMENT PIPE AND POPULATION SERVED

Water Authority	Mains Length			Population		
	Total(1)	AC	AC	TOTAL(1)	SERVED BY AC	SERVED BY AC
	km	km	%	1000's	1000's	%
Anglian Water	28,094	5,441	19	3,539	1,295	37
Water Companies within Authority Boundary	10,404	2,931	28	1,982	1,458	74
Total for Anglian	38,498	8,372	22	5,521	2,753	50
Northumbrian Water	8,281(2)	550	7	1,219(2)	340	28
Water Companies within Authority Boundary	7,959	222	3	1,413	182	13
Total for Northumbrian	16,240	772	5	2,632	522	20
North West Water	36,200(3)	3,213	8	6,788	1,737	26
Severn Trent Water	37,044	3,599	10	6,800	870	13
Water Companies within Authority Boundary	6,781	754	11	1,430	254	18
Total for Severn Trent	43,825	4,353	10	8,230	1,124	14

(1) 1985 Water Services Yearbook

(2) 1984 Water Services Yearbook

(3) WAA Water Industry in Figures Nov 1984

TABLE 2 (CONT)

Water Authority	Mains Length			Population		
	Total(1)	AC	AC	TOTAL(4)	SERVED BY AC	SERVED BY AC
	km	km	%	1000's	1000's	%
Southern Water	11,124	343	3	2,018	168	8
Water Companies within Authority Boundary	11,965	764	6	1,837	390	21
Total for Southern	23,089	1,107	5	3,855	558	14
South West Water	13,800(3)	982	7	1,422(3)	461	32
Thames Water	26,691(3)	992	4	7,179(2)	773	11
Water Companies within Authority Boundary	20,009	308	2	3,995	177	4
Total for Thames	46,700(3)	1,300	3	11,174	950	9
Welsh Water	22,320	3,934	18	2,694	840	31
Water Companies within Authority Boundary	1,816	541	30	259	132	51
Total for Welsh	24,136	4,475	19	2,953	972	33

(1) 1985 Water Services Yearbook

(2) 1984 Water Services Yearbook

(3) WAA Water Industry in Figures Nov 1984

TABLE 2 (CONT)

Water Authority	Mains Length			Population		
	Total(1)	AC	AC	TOTAL(1)	SERVED BY AC	SERVED BY AC
	km	km	%	1000's	1000's	%
Wessex Water	9,200	991	11	1,013	329	32
Water Companies within Authority Boundary	8,333	1,358	16	1,421	810	57
Total for Wessex	17,533	2,349	13	2,434	1,139	47
Yorkshire Water	26,501[3]	1,998	8	4,399[2]	631	15
Water Companies within Authority Boundary	899	6	<1	171	1	<1
Total for Yorkshire	27,400	2,004	7	4,570	632	14
DoE Northern Ireland	17,981	1,991	11	1,562	110	7

(1) 1985 Water Services Yearbook

(2) 1984 Water Services Yearbook

(3) WAA Water Industry in Figures Nov 1984

TABLE 2 (CONT)

Water Authority	Mains Length			Population		
	Total(1)	AC	AC	TOTAL(1)	SERVED BY AC	SERVED BY AC
	km	km	%	1000's	1000's	%
Borders RC	1,380	302	22	90	22	24
Central RC	2,249	58	3	379	50	13
Dumfries & Galloway RC	3,029	800	26	135	75	56
Fife RC	2,407(2)	198	8	351	135	38
Grampian RC	4,941	526	11	435	122	28
Highland RC	4,639	1,684	36	187	80	43
Lothian RC	5,336	163	3	738	84	11
Strathclyde RC	13,441(2)	1,150	9	2,280	400	18
Tayside RC	3,855	1,055	28	395	186	47
Western Isles IC	990	688	69	30	30	100

(1) 1985 Water Services Yearbook

(2) Private Communication

TABLE 3 - SUMMARY OF ASBESTOS CEMENT MAINS AND FAILURES DATA

	Area 1	Area 2	Area 3	Area 4
Conveyed water total hardness as $CaCO_3$ mg/l	300	20 - 50	22	28
Groundwater	Hard	Soft	Soft	Soft
Soil type	Cohesive clay	Sand/Gravel	Sand/Gravel	Sand/Gravel
Pipes laid	1938 - 1984	1935 - 1968	1942 - 1982	1935 - 1981
Failure records	1952 - 1984	1979 - 1984	1972 - 1982	1971 - 1982
Total AC length kms	927	492	389	230
Failure rate /km yr	0.11	0.10	0.026	0.047

TABLE 4

Data Summary: Area 1

Total failures (1952 - 1984) = 1571

Length by Diameter

1.5"	-
2"	-
3"	7.4%
4"	48.1%
5"	-
6"	25.1%
7"	-
8"	-
9"	13.2%
10"	-
12"	3.9%
>12"	2.3%

Diameter of Failures

1.5"	-
2"	-
3"	14.5%
4"	74.5%
5"	-
6"	9.5%
7"	-
8"	-
9"	1.2%
10"	-
12"	0.3%
>12"	-

Ground type for Failures

"No information"	0.1%
"Rock"	0.0%
"Sand & Gravel"	0.1%
"Clay"	99.5%
"Silt"	0.0%
"Fill"	0.0%
"Ballast"	0.1%
"Other"	0.3%

Failure Type

"No information"	0.8%
"Long fracture"	1.0%
"Ring fracture"	96.8%
"Ring fracture & ferrule"	0.5%
"Joint"	0.1%
"Blow out"	0.6%
"Ferrule"	0.2%
"Corrosion"	0.0%
"Other"	0.0%

Cause of Failures

"No information"	100.0%
"Accidental"	0.0%
"Surge"	0.0%
"Subsidence"	0.0%
"Corrosion"	0.0%
"Loading"	0.0%
"Other"	0.0%

Position of Failures

"No information"	13.5%
"Carriageway"	0.3%
"Lt Tarmac Road"	7.3%
"Unmade Road"	26.6%
"Verge/Footpath"	50.3%
"Field"	0.6%
"Other"	1.4%

TABLE 5

Data Summary: Area 2

Total failures of pipe >3" (1979 - 1984) = 306

Length by Diameter

1.5"	NA
2"	NA
3"	33.9%
4"	24.1%
5"	9.7%
6"	15.5%
7"	4.1%
8"	1.5%
9"	3.8%
10"	0.7%
12"	2.8%
15"	3.7%

Diameter of Failures

1.5"	NA
2"	NA
3"	47.7%
4"	37.6%
5"	10.5%
6"	1.0%
7"	2.3%
8"	0.7%
9"	0.3%
10"	0.0%
12"	0.3%
15"	0.0%

Ground type for Failures

"No information"	0.3%
"Rock"	1.3%
"Sand & Gravel"	45.0%
"Clay"	50.3%
"Silt"	0.0%
"Fill"	0.0%
"Ballast"	0.3%
"Other"	2.6%

Failure Type

"No information"	0.3%
"Long fracture"	66.3%
"Ring fracture"	10.1%
"Ring fracture & ferrule"	2.0%
"Joint"	12.1%
"Blow out"	0.7%
"Ferrule"	0.0%
"Corrosion"	1.6%
"Other"	6.9%

Cause of Failures

"No information"	8.2%
"Accidental"	0.0%
"Surge"	23.5%
"Subsidence"	14.7%
"Corrosion"	34.6%
"Loading"	1.6%
"Other"	17.3%

Position of Failures

"No information"	0.7%
"Carriageway"	16.3%
"Lt Tarmac Road"	4.2%
"Unmade Road"	0.0%
"Verge/Footpath"	69.9%
"Field"	8.2%
"Other"	0.7%

TABLE 6

Data Summary: Area 3

Total failures >2" (1971 - 1982) = 108

Length by Diameter

1.5"	NA
2"	NA
3"	40.9%
4"	26.6%
5"	1.1%
6"	21.3%
7"	3.0%
8"	-
9"	5.4%
10"	-
12"	1.7%
>12"	-

Diameter of Failures

1.5"	NA
2"	NA
3"	66.8%
4"	10.6%
5"	0.7%
6"	7.5%
7"	2.7%
8"	-
9"	8.6%
10"	-
12"	2.7%
>12"	-

Ground type for Failures

"No information"	12.8%
"Rock"	4.5%
"Sand & Gravel"	23.1%
"Clay"	47.5%
"Silt"	0.0%
"Fill"	1.9%
"Ballast"	1.9%
"Other"	8.3%

Failure Type

"No information"	3.8%
"Long fracture"	34.6%
"Ring fracture"	20.5%
"Ring fracture & ferrule"	0.0%
"Joint"	19.9%
"Blow out"	4.5%
"Ferrule"	0.7%
"Corrosion"	1.3%
"Other"	14.7%

Cause of Failures

"No information"	25.0%
"Accidental"	0.0%
"Surge"	13.5%
"Subsidence"	9.0%
"Corrosion"	12.2%
"Loading"	14.1%
"Other"	26.2%

Position of Failures

"No information"	62.8%
"Carriageway"	3.8%
"Lt Tarmac Road"	3.2%
"Unmade Road"	0.0%
"Verge/Footpath"	18.0%
"Field"	10.3%
"Other"	1.9%

TABLE 7

Data Summary: Area 4

Total failures >2" (1971 - 1982) = 135

Length by Diameter

1.5"	-
2"	9.9%
3"	20.1%
4"	35.9%
5"	0.6%
6"	22.9%
7"	0.9%
8"	-
9"	7.4%
10"	1.3%
12"	1.1%
>12"	-

Diameter of Failures

1.5"	-
2"	7.2%
3"	29.3%
4"	35.7%
5"	0.0%
6"	22.1%
7"	0.0%
8"	-
9"	4.3%
10"	1.4%
12"	0.0%
>12"	-

Ground type for Failures

"No information"	0.7%
"Rock"	7.9%
"Sand & Gravel"	38.6%
"Clay"	45.0%
"Silt"	0.0%
"Fill"	5.0%
"Ballast"	0.0%
"Other"	2.8%

Failure Type

"No information"	0.7%
"Long fracture"	4.3%
"Ring fracture"	70.0%
"Ring fracture & ferrule"	0.0%
"Joint"	12.9%
"Blow out"	2.9%
"Ferrule"	0.0%
"Corrosion"	0.7%
"Other"	8.5%

Cause of Failures

"No information"	49.3%
"Accidental"	0.0%
"Surge"	0.0%
"Subsidence"	23.6%
"Corrosion"	0.7%
"Loading"	13.6%
"Other"	12.8%

Position of Failures

"No information"	40.7%
"Carriageway"	11.4%
"Lt Tarmac Road"	2.1%
"Unmade Road"	0.7%
"Verge/Footpath"	35.7%
"Field"	8.6%
"Other"	0.7%

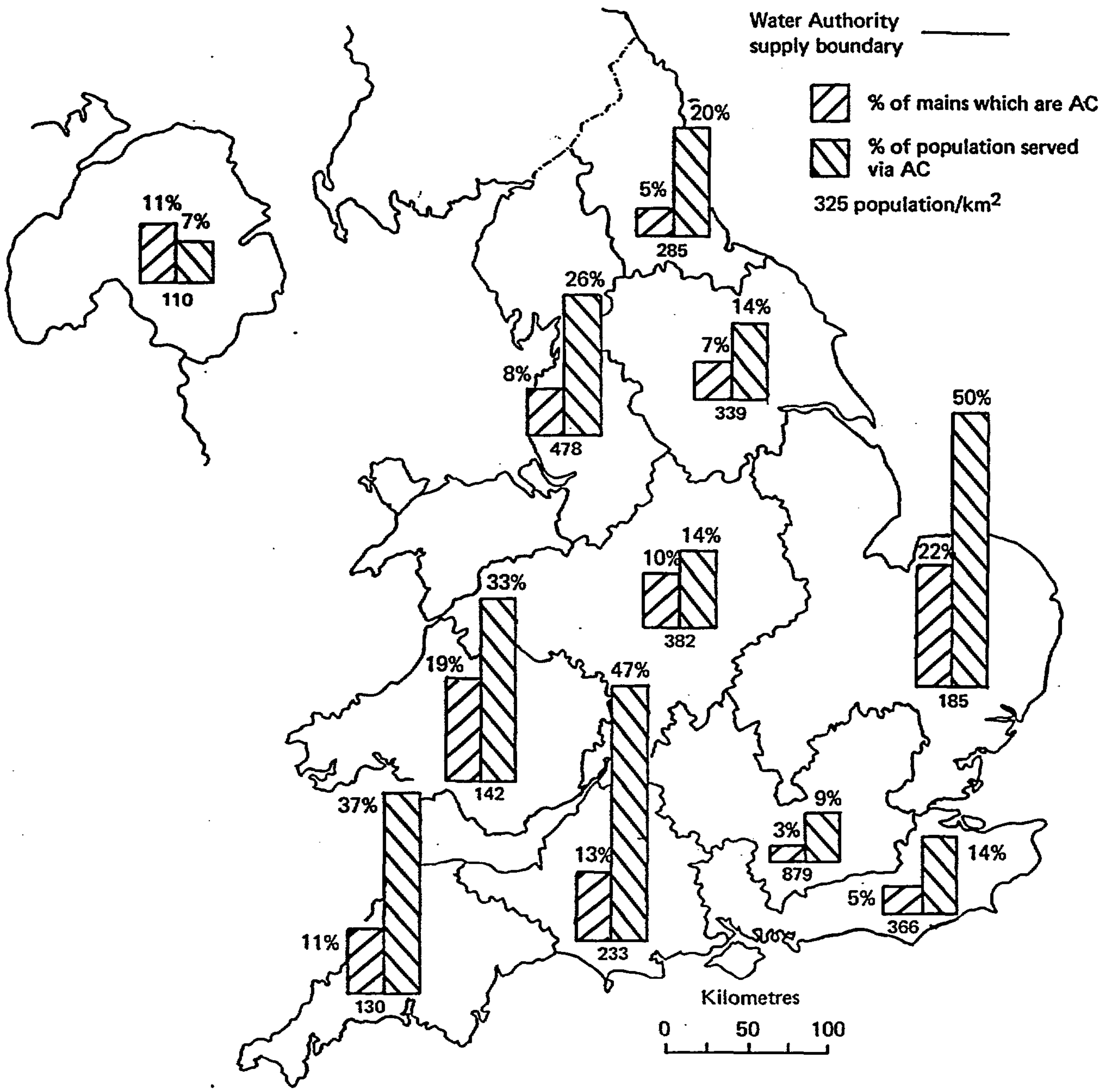


Figure 1A National distribution of asbestos cement pressure pipe and population served — England, Wales and N. Ireland

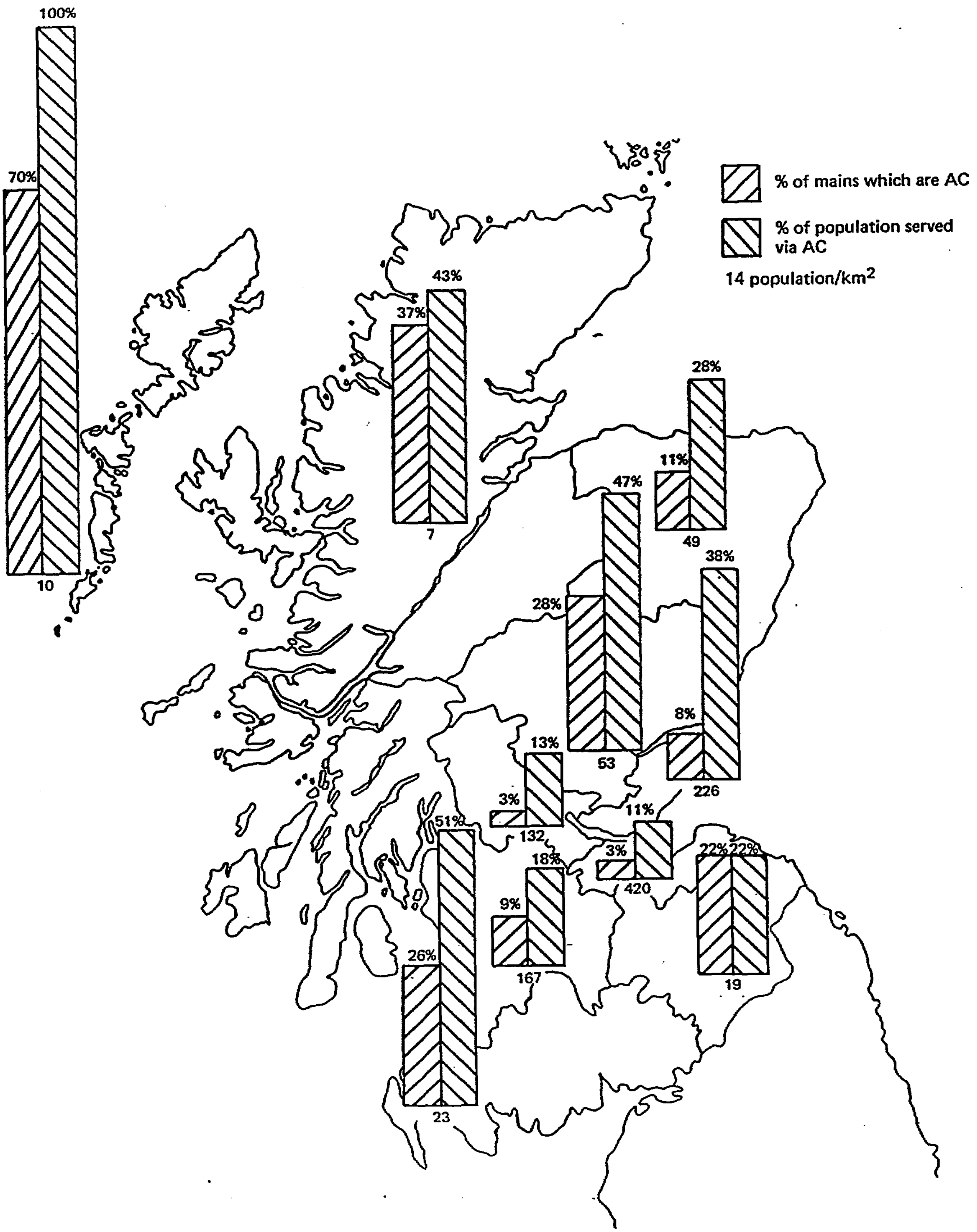


Figure 1B National distribution of asbestos cement pressure pipe and population served – Scotland

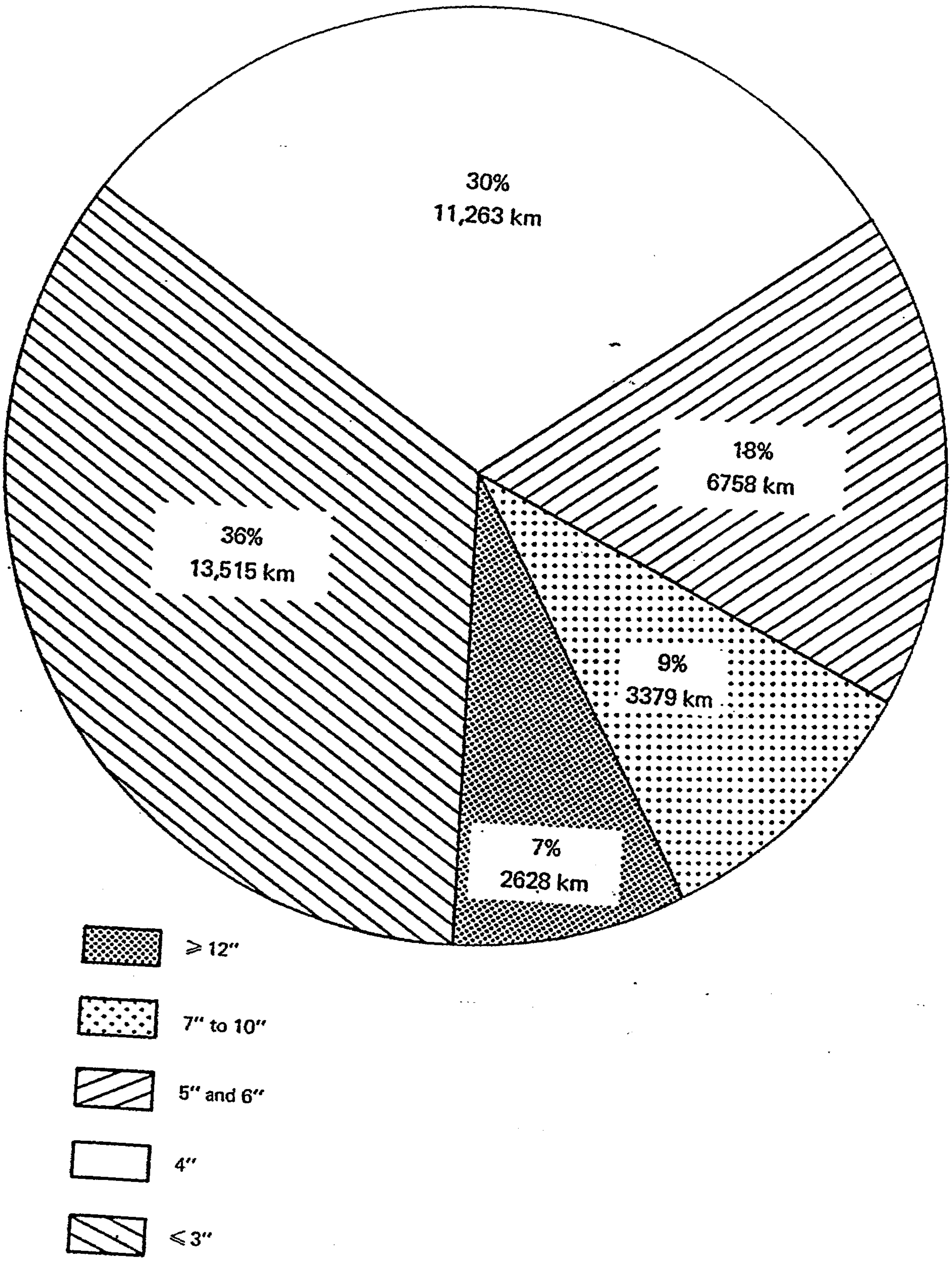


Figure 2 National usage of asbestos cement by diameter

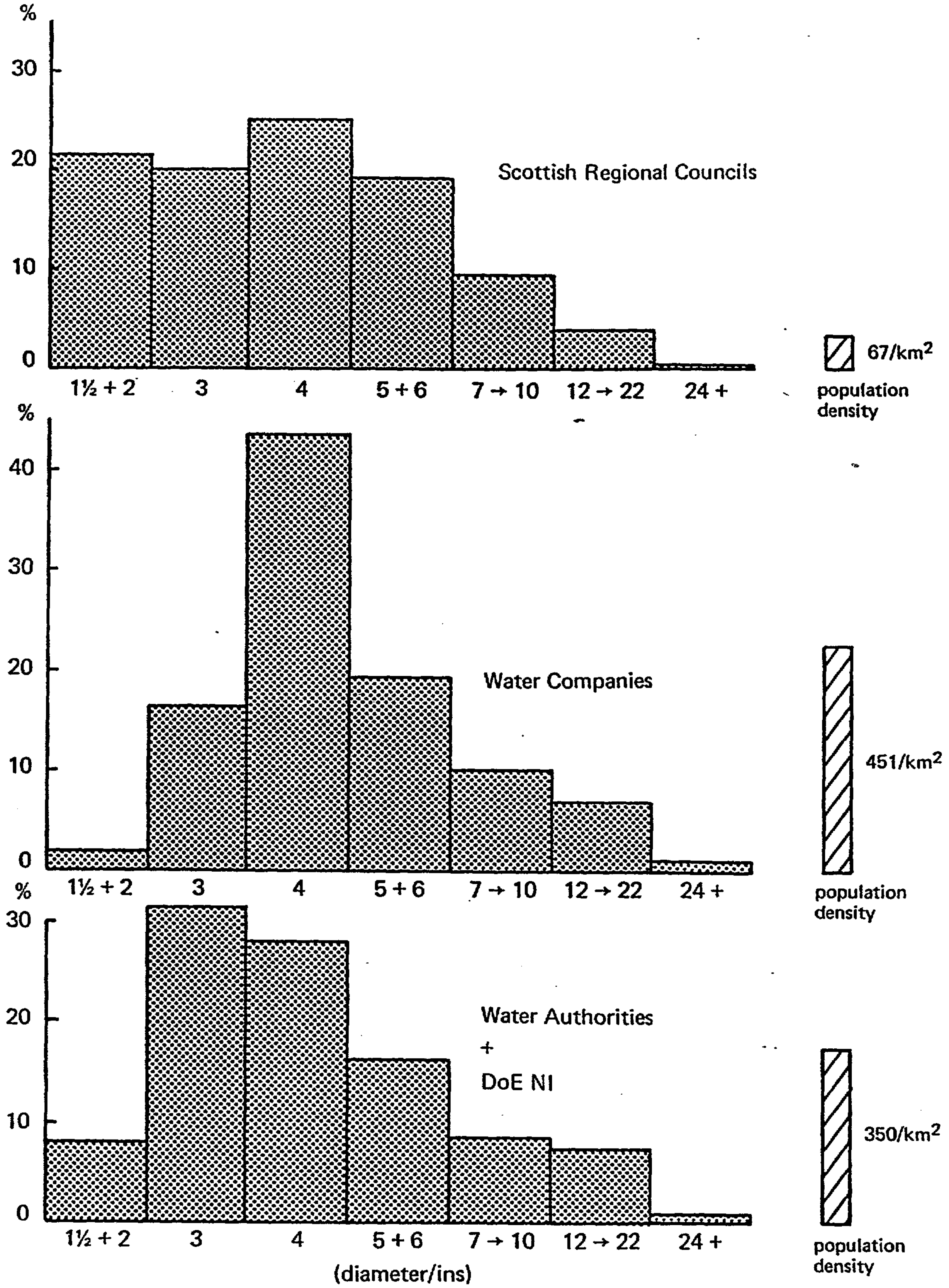


Figure 3 Comparison of diameter use between Water Authorities, Water Companies and Scottish Regional Councils

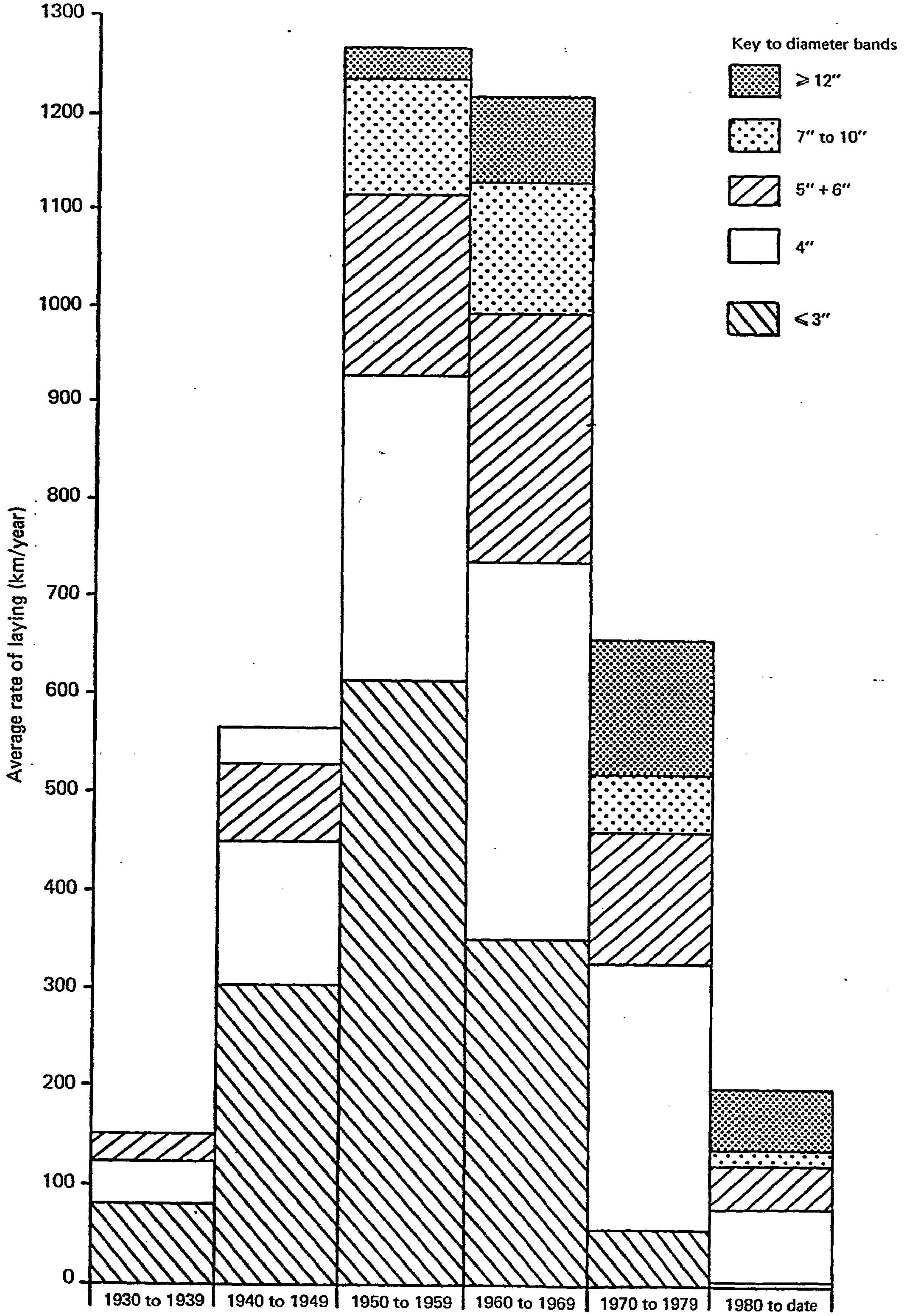


Figure 4 Asbestos cement water mains — annual rate of laying by diameter band against period of laying

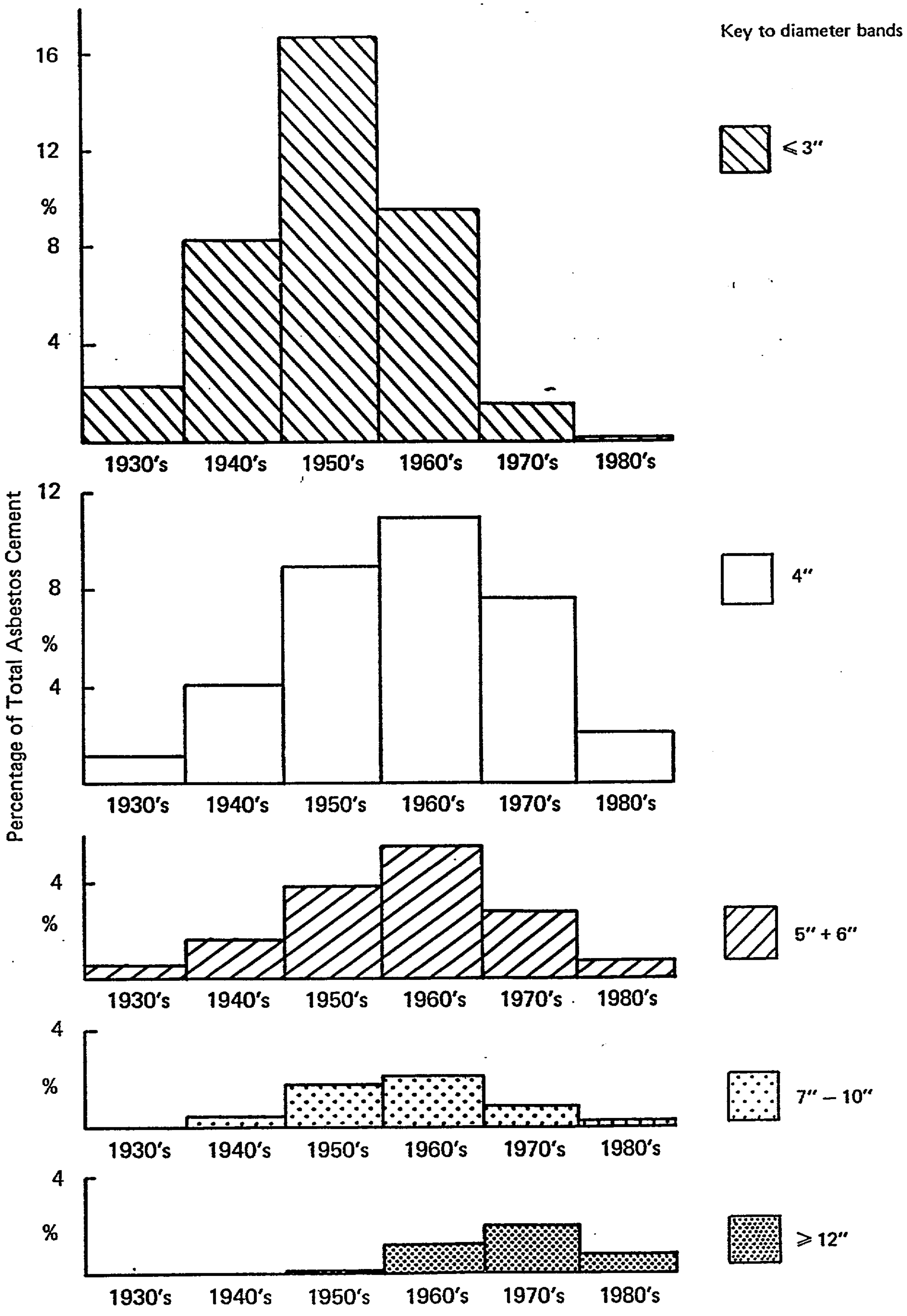


Figure 5 Percentage of total asbestos cement laid for each diameter band

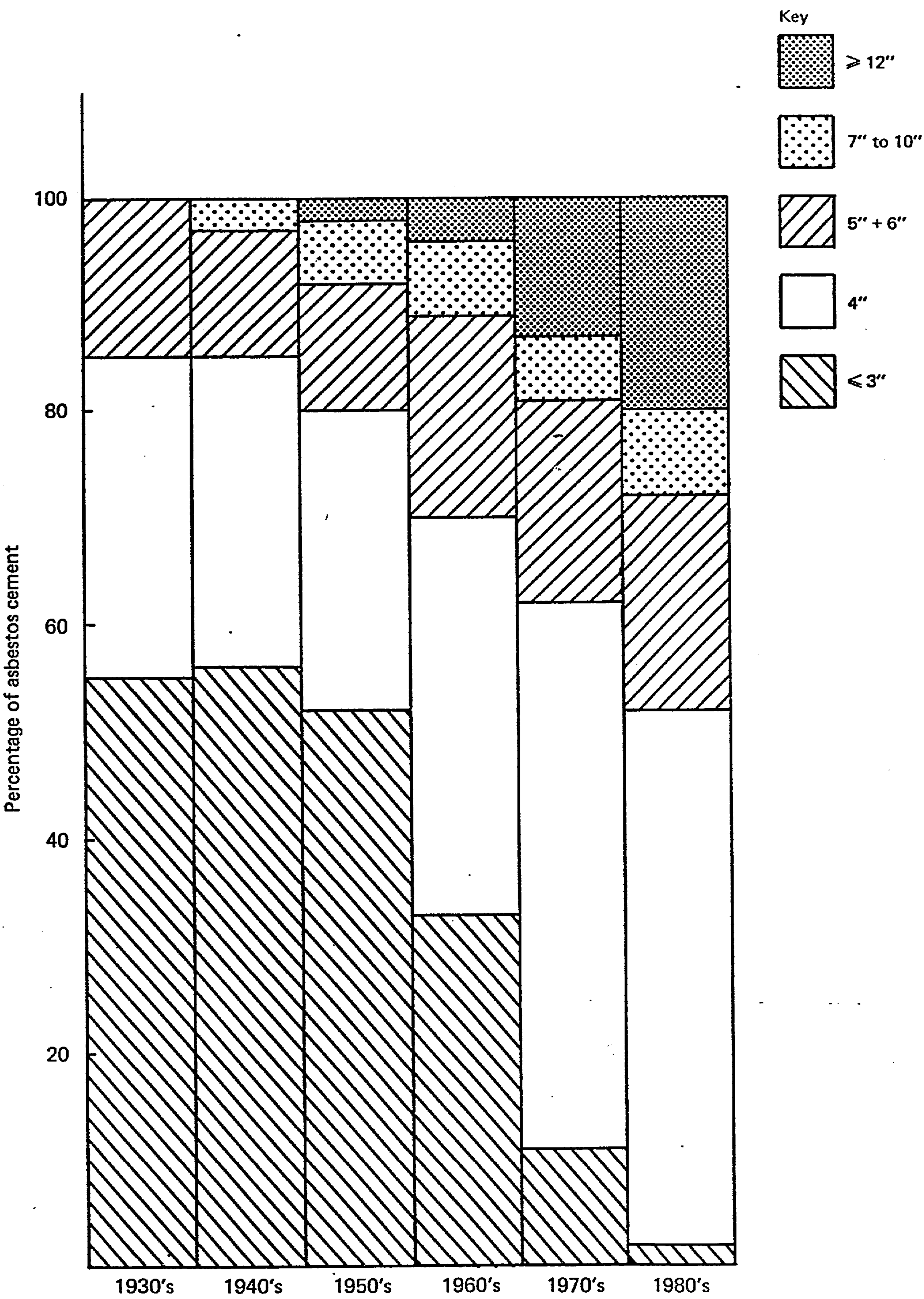


Figure 6 Proportion of asbestos cement mains laid in each diameter band

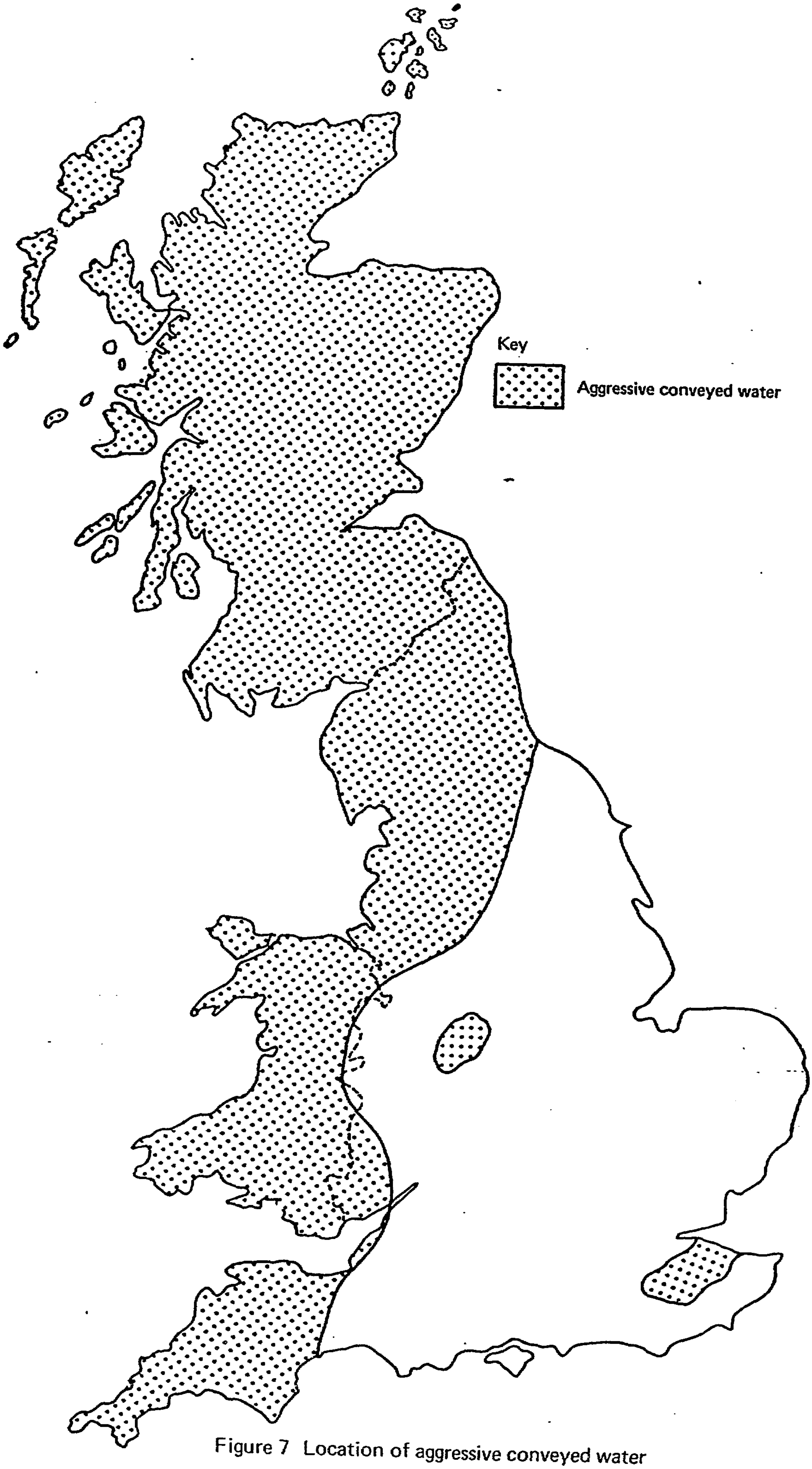


Figure 7 Location of aggressive conveyed water

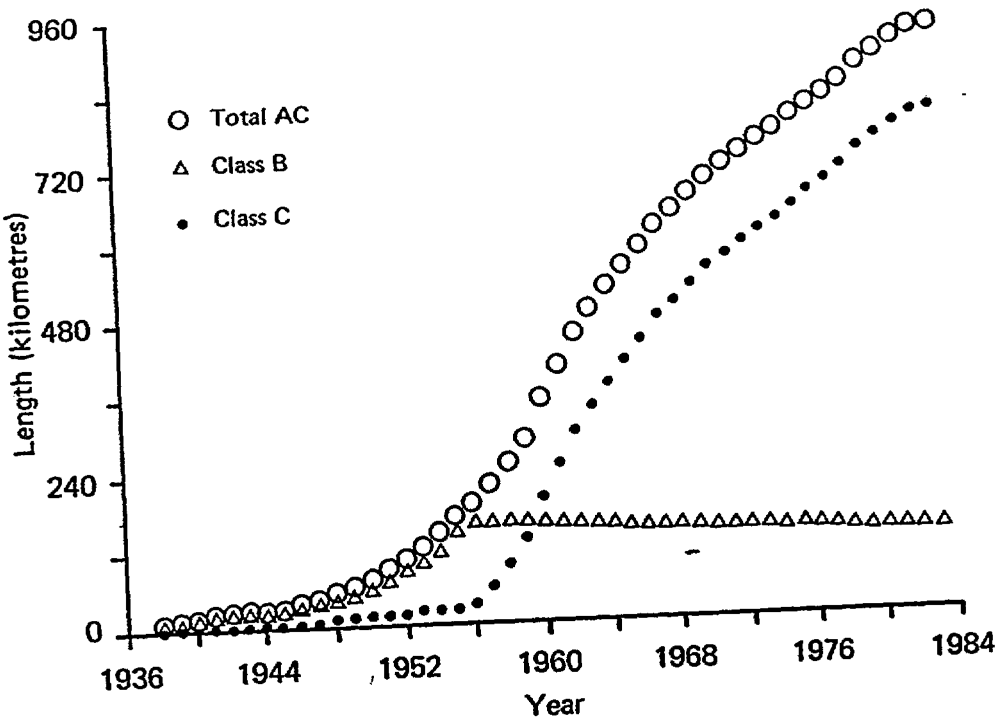


Figure 8A Area 1 — Length of AC pipe (kilometres)

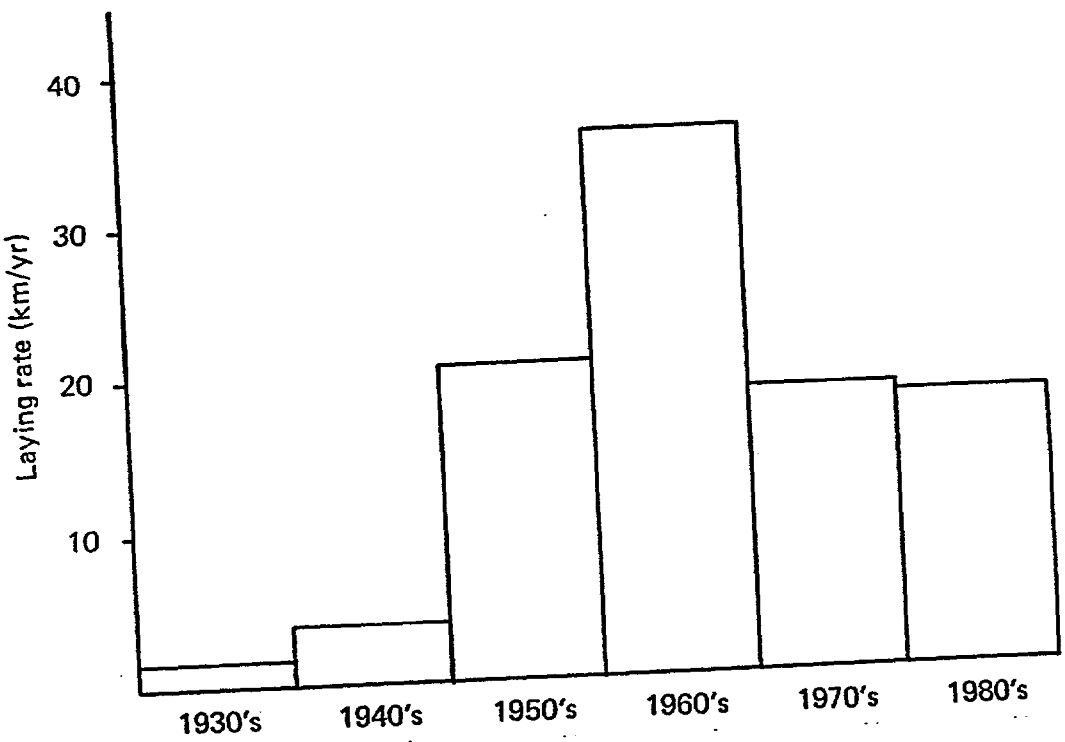


Figure 8B Area 1 — Rate of laying asbestos cement

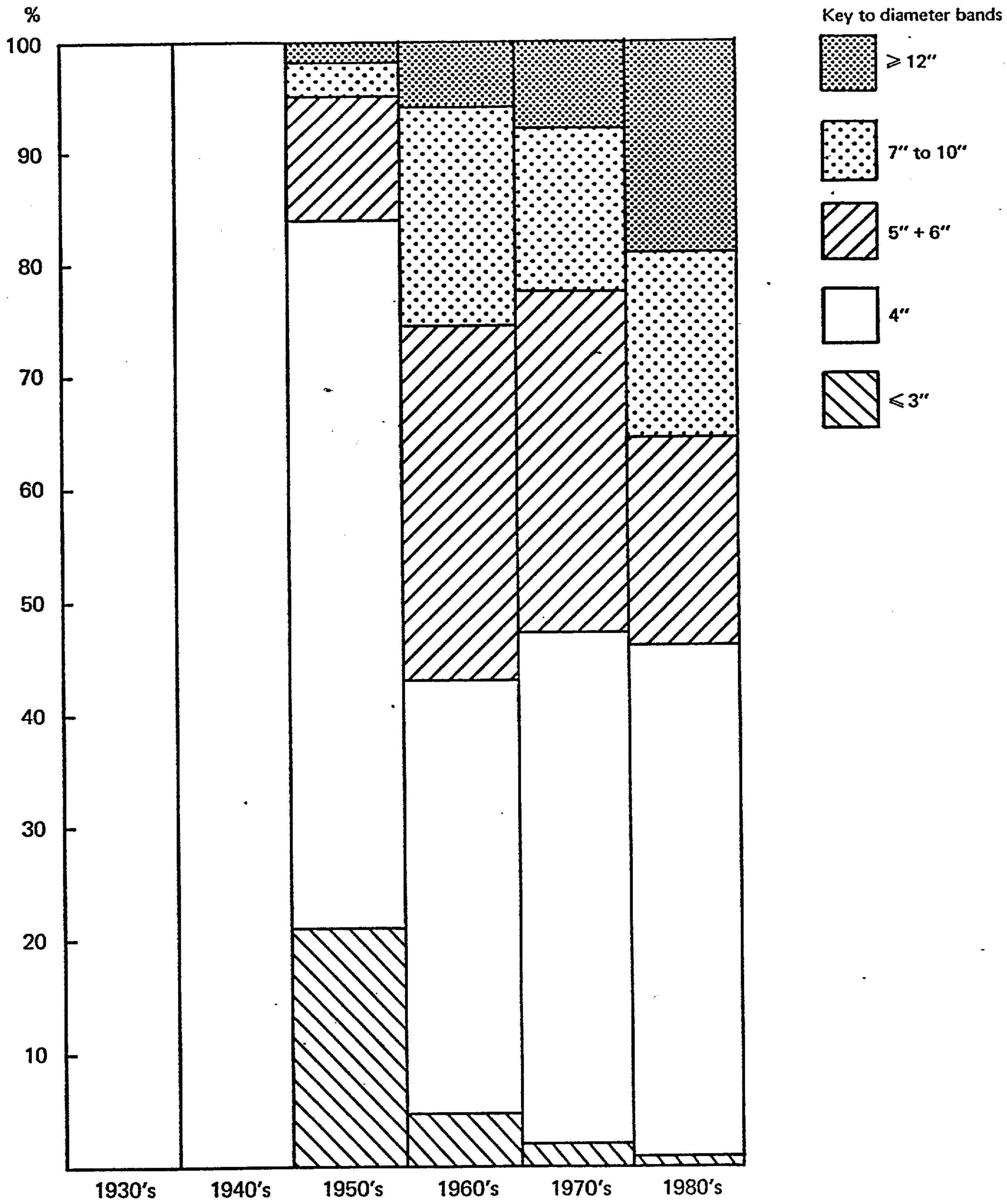


Figure 9 Diameter breakdown of asbestos cement mains laying in Area 1

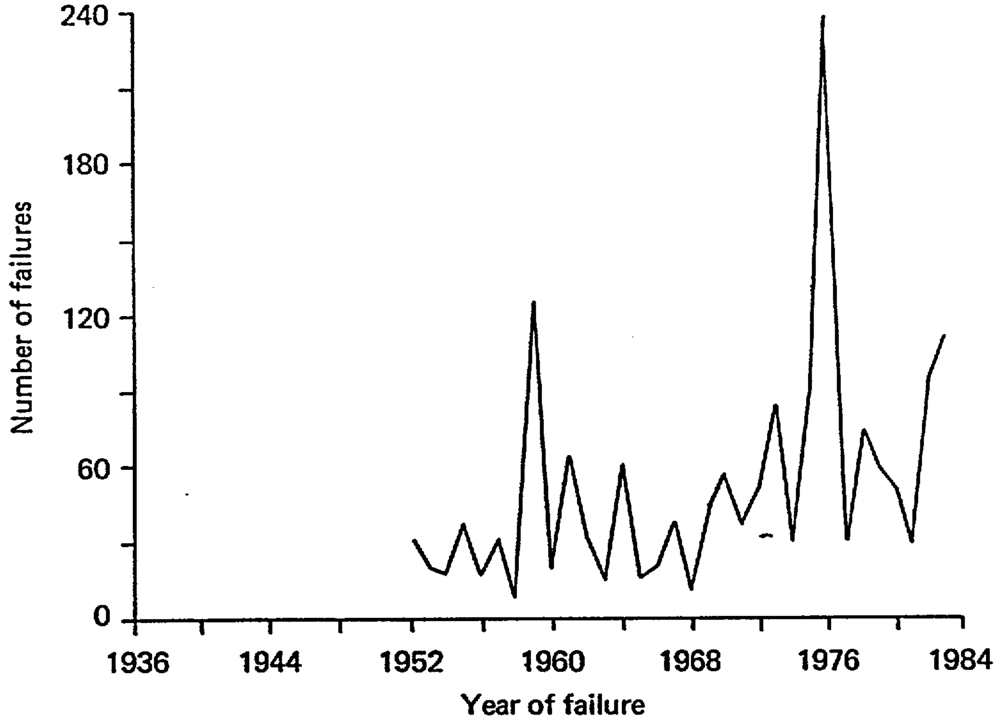


Figure 10A Area 1 — Number of failures versus year

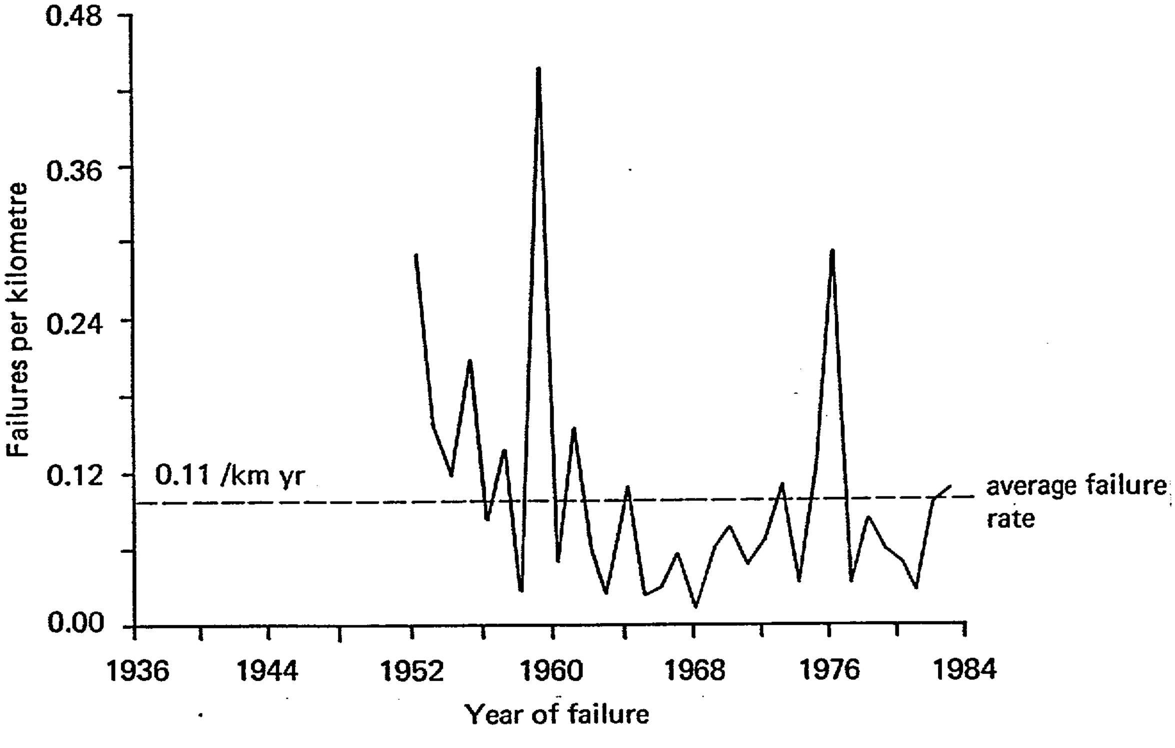


Figure 10B Area-1 — Failures per kilometre versus year

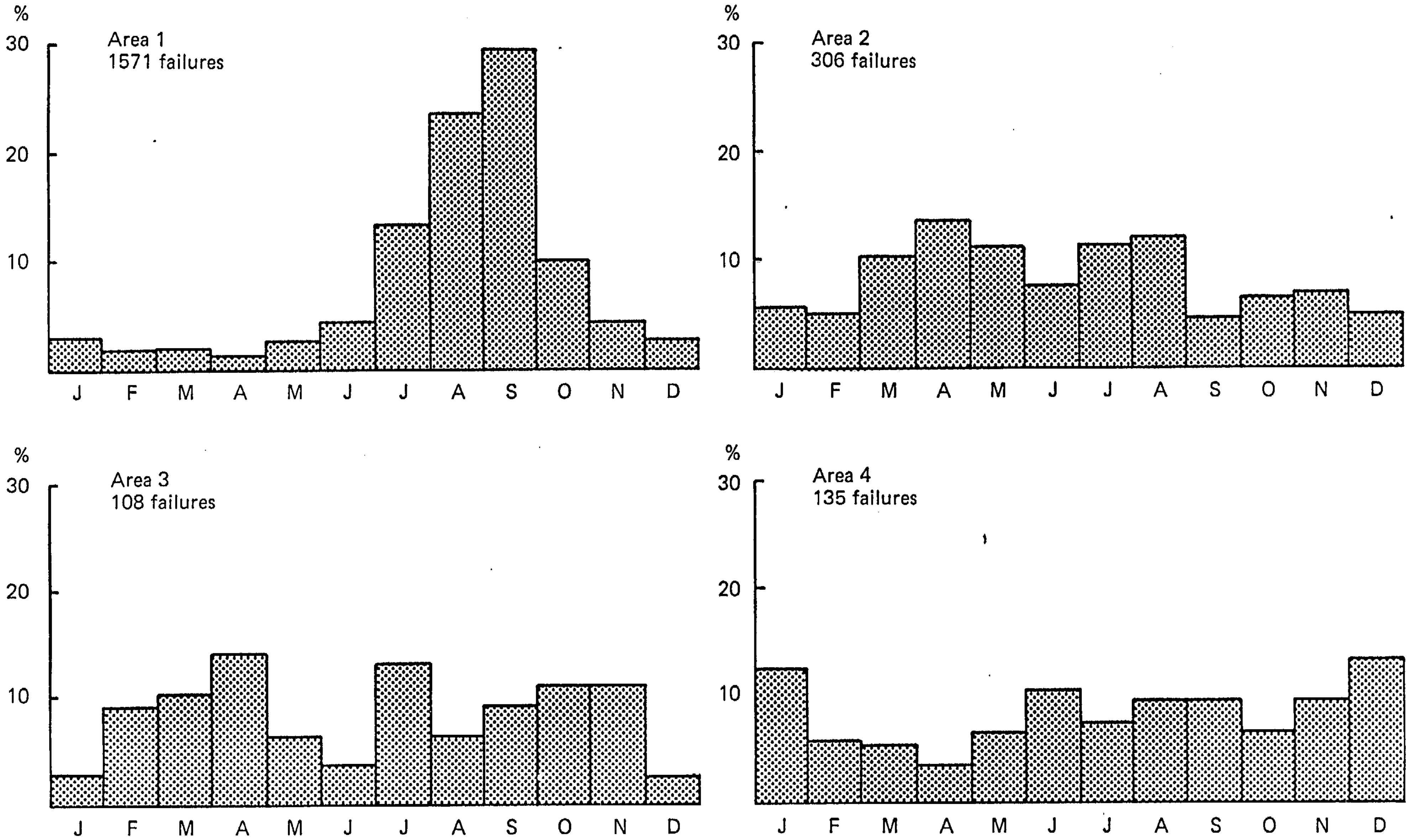
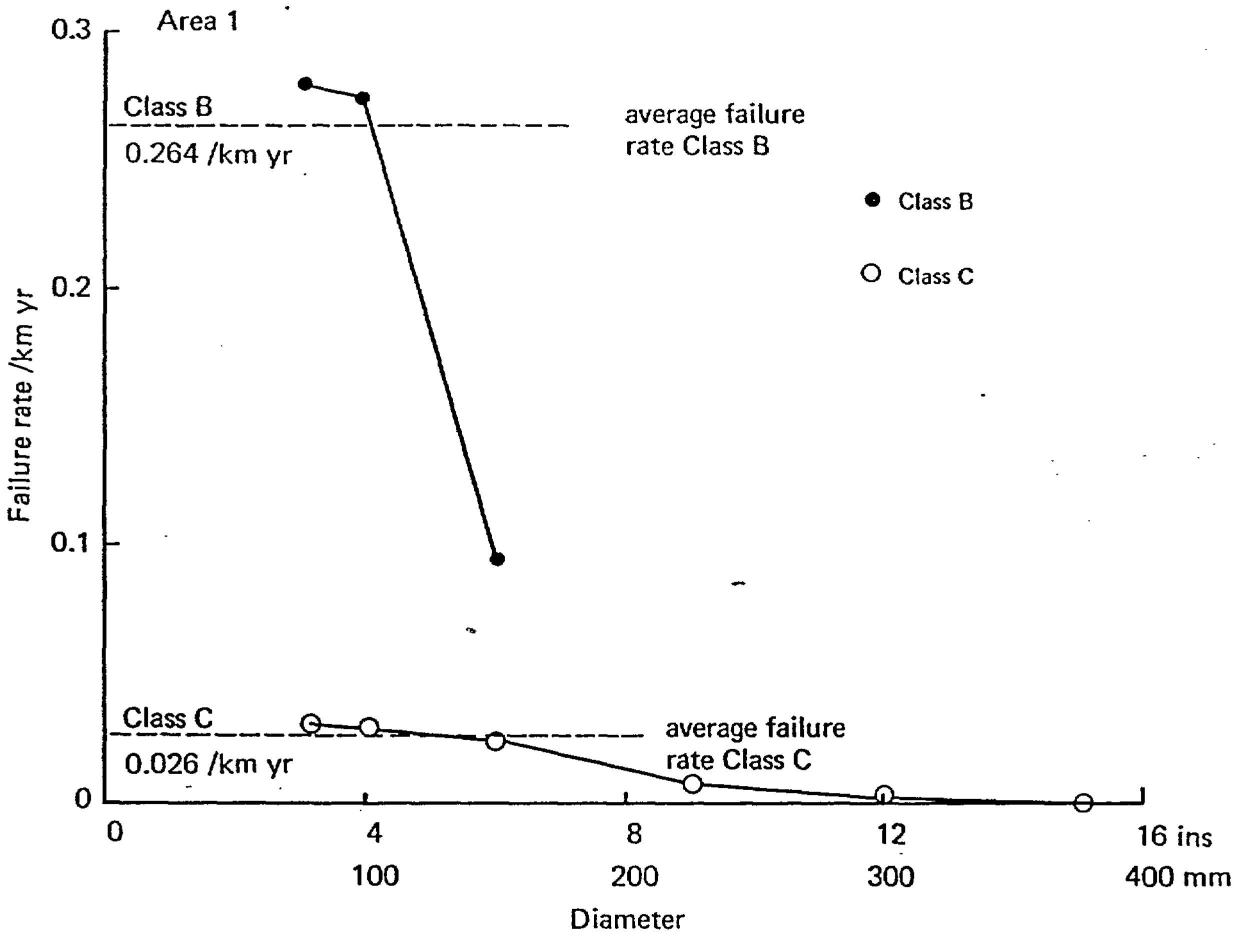


Figure 11 Occurrence of asbestos cement pipe failures throughout the year



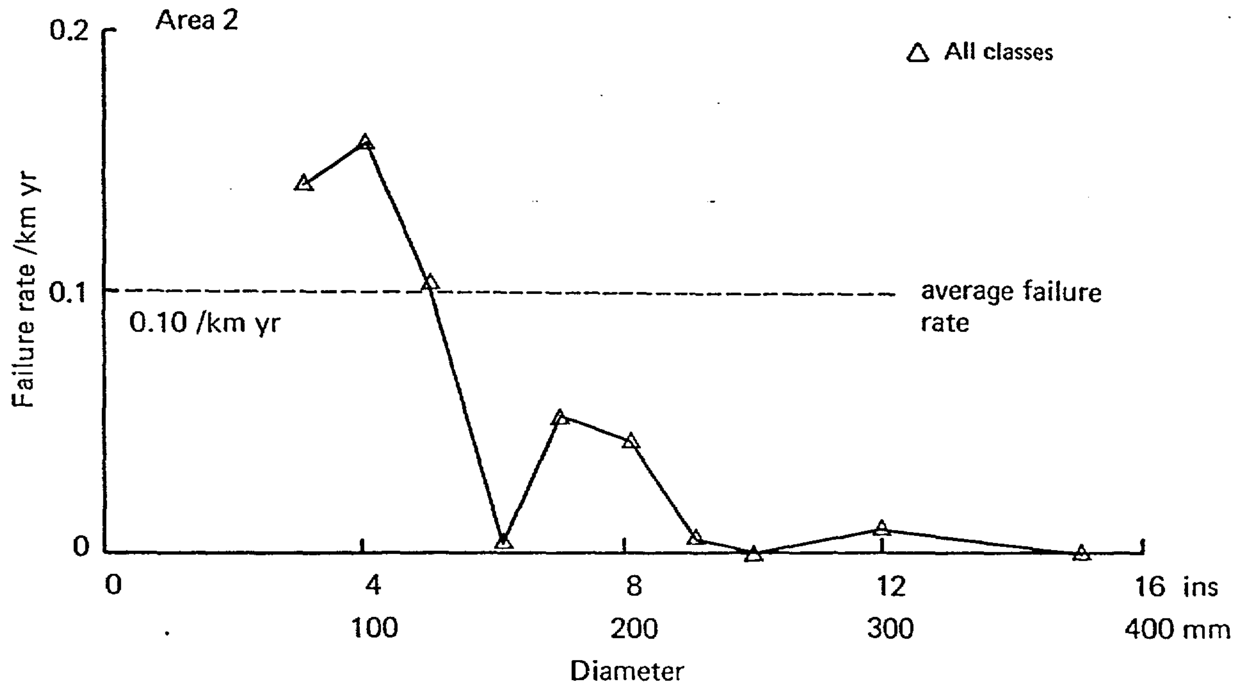


Figure 12 Failure rate against diameter

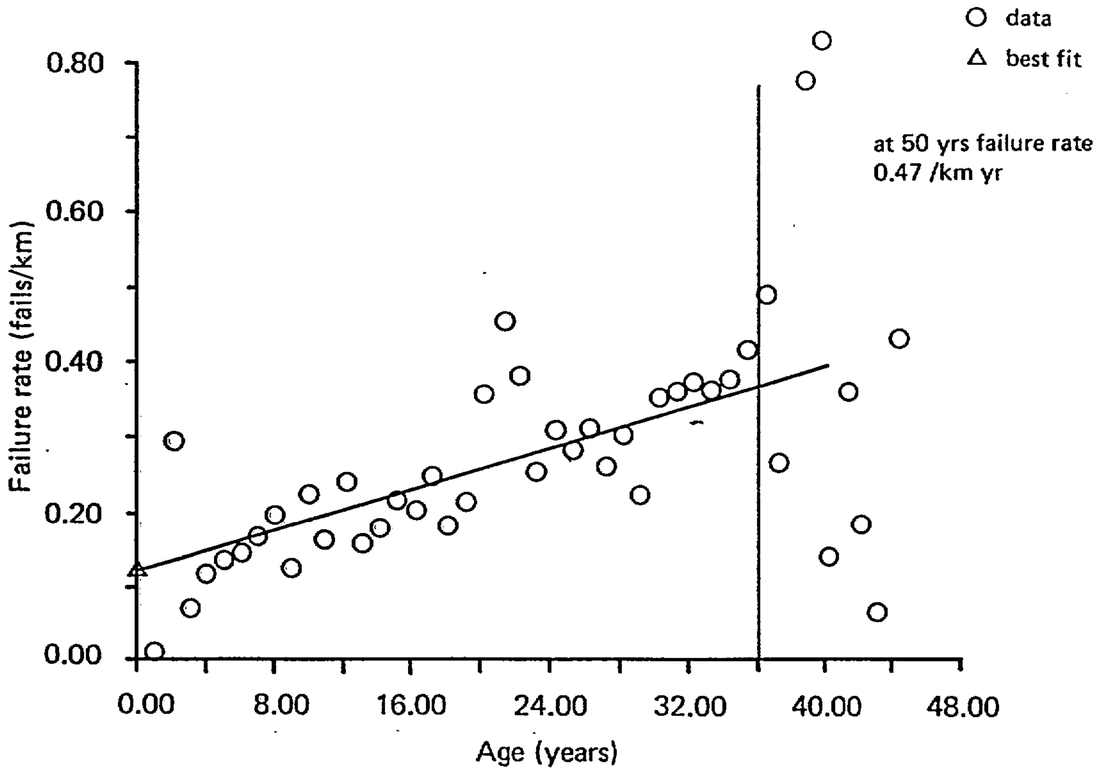


Figure 13 Area 1 — Failure rate against age for Class B pipe

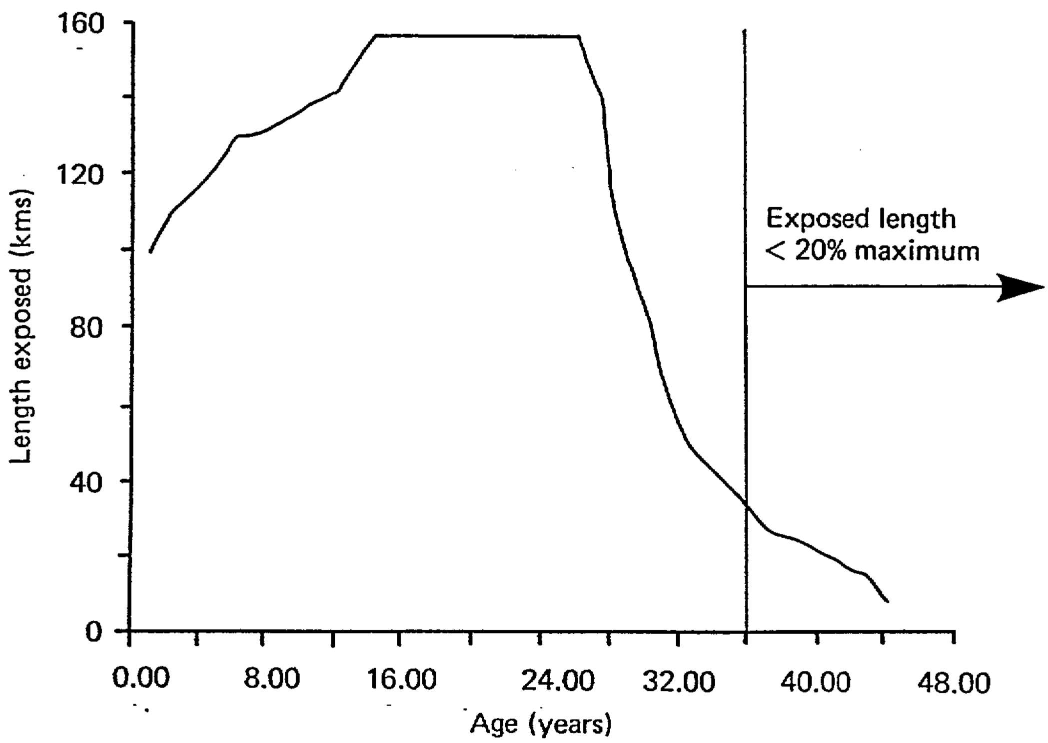


Figure 13 Area 1 — Class B — length exposed

FIGURE 13A AREA 1 - FAILURE RATE AGAINST AGE FOR 4" CLASS B

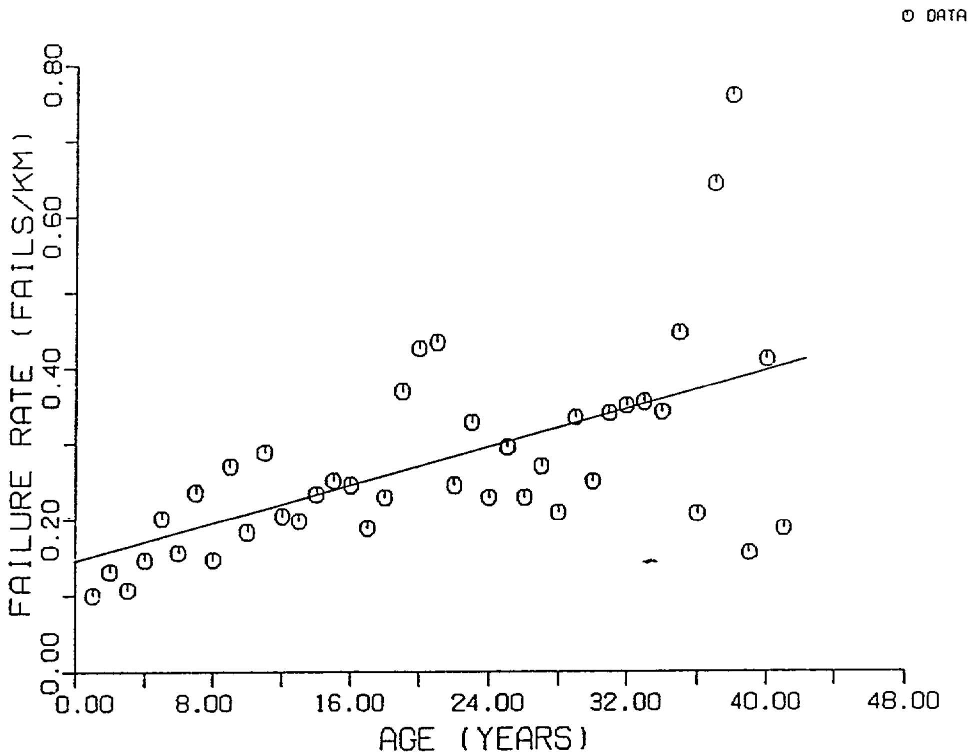
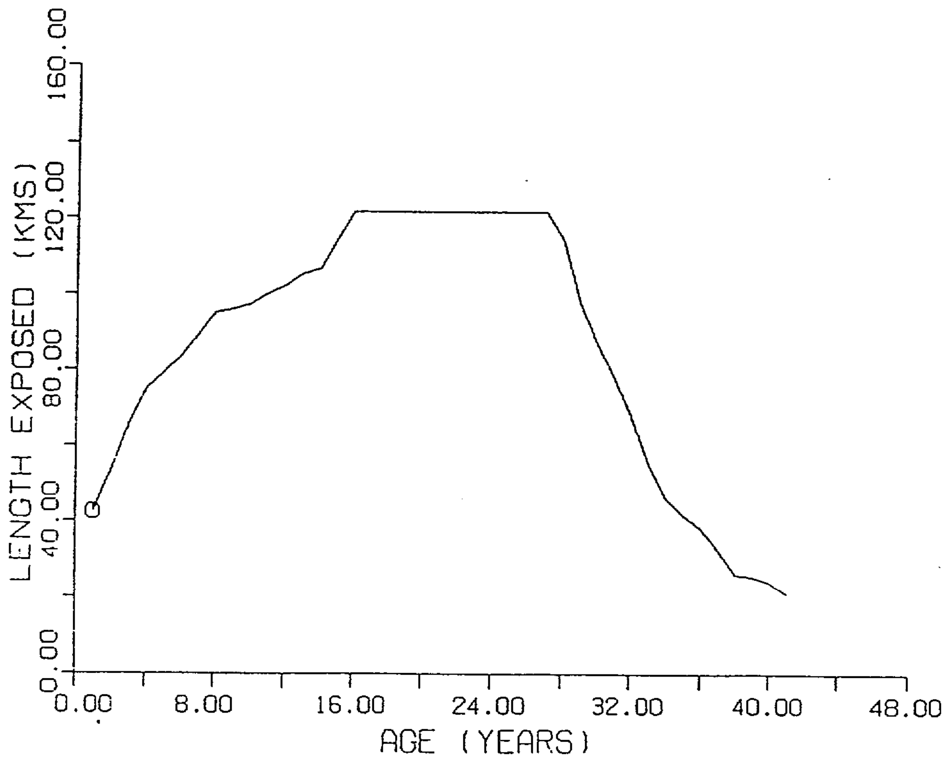


FIGURE 13A AREA 1 - 4" CLASS B - LENGTH EXPOSED



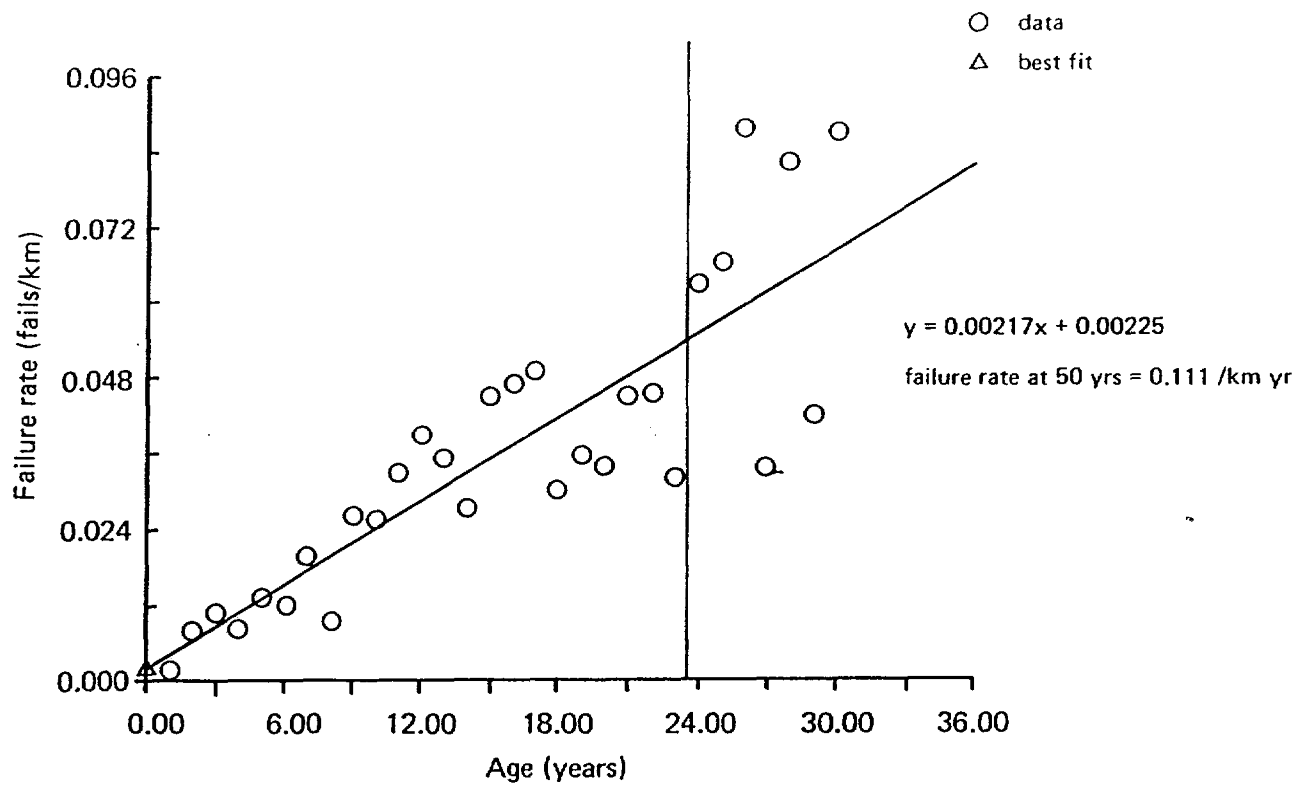


Figure 14 Area 1 – Failure rate against age for Class C pipe

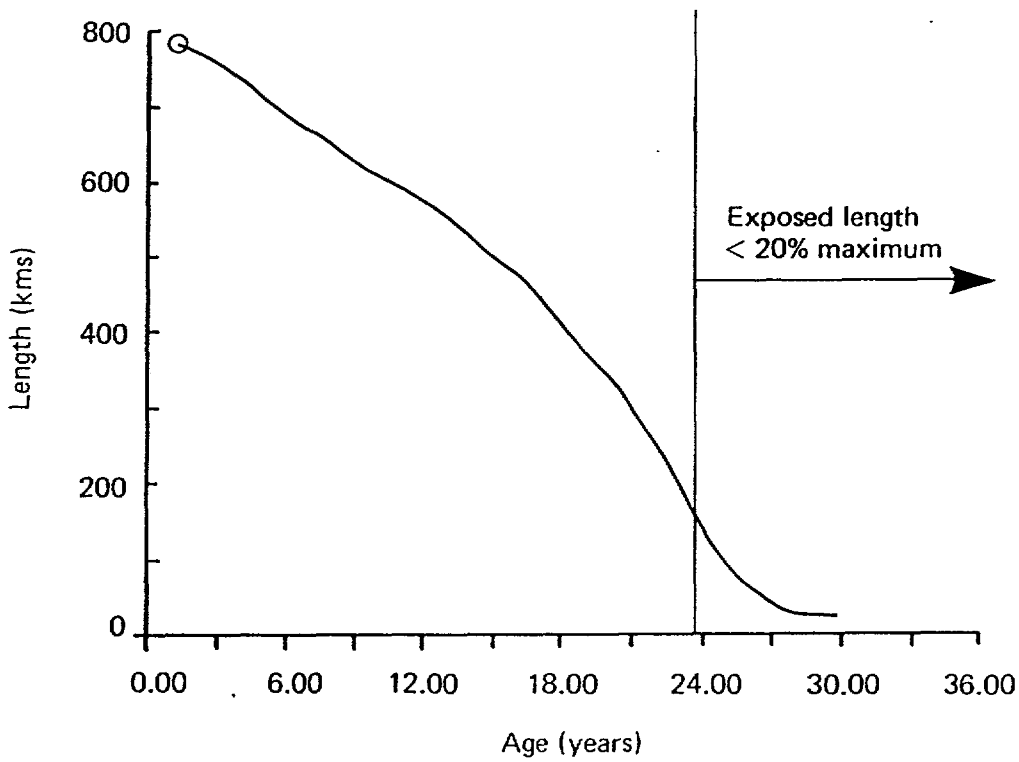


Figure 14 Area 1 – Class C – length exposed

FIGURE 14A AREA 1 - FAILURE RATE AGAINST AGE FOR 4" CLASS C

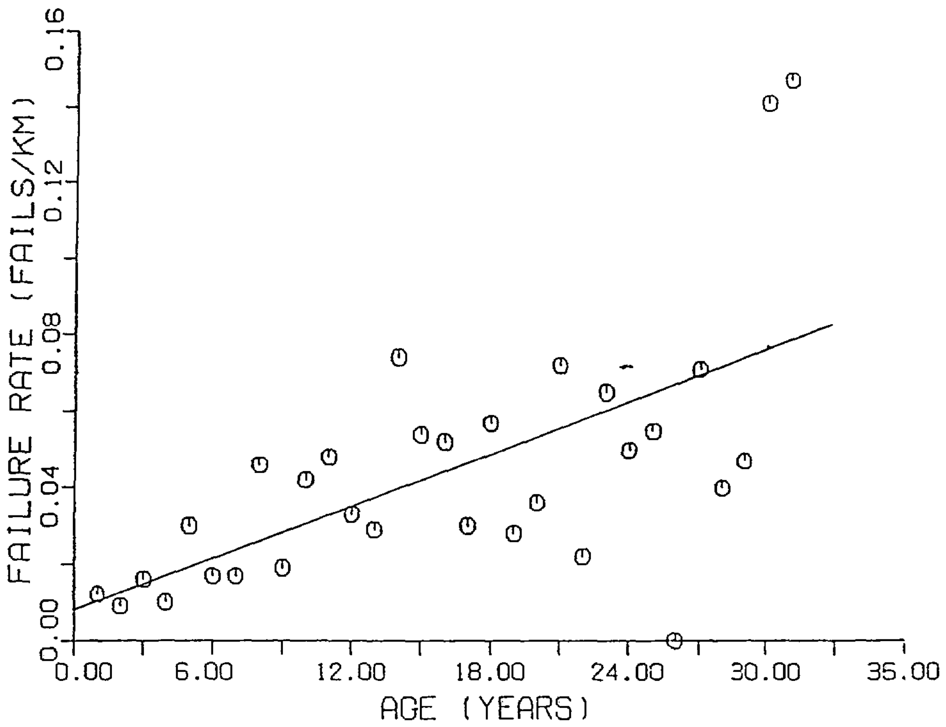
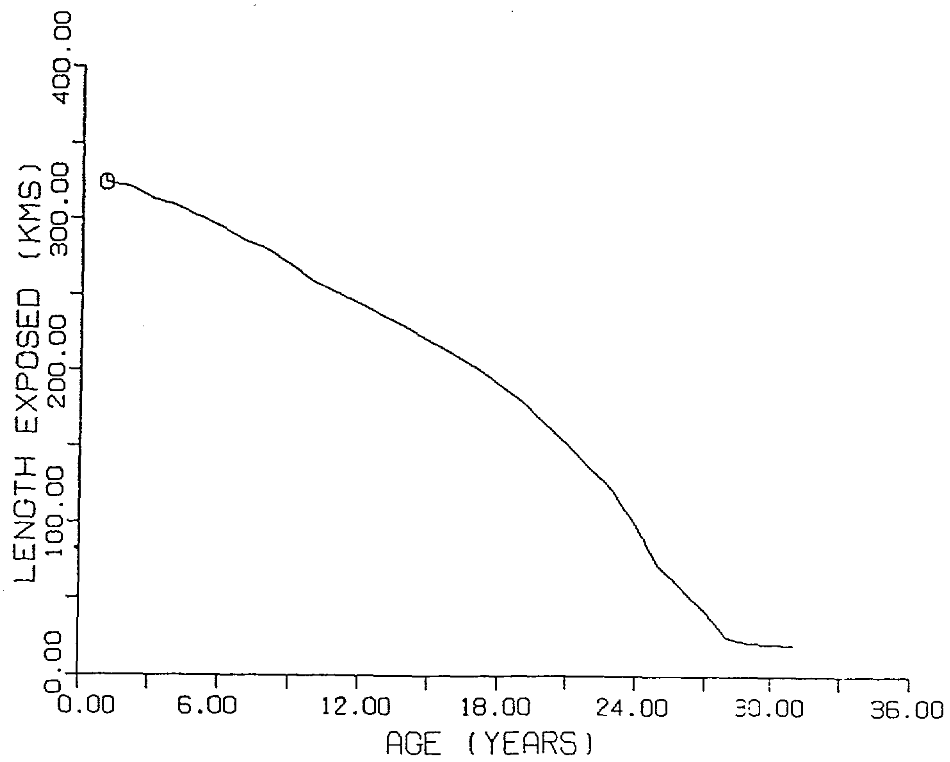


FIGURE 14A AREA 1 - 4" CLASS C - LENGTH EXPOSED



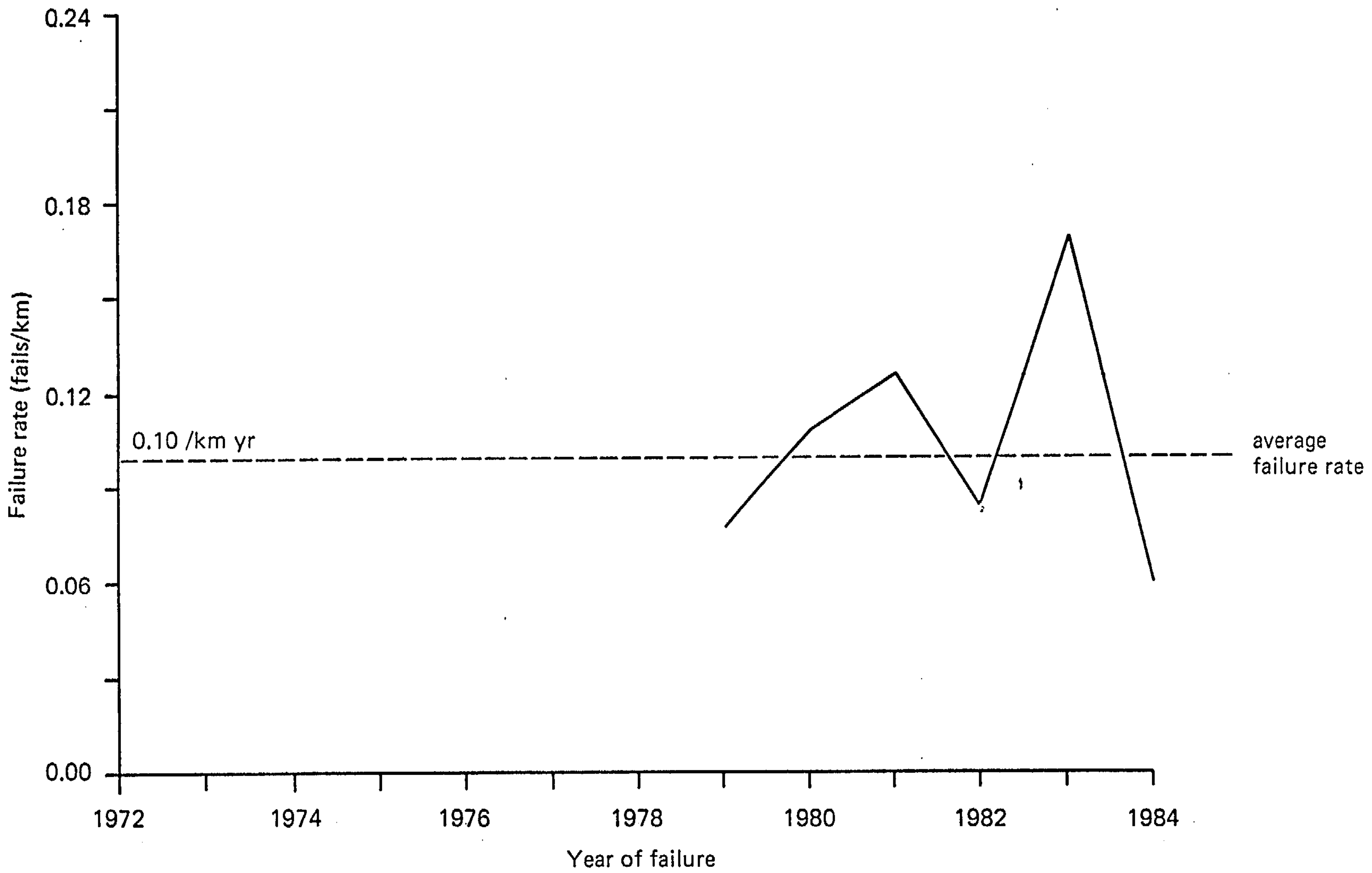


Figure 15 Area 2 – Failure rate versus year for ≥ 3″ diameter

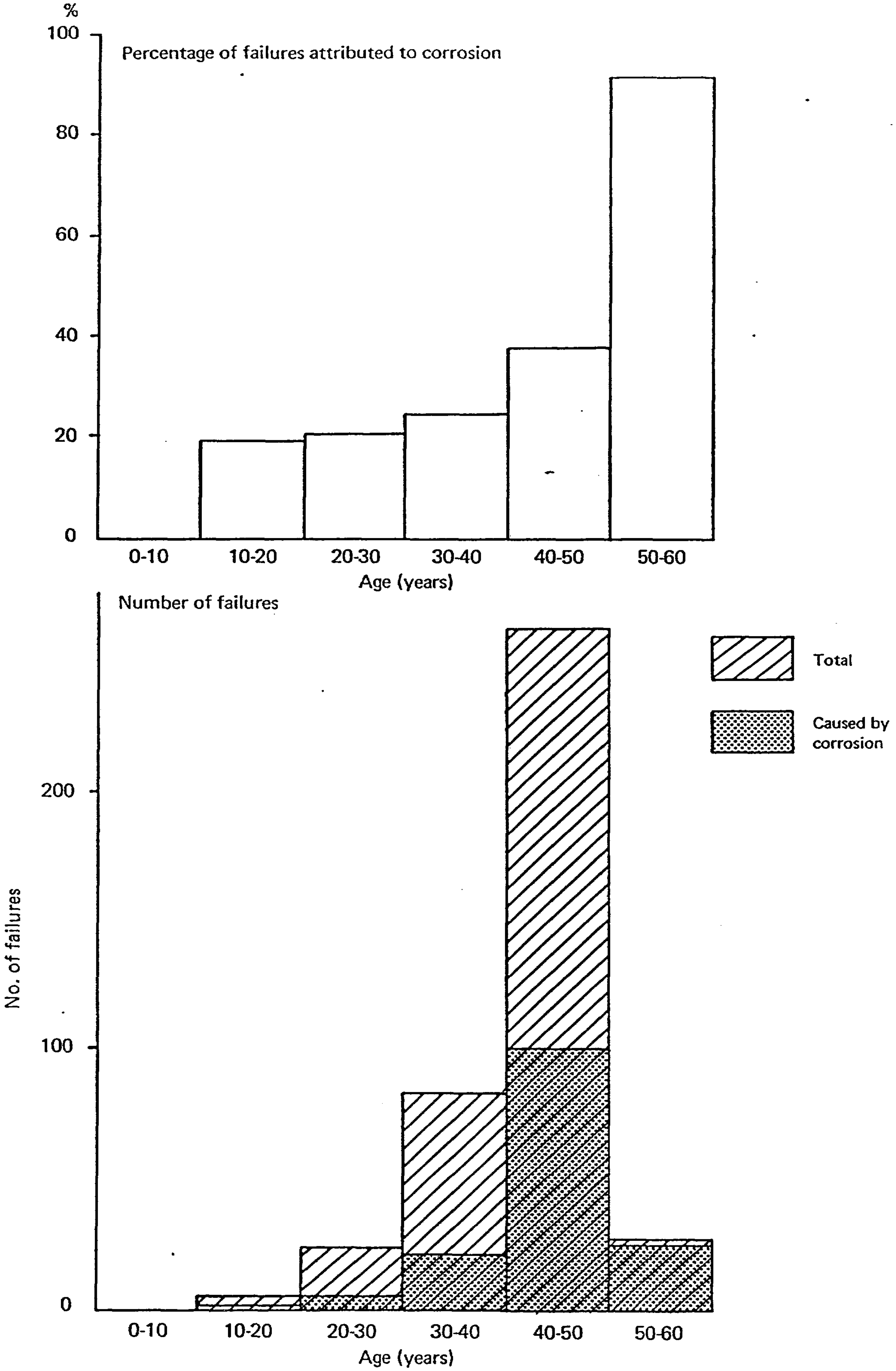


Figure 16 Area 2

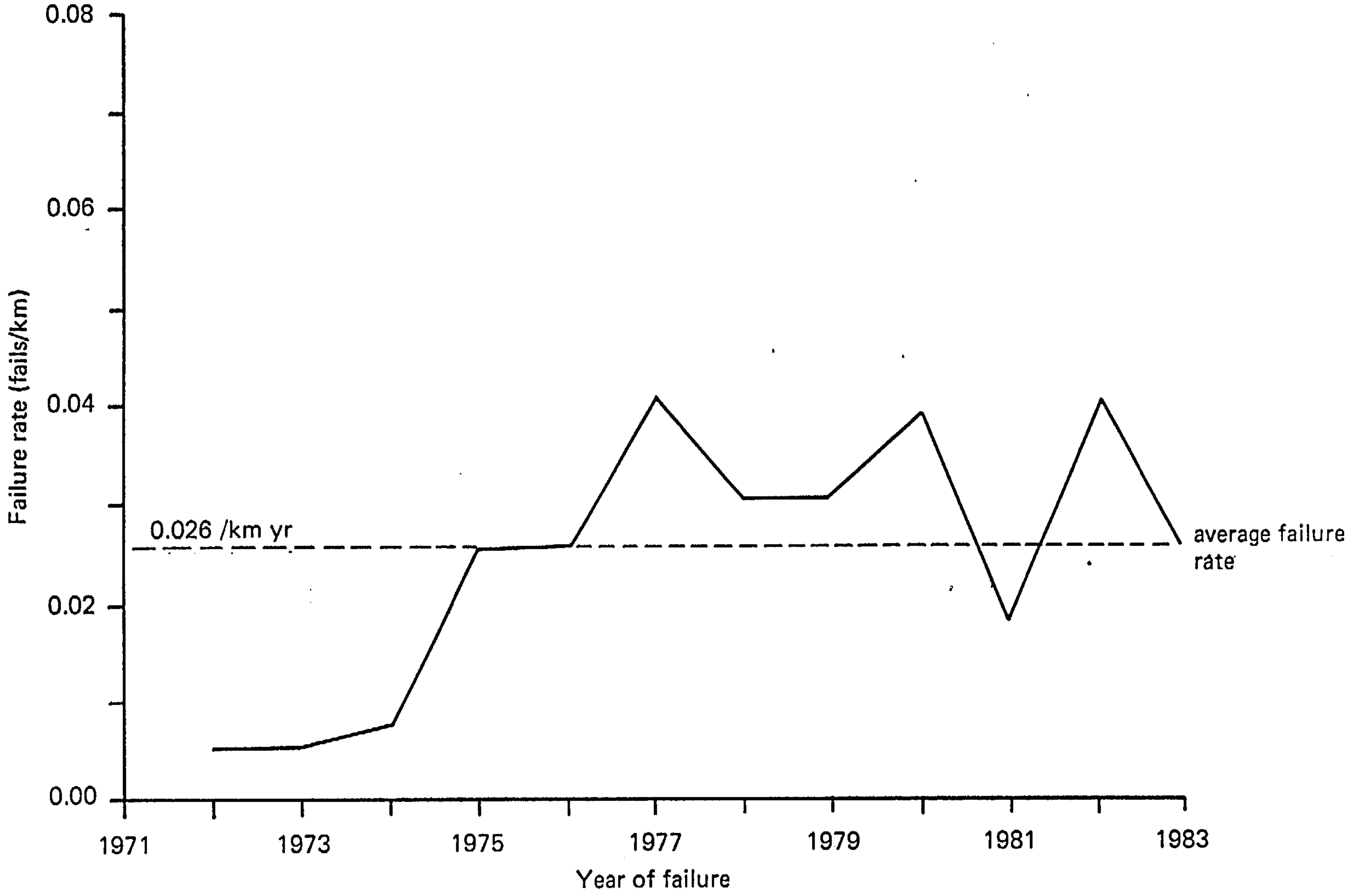


Figure 17 Area 3 — Failure rate versus year

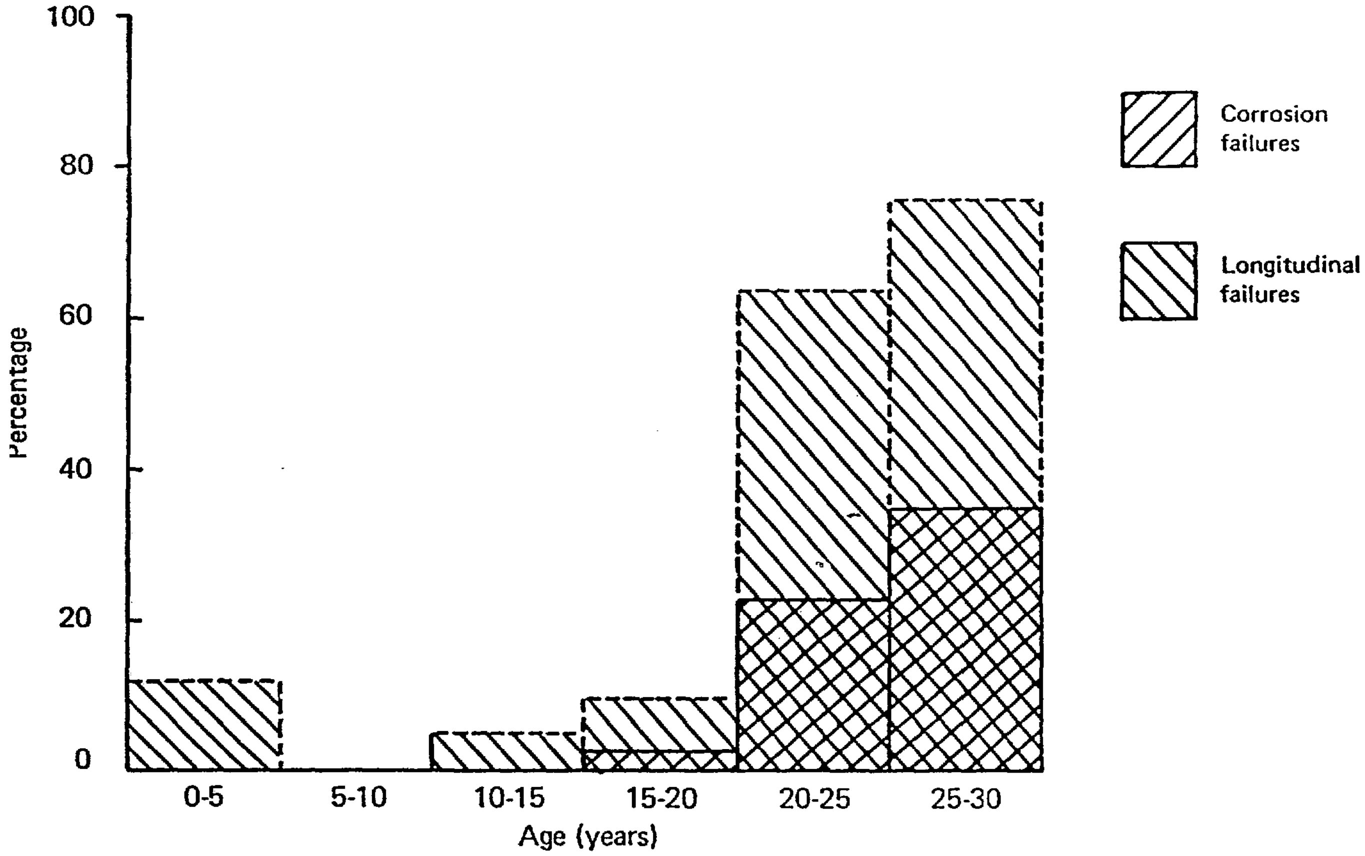


Figure 18A Area 3 — Percentage of corrosion induced and longitudinal failures against age

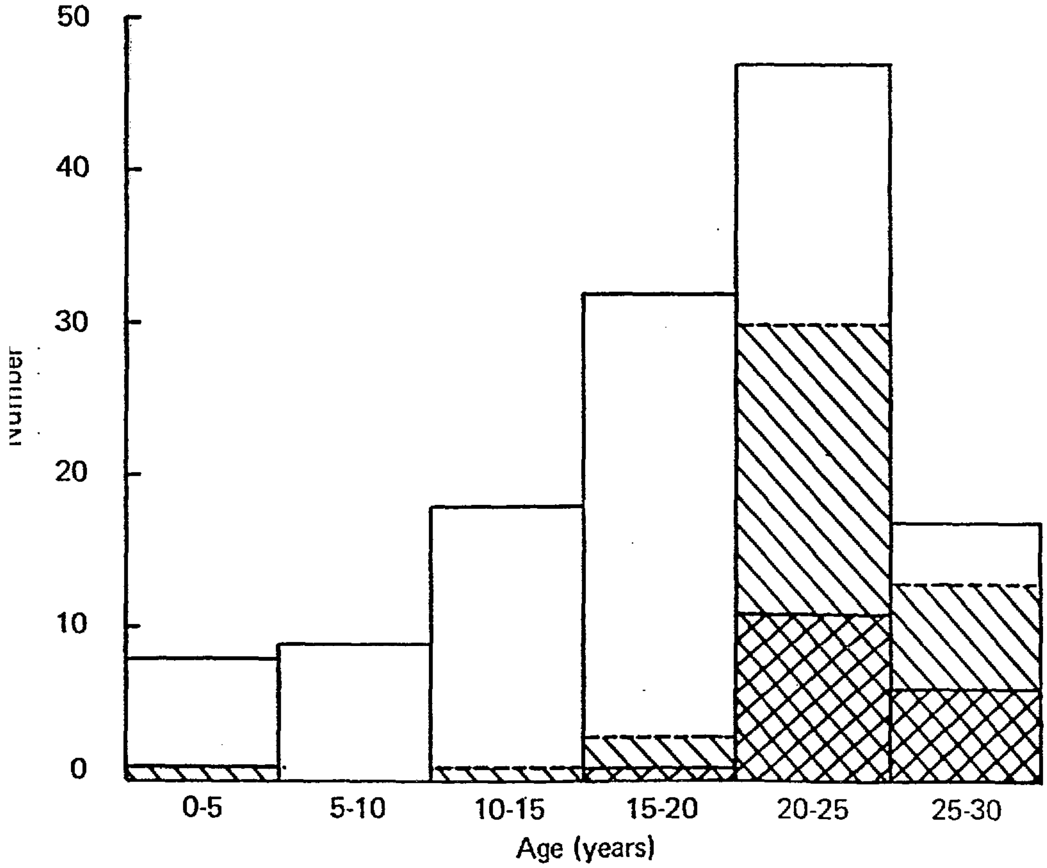


Figure 18B Area 3 — Number of failures against age

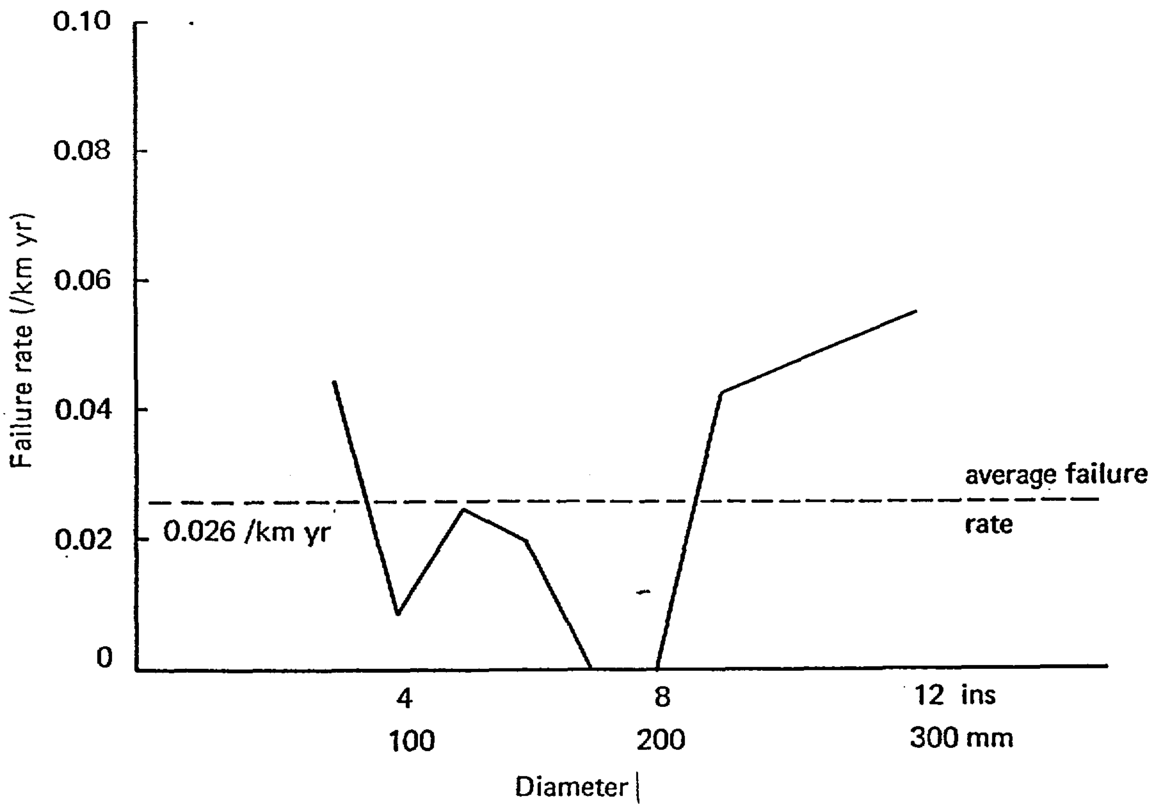


Figure 19A Area 3 — Failure rate against diameter

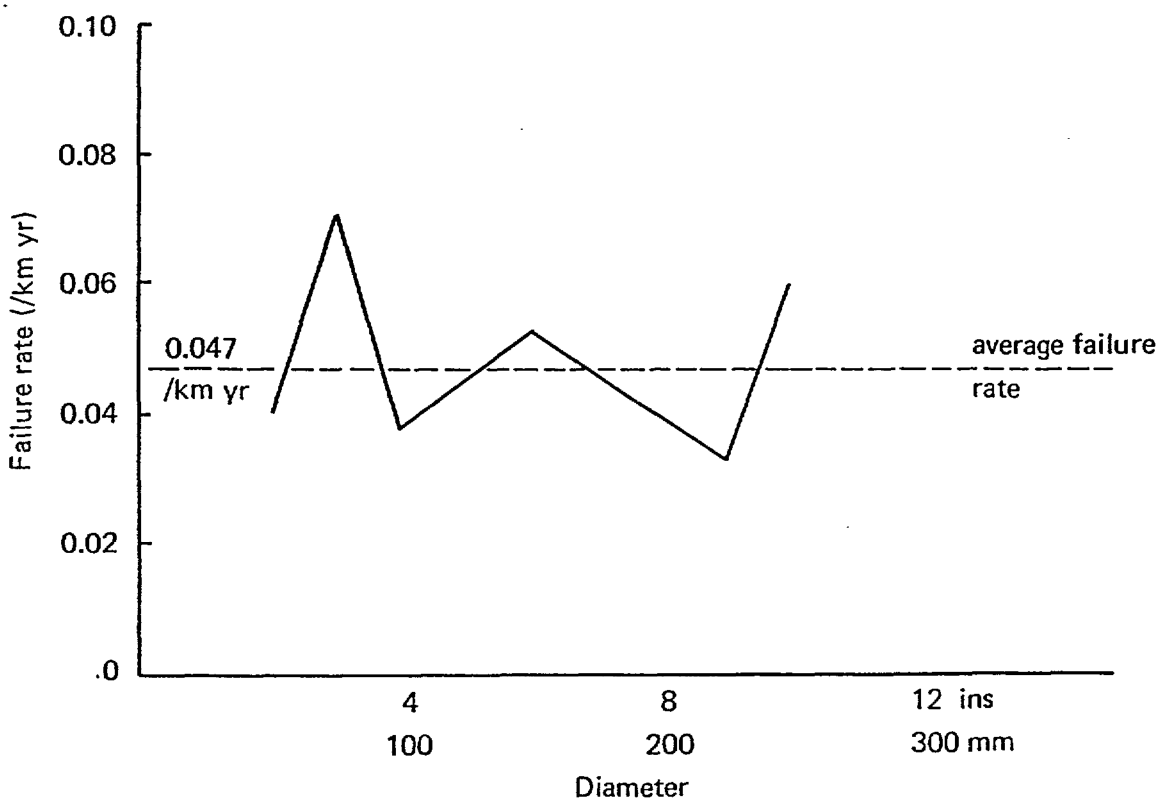


Figure 19B Area 4 — Failure rate against diameter

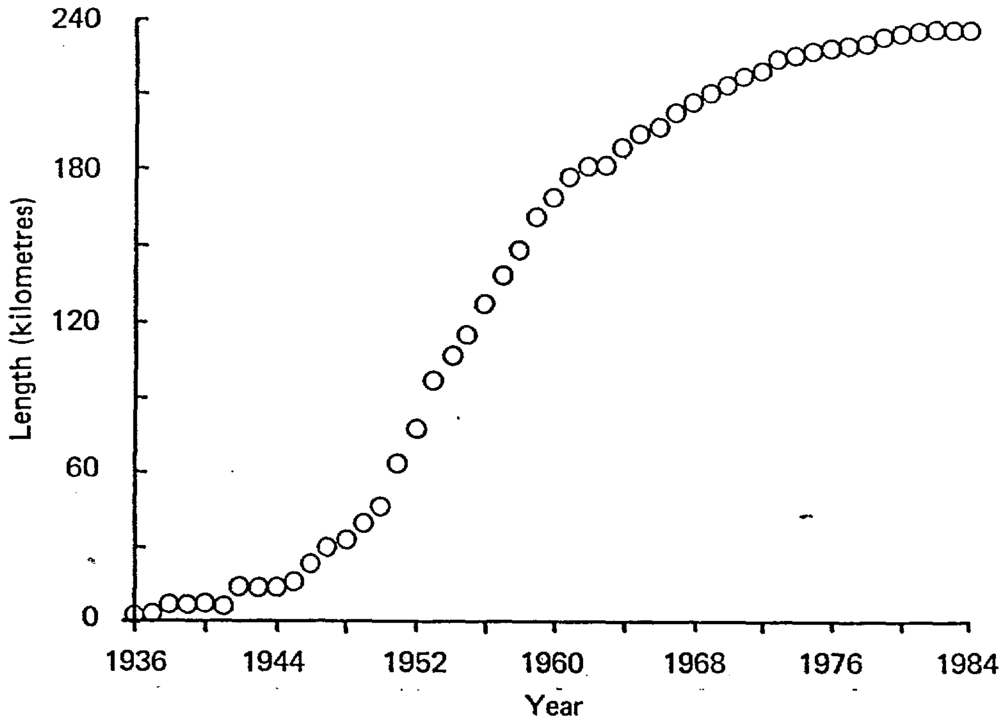


Figure 20A Area 4 — Length of asbestos cement laid

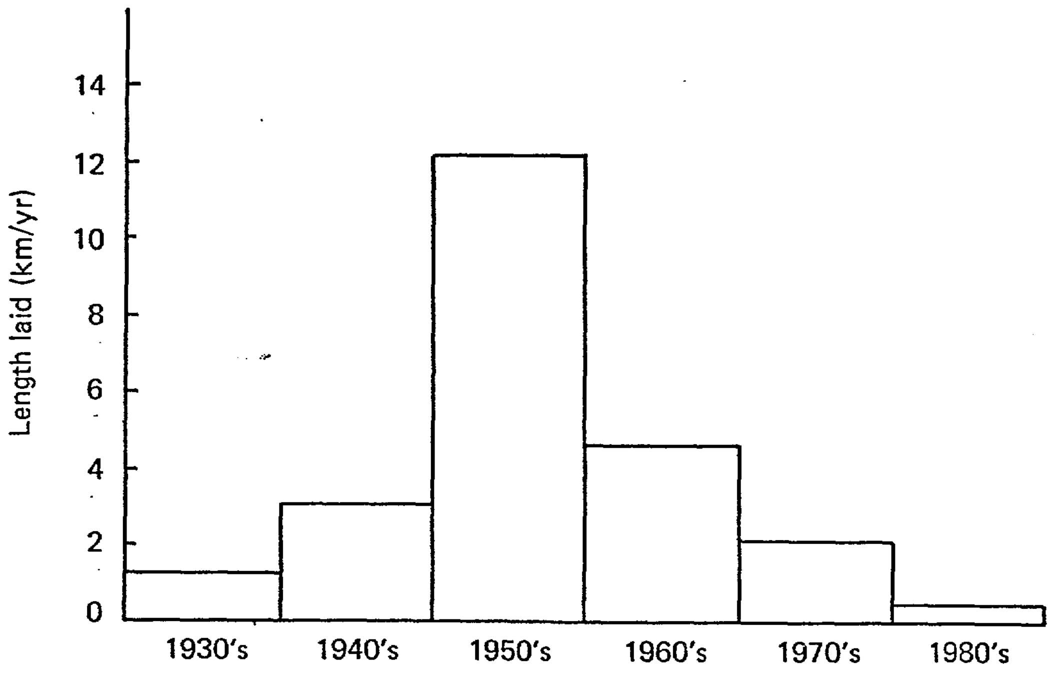


Figure 20B Area 4 — Rate of laying of AC

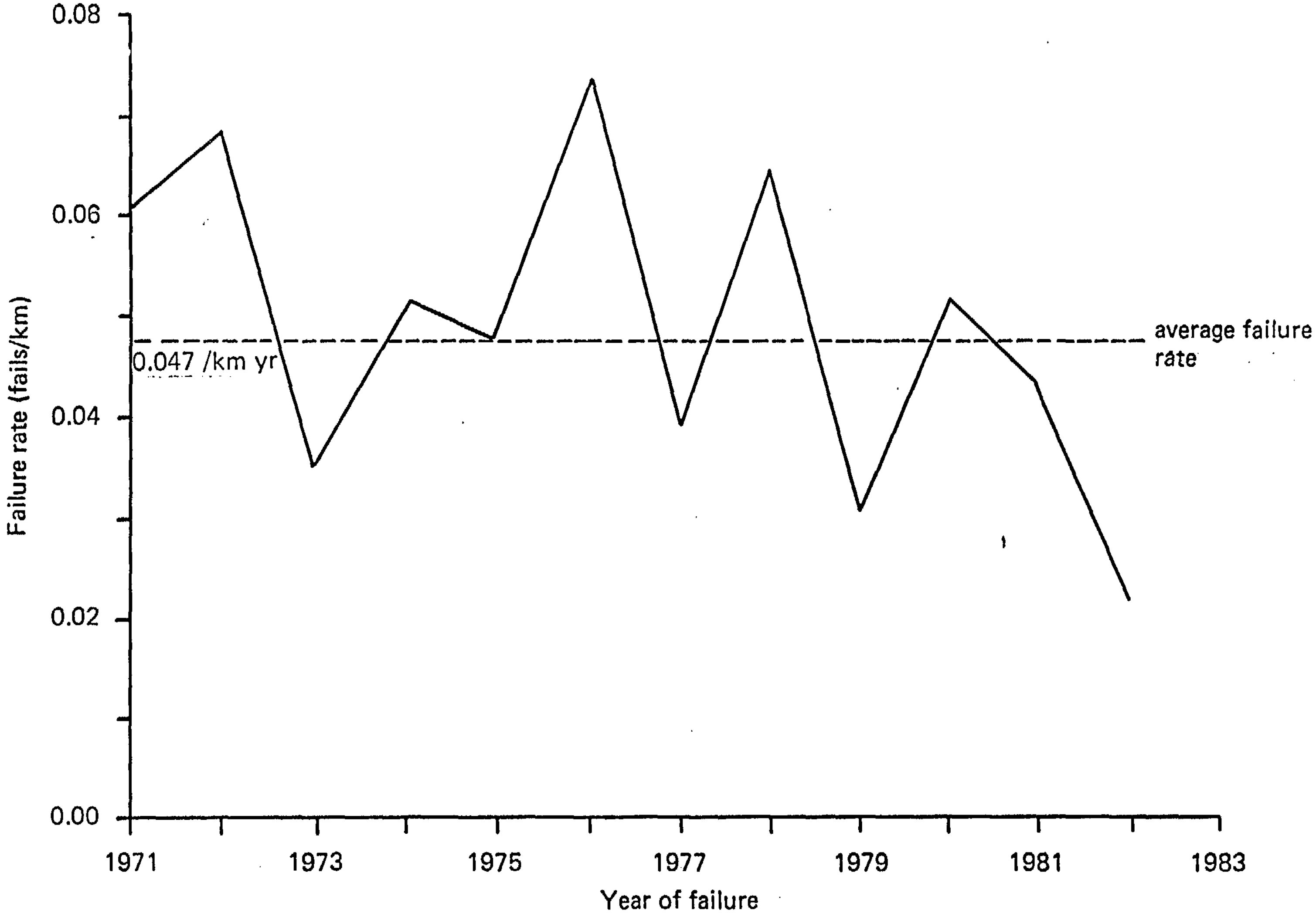


Figure 21 Area 4 — Failure rate versus year

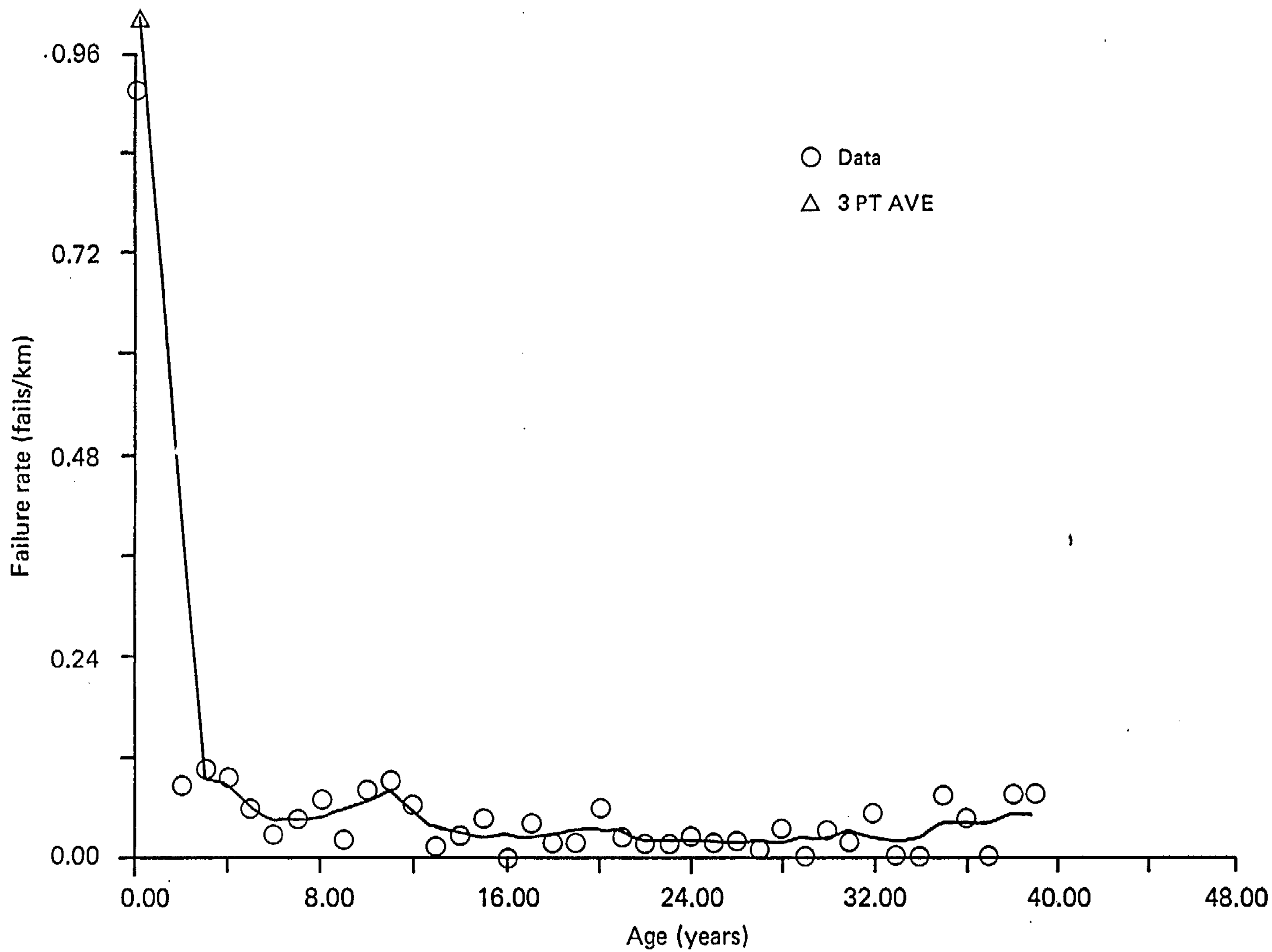


Figure 22 Area 4 — Failure rate against age

APPENDIX 1

i) Langelier Index

The Langelier Index (Langelier 1936) (LI) is the difference between the measured pH of a water (pHm) and the theoretical pH at which the water would be saturated with $CaCO_3$ (pH_s) for the existing concentrations of bicarbonate (HCO_3^-), carbonate (CO_3^{2-}), dissolved CO_2 and calcium (Ca^{2+}) ions. Thus

$$LI = pHm - pHs$$

$$pH_s = 12.3 - (\log C + \log A + 0.025T - 0.011\sqrt{S})$$

Where C = Calcium hardness mg/l
A = Total alkalinity mg/l
T = Temperature ^{o}C
S = Total dissolved solids mg/l

For negative values of LI the water tends to dissolve calcium carbonate.

For positive values of LI the water tends to precipitate calcium carbonate.

Therefore, a broad generalisation would be that waters with a negative LI may be considered aggressive to AC, while waters with a positive LI are non-aggressive.

ii) AWWA Aggressiveness Index

The Aggressiveness Index(AI) (AWWA 1977) is a simplified form of the Langelier Index, notionally modified to account for the temperature dependency of the solubility of calcite, and for the ionic strength of the solution. Although the Index has its critics it is still widely used as a guide to the aggressivity of waters.

The Aggressiveness Index is given as:

$AI = pH + \log (AH)$ where pH = pH of the water
A = total alkalinity mg/l $CaCO_3$
H = calcium hardness mg/l $CaCO_3$

with an AI < 10.0 considered highly aggressive
AI 10.0 to 11.9 considered moderately aggressive
AI > 12.0 considered non-aggressive

iii) **Comparison of AI and LI**

A comparison of the AI and LI is given in AWWA 1977 as:

	AI	**LI**
Highly aggressive	< 10.0	< -2.0
Moderately aggressive	10.0 to 11.9	-2.0 to -0.1
Non aggressive	> 12.0	> 0

APPENDIX 2

Dimensions and Pressure Classifications of AC pipe.

a) Class B, C, D

Nominal dia	CLASS B Test pressure 400ft head			CLASS C Test pressure 600ft head			CLASS D Test pressure 800ft head		
	Thickness	Ext dia	Int dia	Thickness	Ext dia	Int dia	Thickness	Ext dia	Int dia
in	in	in	in	in	in	in	in	in	in
1 1/2							.37	2.25	1.50
2							.37	2.72	1.98
3							.40	3.76	2.96
4							.50	4.80	3.80
5							.60	5.90	4.70
6	.45	6.98	6.08	.61	6.98	5.76	.70	6.98	5.58
7	.51	8.06	7.04	.66	8.06	6.74	.80	8.06	6.46
8	.57	9.14	8.00	.72	9.14	7.70	.90	9.14	7.34
9	.60	10.20	9.00	.79	10.20	8.62	.98	10.20	8.24
10	.64	11.26	9.98	.84	11.26	9.53	1.08	11.26	9.10
12	.68	13.14	11.78	1.00	13.60	11.60	1.30	13.60	11.00
15	.84	16.26	14.58	1.24	16.78	14.30			
18	.95	19.38	17.48	1.47	19.96	17.02			
21	1.10	22.50	20.30	1.60	23.12	19.92			
24	1.25	25.60	23.10	1.80	26.26	22.66			
27	1.40	28.70	25.90	2.00	29.40	25.40			
30	1.50	31.78	28.78	2.20	32.52	28.12			
33	1.60	34.88	31.68	2.40	35.66	30.86			
36	1.70	37.96	34.56	2.55	38.76	33.66			
	Test pressure 112m head			Test pressure 183m head			Test pressure 224m head		
mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
38							9.4	57.1	38.3
50							9.4	69.1	50.3
75							10.2	95.6	75.2
100							12.7	121.9	96.5
125							15.3	149.9	119.3
150	11.4	177.3	154.5	15.5	177.3	146.3	17.8	177.3	141.7
175	13.0	204.8	178.8	16.8	204.8	171.2	20.3	204.8	164.2
200	14.5	232.2	203.2	18.3	232.2	195.6	22.9	232.2	186.4
225	15.3	259.1	228.5	20.1	259.1	218.9	24.9	259.1	209.3
250	16.3	286.0	253.4	21.3	286.0	243.4	27.5	286.0	231.0
300	17.3	333.8	299.2	25.4	345.4	294.6	33.0	345.4	279.4
375	21.3	413.0	370.4	31.5	426.2	363.2			
450	24.1	492.2	444.0	37.3	507.0	432.4			
525	27.9	571.5	515.7	40.6	587.2	506.0			
600	31.7	650.2	586.8	45.7	667.0	575.6			
700	35.5	729.0	657.9	50.8	746.8	645.2			
825	40.6	885.9	804.7	66.6	905.8	783.9			
900	43.2	964.2	877.7	70.4	984.5	854.8			

B Class 15, 20, 25

Pressure Classification

Class	Works test pressure		Maximum allowable sustained working pressure	
	bar	m head	bar	m head
15	15	153	7.5	76.5
20	20	204	10.0	102
25	25	255	12.5	127.5

1 bar = 14.5 lbf/in^2 = 10.197 metres head of water

Pipe Dimensions

Nominal dia	Class 15			Class 20			Class 25		
	Int dia	Ext dia	Thickness at ends	Int dia	Ext dia	Thickness at ends	Int dia	Ext dia	Thickness at ends
mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
75	-	-	-	-	-	-	75	96	10.5
100	-	-	-	-	-	-	97	122	12.5
150	154	177	11.5	-	-	-	147	177	16.5
200	203	232	14.5	195	232	18.5	195	240	22.5
225	228	259	15.5	219	259	20.0	219	268	24.5
250	253	286	16.5	243	286	21.5	243	295	26.0
300	296	334	19.0	296	345	24.5	296	356	30.0
350	350	392	21.0	350	405	27.5	350	419	34.5
400	400	448	24.0	400	463	31.5	400	478	39.0
450	445	498	26.5	445	515	35.0	445	532	43.5
500	508	568	30.0	508	586	39.0	508	605	48.5
600	588	654	33.0	588	672	42.0	588	691	51.5
700	687	761	37.0	687	780	46.5	687	801	57.0
750	731	808	38.5	731	830	49.5	731	852	60.5

NOTE: Subject to availability larger diameters can be supplied on request.

EPW/dlb/120

APPENDIX 3

DEPARTMENT OF THE ENVIRONMENT

SCHEDULE 1 - PROGRAMME OF RESEARCH

TITLE

DETERIORATION OF ASBESTOS CEMENT WATER MAINS

OBJECTIVES

i. To determine the scale and conditions of use of asbestos cement pipes in UK water supply and the population served

ii. To determine the mechanism and rate of deterioration of asbestos cement pipes in a range of water environments. From this information, the potential for fibre release will be assessed.

iii. To evaluate suitable lining materials and water treatment techniques to minimise fibre release.

PROGRAMME OF WORK TO BE CARRIED OUT BY THE CONTRACTOR

1984/85

Collate and analyse data from water undertakings to determine:

a. The quality of asbestos cement pressure pipe in use.

b. The size and age distribution of the pipe.

c. The number of consumers receiving water distributed through AC pipes.

The quality of the water mains records maintained by the water undertakings to be assessed. Data from selected undertakings with detailed mains laying and burst records to be analysed to determine the influence of age and environmental conditions on the failure frequency.

1985/86

Work to be conducted to develop an understanding of the mechanism and rate of deterioration of sealed and unsealed asbestos cement pipe, with specific reference to the potential for fibre release. Pipe samples to be exhumed from selected sites, concentrating on the identified risk areas, and to be examined using a range of analytical techniques, eg scanning, electron microscopy, energy dispersive analysis by X-rays, etc.

1986/87

The potential of various lining materials and chemical treatments to minimise fibre release from deteriorating pipes are to be assessed by experimental pipe rig. Accelerated ageing tests for asbestos cement pipes are to be developed and used to estimate the long term effectiveness of such treatments.

Provide half yearly progress reports and final contract report on completion.

DOE

WTO

Press Notice

272 1 June 1984

ASBESTOS IN DRINKING WATER - RESEARCH REPORT PUBLISHED

A report on the amounts of asbestos present in selected UK water supplies has recently been published by the Water Research Centre.* Generally supplies carried by asbestos cement pipes, or otherwise apparently liable to contamination by asbestos, were chosen for study. The report indicates that asbestos is present in many such supplies but largely in the form of tiny fibres, very much smaller than those which are associated with the effects of asbestos in air that may be breathed in industrial situations.

In reviewing information on health implications of asbestos in water the report concludes that, although there are gaps and inconsistencies in the available evidence, "there is no clear indication that ingestion of asbestos confers an increased risk of cancer." The Department has separately sought medical advice and is satisfied that no increased cancer risk has been shown for small asbestos fibres when swallowed with food or water; this is quite a different situation from the breathing of asbestos fibres in air where there is a proven risk and strict standards have been imposed for occupational exposure.

The report indicates that of the 82 samples of drinking water tested 15 contained concentrations of asbestos fibres greater than 1000 per millilitre. Asbestos is a fibrous material which breaks up to give numerous small fibres, as found in the study, so the numbers represent a very small quantity of asbestos in terms of mass.

The numbers of fibres reported are similar to those found in typical water supplies in the USA and Canada but are substantially lower than those found in water supplies in parts of those countries where asbestos occurs locally as a natural exposed weathered mineral or where it is mined. No supplies affected in this way were found in the UK.

Press Enquiries: 01-212 4686/4690
Night Calls (6.30pm-8.00am)
Weekends and Holidays: 01-212 7071

Public Enquiries: 01-212 3434;
ask for Public Enquiry Unit

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*Technical Report TR 202, Asbestos in Drinking Water - Results of a survey - Water Research Centre, Henley Road, PO Box 16, Medmenham, Marlow, Bucks SL7 2HD.

DOE

WTO

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ask for Public Enquiry Unit

*Technical Report TR 202, Asbestos in Drinking Water - Results of a survey - Water Research Centre, Henley Road, PO Box 16, Medmenham, Marlow, Bucks SL7 2HD.

WRC Water Research Centre
MEDMENHAM LABORATORY.
Henley Road, Medmenham,
P.O. Box 16, Marlow,
Bucks. SL7 2HD
Tel: Hambleden (Bucks) (049 166) 531
Telex: 848632

C E Wright Esq
Department of the Environment
Room A4.55
Romney House
43 Marsham Street
London
SW1P 3PY

Our ref: 4365FF

3 May 1984

MR GOODMAN.
Albert.
They seem OK to me: but I cannot comment on the technical content - will you check please.
PWS
11 MAY 84

Dear Colin

WRC 1984 Open Days
Draft Open Day Hand-outs

I enclose the following draft hand-outs for clearance, I have indicated at the end of each the WRC project(s) number and DOE Subject Area:

E	Ref 1	Identification of Organic Pollutants
E	Ref 3	Identification of Mutagens
E	Ref 4	Organic Contamination: Effects of Distribution
E	Ref 6	Mutagenicity Studies in Drinking Water
E	Ref 7	The Toxicological Assessment of Water Pollutants
E	Ref 8	Asbestos in Drinking Water
E	Ref 9	Household Water Lead
E	Ref 10	Epidemiology
F	Ref 13	Analytical Quality Control (AQC)
EPTS	Ref 25	Inhibition to Bacteria
F	Ref 28	Limits for Contaminants in Sewage Sludge
F	Ref 36	Chemistry of Sewage Sludge Contaminants

These are satisfactory for displays except that, [Ref 8:] This may have to be withdrawn if Mr Waldegrave objects to our publicising the Report. We shall know inside 2 weeks.
AMG 1/5

Yours sincerely

W K Dougan
Project Administrator
WRC Environment

Replied to BD
21 MAY 85
PAE

cc Mr Elson ✓
Mr Vosser
Mr Bussell
Mr Porteous

DOE CIRCULATION

I have divided up these items by Area and would be obliged if you could provide Mr Dougan with the answer he requires.

C E WRIGHT C. E. Wright.
8.5.1984

rhc

IDENTIFICATION OF ORGANIC POLLUTANTS

Identification of organic substances in water is necessary before the significance of such contamination can be ascertained. Most of the development and application of such techniques at Medmenham has been in the area of drinking water, although such techniques are vital to many other areas of research.

As organic compounds are normally present in drinking water at low levels, sensitive analytical techniques are required for their detection. Only a few of the available techniques provide sufficient information to enable unambiguous identification and one method, mass spectromery (MS), has provided almost all of the information available on the identity of organic compounds in drinking water.

Essentially, MS involves the conversion of molecules to ions and the detection of the ions formed (or their product ions), after some form of mass analysis. The ions detected provide information on the structure of the original molecules, which may lead to identification, particularly if reference data are available. To identify a compound in the absence of reference data one can apply different methods for the production of ions (resulting in different characteristic ions being formed), and more discriminating methods of mass analysis.

Separation of the mixture of organics isolated from water is usually required prior to MS. Gas chromotography (GC) has been the most widely used separation technique and combined GC-MS has been routinely applied to the identification of organic compounds isolated from water for over a decade. World-wide this has resulted in the identification of thousands of compounds in a variety of water types.

However, only 10 to 20% of the organic matter present in water is amenable to analysis by GC (i.e. it is not sufficiently volatile). Analysis of the remaining 80-90% requires the use of high-performance liquid chromatography (HPLC) which avoids such limitations. HPLC can separate the mixtures of organics and separated components can then be characterised by MS techniques. These 'non-volatile' organic molecules, either in a solid or liquid matrix, can be converted to ions. Advanced MS techniques are then used to obtain structural information from the ions formed.

Many 'non-volatile' organic compounds isolated from water have now been identified using these methods. Continued development and application of these new techniques is needed so that a better understanding of the significance of organic contamination of water can be obtained.

This work is part funded by the Department of the Environment from whom permission to publish has been obtained.

(WRC Project H 4311C Non Volatile Organic Substances
Area E.)

(Ref 3)

IDENTIFICATION OF MUTAGENS

Mutagenic activity can be readily detected in concentrated extracts of drinking water by the application of bacterial test systems. A limited survey of drinking waters from different sources indicated a significant positive correlation between chlorination practice and mutagenicity as detected by the strain TA 100. The effect of chlorination was confirmed by direct comparison of water sampled before and after final chlorination. It was found that only the extract of the chlorinated water was mutagenic to strain TA 100. Evidence indicates that the precursors of this type of mutagenicity are probably naturally-occurring compounds and widely distributed in source waters.

At present, it is impossible to assess the significance of these findings in terms of a human health risk. Besides carrying out additional bio-assays involving higher cell test systems, it is important to identify the compound or compounds responsible for the mutagenic response. If this can be achieved, available toxicological data can be examined and/or further bio-assays may be performed on the pure material to provide a basis for a health risk assessment.

At WRC mutagenicity assays are combined with trace organic analysis in order to focus on the compounds which are of biological significance. The numerous organic compounds, which are present at very low levels in drinking water, need to be extracted and concentrated prior to mutagenicity testing and analysis. The techniques developed for routine use at WRC are freeze-drying followed by solvent extraction of the solid residue, and adsorption on XAD-resin columns followed by solvent elution. XAD/diethylether extracts are suitable for analysis by gas chromatography - mass spectrometry (GC-MS), and after transfer to dimethyl sulfoxide they can be tested for mutagenic activity. The evidence indicates that the mutagenicity may be due to relatively non-volatile compounds which cannot be identified by GC-MS. To identify non-volatile compounds, field desorption - mass spectrometry (FD-MS) and fast atom bombardment - mass spectrometry (FAB-MS) are used after fractionation of the complex mutagenic extract by high-performance liquid chromatography (HPLC) and testing of the fractions to locate the mutagenic activity. Such techniques have shown a number of mutagenic compounds in extracts of drinking water. The HPLC fractions were still complex, containing many compounds at very low levels.

To simplify the task of identification, the fractionation procedure was applied to extracts of treated water sampled before and after final chlorination. Comparison of the mutagenic fractions ot the chlorinated water with the corresponding non-mutagenic fractions of unchlorinated water allowed elimination of irrelevant compounds.

A complementary approach has involved laboratory chlorination of a range of widely distributed naturally occurring compounds. This is aimed at identification of the likely precursors of mutagenic activity and at identification of the chlorination products under relatively simpler conditions. Chlorination of aqueous solutions of humic acids and amino acids, at concentrations and conditions designed to simulate drinking water chlorination, produced mutagenic activity with similar characteristics to that observed in drinking water. These precursors may account for a significant proportion of the mutagenicity frequently observed in chlorinated drinking waters. Studies are in progress to identify the chlorination products of these compounds, to assess their mutagenicity and to ascertain their presence in drinking waters.

This work is funded by the Department of the Environment from whom permission to publish has been obtained.

[WRC Project No. H4298 Health Aspects of Organics Area E.]

(Ref 4)

ORGANIC CONTAMINATION: EFFECTS OF DISTRIBUTION

In recent years much work has been carried out on the identification of organic substances in drinking water. Most of the data produced relates to finished water (i.e. water leaving the treatment works) and consequently little is known about either the fate of organic contaminants during distribution or the introduction of new contaminants. The aim of the project is to gain a better understanding of the effects of distribution on organic susbtances in drinking water. Such an understanding is important. For example, it may lead to better materials of construction.

In particular, three areas will be investigated.

1. Leaching from pipe linings.

Problems from corrosion of old cast-iron mains have led to the development of rennovation techniques as a cheaper alternative to complete renewal. Renovation processes have been developed, based on various materials such as epoxy resin or bitumen, to line the corroded section of pipe. It is essential that sufficient information exists on the nature of organic leachates from linings so that any effects on water quality can be estimated.

2. Permeation of plastic pipes

It is known that some organic substances can permeate plastic pipes, mainly polyethylene pipe, and cause taste and odour problems. For example, leaks of petrol and other petroleum products can cause offensive odours and tastes in drinking water. It appears that certain constituents of the petroleum products can pass from contaminated soil, through the pipe and into the water supply.

3. Leaching from pipe materials

Insufficient is known of the range of organic compounds which may be leached from materials of construction. For example, recently it has been established that an antioxidant used in the manufacture of polyethylene can leach from polyethylene pipes, in some circumstances, and give rise to objectionable tastes.

In the first part of the project studies on the leaching of organic contaminants from <u>in-situ</u> applied epoxy resin linings are being carried out. Quantitative methods of analysis have been developed for certain compounds known to be present in the resin formulations. These methods involve the use of isolation techniques such as C_{18} adsoprtion (Sep-pak), vacuum evaporation and solvent extraction with separation and quantification using high-performance liquid chromotography, fast atom bombardment-mass spectrometry and gas chromotography-mass spectrometry. Initially studies have been carried out in laboratory-controlled experiments with subsequent verification of laboratory data from field trials.

This work is funded by the Department of the Environment from whom permission to publish has been obtained.

[WRCHA155 Effects of Distribution Organic Contaminants]

1Ub ✓ XOC

MUTAGENICITY STUDIES IN DRINKING WATER

Drinking water contains a complex mixture of organic micropollutants of both natural and synthetic origin. These chemicals are present in water to a varying degree and the majority are "non-volatile" in nature and consequently not amenable to gas liquid chromotography and in turn, broad spectrum analysis. There has been international concern regarding the effects of these micropollutants on the health of consumers, partly because of the increasing level of re-use of waste water which may result in a build up of organic chemicals in the water supply and partly because consumers are exposed to these compounds for very long periods of time.

Conventional evaluation of toxicological data is not possible because the major portion of the organic fraction remains unidentified. It was decided therefore that to obtain a measure of the biological activity of these complex mixtures a bio-assay technique would be used. Conventional toxicity tests would not be appropriate for many reasons so the test system selected for this purpose was the induction of gene mutations in bacteria. Such systems when used with pure substances have been found to have a high qualitative correlation with the induction of cancer in laboratory animals. These tests show whether concentrated extracts derived from water have the potential to induce mutations in the genetic material of the bacterial cells.

Concentrated extracts of water samples are produced by either freeze drying/methanol extraction or adsorption onto XAD resin columns and elution with an appropriate solvent. Freeze drying concentrates about 80% of the organics in water, but we can only process 8 litres of water in about 30 hours. XAD adsorption is a much quicker method but removes only a small proportion of the organics from the water sample, though these do appear to include the mutagenic compounds.

The mutagenicity assay utilises specially-constructed strains of Salmonella typhimurium which have a requirement for histidine and, hence, cannot grow on medium lacking this amino acid. Genetic activity is measured by determining the frequency of reversion of these cells to histidine-independance, which can be monitored by plating onto histidine-free solid agar medium, or in liquid medium using a modified bacterial fluctuation assay. This latter technique has certain advantages for testing concentrated water samples and is the most frequently used method at WRC. The tests can also incorporate a liver enzyme preparation (S9) which attempts to mimic the way chemicals are metabolised in whole animals. Some chemicals only show mutagenic activity following metabolic conversion to an active species.

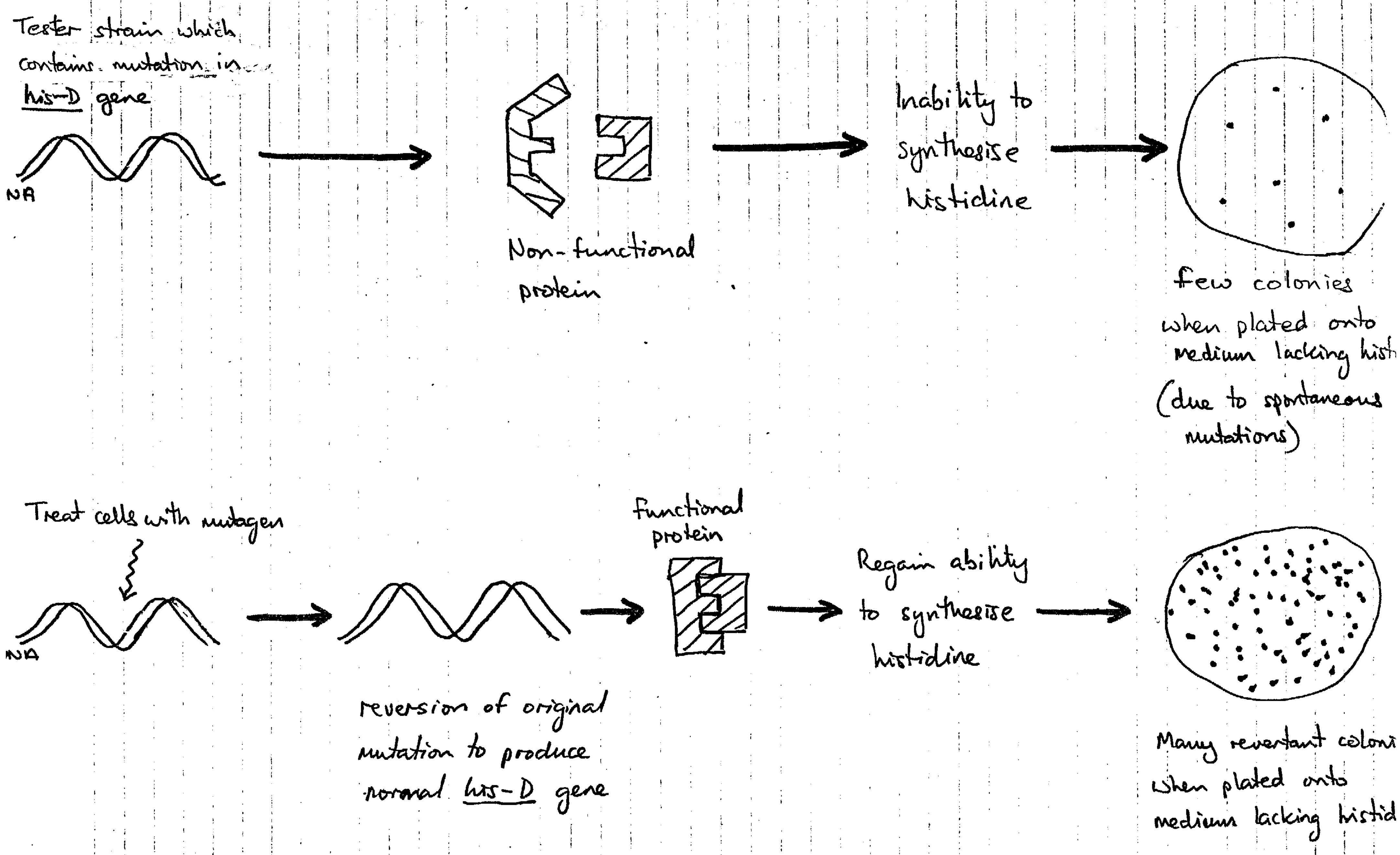
DIAGRAM (see attached - please insert here)

The results of work done to date indicate that chlorinated drinking waters derived from surface sources invariably appear to contain low levels of mutagenic compounds. One of the major sources of these mutagens appears to be the action of chlorine on naturally-occurring compounds, such as humic acids. Mutagenic activity is also occasionally seen in raw waters and in certain groundwaters. Modification to water treatment (particularly factors concerned with chlorination) has been shown to influence to potency of the extracts.

Man is exposed to mutagenic chemicals from other sources, such as food and air, and the significance of low levels of mutagens in the water supply is not clear. Positive results in bacterial mutagenic tests do not necessarily indicate a health risk to man and the results must be confirmed in tests using mammalian cells. Studies are therefore in progress to determine the ability of concentrated water extracts to damage chromosomes in mammalian cells in culture. Positive results in such tests may indicate a qualitative risk to man. However, a quantitative evaluation of the size of any risk will be much more difficult to make.

This work is funded by the Department of the Environment from whom permission to publish has been obtained.

[WRC Project No H 4298 Health Aspects of Organics
Area E]


Tester strain which contains mutation in his-D gene
NA
Non-functional protein
Inability to synthesise histidine
few colonies when plated onto medium lacking hist
(due to spontaneous mutations)
Treat cells with mutagen
NA
reversion of original mutation to produce normal his-D gene
functional protein
Regain ability to synthesise histidine
Many revertant coloni when plated onto medium lacking histid

THE TOXICOLOGICAL ASSESSMENT OF WATER POLLUTANTS

There are several different situations in which a toxicological assessment of chemicals in water supply may be needed.

Unscheduled discharge - Spills Waste dump leachate	Acute operational problem; often time is of the essence.
Scheduled discharge - Industrial effluent Chemicals and materials - For use in water treatment and distribution	Expected or predicted. Requires policy decisions. There is time to think and collect data.
Micropollutants - Organic and inorganic	Longterm and low concentration. A research area.

The situation with water is a difficult one because of the breadth of the problem. All members of the population receive water and therefore we must take into account all the vulnerable groups - the youngest, the oldest, the healthy, the sick.

Information on the toxicity of a chemical can be obtained from published reports and computer data banks. However this information is rarely comprehensive and is rarely intended to solve environmental problems. Further, much of the toxiçological data is generated and held by private organisations who usually regard the information as commercially sensitive.

Having obtained that information which is available it must then be evaluated critically. The quality of the information is usually just as important as the quantity. There are several points which should be remembered.

* Toxicity is dependent on dose and period of exposure.

* Not all species or even strains of the same species will react in the same way.

* The no effect level depends on how closely one looks for an effect.

* Numbers are not absolute. There is a wide individual variation in response, even under controlled conditions, in populations which are closely related genetically. The LD_{50} is not a constant on a par with molecular weight.

The application of toxicity data to a particular situation requires extrapolation, often from high doses to low doses, from animals to man and the results of the extrapolation applied to a population of many different individuals. When dealing with such a situation there are many important points to be considered.

* What is the exposure, both the quantity and period of time.

* Allow for differences between laboratory animals and man, factors such as absorption, excretion and metabolism are important.

* Are there high risk groups such as those with disease or a genetic susceptibility.

* What is the level of exposure from other sources and will that influence the decision.

* Are other compounds present which may alter the situation.

Toxicological evaluation is a difficult and complex task in which the quality of the information available and the influence of local factors need to be taken into account. There are no simple formulae for calculating the probable effects of a water contaminant and the final assessment must be based on balanced professional judgement.

This work is part funded by the Department of the Environment from whom permission to publish has been obtained.

[WRC Project H4298C Health Aspects of Organics
Area E]

ASBESTOS IN DRINKING WATER

Background

Asbestos occurs widely in nature and has a multitude of uses. It can enter the water cycle by a variety of routes

- the direct erosion of asbestiform minerals,
- the direct discharge of waste containing asbestos to rivers or sewers,
- the use of asbestos products in the distribution system,
- as a result of industrial activity (extraction, manufacture, product use or disposal) via air or waste disposal to land.

Recent surveys in the US and Canada have suggested that even where asbestos is not particularly suspected of being present, concentrations of between 10^5 and 1.5×10^6 fibres per litre of drinking water are commonly observed.

WRC Survey

In 1982 WRC completed a survey to investigate the concentrations of asbestos in UK drinking waters. The objectives were:

(a) to determine the concentration and types of asbestos in raw and treated waters in the UK,

(b) to determine whether and in what circumstances the use of asbestos cement (AC) pipes can contribute to asbestos levels in the consumer's supply.

Before this survey there was no information, that would now be considered reliable, about the concentrations of asbestos in UK water supplies. The survey is described in WRC Technical Report TR202.

The asbestos analyses for the survey were sub-contracted to the Ontario Research Foundation in Canada, the same laboratory as is used by the Canadian Government and by the US Environmental Protection Agency for similar work. The methods of sampling and analysis therefore allow comparison with the latest surveys from N. America.

The determination of asbestos in water is expensive, and so the survey was constrained in the number of observations that could be made. These were 72 in number, each observation comprising a pair of samples taken on the same occasion.

Results

To give an overall impression of the results, the numbers of observations together with the median fibre concentrations for different categories of site are shown in Table 1.

Both the treated waters going onto supply and the waters sampled at drinking water taps after passage through AC pipes gave concentrations which are low in relation to the range of concentrations reported from other surveys. The concentrations in samples taken at hydrants were somewhat higher, even when care was taken in turning on the valve. Concentrations observed at dead-end hydrants after deliberate flushing to disturb pipe deposits tended to be higher still and this disturbance can also be reflected in the levels observed at drinking water taps after hydrant flushing has taken place.

If the observations in the categories marked 'P' are taken as representative of potable water then from the 39 available observations we estimate the upper 90 percentile concentration to be 1.8 million fibres per litre for chrysotile and 0.7 million fibres per litre for amphibole.

Asbestos cement pipes can contribute to asbestos levels in water in the distribution system and this is most apparent in samples taken after pipe deposits have deliberately been disturbed. The aggressivity of the water, the length and age of the pipe system and the occurrence of reversals of flow probably all affect the concentrations found.

This work ~~is~~ was funded by the Department of the Environment from whom permission to publish has been obtained.

[WRC Project No H 4310C Asbestos in Drinking Water]

TABLE 1 Concentrations of Fibres

		Number of sites	Median fibre concentratio /million fibres per litre	
			CHRYSOTILE	AMPHIBOLE
	RAW WATERS			
	Upland - at source	5	0.3	0.1
	- after passing through A C pipe	3	0.07	0.06
	Rivers with re-use	3	4	0
	Polluted groundwater	3	9	0
	WATER IN SUPPLY			
P	Treated waters ex-works	17	0.14	0
	<u>After passing through A C pipe</u>			
	Hydrants	8	1.9	0.8
P	Drinking water taps	16	0.13	0
	Dead-end hydrants after flushing	5	11	1.4
	Drinking water taps after flushing end hydrants	6	2.5	2.0
	<u>After storage in A C structures</u>			
P	Reservoirs with asbestos sheet coverning	3	0.04	0.06
P(2)	Domestic storage tanks	3	0.11	0

P indicates categories that should be regarded as potable

HOUSEHOLD WATER LEAD

The objective of the project is to develop reliable, practicable and economical methods for sampling household drinking water supplies, so that population exposure to lead in drinking water can be estimated with known statistical tolerance. The general approach we are following to achieve this objective is to separate and quantify the two main components of sampling variation, namely:-

1) The patterns of intermittent flow of water in the service pipe and house plumbing, controlled by the frequency with which the consumers use water in the house.

2) The rate of build-up of water-lead concentration with stagnation time, which is a function of the diameter of the service pipe and the water chemistry.

As very little information was available on (1) and (2), two surveys were designed to obtain better data:-

1) Survey of Domestic Water Use Patterns

A survey of domestic water use patterns in over 100 households in 22 towns covering the range of household sizes, social groups and types of housing in England, Scotland and Wales was completed in April this year. Specially modified water meters were fitted temporarily into five selected houses in each town, and the time of day, duration and volume of every water usage through the service pipe over a two week period was recorded on a micro-computer. In addition, the consumers were asked to press a button by the kitchen cold tap to flag the uses drawn for drinking or cooking purposes. From the raw data we can derive distributions both of the times between uses (stagnation times) and of the volumes of the uses, separated into drinking and non-drinking categories.

2) Survey of Lead Stagnation Curves

Because of the practical problems associated with the extended sampling of tap-water in houses, we have developed a computer-controlled automatic sampling machine which is capable of taking a series of 12 tap-water samples for lead determination after a pre-set sequence of stagnation times. The equipment has been designed to be used in occupied houses and take samples automatically through the night when no water is being used for other purposes. Currently we are in the early stages of this survey, but we hope to have covered a range of sampling locations by March next year. The stagnation curves obtained from these machines will be used to chec theoretical estimates of the rate of increase of lead concentration with stagnation time based on mass transfer theory, also to determine how lead stagnation curves vary within and between households and with water quality.

This work is funded by the Department of the Environment from whom permission to publish has been obtained.

[WRC No 4156 Trace Elements in Drinking Water & CVD]

(Ref.10)

EPIDEMIOLOGY

Epidemiology is the study of the distribution and determinants of disease frequency in man. Its methods offer one of the most direct approaches to the question whether the chemical components of drinking water are of any importance to public health. Epidemiological studies may be based on whole communities, selected subgroups or on individuals. The objective is usually to investigate the possible relationship between some measurement of health status and the intake or concentration of a given constituent of drinking water. This is attempted by contrasting the observations made on different units of the population (for example towns served by different water sources) that are exposed to the constituent to different extents.

In the nineteenth century epidemiology played an important part in revealing the transmission via water supplies of acute infectious diseases such as enteric fever and cholera. Today interest has largely switched to some of the chronic diseases and non-infectious conditions for which the chemical quality of drinking water may be a contributory factor but is almost certainly not the only cause.

This is a field where it is seldom possible or ethical to carry out designed experiments because humans are involved. In observational studies there are difficulties of fairness of comparison due to confounding factors. The resolution of these often entails complicated statistical reasoning. In addition, many of the measurements on which epidemiological studies are based (for example, estimates of percentage re-use, or sample measurements of water lead) are imprecise. These limitations make epidemiology a blunt tool for providing guidance on the questions that are really of interest to the Water Industry (Should concentrations of THM's in water be reduced?). The immediate relevance of epidemiological findings to man can however still give them a strong emotive impact, especially if they receive disproportionate amplification by the media or by pressure groups. One reason for WRC's involvement in epidemiology is to offer appraisal and interpretation of these matters to the Water Industry.

WRC is able to undertake some epidemiological research by itself in areas where special medical measurements are not needed, but the Centre does not have its own medically qualified staff. For studies that require medical expertise, WRC collaborates with medical research groups, principally in university departments, teaching hospitals or Medical Research Council units.

The results of epidemiology carried out by or with WRC have mostly been published in papers or Technical Reports. An equally important channel of communication is in special reports to committees (for example the DOE/DHSS Joint Committee on Medical Aspects of Water Quality), as input to groups working on revision of water quality standards (for example World Health Organisation) or in answers to direct enquiries from water undertakings about the meaning or validity of epidemiological research.

Main subjects of WRC's epidemiological research

WATER FACTOR	DISEASE OR CONDITION	REFS
Hardness and related constituents	Cardiovascular diseases	1 - 5
'Organics' as characterised by re-use or by type of source	Cancers of gastro-intestinal and urinary tracts	6 - 8
Lead	Blood lead	9
Quantity	-	10

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WRC's part in studies 1 - 9 was funded by the Department of the Environment from whom permission to publish has been obtained.

[WRC Project No H4298 Health Aspects of Organics and H4156 Trace Elements & CVD & H0310 Asbestos]

DOE. Area: E

Exhibit Ref.13

ANALYTICAL QUALITY CONTROL (AQC) - RIVER WATER MONITORING

Under contract to the DOE, the WRC has been co-ordinating the AQC work for the DOE Harmonised Monitoring Scheme for River Water Quality. This project, now in its final stages, has aimed to assess the comparability and accuracy of the analytical results from various water laboratories: see the list of publications overleaf.

ANALYTICAL QUALITY CONTROL FOR MARINE MONITORING

The determination of trace elements at the low levels of interest in coastal and estuarine waters presents particular difficulty.

Responding to an initiative from the Marine Pollution Monitoring Management Group (MPMMG), the RWAs and RPBs advised that a programme of AQC specifically designed for coastal and estuarine monitoring was needed. (They considered that such a programme should be based on that used by WRC in the DOE Harmonised Monitoring Scheme and other national and international monitoring activities.)

WRC's proposals for initial AQC work on cadmium and mercury in marine waters have now been accepted by MPMMG. This work will begin in 1984.

ANALYTICAL QUALITY CONTROL FOR PH MEASUREMENT IN MOORLAND WATERS

Concern about the acid status of UK surface waters, especially in upland areas, has focused attention on this difficult determination. WRC, in conjunction with the Freshwater Biological Association, is engaged in collaborative work with laboratories undertaking such pH measurements. The objectives are: (1) to identify suitable instrumentation and methodology for immediate use and (2) to conduct AQC to ensure that analytical results obtained by different organisations are adequately comparable.

This work is funded by the Department of the Environment from whom permission to publish has been obtained.

PUBLICATIONS ON ANALYTICAL QUALITY CONTROL (HARMONISED MONITORING)

General Approach Comparable of Laboratories	Approach for Achieving to AQC Analytical Results from a Number A L Wilson Analyst 1979, **104**, 273-289

Prepared by the AQC(HM) Committee

Chloride	WRC Technical Report TR 27 Analyst 1979, **104**, 290-298
Ammoniacal Nitrogen	WRC Technical Report TR 58 Analyst 1982, **107**, 680-688
Total Oxidised Nitrogen & Nitrite	WRC Technical Report TR 63 Analyst 1982, **107**, 1407-1416
Suspended Solids & Ash	WRC Technical Report TR 163 Analyst 1983, **108**, 1365-1373
Biochemical Oxygen Demand, BOD(ATU)	WRC Technical Report, in press Analyst paper, in preparation
Conductivity pH	WRC Technical Report TR 190 WRC Technical Report TR 196 Analyst paper on both
determinands, in press	
Cadmium (High Level), Copper, Lead, Nickel and Zinc	WRC Technical Report, in press Analyst paper, in preparation
Cadmium (Low Level) preparation	WRC Technical Report, in
Mercury	WRC Technical Report, in press Analyst paper, in preparation

General

The Use of Cumulative Sum Charts (CUSUM Charts) in Analytical Quality Control	WRC Technical Report TR 174
Sample collection, preservation and stability	WRC Technical Report, in press

WRC No AM4185 Area E
AQC. Paragraph I