Highway Materials Research Laboratory
132 Graham Avenue, Lexington 29, Ky.
December 27, 1950

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Memo To: D. V. Terrell
Director of Research

Attached is our first report of progress on an extensive survey of acid waters and drainage installations throughout the state, a project which has been under way during the past year. Actually, the work was initiated in September, 1949, but it was first considered by the Research Committee at its meeting on December 20, last year. Since that meeting much time and effort have been spent by Messrs. Havens, Young, and Field in an attempt to obtain as much factual information as possible and report it at the earliest opportunity. Had there been much less rainfall during the past summer it is probable that the entire state would have been covered and a complete report could have been made at this time. As it stands, even with more than 13,000 drainage installations inspected and approximately 2400 miles of road included in the condition survey, this report of progress represents only about half the state, and possibly two-thirds the work that was contemplated.

Despite these limitations on the data, a substantial portion of those things of primary interest have been covered. It has been shown that the acid potential in both the eastern and western coal fields is high; that it is probably higher in the West than in the East; that even with this high potential most of the surface water flowing in either of the coal fields is non-acid or mildly acid at most; and that probably the waters containing acids or other corrosive materials are extremely rare in all parts of the state outside the coal fields.

There are many other significant things contained in the results and in the thirteen conclusions drawn from them. Undoubtedly the most gratifying is the fact that exclusive of silting - which is a serious problem that does not receive enough attention - about 98 per cent of the cross drains and almost 90 per cent of the entrance pipe in the areas surveyed are free from any noticeable failures. Considering the dates of construction for some of these roads, the variety of service conditions, and the relatively limited attention which can be given drainage conduits after they are installed, this is a remarkable record. Probably there is no other feature of the highway system on which the Department has been so successful in gaining permanence (and perhaps adequacy) through its designs.

With regard to the counties that were set apart in our memorandum report of April 26, as areas in which caution should be used for design against potential acidity, there is no indication in the present report that the selection was not a good one. Acid waters have been located in most of the 19 counties designated as seriously acid before, but some of these need much more extensive sampling. Thus far, there are few cases where acidity has been found in counties other than those on the list made up in April. In view of those circumstances there is no basis for the present, at least, on which a change could be recommended.

Ultimately the Division of Design may want to give some consideration to acidity surveys for each individual location as projects come up, since non-acid waters predominate even in the coal regions and the influence of the acid is usually limited to a short distance from the place at which it originates. If this were done, however, it would not take into account the effects of mines that would be opened up after the road was in use.

After this report is considered by the Research Committee and comments or suggestions are received, we will make revisions in the procedures of surveying before the work is extended. If there are no suggestions, it will probably be extended during the coming year to about twice the extent of its present scope and made representative of the entire state.

Respectfully submitted

L. E. Gregg

L. E. Gregg
Assistant Director of Research

Copies to:
Research Committee Members
Mack Galbreath (3)

Commonwealth of Kentucky
Department of Highways

Progress Report No. 1

on

A SURVEY OF ACIDITY IN DRAINAGE WATERS AND THE CONDITION OF HIGHWAY DRAINAGE INSTALLATIONS

by

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Highway Materials Research Laboratory
Lexington, Kentucky

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INTRODUCTION

Every creek gulley and draw interrupted by roadway fills and embankments must be provided with an adequate drainage conduit under the pavement. If the natural drainage is impeded or the conduit is not functioning properly, impounded water over-runs the pavement, seeps through the fill, and eventually disintegrates the section or reduces its stability. The topography in Kentucky, though varied sectionally, requires on the average, one cross-drain for every thousand feet of roadway. Obviously, these drainage structures are of considerable economic importance in the highway program, not only from the standpoint of initial construction costs, but also from consideration of the service-efficiency or the permanence of the installation itself. Of these two factors, service-efficiency is undoubtedly the more important factor in determining an integrated service economy. Since permanence of a culvert or cross-drain depends largely on the specific properties of the material with which it is made, considerable advantage may be derived by selecting material for use in areas where their properties are compatible with the conditions of service, and excluding them where conditions are known to be unfavorable.

In September of 1949, the Division of Design expressed concern at the premature disintegration of a series of 40-inch corrugated metal pipe installations under entrances alongside US 60 just south of Ashland. The Research Laboratory, at the suggestion of the Division of Design, made an impromptu investigation (1) and was able to attribute the failure to acidity from mine-water drainage. This was a totally unpredicted instance of incompatibility - not unpredicted with respect to the corrosive action of acid on metal but in the association of acidity with mine-drainage water in the locality.

Even though for years it had been common knowledge that the potential for acid in drainage waters was high throughout the coal-mining regions of the state, the areal distribution of existing, abandoned, and possible mine sites had never been correlated with highway drainage requirements. Also, the need or lack of need for design against acid attack in areas outside the mining regions had never been determined by comprehensive investigation. As a precautionary measure, it had been a policy for many years on all Federal Aide Projects to exclude uncoated metal pipe as cross-drains regardless of the location. Hence, there were reasons to believe that many cases of incompatibility could exist in the highway system and their existence go unrecognized in current design practices.

As a result of these doubtful circumstances, the Research Laboratory was requested to undertake a very comprehensive project on drainage. Primarily, the study was to develop factual data on the distribution of acid waters within the state; beyond that, the objectives were to determine the effects of different acid concentrations on all types of drainage structures, provide information on the means available for designing against rapid deterioration under acid exposure, and in general evaluate the performance of existing drains in the light of their age and service conditions.

From the very earliest inception of the study attention was directed to the coal-producing regions of the state. It was assumed in the beginning that corrosion (due to acid and saline waters) and, to a lesser degree, abrasion were the only two factors (other than structural weakness) that cause rapid failure. Furthermore, all evidence supported an assumption that mine-water drainage was the predominant source of water acidity in this state. This was unavoidably a preconceived conclusion and it is not at all original in this investigation.

Since early in the 1930's the problem of stream pollution from sewage, industrial wastes, and mine-drainage waters has grown steadily in importance as a debatable and controversial issue. During the W.P.A. era a program of air-sealing abandoned mines as a corrective action against pollution from that source was sponsored by the US Public Health Service. More recently, according to Kenneth S. Watson, Assistant Director, Ohio River Sanitation Commission (2)* a U.S.P.H.S. survey estimated that the equivalent of 2,500,000 tons of sulfuric acid originating in underground mines is discharged every year into the Ohio River Basin. Stream pollution is regarded by many as one of the necessary evils of industrialization; there are also those of the opinion that pollution imposes an intolerable condition on one of the country's more desirable resources. No industry, large or small, derives any satisfaction from polluting the streams. Numerous arguments, pro and con, may be charged to the problem, but despite them all, one fact remains unaltered: the cost of eliminating pollution will not be borne by the industry alone but will be pro-rated in the cost of the commodity. The intent behind these comments is not to condemn the mining industry but to emphasize the fact that pollution is a public responsibility and that damage to highway drainage-structures resulting therefrom is of rather minor consequence in comparison with the pollution problem in general.

At one time or another, practically every state in which coal is a major resource has found it necessary to investigate acidity in relation to highway drainage. During the late 20's and early 30's several states conducted culvert surveys, some of them cooperatively. Some of the resulting information was integrated into a report made by Roy W. Crum (3) which was published in the 1932 Proceedings of the Highway Research Board. Of

* Numbers in parenthases refer to the list of References at the end of this report.

the original reports, many of them were never published and copies of the manuscripts are either no longer available or are yet held confidentially by the states. After almost a decade of fruitful research interest in the problem apparently subsided. It had not yet been determined whether the problems were solved to the satisfaction of all concerned or whether the several states just decided to "sweat-out" their own individual problems.

In 1934, the State Road Commission of West Virginia, in cooperation with the University of West Virginia published a report (4) of a culvert survey in that state which is by far the most comprehensive treatise yet reviewed. The author, W. S. Downs, described their situation as follows:

> "A major portion of the state's area contains valuable coal deposits consisting of numerous seams which differ somewhat in the mineral content. Many such coal deposits are being operated or have been operated. In either event the oxidizing effect of the air in contact with the workings causes the drainage water from the mines to be highly impregnated with mineral salts. Most of them show an acid reaction due to the sulfur and iron (free sulfur and sulfur in combination with iron, never iron alone) in the coal so that the effect upon metal or even upon concrete can not be ignored. Under such conditions, it is necessary to exercise discretion in the selection of the culvert type. In certain localities it may be advisable to reject the use of a culvert type which under different conditions has proven highly economical."

Probably the most significant feature of the Down's report was his statistical evaluation of the expected service life of various types of culverts. For the purposes of his survey, it was necessary for him to assume that the annual rate of deterioration remained constant throughout the life of the culvert. From observations on a culvert he estimated a percentage material disentegration and simply divided that percentage by the age of the installation which gave him the annual rate and ultimate life-expectancy. His assumption of a constant rate of deterioration was a recognized expediency even though Crum had found that the rate of deterioration does actually increase with age. The age of culverts rated in the Down's survey ranged from 3 to 12 years and since culverts aged only three years rarely showed perceptible defects, he made a general assumption and charged ten points of depreciation to apparently perfect culverts. The statistical results by Downs are shown (in part) in the tabulation below:

Culvert Type	No. of Culverts Observed	Avg. Expected Service Life
Cast Iron Pipe	130	105 Years
Corr. Metal, General	1277	27 "
Corr. Metal, Plain	832	22 "
Corr. Metal, Paved Invert	445	49 "
Rein. Conc. Pipe, General	1758	50 "
R.C.P. Cast	1185	47 "
R.C.P. Machine Made	430	59 "
Rein. Conc. Box	303	43 "
Stone Box	49	108 "
Vit. Clay Pipe	168	54 "

These results should not be taken without qualification since Downs himself acknowledged that in the cases of cast iron pipe and the stone box, both were located in areas unusually favorable to culvert longevity. In the case of vetrified clay pipe, structural failures were not uncommon.

With regard to the effect of acid water on culvert longevity, Downs found that in water having a pH less than 3, concrete shows an average rate of deterioration four times as great as when the pH is around 7. Quoting again from his report:

> "... It is conclusively shown that mine drainage which possesses a low pH value (highly acid) will rapidly disintegrate the invert of any exposed metal pipe. ...As a general rule, however, this survey shows values ranging from 6 to as low as 2.7. The survey further shows that pipe deterioration (concrete and metal) increases as the pH value of the water decreases."

Almost contemporary with Crum's report or possibly a little later the Pennsylvania Department of Highways conducted a culvert survey (5). Their survey covered approximately 15,000 installations of which over 2,000 were discarded in the data due to extraneous influences such as mine-water, tannery discharge and chemical pollution. On this basis, approximately the same method as used by West Virginia was used to estimate probably life-expectancies and, of course, the results were subject to many of the same assumptions. The conclusions from Pennsylvania in regard to life-expectancy are tabulated below.

Type of Pipe	Condition of Flow	Life Expected
Cast Iron	Intermittent	50 plus years
Cast Iron	Constant	40 years
Concrete	Intermittent	40 years
Concrete	Constant	32-36 years
Corrugated Metal	Intermittent	29 years
Corrugated Metal	Constant	16-20 years

The California Division of Highways has recently made a final (20 year) report (6) on corrugated metal culvert field tests which were started in the 1929-1930 era. In 1928, a report which preceeded the long-time study contained the following conclusion:

> "The average indicated life of corrugated metal culverts in California, in fresh water and with intermittent flow, based on observations of 2500 such structures, is about eighty years.
>
> "Deterioration in corrugated metal culverts is due almost exclusively to corrosion, is preventable in many cases, and may be greatly reduced in others.
>
> "Spelter alone does not provide sufficient protection against corrosion, except under most favorable conditions of exposure, and bituminous and other protective coatings are usually desirable even where spelter is used."

According to correspondence with the California Division of Highways, the 1928 report failed to furnish conclusive data as to the relative corrosion resistance of different base metals and that portion of the report was held confidential, but the conclusion of the 20-year performance test was to the effect that there was no outstanding resistance of any one metal over the others used in the project. Six metals were used including five which conformed to A.A.S.H.O. Specification M-36, plus the sixth which was wrought iron. In this regard too, the State of West Virginia in 1928 and 1929 obtained similar results using highly acid mine water as the condition for exposure. Though this report too has been held in confidence pending more substantiating results it is believed to be a creditable and reliable confirmation of a somewhat elementary fact that acid mine-water and bare metal are extremely incompatible. Under the conditions of the test, bare metal in contact with the highly acid mine-water lasted only 86 days, and there was little if any difference observed in the life of the base metals used.

A study of the relative corrosivity of base metals in various soils and cinders was made in 1937 by the National Bureau of Standards (7), which may be interpreted as a further confirmation of the California conclusion. In this experiment pieces of the metals were buried in corrosive soils of various severity ratings and the samples were periodically evaluated. The cinders corroded the metals almost twice as fast as the severest soil. From this study too, it was concluded that the addition of small amounts of chromium, copper, nickel, and some other elements to iron and steel appears to have no marked effect on the resistance of the alloys to soil corrosion.

There is evidence too that acidity has a somewhat similar but less spectacular effect on concrete drainage structures. As already mentioned, Downs, in his survey, found some rather serious damage of this nature in West Virginia and was able to correlate pH with the annual rate of deterioration. Aside from that, it appears that very little effort has been devoted to this phase of the problem, particularily by the various Highway Departments. About the most outstanding published information came during the same fruitful era of the early 30's when Bailey Tremper* in the State of Washington made a rather exhaustive study (8) of the effect of mildly acid waters (pH 6 to pH 7) on concrete. He found the rate of attack to vary inversely as the pH, and that above pH 7 (neutrality), the rate of attack is too mild to be of practical consequence. Exposures to a naturally acid creek gave results comparable to artificially acidified water in the laboratory. None of a series of Portland Cements used was found to be distinctly superior in resistance. All the specimens exposed to acid water were severely attacked to a depth of 1/32 to 1/16 inch. The rate of attack was very fast at first and diminished to practically nil in a short time.

As the result of numerous tests, Tremper discovered that strength at any length of exposure could be related to the original water-cement ratio and the loss of lime (CaO) from the cement. There seems to be a uniform migration of the lime from the interior as well as the surface of the mass leaving a skeleton structure of the remaining calcium silicate cements, silica gel, and aggregate. Although the surface damage is the only apparent affect, a loss of as much as 50% of the original lime results in a total loss in strength of the structure. Uniformity in loss of lime was found to a depth of about 15 inches.

With regard to surface coatings he found that they afford protection for about two years and thereafter depends on the frequency of renewal.

Unfortunately for this study he did not find in the State of Washington acid concentrations comparable with those that prevail in Kentucky. If his

* Engineer of Tests, State of Washington, Department of Highways.

tests had covered the full pH range, from 2.5 to 7, it would surely have provided a broader application and significance for his findings.

The same type of surface corrosion observed by Tremper was observed in 1927 at the Gould Street Power Plant in Baltimore, Maryland, (9) where coal had been stock-piled and rain-washings had acidified the soil to a considerable depth. Holes were sunk into the soil which filled with water, and concrete specimens were submerged in the water. The highest mineral acidity recorded for the water was 6.32% by weight expressed as sulfuric acid. Although this was a static-immersion type test, surface corrosion progressed rapidly at first to a depth of 1/8 inch but after 291 days, corrosion practically ceased. In this series of tests no thought was given to the possible loss of lime from the interior of the concrete or to the strength-loss sustained. A protective gelatinous film was observed on the surface which, of course, must have been composed largely of silica and ferric hydorxide gel. Efforts were made to "sweeten" the water by the addition of limestone; this too produced a rapid reaction at first, but the iron oxide gel coated the limestone particles and complete neutralization of the acid was never achieved. In the presence of iron it was concluded to be impractical.*

Compared with the rather extensive studies of acid resistance that have been made with concrete and with metal pipe, practically nothing has been done in this respect with vitrified-clay pipe. From this particular standpoint, and quite aside from any other characteristics, it is obvious that such investigations have been considered superfluous in view of the inherent properties of vitrified clay. While the use of this material in drainage installations has generally declined over the years, it still

* For a more detailed treatment of corrosion theories and their physical and chemical aspects, see section on Theories of Corrosion, Appendix (A).

occupies a relatively prominent place in older roads. It is interesting to note, too, that Pennsylvania reports among other things the current use of "...concrete pipe with terra-cotta lining" in mining sections where drainage structures are subject to acid mine waters.

Upon the completion of this survey throughout the entire state next year, and after the test-pipe installation which is a part of this project has been in place several months, the compatibility features of drainage waters and drainage-installation materials should be well established in Kentucky. In the meantime, a large part of the intended work in the mining sections has been completed, and information from this should be of immediate benefit in making design for those regions. On the other hand, this report furnishes only a slight amount of data applicable to the non-mining sections, and therefore, it should not be applied indiscriminatly to those sections.

ACIDITY DETERMINATIONS

Several factors of rather general knowledge were the foundation for planning and carrying out the acidity determinations. The foremost objective was to determine the locations of corrosive drainage waters in the state and to develop data, by survey, sufficient to describe the boundries of critically corrosive areas. The very nature of the geologic areas of the state suggests a means of differentiation. Geologically the eastern and western coal fields are similar. Both areas have sandstone-derived top-soils and substrata of sandstones, shales, and coals. In contrast, the remainder of the state, with the exception of the Purchase area, is dominated by limestones and clay-shales with the drainage conditions largely reflecting the character of these materials. Finally, the Purchase area, which consists almost entirely of unconsolidated deposits within depths that influence drainage, is free from either of these two influences.

Coals are known to contain appreciable quantities of impurities in the form of free sulfur, iron sulfides, and numerous other minerals. The dissolution of sulfur by water and the subsequent exposure to oxygen and light produces a sulfurous or sulfuric acid; and in the same process, sulfides may be converted to sulfates. This is the reason why drainage waters become contaminated with corrosive agents - both acids and salts.

As a further consideration, surface run-off following a rain is usually of comparatively short duration; it washes over and through surface materials which have been repeatedly washed by previous rains. As a consequence, surface run-off has no opportunity to infiltrate down through the substrata to take mineral salts into solution. Water that does infiltrate not only comes into contact with these subsurface deposits but it may eventually arrive at an impervious strata and seek an outlet laterally. In coal regions, subsurface drainage often finds an outlet in mine tunnels, cuts, springs or other discontinuities of the strata. Even shaft-mines have to be pumped daily. Subsurface drainage is usually continuous and not readily affected by rains. The infiltration is slow and the rate of discharge fairly constant. It is not unusual to find flowers of sulfur and iron deposited on the face of cuts by the evaporation of water seeping from exposed coal and highly bituminous shale seams.

Many cross-drains are influenced only by surface run-off. Between rains they may dry up entirely. Ordinarily these were not of any particular concern in this phase of the survey; on the contrary, all locations where flow was continuous were of interest, but obviously only a few could be sampled. At the beginning of the work, continuous flow and proximity to highway cross-drains or culverts were about the only factors considered in selecting sample locations, and from the standpoint of correlating acidity with factors in the condition survey, this was satisfactory. However, the project had not been carried very far until it became apparent that other things must be considered if the results were to show the potential acidity for use in future designs as well as existing acidity and its effect in present performance.

Acid concentration, of course, is greatest near the source of contamination, and it is progressively reduced as the water becomes farther and farther removed from the source and receives surface and subsurface run-off enroute. Thus, to evaluate the potential in most areas it became necessary to resort to selective sampling. Some sources of contamination were sought and measurements were sometimes made deliberately at points rather far removed from an existing highway or drainage installation.

Finally from the standpoint of either objective, weather was an important consideration. Frequently it was necessary to wait from two to five days after a rain to assure normalcy before work could continue. The heavy and frequent rains during 1950 curtailed operations in the field for long periods of time. Occasionally when rain interrupted work in one area of the state, another area could be found where the rain had not occurred. This was particularily so in the eastern part of the state where localized showers are frequent. Unfortunately, these circumstances prevented completion of the survey in one year as was planned.

With this information, the course of sampling was outlined in a general way; but the appraisal of local conditions was obviously dependent upon the judgement of the observer on the spot. County maps and the general knowledge of the coal fields were helpful in determining areas of concentrated mining and for recording sample locations. Had aerial photographs been more readily available, the sampling program might have been conducted more effectively and methodically. Fortunately the observers were familiar with most of the areas of the state and no great waste in effort resulted.

From the standpoint of planning, it seemed advisable to observe and and test conditions of extremity as early as possible in the survey in order to become familiar with the various degrees of acidity that might be encountered. Early experience showed that by observing certain tell-tale features of the streams and culverts, acidity could be recognized with a fair degree of accuracy. Minnows and tadpoles can not live in highly acid and sulfurous water and their presence is an indication of an acid-free location. The presence of vegetation in the bed of an intermittent or braided stream is also an indication of an acid-free water. Of course, the presence of a corroded culvert is positive evidence that the drainage water was acid at one time or another.

Field trips were selected in such a way as to provide a maximum of areal coverage and were usually confined to the numbered state routes. Ordinarily the acidity measurements and the condition survey could be carried along together; but in some instances, such as periods following rains and while run-off was exceptional, condition surveys could be made but acidity determinations were stopped. Likewise, some trips were made for the sole purpose of investigating extreme acidity; and in those instances, culvert condition observations and ratings were held to a minimum or left off entirely.

Equipment and Procedures

Electrical conductivity was used as the method for testing the water despite the fact that the most used and best known method for tests of this sort is the pH determination. Preference for conductivity was based entirely on preliminary judgement and not on experience. The reason for this choice may be justified by explaining the significant difference between the two values. pH is defined as log (1/H+ concentration); as such a pH 7 would indicate a H+(hydrogen ion) concentration of 1×10^{-7} equivalent H+per liter of solution. A pH 1 would represent a concentration of 1×10^{-1} or 0.1 equivalent H^+ per liter. Thus a pH 1 is 10,000,000 times more acid than pH 7; likewise, a pH 6 is ten times more acid than pH 7. But pH serves only to define the acid concentration which is, of course, the severest corrosive agent encountered in drainage waters. It does not indicate the presence of corrosive salts which are usually associated with the acids. On the other hand, electrical conductance does not differentiate between acids and salts, but rather integrates all ions in terms of the current-carrying capacity of the solution.

The ease with which the current may flow depends upon the number of current-carrying ions present and their mobilities. Hydrogen ions, being very mobile, have three or four times as much effect upon conductivity as do ions of calcium and iron. Therefore, a conductivity measurement is a summation of all ionized solutes. Since soluble and ionized salts may, even in the absence of acid, cause severe corrosion; and since conductance takes these into account while pH does not, it was concluded that the more accurate measure of the corrosive potential in the water could be obtained by conductance measurements whether the readings were ever translated into absolute terms of concentrations of the various ions or not.*

For this purpose a Conductivity Bridge, Model RC-16, manufactured by Industrial Instruments, Inc., was employed in conjunction with a platinized electrode assembly shown in Fig. 1.

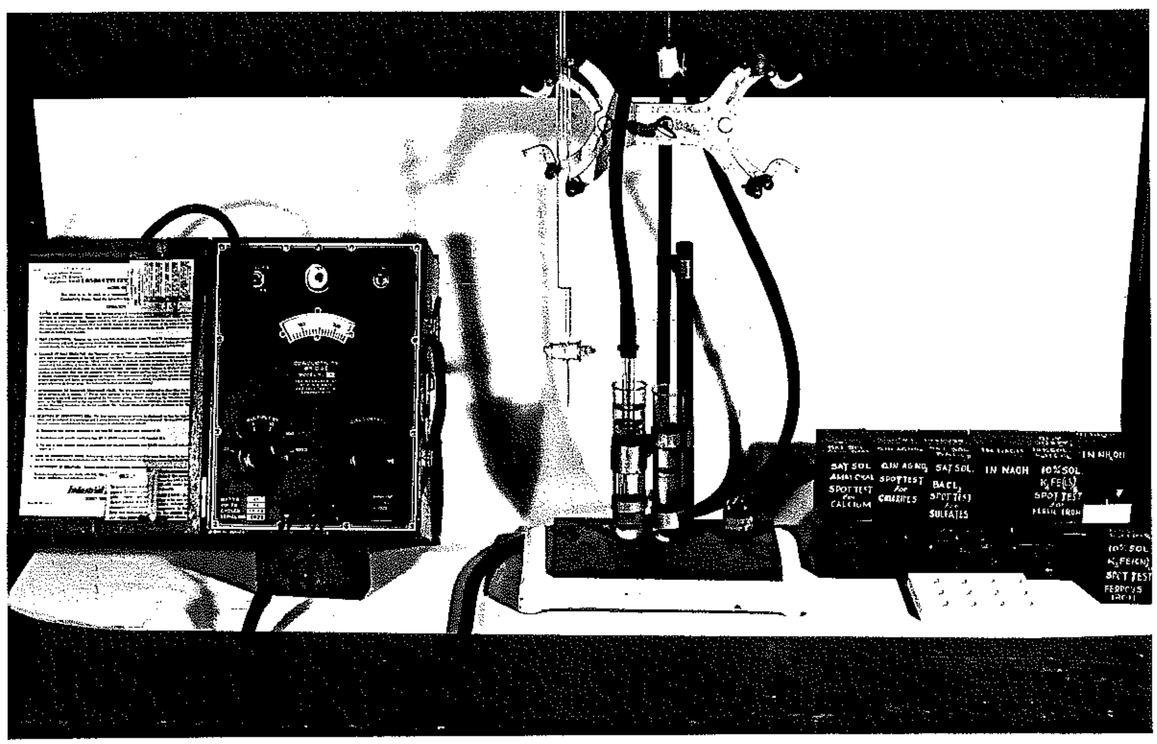


Fig. 1. Water Testing Equipment: Conductivity Bridge, cell, burette, and qualitative reagents.

* For a more thorough theoretical and mathematical treatment of the application of electrical conductivity to aqueous solutions see Appendix B.

With this and accessory equipment, a mobile laboratory was improvised in a 1/2-ton pick-up truck shown at an actual acid location in Fig. 2. By this means it was possible to perform on-the-spot tests in fifteen to twenty minutes.

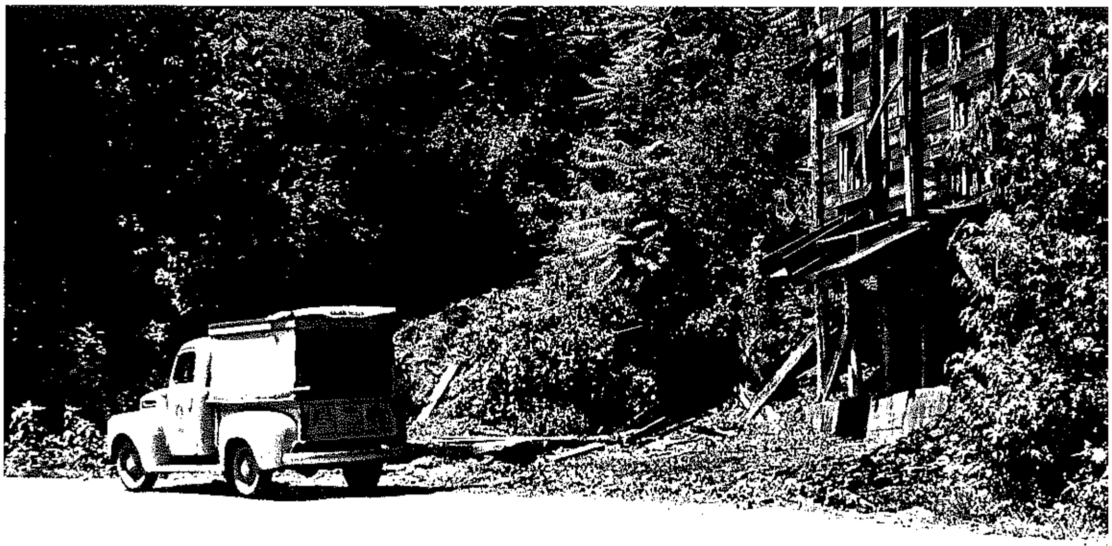


Fig. 2. Mobile Laboratory equipped for on-the-spot analyses, shown at a typical location of high acidity. Abandoned mines such as this one are prevalent along roads in many parts of eastern Kentucky.

Since the conductivity instrument was designed to operate on a 110 volt, 60 cycle, A.C. power supply, a 50-watt Cornell-Dubilier Vibrator converter, Model 6R 5, was used to convert the truck's battery source in order to supply power to the instrument. The entire apparatus was secured on a work-table in the rear of the truck.

For the conductivity measurement, only about a 60 c.c. sample of the water was required. It was dipped up or taken in a syringe, poured into a clear plastic test tube (to prevent breaking the glass housing of the electrodes), and the temperature was adjusted by warming the tube with the hands or cooling it with ice as required. The dip-cell was then inserted into the test tube and a reading taken. Values read from the dial were in ohms, and these in turn were converted to conductivity.

A rather elementary set of qualitative reagents and a spot-plate were provided and a cursory qualitative chemical analysis performed on samples showing extreme pollution in the conductivity test. It was possible with the aid of the burette shown in Fig. 1 to titrate the extent of acidity against a previously standardized alkali. This test too was performed only on the very acid waters. In particularly interesting cases, a quart sample of the water was brought to the laboratory for further analysis. For the titrations, alcholic phenolphthalein indicator was used to determine the total mineral acidity. In some cases the free mineral acidity was determined using methyl orange as the indicator as recommended by Snell and Biffer (10).

In the later stages of the survey, some pH values were taken using indicating paper and color charts.* This method was found to be reliable in most cases, but there were some waters which tended to bleach the indicator, making it impossible to read a satisfactory value. Usually, however, a good correlation was found between pH values calculated from the titrations and those measured by this method, although the values by the two methods were never identical.

These supplementary tests seemed advisable in view of the limitations inherent in the conductivity measurements. It was also of interest to compare values such as pH and titrable acidity with conductivities and to identify the contaminating elements.

* pHydrion paper, manufactured by Micro Essential Laboratory, Brooklyn, N.Y.

Results

Fig. 3 is a map of the state showing the results obtained thus far in the acidity determinations, and also, the extent of the condition survey. It shows the approximate location of the samples and the frequency with which they fall into arbitrarily chosen ranges of acid and salt concentrations as determined by conductivity. The roads shown by solid lines are those covered in connection with the culvert condition phase of the survey as well as in the acid water phase.

The map, by itself, is a limited presentation of the data; for among other things, it does not differentiate sources of samples. Most of the acid and intermediately acid samples represent mine and coal-seam drainage while those classed as non-acid were generally sampled at random from streams and side-ditches, and represent surface and near-surface drainage. Test data for each sample are listed in Appendix D. The data there are cataloged by districts, counties, and roads. Exact locations of sample sites are given by reference points.

In the eastern coal field an effort was made to sample and test every location encountered that might be affected by mine proximity. This does not imply that every mine was tested. Many mines do not drain water, many others were far removed from the road or drained away from it. Usually only one culvert is affected by any one mine or spring. If the water travels far enough before reaching the road, drainage from hills and fields may dilute the water beyond the abbritrary limit of acid and salt contamination.

In the western coal field, the tendency is for some streams to be continuously acid. The gradients of the streams are generally slight and great reservoirs of mine drainage may collect in the channels. As a result of this sluggishness, a given stream may be sampled at several locations along a particular road and yield the same degree of acidity. Surface run-off in this territory is rarely sufficient to flush the streams, and as a result the water usually looks red or yellow.

Both the tabulations of data and the areal distribution of samples shown on the map fail to take such matters into consideration. It is evident that highly acid waters are spread throughout the two coal fields, and yet within these regions there is a predominance of non-acid waters. The ratio of the two, for any number of samples taken, would depend upon the selectivity of sampling. This is especially true in the eastern coal field, but hardly less true in the western. Actually the acid and non-acid waters may exist very close to each other.

A common situation is illustrated by Fig. 4, which shows a drift mine from which highly acid water flows and, although this usually amounts to seepage, it is fairly regular. Water from this mine flowed along the side-ditch, merged with a larger non-acid stream, and then proceeded through a cross-drain. From the point of merger the concentration became progressively lower, and the nearest culvert received only mildly acid water. No other culvert in the vicinity was affected. Where a cross-drain is immediately adjacent to the source, the effect is, of course, quite different. Mines of this type are numerous in the eastern field, and the associated drainage is always acid. In the western field, drift mining is relatively un-important.

In contrast to the primitive mine shown in Fig. 4, the very elaborate mining operation pictured in Fig. 5 produces large quantities of coal. In this case the coal is washed free of mine dust, and by means of the settling basins in the foreground a feeble attempt is made to recover dusts and solids

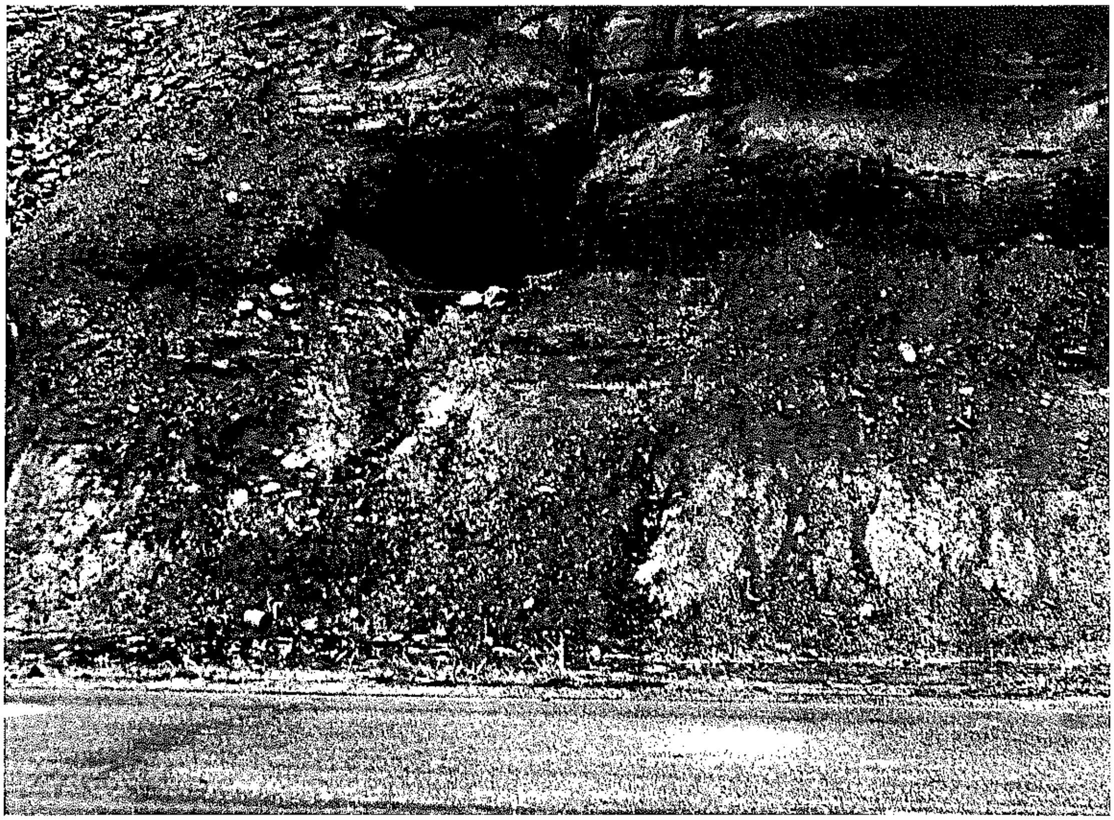


Fig. 4. Drift mine opening in the face of a cut, located on Ky. 180 between Cannonsburg and the Junction with US 23. Boyd County, water sample no. 34. Specific resistance - 346 ohms at 25°C., measured pH -3, titrable acidity - 0.026 eq./ liter, positive qualitative tests for - Ca^{++}, $SO_4^{=}$, Fe^{++}.

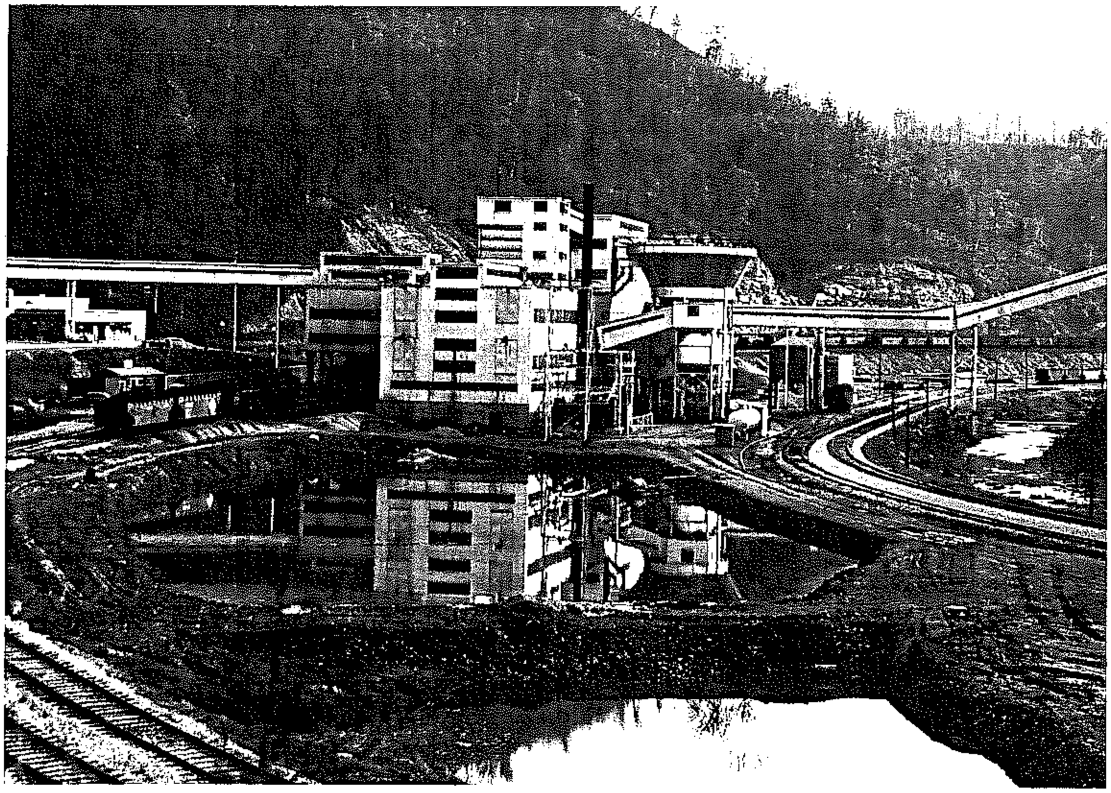


Fig. 5 Tipple and settling basins, Inland Steel Mine, at Wheelwright on Ky. 122. This is one of the largest coal processing plants in the State. The stream at the right is the left fork of Beaver Creek which receives the over-flow from the settling basins in the foreground.

A similar though more recent development is now in progress in Breathitt County at Evanston (Pond Creek, Pocahantas) which promises to be even larger than the one shown above. Both strip and drift mining are already in progress there.

Industries are demanding more and more that coal be washed free of mine dust and dirt and at the present time a good percentage of the dust eventually enters the nearest stream.

There are several of these tipples located at the very headwaters of the state's major streams; the Cumberland in Harlan County, the Kentucky in Letcher County, and the Big Sandy in Pike County. Although critically acid at the source, subsequent dilution by down-stream tributaries reduces the concentration far below the point of critical acidity.

before the water is emptied into the streams. Despite this, streams may be discolored as far as twenty-five miles down-stream. Solubles, acids, and salts are discharged into the streams without further recourse. The concentration of the acids in water discharged from these elaborate operations may not be as great as that coming from the smaller mines, but its influence is carried over a much greater distance due to the greater volume of water discharged.

These particular cases serve to demonstrate the great number of seemingly intangible variables that ought to be considered in any attempt to integrate the data in Appendix D either areally or locally. Taken at face-value, the tabulated results and the map show that acidity can occur indescriminately throughout the coal region and that, depending on the local conditions, it either may or may not exert a direct influence on a highway drainage structure.

It is of interest to this phase of the survey to be able to predict the acid producing potential of an area within the coal fields which may as yet be undeveloped. In this regard, there appears in Appendix C an attempted correlation of the areal distribution and sulfur content of coal deposits. In the absence of actual acidity measurements that would establish the extent of influence, the information is an indefinite yet valuable indicator of the acid-potential of the area.

During the course of this survey, several photographs were taken illustrating representative features encountered. Unfortunately, it was not possible to demonstrate with black and white pictures such significant features as yellow and red streams, rust, and other colorful features of corrosion. Therefore, in addition to the illustrations included herein, several color-transparencies were prepared as part of the permanent records of this report and may be seen upon request.

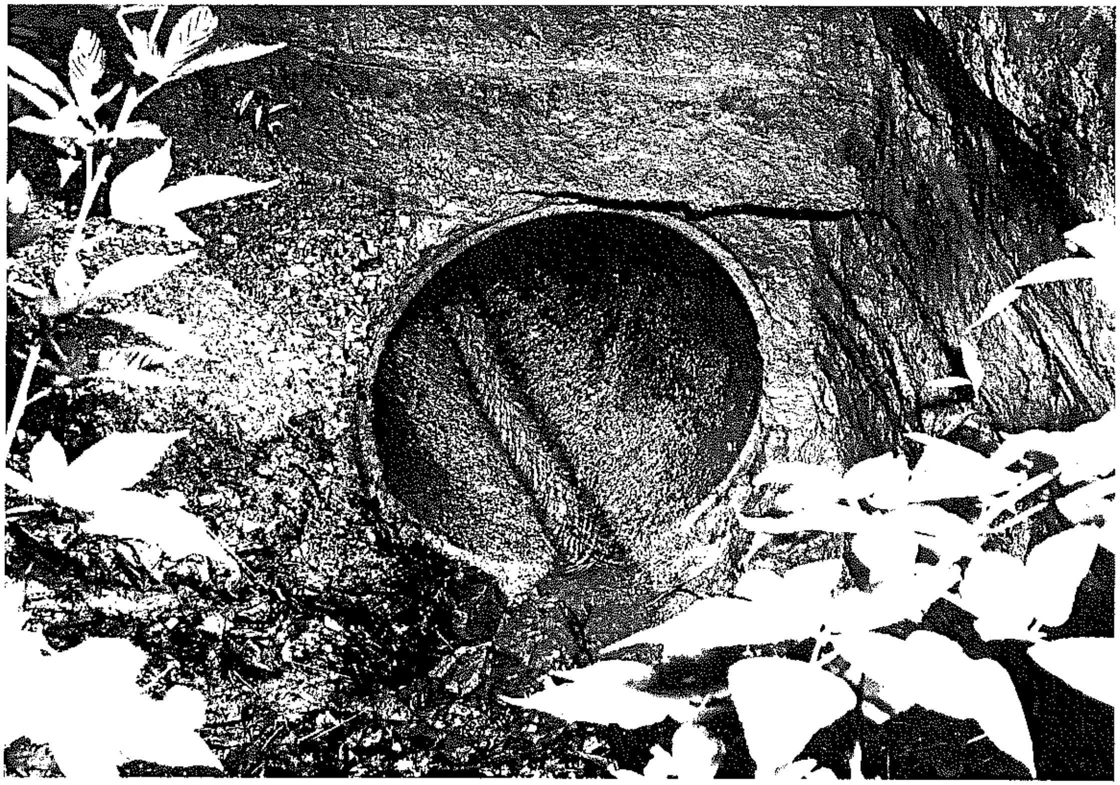


Fig. 6. An etched concrete cross-drain with sandstone masonry headwalls located on Ky. 74 in Bell County, 7 miles from Middlesboro. The sourse of water here was an abandoned mine and slack-pile. The water was continuous flow as evidenced by the corroded channel. It was not possible to determine how long the acidity had existed or what variations have occurred in the degree of acidity. The pipe, according to records available, has been in service since 1927.

Fig. 7. Corrugated metal cross drain on US 60 at Bluestone. This culvert, for which the records indicate service-life of twenty-nine years, was replaced in the process of reconstructing the road shortly after this photograph was taken in June, 1950. The invert has been eaten away and water is standing in the channel. This static water (sample No. 16) showed a specific resistance of 930 ohms and positive qualitative tests for sulfates, chlorides, and calcium. It is not known definitely what the source of contamination has been or how long the corrosive agents have been active. There is a building-stone quarry above the road which has been operated intermittently over the past several years. Also, the location is on the very edge of the eastern coal field.

Fig. 8. Etched wing-wall on US 60 in Union County, 14.8 miles from Crittenden County line. At the time of sampling only residual water was found. Water sample No. CY-13 gave a specific resistance of 357 ohms. Positive qualitative tests were obtained for chlorides only. There are several producing oil wells in this area and, although the source of contamination can not be attributed directly to them, the presence of chlorides and the absence of iron and sulfates seems to indicate that the contaminating source is something other than coal mines. It is not unusual in the drilling of oil wells to pump highly concentrated salt water from the wells.

CONDITION SURVEY

Inasmuch as it was necessary to examine numerous culverts in the search for acid waters, a record of the general culvert conditions observed was considered to be of supplementary interest in conjunction with the acid water data. It was necessary, however, to limit this phase in favor of the acid water study. Based on a rather conservative estimate of 25,000 culverts to be examined and allowing five minutes for each one, a total of 261 working days would be involved exclusive of the time spent enroute between culverts. Consequently, at best, the examinations were considerably abbreviated.

Procedures

The roads covered in the condition survey were largely selected for convenience in a travel itinerary, which in turn was dependent on areas of interest from the standpoint of the acidity determinations. Almost invariably when a road was included in the condition survey, all culverts or cross-drains that could be located throughout the entire length of the road were inspected. The same was not true for entrance pipe, because it was seldom possible to determine whether replacements had been made after the road was first placed in service, and great discrepancies in data pertaining to entrance pipe could easily develop.

Age of an installation was a factor of primary importance, and in the beginning it was intended that this information be developed in the field at the time inspections were made. This did not work out, and recourse to records in the Central Office became necessary. Even then, on very old roads it was difficult to determine whether culverts placed in the original construction had or had not been replaced since that time.

These details in the data have not been sufficiently exploited for the culverts inspected thus far. Age as a factor in the results, has been practically ignored in this report with the intention of giving it full consideration in the final report next year. Likewise, the differences in areas within the state have been relegated to the final report, since only a limited amount of data have been obtained outside the coal regions.

The examination of a culvert was usually made by inspecting from both the entrance and the exit -- hardly ever the exit alone. The culvert was identified as to type, and assigned to one of the five condition categories as follows:

Excellent - The culvert showed no deterioration, cracking or structural defects; no stoppage of any sort, and seemed to be functioning properly.

Silting - Structurally sound, but the passage of water impeded by residual deposits of silt, sand, gravel, rocks or organic matter.

Caving In - Any portion of the culvert broken or bent to the extent that the flow of water was impeded.

Undermined - Water flowing other than through the culvert due to faulted sections or seepage channels.

Miscellaneous - Etching, or corrosion, and abrasion.

Certain features of the culvert such as the presence or absence of headwalls, exposure due to removal of cover material (particularly for entrance pipe), and other factors of influence were noted on the inspection record form. Notes were also taken as to the road-type and condition of the surroundings.

Results

To date, the condition survey has covered 52 counties, only 45 of which are considered complete. A total of 2,376.2 miles of road are represented and 13,149 culverts and entrance pipe are listed. The location of the roads are shown on the map in Fig. 3 (following page 18), and all data taken in this phase of the project are cataloged by counties, roads, and reference points in Appendix E. Table I is a limited statistical summary of these survey results, presented without regard for different areas of the state, the size or age of culverts, or the age of the roads. The significance of the results in each category, if such can be drawn within these limitations, can be best judged when the performance groups are considered individually.

Excellent. On the average, 82.3 percent of the culverts and 58.8 percent of the entrance pipe surveyed to date are showing excellent performance. Insofar as the culverts are concerned, of the principal types that are commonly used in present day construction, only the concrete box was above the average in excellence. This was largely due to silting which, as subsequent discussion will show, is the manner in which the greatest number of drainage installations fail to function properly. The concrete box is particularly free from this, and, of course, the sizes and locations peculiar to these structures set them apart from the general run of cross-drains.

Limitations in the number of samples representing some types of entrance pipes make an analysis hardly valid. Here again silting, as an adverse feature among those pipes inspected was so predominant that not more than 80 percent within any group that is used on construction today could be classed as excellent.

Table 1 Summary of Results From The Condition Survey

Installation	Type	No. Surveyed	Condition Rating									
			Excellent		Silting		Caved In		Undermined		Miscellaneous	
			No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.
Cross Drain	Concrete Pipe	6,203	4,676	75.4	1,506	24.3	8	0.13	1	0.02	12	0.20
	Concrete Box	3,782	3,640	96.2	127	3.4	-	-	11	0.3	4	0.1
	Concrete Slab	120	116	96.7	4	3.3	-	-	-	-	-	-
	Stone Slab	108	95	88.0	13	12.0	-	-	-	-	-	-
	Corrugated Metal	296	183	61.8	45	15.2	8	2.7	-	-	60	20.3
	Vitrified Clay	1,123	858	76.4	256	22.8	9	0.8	-	-	-	-
	Wood & Cast Iron	6	6	100.0	-	-	-	-	-	-	-	-
	Total	11,638	9,574	82.3	1,951	16.8	25	0.2	12	0.1	76	0.65
Entrance Pipe	Concrete Pipe	524	366	69.8	131	25.0	14	2.7	1	0.2	12	2.3
	Concrete Box	20	16	80.0	4	20.0	-	-	-	-	-	-
	Concrete Slab	1	1	100	-	-	-	-	-	-	-	-
	Stone Slab	4	2	50.0	2	50.0	-	-	-	-	-	-
	Corrugated Metal	859	439	51.1	282	32.8	123	14.3	-	-	15	1.8
	Vitrified Clay	106	68	64.2	33	31.1	5	4.7	-	-	-	-
	Wood & Cast Iron	9	4	-	3	-	2	-	-	-	-	-
	Total	1,523	896	58.8	455	29.9	144	9.5	1	-	27	1.8

Silting. Not only was silting the major source of failure among the cross-drains, but all types of installations of any consequence were affected. At face value, the data showed that on the average 16.8 percent of the cross-drains were silted. The rate of silting in the entrance pipe was 29.9 percent. Actually, the figures themselves must be tempered some in judging the severity of this type of failure, for it will be noted that the definition set fourth on page 28 merely indicated that flow was impeded - not necessarily blocked. Actually, the silting ranged from moderate impediment to complete obstruction. A good illustration of the latter condition is shown in Fig. 9.

To attribute conditions of silting to any particular factor would be impossible. About the best correlation should come through consideration of geologic and soil areas, construction features, and maintenance practices. Cleaning a silted drain involves relatively simple measures in comparison with the correction of other failures. Cleaning alone, however, does not eliminate or promise permanent elimination of silting. This is particularly true when erosion control along a good portion of the rights-of-way in the state is not feasible, and still more true when it is shown that erosion from adjacent fields into side ditches is widespread where the rights-of-way are narrow.

Caved In. The figures show that structural failures resulting in collapse or caving-in of cross-drains are negligible. For entrance pipe this factor is much more important, but there the reasons are obvious. Almost invariably, the ends of a pipe have not been protected by a headwall or the width is so restricted that vehicles have crushed the ends, or else the cover material has been removed and direct application of loads from tractors or trucks onto the pipe has caused breakage.

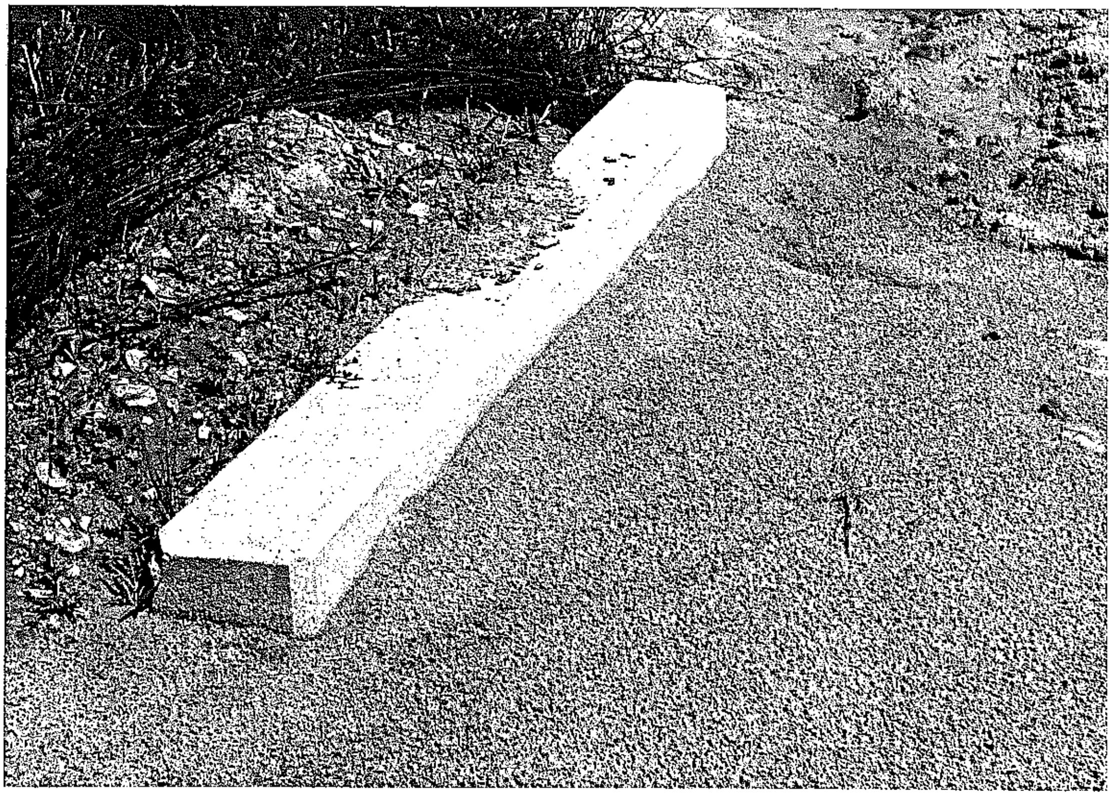


Fig. 9 Entrance to a cross drain completely obstructed by silting. This location on Ky. 174 between Madisonville and Webster County Line, accentuates the importance seeding and mulching for erosion control as soon after construction as possible.

A large number of the silted cross drains observed to date were on newly constructed highways, yet these represented only a small portion of the total. Grading a project one year and surfacing it the next introduces an erosion and culvert-silting situation which is difficult to overcome, particularly when quantities for shouldering are omitted from the original grading contract. Effective cleaning of all cross drains and entrance pipe carried out along with the erosion control measures should be satisfactory, provided erosion control is part of the contract.

In many cases the head-room may be insufficient from the beginning; from a practical standpoint, it seems definite that structural failure of cross-drains is of no concern whatsoever in present day construction practices, and that some measures that would prevent a high rate of damage to entrance pipe are more expensive then the costs of replacing those that fail. Although the results from this survey show only about 10 percent failure of entrance pipe from cave-in, it is known that the figure is actually much greater when replacements that are not represented in the survey are taken into account.

Undermined. The designation "undermined" is a misnomer so far as the causes are concerned. The condition may often be no fault of the drain itself. Spreading of fills as they settle may pull the pipe apart or cause faulting at the joints. Then, too, a very pervious rock fill is conducive to the action; particularly when the water enters the drain satisfactorily, finds some outlet within the drain, and flows through the pervious material beneath the pipe to the downstream side of the fill. Actually, in many instances the drainage may be effective none-the-less, and as long as the structure is not actually undermined to the point of serious settlement and collapse there is no real failure. A situation such as this is shown in Fig. 10, the stone headwalls there being misleading so far as the composition of the fill itself is concerned.

Undermining is even less prevalent than caving-in of cross-drains and certainly can not be considered of any consequence at all in the performance of the existing structures surveyed.

Miscellaneous. The category "miscellaneous" is made up almost entirely

Fig. 10. Undermined culvert on Ky. 15 in Perry County, where water sample No. 1 was taken. The pipe has been pulled apart at joints near the upstream side of the fill, and water passes beneath the pipe to the downstream side during period of flow.

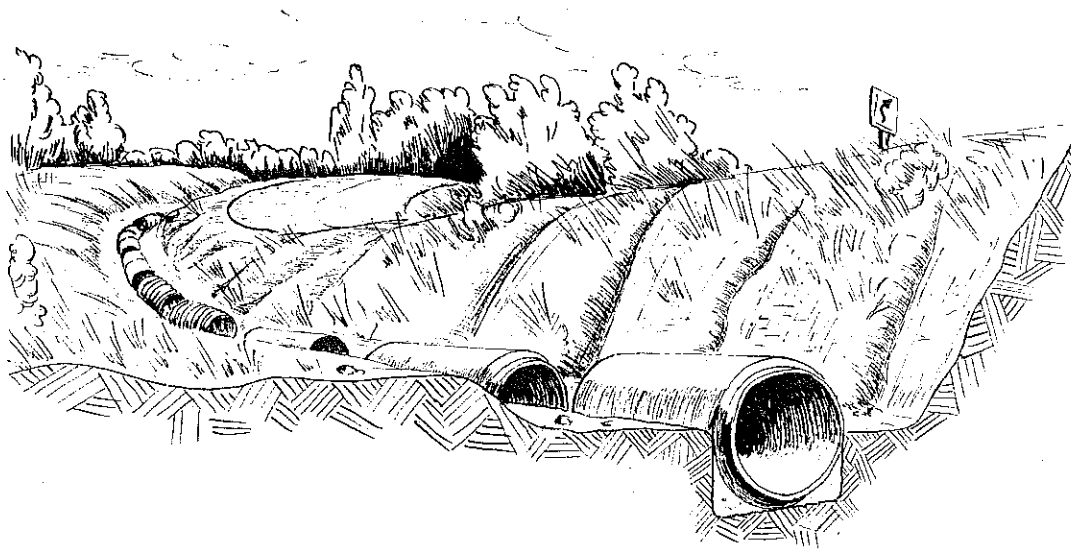
of deterioration under the attack of acids, although corrosion by other means and abrasion caused by coarse, irregular material carried by flowing water are included also. For all culverts or cross-drains taken collectively, the damage to those surveyed did not exceed 1 percent. In view of the fact that the bulk of data in this progress report applies to the mining regions where acids are widespread, it appears certain that the performance finally recorded when the entire state is surveyed will show that acid damage is extremely limited for the state as a whole.

The damage to corrugated metal cross drains surveyed thus far was high-about 20 percent being affected. The degree of failure varied from severe etching to complete corrosion of the invert. It is impossible to estimate the results that would have been obtained had the use of metal pipe for cross-drains been more widespread, or if the metal had been coated at the relatively few installations considered to date. Not a single coated or paved pipe was encountered.

Figures in the miscellaneous category applied to entrance pipe are not good indicators of the conditions pertaining to acids, for the great majority of the recorded entrance pipe were in areas outside the mining regions where acids seem to be of little consequence. The fact that in the mining areas,(particularly in the eastern part of the state) population and industry becomes concentrated immediately adjacent to the roads and entrance pipe have been added from time to time without any record of dates, makes any evaluation uncertain. This,of course, is the same situation that must be considered everywhere so far as replacement of pipe is concerned, and it makes evaluation of entrance-pipe conditions a rather indefinite thing.

Some concrete pipe and box culverts were severely attacked by acids, although only 0.2 per cent of the 6,200 pipe and 0.1 per cent of the 3,800 boxes were thus affected. In some cases, of course, the etching was light and in no case was there evidence of complete disintegration to the point where the concrete had been completely carried away. This does not necessarily mean that damage has not carried through the entire thickness of the pipe where the acid attack has been severe. Further investigation would be necessary to determine the depth of influence.

CULVERT TEST INSTALLATION



Certain fallacies exist in the evaluation of culvert life-expectancies on the basis of field survey data, since many of the relevant factors such as age of the installation and the duration of the corrosive conditions are often indeterminate or vague. This is particularly true on old roads, and even more so with regard to entrance pipe where dates of installation rarely conform to the dates of the original grade-and-drain contracts.

In order to establish more tangible evidence of the relative compatibilities of culvert materials under so-called adverse conditions of acidity, a series of test installations have been proposed adjacent to U. S. 41 at the south city limits of Mortons Gap in Hopkins County. The site selected is at the north end of the L. & N. overpass and on the west side of the pavement. The ditch in which the pipes are to be placed cuts through slack and mine refuse and is fed by seepage from springs or abandoned mine tunnels on the hillside overlooking the site. The basis for selecting this water for testing culvert pipe was its ease of accessibility, continuous flow of very consistently acid water, and minimum excavation required for installing the pipe-sections. The conductivity tests made early during the last summer gave the following results:

Specific Resistance - - - - - - - - -	179 ohms
Pos. qual. tests for- - - - - - - - -	Iron, calcium, Magnesium, and sulfates.
Titratable acidity- - - - - - - - - -	0.0127 equivalents per liter.

The water was tested again approximately one month later and no appreciable change was observed in the concentrations. Only one sample of water analyzed thus far exceeded this sample in acid concentration - as determined by the tests mentioned above.

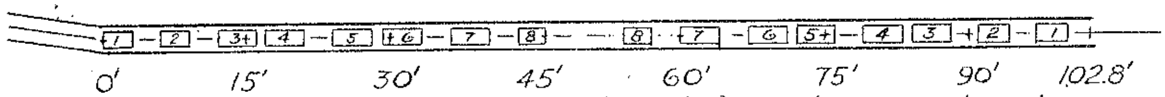
Since part of the installation may extend outside the present right of way held by the Department, an easement on the adjoining property has been secured from the Western Kentucky Coal Company, and the pipe sections to be tested are on hand. Unfortunately, freezing weather and snow has, up to the time of this report, prevented their actual installation.

In lieu of actual photographs, a plot plan, plan view and profile diagram of the proposed installation are shown by Fig. 11. The following pipes will be tested:

1. Reinforced Concrete Pipe.
2. Reinforced Concrete Pipe - Bituminous Coated*
3. Corrugated Metal - Plain Galvanized - Asbestos Bonded-Coated &Paved
4. Corrugated Metal - Plain Galvanized - Paved and Coated.
5. Corrugated Metal - Plain Galvanized - Half Coated & Paved.
6. Corrugated Metal - Plain Galvanized - Full Double Coated
7. Corrugated Metal - Plain Galvanized
8. Vitrified Clay Pipe - Double Strength

All pipe are 24 inches in diameter and two sections of each type have been procured.

* A light coating of asphalt cement will be applied by brush or spray prior to installation. This is not a standard product of the concrete pipe industry, but the coating - applied by Department personnel - is of interest since some concrete structures have been corroded by acids.

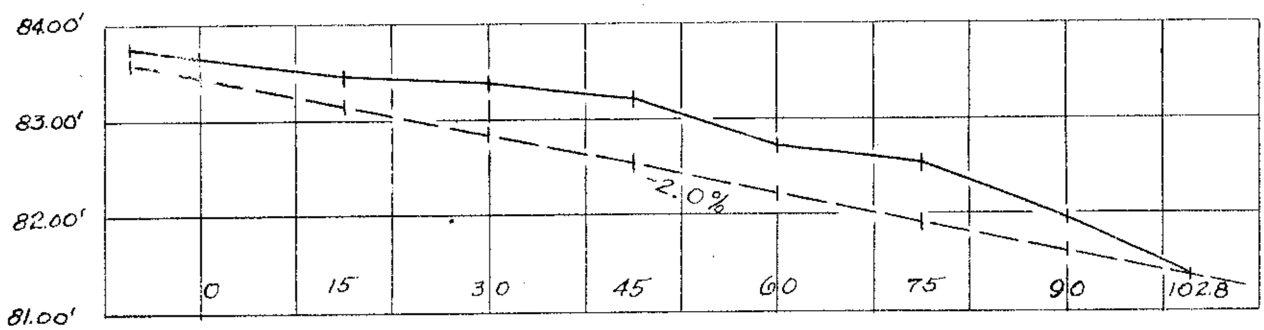


PLAN VIEW

℄ AND CHANNEL

SCALE $\frac{1}{4}''$ = 5'-0"

1. [redacted] reinforced concrete pipe
2. reinforced conc. pipe coated
3. C.M. asb. bond. coated & paved
4. C.M.(plain galv.) coated & paved, Ky. spec.
5. C.M. paved & half coated
6. C.M. double full coated only
7. C.M. plain galvanized
8. vitrified clay



PROFILE ℄ AND CHANNEL

VERTICAL SCALE $\frac{1}{2}''$ = 0.1'
HORIZONTAL SCALE $\frac{1}{4}''$ = 5'-0"

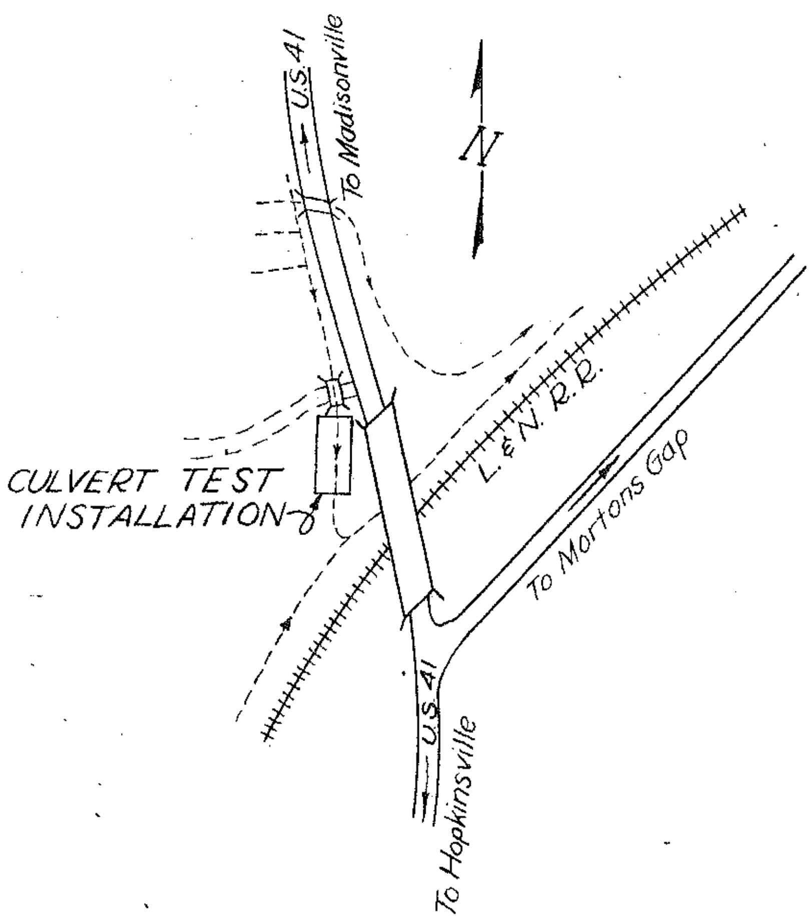


Fig. 11

PLOT PLAN
CULVERT TEST INSTALLATION

In order to eliminate possibilities of any end effects; such as neutralization of the acid by upstream pipes, two series of the pipe will be installed. The series of the downstream set will be in reverse order to the upstream set. Thus, comparable rates of corrosion in both series for any type of pipe will be an assurance that no such extraneous influences occurred.

There are some uncertainities in this project since there is no assurance that the flow of water will be continuous through the next several years, or that the acid and salt concentrations will remain constant. During rains, the pipe will have to accommodate surface run-off as does any other pipe, but this will be of minor importance as far as corrosion is concerned since rainfall and consequent dilution of the acid water will occur a relatively small portion of the time. A periodic check will be made on the condition of the water to make certain that any changes that do occur will be considered in the final evaluation.

In view of the apparent severity of the corrosive agents present in this water, the test will be rigorous; yet it may take from six months to a year to realize any results from the test - that is failure of a pipe that would be entirely unsatisfactory under corrosive conditions. Of course, the more resistant pipes may never show any appreciable damage.

CONCLUSIONS

To the extent that this survey may represent the state as a whole or the areas within the state that were surveyed, the following conclusions are drawn:

1. Coal and other sulfur-bearing natural deposits are the foremost and probably the only widespread sources of severely corrosive drainage waters in the state. However, corrosive agents other than acids are produced and are important though their effects are localized

2. Although the acid concentrations in waters throughout the two coal fields may be very high, the vast majority of the water carried in ditches and through drainage structures in the highway system is non-acid or mildly acid at the most.

3. The acid potential is generally greater in the Western Coal Field than in the Eastern Coal Field. The three principal reasons for this are: the higher average sulfur content of the coal, the type of mining operations which expose more of the sulfur-bearing materials to surface water, and the topographic features which limit the gradients of drainage ways and permit the accumulation of acids under virtual conditions of ponding.

4. Viewed from the standpoint of distribution by counties, waters in Hopkins and Muhlenberg counties are the most seriously acid of all in the state.

5. Within the region of high acid potential, corrosion at a highway drainage installation depends upon the location of the drain with respect to the source of the acid. The concentration of acid is greatest at the source, but the acid usually becomes diluted by tributrary water and the concentration is rapidly reduced. Drainage structures which receive water only a short distance from the source of acidity are always damaged unless

they are of acid resistant materials.

6. All types of culverts of modern design, except vitrified clay pipe, were damaged to various degrees by acid waters. The highest percentage of damage in cross-drains was sustained by uncoated corrugated metal. There was no possibility for evaluating the effect of acids on bituminous-coated or paved metal pipe since none has as yet been encountered in the survey.

7. Silting was by far the most extensive type of failure in cross-drains and entrance pipe. Undoubtedly this varies greatly with the areas of the state, but the data thus far are not sufficient to differentiate them on that basis.

8. Silting is a result of erosion of exposed soil and debris in the drainage area and within the drainage-way contributing to a culvert. Some of this is outside the highway rights-of-way, but a substantial amount of the "silt" originates within the land that is a portion of the roadway.

9. Some of the most severe silting occurs on projects constructed with in the past few years, where effective erosion control measures would relieve many drainage structures of silting. However, the greatest amount of silting occurs along old roads with limited rights-of-way and steep backslopes where erosion control may not be feasible.

10. Cleaning cross-drains and entrance pipe provides temporary relief from silting, but cleaning alone does not correct the cause of the failure.

11. Structural failures of cross-drains are so limited in the highways surveyed thus far that this type of failure may be regarded as insignificant in the performance of cross-drains. An appreciable percentage of the entrance pipe have been caved in, but design or construction features that provide limited head-room or expose the ends of the pipe to damage account for most of this. Also, removal of material from above the drain permitting the application of heavy loads directly on the pipe is indicated in many cases.

12. Throughout the areas and roads surveyed to date, the cross-drains, on the average, are functioning properly in better than 80 per cent of the cases; but for the entrance pipe (where figures are less reliable) less than 60 per cent of the installations are in excellent condition. Exclusive of silting, approximately 98 per cent of the cross-drains and almost 90 per cent of the entrance pipe show no deficiencies in performance.

13. Final judgement of the condition of drainage installations through out the state should take into account, not only the data covering additional roads which will be surveyed next year, but also, topographic features, soil areas, age of installation, and the prevailing conditions of the drainage waters in the areas of the state not yet covered.

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Appendix A

THEORY OF CORROSION

Corrosion is defined as the disintegration of metallic and other solid surfaces by chemical action.

Every year inestimable damage is caused by this gnawing action on construction materials and industrial equipment. There is no single explanation for why corrosion occurs nor is there a definite scale of relative corrodibility of materials. Most instances of resulting damage can be explained by careful study of existing conditions. Often, a knowledge of chemistry, careful planning, and protective measures commensurate with the cost of an installation will prevent or avert damage. Such matters are very important to manufacturers and design engineers who bear the responsibilities of qualifying a material to perform satisfactorily under severe exposure conditions. It is understandable that industry would devote a great deal of time and energy to research and study of the causes and prevention of corrosion. This brief digest on causes and prevention is offered as a record of research preliminary to development of equipment and procedures for the survey in Kentucky.

All acids contain hydrogen. Metals reacting with an acid liberate hydrogen in the form of a gas. If the acid is sufficiently strong the reaction may progress violently. Those metals which are the most active in liberating hydrogen are also the most active in combining with oxygen to form oxides (rust). On this basis an activity series has been suggested, sometimes called the electro-chemical series, which is listed below in order of decreasing activity.

1. Potassium	6. Zinc	11. Copper
2. Sodium	7. Iron	12. Mercury
3. Calcium	8. Tin	13. Silver
4. Magnesium	9. Lead	14. Gold
5. Aluminum	10. Hydrogen (3)	

The metals at the top of the series react violently with water and often explosively. Magnesium will react noticeably with hot water but only slightly with cold water. The other metals react progressively less spectacularly and finally gold, silver and the more noble metals do not liberate hydrogen at all. However, super-heated steam passed over red-hot iron will liberate hydrogen and results in the formation of Iron Oxide rust. These are the fundamental reactions in the corrosion of metals. Usually in the case of metals used as structural members and given protective coatings, the progress is too slow to be observed and may continue for years before the tell-tale evidences are discovered.

The ancients evidently understood corrosion and developed methods for protection against it. Bronze statuettes recovered from excavations at the pyramides still have coatings of bituminous material. The same technique, being well known, is used extensively in these modern times, with the object being to inhibit deterioration of metallic surfaces under attack by the elements. Other protective coatings, such as paints, lacquers, or plating of more noble metals are used where circumstances warrant them. From a scientific standpoint, each metal, as well as each alloy, presents its own individual problems.

Air and water are by far the most important natural carriers of corrosive agents. Iron will not rust in dry air, neither will it rust in pure water; but either aerated water or moist air will cause it. Consider rain water as it falls through the air. When it reaches the ground, it is very nearly saturated with both oxygen and carbon dioxide. In some industrial areas it may contain some SO_3 (sulfur trioxide), but for the present conside only water containing dissolved oxygen and carbon dioxide. For any concentration of carbon dioxide in water, there is in equilibrium with it a definite though very small concentration of carbonic acid. The presence of the hydrogen ion accelerates the solution of iron. When two ions of H^+

discharge and are liberated, one ion of Fe^{++} goes into solution. Under mild conditions the liberated hydrogen gas may be reabsorbed on the surface and form an electro-postive film and repel the driving force of other hydrogen ions, thus stopping the corrosion. According to McKay and Worthington (12), if oxygen is present it will oxidize the hydrogen, depolarize the metal surface and permit corrosion to proceed. Between pH 6 and pH 9, the rate of corrosion is practically determined by the oxygen concentration. If the water is more acid than pH 5, corrosion will proceed whether oxygen is present or not. Above pH 12 there will not be enough hydrogen ions present to cause measurable corrosion whether oxygen is present or not. These facts are presented graphically below.

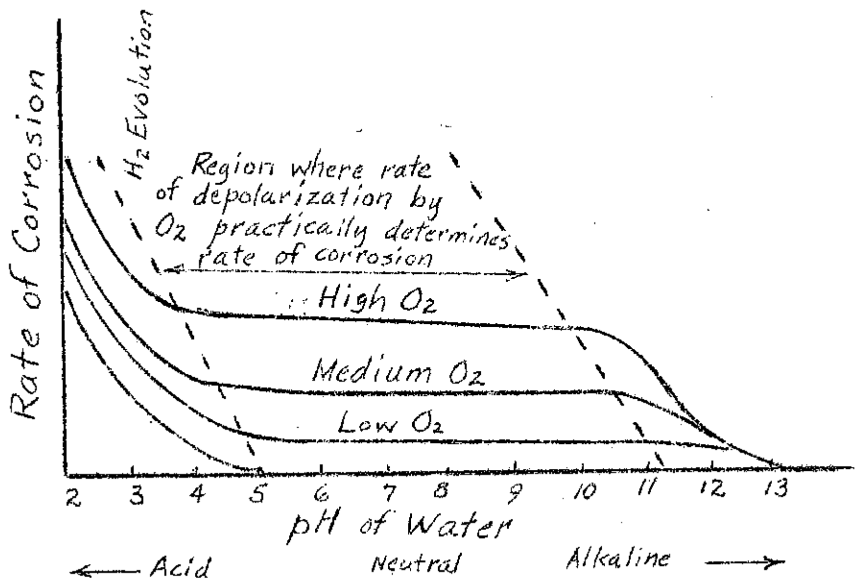


Fig. The influence of pH and oxygen concentration on the rate of corrosion of iron. From McKay and Worthington.

Water that is running and cascading would be expected to be more corrosive because of aeration and the replenishing oxygen concentration. Most of the corrosion that is of industrial importance takes place in mildly acid solutions where oxygen is a cooperating agent.

Some metal oxides form protective coatings, but iron rust is not one of them. Metals such as chromium and to a lesser extent aluminum and magnesium do form protective oxide films. The merit of such films has been explained by their virtual thinness which prevents the occurrence of concentration cells, a type of corrosion to be explained in a later paragraph. Some types of heat treatment can be used to prepare such films on steel. Controlled heating in the presence of steam leaves a blue oxide film which is quite resistant. So, the activity series mentioned at the beginning of this discussion fails to take into account the differences in protection afforded by the presence of these oxide films. The presence of a non-resistant oxide rust on iron and steel actually tends to increase the rate of corrosion by entrapping air and moisture under the scale. That is why it is essential that bridges be carefully cleaned with sand-blast before re-painting. Otherwise the rusting will continue under the paint film.

Two general circumstances are conducive to corrosion: the formation of concentration cells and galvanic cells. A metal in contact with a solution of its ions exerts a solution pressure which tends to force its ions into the solution. In doing so they leave electrons behind which charge the metal negatively and the solution positively. A double electric layer is set up creating a potential difference between the metal and the solution. In an isolated system the dissolution rate is immediately equilibrated with a process in the opposite direction and the metal suffers no further loss of weight. If, however, the system is short circuited with a reversible electrode, the rate of dissolution will be greatly increased. If a metal of greater nobility is immersed in the solution and the two are connected, dissolution of the one will be hastened.

With an increase in the hydrogen ion concentration, the potenital for gas evolution is made less negative and so the tendency for the metal to dissolve is further increased. This condition is not unlike the reactions in a short-circuited storage battery - but this type of corrosion in nature results from contact between two dissimilar metals exposed to electrolytic solutions.

The concentration cell type of corrosion may be explained by imagining an iron rod with one end immersed in a solution of salt or acid of high concentration and the other in a low concentration solution. An electric potential exists between the two ends of the rod and the end at the lower concentration will dissolve.

Localizations of moisture and oxygen in cracks, pits and under scale or even under a damp cloth where differential drying can take place, automatically set up oxygen and salt type concentration cells and corrosion results. In such areas where oxygen concentrations are high, depolarization of hydrogen will occur readily and localized decomposition will result.

There is no hard and fast rule of corrosion to follow and exceptions are more numerous than the generalities already drawn. It is important, however, to associate some of these principles with metal drainage pipe in service conditions. Consider a corrugated metal pipe after a rain: residual water in the corrugations of the invert evaporates more readily at the ends. These are in essence concentration-cells. As evaporation continues any mineral acids present become more and more concentrated, oxygen is readily available to depolarize the metal surface, and decomposition of the metal results. After the zinc coating is gone, the formation of rust scale on the steel further accelerates the corrosion.

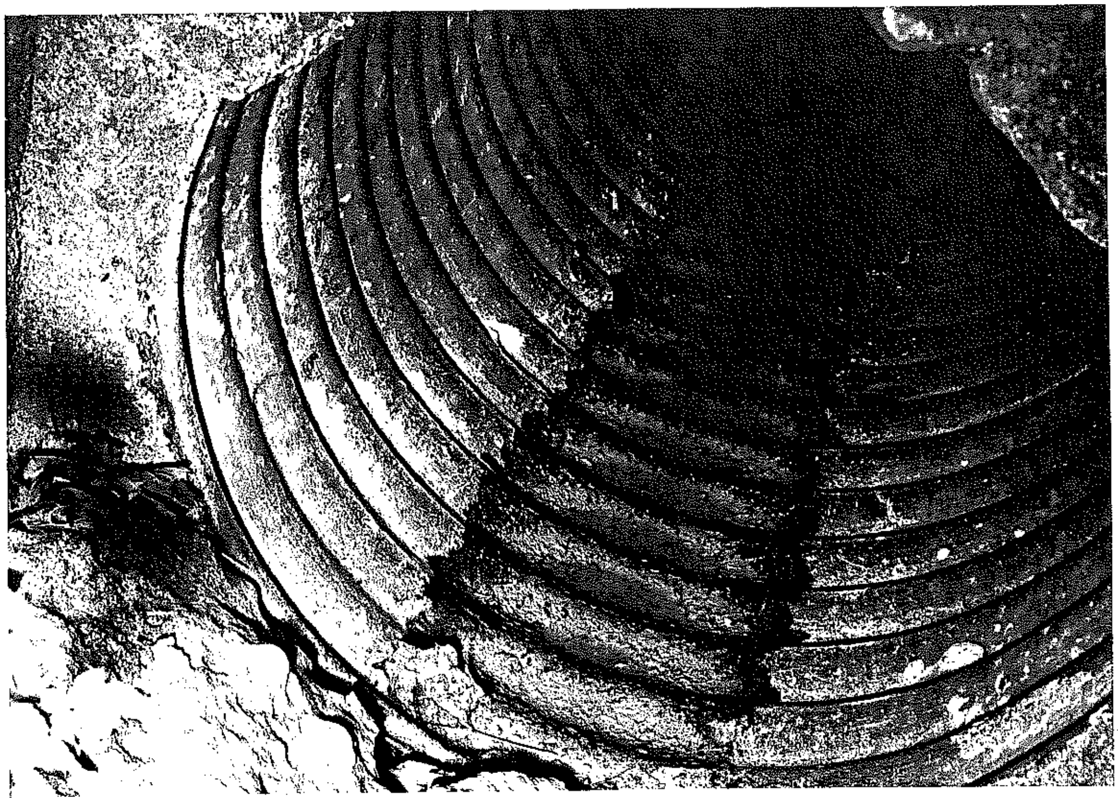


Fig. 13. Plain corrugated metal cross-drain located on Ky. 36 in Bath County. According to the best records available the date of installation was 1926. It is located in a limestone region and apparently accomodates only surface run-off. A sample of residual water taken below the exit showed a specific resistance of 1880 ohms at 25 degrees Centigrade. Although this is a comparatively low value, it cannot be attributed to acidity or the severely corrosive salts.

The water filling the corrugations demonstrates the oxygen and concentration-cell corrosion. Obviously, there has never been appreciable concentration of acid here. The type of rusting or corrosion shown here is very slow in comparison with severely acid exposure.

It may be further interest to note that the formation of rust scale occurs in the presence of even feebly acid or neutral solutions; but when critically acid solutions are present, corrosion can be easily detected by the utter absence of scale and the presence of a clean cut channel through the invert.

The corrosion of concrete has not been so thoroughly explained; but by the same previous analogies, the cement or mortor of concrete may be considered a calcium salt of silicic acid. The attack by acid causes the replacement of the calcium with hydrogen leaving gelatinous silicic acid where there was once strong calcium silicate cements.

The formation of the gel under static immersion may act as an repellent barrier and slow the progress of further corrosion. In turbulent immersion, however, the gel would be continously washed away from the surface as it formed, and in effect, a fresh surface would be kept in contact with the corrosive acid. Free lime (hydrated CaO), a product of cement hydration, would be expected to react very readily with the acids. This dissolution of the lime would leave a "honeycombed" structure permitting the infilration of the acid through the mass to attack the calcium silicate cements. By the loss of cementing materials, the concrete suffers a corresponding loss in strength. It has been found that a dense concrete, prepared with a minimum of mixing water, is more resistant than otherwise porous concrete. Massiveness of concrete structure so exposed is always an advantage. The deterioration is slow and even a shell of previously affected concrete tends to insulate the interior of the mass from corrosion.

In the presence of mine water containing appreciable amounts of iron sulfates and sulfuric acid, the naturally alkaline condition of the concrete tends to neutralize the acid at the surface of contact and as a result the iron may be precipitated from the solution in the form of a very red ferric hydroxide gel. This gel too tends to insulate the concrete against rapid corrosion. This condition has been observed on numerous wing-walls in the Western Coal Field. This was the condition observed by Wolf (9) in the attempted sweetening of coal-stockpile washings with limestone. The alkalinity of the limestone causes the precipitation of ferric hydroxide gel on the surface of the limestone particles sealing them from the acid.

In the absence of gel-forming elements such as iron and aluminum, the limestone could very effectively neutralize the acid. But then, the absence of iron from mine water would certainly be a rare occurrence.

Tremper (8) plotted the log of the percentage of the original lime lost against the log of the time of exposure in days and found a straight line relationship. By writing the equation for the line, he was able to predict life expectancies. His equation is shown below.

$$\text{Log } L = K \log T$$

Where L = percent of original lime lost

K = slope of the line

T = time of exposure in days

He found that corrections for the intercept were small and that it was not necessary to include them. The constant, K, undoubtedly depends a great deal upon the pH of the water; and, of course, such values for the full pH range have not been verified. - Assuming the relationship to be valid it would be a rather difficult task just to analyze an ancient concrete structure for lime content. In addition, the original content would always be doubtful.

Some aggregates, such as limestone, once exposed to turbulent or abrasive acid water conditions may be expected to corrode away very rapidly.

Quartzites, granites, and river gravels low in carbonates or any of the silicate minerals would be more resistant to acid attack. Numerous etched culverts were observed in this survey in which the cement had deteriorated from around gravel particles which had suffered no apparent damage.

As in the case of metal surfaces, concrete too can be treated with seal-type coatings which greatly extend its life expectancy under corrosive conditions.

Sandstones used as masonery head-walls are usually very acid-resistant. This is understandable since sandstones were formed under slightly acid conditions. A slight acidity was necessary for the precipitation of the silica. High silica glass and quartz conduits are used in many chemical processes where extremely concentrated acids are conveyed. Vitreous enamels and porcelain ware are highly acid resistant. For the same reason, vitrified clay pipe is found to be a desireable drainage structure in even the severest acid conditions.

Appendix B

THEORY OF CONDUCTIVITIES

The measurement of electrical resistance in any conductor is based on Ohm's Law, $I = E/R$. Resistance is determined by applying a small voltage across a conductor of known dimensions and measuring the voltage-drop, E, and the current, I. Resistance, R, can then be calculated from the equation. Resistance in any conductor varies directly as the length of the conductor, ℓ, and inversely as the cross-sectional area, A. Resistance for a conductor is related to its dimensions by:

$$R = \frac{\ell}{A} S$$

Where S = the specific resistance of the conducting material.

Of course, when ℓ and A are reduced to unit dimensions, R is equal to the specific resistance. The counter part of resistance is conductance and is defined simply as 1/R which may also be reduced to specific conductance. Resistance in a conductor may be regarded as a measure of the reluctance opposing the flow of current, and conductance as a measure of the ease with which the current may flow.

When these principles are applied to liquids and solutions, specific electrical resistance is visualized as the resistance in Ohms between opposing faces of a cube 1 cm. on an edge. If two non-polarizing electrodes were constructed to embrace exactly a 1 cm. cube of an aqueous solution; that is, each electrode 1 cm. square, and fixed exactly 1 cm. apart, then specific resistances could be measured directly. In practice; however, these refinements are too expensive and not really necessary. Generally

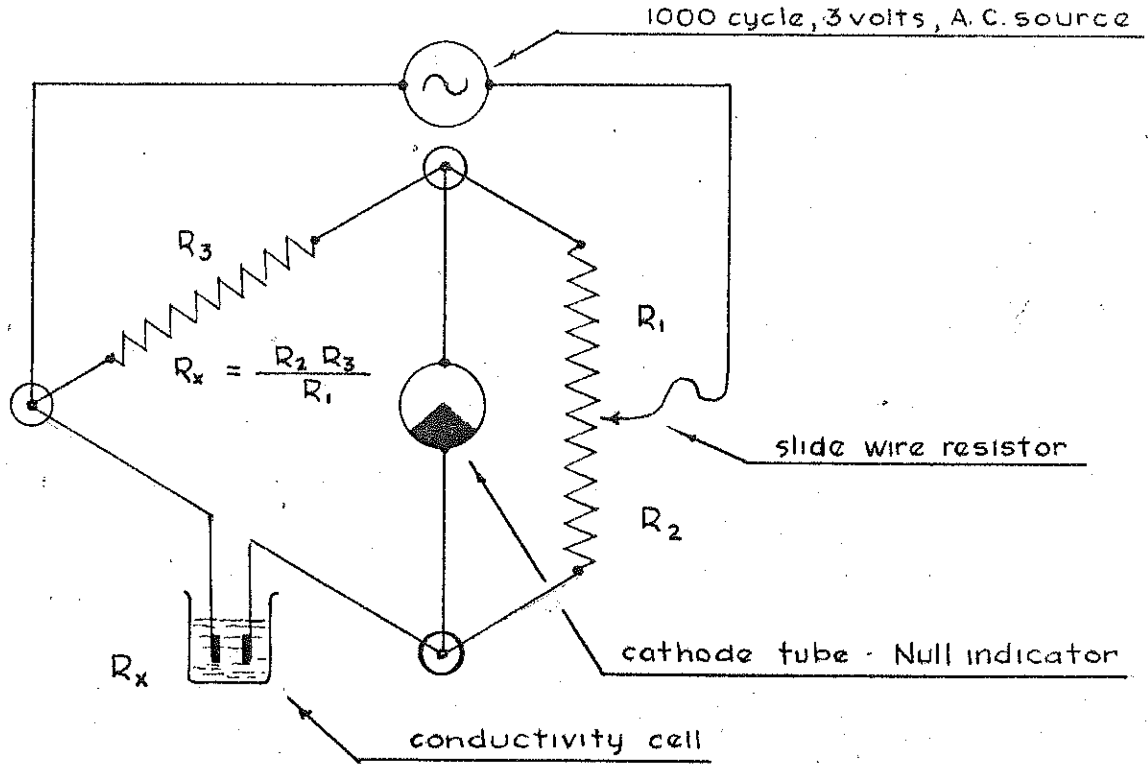


Fig. 14

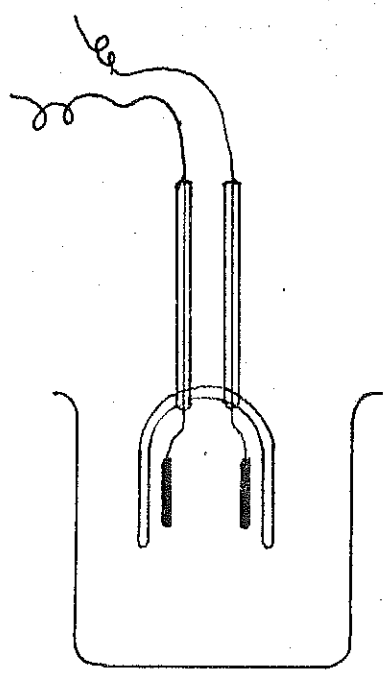
WHEATSTONE BRIDGE CONDUCTIVITY CIRCUIT

CALCULATIONS

$$R_x = \frac{R_2 R_3}{R_1}$$

R_3 = CONSTANT KNOWN VALUE

R_2/R_1 = OBTAINED FROM INSTRUMENT DIAL READING



DIP-TYPE CELL

cells of this type are constructed to the approximate dimension and calibrated against a standardized solution of known specific resistance, usually KCl. This introduces a cell calibration factor which relates the actual dimensions of the electrodes as a proptortional part of the idealized dimensions. Actual values of R are then calculated from the measured R by simply multiplying by the cell factor.

Figure 14 shows a schematic diagram of a Wheatstone Bridge circuit adapted to measure the electrical resistivity of aqueous solutions. This type instrument is used extensively in industry to control contaminations in waste-water, and for electro-plating solutions, concentration baths, ionized impurities, and similar features. Committee D-19 on Industrial Water of the American Society for Testing Materials has recently proposed a tentative method of test for the electrical conductivity of industrial water which is very similar to the procedure used in this study.

The eventual objective in conductivity measurements is to relate measured values to concentrations of the solute. Water which is ultra-pure is in fact an idealized condition, but waters which exhibit resistances as high as 20 million ohms per cubic centimeter have been prepared by repeated distillations. Ordinary distilled water shows about 300,000 ohms. The flow of electricity through water is possible only when it contains some ionized impurities. Such impurities which render water conducting are appropriately termed "electrolytes". Chemically electrolytes are salts or acids which ionize or dissociate into individual ions in solution. In chemical nomenclature this may be illustrated by:

$$NaCl \xrightarrow{Solution} Na^{+} \text{ and } Cl^{-}$$

$$HCl \xrightarrow{Solution} H^{+} \text{ and } Cl^{-} \text{ and}$$

$$KOH \xrightarrow{Solution} K^{+} \text{ and } OH^{-}$$

These individual ions are the current-carriers and actually transport electrons across the gap separating the electrodes. It would be expected that conductance would increase in direct proportion to the number of those ions, but in reality there is some deviation from a direct proportionality. As the ions become more concentrated, their mean-free-paths become slightly more restricted because they are more frequently diverted from their course by frequent collisions with other ions.

Organic salts and acids are classed under a separate category since they ionize only slightly in solution. Here the proportionality is further complicated by the degree of dissociation which is a function of concentration. These are appropriately termed "weak electrolytes."

Using the symbol L to designate conductance, these principles may be expressed by the general equation:

$$L\ (\text{ions}) = L\ (\text{solution}) - L\ (\text{water}).$$

Since $L = 1/R$, a 300,000 ohm correction for the water itself is of little consequence when L (ions) is in the range of 1/2,000.

Specific resistance is related to concentrations in a manner described by typical curves as shown in Figure 15 for several strong electrolytes. These relations do not in themselves indicate the number of ions introduced per unit weight of the solutes because concentrations are expressed in grams of salt per 1000 grams of solution. The curves represent extremely high concentrations - many times higher than could ever be ex-

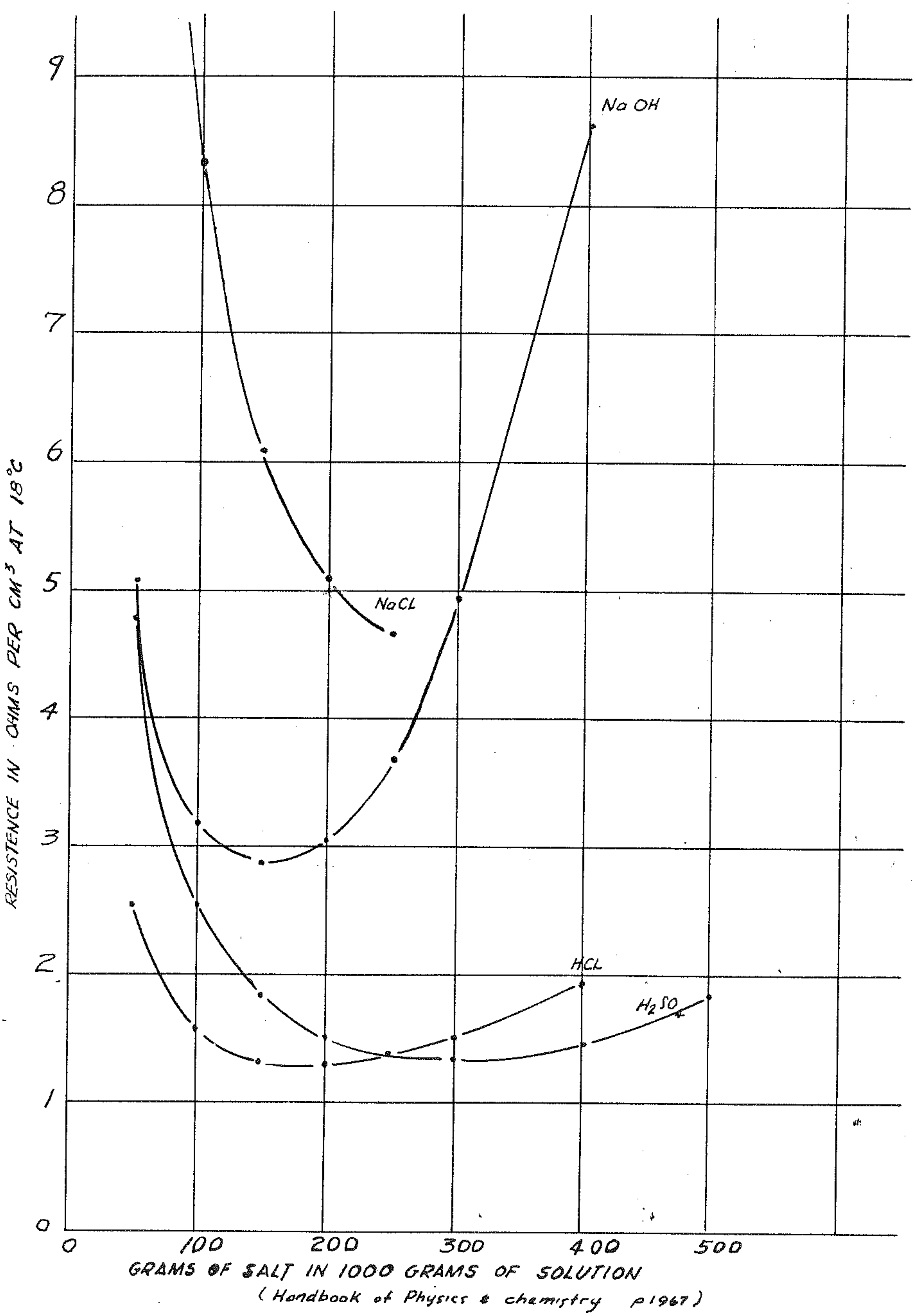


Fig. 15 Showing Specific Resistance Curves

perienced in natural drainage water. It will be noted, however, that as the concentration approaches zero, specific resistances approach infinity. It is these lower ranges with which this study is concerned.

Theoretically it would be possible to extend these curves and use them to quantitatively relate concentration to specific resistance, but a more simple and yet a more fundamental mathematical relation has been derived by expressing concentrations in gram-equivalent weights of the solute per liter. According to the law of mass action, equivalent numbers of molecules take part in any chemical reaction involving only two atoms or ions such as Na+ and Cl-. One gram-molecular weight of sodium weighs 23 grams, the same number of ions of chlorine, 6.02×10^{23}, weighs 35.5 grams. They react to form one gram-molecular weight of sodium chloride weighing 23 + 35.5 grams. Any quantity of a reactant may be expressed as a fraction of a gram-molecular weight and equivalent fractions then designate equal numbers of ions. The full significance of these facts are realized in the derivations which follow.

When specific resistances are measured in ohms per centimeter cubed and concentrations in gram-equivalent weights per liter, specific resistance x 1000 gives the resistance of a liter of that solution. If this value is divided by the concentration, the resulting value is the resistance of an imaginary volume of the solution required to contain 1 gram equivalent weight of the solute.

Finally by expressing resistance in terms of conductance, 1/R; these relations may be integrated into a single equation:

$$\Lambda = \frac{1000 \times 1/R \times K}{C}$$

Where Λ = equivalent conductance
R = specific resistance
C = concentration in gm. eq. wt./liter
K = cell calibration factor (peculiar to each cell)

Characteristic curves illustrating equivalent conductance values for several salts and acids are shown in Figure 16 . These curves as noted, are based on data published in the Handbook of Chemistry and Physics; similar and more extensive data expressed in a slightly different way are listed in Table 2 .

Interpretation of measured resistances is made very simple by the formula for equivalent conductance when only one salt or acid is known to be in the solution tested. By taking an anticipated value from the appropriate curve in Figure 16, for Λ, an approximate value of C can be calculated for the measured R. Using the more exact value of C, further reference to the curve will yield a more exact value of Λ. Re-calculations by this procedure diminish the errors until a high degree of accuracy is attainable.

This system breaks down, of course, when several salts and acids are dissolved in the water. When mixtures of solutes are measured the resistance obtained represents an integrated or summation value for all the electrolytes present, and values for Λ are indeterminate. At first glance, this statement seems to leave the entire method without merit in-so-far as measuring the concentrations of corrosive salts and acids in natural drainage water are concerned; but then inspection of the curves in Figure 16 show that average values of Λ are about 100 for neutral salts. Strong acids - being more highly conducting - range from 3 to 4 times higher in equivalent conductance. These acids are also much more corrosive than the neutral salts.

pH measurements can be used to define concentration of the acid-equivalent only, but they do not take into consideration the presence of the corrosive salts. It was this one factor which favored the selection of conductivity methods over pH methods. The eventual conclusion in the matter was that conductivity, whether actually translated into terms of concentrations or not, would better describe the corrosivity of natural drainage water than any method of test short of a complete chemical analysis. These are recognized limitations, and for that reason conductivity tests have been supplemented by qualitative chemical tests in instances of high concentration to demonstrate that elements such as iron, aluminum, calcium, magnesium, sulfates, chlorides, etc. do exist in the water in addition to what ever acids may be present. In instances of extreme contamination, total acidity and mineral acidity were titrated against standard alkali solutions.

There are many so-called water-hardness meters now available which are calibrated in terms of parts per million of a salt like sodium or calcium chlorides. These instruments are usually conductivity bridge circuits which are designed on the assumption of a value for Λ representing that particular reference salt, and therefore the extent of contamination is reported as being equivalent to so many parts per million of sodium or calcium chloride. Such values as these are often misleading and the method was rejected in this study in favor of reporting conductance as a measure of contamination with supplementary tests for acidity and general character of the dissolved minerals.

Table 2 - Equivalent Conductances of Electrolytic Solutes
(Abstracted From International Critical Tables)

Solute	Equivalent Conductance at 18° C — Milli Formula Wt.									
	0.1	0.2	0.5	1.0	2.0	5.0	10.0	20.0	50.0	100.0
$\frac{1}{2}$ Mg SO_4	109.6	107.8	104.2	99.9	94.21	84.31	76.07	67.56	56.73	49.57
$\frac{1}{2}$ Ca SO_4	115.5	114.0	109.25	103.94	97.16	86.42	77.42	68.30	-	-
$\frac{1}{2}$ Na_2 SO_4	109.7	108.8	107.3	105.8	104.1	100.2	96.1	91.0	83.68	77.6
$\frac{1}{2}$ K_2 SO_4	130.5	129.8	128.3	126.7	124.4	120.1	115.6	110.1	101.84	94.82
$\frac{1}{2}(NH_4)_2SO_4$	130.	128.	127.	124.5	122.0	117.9	113.5	107.4	98.9	92.0
$\frac{1}{2}$ Zn SO_4	109.6	107.6	103.4	98.5	92.1	81.8	72.8	63.8	52.8	45.4
$\frac{1}{2}$ $CaCl_2$	115.01	114.39	113.18	111.80	109.92	106.55	103.23	99.24	93.16	88.07
NaCl	107.88	107.60	106.95	106.27	105.31	103.54	101.72	99.40	95.51	91.82
KCl	128.84	128.48	127.86	127.07	126.05	124.15	122.18	119.72	115.51	113.7
NH_4Cl	129.3	128.9	128.2	127.5	126.2	124.3	122.3	118.2	115.3	110.8
HCl	-	-	-	377.	375.5	372.4	369.3	364.9	357.6	350.1
$\frac{1}{2}H_2SO_4$	-	374.4	371.3	-	353.4	-	308.6	-	253.1	232.9
H_3 PO_4	-	330.4	-	-	282.8	273.0	202.7	166.7	122.5	96.4
HNO_3	-	330.4	373.3	372.6	370.6	366.8	364.0	360.4	353.0	345.7
	Equivalent Conductance at 25° C									
HCl	424.64	424.24	423.04	421.38	419.17	415.11	411.08	406.07	397.80	389.8
$\frac{1}{2}H_2SO_4$	-	417.9	413.1	399.5	390.3	364.9	336.4	308.0	272.6	250.8
H_3 PO_4	-	366.8	-	-	311.5	-	221.7	180.3	132.4	103.9
HNO_3	-	-	416.2	414.6	412.9	409.0	405.2	400.8	392.5	384.2
$\frac{1}{2}$ $Ca(HCO_3)_2$	109.5	106.0	102.0	99.3	96.6	91.7	87.0	80.9	-	-
$NaHCO_3$	-	-	94.4	93.5	92.5	90.3	88.1	85.5	80.6	76.1
$\frac{1}{2}$NaH SO_4	-	-	-	262.8	254.5	236.8	218.5	197.35	168.62	148.27

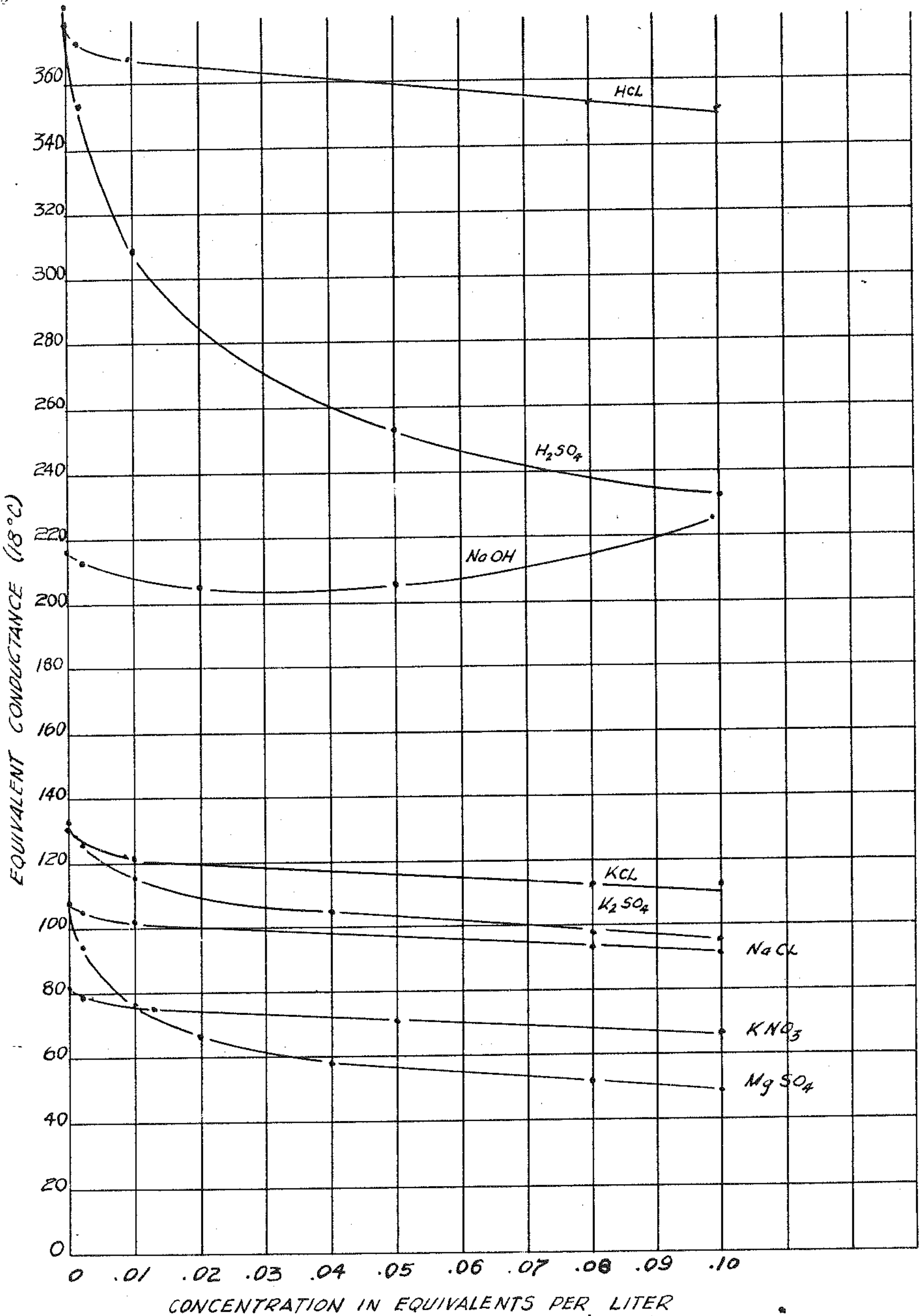


Fig. 16 Showing Equivalent Conductance Curves

Appendix C

AREAL DISTRIBUTION AND SULFUR CONTENT OF COAL DEPOSITS

The coal-producing areas of Kentucky comprise one-third of the state. Within these sections are forty-six counties listed as producing coal by the Kentucky Department of Mines and Minerals in its 1948 Annual Report. The two general fields are designated as "Eastern Coal Field" (32 counties) and "Western Coal Field" (14 counties).

The Eastern Coal Field constitutes a part of the vast Appalachian Coal Field of the Eastern United States which is noted for its high quality coal. The coals produced there are high in heating value and generally low in sulfur and ash. They are used extensively for by-product "coke" which is a mark of quality.

The Western Coal Field has on the average a much lower quality coal with a high sulfur and ash content. Because of these properties the use of this coal is more restricted so far as a variety of applications is concerned. The Western Field developed prior to the Eastern Field because of accessibility and better waterways in the western part of the state. Until 1911 it led the Eastern Field in production, but the higher quality of coal in the East gave impetus to eastern development.

Coal development and production during the past few years has taken a tremendous leap; but despite this estimated reserves are tremendous. According to one estimate (13), as of 1939, Kentucky had exhausted 1 percent of her reserves. Later estimates are not available, but it seems certain that coal mining will be a major industry in Kentucky for some time to come. Accordingly, plans should be made to accommodate this industry from the standpoint of permanent cross drainage.

Modern mining methods include washing and screening coal before distribution. This operation concentrates sulfur and free ash in the wash water, which of course increases the acidity of the closest stream. Conservation Officers are requiring damming and pooling of streams to alleviate acidity, but this helps highway drainage installations very little.

Sulfur content of coals gives some approximation of the acidity which might be produced in water when the water comes into contact with the coal. Similar deductions can be made for highly bituminous shales. It is desirable to be able to predict what drainage problems would develop by opening up new mining property or continued operation of an old mine. The Annual Report of the Kentucky Department of Mines and Minerals lists most of the known mines and their production, but does not give any chemical analysis. Mines of any consequence are requested to furnish an analysis. Many seams which are small and only mined by truck-mines do not have any analysis. A sufficient number of these have been reported to be of help in checking sulfur contents.

These figures for percentage sulfur recorded and tested in this Appendix, then are at best rough indicators of the conditions that might be found reflected in water acidity. They do, however, form a valuable basis for estimates of acid potential, and in lieu of actual acidity measurements in a locality of interest they are highly valuable for reconnaissance.

An attempt is made here to integrate these data by counting every coal seam that was mined in each county and the number of mines working each seam. The percent sulfur was multiplied by the number of mines for every seam and an average was taken for all seams mined. On a plot of average percent sulfur versus annual production, the various counties tend to group into three categories is shown in Fig. 17. From this analogy, three categories seem to describe a natural basis for classification. By further projection the classification may be defined in more definite terms, as follows:

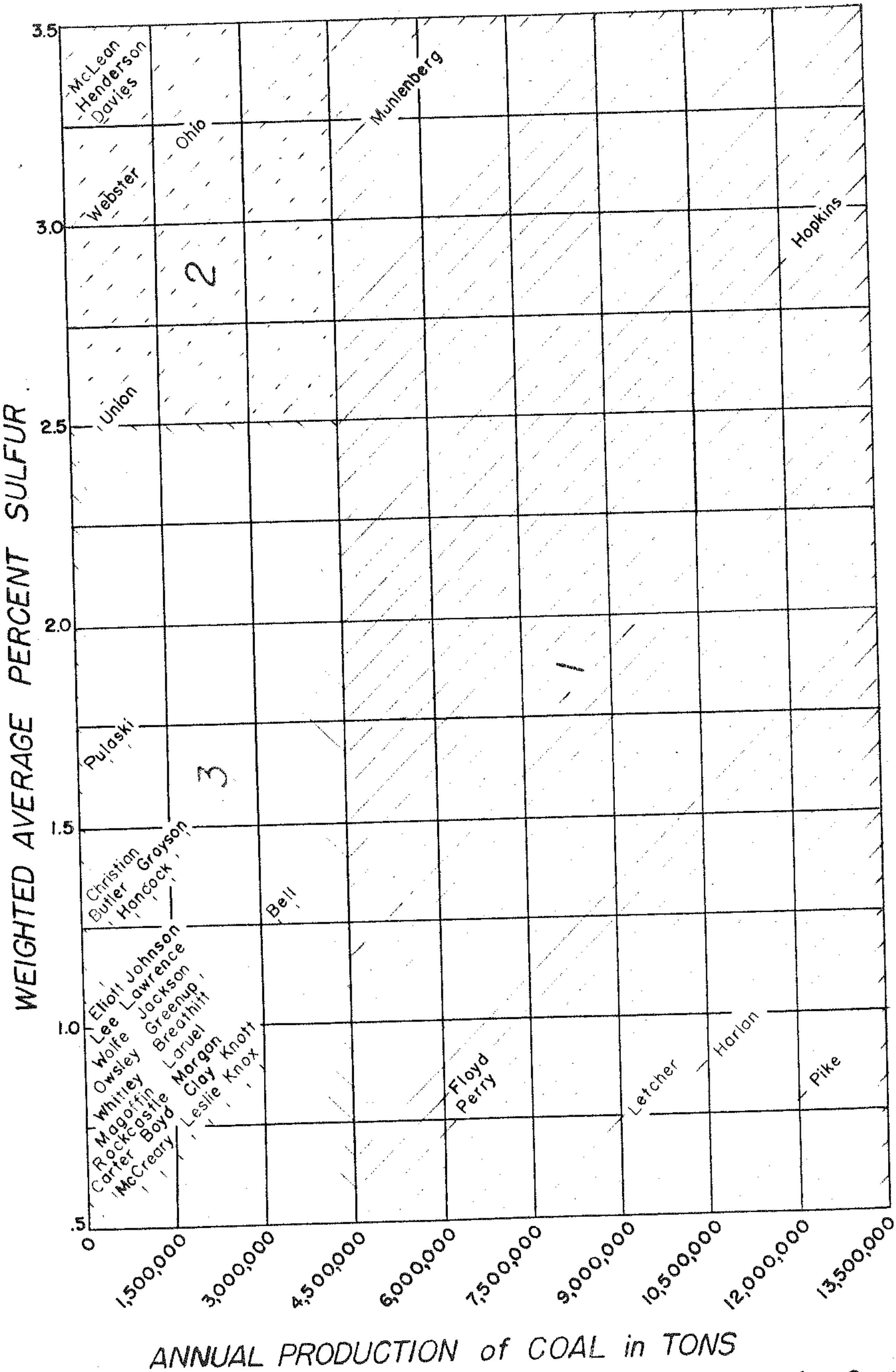


Fig. 17 Showing Grouping of Counties by Production and Sulfur Content

Category No. 1 - By virture of production alone and also production - sulfur content, it seems advisable to class all counties in this position as - potentially serious from the standpoint of acidity. The counties are Floyd, Perry, Letcher Harlan, Pike, Muhlenberg and Hopkins. All of them produce six million or more tons of coal annually. The abundance of production is spread throughout a large number of mines. The very nature of these counties is for coal to be encountered everywhere so that practically all water has access to coal at one time or another. Run-off varies, and local situations causing pooling of water vary. Condition of waters under this situation can be acid or non-acid, but it is highly probable that all water will at some time during the year be acid. Muhlenberg and Hopkins counties, in addition to high production have average sulfur contents exceeding 2.5 per cent. The combination of these two factors make these counties extremely prominent as acid water producers.

Category No. 2 - This is assigned to counties where there is a high sulfur content but low production. Mine drainage should be acid in every case. Counties in this group are; Union, McLean, Henderson, Webster, Daviess and Ohio. All counties have average sulfur contents in excess of 2.5 per cent but production is lower than 3 million tons annually. Practically every mine drains acid water the year round so that drainage structures close to the mines in these counties should be liable to severe attack. Some outstanding examples of etching of concrete and metal cross drains are present in this area.

Category No. 3 - This is assigned to low sulfur content - low production counties where waters may or may not be acid. Bell, Boyd, Breathitt, Butler, Carter, Christian, Clay, Clinton, Crittenden, Edmonson, Elliott, Grayson, Greenup, Hancock, Jackson, Johnson, Knott, Laurel, Lawrence, Lee, Leslie, Magoffin, Martin, McCreary, Menifee, Morgan, Owsley, Pulaski, Rockcastle, Wayne, Whitley, and Wolfe counties are in this group. All are low in average percent sulfur. Situations resulting in acid action on cross drains are not apt to be predictable. Depending upon the seam mined, its sulfur content, amount of drainage water, pooling effect, length of time in contact with coal and some few other factors, drainage water that may be acid in varying degrees; they may be acid during certain seasons. It is entirely possible of course to find drainage water coming from a mine or even pooled with coal residue that is non-acid in these counties.

Table 3, included herein, shows annual coal production by counties for 1948. The table also contains data pertinent to the type of mines, the major seams mined, and average sulfur contents for each county. Table 4 shows the average sulfur content for the most important seams. All these data were condensed from information obtained from the Kentucky Department of Mines and Minerals.

Special significance is attached to strip mining as opposed to other methods of recovering coal. The usual effect is a pooling of water, allowing more complete solution of iron, sulfur, and other constituents. This increased concentration of salts makes water extremely acid; so much so, that water is unable to carry all the salts in solution, so they are deposited on the stream bottom, only to be taken up again later by additional flowing water. Effects of this are far reaching and as evidence of this, the fish population in the major streams (as Kentucky River) is destroyed by small tributaries emptying into them.

Railroad mines are big producers, as much as one hundred times larger than the average truck mine. With their size, special production methods of handling coal cause more acid conditions. Machinery spills much coal, and washing-screening operations tend to concentrate sulfur and ash in the drainage water. A railroad mine then is to be considered as potentially more acid-producing than a truck mine.

Slope mines or mines working down a sloping seam have better internal drainage than horizontal seams mined by drifting methods. Thus, mines with sloping seams tend to avoid concentration of acid-water.

Another acid producing feature of coal mines, of course, is the slack pile which also embraces coal spilled around the yard. Roads built up with coal and slack are so acid that there can be no vegetation within a considerable distance around the area.

Table 3 - Tonnage, Indicated Sulfur Contents, and General Features of Mines in Kentucky.

COUNTY	1948 PRODUCTION (TONS)	WEIGHTED AVG. PCT. SULFUR	NUMBER, TYPE, AND SEAMS
Bell	3,089,224	1.03	Drift and slope mining, 23 railroad mines, 101 truck mines. Seams mined are: Mason*, St. Creek*, Stray, Rim*, Jellico, Popular Lick, Lower Dean, Dean, Apex, Splint, Barner, Blue Jim, Jack Rock, Turkey Pen, Lower Hignite, Dixie Gem, Sterling, Hignite, Buckeye, Nugym, Red Bird, Red Springs, Harlan, Crockett, Turner, Creech and Collier.
Boyd	531,225	.76	Strip and drift mining, 2 railroad mines, 21 truck mines. Seames mined are: No. 6 and No. 7*.
Breathitt	173,768	.76	Drift and slope mining, 2 railroad mines, 63 truck mines. Seams mined are: Hazard No. 4, No. 4 Rider, Elkhorn, Elkhorn No. 3*, No. 4* and No. 7.
Butler	126,076	1.25	Strip, drift, and slope mining, 12 truck mines. Seam mined is No. 6*.
Carter	502,395	.81	Drift and slope mining, 15 truck mines. Seams mined are: No. 7* and Millers Creek.
Christian	11,430	1.25	Drift and slope mining, 3 truck mines. Seams mined are: No. 6 and No. 6 Stray*.
Clay	576,670	.78	Strip, drift and slope mining, 32 truck mines. Seams mined are: Horse Creek*, No. 4, Hazard No. 4 and "B".
Clinton	81,040	--	Drift and slope mining, 5 truck mines. Seams mined are: Stearns No. 3 and Stearns No. 1*.
Crittenden	3,973	--	Strip Mine, 1 truck mine. Seam mined: Bell.
Daviess	647,398	3.457	Strip and drift mining, 2 railroad mines, 31 truck mines. Seams mined: No. 9* and No. 6 Stray.

* Main Producing Seams

COUNTY	1948 PRODUCTION (TONS)	WEIGHTED AVG. PCT. SULFUR	NUMBER, TYPE, AND SEAMS
Edmonson	11,120	--	Drift and slope mining, 4 truck mines, Seam mined: Stray*.
Elliott	60,219	.907	Drift and slope mining, 13 truck mines. Seam mined: Splint and No. 7*.
Floyd	6,734,525	.817	Drift and slope mining, 31 railroad mines, 579 Truck mines. Seams mined: No. 2 Elkhorn*, No. 3 Elkhorn*, No. 1 Elkhorn*, No. 4, Elkhorn, No. 3, Whitesburg, No. 1*, No. 2, No. 4 Elkhorn, Millers Creek, No. 4 Whitesburg.
Greenup	94,052	.76	Drift and slope mining, 20 truck mines. Seams mined: Clod*, No. 7, No. 6.
Grayson	9,211	1.25	Strip mining, 2 truck mines. Seams mined: No. 6, No. 6 Stray.
Hancock	229,845	1.25	Strip and drift mining, 1 railroad mine, 6 truck mines. Seams mined: No. 6 Stray*.
Harlan	11,387,265	.90	Drift, slope, and strip mining, 54 railroad mines, 60 truck mines. Seams mined: Harlan*, Dean, Low Splint, High Splint, No. 5, Kellioka, Imperial, Draby*, High Cliff, Wallins, Darby No. 5, Harlan No. 5, Creech No. 6, B & C*, No. 10, Taggart, Mason*, Mason No. 2, A, Blue Gem, Bulldog.
Henderson	264,296	3.4	Drift and shaft mining, 15 truck mines. Seams mined: No. 9*, No. 14.
Hopkins	12,943,515	2.94	Drift and strip mining, 45 railroad mines, 58 truck mines. Seams mined: No. 11*, No. 9*, No. 6, No. 14, No. 12.
Jackson	129,962	.81	Drift and strip mining, 21 truck mines. Seams mined: Cannel, Bond*, Middle, Horse Creek, Jackson, Beattyville.
Johnson	828,742	1.12	Drift and slope mining, 3 railroad mines. Seams mined: Millers Creek*, No. 1, Millerite, No. 3.
Knott	1,256,789	.81	Drift, slope and strip mining, 6 railroad mines, 144 truck mines. Seams mined: No. 4, No. 9, No. 1 Elkhorn, No. 4, Hazard No. 4*, No. 3 Elkhorn*, Whitesburg No. 4, Whitesburg No. 3,

* Main Producing Seams

COUNTY	1948 PRODUCTION (TONS)	WEIGHTED AVG. PCT. SULFUR	NUMBER, TYPE, AND SEAMS
Knox	608,680	.76	Drift and strip mining, 5 railroad mines, 123 Truck mines. Seams mined: Jellico*, Dean, Straight Creek, Blue Jim*, Stray, Fisher.
Laurel	253,903	.81	Drift and strip mining, 2 railroad mines, 30 truck mines. Seams mined: River, Lily, Stearns No. 2, Horse Creek No. 1, Chainy Ridge*, Stearns, No. 3, Pittsburg*.
Lawrence	117,623	.77	Drift and strip mining, 19 truck mines. Seams mined: No. 7, No. 4 Hazard, McHendrich, Blackburn.
Lee	96,777	.81	Drift mining, 7 truck mines. Seams mined: Beattyville*.
Leslie	928,795	.77	Drift and slope mining, 47 truck mines. Seams mined: Hazard No.4*, Hazard No. 2, No. 4*.
Letcher	10,839,921	.75	Drift, slope and strip mining, 14 railroad mines, 801 truck mines. Seams mined: High Splint, Hazard No. 4*, Elkhorn No. 3, Elkhorn No. 4, Eklhorn*, Whitesburg*, Amburgey, No. 4 and No.4*, No. 3, Fire Clay, No. 5 Whitesburg, Darby-B, C, Shelby Gap.
Magoffin	171,068	.85	Drift and Strip Mining, 1 railroad mine, 66 truck mines. Seams mined: Hindman, Millers Creek*, Hazard No. 4*, Elkhorn No. 3*, No. 3, Cannel, No. 7, Elkhorn No. 4.
Martin	432,190	1.00	Drift mining, 2 railroad mines, 19 truck mines. Seams mined: Warfield*, Coalburg Winford.
Menifee	36,283	--	Drift mining, 4 truck mines. Seams mined: Cannel*.
McCreary	816,703	.93	Drift and strip mining, 4 railroad mine, 14 truck mines. Seams mined: Stearns No. 1½*, No. 14½, No. 2, River Jim, No. 3.
McLean	124,807	3.44	Drift and strip mining, 13 truck mines. Seams mined: No. 11, No. 9*.

* Main Producing Seams

COUNTY	1948 PRODUCTION (TONS)	WEIGHTED AVG. PCT. SULFUR	NUMBER, TYPE, AND SEAMS
Morgan	394,619	.76	Drift and slope mining, 59 truck mines. Seams mined: Cannel*, Elkhorn No. 3.
Muhlenburg	5,599,966	3.45	Strip, shaft and drift mining, 24 railroad mines, 44 truck mines. Seams mined: No. 11*, No. 9*, No. 12, No. 6.
Ohio	1,938,442	3.20	Strip and drift mining, 15 railroad mines, 27 truck mines. Seams mined: No. 9*, No. 6, No. 14, Stray.
Owsley	3,500	.81	Drift mining, 5 truck mines. Seams mined: No. 3, Beattyville.
Perry	6,245,410	.78	Drift and slope mining, 28 railroad mines, 140 truck mines. Seams mined: Hazard No. 4*, Hazard No. 6, No. 4*, No. 7, No. 6, Leatherwood, Hazard No. 7, No. 9, 5A Hazard, No. 9 Hazard.
Pike	12,169,708	.82	Drift, slope and strip mining, 43 railroad mines, 918 truck mines. Seams mined: Alma, Pond Creek*, Thacker, Clintwood, Elswick, Elkhorn No. 2*, Elkhorn No. 3*, Winifrede, Alma No. 12, Cedar Grove, Freeburn, Upper Feds Creek Lower Elkhorn, Lower Gem, Warfield, Upper Elkhorn, Elkhorn No. 1*, Elkhorn No. 5, Elkhorn, No. 2, Splash Dam, Millers Creek, Shelby Gap, Elkhorn No. 4, No. 3, No. 4, Whitesburg, No. 1, Flatwood.
Pulaski	72,450	1.66	Drift and slope mining, 24 truck mines. Seam mined: No. 3.
Rockcastle	70,854	.78	Strip and slope mining, 18 truck mines. Seams mined: Dean*, Mayflower, Sand Springs*, Horse Creek No. 1, Horse Creek.
Union	618,390	2.56	Slope mining, 1 railroad mine, 4 truck mines. Seams mined: No. 9*, No. 6*, No. 11.
Wayne	64,780	--	Slope mining, 13 truck mines. Seams mined: No. 3 Stearns*, Stearns.
Webster	596,687	3.04	Strip, shaft and slope mining, 5 railroad mines, 15 truck mines. Seams mined: No. 9*, No. 8, No. 11, No. 6.

COUNTY	1948 PRODUCTION (TONS)	WEIGHTED AVG. PCT. SULFUR	NUMBER, TYPE, AND SEAM
Whitley	259,031	.74	Drift and strip mining, 4 railroad mines, 43 truck mines. Seams mined: River Gem, River, Jellico*, North Jellico, Blue Jim*, Dean, No. 1½ Vanderpool, Blue Heron.
Wolf	16,441	.76	Drift Mining, truck mines. Seams mined: No. 4*, Hazard No. 4*.

Table 4

Analysis of Coal

(Average Figures of Each Seam of Coal)

West Kentucky District

Seam	Sulphur	Seam	Sulphur
# 6	1.25	# 12	5.76
# 9	3.45	Green River	1.90
# 11	3.43		

Big Sandy - Tug River District

Seam	Sulphur	Seam	Sulphur
Alma	.69	Millers Creek	1.12
Cedar Grove	.62	Pond Creek	.57
Elkhorn	.67	Thacker	1.39
Elkhorn # 1	.76	Upper Feds Creek	.75
Elkhorn # 2	.90	Warfield	1.18
Elkhorn # 3	.77	Winifrede	.64
Freeburn	.59		

Kentucky River District

Seam	Sulphur	Seam	Sulphur
#8	.63	Hazard # 6	.70
#9	1.07	Hazard # 7	.78
Elkhorn # 1	.97	Leatherwood	.76
Hazard # 4	.76		

Cumberland River District

Seam	Sulphur	Seam	Sulphur
# 1	2.25	Hignite	.60
# 1½	.74	Jellico	.67
# 2	2.25	# 3 Kellioka-Keokee-Elkhorn	1.66
# 4	1.20	Low Splint	5.09
# 5	.57	Marker	.65
# 9	1.91	Red Springs	.58
Collier	3.63	Sterling	.93
Creech-Mason-Mingo	1.14	Straight Creek "Blue Jim" or "Blue Gem"	.92
Darby # 5	.40	Taggart	.59
Dean-Polar Lick-Wallin	.78	Turner	.65
Harlan	.79	Wallin-Dean	.71
High Splint	.66		

APPENDIX D. Water Survey Data (Highway District I)

Road and Sample Location	Sample No.	Measured Resistance in Ohms	Temp. °C.	Qualitative Tests					Titrated Acidity	Calculated ph	Measured ph	Remarks
				Cl	SO_4	Ca	Mg	Fe				
Ballard Co. U.S. 60, McCracken Co. L.-Wickliffe, agricultural land run-off	CY-1	16550	20									
Calloway Co. KY. 95, 5.8 Mi. S. of Marshall Co. Line, woodland and springs	CY-7	1610	21.3									
Carlisle Co. U.S. 62, 21 Mi. W. of Paducah, farmland surface drainage	CY-3	6250	26									
Crittenden Co. U.S. 60, 15 Mi. from Livingston Co. Line, farmland and woods surface drainage	CY-11	5720	26									
Fulton Co. Ky. 94, 12.5 from Jct. with U.S. 51, woodland run-off	CY-4	1880	24									
Graves Co. U.S. 45-E, 3.8 Mi. E. of Hickman Co. Line gravel pit run-off	CY-5	14680	22									

APPENDIX D. Water Survey Data (Highway District I)

Road and Sample Location	Sample No.	Measured Resistance in Ohms	Temp. °C.	Qualitative Tests: Cl	SO4	Ca	Mg	Fe	Titrated Acidity	Calculated pH	Measured pH	Remarks
Livingston Co. U.S. 60, 1.1 Mi. S. of Salem, farmland drainage	CY-10	6220	23.5									
U.S. 62, at Iuka, woodland drainage	CY-9	2280	24									
Marhshall Co. Ky. 58, 6½ Mi. from Graves Co. Line, wood farmland drainage	CY-6	14500	22.75									
McCracken Co. U.S. 62-W, 4.1 Mi. W. of Paducah, farmland drainage	CY-2	4440	30.5									
Trigg Co. U.S. 68, 10.6 Mi. from Marshall Co. Line, farm and pasture drainage	CY-8	2685	21.8									

APPENDIX D. Water Sample Data (Highway District II)

Road and Sample Location	Sample No.	Measured Resistance in Ohms	Temp. °C.	Qualitative Tests: Cl	SO_4	Ca	Mg	Fe	Titrated Acidity	Calculated pH	Measured pH	Remarks
Daviess Co. U.S. 60 Owensboro-Reed 7.5 Mi. E. of Owensboro	9	855	25	–	–	Pos.	–	–	$1.2x10^{-3}$	2.9	5.5	
Ky. 75, Utica to McLean Co. Line, 3 Mi. N. of Co. Line	18	4470	25	–	–	–	–	–	–	–	4.5	
Ky. 75, Owensboro - Masseyville, 1 Mi. N. of Pettit	19	2860	25	–	–	–	–	–	–	–	5.0	
Ky. 54, Philpot to Ohio Co. Line 1/2 Mi. S.E. of Philpot	20	7830	25	–	–	–	–	–	$3.8x10^{-4}$	3.4	5.0	
Ky. 54, Philpot to Ohio Co. Line 1/2 Mi. N.W. of Ohio Co. Line	21	5280	25	–	–	–	–	–	–	–	4.5	
Henderson Co. Ky. 54, Zion-Hebbardsville Henderson Mining Co. Prop.	1	550	27.5	Pos.	Pos.	–	–	Pos.	–	–	–	

APPENDIX D. Water Sample Data (Highway District II)

Road and Sample Location	Sample No.	Measured Resistance in Ohms	Temp. °C.	Qualitative Tests Cl	SO4	Ca	Mg	Fe	Titrated Acidity	Calculated pH	Measured pH	Remarks
Henderson Co. U.S. 60 Henderson-Union Co. Line	CY-14	1250	20	-	-	-	-	-	-	-	-	
Ky. 54 3/4 Mi. N.W. of Hebbardsville	7	754	25	Pos.	-	-	-	-	$3.8x10^{-2}$	1.42	5.5	
U.S. 60, Henderson to Reed, 10 Mi. E. of Henderson	9	530	25	-	Pos.	Pos.	-	-	$9.1x10^{-4}$	3.06	4.5	
Hopkins Co. U.S. 41-S, 7.8 Mi. from Webster Co. Line	CY-20	4020	25	-	-	-	-	-	-	-	-	
Ky. 70-W, 4.2 Mi. W. of Madisonville	CY-21	246	26	-	Pos.	Pos.	Pos.	-	-	-	-	
U.S. 41S, Madisonville-Christian Co.L. 6.7 Mi. S. of Madisonville	CY-22	179	35	-	Pos.	Pos.	Pos.	Pos.	-	-	-	
U.S. 62, 0.4 Mi. from Muhlenberg Co.L	CY-23	12900	34	-	-	-	-	-	-	-	-	

APPENDIX D. Water Sample Data (Highway District II)

Road and Sample Location	Sample No.	Measured Resistance in Ohms	Temp. °C.	Qualitative Tests: Cl	SO_4	Ca	Mg	Fe	Titrated Acidity	Calculated pH	Measured pH	Remarks
Hopkins Co. U.S. 62, 12 Mi. from Muhlenberg County Line	CY-24	298	29.5	-	Pos.	Pos.	-	Pos.	-	-	-	
U.S. 41, 2.1 Mi. West of Nebo	2	3510	25	-	-	-	-	-	-	-	4.5	
Ky. 85, Madisonville-Sacramento 3.3 Mi. E. of Jct. 85-254 (Ky.)	4	2220	25	-	-	-	-	-	$9.1x10^{-4}$	2.1	3.0	
U.S. 62, 3/4 Mi. E. of Nortonville	10	465	25	-	Pos.	Pos.	-	Pos.	$4.9x10^{-3}$	2.3	3.0	
U.S. 62, 2 Mi. S.W. of Muhlenberg County Line	11	8210	25	-	-	-	-	-	-	-	4.5	
Ky. 70, 14 Mi. from first R.R. Intersec. S.W. Muhlenberg Co.L.	15	478	25	-	Pos.	Pos.	-	-	$3.6x10^{-3}$	2.4	3.0	
McLean Co. Ky. 85, Calhoun-Semiway 11 Mi. S.E. of Calhoun	5	3730	25	-	-	-	-	-	-	-	4.5	
Ky. 56, Beechgrove-Calhoun, 9 Mi. N.W. of Calhoun	6	2930	25	-	-	-	-	-	-	-	5.5	

APPENDIX D. Water Sample Data (Highway District II)

Road and Sample Location	Sample No.	Measured Resistance in Ohms	Temp. °C.	Qualitative Tests					Titrated Acidity	Calculated pH	Measured pH	Remarks
				Cl	SO4	Ca	Mg	Fe				
McLean Co. Ky. 75, Livermore-Muhlenberg Co. L. 1/4 Mi. S. of Island	17	10800	25	-	-	-	-	-	-	-	4.5	
Muhlenberg Co. Ky. 70-75	2	200	31	-	Pos.	-	Pos.	Pos.	$1.7x10^{-2}$	1.8	-	
Ky. 70-75	3	219	34.5	-	-	-	-	-	-	-	-	
U.S. 62, 1 Mi. E. of Co. Line	12	531	25	Pos.	-	-	-	Pos.	$5.4x10^{-3}$	2.3	3.0	
Ky. 176, Greenville-Drakesboro, 5 Mi. E. of Greenville	13	2620	25	-	-	-	-	-	$4.9x10^{-4}$	3.3	3.0	
Ky. 70, Earles-Central City, 6 Mi. W. of Central City	14	592	25	-	Pos.	-	-	Pos.	$2.5x10^{-3}$	2.6	3.5	
Ky. 75, Livermore-S. Carrollton, 1 Mi. N. of Moorman	16	6300	25	-	-	-	-	-	-	-	4.5	
Ohio County U.S. 62	4	224	25	-	-	-	-	-	-	-	-	
Ky. 69, Hartford-Fordsville, 3 Mi.	22	9880	25	-	-	-	-	-	-	-	4.5	
Ky. 69, Hartford-at Jingo, Ky.	23	6170	25	-	-	-	-	-	-	-	-	

APPENDIX D. Water Sample Data (Highway District II)

Road and Sample Location	Sample No.	Measured Resistance in Ohms	Temp. °C.	Qualitative Tests Cl	SO4	Ca	Mg	Fe	Titrated Acidity	Calculated pH	Measured pH	Remarks
Ohio Co. Ky. 71, Hartford-Rosine, 2 Mi. E. of Int. with U.S. 62	24	1445	25	–	–	–	–	–	$3.4x10^{-4}$	3.1	3.0	
Union Co. U.S. 60, 1 Mi. S. of Sturgis	CY-12	501	20	Pos.	Pos.	–	–	–	$1.8x10^{-4}$	3.7	–	
U.S. 60, 14.8 Mi. from Union-Crittenden Co. L.	CY-13	358	20	Pos.	–	–	–	–	$5.0x10^{-4}$	–	–	
Ky. 85 N., 1.9 Mi. N. of Sturgis	CY-16	402	23	–	Pos.	Pos.	–	Pos.	$1.4x10^{-2}$	1.9	–	
Ky. 56, 10.3 Mi. from Shawneetown Ferry	CY-17	3350	23	–	–	–	–	–	–	–	–	
Webster Co. Ky. 132, 4.9 Mi. W. of Dixon	CY-19a	380	23	–	Pos.	Pos.	–	Pos.	$2.9x10^{-2}$	1.7	–	
Ky. 85, 2.4 Mi. W. of Jct. Ky. 132	CY-18a	268	26	–	Pos.	Pos.	–	–	$3.0x10^{-2}$	1.5	–	
Ky. 132, 4.9 Mi. W. of City Lim. of Dixon	CY-19b	515	20	–	–	–	–	–	–	–	5.0	

APPENDIX D. Water Sample Data (Highway District II)

Road and Sample Location	Sample No.	Measured Resistance in Ohms	Temp. °C.	Qualitative Tests: Cl	SO4	Ca	Mg	Fe	Titrated Acidity	Calculated pH	Measured pH	Remarks
Webster Co. Ky. 149, Sebree-Hopkins Co. Line Near Jct. Ky. 147	1	4640	25	-	-	-	-	-	-	-	-	
Ky. 56, Tilden-Union Co. Line	3	4830	25	-	-	-	-	-	-	-	5.25	

APPENDIX D. Water Survey Data (Highway District VI)

Road and Sample Location	Sample No.	Measured Resistance in Ohms	Temp. °C.	Qualitative Tests					Titrated Acidity	Calculated pH	Measured pH	Remarks
				Cl	SO_4	Ca	Mg	Fe				
Clark Co. Rural Road, surface drainage	1	2320	25									
Rural Road, side drains and pond overflow	2	2630	25									
Rural Road, farm land surface drainage	3	1743	25.8									
Rural Road, surface run-off	4	2190	24.7									
Rural Road, pasture land surface drainage	5	2770	19									
Rural Road, pasture surface drainage	6	2590	25									
U.S. 60 in Clark County	2	3490	25									
Estill Co. Ky. 89, Irvine-Winchester pasture surface drainage	7	4160	25.5									
Ky. 89, Irvine-Winchester surface drainage	8	2910	25									
Ky. 89, Irvine-Winchester surface drainage	9	5000	25.9									

APPENDIX D. Water Survey Data (Highway District VI)

Road and Sample Location	Sample No.	Measured Resistance in Ohms	Temp. °C.	Qualitative Tests Cl	SO4	Ca	Mg	Fe	Titrated Acidity	Calculated pH	Measured pH	Remarks
Estill Co. Ky. 89, Irvine-Winchester surface drainage	10	4390	25		–							
Fayette Co. U.S. 60, pasture surface run-off	1	2820	25									
Lee Co. Ky. 52, Beattyville, shale seeps and spring	1	2770	18									
Ky. 52, Beattyville to Estill Co. L. seepage	11	850	25		Pos.			Pos.	..-3			Spring under road.
Ky. 52, Beattyville to Estill Co. Line, mine seepage	12	590	25		Pos.			Pos.	2.2×10^{-3}	2.7		
Ky. 52, Beattyville to Estill Co. Line, surface drainage	13	8140	25									
Madison Co. U.S. 25, Richmond-Berea surface drainage from pasture	1	2070	26.1									
U.S. 25, Richmond-Berea cornfield surface drainage	2	3320	26.1									

APPENDIX D. Water Survey Data (Highway District VI)

Road and Sample Location	Sample No.	Measured Resistance in Ohms	Temp. °C.	Qualitative Tests					Titrated Acidity	Calculated pH	Measured pH	Remarks
				Cl	SO4	Ca	Mg	Fe				
Madison Co. Ky. 21, Berea-Bighill, pasture surface drainage	3	3490	26.1									
Ky. 21, Berea-Bighill, pasture surface drainage	4	6480	26.1									
Ky. 21, Berea-Bighill, pasture surface drainage	5	10950	26.1									
Ky. 21, Berea-Bighill, woodland surface drainage	6	7090	26.1									
Ky. 21, Berea-Bighill, pasture surface drainage	7	6350	26.1									
Scott Co. Ironworks Pike, pasture and spring drainage	1	4070	18									
Ironworks Pike, pasture surface drainage	2	3780	21.2									
Pearidge, pasture and spring drainage	3	3130	18									
Pearidge, spring and pasture drainage	4	3330	22.2									
U.S. 25, Fayette Co. L.-Grant Co. L.-pasture run-off	1	10100	20									

APPENDIX D. Water Survey Data (Highway DistrictVI)

Road and Sample Location	Sample No.	Measured Resistance in Ohms	Temp.	Qualitative Tests					Titrated Acidity	Calculated pH	Measured pH	Remarks
				Cl	SO4	Ca	Mg	Fe				
Scott Co. U.S. 25, pasture surface drainage	2	4830	18.5									
U.S. 25, pasture and woodlands	3	no	measurement									
U.S. 25, pasture run-off	4	4600	18									
U.S. 25, pasture run-off	5	7380	19									
U.S. 62, pasture surface drainage	6	5450	14.8									
Woodford Co. Ky. 33, Versailles to Jessamine Co. Line pasture run-off	1	2870	19.3									
Ky. 33, Versailles to Jessamine Co. Line pasture run-off	2	no	measure									
Ky. 33, Versailles to Jessamine Co. Line pasture run-off	3	no	measure									
Ky. 33, Versailles to Jessamine Co. L. woodland and pasture surface drain.	4	2560	17.7									

APPENDIX D. Water Survey Data (Highway District VI)

Road and Sample Location	Sample No.	Measured Resistance in Ohms	Temp. °C.	Qualitative Tests: Cl	SO_4	Ca	Mg	Fe	Titrated Acidity	Calculated pH	Measured pH	Remarks
Woodford Co. Ky. 33, Versailles to Jessamine Co. Line, woodland and pasture surface drainage	5	no measure										
Ky. 33, Versailles to Jessamine Co. Line, woodland and pasture surface drainage	6	no measure										
Ky. 33, Versailles to Jessamine Co. Line pasture run-off	7	3440	17.8									
Ky. 33, Versailles-to Jessamine Co. Line, swamp and surface drainage	8	3040	18.8									
Ky. 33, Versailles to Jessamine Co. Line, pasture run-off	9	no measure										
U.S. 62, Jct. U.S. 50-Midway	10	no measure										
U.S. 62, Jct. U.S. 50-Midway, pasture run-off	11	5360	19									
U.S. 62, Jct. U.S. 50-Midway, pasture surface drainage	12	3110	18.8									

APPENDIX D. Water Survey Data (Highway District VI)

Road and Sample Location	Sample No.	Measured Resistance in Ohms	Temp. °C.	Qualitative Tests: Cl	SO4	Ca	Mg	Fe	Titrated Acidity	Calculated pH	Measured pH	Remarks
Woodford Co. U.S. 62, Jct. U.S. 50-Midway, pasture surface drainage	13	no results										
U.S. 62, Jct. U.S. 50-Midway, pasture and woodlands drainage	14	4450	18.4									
Ky. 50, Midway-Franklin Co. Line, pasture surface drainage	15	4475	18.2									
U.S. 60, Franklin Co. Line-Versailles, wooded surface drainage	16	2260	18.3									
U.S. 60, Franklin Co. Line-Versailles seepage from pond	17	2370	18.0									
U.S. 60, Franklin Co. Line-Versailles	19	no values										
U.S. 60, Franklin Co. Line-Versailles surface run-off	19	3660	21.2									

APPENDIX D. Water Sample Data (Highway District VII)

Road and Sample Location	Sample No.	Measured Resistance in Ohms	Temp. °C.	Qualitative Tests Cl	SO_4	Ca	Mg	Fe	Titrated Acidity	Calculated pH	Measured pH	Remarks
Floyd Co. Ky. 306 at Wheelwright, from mine	8	1070	25	–	Pos.	–	–	–	9.8×10^{-5}	4.4	5.5	
Ky. 122 from Beaver Creek below Inland Steel Tipple	9	1770	25	–	–	–	–	–	1.2×10^{-3}	2.9	5.0	
Ky. 122 Mine at McDowell	10	2760	25	–	–	–	–	–	–	–	5.0	
U.S. 23-460 Allen-Prestonsburg Hillside Seepage	12	2510	25	Neg.	–	–	–	–	7.3×10^{-5}	4.1	5.0	
U.S. 23-460 E. City Lim. Prestonsburg abandoned mine	13	310	25	–	Pos.	–	–	–	2.2×10^{-2}	1.7	3.5	
Ky. 80 at Hueysville, Mine and surface drainage	43	2630	25	Neg.	–	–	–	–	3.9×10^{-4}	3.4	5.5	

APPENDIX D. Water Sample Data (Highway District VII)

Road and Sample Location	Sample No.	Measured Resistance in Ohms	Temp. °C.	Qualitative Tests: Cl	SO_4	Ca	Mg	Fe	Titrated Acidity	Calculated pH	Measured pH	Remarks
Floyd Co. C&O RR Mile Post No. 74, Seepage from cut	1	254	25	–	–	–	–	–	–	–	–	
C&O RR at Prestonsburg Seepage from cut	2	500	25	Neg.	Pos.	Neg.	Neg.	Pos.	–	–	–	
C&O RR Mile Post 74+.25 Seepage from cut	3	206	25	Neg.	Pos.	Pos.	Pos.	Pos.	$3.2x10^{-2}$	1.5	–	
C&O RR Mile Post 74+.3 Seepage from cut	4	322	25	Neg.	Pos.	Neg.	Neg.	Pos.	$2.09x10^{-2}$	1.7	–	
Big Sandy River at Prestonsburg	6	4200	25	Neg.	Neg.	Neg.	Neg.	–	–	–	–	
Johnson Co. U.S. 23-460 Hager Hill Mine Drainage	14	10800	25	–	–	–	–	–	–	–	4.0	Diluted by Surface Water
Ky. 40 Meally Mine Drainage	15	1715	25	Neg.	Neg.	Neg.	Neg.	Neg.	$3.8x10^{-4}$	3.4	5.0	

APPENDIX D. Water Sample Data (Highway District VII)

Road and Sample Location	Sample No.	Measured Resistance in Ohms	Temp. °C.	Qualitative Tests					Titrated Acidity	Calculated pH	Measured pH	Remarks
				Cl	SO_4	Ca	Mg	Fe				
Knott Co. Ky. 80 Lackey-Mousie, Old abandoned mine	44	890	25	–	Pos.	–	–	–	4.3×10^{-4}	3.4	5.5	
Ky. 80, 3.8 Mi. W. of Hindman Hindman-Dwarf Truck mine drainage	45	4400	25	–	–	–	–	–	–	–	–	
Letcher Co. Ky. 15 Cody-Whitesburg Mine drainage	3	625	22	–	–	–	–	–	–	–	–	
U.S. 119 N. of Jenkins from Elkhorn Creek	5	1700	22	–	–	–	–	–	–	–	–	
U.S. 119 N. of Jenkins, Mine drainage	5a	2260	25	–	–	–	–	–	–	–	–	Drains Consolidated Mine 204, National Champion Coal Co.
U.S. 119 W. City Limits Jenkins, head of Elkhorn Creek, Mine drainage	6	795	25	–	–	–	–	–	–	–	–	

APPENDIX D. Water Sample Data (Highway District VII)

Road and Sample Location	Sample No.	Measured Resistance in Ohms	Temp. °C.	Qualitative Tests: Cl	SO_4	Ca	Mg	Fe	Titrated Acidity	Calculated pH	Measured pH	Remarks
Martin Co. Ky. 40 N.W. of Tomahawk from red stream.	16	18000	25	–	–	–	–	–	–	–	5.0	
Ky. 3, Inez-Fort Gay from Diamond Mine	17	6600	25	–	–	–	–	–	–	–	4.5	
Perry Co. Ky. 15 Hazard-Lothair Seepage from hill	1	2680	25	–	–	–	–	–	–	–	–	
Ky. 15 Lothair-Knott Co. Line Surface drainage	2	1160	25	–	Pos.	–	–	Pos.	–	–	–	
Ky. 15 Hazard-Knott Co. Line Seepage and run-off	3	780	25	–	Pos.	–	–	Pos.	–	–	–	
Ky. 15 Hazard-Knott Co. Line-slack pile drainage	4	1600	25	–	–	–	–	–	–	–	–	

APPENDIX D. Water Sample Data (Highway District VII)

Road and Sample Location	Sample No.	Measured Resistance in Ohms	Temp. °C.	Qualitative Tests: Cl	SO_4	Ca	Mg	Fe	Titrated Acidity	Calculated pH	Measured pH	Remarks
Perry Co. Ky. 15 Hazard-Knott Co. Line hill-side drainage	5	7600	25	–	–	–	–	–	–	–	–	
Ky. 7, Hazard-Letcher Co. Line, shale cut	6	1200	25	–	–	–	–	–	–	–	–	
Ky. 7, Hazard-Letcher Co. Line, surface drainage	7	9450	25	–	–	–	–	–	–	–	–	
Ky. 7, Hazard-Letcher Co. Line, surface drainage	8	12300	25	–	–	–	–	–	–	–	–	
Ky. 7, Hazard-Letcher Co. Line, shale cut	9	4250	25	–	–	–	–	–	–	–	–	
Ky. 7, Hazard-Letcher Co. Line, surface drainage	10	3500	25	–	–	–	–	–	–	–	–	

APPENDIX D. Water Sample Data (Highway District VII)

Road and Sample Location	Sample No.	Measured Resistance in Ohms	Temp. °C.	Qualitative Tests					Titrated Acidity	Calculated pH	Measured pH	Remarks
				Cl	SO4	Ca	Mg	Fe				
Perry Co. Ky. 15, from Jct. Ky. 7-15 to Vicco Surface drainage	16	2360	25	–	–	–	–	–	–	–	–	
Ky. 15, from Jct. Ky. 7-15 to Vicco, slack pile drainage	15	3880	25	–	–	–	–	–	–	–	–	
Ky. 15, from Jct. Ky. 7-15 to Vicco, surface drain by coal mine	14	6250	25	–	–	–	–	–	–	–	–	
Ky. 80 Hazard-Leslie Co. Line Surface drainage	13	9150	25	–	–	–	–	–	–	–	–	
Ky. 80 Hazard-Leslie Co. Line Stream	12	11500	25	–	–	–	–	–	–	–	–	
Ky. 80 Hazard-Leslie Co. Line Wooded hillside and spring	11	885	25	–	Pos.	–	–	–	–	–	–	

APPENDIX D. Water Sample Data (Highway District VII)

Road and Sample Location	Sample No.	Measured Resistance in Ohms	Temp. °C.	Qualitative Tests					Titrated Acidity	Calculated pH	Measured pH	Remarks
				Cl	SO_4	Ca	Mg	Fe				
Perry Co. Ky. 15 Hazard-Hillside seepage	17	14300	25	–	–	–	–	–	–	–	–	
Pike Co. U.S. 23-119 Jenkins-Shelbiana Mine and surface drainage	6	2730	25	–	–	–	–	–	–	–	–	
Ky. 80 Marrowbone-Elkhorn City Mine and surface drainage	1	10600	25	–	–	–	–	–	–	–	4.5	
Ky. 80 Marrowbone-Elkhorn City 3 mi. downstream from Republic Mine	2	3400	25	–	–	–	–	–	–	–	5.0	
Ky. 80, City Lim. Elkhorn City Russell Fork of Beaver Creek	3	3750	25	–	–	–	–	–	–	–	4.5	

APPENDIX D. Water Sample Data (Highway District VII)

Road and Sample Location	Sample No.	Measured Resistance in ohms	Temp. °C.	Qualitative Tests Cl	SO4	Ca	Mg	Fe	Titrated Acidity	Calculated pH	Measured pH	Remarks
Pike Co. Ky. 197 at Sycamore, stream	4	12100	25	–	–	–	–	–	–	–	4.5	
Ky. 99 at McVey at mine	11	22680	25	–	–	–	–	–	$1.2x10^{-3}$	2.9	5.0	
Ky. 122 Virgie-Melvin abandoned mine drainage	7	172	25	–	Pos.	Pos.	Pos.	Pos.	$3.8x10^{-2}$	1.4	3.0	

APPENDIX D. Water Survey Data (Highway District VII)

Road and Sample Location	Sample No.	Measured Resistance in Ohms	Temp. °C.	Qualitative Tests Cl	SO_4	Ca	Mg	Fe	Titrated Acidity	Calculated pH	Measured pH	Remarks
Bath Co., U.S. 60 4 Mi. E. of Owingsville pasture land drainage	1	1840	25									
U.S. 60, 4.25 Mi. E. of Owingsville, seepage from cut	2	1500	25									
U.S. 60, 5 Mi. E. of Owingsville, pasture land drainage	3	1520	25									
U.S. 60, 6.4 Mi. E. of Owingsville, surf. drain.	4a	2680	25									
U.S. 60, 6.4 Mi. E. of Owingsville, surf. drain.	4b	8200	25									
U.S. 60, 1/2 Mi. E. of Folksville, seepage from red shale	5	2950	25									
Ky. 211, 3 Mi. S. of Salt Lick, pasture land drainage	6	8150	25									
Ky. 211, 3-1/2 Mi. S. of Salt Lick, surf. drain.	7	6350	25									
Ky. 36, at Olympia Springs, pasture land drainage	8	6050	25									

APPENDIX D. Water Survey Data (Highway District VIII)

Road and Sample Location	Sample No.	Measured Resistance in Ohms	Temp. °C.	Qualitative Tests: Cl	SO4	Ca	Mg	Fe	Titrated Acidity	Calculated pH	Measured pH	Remarks
Bath Co., Ky. 36, 1.3 Mi. N. of Olympia Springs, pasture land drainge	9	3800	25									
Ky. 36, 1 Mi. N. of [illegible] Owingsville, pasture land drainage	10	1880	25									
Breathitt Co., Ky. 52-Ky. 30, 3/4 Mi. S. of Elkatawa, slack pile drainage	2	2370	25									
Ky. 15, 2 Mi. W. of Perry Co. Line, residual ditch water	46	9600	25								5.0	
Ky. 15, 5 Mi. W. of Quicksand, hillside seepage	47	7500	25								4.5	
Ky. 15, 2 Mi. W. of Wilhurst, seepage from cut	48	12750	25									
Boyd Co., U.S. 23, 3 Mi. S. of Jct. Ky. 180 from 3 drift mines	20	3600	25						3.8×10^{-4}	3.4	4.0	
Ky. 80, Cannonsburg-Jct. U.S. 23, from drift mine in cut	34	344	25	Pos.	Pos.	Pos.	Neg.	Pos.	2.6×10^{-2}	1.6	3.0	

APPENDIX D. Water Survey Data (Highway District VIII)

Road and Sample Location	Sample No.	Measured Resistance in Ohms	Temp. °C.	Qualitative Tests: Cl	SO_4	Ca	Mg	Fe	Titrated Acidity	Calculated pH	Measured pH	Remarks
Boyd Co. U.S. 60, S. of Princess, strip mine drainage	33	840	25		Pos.				2.1×10^{-3}	3.7	3.5	
Carter Co., U.S. 60, 5 Mi. S. of Olive Hill, pasture land drainage	24	4820	25								5.0	At Globe, Kentucky.
U.S. 60, 5 Mi. E. of Grayson, slide seepage	32	3340	25								5.0	
FI-13(3), hillside and pasture land drainage	1	10500	25									
FI-13(3), seepage from shale in cut	2a	937	25									Sampled at 2 different places in cut 2a-b
FI-13(3), same location run-off from cut.	2b	2500	25		Pos.	Pos.		Pos.			5.[illegible]	
Ky. 182, at Carter Cave State Park, Tygarts Creek	23	4850	25								5.0	
Ky. 7, 2 Mi. N. of Grayson residual ditch water	22	2400	25	Neg.	Neg.	Neg.	Neg.	Neg.	9.8×10^{-5}	4.0	4.5	
Elliott Co. Ky. 32, 1 Mi. W. of Newfoundland, residual ditch water	26	8850	25								5.0	
Ky. 32, Isonville, mine drainage	27	528	25		Pos.			Pos.	4.7×10^{-3}	2.3	3.0	

APPENDIX D. Water Survey Data (Highway District VIII)

Road and Sample Location	Sample No.	Measured Resistance in Ohms	Temp. C.	Qualitative Tests Cl	SO4	Ca	Mg	Fe	Titrated Acidity	Calculated pH	Measured pH	Remarks
Elliott Co. Ky. 7, 2 Mi. S. of Carter Co. Line, seepage from a slide	35	12300	25								5.0	
Fleming Co., Ky. 158, Hilda-Hillsboro	3	3660	25.8									
Greenup Co., Ky. 1, 3½ Mi. S. of Argillite, pipe line excavation	21	8320	25								4.5	
Lawrence Co., Ky. 3, Inez-Fort Gay, along river bluff	18	5460	25								5.0	Roadside spring, iron stained.
Ky. 32, Louisa-Blaine, branch water	28	10180	25								4.0	No reason for acidity
U.S. 23, above Fallsburg, ditch water	19	5540	25								5.0	Residual ditch water
Ky. 1, Fallsburg-Webbville, branch water	29	4830	25								5.0	No reason for acidity
Ky. 1, 5 Mi. E. of Webbville, Webbville Mining Co.	30	635	25						6.0×10^{-3}	2.2	3.5	Strip mine, abandoned 5 years
Ky. 1, 3 Mi. N. of Webbville, abandoned mine	31	955	25		Pos.				3.4×10^{-3}	2.5	3.5	Cont. flow

APPENDIX D. Water Sample Data (Highway District VIII)

Road and Sample Location	Sample No.	Measured Resistance in Ohms	Temp, °C.	Qualitative Tests: Cl	SO4	Ca	Mg	Fe	Titrated Acidity	Calculated pH	Measured pH	Remarks
Rowan Co., U.S. 60, Bath-Carter Co. Line	11	4460	25									Surface run-off, discolored.
"	12	594	25	Neg.	Pos.	Pos.	-	Pos.	$2.2x10^{-3}$		2.7	Seepage from shale cut.
"	13	8480	25.5									Surface run-off and seepage.
"	14	980	25.4		Pos.							" "
"	15	9800	25									Wooded hill run-off.
"	16	930	25									Seepage, disintegrated culvert.
"	17	4790	25	Pos.	Pos.	Pos.	Neg.	Pos.				Wooded hill run-off.
"	18	14520	25									Seepage and surface run-off.
"	19	8940	25									Surface run-off.
Ky. 32, Morehead-Fleming Co. Line	1	2230	29									Surface run-off.
Ky. 32, 4 Mi. E. of Morehead, quarry drainage	25	8560	25								5.0	Diluted by rain, muddy.
Wolfe Co., Ky. 203 N. of Hazelgreen at cross-drain.	53	21300	25								4.5	Pastureland
Ky. 191, 1 Mi. off Ky. 15 at cross-drain	49	20000	25								4.5	Wooded area

APPENDIX D. Water Survey Data (Highway District VIII)

Road and Sample Location	Sample No.	Measured Resistance in Ohms	Temp. °C.	Qualitative Tests					Titrated Acidity	Calculated pH	Measured pH	Remarks
				Cl	SO4	Ca	Mg	Fe				
Mongtomery Co., U.S. 60 Clark-Bath Co. Line, creek water	1	3110	25									
Ky. 11, Mt. Sterling-Frenchburg, creek water	2	2280	25									
Ky. 11, Mt. Sterling-Frenchburg, creek water	3	3280	25									
Morgan Co., U.S. 460, 1/2 Mi. E. of Index, branch water	52	8940	25								4.5	Mines in area, this drains pas-tureland.
Ky. 191, downstream from Cannel City, creek water	51	6880	25								4.5	Numerous mines upstream.
U.S. 460, 3 Mi. E. of W. Liberty, surface runoff.	37	10700	25								3.5	Residual, surface runoff.
Ky. 7, S. of Wrigley, surface runoff	36	8920	25								5.0	Raining.

APPENDIX D. Water Sample Data (Highway District VIII)

Road and Sample Location	Sample No.	Measured Resistance in Ohms	Temp. °C.	Qualitative Tests					Titrated Acidity	Calculated pH	Measured pH	Remarks
				Cl	SO_4	Ca	Mg	Fe				
Wolfe Co. Ky. 191, between Ky. 205 and Adele, mine drainage	50	594	25		Pos.			Pos.	5.4×10^{-3}	2.3	3.0	
Ky. 15, 1/2 Mi. E. of Campton, side of road	54	17200	25								5.0	Residual ditch water.
Ky. 15, 2 Mi. W. of Pine Ridge ditch water	55	26000	25								4.5	

APPENDIX D. Water Survey Data (Highway District IX)

Road and Sample Location	Sample No.	Measured Resistance in Ohms	Temp. °C.	Qualitative Tests Cl	SO_4	Ca	Mg	Fe	Titrated Acidity	Calculated pH	Measured pH	Remarks
Bell Co. U.S. 25-E, Middlesboro, 1.4 Mi. from Va. Line at Cumberland Gap	1	14300	25	-	-	-	-	-	-	-	-	Run-off and sewage.
Ky. 74 Middlesboro-Tenn. Border, run-off	2	12500	25	-	-	-	-	-	-	-	-	Wooded
Ky. 74, Middlesboro-Tenn. Border, 7 Mi. from Middlesboro	3	1340	23	-	-	-	-	-	-	-	-	Coal slack pile.
Ky. 74, Middlesboro-Tenn. Border, 11.6 Mi. from Middlesboro	4	393	25	Neg.	Pos.	Pos.	Pos.	Pos.	-	-	-	1940 construction, damaged by coal mine drainage.
Ky. 74, Middlesboro-Tenn. Border run-off coal mine water	5	1475	28.5	-	-	-	-	-	-	-	-	Dirty water
U.S. 25-E, Middlesboro-Pineville, Stream, woodland run-off	6	1270	25	-	-	-	-	-	-	-	-	High resistance for stream.
U.S. 25-E, Middlesboro-Pineville Stream, woodland run-off	7	2510	25	-	-	-	-	-	-	-	-	

APPENDIX D. Water Survey Data (Highway District IX)

Road and Sample Location	Sample No.	Measured Resistance in Ohms	Temp. °C.	Qualitative Tests Cl	SO4	Ca	Mg	Fe	Titrated Acidity	Calculated pH	Measured pH	Remarks
Bell County												
U.S. 25-E, Va. Line to Middlesboro road-side run-off & seeps	8	3850	33	-	-	-	-	-	-	-	-	
U.S. 119, Pineville-Harlan Co. Line, woodland run-off	9	17400	30	-	-	-	-	-	-	-	-	
Clay Co.												
Ky. 80, Laurel Co. Line-Manchester seepage from cut	1	8400	25	-	-	-	-	-	-	-	-	
Ky. 80, Laurel Co. Line-Manchester seepage	2	10620	25	-	-	-	-	-	-	-	-	
Ky. 80, Laurel Co. Line-Manchester Surface drainage and seeps	3	2550	25	-	-	-	-	-	-	-	-	Also drains sewage.
Ky. 80, Laurel Co. Line-Manchester Surface drainage	4	11600	25	-	-	-	-	-	-	-	-	
Ky. 21, Manchester-Jackson Co. Line Surface Drainage	5	5810	25	-	-	-	-	-	-	-	-	

APPENDIX D. Water Survey Data (Highway District IX)

Road and Sample Location	Sample No.	Measured Resistance in Ohms	Temp. °C.	Qualitative Tests Cl	SO4	Ca	Mg	Fe	Titrated Acidity	Calculated pH	Measured pH	Remarks
Clay Co. Ky. 21, Manchester-Jackson Co. Line Spring	6	3130	25	–	–	–	–	–	–	–	–	
Ky. 21, Manchester-Jackson Co. Line Surface & coal mines	7	2060	25	–	–	–	–	–	–	–	–	
Ky. 21, Manchester Jackson Co. Line farm drainage	8	12600	25	–	–	–	–	–	–	–	–	
Harlan Co. Ky. 160, vic. Lynch run-off and coal mines	4	1340	19	–	–	–	–	–	–	–	–	
Ky. 219, Wallins-Creech run-off and seeps	10	1788	25	–	–	–	–	–	–	–	–	
Ky. 219, Wallins-Creech run-off and seeps	11	19680	25	–	–	–	–	–	–	–	–	Has been acid at one time.
Ky. 219, Wallins-Creech, stream on coal mine property	12	2680	25	–	–	–	–	–	–	–	–	Rain diluted this, another measure.
Ky. 421 & 66, Harlan to Turtle Creek Coal loading zone	13	2950	25	–	–	–	–	–	–	–	–	Signs of acidity at culvert.

APPENDIX D. Water Survey Data (Highway District IX)

Road and Sample Location	Sample No.	Measured Resistance in Ohms	Temp. °C.	Qualitative Tests: Cl	SO4	Ca	Mg	Fe	Titrated Acidity	Calculated pH	Measured pH	Remarks
Jackson Co. Ky. 30, Tanner to Owsley Co. Line Surface run-off, spring	9	32200	25	–	–	–	–	–	–	–	–	
Laurel Co. U.S. 25 Rockcastle Co. Line-London, pasture surface drainage	5	5280	25	–	–	–	–	–	–	–	–	
U.S. 25 Rockcastle Co. Line-London, forest surface drainage	6	4200	25	–	–	–	–	–	–	–	–	
U.S. 25 Rockcastle Co. Line-London, seepage and surface drainage	7	17900	25	–	–	–	–	–				
Ky. 80, London-Clay Co. Line, seepage and surface drainage	8	805	25	Neg.	Pos.	Neg.	Neg.	Pos.	–	–	–	
Ky. 80, London-Clay Co. Line, mine slack	9	715	25.5	Neg.	Pos.	Neg.	Neg.	Pos.	–	–	–	Stream carrying some algae.
Ky. 80, London-Clay Co. Line, seepage from hill	10	7240	25	–	–	–	–	–	–	–	–	

APPENDIX D. Water Survey Data (Highway District IX)

Road and Sample Location	Sample No.	Measured Resistance in Ohms	Temp. °C.	Qualitative Tests Cl	SO4	Ca	Mg	Fe	Titrated Acidity	Calculated pH	Measured pH	Remarks
Owsley Co. Ky. 30, Jackson Co. Line-Booneville, forest surface drainage	10	23300	25	–	–	–	–	–	–	–	–	
Pulaski Co. Ky. 80, Rockcastle Co. Line-Somerset, surface seepage	11	2100	25	–	–	–	–	–	–	–	–	Strip mining area
Ky. 80, Somerset to Laurel Co. Line, coal property run-off	17	6000	25	–	–	–	–	–	–	–	–	
Rockcastle Co. U.S. 25, Mt. Vernon-Laurel Co. Line, surface drainage and seeps	1	4200	25	–	–	–	–	–	–	–	–	
U.S. 25, Mt. Vernon-Laurel Co. Line, slack pile and seeps	2	1300	25	–	–	–	–	–	–	–	–	
U.S. 25, Mt. Vernon-Laurel Co. L., seepage and surface run-off	3a	2100	25	–	–	–	–	–	–	–	–	
Slack Pile	3b	1030	25	–	–	–	–	–	–	–	–	
U.S. 25, Mt. Vernon-Laurel Co. L. slack pile	4	no results recorded										

APPENDIX D. Water Survey Data (Highway District IX)

Road and Sample Location	Sample No.	Measured Resistance in Ohms	Temp. °C.	Qualitative Tests Cl	SO_4	Ca	Mg	Fe	Titrated Acidity	Calculated pH	Measured pH	Remarks
Whitley Co. U.S. 25-W, Williamsburg-Jellico. slack pile drainage	14	1115	21	-	-	-	-	-	-	-	-	
Ky. 92, Williamsburg-Holly Hill, wooded area with coal property	15	1610	25	-	-	-	-	-	-	-	-	
Ky. 92, Williamsburg-Holly Hill, coal mine and slack pile	16	515	29	Neg.	Pos.	Neg.	Neg.	Neg.	-	-	-	

APPENDIX E. Culvert Survey Data (Highway District I)

County Route No. & Location	Concrete Pipe	Concrete Box	Concrete Slab	Corrugated Metal	Vitrified Clay	Remarks
Ballard Co. U.S. 60 McCracken Co. Line to Wickliffe	20-ex. 9-grown over 1-silting 1-ex. entr.	36-ex. 3-grown over	1-ex.	4-ex. entr. 9-silted entr. 4-cave entr. 2-grown entr.	2-grown entr.	Gently rolling river terraces, internal drainage, principally agricultural, no evidence of acidity.
U.S. 51-62 Wickliffe to Carlisle Co. Line	2-silted	1-ex. 1-silted		1-ex. entr.		Road is all fill-section, culverts listed as silting are filling with sand.
Caldwell Co. U.S. 62 Hopkins Co. Line to Lyons Co. Line	40-ex. 18-silted 3-ex. entr. 6-silted entr.	28-ex. 1-silted		15-ex. 5-ex. entr. 7-silted entr. 3-caved entr.		Princeton to Lyon Co. Line all Corr. Metal-No Headwalls, agricultural area, no acidity observed.
Ky. 91 Christian Co. Line to Princeton	15-ex. 9-silted 1-ex. entr. 2-silted entr.	22-ex.		2-ex. entr. 2-silted entr.		Limestone-shale area, lot of silting, no indication of acidity.
Ky. 91 Princeton to Crittenden Co. Line	2-ex. 2-ex. entr. 2-silted entr.	33-ex. 4-silted		14-ex. 13-silted 2-silted entr. 3-caved entr.		Limestone-shale area, agricultural, lot of silting, no indication of acidity.
Ky. 293 Princeton to Jct. Ky. 70	14-ex. 13-silted	12-ex.		1-ex. entr. 1-silted entr.		Agricultural region, culverts silted and overgrown.

APPENDIX E. Culvert Survey Data (Highway District I) (Con't.)

County Route No. & Location	Concrete Pipe	Concrete Box	Concrete Slab	Corrugated Metal	Vitrified Clay	Remarks
Caldwell Co. Ky. 128 Princeton to Trigg Co. Line	3-ex. 5-silted 3-silted entr.	15-ex. 1-ex. entr.		1-ex. entr. 3-silted entr.	4-ex. 2-silted 1-silted entr. 2-caved entr.	Good internal drainage, sink holes, limestone area. No headwalls on vitrified clay pipe.
Calloway Co. Ky. 94 Graves Co. Line to Murray	3-ex. 8-ex. entr. 1-silted 2-silted entr.	24-ex. 3-silted		7-ex. entr. 3-silted entr. 5-caved entr.		No indication of acidity, farm land.
Ky. 95 Murray to Marshall Co. Line	32-ex. 4-ex. entr. 11-silting	28-ex.		8-ex. entr. 1-silted entr.		Turf coverage very good except for cuts through gravel banks.
Ky. 121 Graves Co. Line to Murray	9-ex. 8-ex. entr. 4-silted 4-silted entr.	18-ex. 1-silted		4-ex. entr. 10-silted entr. 1-caved entr.		Few culverts required. No indication of acidity.
Ky. 121 Murray to Tenn. Line	8-ex. 4-ex. entr. 8-silted 1-silted entr.	37-ex.	1-ex. entr.	1-ex. entr.		Gravel banks and clay deposits.
Ky. 95 Tenn. Line to Murray	6-ex. 5-silted 3-ex. entr. 2-silted entr.	15-ex. 2-silted 1-undermined		3-ex. entr. 2-silted entr. 1-caved entr.		Agricultural area, no indication of acidity.
Ky. 95 Murray to Marshall Co. Line	4-ex. 8-silted 2-ex. entr.	36-ex.				(Same as above)

APPENDIX E. Culvert Survey Data (Highway District I) (Con't.)

County Route No. & Location	Concrete Pipe	Concrete Box	Concrete Slab	Corrugated Metal	Vitrified Clay	Remarks
Carlisle Co. U.S. 51 Ballard Co. Line to Bardwell	4-ex. 2-ex. entr. 2-silted	8-ex.		2-ex. entr.		Mostly fill-section, Non-acid area.
U.S. 51-62 Bardwell to Hickman Co. Line	15-ex. 6-silted 4-ex. entr.	20-ex. 2-Undermined				No water available for sampling, rapid run-off, non-acid area.
U.S. 62 Bardwell east to Ballard Co. Line	23-ex. 15-silted 2 ex. entr.	29-ex.		4-ex. entr.		Lowland, poor drainage, stagnant water - No evidence of acidity.
Christian Co. Ky. 91, Jct. 68 to Caldwell Co. Line	12-ex. 17-silted 3-ex. entr. 1-caved	30-ex. 1-silted		7-ex. entr. 5-silted entr. 1-caved entr.	1-ex. entr.	Limestone and shale area, no indication of acidity.
U.S. 68 Trigg Co. Line to Hopkinsville	9-ex. 2-silted 4-ex. entr.	10-ex.		30-ex. 5-silted		Silting results from adjacent plowed fields, concrete pavement, good turf on shoulders and slopes.
U.S. 41 Alt., Hopkinsville to Tenn. Line	11-ex. 3-silted 6-ex. entr.			3-ex. entr. 3-silted entr. 1-caved entr.		Region similar to Bluegrass in appearance, concrete pvt., few culverts.
U.S. 41, Hopkinsville to Todd Co. Line	17-ex. 5-ex. entr. 1-silted entr.	11-ex.		1-ex. entr.		Few culverts required, (see above).

APPENDIX B. Culvert Survey Data (Highway District I) (Con't.)

County Route No. & Location	Concrete Pipe	Concrete Box	Concrete Slab	Corrugated Metal	Vitrified Clay	Remarks
Christian Co. U.S. 68 Todd Co. Line to Hopkinsville	21-ex. 12-silted 2-ex. entr.	16-ex.		2-ex. entr. 1-caved entr.	1-ex. entr.	Ditches, grown over prevents silting, no indication of acidity
Ky. 107 Hopkinsville to LaFayette	17-ex. 13-silting 2-ex. entr.	11-ex. 1-silted entr.		3-ex. entr. 5-silted entr. 3-caved entr.		Few culverts required, several are not functional, no indication of acidity.
Ky. 107 Hopkinsville North to Todd Co. Line	10-ex. 15-silted 1-silted entr.	20-ex. 1-ex. entr.		1-ex. entr. 1-caved entr.	1-ex. engr.	Agricultural Region, gently rolling, no indication of acidity.
U.S. 41 Hopkinsville to Hopkins Co.Line	24-ex. 4-silted 2-ex. entr.	30-ex. 2-silting		5-ex. entr. 1-silted entr. 2-caved entr.	1-ex. entr. 1-silted entr.	North end of road enters coal region, some coal exposed in cuts, potentially acid.
Crittenden Co. U.S. 60 Livingston Co. Line to Union Co. Line	40-ex. 5-silted 8-ex. entr. 2-silted entr.	76-ex. 1-silted		7-ex. entr. 5-silted entr. 4-caved entr.	22-ex. 13-silted 1-caved 1-ex. entr.	Vitrified clay to Marion, (uncemented SS headwalls) Agricultural Area, no indication of acidity.
Ky. 91 Marion-North to Ohio River	27-ex. 5-silted	37-ex.				Limestone area approaching river, no indication of acidity.
Ky. 91 Marion-South to Caldwell Co.Line	2-ex. 1-silted 1-caved entr. 6-ex. entr.	18-ex. 1-silted 11-undermined		6-ex. 3-silted 6-ex. entr. 3-silted entr. 4-caved entr.		Mild rusting noted on corr. metal pipe but no indication of acidity.

APPENDIX E. Culvert Survey Data (Highway District I) (Con't.)

County Route No. & Location	Concrete Pipe	Concrete Box	Concrete Slab	Corrugated Metal	Vitrified Clay	Remarks
Graves Co. U.S. 45 McCracken Co. Line to Mayfield	12-ex. 8-silted 6-ex. entr. 3-silted entr.	30-ex.		2-ex. entr.		
U.S. 45 Hickman Co. Line to Mayfield	28-ex. 20-silted 5-ex. entr. 8-silted entr.	26-ex. 1-ex. entr. 1-silted		3-ex. entr. 4-silted entr.	1-ex. entr.	Flat terraces, agricultural, no evidence of acidity. Internal drainage, no water available for sample.
Ky. 98 Mayfield to Carlisle Co. Line	8-ex. 17-silted 4-silted entr.	26-ex. 2-silted 2-undermined				Grading operations on shoulders covered up some culverts gravel deposits erode easily and fill culverts.
Ky. 98 Mayfield to Marshall Co. Line	4-ex. entr. 2-silted	20-ex. 1-silted		2-ex. entr. 1-silted entr. 1-caved entr.	10-ex. 25-silted 1-ex. entr.	Often culverts submerged, water standing in ditches-need maintenance.
Ky. 97 Mayfield to Tenn. Line	4-ex. 8-ex. entr. 1-silted entr.	52-ex. 17-silted 3-undermined	2-ex.	1-ex. 13-ex. entr. 3-silted entr. 4-caved entr.	2-ex. entr.	Mostly agricultural, no evidence of acidity
Hickman Co. U.S. 45 Fulton Co. Line to Graves Co. Line	6-ex. 7-silted 2-ex. entr.	7-ex. 1-silted		1-ex. entr.		Flat terrain, alluvial soil no indication of acidity.

APPENDIX E. Culvert Survey Data (Highway District I) (Con't.)

County Route No. & Location	Concrete Pipe	Concrete Box	Concrete Slab	Corrugated Metal	Vitrified Clay	Remarks
Hickman Co. U.S. 51 Clinton to Fulton Co. Line	20-ex. 9-silted 1-ex. entr.	5-ex. [illegible]		1-silted entr. 3-caved entr.		Flat terrain, alluvial soil, no evidence of acidity.
Ky. 58 Clinton to Graves Co. Line	37-ex. 14-silted 1-ex. entr. 3-silted entr.	9-ex. 1-ex. entr.		2-ex. entr. 12-silted entr. 2-caved entr.		Agricultural area, some internal drainage. No indication of acidity.
U.S. 51 Carlisle Co. Line to Clinton	16-ex. 7-silted 1-silted entr. 1-caved	8-ex. 2-silted		1-ex. entr. 2-silted entr.		Internal drainage area, no evidence of acidity, alluvial soil region.
Livingston Co. U.S. 62 Lyon Co. Line to Smithland	12-ex. 4-silted 2-ex. entr. 1-silted entr.	43-ex. 3-silted		11-ex. 2-silted 2-caved 2-ex. entr. 2-corroded		Agricultural area, no indication of acidity. 2-corroded must be due to natural rusting. See mildly acid sample in adjoining Calloway Co.
U.S. 60-62, Smithland to McCracken Co. Line	24-ex. 4-silted 2-ex. entr.	24-ex.				Agricultural area, internal drainage, no indication of acidity.
U.S. 60 Smithland to Crittenden Co. Line	48-ex. 6-silted 4-ex. entr. 1-silted entr.	35-ex.		3-ex. entr. 1-caved entr.		Principally agricultural, No indication of acidity

APPENDIX E. Culvert Survey Data (Highway District I) (Con't.)

County Route No. & Location	Concrete Pipe	Concrete Box	Concrete Slab	Corrugated Metal	Vitrified Clay	Remarks
Lyon Co. U.S. 62 Livingston Co. Line to Caldwell Co. Line	28-ex. 12-silted 1-ex. entr. 1-silted entr.	55-ex. 3-silted 4-ex. entr.		1-ex. entr. 1-silted entr.	1-ex. entr. 1-silted entr.	Flat terrain, no indication of acidity.
Ky. 93 Eddyville to Trigg Co. Line	14-ex. 3-silted	22-ex.				Drainage parallels highway, few culverts required. No indication of acidity.
Ky. 93 Kuttawa to Caldwell Co. Line	25-ex. 6-silted 1-ex. entr.	6-ex.	(Stone Slab) 1-silted entr.	2-ex. entr. 1-silted entr.		Culverts overgrown, flat farm land, non-acid.
Marshall Co. Ky. 98 Graves Co. Line to Jct. US-68 Aurora	11-ex. 11-silted 2-ex. entr. 1-silted entr.	45-ex.		2-ex. entr. 2-silted entr.		Agricultural, alluvial, no indication of acidity, few culverts, long fill section.
U.S. 68 Aurora to Benton	18-ex. 7-silted 11-ex. entr. 6-silted entr.	40-ex. 3-silted	2-ex.	8-ex. entr. 4-silted entr. 1-caved entr.		No indication of acidity.
U.S. 68 Benton to McCracken Co. Line	30-ex. 8-silted 2-caved 5-ex. entr 2-silted entr.	36-ex. 5-silted 2-undermined		3-ex. entr. 3-silted entr. 1-caved entr.		Widening was in progress, entr. pipe being replaced, no indication of acidity.

APPENDIX E. Culvert Survey Data (Highway District I) (Con't.)

County Route No. & Location	Concrete Pipe	Concrete Box	Concrete Slab	Corrugated Metal	Vitrified Clay	Remarks
Marshall Co. Ky. 95 Calloway Co. Line to Benton	7-ex. 7-silted 8-ex. entr. 1-silted entr.	21-ex. 4-silted		1-ex. entr. 2-silted entr. 1-caved entr.		Ditches were being cleaned at time observed, no indication of acidity.
McCracken Co. U.S. 68 Marshall Co. Line to Paducah	5-ex. 16-ex. entr.	17-ex.		2-ex. entr.	1-ex. entr. 1-silted entr.	Flat, alluvial, residential and agricultural, no indication of acidity.
U.S. 45 Paducah to Graves Co. Line	7-ex. 5-silted 5-ex. entr. 2-silted entr.	22-ex. 1-silted 1-undermined		1-ex. 2-ex. entr. 2-silted entr.	2-ex. 3-ex. entr. 2-silted entr. 1-caved entr.	(Same as above)
U.S. 62 Ballard Co. Line to Paducah	14-ex. 9-silted 1-caved 2-ex. entr. 1-silted entr.	41-ex. 4-silted	1-ex.	3-ex. entr. 1-silted entr. 1-caved entr.	1-ex. entr.	(Same as above)
U.S. 60 Paducah to Ballard Co. Line	16-ex. 2-silted 4-ex. entr. 3-silted entr.	39-ex. 1-silted		2-ex. entr. 1-silted entr.	1-ex. entr.	(Same as above)

APPENDIX E. Culvert Survey Data (Highway District I) (Con't.)

County Route No. & Location	Concrete Pipe	Concrete Box	Concrete Slab	Corrugated Metal	Vitrified Clay	Remarks
Trigg Co. Ky. 139 Cadiz to Jct. Ky. 164	20-ex. 11-silted 1-ex. entr.	9-ex.		4-ex. entr.		Agricultural area, non-acid.
Ky. 139 Cadiz to Caldwell Co. Line	11-ex. 3-silted 2-ex. entr.	12-ex.		1-ex. entr.		(Same as above)
U.S. 68 Marshall Co. Line to Cadiz	21-ex. 2-silted 7-ex. entr.	47-ex. 2-ex. entr.		2-ex. entr.	1-ex. entr.	(Same as above)
U.S. 68 Cadiz to Christian Co. Line	9-ex. 1-ex. entr.	13-ex.		1-silted entr.	2-ex. entr. 2-silted entr.	(Same as above)

Abbreviations: ex. = excellent condition
entr. = entrance pipe

APPENDIX B. Culvert Survey Data (Highway District II) (Con't.)

County Route No. & Location	Concrete Pipe	Concrete Box	Concrete Slab	Corrugated Metal	Vitrified Clay	Remarks
Daviess Co. Ky. 54 Henderson Co. Line to Jct. Ky. 81	4-ex.				1-ex.	Very few culverts required, indications of acidity.
Ky. 81, Jct. Ky. 54 to McLean Co.Line	10-ex.	17-ex.		1-caved entr.		Recent construction, flat terrain, few drainage units required.
Ky. 75, Jct. Ky. 140 to Owensboro	13-ex. 1-silted 1-silted entr.	7-ex.		1-ex. entr.		Flat, some internal drainage.
Ky. 71 Owensboro to Hartford (in Ohio Co.)	49-ex. 18-silted	45-ex. 1-silted		5-ex. entr.		Recent construction, 1 mine near Hartford. Indications of acidity
Henderson Co. U.S. 60 Daviess Co. Line to Henderson	22-ex. 2-silted 1-ex. entr. 1-corr. entr.	35-ex. 1-corroded		6-ex. entr.	8-ex. 1-ex. entr.	Shaft mine 7 mi. from Henderson, flat, no drainage water available for sample.
U.S. 60 Henderson to Union Co.Line	19-ex. 6-silted	30-ex.				Differential settling at box culverts, various soil types, some internal drainage.

APPENDIX I. Culvert Survey Data (Highway District II) (Con't.)

County Route No. & Location	Concrete Pipe	Concrete Box	Concrete Slab	Corrugated Metal	Vitrified Clay	Remarks
Henderson Co. U.S. 41, Jct. U.S. 60 (285) to Webster Co. Line	24-ex. 2-silted 1-ex. entr.	18-ex.	1-ex.	1-ex. entr. 1-caved entr.		No indication of acidity, terrain flat, internal drainage.
Ky. 416, Jct. U.S. 41 to Jct. Ky. 283	3-ex.	6-ex.	2-ex. 1-silted	3-ex. 1-caved entr. 5-rusted		Metal pipe has no headwalls, appear very old.
Ky. 283, Jct. Ky. 416 to Jct. Ky. 136		8-ex.				Gravel road, spongy
Ky. 149, Jct. Ky. 283 to Jct. Ky. 136	13-ex. 4-silted 1-ex. entr.	10-ex.		3-ex. entr. 1-silted entr.		Recent grade and drain, Loess slopes eroding.
Ky. 54 Henderson to Daviess Co. Line	28-ex. 14-silted 6-ex. entr. 2-silted entr. 1-corroded	21-ex.		1-ex. entr.		Mines 8 mi., 10 mi. and 12 mi. from Henderson, one very acid.
Hopkins Co. U.S. 41 Webster Co. Line to Madisonville	5-ex. entr. 14-silted	35-ex.		1-ex. entr. 7-silted entr.		Soil: Loess, causes silting, some internal drainage.
Ky. 85 Madisonville to McLean Co. Line	9-ex. 7-silted 1-ex. entr. 1-silted entr.	10-ex. 1-silted		4-ex. entr. 2-silted entr. 4-caved entr.	1-ex. entr.	Remarkably few culverts, no indication of acidity,

APPENDIX E. Culvert Survey Data (Highway District II) (Con't.)

County Route No. & Location	Concrete Pipe	Concrete Box	Concrete Slab	Corrugated Metal	Vitrified Clay	Remarks
Hopkins Co. Ky. 147 Madisonville to Webster Co. Line	2-ex. 3-silted	19-ex.		6-ex. entr.		Sandstone area, see photos showing extreme silting, no indication of acidity.
Ky. 70 Madisonville to Beulah	17-ex. 6-silted 8-ex. entr. 3-silted entr. 1-caved entr.			6-ex. entr. 2-silted entr. 2-caved entr.	1-ex.	Extensive strip mining, several silted culverts, extremely acid streams have wood bridges.
U.S. 41 Madisonville to Christian Co. Line	2-ex. 18-silted 1-ex. entr. 4-silted entr.	18-ex.		1-ex. entr. 2-silted entr.		Extensive strip mining, generally acid conditions. Doubtful culvert inspections due to overgrowth.
U.S. 62 Muhlenberg Co. Line to Caldwell Co. Line	30-ex. 27-silted 4-ex. entr. 1-silted entr. 1-caved entr.	31-ex. 1-silted 2-ex. entr.		1-ex. 1-silted entr. 1-caved entr.	2-ex. entr. 3-silted entr.	Acid conditions observed, few culverts.
Logan Co. U.S. 79 Todd Co. Line to Russellville	19-ex. 1-silted	12-ex.				Agricultural, no indication of acidity, sinkholes, similar to Blue Grass Area in appearance.
Ky. 75 Russellville to Tenn. Line	22-ex. 3-silted	6-ex.		1-ex. entr.	2-ex. entr.	Non-acid area, few culverts.

APPENDIX E. Culvert Survey Data (Highway District II) (Con't.)

County Route No. & Location	Concrete Pipe	Concrete Box	Concrete Slab	Corrugated Metal	Vitrified Metal	Remarks
Logan Co. Ky. 75 Russellville to Muhlenberg Co. Line	37-ex. 2-silted	14-ex.		3-ex. entr. 1-silted entr. 3-caved entr.		Flat terrain, few culverts, non-acid.
McLean Co. Ky. 75 Muhlenberg Co. Line to Daviess Co. Line	15-ex. 1-silted	21-ex.				Acidity observed, 1 mine, principally agricultural.
Ky. 136 Ohio Co. Line to Calhoun	33-ex. 1-silted 1-caved entr.	11-ex.				Concrete cross-drains, no headwalls.
Ky. 136 Calhoun to Beech Grove	43-ex. 4-silted	25-ex.			2-ex. entr.	Very flat terrain.
Ky. 81 Calhoun Co. Line to Muhlenberg Co. Line	26-ex. 5-silting	8-ex.				Lowland fill, few structures-no indications of acidity.
Muhlenberg Co. U.S. 62-E Central City to Ohio Co. Line	21-ex. 1-silted	11-ex.		1-silted entr.		Indications of acidity, coal outcroping near Ohio Co. Line

APPENDIX E. Culvert Survey Data (Highway District II) (Con't.)

County Route No. & Location	Concrete Pipe	Concrete Box	Concrete Slab	Corrugated Metal	Vitrified Pipe	Remarks
Muhlenberg Co. Ky. 75 N. Central City to McLean Co.	34-ex. 4-ex. entr. 4-silted	21-ex.		4-silted entr. 1-caved entr.	1-ex. entr. 1-silted entr.	Indications of acidity, mostly agricultural.
Ky. 70-Ky. 75 Central City to Drakesboro	23-ex. 1-ex. entr.	15-ex.				Very acid conditions, yellow streams, strip mining.
Ky. 75 Drakesboro to Logan Co. Line	23-ex. 2-ex. entr. 16-silting 1-silted entr.	44-ex.		1-ex. entr. 1-silted entr. 1-caved entr.		Very acid conditions all along road, several small coal mines with slack access roads.
Ky. 176 Drakesboro to Greenville	13-ex. 3-ex. entr. 4-silted	15-ex.		1-ex. entr.	2-ex. entr.	Acid water found here, several mines, drainage from refuse.
U.S. 62 Greenville to Hopkins Co. Line	24-ex. 5-silted	14-ex.			1-ex. entr.	Very acid condition, extensive strip mining.
Ky. 189 Jct. U.S. 62 to Christian Co. Line	10-ex. 1-ex. entr. 12-silted	13-ex.		1-silted entr. 1-caved entr.		Lots of stripping and acid conditions.
Ky. 181 Greenville to Todd Co. Line	30-ex. 11-silted	12-ex.		1-ex. entr. 3-rusting		No indications of acidity, near edge of coal field.

APPENDIX E. Culvert Survey Data (Highway District II) (Con't.)

County Route No. & Location	Concrete Pipe	Concrete Box	Concrete Slab	Corrugated Metal	Vitrified Clay	Remarks
Muhlenberg Co. Ky. 81, McLean Co. Line to Jct. with Ky. 75	32-ex. 2-silted	10-ex.			1-ex. entr.	None.
Ohio County U.S. 62-E Beaver Dam to Grayson Co. Line	39-ex. 1-ex. entr. 9-silted	28-ex.		1-ex. entr.		Excellent pavement-two strip mines draining across road-strong acid action evident.
U.S. 62-E Muhlenberg Co. Line to Beaver Dam	27-ex.	21-ex.		1-ex. entr.		Coal mining activity, water stained, no evidence of deterioration.
Ky. 69 Hartford to Fordsville	32-ex. 25-silted 1-caved entr.	30-ex. 1-silted		1-caved entr.		Bituminous surface practically gone, mining activity, acid water.
Ky. 54 Fordsville to Owensboro	64-ex. 13-silted	20-ex. 3-silted				Bituminous pavement, drains overgrown and silting.
Ky. 136 Jct. Ky. 71 to McLean Co. Line	37-ex. 4-ex. entr. 5-silted 3-caved entr.	21-ex. 1-silted		4-ex. entr.	1-caved entr.	No indication of acidity.

APPENDIX E. Culvert Survey Data (Highway District II) (Con't.)

County Route No. & Location	Concrete Pipe	Concrete Box	Concrete Slab	Corrugated Metal	Vitrified Pipe	Remarks
Todd County Ky. 181 Muhlenberg Co. Line to Elkton	27-ex. 2-ex. entr. 2-silting 2-silted entr. 1-caved entr.	15-ex.				Outside coal field.
Ky. 181 Elkton to Guthrie	7-ex.	11-ex.		7-ex.	5-ex.	No headwalls on corrugated pipe and no indication of acidity.
Ky. 79, Jct. U.S. 41 to Logan Co. Line	11-ex.	11-ex.		2-ex.		No indication of acidity.
Union County U.S. 60 Crittenden Co. to Henderson Co.	52-ex. 7-ex. entr. 5-silting	48-ex.		10-ex. entr. 1-silted entr. 1-caved entr.	8-ex. 8-ex. entr. 1-silting	Agricultural region - spotted area, acidity.
Ky. 85, Sturgis to Jct. Ky. 56	25-ex. 1-ex. entr. 16-silting 4-silted entr.	28-ex. 5-silting		1-ex. entr. 2-silted entr.	3-ex. entr.	On very edge of coal region.
Ky. 56 Shawneetown Ferry to Morganfield	23-ex. 9-silted 1-silted entr.	28-ex.				Agricultural region.
Ky. 56 Morganfield to Jct. U.S. 41	9-ex. 1-ex. entr. 3-silted 1-silted entr.	48-ex. 1-silted 1-silted entr.		5-ex. 1-ex. entr. 1-silted 1-silted entr. 1-caved entr.		Agricultural region.

APPENDIX E. Culvert Survey Data (Highway District II) (Con't.)

County Route No. & Location	Concrete Pipe	Concrete Box	Concrete [illegible]	Corrugated Metal	Vitrified Pipe	Remarks
Webster Co. U.S. 41-S Henderson Co. to Dixon	4-cx. 3-cx. entr. 10-silted 1-silted entr.	18-cx.			1-cx. entr. 2-silted entr.	Internal drainage, but slow run-off yielding silted conditions, agricultural area.
Ky. 132 Ky. 85 Jct. US-41-S to Union Co.	12-cx. 2-cx. entr. 6-silted 1-silted entr.	32-cx. 1-undermined		1-cx. entr.	3-cx. entr.	Strip mining region and acidity present.
Ky. 132 and Ky. 56 Dixon to McLean Co.	31-cx. 2-cx. entr. 1-silted 2-caved	12-cx.		5-cx. 1-cx. entr. 1-caved entr.	1-silted entr.	Agricultural and woodland region, masonry headwalls, some occasional acid water.
U.S. 41 Dixon to Hopkins Co.Line	7-cx. 2-cx. entr. 17-silted 1-silted entr.	11-cx.		1-cx. entr. 4-silted entr.	1-cx. entr. 1-silted entr.	Silting bad, agricultural region.

APPENDIX E. Culvert Survey Data (Highway District VI) (Con't.)

County Route No. & Location	Concrete Pipe	Concrete Box	Concrete Slab	Stone Slab	Corrugated Metal	Vitrified Clay	Remarks
Bourbon Co. U.S. 27 Harrison Co. Line to Paris		2-ex.	1-ex.	6-ex.	16-ex. 6-ex. entr.	1-ex.	Blue grass area, non-acid.
U.S. 68 Paris to Nich- olas Co. Line		4-ex.	2-ex.	19-ex. 1-silted	5-ex. 5-ex. entr.	1-ex. 1-silted	Same as above.
U.S. 27 & 68 Fayette Co. Line	3-ex. 6-ex. entr.	5-ex.			3-ex. 3-ex. entr. 1-caved	1-caved	Same as above.
U.S. 460 & 60 Paris to North Middletown	1-ex.	2-ex.	3-ex.	13-ex.	15-ex. 9-ex. entr. 3-silted 1-caved entr. 1-rusted	8-ex.	Same as above.
Clark Co. Ky. 89 Winchester to Estill Co. Line	26-ex. 6-ex. entr. 7-silted	29-ex. 4-silted			8-ex. entr. 1-silted entr.		East edge of Bluegrass area, non-acid.
U.S. 227 Winchester to Paris	1-ex. entr.	4-ex.	2-ex.	7-ex.	2-ex. 1-silted entr.	3-ex. 1-ex. entr.	Same as above
U.S. 60 Winchester to Montgomery Co. Line	8-ex. 1-silted	19-ex. 2-silted			6-ex. entr.		Same as above

APPENDIX E. Culvert Survey Data (Highway District VI) (Con't.)

County Route No. & Location	Concrete Pipe	Concrete Box	Concrete Slab	Stone Slab	Corrugated Metal	Vitrified Clay	Remarks
Franklin Co. Ky. 421 Henry Co. Line to Frankfort	11-ex.	22-ex.			4-ex. entr. 1-silted 1-silted entr.	52-ex. 1-ex. entr. 11-silted	Same as above.
Jessamine Co. Keene to Nicholasville	2-ex. entr. 7-ex. 2-silted	8-ex.		4-ex.	1-ex. 1- ex. entr.	20-ex.	Central Bluegrass, non-acid.
U.S. 27 Camp Nelson to Nicholasville		1-ex. 1-silted entr.	1-ex.	10-ex.	1-ex. 2-ex. entr. 1-silted entr.	1-ex.	Same as above
Madison Co. Ky. 169 Big Hill to Speedwell	9-ex.	8-ex.			1-ex. 1-ex. entr. 1-silted entr.		Edge of Bluegrass, black shale out-croppings, evidence of mild acidity.
Ky. 21 Berea to Big Hill	1-ex. 1-silted	4-ex. 1-undermined			4-ex. 2-silted	5-ex.	Same as above
U.S. 25 Ky. River to Berea	41-ex. 3-silted 2-silted entr.	35-ex.	4-ex.		12-ex. 3-ex. entr.	15-ex. 4-silted	Bluegrass, non-acid.

APPENDIX E. Culvert Survey Data (Highway District VI) (Con't.)

County Route No. & Location	Concrete Pipe	Concrete Box	Concrete Slab	Stone Slab	Corrugated Metal	Vitrified Clay	Remarks
Fayette Co. U.S. 60 Lexington to Nicholasville	16-ex. 6-ex. entr. 3-silted	6-ex.			18-ex. entr. 12-silted entr.		Central Blue grass, non-acid.
U.S. 60 Lexington to Winchester	11-ex. 6-ex. entr. 1-silted	19-ex.	3-ex.		6-ex. entr.	17-ex. 1-ex. entr. 2-silted	Same as above, very old, about 1920 construction.
U.S. 27 & 68 Lexington to Paris	5-ex. 3-ex. entr. 2-silted entr.	1-ex.		1-ex.	3-ex. entr. 1-caved entr.		Central Bluegrass, non-acid.
Ky. 50 Lexington to Scott Co. Line	4-ex. 2-ex. entr. 1-silted	7-ex.			1-ex. entr.		Central Bluegrass, non-acid.
U.S. 25 Ironworks Pike to Lexington	1-ex.	1-ex.	2-ex.	1-ex.			Same as above.
Franklin Co. U.S. 60 Shelby Co. Line to Frankfort	18-ex. 17-ex. entr. 1-silted	20-ex.			9-ex. entr.		Central Bluegrass, non-acid.
U.S. 460 Scott Co. Line to Frankfort	7-ex. 1-ex. entr.	2-ex.		4-ex.	5-ex. entr.		Same as above.

APPENDIX E. Culvert Survey Data (Highway District VII) (Con't.)

County Route No. & Location	Concrete Pipe	Concrete Box	Concrete Slab	Stone Slab	Corrugated Metal	Vitrified Clay	Remarks
Floyd Co. Ky. 114 Magoffin Co.Line to Prestonsburg	35-ex. 21-silted	19-ex. 1-ex. entr. 1-silted 1-silted entr.			1-ex. 2-ex. entr. 1-silted entr.		Several small mines near Prestonsburg.
U.S. 23-460 Prestonsburg to Pikeville	74-ex. 20-silted	20-ex. 2-silted			2-ex. entr. 3-silted entr. 1-caved entr.		Road runs along bluff of Big Sandy, extreme acidity at Prestonsburg city limits, several abandoned mines.
U.S. 23 Prestonsburg to Paintsville	37-ex. 19-silted 1-caved	18-ex.					Mines at Van Lear.
Johnson Co. U.S. 23-N Jct. U.S.460-23 to Lawrence Co. Line	30-ex. 9-silted	10-ex. 2-silted	1-ex. entr.		1-ex. entr. 3-silted entr. 1-caved entr.		Scattered mines, none of importance, highly developed agriculturally, some coal exposed in cuts.
Knott Co. Ky. 80 Perry Co.Line to Hindman	56-ex. 12-silted	25-ex.					Mild acidity evident.
Ky. 160 Hindman to Cody	58-ex. 2-silted	14-ex.	1-ex.	3-ex.			Coal mining activity.
Letcher Co. U.S. 119 Whitesburg to Jenkins	68-ex. 11-silted	3-ex.	3-ex.		2-ex. entr.		Mines in vicinity, acidity prevalent.

APPENDIX E. Culvert Survey Data (Highway District VII) (Con't.)

County Route No. & Location	Concrete Pipe	Concrete Box	Concrete Slab	Stone Slab	Corrugated Metal	Vitrified Clay	Remarks
Letcher Co. U.S. 119 Jct. Ky. 15 to Harlan Co. Line	36-ex. 25-silted	20-ex.			9-ex. 2-ex. entr. 8-silted 1-silted entr.		Some coal mining, mostly woodlands.
Ky. 15 Cody to Whitesburg	58-ex. 11-silted	12-ex.	12-ex.	2-ex.	21-rusted		Very acid seepage from coal seams.
Magoffin Co. U.S. 460 Johnson Co. Line to Salyersville	38-ex. 9-silt	22-ex.			1-ex.		None
Ky. 30 Salyersville to Breathitt Co. Line	41-ex. 18-silted 2-silted entr.	27-ex. 1-silted			3-ex. entr. 4-silted entr. 1-caved entr.		Three or four active truck mines.
Ky. 114 Salyersville to Floyd Co. Line	16-ex. 5-silted	25-ex. 1-silted			3-ex. entr. 2-silted entr. 1-caved entr.	12-ex. 2-silted	None
Martin Co. Ky. 40 W.Va. Line to Inez		14-ex.			2-silted entr.	47-ex. 11-silted 1-caved	Several coal mines, vitrified clay cross-drains.
Ky. 40 Inez to Johnson Co.	48-ex. 7-silted 1-caved	18-ex.					Few mines, mostly agricultural.

APPENDIX E. Culvert Survey Data (Highway District VII) (Con't.)

County Route No. & Location	Concrete Pipe	Concrete Box	Concrete Slab	Stone Slab	Corrugated Metal	Vitrified Clay	Remarks
Perry Co. Perry Co. Road-Jct. Ky. 7 to Daisy	1-silted 1-broken		1-silted	2-ex. 6-silted 1-caved	1-silted 1-caved entr.		Leatherwood Creek showing large amount of coal residue.
Ky. 15 Hazard to Whitesburg	22-ex. 2-ex. entr. 8-silted	1-ex. 1-silted	3-ex. 1-silted	1-ex. 2-silted	2-ex. entr. 1-silted entr. 1-rusted entr.	9-ex. 2-silted 2-silted entr.	Several railroad mines off the highway, road parallels Kentucky River
Ky. 7 Jeff to Blackey	7-ex. 5-silted	30-ex. 7-silted			30-ex. entr. 22-silted entr.	23-ex. entr. 20-silted	Jct. Ky. 7 Road parallels Ky. River, extensive mining.
Ky. 15 Carrfork to Breathitt Co. Line	102-ex. 15-silted	11-ex. 5-silted	5-ex. 2-silted		6-ex. entr. 2-silted entr. 1-caved entr.	1-ex. 1-silted	Mostly truck mines, few railroad mines.
Co. Road Jct. Ky. 80-28 to Blue Diamond Mine	13-ex. 1-silted 1-caved	2-ex.		7-ex.	1-ex. entr. 3-rusted entr.	3-ex. 1-silted	First Creek heavily polluted with coal dust from Blue Diamond Mine.
Ky. 80 Hazard to Leslie Co.	2-ex. entr. 4-silted 2-silted entr.			14-ex. 4-silted	3-ex. entr. 12-silted entr.	49-ex. 33-silted 1-silted entr. 6-caving	Active mines, scattered, several acid springs.
Pike Co. Ky. 122 Floyd Co. Line to Jct. U.S. 23-460	74-ex. 20-silted	28-ex. 1-silted			1-ex. entr. 3-silted entr.		General mining area.

APPENDIX E. Culvert Survey Data (Highway District VII) (Con't.)

County Route No. & Location	Concrete Pipe	Concrete Box	Concrete Slab	Stone Slab	Corrugated Metal	Vitrified Clay	Remarks
Pike Co. Ky. 122-W From Jct. US 23-119 to Floyd Co. Line	8-ex. 3-silted	9-ex.			1-ex. 1-ex. entr. 1-caved entr.	1-ex.	Slides stopping some culverts. Very large mines operated by Inland Steel at Wheelwright.
U.S. 460 From Jct. Ky. 194 US-460 to Pikeville	80-ex. 2-ex. entr. 12-silted 3-silted entr.	21-ex. 1-silted		1-silt entr.	4-ex. entr. 3-silted entr.	1-ex. entr. 2-silted entr.	Numerous slides stopping some culverts, side roads to mines.
Ky. 194 From Phelps to Jct. Ky. 194 U.S. 460	50-ex. 32-silted	15-ex. 1-ex. entr.			5-silted entr.		Mining district around Phelps (mining town)
U.S. 119 Pikeville to Canada	20-ex. 85-silted 1-caved entr.	31-ex. 1-silted			2-silted entr.	4-ex. 11-silted	Several coal mining towns off U.S. 119, one mine on road near Pikeville.
U.S. 23 & 119 Jenkins to Shelbiana	120-ex. 12-silted	20-ex.	6-ex.				Shelby Creek black with coal dust, several coal mines.

APPENDIX E. Culvert Survey Data (Highway District VIII) (Con't.)

County Route No. & Location	Concrete Pipe	Concrete Box	Concrete Slab	Stone Slab	Corrugated Metal	Vitrified Clay	Remarks
Boyd Co. Line U.S. 60 Cannonsburg to Grayson	1-ex.	25-ex.			1-ex. 1-ex. entr. 1-silted 1-silted entr.	55-ex. 21-silted	Both clay and coal mining in vicinity of Princess.
U.S. 23-N Lawrence Co. Line to Cannonsburg	3-ex. entr.	16-ex. 1-silted			2-silted entr.	41-ex. 17-silted	Coal outcroppings in cuts.
Breathitt Co. Ky. 30 Magoffin Co. Line to Jct. Ky. 15	94-ex. 3-ex. entr. 24-silted 1-silted entr.	45-ex. 1-silted			5-ex. entr. 2-ex. entr. 2-caved entr. 2-silted entr.		Road follows Quicksand Creek which drains Pond Creek-Pocahontas Mines at Evanston.
Ky. 15 Jackson to Perry Co. Line	72-ex. 13-silted	30-ex.					Scattered mining, evidence of mild acid water action.
Ky. 52 Beattyville to Jackson	60-ex. 2-ex. entr. 55-silted	46-ex.			3-ex. entr. 1-silted entr.		Coal mining region, culverts generally not directly affected.
Carter Co. Ky. 7 Grayson to Elliott Co. Line	1-ex. entr. 1-silted entr.	28-ex.				35-ex. 1-ex. entr. 16-silted 1-silted entr.	Road runs along Little Sandy River, scattered coal mining.

APPENDIX E. Culvert Survey Data (Highway District VIII) (Con't.)

County Route No. & Location	Concrete Pipe	Concrete Box	Concrete Slab	Stone Slab	Corrugated Metal	Vitrified Clay	Remarks
Elliott Co. Ky. 7 Carter Co.Line to Morgan Co. Line	87-ex. 3-ex. entr. 9-silted	60-ex. 4-silted 1-silted entr.	2-ex.		10-ex. entr. 5-silted entr.	4-ex. entr. 1-silted entr.	Scattered coal mining, agricultural and forest areas.
Lawrence Co. Ky. 3 Louisa to Martin Co.Line	40-ex. 5-ex. entr. 14-silted 2-silted entr.	9-ex.			1-ex. entr. 3-silted entr.		Road follows bluff of Tug Fork, acid springs, few mines.
U.S. 23-N Johnson Co. Line to Louisa	45-ex. 13-silted 2-silted entr.	12-ex. 2-silted			2-ex. entr. 1-silted entr.		Piled stone head-walls, scattered mining.
U.S. 23-N Louisa to Boyd Co. Line	3-ex. entr. 4-silted entr.	40-ex.				108-ex. 36-silted 2-silted entr.	No mines in vicinity, agricultural.
Montgomery Co. Ky. 11-U.S.460 Bath Co. Line to Frenchburg	20-ex. 6-ex. entr.	15-ex.		2-ex.	4-ex. entr. 2-silted entr.	15-ex. 2-ex. entr. 1-silted	West end in Blue-grass, transcends Black Shale to very edge of coal region at Frenchburg.
U.S. 60 Clark Co.Line to Bath Co. Line	46-ex. 1-ex. entr. 1-silted	12-ex.	3-ex.	1-ex. entr. 1-under-mined	2-ex. entr. 1-silted entr.		Section undergoing widening, all drainage brought up to Standard. Limestone Area.

APPENDIX E. Culvert Survey Data (Highway District VIII) (Con't.)

County Route No. & Location	Concrete Pipe	Concrete Box	Concrete Slab	Stone Slab	Corrugated Metal	Vitrified Clay	Remarks
Morgan Co. U.S. 460-E W. Liberty to Magoffin Co. Line	30-ex. 10-silted	24-ex.					Coal region, mostly agricultural, several cuts expose shale and coal.
Ky. 7 Elliott Co. to West Liberty	1-ex. 2-ex. entr.	40-ex.	1-ex.		2-silted entr.	39-ex.	Mostly agricultural.
Rowan Co. Ky 32 Morehead to Flemingsburg		1-silted				1-ex.	Transcends boundry between Bluegrass and coal region.

APPENDIX E. Culvert Survey Data (Highway District IX) (Con't.)

County Route No. & Location	Concrete Pipe	Concrete Box	Concrete Slab	Stone Slab	Corrugated Metal	Vitrified Clay	Remarks
Bell Co. U.S. 119 Pineville to Harlan Co.Line	24-ex. 1-ex. entr. 10-silted	18-ex.	2-ex.		2-silted 21-rusted 2-rusted entr.	2-ex.	All metal pipes have rusted through in lower arch. No mine drainage observed.
U.S. 25-E Pineville to Knox Co.Line	20-ex. 7-silted	8-ex.			4-ex. entr.		No mine drainage, seepage producing mild acidity.
U.S. 25-E Middlesboro to Pineville	58-ex. 15-silted	19-ex.	1-ex.		8-ex. entr. 3-silted entr.		No headwalls in part, acid action expected. Streams polluted with coal dust.
U.S. 25-E Virginia Line to Middlesboro	9-ex. 1-ex. entr. 3-silted	4-ex.			3-ex. entr. 2-silted entr. 1-caved entr.	2-silted entr.	No mines along road.
Ky. 74 Middlesboro to Tennessee Line	38-ex. 2-ex. entr. 26-silted 3-silted entr. 1-caved entr.	2-ex. 1-ex.entr.	11-ex.		2-ex. entr. 2-silted entr.	7-ex. 3-ex. entr.	Acidity in several locations, soft sandstone, causing silting and abrasion of pipes, two large mines on this road.
Harlan Co. U.S. 119 Letcher Co.L. to Cumberland	21-ex. 5-silted 1-silted entr.	11-ex					Some coal mining.

APPENDIX E. Culvert Survey Data (Highway District IX) (Con't.)

County Route No. & Location	Concrete Pipe	Concrete Box	Concrete Slab	Stone Slab	Corrugated Metal	Vitrified Clay	Remarks
Harlan Co. Ky. 160 Cumberland to Virginia State Line	60-ex. 2-ex. entr. 3-silted	3-ex.					Strip and drift mining, polluted streams.
Ky. 119 Harlan to Bell Co. Line	26-ex. 3-ex. entr. 2-silted	5-ex.	17-ex.		2-ex. entr. 1-silted entr. 3-caved entr.	41-ex. 2-ex. entr. 7-silted	Sandstone headwalls, abraded pipe, mild acidity expected.
Ky. 219 Wallins to Creech	1-ex. 1-silted				1-silted 2-caved 4-rusted		Mild acidity.
Ky. 421 & Ky. 56 Harlan to Turtle Creek	1-ex. entr.		10-ex.			24-ex. 5-silted	Coal mining town.
Ky. 38 Harlan to Evarts	6-ex. 1-ex. entr. 17-silted	4-ex.		10-ex. 2-caved	1-ex. entr. 3-silted 1-caved	3-ex. 1-ex. entr. 3-silted	Coal dust washings empty into creek.
Ky. 72 Jct. Ky. 119 to Alva	5-ex. 2-ex. entr. 1-silted	14-ex.	1-ex.		1-silted 2-silted entr. 1-rusted 1-rusted entr.	19-ex. 2-silted 2-silted entr.	Coal washings in creek, road stops at mine, settling basins at head of creek.

APPENDIX E. Culvert Survey Data (Highway District IX) (Con't.)

County Route No. & Location	Concrete Pipe	Concrete Box	Concrete Slab	Stone Slab	Corrugated Metal	Vitrified Clay	Remarks
McCreary Co. U.S. 27 Jct. Ky. 92 to Pulaski Co.Line	57-ex. 2-ex. entr. 4-silted 2-silted entr.	9-ex.			2-silted entr. 3-caved entr.		Sandstone area, road follows ridge.
Ky. 90 Parkers Lake to Cumberland Falls	39-ex. 1-silted	6-ex.			3-ex. entr. 2-caved entr.		Forest area, no acidity, sandstone predominantly.
Pulaski Co. Ky. 80-W Somerset to Laurel Co.Line	66-ex. 2-ex. entr. 10-silted	35-ex. 1-ex. entr.			6-ex. entr. 2-silted entr. 6-caved entr.		Few coal mines, acid conditions localized near Laurel Co. Line
U.S. 27 Parkers Lake to Somerset	21-ex. 1-ex. entr. 5-silted 1-silted entr.	16-ex.	1-ex.		6-ex. entr. 4-silted entr. 4-caved entr.	46-ex. 11-silted	Some coal mines off road.
Whitley Co. U.S. 25-W Corbin to Williamsburg	88-ex. 5-ex. entr. 3-silted 3-silted entr.	27-ex.			8-ex. entr. 9-silted entr. 10-caved entr.	1-ex. entr. 2-silted entr.	Several cuts expose coal and shales.
U.S. 25-W Williamsburg to Jellico	27-ex. 5-ex. entr. 6-silted 4-caved entr.	21-ex.	2-ex.		5-ex. entr. 2-silted entr. 2-rusting	2-ex. entr.	Black shales producing acidity were observed.

APPENDIX E. Culvert Survey Data (Highway District IX) (Con't.)

County Route No. & Location	Concrete Pipe	Concrete Box	Concrete Slab	Stone Slab	Corrugated Metal	Vitrified Clay	Remarks
Whitley Co. Ky. 92-W Williamsburg to Pine Knot	88-ex. 2-silted	21-ex. 1-silted		7-ex. 1-silted	18-ex. entr. 3-silted entr. 13-caved entr. 5-rusted 3-rusted entr.	40-ex. 1-ex. entr. 3-silted	Coal mines on mountain pollute streams in valley.
Leslie Co. Ky. 80 Manchester to Eyden	156 ex. 42-silted 4-silted entr. 3-caving 1-caved entr. 1-undermined	33-ex. 1-silted	20-ex.				Sandstone masonry and concrete headwalls, several large truck mines.
Ky. 2257 U.S. 421 Hyden to Harlan Co.Line	140-ex. 70-silted				1-silted entr.		Few mines, mild acidity, mostly logging operations.
Ky. 80 Hyden to Perry Co.Line	37-ex. 7-silted	6-ex.	1-ex.		1-caved entr.	18-ex. 3-silted	Some coal mining.