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OCCURRENCE OF DISSOLUTION PIPES THROUGH INDURATED CALCIC HORIZONS

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ABSTRACT

In arid regions worldwide, dissolution pipes have been observed in indurated calcic horizons. Pipes are defined as dissolution cavities that penetrate the calcic horizon completely and form conduits between the soil layers over- and underlaying it. Since pipes are hidden subsurface soil features little is known about them. The objectives of this study are (i) to gather field data for the determination of the frequency of pipe occurrence in indurated calcic horizons and (ii) to develop a statistical method to estimate pipe density from observations along a long trench. We have found that pipes are a common feature of calcic horizons in New Mexico. The focus of this study is on two sections in a 32 km long trench on the Lower La Mesa surface in southern New Mexico. The pipes in these two sections showed a wide variety of features with mean diameters ranging from 4.2 m in Section One to 8.5 m in Section Two. Our field observations showed that 13 to 16% of the Lower La Mesa surface is underlain by pipes. This percentage is nearly one order of magnitude larger than any number previously reported in the literature. The pipe density varied from 14 pipes per hectare in Section Two to 150 pipes per hectare in Section One; however in Section Two the sizes of the pipes are bigger. The results of this investigation have important implications for environmental management strategies. On the one hand the frequent occurrence of dissolution pipes and their possible enhancement of downward water fluxes may make desert sites underlain by indurated calcic horizons vulnerable for ground water contamination from hazardous materials stored on the desert floor. On the other hand the pipes may lead to an overall increase of regional ground water recharge.

INTRODUCTION

In arid regions worldwide, dissolution pipes have been observed in indurated calcic horizons. Pipes are defined as dissolution cavities that penetrate the calcic horizon completely and form conduits between the soil layers over- and underlaying it. Bretz and Horbert (1949) reported solution cavities in calcic horizons on the Mescalero Plain (New Mexico) and broad funnel-shaped pipes on the Llano Estacado (New Mexico). Gile *et al.* (1966) and Bachman and Machette (1977) described thick calcic horizons on the La Mesa surface (New Mexico) that are penetrated by funnel-shaped pipes. Gile and Hawley (1966) found pipes through calcic horizons on alluvial fans at the southern end of the Jornada del Muerto basin (New Mexico). Johnson (1997) observed large and small pipes in the southern Tularosa Basin and Otero Mesa in southern New Mexico. McGrath (1984), Osterkamp and Wood (1987), and Reeves (1976) reported that pipes are common in the Ogallala and Blackwater Draw Formations on the Llano Estacado in Texas. Shreve and Mallery (1932) studied calcic horizons within a 320 km radius of Tucson in Arizona. Although they didn't refer directly to pipes, they did report that the lateral extent of calcic horizons is "extremely variable, and the continuity of the surface is frequently broken." Knox (1977) observed pipes around Saldanha Bay (South Africa) in caliche profiles with calcretes that are similar to those described by Bretz and Horbert (1949) in New Mexico. There are different hypotheses regarding the formation of pipes through indurated calcic horizons. The most widely known hypothesis postulates that the pipes have been formed during Pleistocene pluvials as a result of dissolution processes along fractures, animal burrows, or cavities created when large roots decay (Gile *et al.,* 1981). Another hypothesis postulates that the pipes are formed by animals digging through the calcic horizon (Johnson, 1997). Dating of the laminar layers covering the sides of many pipes yields evidence that they have formed during the late Pleistocene. After their formation they have been exposed to atmospheric conditions and have been filled with young materials like fluvial and eolian deposits. Indeed, large fluvial fans with complex channel patterns have formed on the La Mesa surfaces during the late Pleistocene and the Holocene (Love and Seager, 1996).

The diameters of dissolution pipes vary greatly. Gile and Hawley (1966) measured an average width of 0.4 m with a minimum and maximum of 0.2 and 0.6 m. Bretz and Horbert (1949) observed pipes with diameters of several meters, whereas Gile *et al.* (1981) report diameters from a few centimeters to ten meters or more. The latter authors found a correlation between pipe diameter and soil age; the widest and most complex pipes are found in the oldest soils. Although most references indicate that pipes are a common feature in well developed calcic horizons, only Gile and Hawley (1966) have measured the frequency of pipe occurrence. They surveyed a 150 m long transect in Southern New Mexico where pipes are relatively numerous and counted 11 pipes with an average width of 0.4 m. The distance between the pipes varied from 3 to 18 m. They calculated that the pipes covered about two percent of the measured transect. The depths of the indurated calcic horizons in which pipes have been found, vary from about one meter to several meters (Gile et al., 1981; Reeves, 1976).

Field observations and laboratory analyses reported in the literature indicate that individual pipes act as conduits for water flow. Soils in pipes contain less exchangeable sodium than surrounding soils due to more frequent deep wetting (Gile *et al.*, 1981). Gile *et al.* (1966, 1981) argue that the sequence and age of the carbonate accumulations within and outside pipes suggest that pipes "must have been regularly flushed by water". Gile and Hawley (1966) observed reddish, high-chroma clay that may be traced downward from some pipes and spreads out or slightly penetrates the underlying paleosol. Osterkamp and Wood (1987) have made similar observations in the upper Ogallala Formation. Where excavations expose beds beneath organic-rich playa deposits, it is common to encounter a zone with white leached sand. Below this sand layer, cemented zones of iron and manganese oxides are common. The leached sandy zones are an indication for transport of reduced forms of these metals dissolved in recharge water that flows downward through solution pipes. Gile *et al.* (1981) hypothesize that the laminar and plugged calcic horizons surrounding pipes, due to their low hydraulic conductivity compared to the sand soil inside the pipe, deflect water into the pipes. Such a lateral deflection will cause a concentration of water towards the pipe resulting in a preferential flow process and increased depths of water penetration (Hendrickx and Flury, 2001; Hendrickx et al., 2003). Rodríguez-Marín et al. (2003) simulated water flow through a small representative pipe in the bare, eolian soils of the La Mesa surface in southern New Mexico. The downward water fluxes through the 3 m deep bottom of the pipe varied from about 20 to 95 mm per year during the period 1960-1990. These fluxes are about 10 to 50 times higher than the downward fluxes simulated through soil profiles with indurated calcic horizons without pipes.

Hendrickx and Walker (1997) discuss the importance of localized ground water recharge for the water balance of arid regions. They review a number of field investigations (e.g. Meyboom, 1966; Wood and Sanford, 1995) and modeling studies (Boers, 1994; Kearns and Hendrickx, 1998; Nieber et al., 1993) that demonstrate how accumulation of water in small surface depressions after large precipitation events may cause a large increase in downward water fluxes. However, it seems unlikely that preferential water flow through pipes can impact the regional water balance if they only cover two percent of the area as measured by Gile and Hawley (1966). Unfortunately, due to their concealed subsoil location, it is very difficult to investigate pipe occurrence, which explains why so few data have been reported in the literature. Therefore, the objectives of this study are (i) to gather field data for the determination of the frequency of pipe occurrence in indurated calcic horizons and (ii) to develop a statistical method to estimate pipe density as well as the distribution of pipe diameters from observations along a long trench.

METHODS AND MATERIALS

Field Observations

During the course of this study we have observed pipes in indurated calcic horizons at several sites in the Rio Grande Basin of New Mexico as will be reported in the Results and Discussion section. However, in this study we will focus on the Lower La Mesa surface. The La Mesa surface which consists of the Upper and Lower La Mesa surfaces, has developed on axial Rio Grande deposits that mainly consist of sands and gravels. The surface was abandoned by the Rio Grande during the early-middle Pleistocene. Since that time, a calcic soil with an indurated calcic horizon has formed. The Upper La Mesa represents an older Camp Rice fluvial plain that probably was uplifted with the Robledo fault block much earlier than deposition of the surficial gravel and sand of the Lower La Mesa (Gile *et al.*, 1981). The Lower La Mesa is a relict basin-floor surface with generally non-calcareous or slightly calcareous parent sediments. Coppice dunes occur over most of this surface. Vegetation is mostly confined to the dunes and consists of mesquite and occasionally four-wing saltbush. Many areas between the dunes are barren. The water table is 90-100 m below the surface. Typic Torripsamments are found in the dune area while Haplargids are in the areas between the dunes. The Haplargids are characterized by an argillic horizon with some macroscopic carbonate and a thick, stage III-IV petrocalcic horizon at depths ranging from 1 to 1.5 m. Laminar horizons do occur in places (Gile *et al.,* 1981).

We have made an inventory of dissolution pipes occurring in a 32 km trench, 2.2 m deep and 0.6 m wide, which had been excavated on the Lower La Mesa surface for the installation of a gas pipe line. The trench started in southern direction at the intersection of the gas pipeline with W. Afton Road, approximately at UTM coordinates Easting 333084 and Northing 3552134 (datum: WGS 1984). Since the trench was almost immediately backfilled we only could survey two sections in detail: Section One with length 4 km and Section Two with length 6 km. Section One started to the South of County Road at approximate UTM coordinates Easting 337677 and Northing 3535971. Section Two started to the South of W. Afton Road at approximate UTM coordinates Easting 335906 and Northing 3546594. In each of these sections the following information was recorded: the depth of the calcic horizon, the location of each pipe, and the chord of each pipe (measured at the top of the calcic horizon as well as at the bottom or in very thick calcic horizons measured at the bottom of the trench) that resulted from the intersection with the trench. From these data we derived the distribution of pipe chords, the distance between pipes, and the pipe density.

Mathematical Data Analysis

Although pipe circumferences often are somewhat irregular, many field observations indicate that the assumption of a circular pipe shape is quite reasonable. Thus, we start with the assumption that the pipes observed on the La Mesa surface can be simulated by a set of circular holes uniformly distributed in a plane area of size L by W. We select a line that crosses the plane, and observe all intersections between the circles and our transect line (Figure 1) similar to our field observations along the trench. Given these observations, how can we estimate the density of circles in the plane? How can we estimate the distribution of the radii of the circles? This section develops a method to obtain these estimates from observed data along a transect.

Probability of Hitting a Circle: As Figure 1 shows, a circle of radius R will intersect the transect line only if the center of the circle lies within R of the transect. Thus, the conditional probability P of a given circle with radius R intersecting the transect is

$$P(\text{circle intersects transect} \mid R = r) = \frac{2r}{W} \qquad [1]$$

This probability depends on the radius of the circle R and the width of the area W. If we know the distribution of circle radii $f_R(r)$, then we can compute the unconditional probability p of a circle intersecting the transect by conditioning on R (Ross, 1994).

$$p = P(\text{circle intersects transect}) = \int_0^\infty \frac{2r}{W} f_R(r)\, dr \qquad [2]$$

Once we have computed probability p, we can estimate the density d of circles by counting the number N of circles that intersect the transect, and then evaluating

$$d = \frac{N}{p} \quad \frac{1}{LW} = \frac{N}{\int_0^\infty 2r \quad f_R(r) \quad dr} \quad \frac{1}{L} = \frac{N}{2E[R]L} \qquad [3]$$

Thus, the density d of circles can be determined without knowing the width W of the area.

Distribution of Circle Radii: In this section we will derive an integral equation for the distribution of $f_R(r)$ of pipe radii in terms of the distribution of the lengths of the chords in which circles intersect the transect line. First consider what happens when the transect line intersects a circle of radius R (Figure 2). The length of the chord will be denoted by $2C$. The factor of 2 simplifies the following calculations. The distance X is the distance from the center of the circle to the transect line. X will be uniformly distributed between 0 and R.

Our goal is to find the distribution $f_C(c)$ of C. The value of C is related to X by the equation

$$C = g(X) = \sqrt{R^2 - X^2} \qquad [4]$$

This is a monotone function of *X*, so by theorem 7.1 of Ross (1994), we can compute the distribution of *C* in terms of the distribution of *X* and the derivative of *g(X)*

$$f_{C|R}(c) = f_{X|R}(g^{-1}(c))\left|\frac{d}{dc}g^{-1}(c)\right| \quad [5]$$

Since

$$g^{-1}(c) = \sqrt{R^2 - c^2} \quad [6]$$

we have that

$$f_{C|R}(c) = f_{X|R}(\sqrt{R^2 - c^2})\left|\frac{-c}{\sqrt{R^2 - c^2}}\right| \quad [7]$$

Since *X* is uniformly distributed between 0 and *R*,

$$f_{X|R}(\sqrt{R^2 - c^2}\,|\,R = r) = \frac{1}{r} \quad [8]$$

and

$$f_{C|R}(c\,|\,r) = \frac{c}{\sqrt{r^2 - c^2}}\ \frac{1}{r}. \quad [9]$$

We will find an equation for the distribution of *C* by conditioning on *R*. Note that we can only intersect a circle of radius *R* and obtain a half-chord of length *C* if *C*≤*R*. Also, we must account for the probability that the transect will even intersect the circle. By conditioning on the radius *R*, we obtain

$$f_C(c) = \int_c^{\infty} P(\text{circle intersects transect})\ f_{C|R}(c|r)\ f_R(r)dr\ . \qquad [10]$$

Substituting in our earlier formulas for the probability of intersection and $f_{C|R}(c \mid r)$, we obtain

$$f_C(c) = \int_c^{\infty} \frac{2r}{W} \frac{c}{\sqrt{r^2 - c^2}} \frac{1}{r} f_R(r)dr\ . \qquad [11]$$

This simplifies to

$$f_C(c) = \int_c^{\infty} \frac{2c}{W\sqrt{r^2 - c^2}} f_R(r)dr\ . \qquad [12]$$

In practice, we actually want the distribution of the chord half lengths for those circles which actually intersect the transect. Since the probability that any given circle will intersect the transect is p, we can again use conditioning to write

$$f_C(c) = pf_{C|hit}(c) + (1-p)f_{C|miss}(c) \qquad [13]$$

$$f_C(c) = pf_{C|hit}(c) + (1-p)0 \qquad [14]$$

Thus

$$f_{C|hit}(c) = f_C(c)/p \qquad [15]$$

In analyzing field data, we have a collection of observations of the chord lengths of those circles which actually intersected the transect. The histogram of these observations is an approximation to $f_{C|hit}(c)$. We multiply this histogram by p to obtain an estimate of $f_C(c)$. We then discretize the integral equation [12] to produce a linear system of algebraic equations for the histogram of $f_R(r)$ (Twomey, 1994). This linear system of algebraic equations is solved to obtain a histogram approximating $f_R(r)$.

RESULTS AND DISCUSSION

Occurrence of Pipes in the New Mexico Rio Grande Basin

During the course of our study we have observed pipes at a number of locations in the Rio Grande Basin of New Mexico. From South to North the sites are: the Potrillo Maar near the

U.S.-Mexico boundary west of El Paso on the Upper La Mesa surface, the Lower La Mesa surface southwest of Las Cruces, the Las Cañas Surface northeast of Socorro, the Llano de Albuquerque west of the city of Albuquerque and the Mesa del Sol southeast of Albuquerque (Rodríguez-Marín, 2001). These field observations and the previously described literature data are clear evidence that dissolution pipes through indurated calcic horizons are a common soil feature in New Mexico.

General Description of Pipes on the Lower La Mesa Surface Transect

The focus of this paper is on the analysis of our pipe observations along the transect on the Lower La Mesa surface in southern New Mexico. The field survey along Sections One and Two revealed the presence of a large number of pipes of different shapes and sizes (Figures 3 and 4). The features of the two sections are quite different. The depth of the calcic horizon in Section One is less than 0.65 m whereas in Section Two it is 1.2 to 1.5 m. The overlying sediments in Section One are all eolian sands whereas in Section Two the sediments are either of fluvial or eolian origin. The fluvial sediments are found within the pipe and are covered with an eolian layer. In Section One there are indications of present day dissolution: (i) the calcic horizon surface is often quite soft; (ii) the yellow to light brown color in the top 10 cm of the calcic horizon is an indication of accumulation of fine soil particles and suggests seepage of water through this layer; (iii) at some locations the calcic horizon has broken up into blocks that are found in the underlying soil; (iv) many dissolution spaces in the calcic horizon resemble karstification features. In both sections, laminar layers have been observed covering the calcic horizon inside as well as outside of the pipes. In Section One, some pipes tend to have more of an hourglass shape: narrowing from top to center, widening from center to bottom of the pipe (Figure 5).

Whereas each individual pipe has its own often odd shape, our observations clearly show that pipe shapes and dimensions tend to occur in clusters at certain places in the landscape. There seems to be some unknown relation between the location of a pipe in the landscape and its shape. Questions also arise about the origin and development of pipes. Will the smaller pipes observed along the trench become similar to the big ones as geological time proceeds or are the big and small pipes the result from different pipe forming processes? The goal of this paper is to establish how frequent pipes do occur in the landscape. If pipes are a rare anomaly, further study will be only of academic interest. On the other hand if pipes are found in large numbers a better understanding of their origin and development as well as of their impact on ground water recharge will have a high societal relevance.

Pipe Chords

Reports in the literature (Bachman and Machette, 1977; Bretz and Horbert, 1949; Gile *et al.*, 1966; Gile and Hawley, 1966) and our field observations indicate a wide variety of pipe shapes and chords or diameters (Figures 3-5). Yet there are similarities. A typical pipe in our survey can be characterized by a top chord that often is larger than its bottom chord (Figure 4). In Sections One and Two the average top chords of the pipes are 4.2 and 8.5 m, respectively, while the average bottom chords are 2.9 and 4.5 m (Table 1). The pipe chords are quite variable and range from approximately 1-15 m in Section One and from 2-21 m in Section Two. The average pipe top chord in Section Two is twice that of Section One, but the standard deviations are 3.7 m for both sections (Table 1). The coefficient of variation decreases from 88% in Section One to 44% in Section Two, indicating that the larger pipes in Section Two have less variation in their chords than the smaller pipes in Section One.

The frequency distributions of the chords demonstrate a non-normal distribution (Figure 6). A non-parametric *t*-test on the ranks of the chords (Conover and Iman, 1981) revealed a significant difference between the medians of the chords in Section One (3.0 m) and Section Two (8.7 m). This indicates that the two sections have indeed completely different distributions of pipe chords.

Pipe Distances

The average distance between pipes (from edge to edge) in Sections One and Two is, respectively, 22 and 58 m. The respective standard deviations and coefficients of variation are 33 and 54 m and 149 % and 93 % (Table 1). Thus, the larger pipes in Section Two have less variation in their distances than the smaller pipes in Section One. In both sections the minimum and maximum distances vary widely; from, respectively, 0.4 to 291 m in Section One and 5.0 to 327 m in Section Two. The frequency distributions of the distances (Figure 7) demonstrates an approximately exponential distribution, which is consistent with a uniform distribution of the pipe centers in the plane.   A non-parametric *t*-test on the ranks of the chords (Conover and Iman, 1981) revealed a significant difference between the medians of the distances in Section One (13.9 m) and Section Two (42.9 m). This indicates that the two sections have completely different distributions of pipe distances. No significant correlation could be established between the pipe chords and their distances.

Area Covered by Pipes

Using the average pipe chords and distances from Table 1 the percentage of the total surface area covered by pipes is calculated as 4.2/(22+4.2)H100=16% for Section One and 8.5/(58+8.5)H100=13% for Section Two. These percentages are six to eight times larger than the two percent previously reported by Gile and Hawley (1966). One reason for this discrepancy may be that their area of investigation at the southern end of the Jornada del Muerto basin, New Mexico, is different from the La Mesa surface. They report pipe distances between 3-20 m and pipe diameters (or chords) from 0.25-0.6 m; the former not unlike the distances found in this study, the latter somewhat smaller. Another reason may be that they only surveyed a transect of 150 m on which they found 11 pipes. This number of pipes is much smaller than the 239 pipes used in this study to derive pipe statistics.

Pipes Density

An important characteristic is the pipe density, i.e. the number of pipes per hectare. Figure 6 shows the observed distributions of the pipe chords in Sections One and Two. Figure 8 shows the estimated distributions of pipe radii obtained from Eq. [12] in Sections One and Two. In Section One about 40% of the observed chord values are less than 1 meter, while over 60% of the estimated radius values are less than 1 meter. This is a consequence of the fact that we are less likely to observe small circles. For this data set, the estimated pipe density was 0.015 pipes per square meter or 150 per hectare. In Section Two there are very few small chords, and in most cases, the chords are between 1 and 8 meters. The distribution of the pipe radii (Figure 8) is concentrated between 2 and 8 meters. The pipe density was estimated at 0.0014 pipes per square meter or 14 pipes per hectare.

Using the estimated pipe radii distributions in Figure 8 with the estimated pipe densities, we expect a pipe with diameter 1 to 4 m in each 8×8 m square of Section One and a pipe with diameter 8 to 12 m in each 27×27 m square of Section Two. Therefore, the proper conceptual model for an indurated calcic horizon is not that of an impermeable barrier for water and contaminants; it rather is that of a "Swiss cheese" full of holes that will allow and probably enhance downward water flow and contaminant transport.

CONCLUSIONS

The main goal of this study was to gather field observations on the occurrence of dissolution pipes through indurated calcic horizons in New Mexico and perform statistical analyses to predict the density and distribution of the pipes. Our field observations of pipes along a 32 km long trench dug for a gas pipe line on the Lower La Mesa surface in southern New Mexico demonstrate that 13 to 16% of the Lower La Mesa surface is underlain by pipes. This percentage is nearly one order of magnitude larger than any number previously reported in the literature.

Sections One and Two showed differences not only in the field observations but also in the statistical analysis. Density of the pipes are 150 holes per hectare in Section One and 14 holes per hectare in Section Two; however, in Section Two the sizes of the pipes are bigger. The field observations in Section One suggest that the formation of the pipes is still active. In Section One, the younger pipes filled with eolian materials may conduit water in more effective way than pipes in Section Two, filled in part with older fluvial material.

The large fraction of the La Mesa surface underlain by pipes is a strong indication that pipes will affect downward water fluxes and, therefore, may play an important role in the water balance of this arid region.

The results of this investigation have important implications for environmental management strategies. On the one hand the frequent occurrence of dissolution pipes and their possible enhancement of downward water fluxes may make desert sites underlain by indurated calcic horizons very vulnerable for ground water contamination from hazardous materials stored on the desert floor. On the other hand the pipes may lead to an overall increase of the regional ground water recharge. We will address these issues in future publications.

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Table 1 Descriptive statistics of pipe chords and distances between pipe edges observed in Sections One and Two.

	Section One					Section Two				
Length of Section	3790 m					6441 m				
Number of Pipes	143					96				
Statistic	Mean	Min	Max	SD	CV	Mean	Min	Max	SD	CV
	m	m	m	m	%	m	m	m	m	%
Top Chord	4.2	0.4	15.1	3.7	88	8.5	1.5	21.6	3.7	44
Bottom Chord	2.9	0.3	11.4	2.6	92	4.5	0[¶]	12.4	2.9	64
Distance	22	0.4	291	33	149	58	5.0	327	54	93

¶ Note that a zero chord does not mean that the pipe has not bottom exit. It is more likely that the trench intersected the pipe at some distance away from its center.

LIST OF FIGURES

Figure 1 Schematic of problem.

Figure 2 The intersection of a circle and the transect through chord C.

Figure 3 Typical pipes observed in Section One of the transect on the Lower La Mesa surface (New Mexico).

Figure 4 Typical pipes observed in Section Two of the transect on the Lower La Mesa surface (New Mexico).

Figure 5 Typical pipe shape observed in Section One of the trench on the La Mesa surface; the top and bottom chords have similar dimensions while the pipe shows a constriction in its middle section. Note the light brown color in the top 10 cm of the left calcic horizon which indicates water seepage towards the pipe.

Figure 6 Frequency distributions of pipe chords in Sections One and Two.

Figure 7 Frequency distributions of pipe distances in Sections One and Two.

Figure 8 Estimated frequency distributions of the pipe diameters in Sections One and Two.

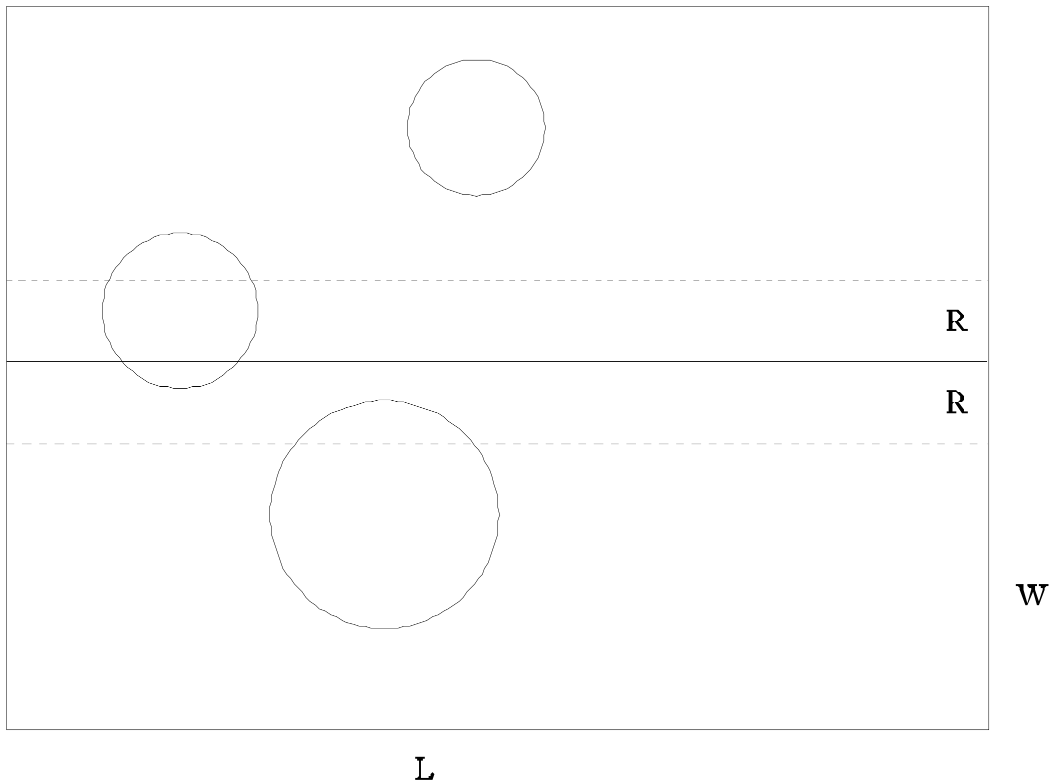


Figure 1. Schematic of the problem.

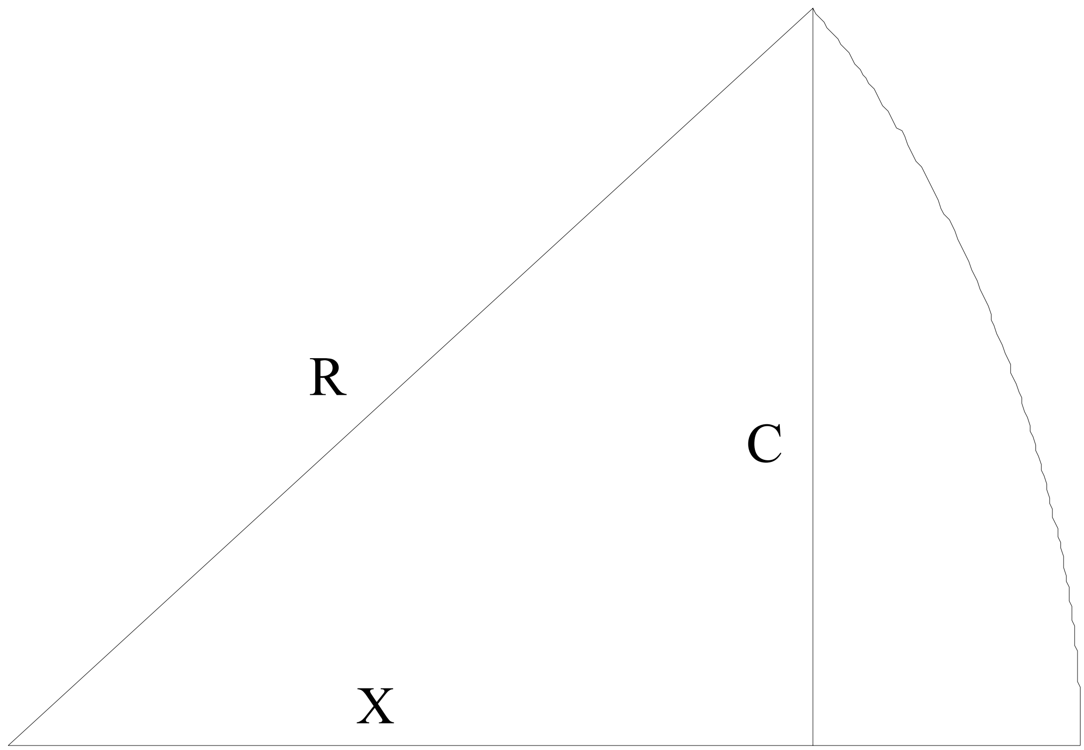


Figure 2. The intersection of a circle and the transect through chord C.

Figure 3 Typical pipes observed in Section One of the transect on the Lower La Mesa surface (New Mexico).

Figure 4 Typical pipes observed in Section Two of the transect on the Lower La Mesa surface (New Mexico).

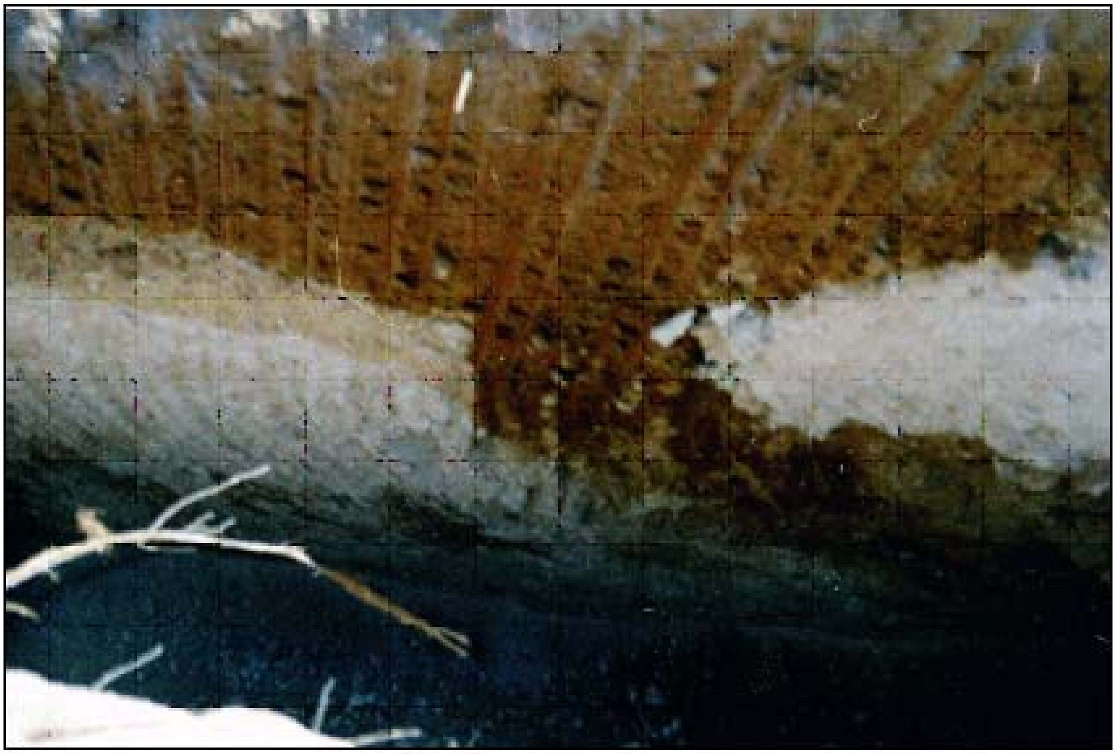
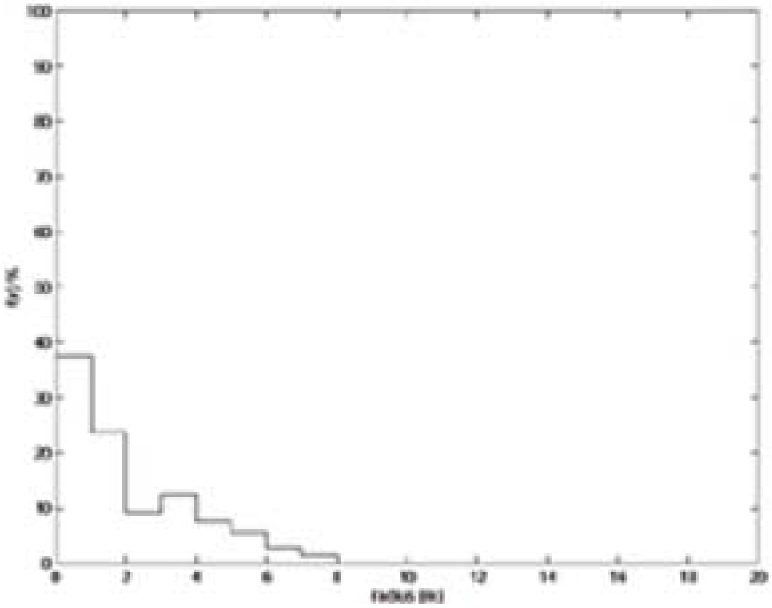


Figure 5 Typical pipe shape observed in Section One of the trench on the La Mesa surface; the top and bottom chords have similar dimensions while the pipe shows a constriction in its middle section. Note the light brown color in the top 10 cm of the left calcic horizon which indicates water seepage towards the pipe.

Section One



Section Two

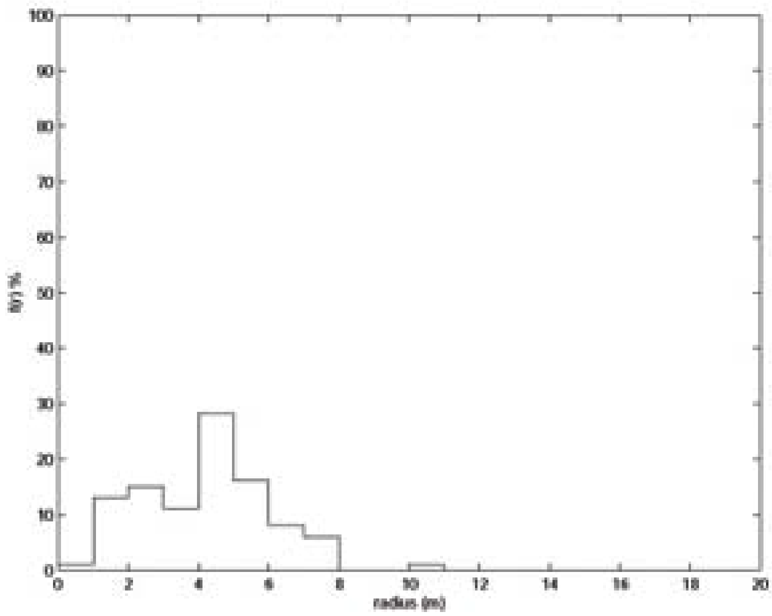
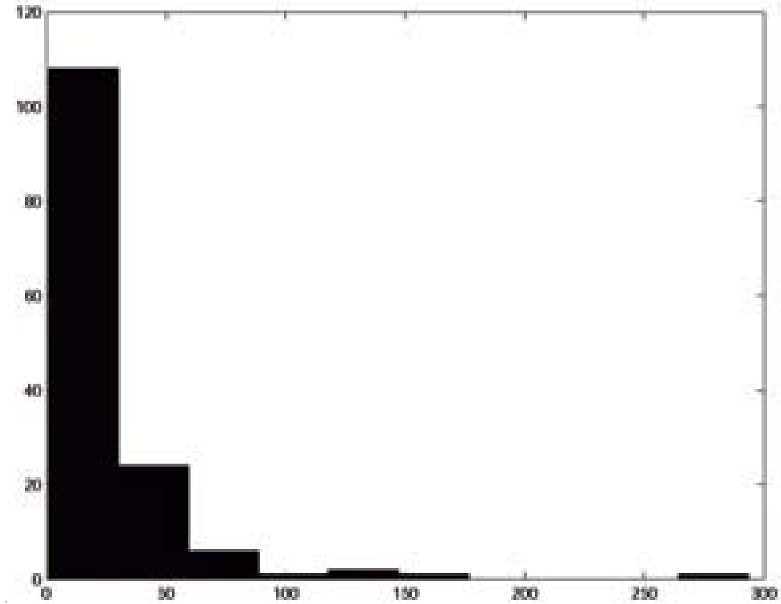


Figure 6 Frequency distributions of pipe chords in Sections One and Two.

Section One



Section Two

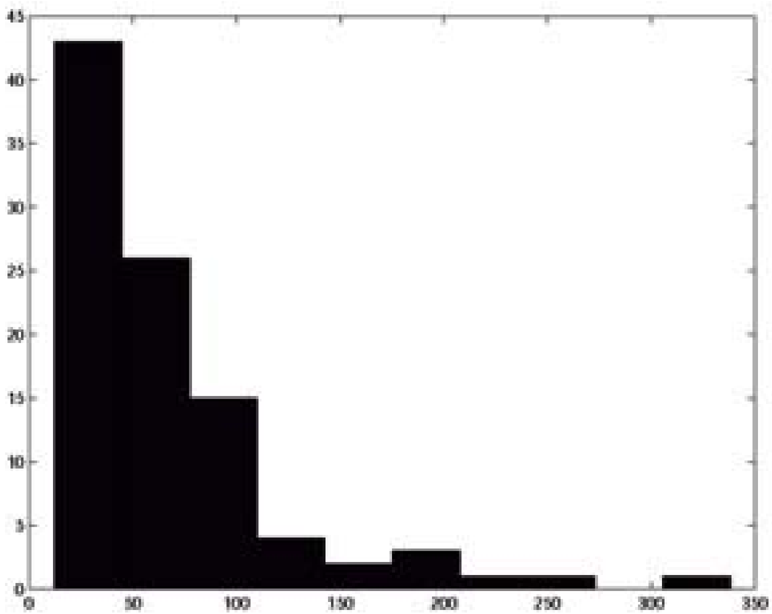


Figure 7 Frequency distributions of pipe distances in Sections One and Two. Distance (m) on horizontal axis versus frequency.

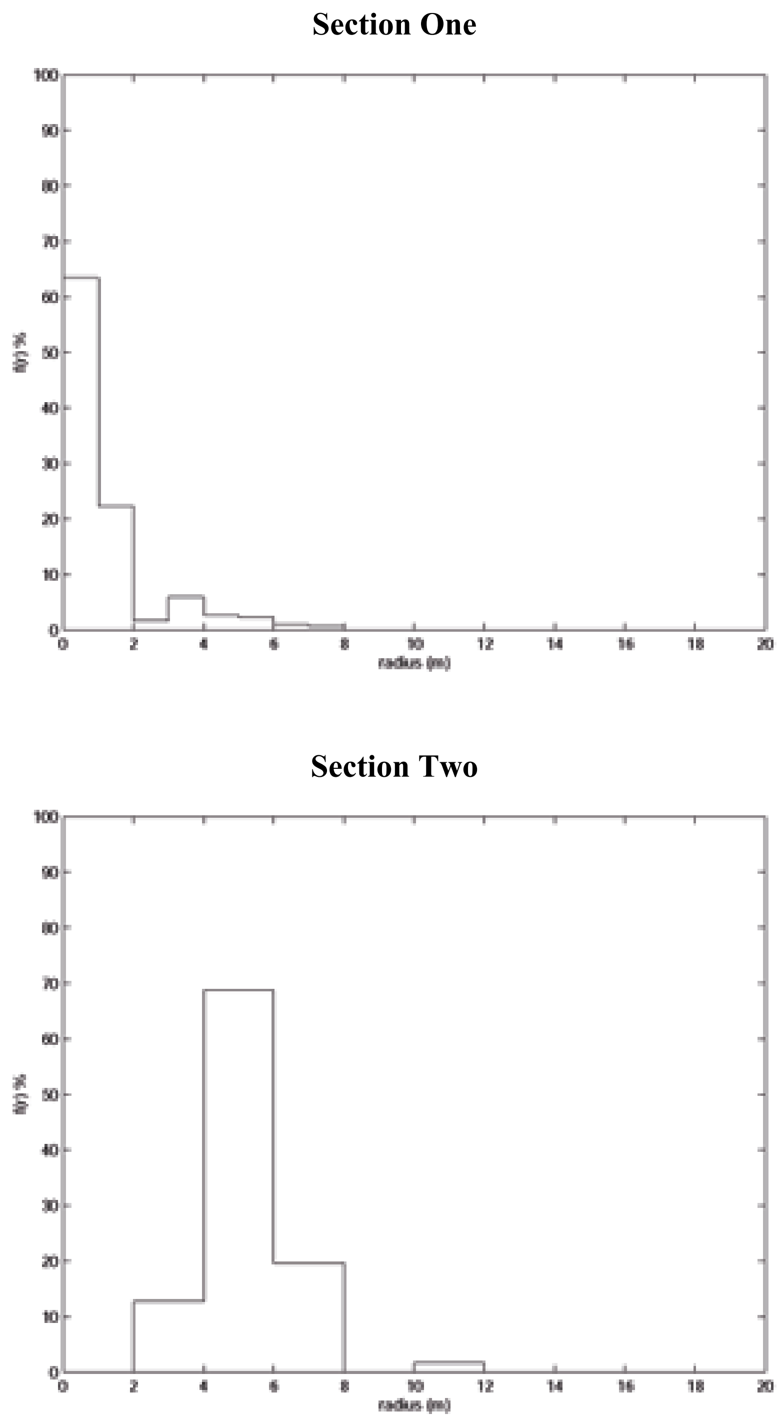


Figure 8 Estimated frequency distributions of the pipe radii in Sections One and Two.