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Illustrations

Preliminary Report on Ground Movements at Helper, Carbon County, Utah

by

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Abstract

Many houses built upon an alluvial fan at Helper, Utah show cracks and other damages. The present survey has demonstrated small movements of the ground surface and generally larger movements of the house foundations. Three types of ground movement are indicated as possible; a) slow mass movement of the fan material over the underlying shale, b) movement within the fan material due to removal of the fine particles, and c) movements due to shrinkage by drying of the interstitial clay and silt in the fan. Evaluation of these causes depends upon factors not now known, such as the distribution, movement, and variation in amount of water in the fan, and upon the location and shape of the underlying shale surface. Recommendations are made for reducing the water content of the fan, for exploratory drilling, and for studying the methods and materials of construction.

Introduction

Occasional cracking of houses, breaking of water mains, and cracking of the ground in a residential district of Helper have been noticed for about 10 years. In 1946 and 1947 the situation became more serious with the very severe cracking of several new houses and continued trouble with the older houses. The damages within an area of somewhat more than a city block had caused the loss of many thousands of dollars in repairs and decrease of property values, and the necessity for finding the cause of the damage became urgent.

The purpose of the work was to obtain geologic and other kinds of information that may be of value in determining the cause of damage to the houses. The scope of the study was restricted to mapping the surficial geology and the topography, making a cursory examination of the houses, determining how much the ground is moving, if at all, and to measuring how much some of the houses are settling. We have made no detailed study of the methods of construction employed on the houses or of the materials used.

The problem was brought to the attention of the Geological Survey in December, 1947. At that time the area was visited by Mr. C. B. Hunt, Regional Geologist at Salt Lake City, in company with several representatives of the Federal Housing Authority. The Geological Survey began a study of the area early in July, 1948. This preliminary report presents the results obtained through the middle of October, 1948.

The mapping and horizontal control were done by the writer and Mr. Richard Van Horn with the capable assistance of LeRoy Tucker and Paul Weis. Leveling was under the direction of Mr. Emmett Coon. City officials kindly furnished both men and materials to aid the study.

Description of the area

Helper is in Carbon County, east-central Utah, on U. S. Highways 6 and 50, and on the main line of the Denver & Rio Grande Western Railroad (see index map on fig. 1, in pocket). Helper is primarily a railroad town but it is also centrally located within a very active coal mining district. The nearest mines are several miles away from the town proper. Helper had a population of 2,843 in 1940 and is at an altitude of about 5,850 feet above sea level.

Helper is built on stream terraces and alluvial fans along both sides of the Price River, where the southward-flowing river issues from a canyon cut through the Book Cliffs. The lower and gentler slopes of the Book Cliffs are eroded from the Mancos shale; the higher cliff-forming sandstones belong to the Star Point sandstone and the Blackhawk formation. All these rocks are of Cretaceous age. The lower slopes, together with the upper cliffs, form an abrupt scarp that rises 1,200 to 1,300 feet above the northeast part of town.

The most severe damage to houses has been along D and E streets in the northeast part of the town and within the area shown on fig. 1. The houses here are built upon a southward and southwestward-sloping fan of wash material derived from the slopes and cliffs immediately to the north. This debris is composed of sandstone fragments, which have rolled or washed down to the lower slopes, embedded in clay, silt, and sand derived from weathering of the shale and of the loosely cemented sandstone. (See fig. 2). Sandstone fragments in the fan material vary in size from small pebbles to angular blocks 15 feet in diameter. A large proportion of these near the houses are 1 to 4 feet in diameter.

Fig. 2. Fan material overlying shale, as exposed in railroad cut.

So far as we know, shale bedrock has not been reached in excavations for foundations in this vicinity. We estimate that the fan is probably several tens of feet thick where the houses rest upon it, although there is no direct evidence from wells or borings. The contour of the shale surface beneath the fan cover is also unknown, but it is probably irregular. The fan heads to the north in tongues separated by ridges of shale, and it is likely that these ridges project southward beneath the cover of alluvial debris. The slope of the fan surface between D and E Streets is 8 to 10 feet per hundred feet.

The surface of the fan is cut by numerous channels, which quickly concentrate the runoff during heavy rainfall. Runoff in several of the larger channels is diverted by the Kenilworth Branch railway embankment to a culvert that passes under the ballast (see fig. 1). The water from the culvert ordinarily enters a shallow gully in the vacant lot between 109 and 113 E Street, crosses E Street, and sinks into the ground in the ditch along the east side of North View Street. During very heavy rains the water crosses North View Street, passes through the flume over the irrigation ditch and discharges into the alley back of the houses along lower D Street. We did not have an opportunity to trace the movement of surface waters across the upper part of E Street.

No precipitation records are available for Helper, but the Weather Bureau data for Price, 8 miles to the south, shows the average annual precipitation to be 10.21 inches. The months of highest rainfall are July, August, September and October. During these months the major part of the precipitation is due to occasional heavy rains which produce correspondingly heavy runoff. At least part of this runoff sinks into the ground at the lower end of the area which contains the damaged houses.

Damages

The most obvious kinds of damage, and those selected for study, are the cracking and warping of houses, the breaking of water mains, and cracking of the ground surface.

Houses.- Most of the damaged houses are along the north side of D street. Typical cracks in exterior walls and foundations of the houses may be seen in the photographs (figs. 3-6) and sketches (fig. 7).

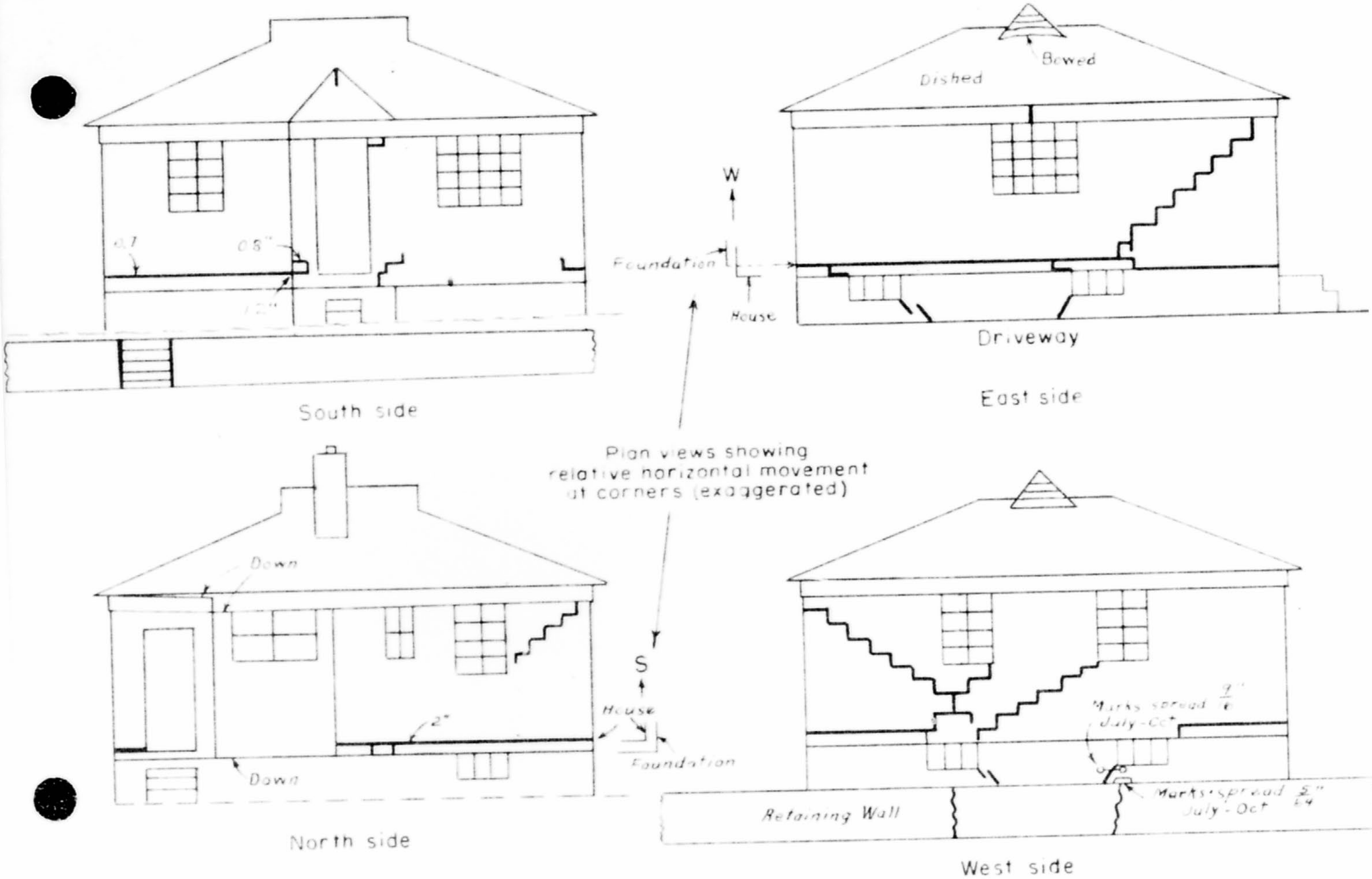
The most severely damaged house is 103 D Street, a cinder block structure occupied by Mr. Cliff Memmott. The interior of this house also shows numerous cracks, door frames are skewed, and part of the basement floor is said to have sunk. Two tie bars between the east and west foundation walls, presumably tight when put in, were slack in July, 1948. A procedure of repair followed in July was to jack up the superstructure, support it on 6" x 6" uprights to the basement floor, and fill in the horizontal crack above the foundation with cement. This operation must be repeated as the foundation walls sink deeper. The foundation itself has cracked in two places in the west wall.

Fig. 3. Cracks in the northeast corner of 110 E Street

Fig. 4. Cracks in the northwest corner of 154 D Street

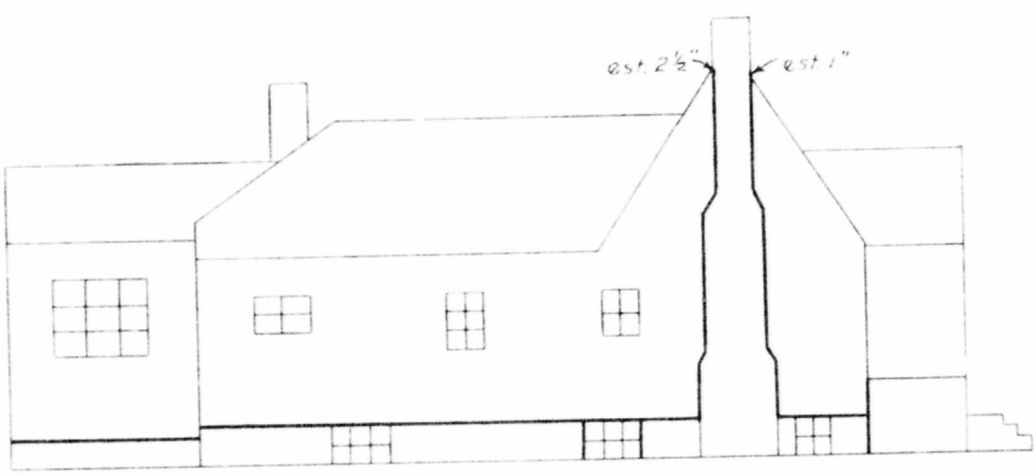
Fig. 5. View of southwest corner of 103 D Street

Fig. 6. View of north side of 103 D Street



103 D Street

Cracks shown in heavy lines



West side

105 D Street

Figure 7 SKETCHES OF CRACKED HOUSES

July - Oct 1948

The houses at 101 D and 105 D are also conspicuously cracked above the foundations (see fig. 7). At 105 D the most prominent cracks are those along either side of the chimney where it adjoins the house. Many other houses in the immediate neighborhood show slight to severe damage.

The trouble apparently has been going on for about 10 years, although several of the most severely damaged houses were erected more recently. Both new and old houses have been affected. Mr. Hatch at 105 D Street has had to make repairs every year for at least 5 years. Just after the foundation and basement floor at 109 D Street were completed in 1941 (?), a diagonal crack completely separated the structure from corner to corner. When the apartment house at 105 E Street was built (probably more than 10 years ago) trouble was anticipated and a number of old automobile frames and much steel cable were incorporated in the foundation. No signs of severe damage were noticed in this structure.

Water mains:- House mains have broken repeatedly along D Street. The service main into 103 D Street broke 3 times in 1947, both at the house and near the curb. The water mains into 105 and 107 D Street broke in April, 1948. The break at 107 D Street was not discovered until approximately 52,000 gallons of water had escaped beneath the house. Mr. Carr, the owner, reported that at that time the house settled to the south and east. Mr. Broadbent at 109 D Street said that his water main broke several times over a period of several years until he put in an elbow joint which could rotate as the house moved. Since then he has had no trouble.

The main 4-inch strut lines also have failed. Mr. Dominick Bruno, City Plumber, said that the main line down D Street pulled apart in 1941, and the main along the north side of E Street broke between 109 and 113 E Street about 1945. In July, 1948 the main along the west side of North View Street was cut to put in a T-joint across from 105 E Street. When the small section was removed, the cut ends immediately butted together and another section had to be removed to make space for the joint.

Cracks in the ground:- The only crack in the ground now visible is that shown on fig. 1; it is parallel to D Street and behind the lots that front on the north side of D Street. It was traced for about 160 feet, beginning in 2 or 3 small cracks back of 105 D Street and continuing in an irregular easterly course nearly to the fill in the back yard of 115 D Street. Mr. Llewellyn at 115 D Street reported that he exposed the crack while preparing the ground for a lawn on the north side of his house. The crack does not appear north of E Street, nor does the street show damage.

This crack is 1 inch to 6 inches wide (see fig. 8) and appears to be at least 5 feet deep, although the bouldery ground would not allow complete probing. The sides of the crack show no noticeable vertical offset. The age of the crack is unknown; Mrs. Hatch believed it to be 8 or 9 years old; Mr. Young reported it opened or reopened after heavy rains in August or September 1947.

Fig. 8. View of crack in ground

In 1933 or 1934 a crack opened up in the orchard and garden back of 105 E Street. It extended southward from the base of the slope south of the railroad to about 50 feet from the house, then curved westward and ended (see fig. 1). Mr. Gibson reported he ran water from a garden hose into the crack for 24 hours without filling it up. Mr. Llewellyn reported seeing a crack south of and parallel to D Street, before the houses at 152-156 D Street were built. This area is now covered with fill.

The pavement and curbs along D Street do not show evidence of movement. The street is surfaced with natural asphalt and the curbs and gutters are jointed and calked with tar, so that small movements probably would not be apparent.

Measurements

Although cracks in the houses could possibly be explained by unequal consolidation of the foundation materials, some actual movement of the ground nearby was indicated by the breaking of water mains in the streets and by the open crack. Yet there was no evidence of what is commonly considered a mass landsliding movement such as large displacements or buckling of the streets and ground surface. Moreover, the cracks that were seen or reported ran down the gentle fan slope rather than across it, contrary to the direction of cracks in typical landslides.

In an attempt to determine the amount and kind of movement which may be going on, a network of survey points was established within the area in July 1948. The stations were set on an intersecting grid of straight lines. The horizontal positions of the stations were determined, generally for one direction only, by the line on which each station was set. Some stations were set at the intersection of two lines, thus giving a check on the total amount and direction of relative movement. The elevations of the ground stations and points scribed on the house foundations were determined by first order leveling.

The stations themselves are 2-inch iron pipes driven 2½ to 3 feet into the ground and marked with a reference point to which measurements are made. Those along the southern east-west line were driven to below sod level, so as to be inconspicuous and to lessen the danger of accidental disturbance. The locations of the survey stations and the amount of horizontal and vertical movement for each are shown on fig. 9.

The topographic map was prepared before levels were carried into the area, hence the contours shown on figs. 1 and 9 are based upon an assumed datum and to not represent true altitudes above sea level.

Leveling and vertical movements:- A line of levels was brought into the area from the U. S. Coast and Geodetic Survey bench mark W 14, whose description is: "About 2.0 miles north along D. & R. G. W. R. R. from Helper, Carbon County, Utah, at bridge 628.49 in the top of the south abutment and 9 feet east of the centerline of the track. A standard disk stamped 5984.128 W14 1927". From this bench mark a line was run south along the railroad and temporary bench marks were established in places convenient to the area to be surveyed but presumably on stable ground.

The temporary bench mark to which all station elevations are referred is on the D. & R. G. W. Railroad about 3/4 mile north of the center of Helper, near the junction with the Kenilworth Branch, at mile 627.3, the top of the northeast bolt in the northwest concrete support block for the overhead signal. For the purposes of all leveling work, the altitude of this point is arbitrarily fixed at 5880.703 feet above sea level.

Two other temporary bench marks were established: 1) on the D. & R. G. W. Railroad at D Street, east side of crossing, top of northwest bolt on base of crossing signal, mean altitude 5859.906 ± .003 feet above sea level (average of 12 runs in 6 closed circuits), and 2) at Helper Postoffice, a chiseled square on north side of base of flagpole north of the Postoffice; mean altitude based on 6 runs in 3 closed circuits from D Street crossing is 5835.360 ± .005 feet above sea level.

As may be seen from the figures for the probable errors accompanying the above altitudes, the precise altitudes of the D Street crossing and Postoffice benchmarks remain in doubt. The difficulty experienced in running closed circuits of first-order accuracy along the railway between the temporary bench marks is probably due to elastic deformation of the railroad ballast under the nearly constant passage of trains. All circuits run from the primary bench mark at signal 627.3 to stations in the area of damaged houses were largely free of disturbances caused by trains and closed within the limits of error in first-order leveling.

It has been assumed that the temporary bench mark at signal 627.3 has remained stable throughout the period from July to October 1948, and all elevations are based upon it. There is no visible evidence yet that this or any of the other bench marks are unstable.

In addition to the levels run on the pipes driven into the ground, levels were also run on points scribed in the foundations of several of the houses. The results of leveling in July and October 1948 are shown in the table below, and on fig. 9.

Table 1

Station number	Elevations of stations in feet: July 1948 elevation	Elevations of stations in feet: October 1948 elevation	Difference in feet: rise	Difference in feet: fall
78	5942.049	5942.059	.010	
141	5893.322	Destroyed		
160	5885.998	5886.022	.024	
193	5896.886	5896.839		.047
194	5898.986	5898.960		.026
195	5900.114	5900.113		.001
196	5900.765	5900.771	.006	
197	5901.346	5901.353	.007	
198	5904.729	5904.738	.009	
199	5925.908	5929.922	.014	
200	5907.051	5907.050		.001
201	5912.717	5912.687		.030
202	5916.643	5916.640		.003
203	5901.808	5901.828	.020	
204	5900.756	5900.766	.010	
205	5903.017	5903.032	.015	
206	5911.205	5911.211	.006	
207	5916.686	5916.691	.005	
208	5918.388	5918.397	.009	
209	5920.823	5920.820		.003
210	5905.404	Destroyed		
211	5914.468	5914.482	.014	
269	5922.294	5922.310	.016	
274	5910.277	5910.254		.023
275	5898.198	5898.222	.024	
		Foundation points		
F-1	5903.746	5903.743		.003
F-2	5903.460	5903.451		.009
F-3	5903.461	5903.452		.009
F-4	5903.460	5903.425		.035
F-5	5902.959	5902.912		.047
F-6	5902.959	5902.885		.074
F-7	5902.959	5902.937		.022
F-8	5902.371	5902.370		.001
F-9	5898.768	5898.690		.078
F-10	5898.768	5898.739		.029
F-11	5898.769	5898.634		.135
F-12	5899.216	5899.163		.053
F-13	Set in October	5901.964		
F-14	"	5901.964		
F-15	"	5901.549		
F-16	"	5901.549		

Resurvey of the ground stations indicated that there are two general areas in which the survey points sank along the southern east-west line. One area is in front of 101 D Street, and the other is between 109 and 113 D Street. All stations along the northern east-west line rose slightly except station 209, which may have been accidentally depressed by bulldozer work along E Street.

In contrast to the erratic results of the resurvey of the ground stations, releveling of points on the foundations of the houses showed that all points had sunk. Moreover, the settlement of each house is not uniform. At both 101 and 103 D Street a general settlement plus a tilting to the northwest is indicated, and at 105 D Street the few points measured indicate more settlement in the rear of the house than in the front. The maximum settlement recorded is 0.135 feet or 1.62 inches at the northwest corner of 101 D Street.

Horizontal movements:- The stations in the area of damaged houses were set along straight lines. Movements of the stations relative to each other in a horizontal plane could then be detected by measuring the departure of the stations from the original straight line.

In most instances, the lines along which the stations were set are defined by the stations at the ends of the lines. An exception is the southern east-west line, whose azimuth is defined by station 199 and a point on a low building about 1 mile to the west. A set of horizontal angles to distant peaks, including the azimuth point, were measured about station 199 to detect any future general swing in the line.

Due to the rocky ground, the pipes could never be driven exactly on line, so the initial departures of the marks on the pipes from the lines were measured. Various methods of measuring these initial departures were used, depending upon whether or not the mark itself was visible from the transit. Each method gave reproducible results. Sets of observations, consisting of at least two readings, and for some points as many as five, were taken until it was believed that the departure of the point from its line was known to within 0.03 inch. Most of the measurements along the lines were taken at night when the air was still.

The horizontal movements of ground stations relative to points assumed to be fixed and in directions perpendicular to their respective lines are shown on fig. 9.

Measurements were made at two places between stakes on either side of the crack in the ground, and between several sets of points on either side of cracks in the foundations and retaining walls of the houses. The location of the two lines across the crack in the ground and the changes in the lengths of these lines are also shown on fig. 9. The widths of some of the cracks in the houses, and changes in widths of some of these cracks between July and October, are shown on the sketches of the houses (fig. 7).

The rerunning of the network of lines showed that all stations had moved relative to the end points of each line. The end points of two lines were accidentally destroyed between July and October. For these two lines, it was assumed that the next to the last points had not moved, and by using original departures of these points the lines were reestablished.

The resurvey in October demonstrated small relative movements along the stations, and generally much larger movements of the stations along the southern east-west line compared to those along the northern east-west line. The most remarkable result of the resurvey is that all stations along the southern east-west line, except No. 198, had a component of movement to the north. The maximum movement recorded is for station 196, which had a northward component of movement of 0.54 inch. The few data available from the north-south lines indicate that stations along the southern east-west line also had a component of movement to the west, yielding a resultant total displacement toward the northwest.

The stations on the northern east-west line showed small movements in various directions, all less than 0.15 inch. There is no consistent relation between the amount of horizontal movement and the amount of vertical movement of the stations.

Interpretation of data

More resurveys must be made over a period of many months before the movements of the stations may be expected to show a trend or pattern. On the basis of all information gathered to date, the fan material is apparently moving a small amount. The cracks which have appeared, the breaking of main water lines along the streets, and the consistent northward component of movement shown by the stations along the southern east-west line, indicate that some of the movement may involve large masses. The available data indicate the possibility of three types of movement, which may be operating alone or in concert.

1). The fan material may be slowly creeping over the shale surface upon which it rests. The amount of movement is very small, and the direction is, as yet, indeterminate. The apparent northwestward movements of the stations on the southern east-west line and the tilt of the houses at 101 and 103 D Street also to the northwest, although it does not coincide with the direction of the greatest slope of the ground surface, indicate that creep movements may be controlled by the slope and shape of the underlying shale surface. The shape of the shale surface may have no relation to the topography of the present ground surface.

2). The movements of the remainder of the stations are generally small and erratic, but they help support a second theory of movement which is based largely on geologic reasoning and which is believed to hold the correct explanation. It is believed that a nearly continual rearrangement of the fine clay and silt particles takes place between the individual pebbles and boulders of the fan material; and that these small particles move about under the action of percolating waters, aided perhaps by vibrations from nearby railway traffic.

The fan material was originally deposited by running water of varied force, from the strongest torrents caused by cloudbursts to the smallest rills of a light rain. The material within the fan is therefore highly variable in size and distribution. The larger fragments are angular and do not form a strong coherent mass (see fig. 2). The entire deposit contains many small voids or open spaces, formed as the material was laid down. It is reasonable to expect that as the fan is subjected to the percolation of rainfall, and especially to unusual amounts of water from lawns and gardens, the finest material in the fan would wash away from between the large rocks and move on down the slope. This removal of fines would allow the boulders to settle or rotate in any part of the fan which happens to contain moving water, resulting in irregular movements at the surface of the fan.

3). A third type of movement may be expected from this geologic environment, and has in fact been studied in England, where dwellings with footings above the zone of permanent saturation were built upon clayey ground/. This type of movement within the fan would result

/ Cooling, L. F., Some examples of foundation movements due to causes other than structural loads: Proceedings of the Second International Conference on Soil Mechanics and Foundation Engineering, vol. 2, pp. 162-167, Rotterdam, 1948.

from shrinkage by drying of the interstitial clay and silt between the sandstone boulders, through seasonal changes in evaporation and rainfall or through the transpiration of shrubs and trees. This theory would furnish a satisfactory explanation of small up and down movements of the stations.

Frost heave could also cause movement of the stations, although this possibility must be ruled out in explaining the movements recorded during the summer of 1948.

At this point it should be emphasized that the occurrence and severity of each of these types of movement is largely dependent upon the quantity, distribution, movement, and seasonal variation in the amount of water within the fan material. These factors are unknown and will remain so unless exploratory methods beyond the scope of the Geological Survey's preliminary work are used.

The various types of movement outlined above, especially if they operate together, are sufficient to explain the movement of stations set in the ground, the formation of cracks, and the breaking of water mains. It is possible that the same processes, operating under and near the houses are sufficient to explain the observed damage. In regard to the houses, however, other factors must be considered which the Geological Survey is not in position to evaluate. The two principal factors are:

1). The methods of construction, especially the relation of the load per unit area of the footings to the strength of the supporting earth material; and

2). The materials of construction. To be specially studied in this connection are a) the possible effects of deleterious material, such as chert, chalcedony and other forms of amorphous silica, if used as aggregate in concrete, and b) the resistance of the concrete used in construction to waters high in sulfate. In regard to the latter point, we analyzed a sample of the Mancos shale from a nearby outcrop and found it to contain about 2 percent of soluble sulfate in the form of gypsum.

Summary and recommendations

This study has to date resulted in the preparation of a topographic and surface geologic map of the area, in the demonstration that small movements of the ground and generally much larger vertical movements of the surveyed houses is now going on, and in suggestions, based upon geologic evidence, as to the types of movement that may be taking place.

The study has not proved the cause of the observed movements, nor the cause of the damages; and further study only along the lines so far pursued will probably not bring forth the answers. Suggestions for further study are included in the general recommendations below.

Recommendations:-

1). That no more houses be built in the area known to be subject to damage until the cause of the damage be more certainly known and effective preventive measures determined.

2). That until the effect of water in the fan material has been determined, every effort be made to lessen the water content of the fan. This should include: a) the diversion of runoff from the fan at least as far up the slope as the north side of the ballast of the Kenilworth Branch, and leading it away by lined ditches so that the water has no opportunity to seep into the ground south of the railroad, b) the use of discretion in watering lawns and gardens near the houses, and c) the placing of weep holes in all retaining walls near the houses.

3). As water lines are repaired, flexible couplings should be installed so that not only will repairs become less frequent, but also the possibility of water escaping from broken mains will be lessened.

4). That an investigation be made by competent construction and foundation engineers looking toward:

a. Methods of stabilizing the foundation materials of the houses, either to improve the physical properties of the earth material or to give a greater effective bearing area for the load of the house, in order to decrease further damage.

b. Determination of the safe bearing capacity and consolidation rate of the fan material.

c. Determination of the kind of construction and the kinds of aggregate, cement, and reinforcing materials suitable in this area for concrete work subjected to possible high stress and to the presence of sulfate-charged waters.

3). The determination of the actual causes of movement and of the methods applicable to prevent them calls for additional information. If the interested parties believe it worth the cost to get this information, the following should be done:

a. Borings should be put down at least to the top of the underlying shale to determine the thickness of the fan, the shape of the shale surface, the presence or absence of a slippery zone at the top of the shale upon which the fan may be creeping, and the depth to and slope of the water table. Samples of the fan and shale material should also be obtained for testing.

b. The feasibility of using geophysical methods to determine the shape of the ground water table and the position of the shale surface should be considered.