DRAFT REPORT

To

COLORADO STATE DEPARTMENT OF HIGHWAYS
DIVISION OF HIGHWAYS

GEOPHYSICAL INVESTIGATIONS OF MINE TUNNEL SUBSIDENCE AT THE HIDDEN VALLEY INTERCHANGE, INTERSTATE-70, CLEAR CREEK COUNTY

From

EXPLORATION RESEARCH LABORATORY

of

DEPARTMENT OF GEOPHYSICS
COLORADO SCHOOL OF MINES

INTRODUCTION

The Colorado Division of Highways has experienced subsidence problems along Interstate-70 near the Hidden Valley interchange. These problems are believed to be related to old mine tunnel roof support failure. Geophysical investigations were conducted in late August and early September, 1981, to determine if certain geophysical techniques could delineate zones of imminent failure. These techniques included seismic refraction surveys, electromagnetic (EM) conductivity measurements, and DC resistivity measurements.

Although the EM and DC methods did not prove to be reliable in detecting void zones, the seismic refraction technique did show a good correlation between delayed (anomalous) seismic P-wave arrivals and void zones as discovered by drilling.

Several anomalous zones which may be associated with tunnel workings were observed in areas which had not been drilled. These anomalous zones appear in Figure 1.

FIELD WORK--PHASE I

Geophysical tests for Phase I included seismic refraction surveying, DC resistivity surveying, and electromagnetic (EM) surveying. The DC method and the EM method proved not to be interpretable in terms of locating voids in the subsurface, therefore, Phase II work did not include these methods.

a. DC method: About 600 linear feet of survey was conducted over areas of known voids and tested areas which contained no voids with the DC resistivity method. Good correlations between known void zones and resistivity anomalies were not observed. This was probably due to dry ground conditions prohibiting good current coupling with the earth. Data from areas which were drilled and found to be voidless, did not vary consistantly from data gathered in known void areas. Inasmuch as resistivity would not reliably indicate void areas, Phase II work did not contain this method.

b. EM method: Approximately one-half or 1,000 feet of the area of interest was traversed with an electromagnetic conductivity meter. As was done with the DC survey, known void areas and tested areas which showed no voids were surveyed. EM data obtained did not show a distinctive "signature" over known void areas. It is our belief the very dry sands and gravels formed an insulating blanket which precluded surveying to a depth which might prove useful to void detection. Both the electromagnetic and resistivity surveys may show appreciably better data with damp to wet ground conditions as is common in the early spring season.

c. Seismic Refraction: Ten test lines were conducted. These lines were placed so that known void areas, as revealed by drilling, were crossed. Plots were made of travel time versus distance for each seismic line shot. Figure 2 shows seismic data from an area believed to have no voids or disturbed ground as revealed by drilling. Figure 3 shows data from a void zone revealed by the drilling program. Inspection of these figures suggests that unusually high travel times may be associated with the voids and disturbed subsurface located by the drilling program. Those seismic waves which arrived very late are interpreted as having been delayed by loose, disturbed material or voids associated with mine tunnel subsidence.

FIELD WORK--PHASE II

Based on Phase I test results, Phase II work was confined to seismic refraction surveys. Sixteen additional survey lines were conducted. These surveys cover the remaining areas of the Interstate from station 210+00 to 220+00 which were not covered by Phase I work or drill holes.

A map showing the Interstate-70 corridor from station 210+00 to station 220+00 appears in Figure 1. This map shows the location of seismic lines 8 through 25 and the zones which showed travel time anomalies. Note that lines 8, 9, and 10 were part of the Phase I work, here included to show the correlation between known void zones and patterns of disturbed seismic waves. Several areas which were not drilled in the program conducted by the Colorado Division of Highways, show anomalous travel time characteristics.

a. On the westbound ramp, these include zones (see Figure 1) around station 218+80, 217+60, and 217+00.

b. On the westbound mainline, anomalous zones were found around station 212+60 and in a region from station 210 to 211 not far from the bridge over Clear Creek.

c. On the eastbound mainline, another small zone was observed near station 212+60, correlating with a similar zone on the westbound mainline.

d. Other small zones were observed near the beginning of the eastbound exit ramp near station 214+20 and near station 218+00.

In view of past experience in this area, these zones of anomalous sismic wave propogation must be interpreted as possible

zones of failure above old mine workings. The areal extent of anomalous zones can be estimated within limits set by hammer point and geophone spacings--plus or minus five feet. These zones of seismic wave interruption appear in Figure 1 as corridors, limited by seismic travel paths which showed no interruption.

CRITERIA FOR TEST RESULTS

To produce the Figure 1 map, several tests were applied to the seismic refraction data. First, the seismic arrivals from each hammer source point were plotted as travel time versus distance to each geophone. From this plot, a "normal" arrival time for any given source to geophone distance was established. Seismic propagation velocities of alluvial gravels and bedrock were also calculated.

From this information, travel time between source and any given geophone was predicted and compared to the actual field data. Those source/geophone paths which differ from the predicted travel time by 20% or more were termed anomalous. The 20% "normal" variation allows for inconsistancies in subsurface material, undulations on the refractor (bedrock) surface which is assumed to be flat, and topographic changes on the ground surface where the geophones are located.

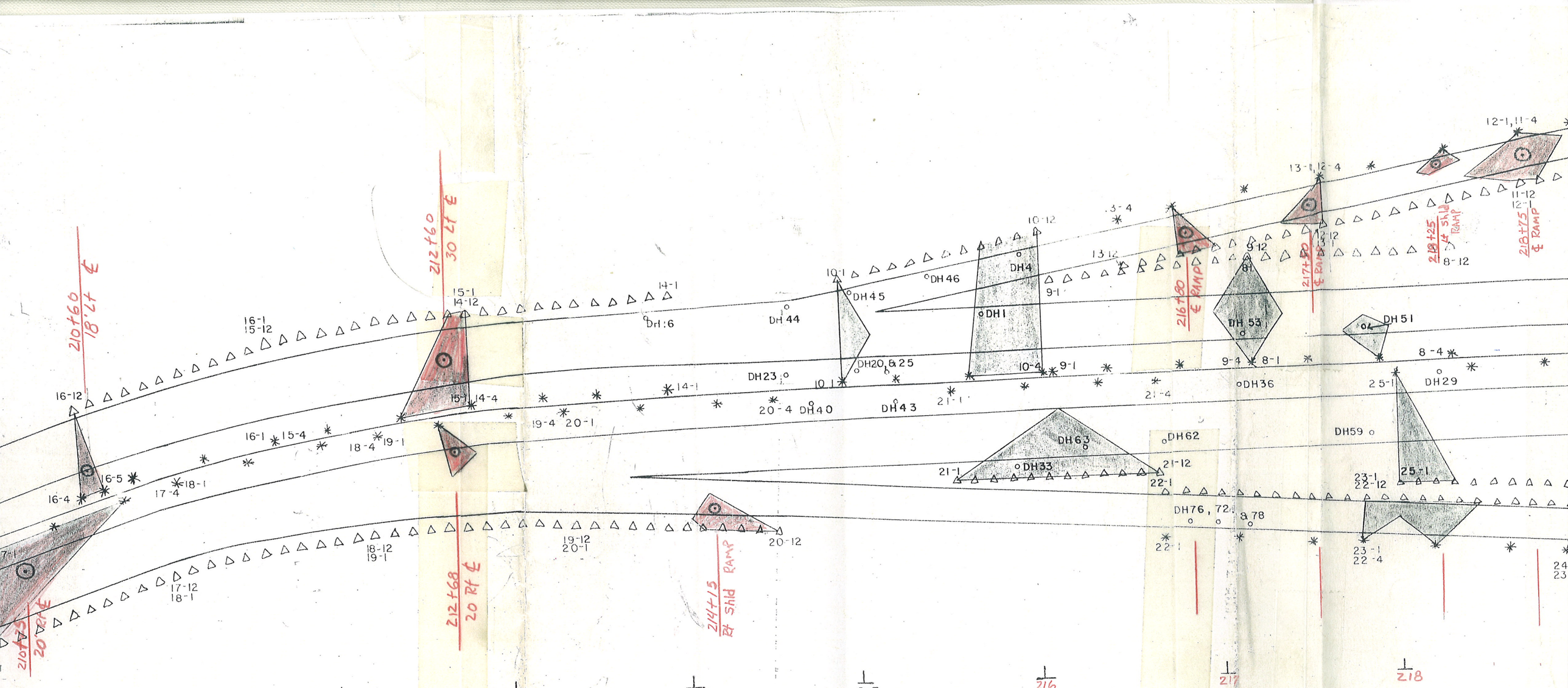
Once the anomalous raypaths were selected, they were plotted in map view along with the geometric configuration of the seismic line. The locations of anomalous raypaths were compared with "normal" raypaths to determine which subsurface regions contributed to the anomalous delays. Viewed in this way, the anomalous

paths define a zone which may be suspected of containing cavities or material disturbed and weakened by the old tunnelling operations. Figure 4 is an example of anomalous data collected from an undrilled area. This survey line was located on the eastbound mainline between stations 210 and 211. Note the late arrivals from certain raypaths.

CONCLUSIONS

Of the three geophysical techniques attempted at the Hidden Valley site, seismic refraction proved to be the most reliable. The electromagnetic and DC resistivity techniques did not consistently resolve known void and known solid areas. Climactic conditions may have been a factor for the unreliability of these techniques.

The seismic data showed zones with time delayed raypaths. These delays can be empirically related to disturbed ground and void zones located by drilling. By extension of the empirical relationship to seismic data gathered in undrilled regions, zones of anomalous travel time can be mapped. These zones may define additional regions of subsurface voids and/or disturbances related to old placer tunnel excavations. It is hoped the definition of anomalous zones will prove to be of aid to the Division of Highways in locating additional areas which have not yet failed but which may potentially fail in the future.



APPROXIMATE SCALE
1" = 50'

HIGHWAY PLAN VIEW AFTER SHEET 51, TRAFFIC CONTROL PLAN 1 of 3

LEGEND

22-1 * SHOT POINT, SHOWING LINE AND SHOT NUMBER

22-1 △ GEOPHONE, NOTATION AS ABOVE

DH23 ○ DRILL HOLE AND NUMBER

ANOMALOUS ZONE

⊙ Areas requiring additional drilling. Larger areas up to 3 holes. Smaller areas 1 hole should be sufficient.

FIGURE 1
SEISMIC REFRACTION TESTS AND ANOMALOUS TRAVEL-TIME ZONES HIDDEN VALLEY AREA