

APPLICATION OF AERIAL MAPPING TO DEVELOPMENT OF HIGHWAYS

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Aerial photography can effectively be applied to the development of preliminary engineering plans, environmental analysis, community impact studies, and financial feasibility studies for limited-access highways. New methodology and techniques provide an excellent tool for rapidly and inexpensively developing preliminary data required for technical and scientific investigations. The Atlanta Tollway Project is a \$200 million system composed of 35 miles of limited-access highways and 10 miles of high-speed rapid transit in the median. Most of the aerial mapping techniques discussed in this paper were used in the development of the financial feasibility, the environmental, and the community impact studies for that project.

•THE GEORGIA Department of Transportation, in cooperation with local and federal agencies, has developed a comprehensive transportation plan for the metropolitan Atlanta area. This long-range plan envisions a balanced system of arterial and limited-access highways and transit facilities. As in most large American cities, the transportation needs are far greater than the state's ability to finance them through conventional methods.

In an attempt to implement the highest priority projects at the earliest possible date, the department turned to an alternate method of highway financing: revenue bonds. This type of financing for urban and rural highway projects has been successfully used throughout the country for many years. Such a procedure appeared to offer the greatest potential for early construction of the most desperately needed limited-access highways identified in the Atlanta Transportation Study.

The initial step in developing highway projects that anticipate revenue-bond financing is to determine relative financial feasibility, that is, to estimate the cost to provide the facility and the anticipated revenues the project will generate from tolls collected from motorists using the highway.

Until financial feasibility has been determined, the planning process for projects financed by revenue bonds is different from that of projects financed by conventional methods. The initial step, after the decision has been made to explore revenue-bond financing, is to develop a rapid low-cost assessment of the total project cost for comparison with projected revenues.

Aerial photographs, remote sensing, and photogrammetric mapping techniques offer the best method for expeditiously and inexpensively determining existing topographic features.

In addition to conventional data that are historically obtained from aerial mapping, pertinent information can also be compiled to evaluate the potential environmental and community impact effects of the proposed highway facility. These are important factors that can greatly influence the location of the proposed facility and should be considered at an early stage in project development. Ameliorative measures to offset some of the environmental and community problems represent a significant percentage of the project cost and must be identified prior to feasibility testing. Aerial photography techniques can adequately satisfy the needs.

THE PROCEDURE

On projects that have little or no preliminary engineering history, alternate route locations within the corridors established in the regional transportation plan must be identified and examined. Conventional aerial photographs are used to identify existing demographic features and other route constraints. Next, test alignments are prepared and evaluated for adequacy of geometrics, traffic service, and basic route quality.

After the various feasible alternates have been identified, aerial mapping is obtained for the alternate alignments. Standard photogrammetric plotters are used to compile topographic features, usually to a scale of 1 in. = 100 ft. The manuscript is then used to begin development of preliminary engineering data required to obtain construction costs. Topographic features for all alternates can be ascertained from the raw manuscripts, without elaborate final scribing, thus saving time and money at a very critical stage in the feasibility analysis process (Fig. 1).

On projects where electronic computers are employed, a terrain model is defined for computer processing from photogrammetric mapping. The data can be obtained by manually tabulating cross sections from contours or from a digital terrain recorder. If terrain data for the study corridor are available in the computer, various combinations of vertical and horizontal alignments are examined (Figs. 2 and 3). At this stage, relative route quality and preliminary estimates of construction costs for potential alternates are determined, and a preliminary assessment of potential environmental impact is made.

COMMUNITY IMPACT ANALYSIS

Each of the community impact (socioeconomic) and scientific environmental disciplines are investigated by the use of aerial mapping techniques. Existing demographic barriers, both natural and man-made, are identified from aerial photography and depicted on transparent overlays. Land use characteristics are shown on the demographic base maps; the data are obtained from field reconnaissance and census tapes. Superimposing alternate highway alignments over the demographic and land use maps gives a general indication of relative community impact of the various alternates (Fig. 4).

At this point, experienced judgment is needed to interpret preliminary indications from generalized values. Although photo-identifiable route constraints and basic impact on community settlement areas are the initial values to be considered, early adoption of a specific alignment at this point could result in a project cost far greater than financing capabilities. An exchange of data among traffic, revenue, and engineering investigations is in order so that a relative degree of estimated patronage of the various alternates can be obtained.

ENVIRONMENTAL ANALYSIS

Aerial photography offers unique opportunities to make an accurate assessment of environmental impact at an early stage in the planning process. Environmental factors that are particularly amenable to investigation by aerial mapping techniques include ecology, acoustic noise, seismic noise, hydrology, and erosion control.

Ecological impact, or the natural biotic communities that may be altered by a highway project, warrants special concern. The procedure usually employed to assess environmental impact on such natural areas is to examine aerial contact prints in stereoscopic pairs with a minimum of 60 percent end overlay. These prints are reviewed generally for identification of area and gross topographic features and cover types. Individual photographs are then inspected in detail by stereoscope, and individual features, i.e., forest types, residential structures, pavement covers, are marked on the prints. The marked prints are verified in the field where features and objects not identifiable from photographs alone are identified.

A photomosaic is constructed from the contact-size photograph, and the photograph interpretation is depicted on transparent material at the same scale as the demographic and land use base maps.

Figure 1. Alternative alignments on raw manuscripts.

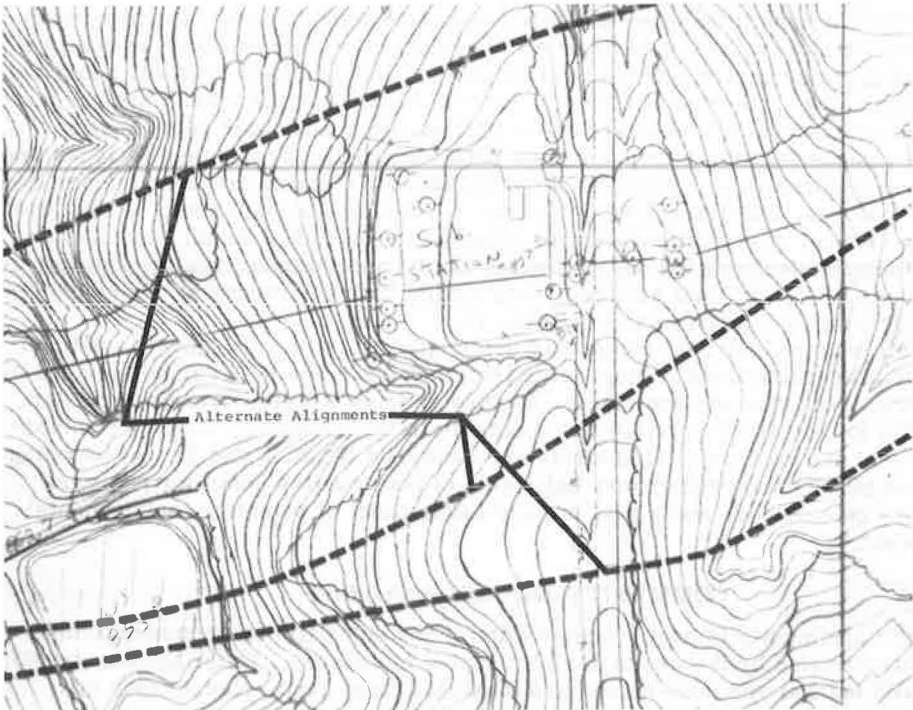


Figure 2. Earthwork information.

BL STA	CL STA	CUT VOL	FILL VOL	ACUM CUT	ACUM FILL	MASS HAUL	CUT A	FILL A
32800.00	32800.00	0.0	-22926.4	3766394.	-2206426.	1559968.	0.0	-5006.7
32900.00	32900.00	484.1	-15283.4	3766878.	-2224766.	1542112.	261.4	-3246.3
33000.00	33000.00	484.1	-9705.2	3767362.	-2236412.	1530950.	0.0	-1994.5
33100.00	33100.00	1550.3	-4864.2	3768912.	-2242249.	1526653.	837.1	-632.1
33200.00	33200.00	6088.2	-1364.4	3775000.	-2243886.	1531114.	2450.4	-104.5
33300.00	33300.00	10583.6	-193.6	3785584.	-2244118.	1541465.	3264.7	0.0
33400.00	33400.00	8443.0	-436.3	3794027.	-2244642.	1549385.	1294.5	-235.6
33500.00	33500.00	3129.4	-613.0	3797156.	-2245377.	1551778.	395.3	-95.3
33600.00	33600.00	7352.0	-176.6	3804508.	-2245589.	1558919.	3574.7	0.0
33700.00	33700.00	7008.5	-764.5	3811516.	-2246506.	1565010.	209.8	-412.8
33800.00	33800.00	1000.5	-2561.5	3812517.	-2249579.	1562937.	330.4	-970.3
33900.00	33900.00	4525.1	-1797.0	3817042.	-2251735.	1565306.	2113.1	0.0
34000.00	34000.00	6800.4	-504.5	3823842.	-2252341.	1571501.	1559.0	-272.4
34100.00	34100.00	8950.3	-504.5	3832792.	-2252946.	1579845.	3274.1	0.0
34200.00	34200.00	8310.2	0.0	3841102.	-2252946.	1588155.	1213.3	0.0
34300.00	34300.00	3877.6	-1193.3	3844979.	-2254378.	1590601.	880.5	-644.3
34400.00	34400.00	3751.4	-1213.7	3848730.	-2255834.	1592896.	1145.2	-11.0
34500.00	34500.00	5395.4	-20.4	3854125.	-2255859.	1598266.	1768.2	0.0
34600.00	34600.00	6681.4	-2.9	3860806.	-2255862.	1604944.	1839.7	-1.5
34700.00	34700.00	7846.4	-58.1	3868652.	-2255932.	1612720.	2397.3	-29.8
34800.00	34800.00	4549.3	-1610.4	3873201.	-2257864.	1615337.	59.2	-839.7
34900.00	34900.00	109.7	-13347.7	3873311.	-2273881.	1599430.	0.0	-6368.0
35000.00	35000.00	0.0	-25631.1	3873311.	-2304638.	1568673.	0.0	-7472.8
35100.00	35100.00	0.0	-29327.2	3873311.	-2339830.	1533480.	0.0	-8363.9
35200.00	35200.00	0.0	-28893.2	3873311.	-2374502.	149809.	0.0	-7238.4
35300.00	35300.00	0.0	-23230.8	3873311.	-2402379.	1470932.	0.0	-5306.1
35400.00	35400.00	0.0	-17103.3	3873311.	-2422902.	1450408.	0.0	-3929.6
35500.00	35500.00	273.0	-10666.7	3873584.	-2435702.	1437881.	147.4	-1830.4
35600.00	35600.00	1160.4	-5882.4	3874744.	-2442761.	1431983.	479.2	-1346.0
35700.00	35700.00	2369.7	-2959.7	3877113.	-2446312.	1430801.	800.4	-252.1
35800.00	35800.00	7682.0	-467.0	3884795.	-2446872.	1437923.	3347.8	0.0

Total Waste (cu. yd.)

Total Fill (cu. yd.)

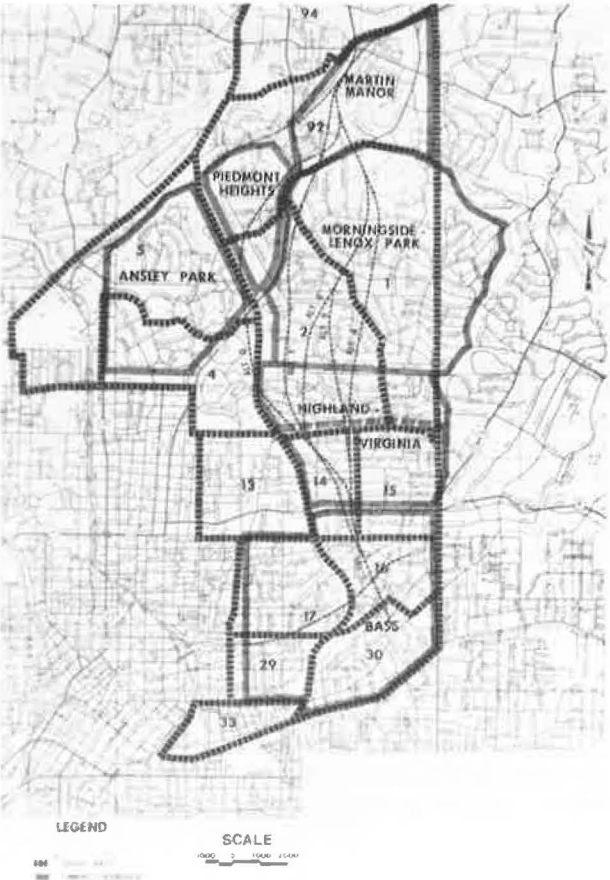
Total Cut (cu. yd.)

Figure 3. Slope-stake information.

BASELINE STATION	C/L	SLOPESTAKES	
		LEFT	RIGHT
3800.00	STA= 3800.00 EL= 870.36	OFF=-124.60 GR EL= 842.50	OFF= 161.89 GR EL= 823.80
3900.00	STA= 3900.00 EL= 871.97	OFF=-113.50 HF EL= 860.00	OFF= 154.89 GR EL= 828.90
4000.00	STA= 4000.00 EL= 873.80	OFF=-118.60 MF EL= 864.40	OFF= 134.10 GR EL= 841.19
4100.00	STA= 4100.00 EL= 875.83	OFF=-126.00 HF EL= 860.69	OFF= 121.10 GR EL= 849.69
4200.00	STA= 4200.00 EL= 878.06	OFF=-119.80 GR EL= 852.59	OFF= 121.00 GR EL= 852.00
4300.00	STA= 4300.00 EL= 880.50	OFF=-127.50 GR EL= 851.19	OFF= 120.69 GR EL= 854.50
4400.00	STA= 4400.00 EL= 883.07	OFF=-136.20 GR EL= 849.40	OFF= 113.80 GR EL= 860.59
4500.00	STA= 4500.00 EL= 885.64	OFF=-110.60 GR EL= 864.69	OFF= 116.30 GR EL= 861.90
4600.00	STA= 4600.00 EL= 888.22	OFF= -90.50 LF EL= 884.30	OFF= 120.80 GR EL= 862.19
4700.00	STA= 4700.00 EL= 890.79	OFF=-115.60 HC EL= 898.50	OFF= 130.30 HF EL= 874.59
4800.00	STA= 4800.00 EL= 893.36	OFF=-130.60 HC EL= 908.59	OFF= 124.30 MF EL= 883.09
4900.00	STA= 4900.00 EL= 895.93	OFF=-128.30 HC EL= 910.00	OFF= 119.19 HC EL= 905.40
5000.00	STA= 5000.00 EL= 898.50	OFF=-124.39 HC EL= 910.59	OFF= 152.80 HC EL= 924.80
5100.00	STA= 5100.00 EL= 901.07	OFF=-125.60 HC EL= 913.80	OFF= 159.89 HC EL= 931.00
5200.00	STA= 5200.00 EL= 903.40	OFF=-134.10 HC EL= 920.40	OFF= 178.60 HC EL= 942.59
5300.00	STA= 5300.00 EL= 905.32	OFF=-129.39 HC EL= 919.90	OFF= 189.89 HC EL= 950.19
5400.00	STA= 5400.00 EL= 906.83	OFF=-161.50 HC EL= 937.50	OFF= 190.20 HC EL= 951.80
5500.00	STA= 5500.00 EL= 907.94	OFF=-176.50 HC EL= 946.09	OFF= 166.50 HC EL= 941.09

These Codes Indicate Cut or Fill, High or Low, etc.

Figure 4. Community boundaries and census tracts.



Alternate test alignments depicting route details and tentative right-of-way requirements are overlaid on the biotic community base maps to determine the total number of areas removed by each alternate (Fig. 5). In addition, the relative impact on the communities adjacent to each alternate can be assessed, and the opportunities can be considered for acquiring lands adjacent to the proposed roadway to preserve the existing biotic communities. Those areas have been designated as "hold-and-save" areas and serve to provide in perpetuity a buffer of natural growth between the roadway and existing communities. Those areas are evaluated with respect to both environmental and community considerations.

Acoustic sound (the audible noise generated by highway traffic) is generally considered to be an offensive by-product of urban highways. An early evaluation of the impact of highway traffic noise for the various alternates under consideration is essential because of the high cost to provide ameliorative devices. Computations of acoustic noise production can be made from basic alignment geometrics developed from aerial mapping as previously discussed. Locations of toll barriers, points of ingress and egress, horizontal curvature, and profile gradients for the various alternates are all parameters in computing traffic noise. Noise levels, based on volume, operating characteristics, and vehicular mix of traffic, are depicted as contours (Fig. 6). These raw contours are superimposed over terrain contours shown on the photogrammetric mapping. Adjustments are made for topographic relief to obtain anticipated sound conditions that could result on the site when the highway is operating.

Land uses and physical installations sensitive to increases in acoustic noise are located on the photogrammetric mapping. In addition, other areas that may be subjected to increased noise levels are defined. Noise attenuation devices such as acoustic berms and barriers are located in critical areas and depicted on the photogrammetrics. Line-of-sight protection from the attenuating devices is tested by plotting random angular and right-angle sections from terrain data obtained from the terrain contours. Acoustic berms and barriers or a combination of both is depicted on the base maps, and quantities are obtained for cost estimating.

Seismic noise (vibrations) generated by highway construction and operation is generally transmitted by surface soils. Topographic relief is one of the best forms of attenuation of seismic noise; another is total distance from the point of production to location of observer. Seismic noise investigations of the Atlanta Tollway Project (Table 1) have provided some of the first available literature on seismic noise production from highway construction and operation. The conductivity of the surface soils can be determined from available geologic data by the use of seismic generation magnitude (particle velocity). Terrain features can be obtained from photogrammetric mapping.

Facilities where levels of seismic noise may be "easily felt" can be readily identified, and ameliorative measures, such as slope contours and intermediate berms, can be located on the aerial base maps. Costs to provide attenuating devices can then be estimated.

Photogrammetric mapping, with large or small contour intervals, provides the necessary topographic data to make preliminary hydrological and drainage investigations. Drainage areas can be delineated from contours to determine total watershed size. Run-off characteristics and times of concentration are developed from ground cover conditions and topographic relief obtained from the aerial mapping and contours. From those data, tentative sizes for openings of watercourses under the highway project are calculated.

High water data from geological survey records or other local sources and contours shown on the photogrammetric mapping can be used to define floodplain storage areas. The impact on the floodplain by the various alternate highway alignments can be determined, and the amount of excavation required to replace any storage volume lost as a result of the highway embankment can be computed.

Upstream and downstream watercourses are examined for adequacy to discharge design storms. Outfall requirements are determined, and preliminary outfall designs and cost estimates are developed.

Erosion potential from highways has taken on new significance in recent years. Soil erosion, especially during construction, can raise turbidities in the receiving water-

Figure 5. Biotic communities and alternate alignments.

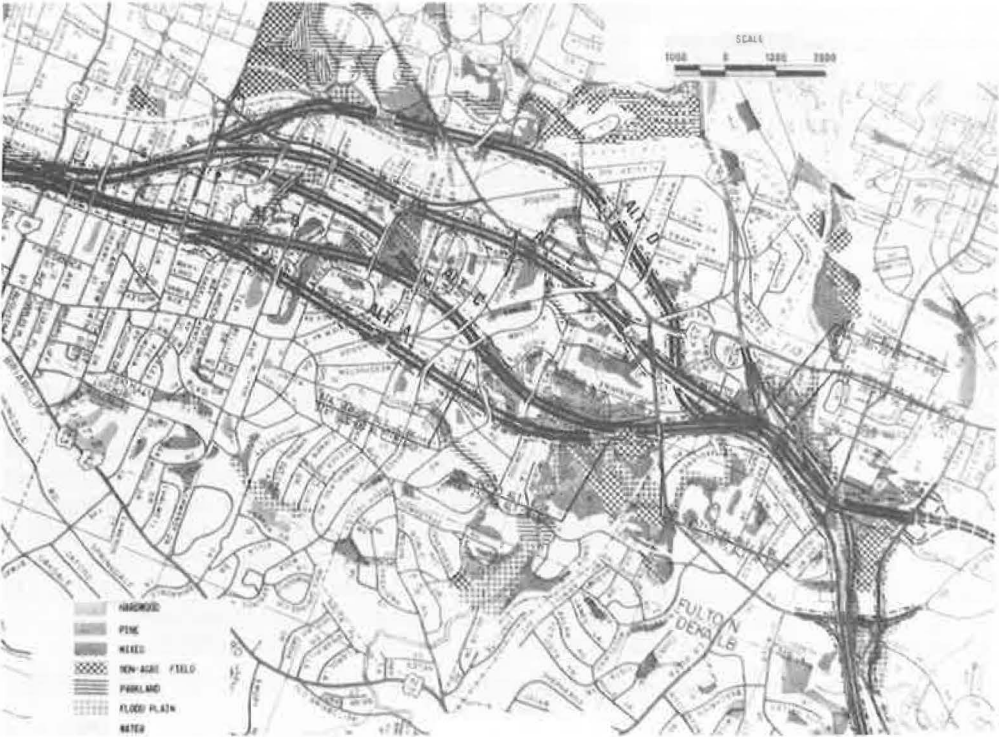


Figure 6. Noise contours and attenuation by barriers.



courses to levels above the tolerance of marine biota. Permanent damage can result, even if the increase in turbidities is only a temporary phenomenon that will subside to preconstruction levels after protective ground cover has been established.

To determine the degree of erosion hazard that can be expected, an analysis is made of generalized soils classifications from geological survey data and agricultural maps. These data are supplemented by field borings at selected locations to verify the existing geological data. The boundaries of the various soils classifications are delineated on the topographic maps to determine the existing slopes for each type. The ecological base maps depicting cover types are superimposed over the soil classification maps to assess gross areas of each degree of erosion hazard (Fig. 7).

After the areas of high erosion potential are determined, locations of temporary and permanent erosion-control devices are depicted on the photogrammetric mapping. Estimated quantities of material required to construct the various devices are estimated for use in developing construction costs.

In addition to more conventional methods of obtaining data from aerial and photogrammetric mapping, remote sensing provides additional opportunities to obtain data quickly and inexpensively. Remote sensing traditionally has meant recording, with cameras, invisible portions of the electromagnetic spectrum. Two principal types of remote sensing are employed in obtaining data for environmental analysis: ultraviolet sensing in the spectrum range below visible light and infrared scanning in the range above visible light. The data obtained from photography and infrared scanning offer scientists a unique means of examining vast areas within a project's influence. Remote sensing is normally accomplished by cameras located aboard low-flying aircraft. On large rural turnpike projects, sensing from satellites should be considered.

The following data are obtained from the various types of photography:

1. Black and white infrared photography identifies edge of water and soil and delineates drainage areas;
2. Color infrared photography detects and portrays some information that the human eye cannot see, is used for previsual detection of diseases and infestation of plants and trees, readily records by means of changing vegetative vigor effects of environmental changes—especially man-made changes, and is used by scientists to portray and quantify natural phenomena such as marsh grass in estuarine locations;
3. Multispectral photography (simultaneous exposure of film through 4 different lenses and filters) enables qualitative interpretation of natural resource data and ability to color enhance information in a more or less infinite manner and is used in resource analyses; and
4. Thermal imagery detects and portrays subtle differences in the emissivity (non-visible) of things on the earth's surface, such as current patterns of water, heated water discharge, chemical and biological pollution of water, vegetation on surface or near to water surface, vegetation vigor due to respiration differences, soil moisture content, drainage patterns, and potential leaks in levees.

RIGHT-OF-WAY AND UTILITIES

Aerial mapping is also used to estimate right-of-way requirements and prepare an estimate of acquisition costs. Tax records and identifiable features, such as fences, back of sidewalks, and hedges, from photogrammetric mapping are used to establish existing property lines and street rights-of-way. From this base information, preliminary right-of-way strip maps are prepared that depict existing property lines and right-of-way requirements for each alternate under consideration. The right-of-way requirements are based on normal roadway needs and environmental and community considerations. The preliminary right-of-way strip maps are then used in preparing preliminary estimates of right-of-way acquisition costs.

Preliminary utility data for use in determining highway feasibility are developed by novel applications of aerial mapping. Before aerial photography is obtained for use in compiling photogrammetric maps, a field reconnaissance is made to target all identifiable utilities on the surface, i.e., manhole covers, water valves and hydrants, gas valves and drips, and telephone and electrical manholes and vaults. A legend is established for marking the photo-identifiable targets on the photogrammetric maps.

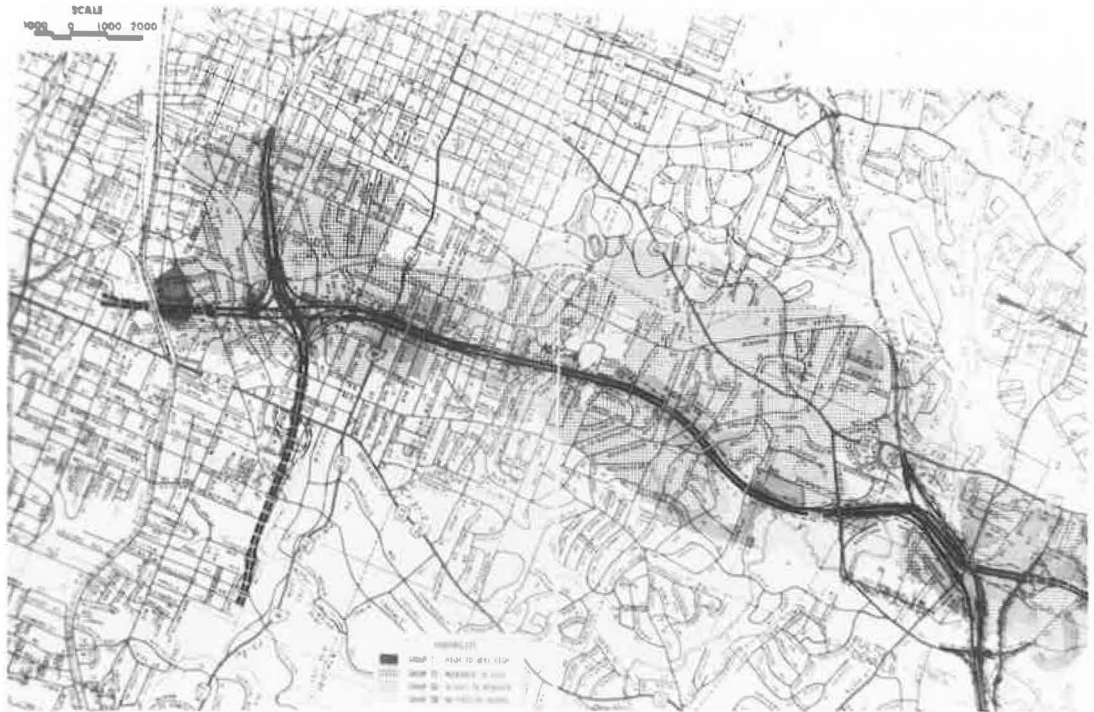
Table 1. Seismic noise levels of alternative routes.

Route	Sensitive Area	Distance From Near Lane of Roadway (ft)	Seismic Noise Level (mm/sec)
A	Closest right-of-way	40	0.680 ^a
	Orme Park	100	0.100
	Greater St. Peter AME Church	200	0.045
	Christian Fellowship House of Prayer	400	0.016
C	Closest right-of-way	40	0.068 ^a
	Hillpine Park	100 ^b	0.100
	Greater St. Peter AME Church	200	0.045
	Christian Fellowship House of Prayer	400	0.016
	Virginia Baptist Church	400	0.016
D	Closest right-of-way	40	0.680 ^a
	Piedmont Park	50 ^b	0.500 ^a
	Greater St. Peter AME Church	200	0.045
	Christian Fellowship House of Prayer	400	0.016
	Virginia Baptist Church	400	0.016
	McClatchey Park	400	0.016
E	Closest right-of-way	40	0.680 ^a
	Hillpine Park	150 ^b	0.060
	Greater St. Peter AME Church	200	0.045
	WABE Radio	200	0.045
	Christian Fellowship House of Prayer	400	0.016
	Virginia Baptist Church	400	0.016
	Morningside Baptist Church	400	0.016

^aLittle intervening topography.

^bRight-of-way.

Figure 7. Soil erosion characteristics.



Both the available utility company records and the legend of identifiable targets are used to develop and depict the fabric of the utility systems on the photogrammetrics. The utility strip maps are then used, in conjunction with the horizontal and vertical alignment features previously developed for the various alternates, to identify conflicts and estimate replacement and relocation costs.
