IMPACT OF DIGITAL TERRAIN ELEVATION DATA (DTED) RESOLUTION ON TERRAIN VISUALIZATION: SIMULATION VS. REALITY

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ABSTRACT:

This study provides evidence of the influence of DTED resolution (in regions with different terrain roughness) on Army terrain data applications. The report documents results of the U.S. Army Topographic Engineering Center's (TEC) DTED resolution analysis including extensive field work and terrain visualization undertaken to investigate DTED integrity in comparison to the actual terrain. Finally, the report offers conclusions regarding DTED support for Army tactical and simulation applications.

KEY WORDS: DTED, Resolution, Terrain, Visualization, Simulation, Sigma-t

INTRODUCTION

The following paper is a synopsis of a study that evolved from U.S. Army Topographic Engineering Center (TEC) special report number 6, entitled " Digital Terrain Elevation Data (DTED) Resolution and Requirements Study: Interim Report" (Nov. 1990). A majority of users throughout the Mapping, Charting and Geodesy (MC&G) community have at one time or another expressed their concerns about the quality (resolution and accuracy) and quantity (worldwide coverage) of DTED. These concerns have focused on several issues such as cost of producing high resolution data, availability and acquisition of source material, and time required to produce a worldwide database. As DTED is employed in a majority of digital applications, it is the foundation product that most users require. Given this stature, an understanding of its limitations and appropriate applications is of utmost importance.

PURPOSE/SCOPE

This paper documents results of a TEC DTED resolution analysis for determination of the most desirable DTED resolution for various Army tactical and simulation applications. The terrain visualization portion of the study has been synopsized for this paper.

METHODOLOGY

The methodology employed in this effort was to select several geographic regions (Figure 1) with different terrain roughnesses. This evaluation attempts to show the comparison of these regions using simulated terrain for three DTED Levels: Level 1, Level 2, and the Level 2 Downsampled (Level 2 (D)). The Level 2 (D) was produced by merely thinning the Level 2 to match the same post spacing as Level 1. Sigma-t values of DTED, which indicate the standard deviation of terrain height, were used to determine terrain roughness categories and respective geographic areas of interest. They are as follows:

Region	Terrain Roughness Classification	Sigma-t (feet)
Iran	Very rough	>800
California	Rough	200-800
Maine	Moderate	60-200
Arkansas	Smooth	<60

The specific Sigma-t values for the above study areas are detailed in Table 1.

This report includes a visual display analysis for each of the various terrain roughness types. Perspective views of these terrain types were generated on a Terrain Visualization Testbed system at USATEC for comparative analysis of DTED Levels 1 and 2. Field data, collected on site for varying terrain roughness classifications, were also incorporated into the investigation.

DTED SOURCES

Selected DTED coverage representing the range of terrain roughness classifications was obtained from the Defense Mapping Agency (DMA). All of the DTED in this analysis was compiled from photo source. Use of this common source allowed us to focus on compilation resolution, the key variable of interest.

QUALITATIVE VISUAL ANALYSIS

Hardcopy perspective area plots were produced for the following specific geographic areas: Qasr Od Dasht, Iran; Redding, California; Millinocket, Maine and El Dorado, Arkansas (Figure 1). Corresponding field data were collected and compared to the perspective plots as described below.

Field Study

In the interim report referred to earlier and in other similar analyses throughout the joint services, DTED resolution is compared in terms of overall definition of features and surface roughness for a number of applications. Because of its higher resolution, DTED Level 2 is usually assumed to be the "real world" model or as near to reality as possible. To enhance the perspective view analyses for this study, and to create a true "real world" control mechanism, a field team visited the three domestic study areas to record their surface conditions by photograph. These photographs were taken throughout each study area, so as to fully represent the terrain characteristics of that particular area. 1:24,000 scale USGS quadrangles were utilized to assure positioning and a compass was used to determine the azimuth of each photograph around the chosen site. For this synopsis, one site per study area is illustrated.

52° 12" E — 52° 30" E; 29° 45" N — 29° 20" N

164	664	796	706
517	243	433	696
1232	177	407	1112
975	596	209	832
1040	1185	1270	721

Row boundaries: 29° 45" N, 40', 35', 30', 25', 29° 20" N. Column boundaries: 52° 12" E, 16' 30", 21', 25' 30", 52° 30" E.

SIGMA-T VALUES (IN FEET) FOR IRAN

68° 30" W — 68° 00" W; 46° 00" N — 45° 15" N

91	89	63	65
71	89	63	59
75	73	48	70
86	72	57	63
89	70	54	75
70	68	81	125
116	68	45	130
118	123	124	170
127	109	98	104

Row boundaries: 46° 00" N, 55', 50', 45', 40', 35', 30', 25', 20', 45° 15" N. Column boundaries: 68° 30" W, 22' 30", 15', 7' 30", 68° 00" W.

SIGMA-T VALUES (IN FEET) FOR MAINE

122° 30" W — 122° 00" W; 41° 00" N — 40° 30" N

751	581	694	511
900	425	674	365
606	395	273	307
282	43	114	228
248	54	94	289

Row boundaries: 41° 00" N, 55', 50', 45', 40', 35', 40° 30" N. Column boundaries: 122° 30" W, 22' 30", 15', 7' 30", 122° 00" W.

SIGMA-T VALUES (IN FEET) FOR CALIFORNIA

93° 00" W — 92° 36" W; 33° 50" N — 33° 10" N

53	31	38	25	50
42	31	27	34	39
44	54	22	28	27
37	42	26	25	29
38	36	53	24	26
36	34	38	37	25
39	38	37	32	48
32	26	31	30	38

Row boundaries: 33° 50" N, 45', 40', 35', 30', 25', 20', 15', 33° 10" N. Column boundaries: 93° 00" W, 56', 51', 46', 41', 92° 36" W.

SIGMA-T VALUES (IN FEET) FOR ARKANSAS

Table 1. Study Area Sigma-t Values

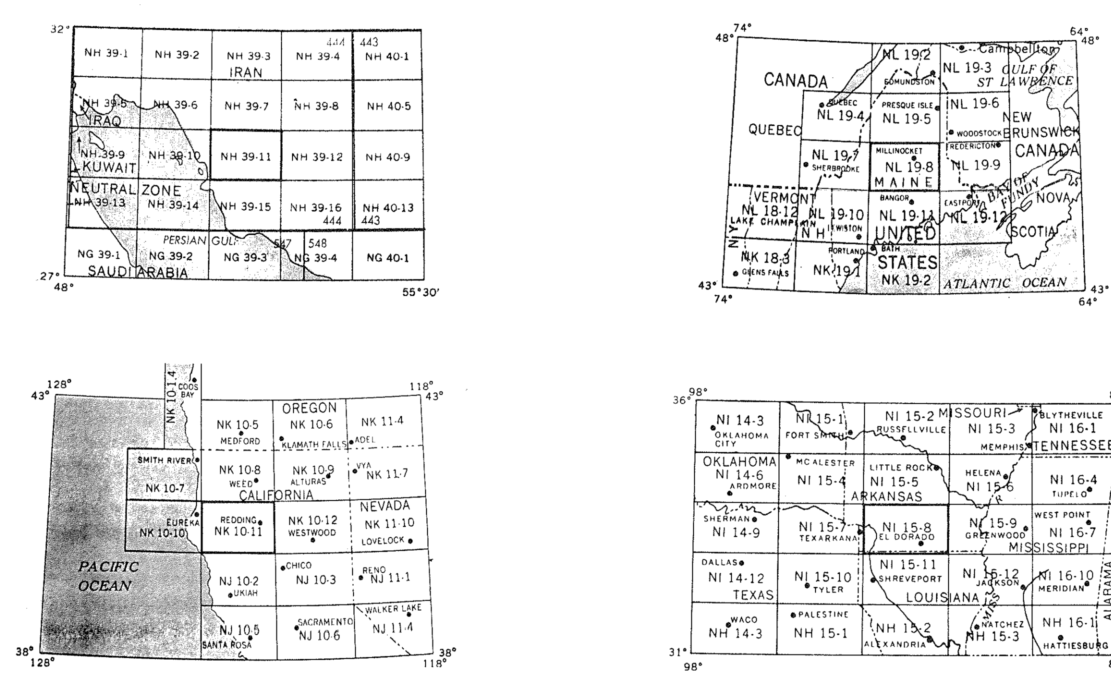


Figure 1. Study Area Locations

Analyses

DTED Level 2(D) review

It was determined, during the early stages of this evaluation, that differences between the Level 1 and Level 2(D) plots were insignificant. A discussion of the terrain representations for the Level 1 and 2(D) data is included in the following very rough terrain (Iran) analyses since these were among the first completed. It is believed that these findings are representative of those for the full range of terrain roughness types. Therefore, analyses and graphics of the Level 2(D) plots for the domestic study areas were not included in subsequent analyses.

Very Rough Terrain (Qasr Od Dasht, Iran) The Iran study area is considered very rough with sigma-t values of over 800 feet (Table 1). In examining the Iranian perspective plots for site 2 (Figure 2), the Level 2 data exhibits visibly more surface roughness particularly in the rolling terrain in the foreground. Improved resolution in this type of the terrain is important since it may provide substantial areas of concealment or impediments to cross country movement (CCM). Microrelief is especially evident on the Level 2 plots, yet not readily observable in the Level 1 data. Although depth of field is poor in the foreground, the very rough terrain nearer to the horizon is well characterized in the Level 1 as well as the Level 2 plots. This may indicate that very rough terrain can be adequately depicted **(depending on application)** using lower resolution data.

DTED Level 1 vs. DTED Level 2(D) In the interim report, which was based on a mixture of photographic and cartographic source data, the Level 2 data had the best overall definition. The Level 2(D), while exhibiting less detail than Level 2, was **clearly** superior to Level 1. In this study, however, utilizing solely photographic source DTED, no clear distinction between the Level 2(D) and Level 1 data was determined. Figure 2 exemplifies that the Level 2(D) plot exhibits little, if any, additional detail when compared to the Level 1 plot. This observation was consistent throughout all of the ranges of terrain roughness. It appears that the collection of DTED from photographic source has enhanced the fidelity of the Level 1 data thereby virtually eliminating the differences between the Level 2(D) and Level 1. **DTED Level 2 still exhibits the highest level of feature detail.** These findings highlight the importance of using photographic source materials for all Levels of DTED collection.

Rough Terrain (Redding, California) The majority of the California study area is considered rough terrain with sigma-t values between 200 and 800 feet (Table 1). Several trends can be observed in the analysis of the perspective plots for the California study area. The Level 2 plots exhibit excellent overall coincidence with the field photographs. Most terrain features are clearly evident and well defined, especially microrelief in the foreground and on hillsides. There was a general degradation of detail in the Level 1 plots. Although overall feature patterns were visible in the Level 1 data, correlation to the field photographs was variable.

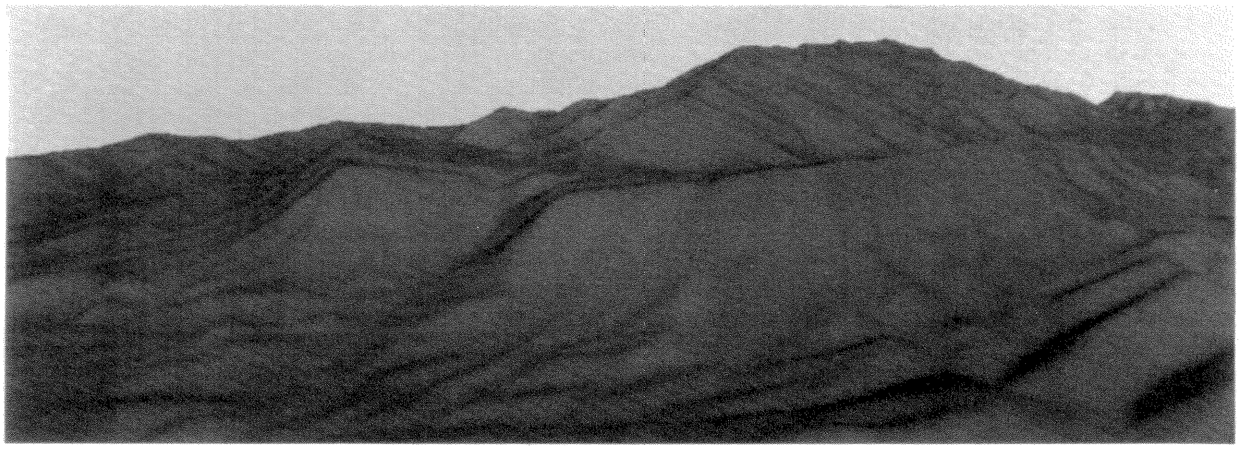
The Level 1 plots exhibited poor correspondence in four of the six sites analyzed. For example, at site 10 (Figure 3), the predominant terrain feature is the large river and valley appearing in the center of the scene. In the Level 1 data, a depression in the center of the plot is discernable, but the true character of the river valley--its width, depth and bank slope--is not apparent. These factors are much more clearly visible in the Level 2 plot, which also gives a clear indication of the river bed and its meandering nature. The Level 2 data also depicts a substantial amount of surface roughness (hummocky nature of terrain) on both sides of the river (see foreground, ≈147° to ≈200°) which is not visible in the Level 1 image. Mispredictions of this sort are excellent examples of the degradation of critical terrain features which are required for many Army applications including line-of-sight (LOS), cross country movement (CCM), helicopter landing zones (HLZ), and threat analysis.

Analysis of the two remaining sites revealed better correspondence between the Level 1 and 2 data and the field photographs. Although the Level 2 plots still exhibited the most realistic depiction of surface roughness, the Level 1 data also represented the terrain adequately for the most part, and did not appear to be especially misleading in any feature aspect.

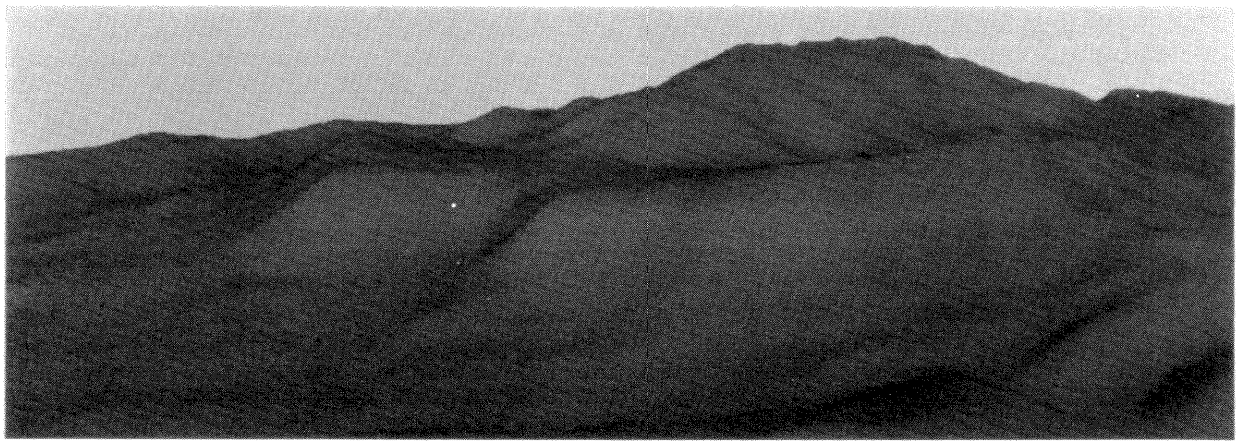
Moderate Terrain (Millinocket, Maine) The Maine study area is considered moderate terrain with sigma-t values between 60 and 200 feet (Table 1). Analysis of the perspective plots for the Maine study area revealed a similar pattern to that described for California. The Level 2 plots were the most realistic in terms of overall terrain features and microrelief and exhibited a high level of correspondence with the field photographs. Again, there was a general degradation of detail on the Level 1 plots, but this reduced definition was more critical at some sites than others when compared to the field data. The Level 1 plots for three of the six sites were sufficiently lacking in detail and/or contain terrain discrepancies which are potentially misleading for battlefield applications.

Analysis of the field photographs and perspective view plots for site 6 (Figure 4) reveals at least four valleys between the observation point and the most distant hill (see especially between 180° and 205°). The Level 2 plot has sufficient resolution to clearly depict all of the valleys in question, the important hummocky terrain in the foreground, and even the slight rise upon which the observation point is situated. The Level 1 plot is deceptively smooth in the foreground. It gives the impression of a large open plain lacking feature definition until one reaches the base of the larger hills. At best, only two of the four or more foreground valleys are discernable.

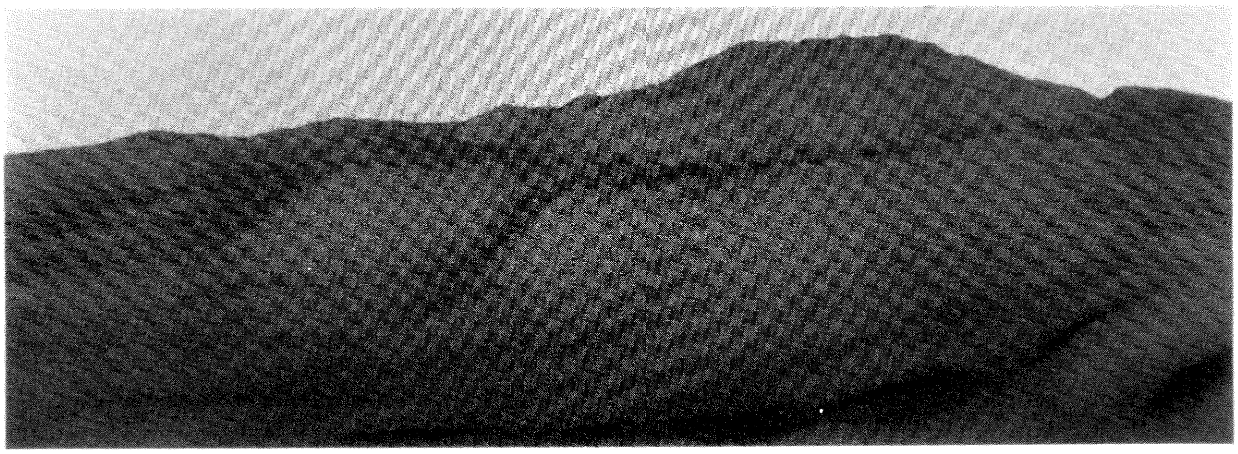
Analysis of the remaining sites revealed increased correspondence between the Level 1 and 2 data and the field photographs. The Level 2 plots still exhibited the most realistic depiction of the terrain, especially in the foreground and in the more subtle features. However, the Level 1 data at these sites also represented the terrain adequately, particularly as surface roughness increased; and did not appear to be especially misleading except in certain areas of micro relief (i.e. rolling



DTED Level 2

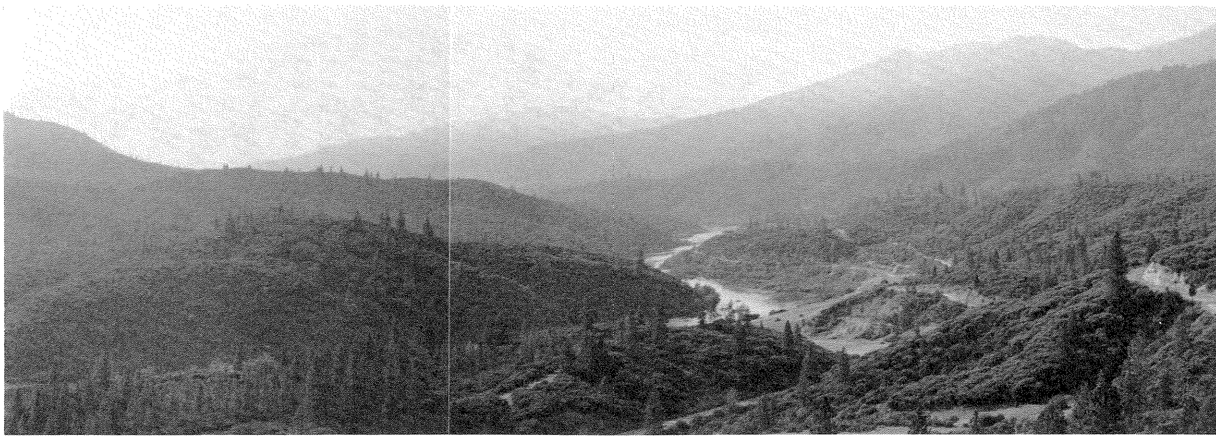


DTED Level 2(D)

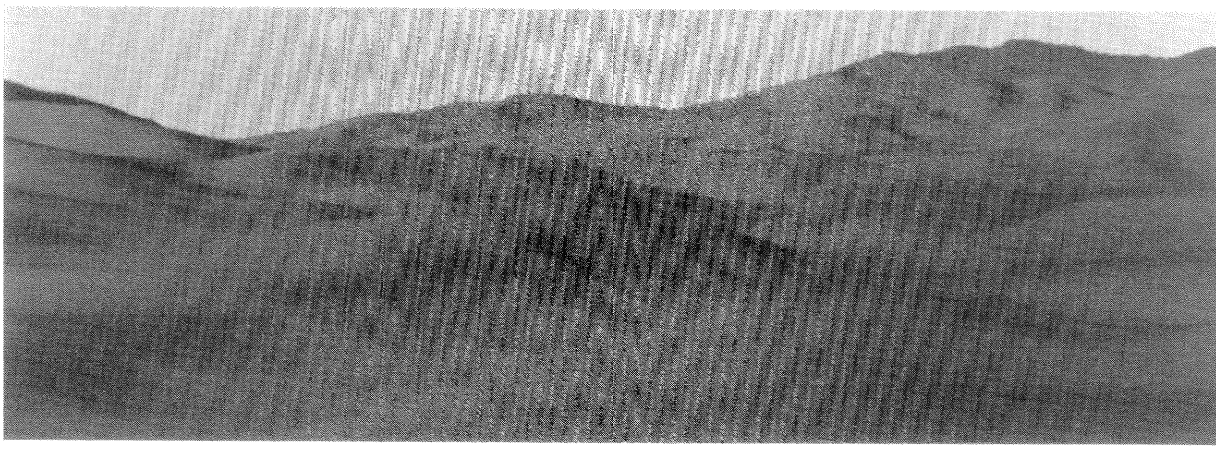


DTED Level 1

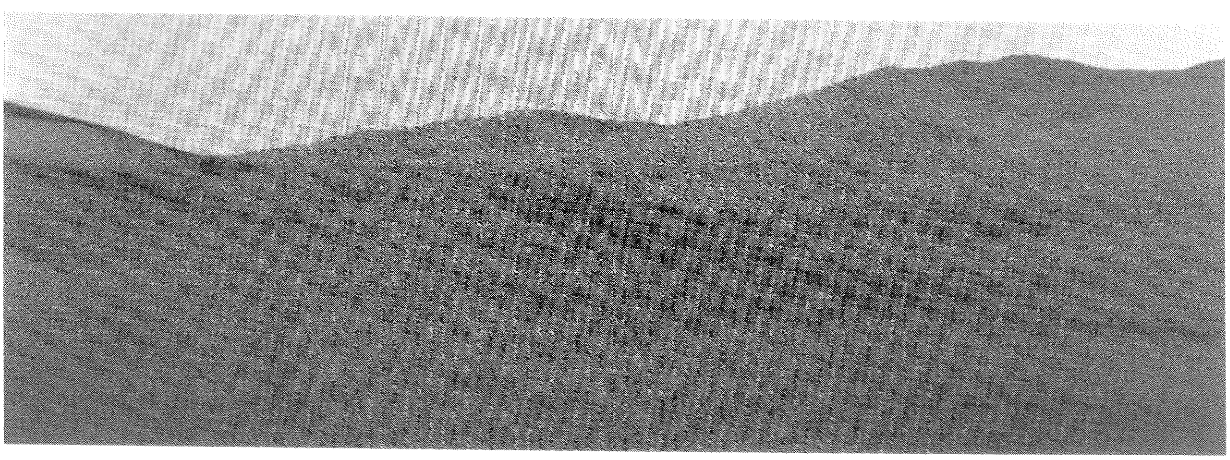
Figure 2. Site 2, Very Rough Terrain / Qasr Od Dascht, Iran



Field Photograph

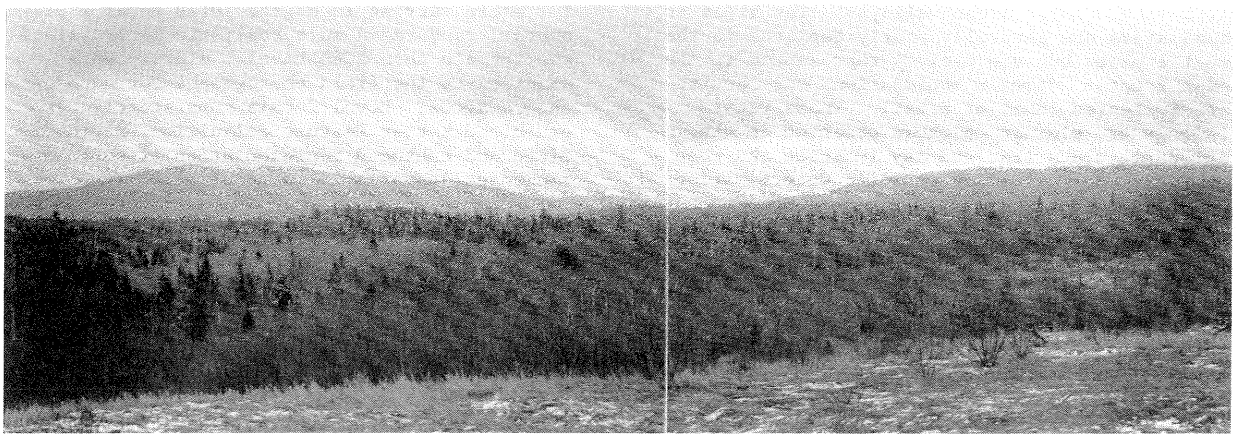


DTED Level 2

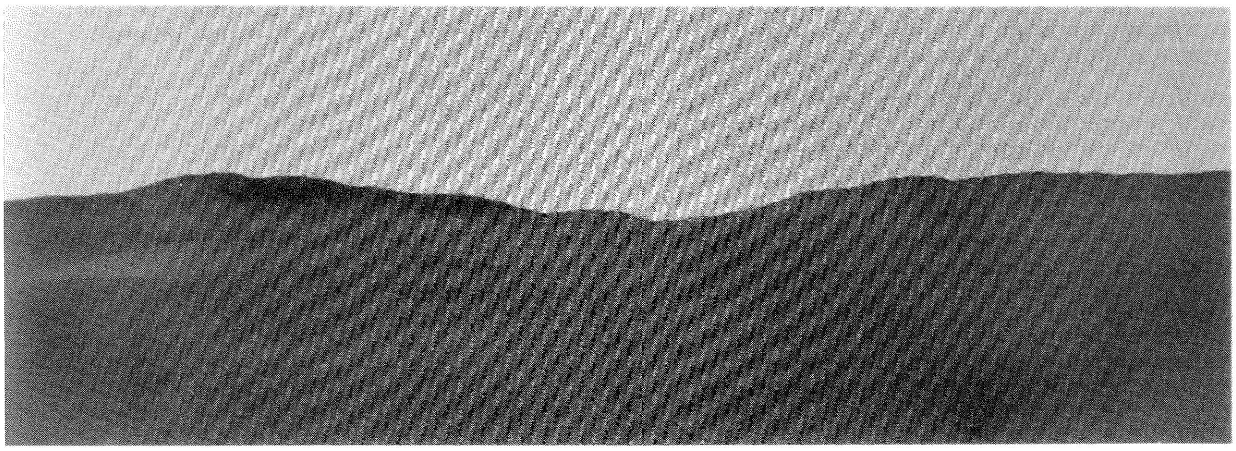


DTED Level 1

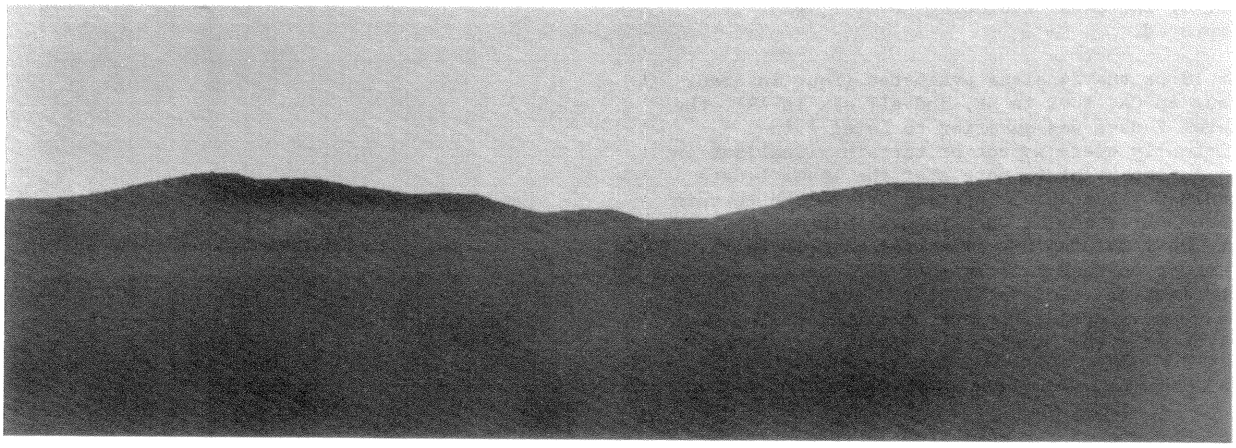
Figure 3. Site 10, Rough Terrain / Redding, California



Field Photograph



DTED Level 2



DTED Level 1

Figure 4. Site 10, Moderate Terrain / Millinocket, Maine

hills within large broad valleys). The hills in these areas are generally poorly depicted in the Level 1 plots but are clearly represented in the Level 2 data. Certain applications may require this increased level of detail. These varied findings are similar to those observed in the California study area and may indicate the need for area and application specific determinations of DTED requirements in moderate (> 100 feet sigma-t) to rough terrain.

Smooth Terrain (El Dorado, Arkansas) The Arkansas study area is considered smooth terrain with sigma-t values under 60 feet (Table 1). Analysis of the perspective plots for the area revealed some of the most marked differences between the Level 1 and Level 2 data when compared to the field photographs. The Level 2 data was at all sites superior to Level 1 in delineating terrain features. This region is characterized by generally smooth terrain with occasional, albeit subtle, landscape variations. Despite this characteristic, the Level 2 plots revealed well defined features, such as low ridges, gentle hills and small valleys. The most stark differences between the Level 1 and Level 2 perspective plots occurred at site 10 (Figure 5). In this area, the Level 2 data exhibited nearly perfect correspondence with the field photographs, realistically portraying the low hills and valleys throughout the entire depth of field (foreground to horizon) and the gradual sloping gradient upon which the observation point is situated. Conversely, the Level 1 data is almost devoid of detail, displaying only certain tonal changes which may indicate the presence of terrain features. This significant decrease in overall feature definition in the Level 1 plots is extremely misleading and masks the true and potentially critical terrain variations of the area.

SUMMARY

Utilization of solely photographic source DTED and addition of field data in the comparison analyses were two important enhancements incorporated in this study that were not present in the interim report. As expected, fidelity of all of the data, including Level 1, was improved.

At 18 of the 24 sites evaluated (four in Iran, four in CA, four in ME, and all six in AR), the Level 2 data was superior to Level 1 in virtually every aspect of terrain visualization. It is important to note that the Level 1 data could not adequately portray the smooth terrain inherent at any of the Arkansas sites. However, at the remaining six sites (especially in the rougher terrain in Iran and California), portions of the Level 1 plots were found to adequately define various terrain features, although with less overall detail than Level 2.

CONCLUSIONS

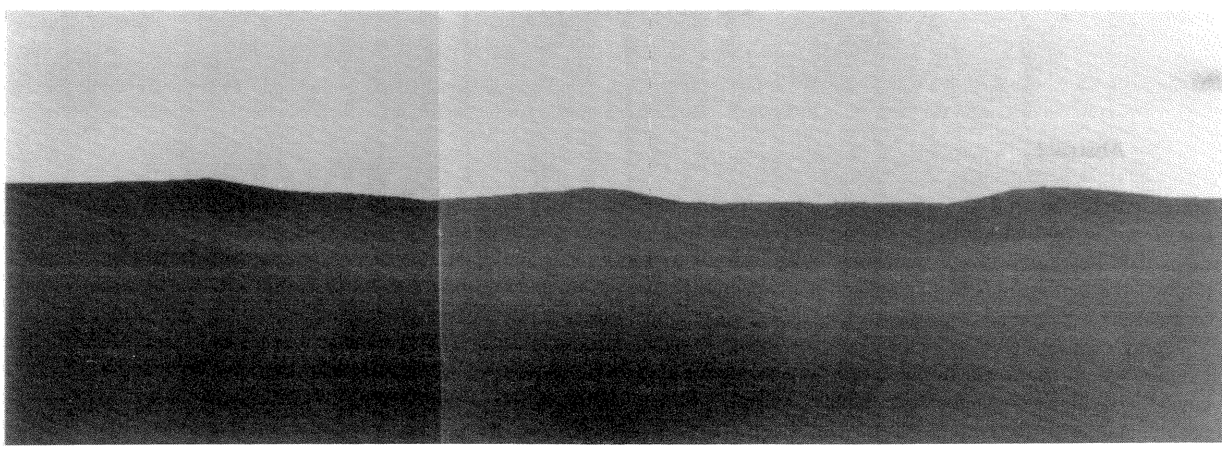
1. Based upon the completed analyses, it is clear that the resolution inherent in DTED Level 2 (1 arc second post spacing) is required for realistic terrain visualization in most situations; and is absolutely critical for portrayal of moderate (< 100 feet Sigma-t) to smooth terrain.

2. While varying in degree, DTED Level 2 plots overall rendered a more realistic portrayal of the terrain than DTED Level 1 plots. When compared to the field photographs for each of the 24 sites, Level 2 data consistently exhibited better feature definition, depth of field and enhanced representation of surface roughness, especially microrelief.

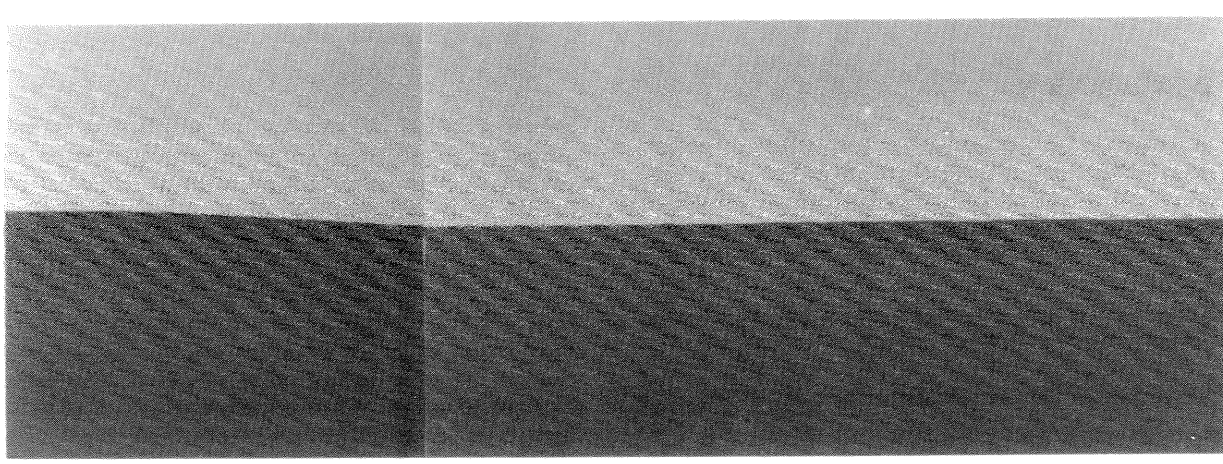
3. DTED Level 1 data used in this study exhibited substantially more fidelity than the Level 1 data analyzed in the interim report. This is directly attributable to the use of photographic source data. Data collection from solely photographic sources is strongly suggested for future DTED Levels 1 and 2 production. Moreover, a mechanism to determine the type, scale and reliability of DTED source materials should be made available to users.

4. The fact that DTED Level 1 performed well in some of the rougher terrain, albeit in a limited number of sites, may indicate the need for determination of DTED Level 1 and 2 area production based on terrain roughness and specific user applications/requirements.

Field Photograph



DTED Level 2



DTED Level 1

Figure 5. Site 10, Smooth Terrain / El Dorado, Arkansas