AN ABSTRACT OF THE THESIS OF

Robert A. Gagliuso for the degree of Master of Science in Forest Science presented on December 16, 1991.

Title: Habitat Alteration and Human Disturbance: Their Impact on Cougar Habitat Utilization in Southwest Oregon

Signature redacted for privacy.

Abstract approved: ______________________
David S. deCalesta

Eight cougars were radio-collared and monitored during 1985 - 1987. Home range size, determined by minimum convex polygons, averaged 153.1 km^2 for females, 543.5 km^2 for males. Core home range size, determined by harmonic mean analysis, averaged 21.7 km^2 for females, 17.9 km^2 for males. Home ranges of males and females overlapped, but core areas never overlapped, regardless of sex. Two juvenile females and one juvenile male displaced over 60 km. Cougars utilized habitats in a preferential manner, avoiding clearcuts and preferring mature forest stands. Cougars did not appear to select for riparian areas, although continuous monitoring periods revealed that cougars traveled extensively along riparian areas and topographic features. Cougars did not avoid active timber harvest sites, but rather were closer to them than random locations scattered throughout their home ranges. Cougars did not avoid paved, arterial, feeder, or spur roads but rather were closer to them than random locations. Cougars did not avoid

campsites, but did appear to avoid permanent residences. However, movement patterns of cougars also suggested that they did not avoid roads, campsites, or permanent residences. These results were contrary to the only other published study addressing the impacts of human disturbances on cougar habitat use. It is hypothesized that difference in vegetative cover between the two studies (the other study was in an area of sparse understory vegetation) is the primary reason for the differing results. Perhaps the most important impact of humans on cougars in this study was heightened mortality (legal and illegal harvest, road kills) resulting from increased human access to cougar habitat.

Habitat Alteration and Human Disturbance: Their Impact on Cougar Habitat Utilization in Southwest Oregon

by

Robert A. Gagliuso

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Completed December 16, 1991

Commencement June 1992

APPROVED:

Signature redacted for privacy.

Associate Professor of Forest Science in charge of major

Signature redacted for privacy.

Head of Department of Forest Science

Signature redacted for privacy.

Dean of Graduate School

Date thesis is presented December 16, 1991

Typed by Robert A. Gagliuso

Formatted by Robert A. Gagliuso

Acknowledgements

This project was supported in large part by the volunteer efforts of **Don and Ula Pankey**, who for over two years, daily provided many enjoyable hours of hounds and experiences. Their interest and effort in this research made it possible when state and federal money was not available.

Also, I wish to thank all the other hound owners (too numerous to list here) who contributed time and dogs to aid in capture activities.

Several people require special acknowledgement and thanks:

Dr. David S. deCalesta, served as major professor and remained committed to the project through seven long years and many changes.

Dr. Melody Roelke provided practical advice, logistical support, and unbridled enthusiasm when it was needed most.

Jim Kiser, Director of the Forest Photogrammetry Research Lab, contributed much in the way of equipment and advice during the final three years of this research.

Partial funding was provided by the Boone and Crockett Club, who awarded 5,000.00 dollars to the research. Also, several state and federal agencies contributed small levels of funding in kind: Oregon State University, Department of Forest Science, Oregon Department of Fish and Wildlife, Oregon Department of Forest Protection, and the Bureau of Land Management.

The USFS FSL in Burlington provided a critical computer link to Warren, PA. The USFS FSL Warren assisted in the data analyses by providing computer support.

Weyerhaeuser and Roseburg Lumber companies allowed access to their lands.

The following state and federal personnel contributed in various ways to the completion of this research: Bud Adams, Larry Bright, Lu Berger, Steve Denny, Dan Edwards, Blake Farnsworth, Dennis Issacson, Mike Lent, Joe Lint, Bill McComb, Robin Sether, Sen Wang.

Thanks to committee members Dr. David Perry (Forest Science) and Dr. Bruce Coblentz (Fisheries and Wildlife) for their input; and also to Dr. Dan Edge (Fisheries and Wildlife) for replacing Dr. Coblentz during the thesis defense.

Most importantly, continued thanks and love to **Jenifer** and **Tyler**, my new family, who make everything worthwhile.

And finally....

To **BUCK**, **BONES**, **SHORTY**, **NOISY**, **DOC**, and **VERNY** who taught me what it really means to be a hound dog.

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HABITAT ALTERATION AND HUMAN DISTURBANCE: THE IMPACT ON COUGAR HABITAT UTILIZATION IN SOUTHWEST OREGON

INTRODUCTION

The cougar (Felis concolor) was one of the most widely distributed mammalian predators in the Americas (Hall 1981). Its former range included the contiguous United States, the majority of South America, and a large portion of Canada (Hall 1981). In North America, the cougar was rapidly extirpated from most of its range during the westward settlement of the continent (Young and Goldman 1946, Anderson 1983a). The cougar's current North American range is restricted to western states and provinces, with the exception of small known or suspected populations in other areas (Hall 1981). Although the causes of this decline are unclear, unrestricted harvest and the loss of habitat free from human disturbances have been attributed as major factors (Anderson 1983a, Nowak 1976).

Cougars are distributed throughout Oregon, with the highest concentrations believed to be in the northeastern and southwestern portions of the state (ODFW 1987). The forestlands of Douglas County, located in southwestern Oregon, are thought to support higher than average cougar population densities (ODFW 1987). The timber industry forms one of the primary economic bases of the county. During the previous 5 decades, timber harvest rapidly converted old growth forests to early successional stages, and produced a thriving black-tailed deer (Odocoileus hemionus columbianus) population. Deer constitute the major dietary item of cougars in western Oregon (Toweill and Meslow 1977, Toweill and Maser 1985, Trainer et al. 1988).

Previous studies demonstrated that an adequate prey base is one of the primary characteristics of productive cougar habitat (Robinette et al. 1959, Hornocker 1970, Seidensticker et al. 1973, Shaw 1980); habitats with viable deer populations such as those in Douglas County should support thriving cougar populations. Indeed, this area supports one of the highest estimated cougar densities in the state, an indication that it provides prey densities and structural habitat characteristics which combine to create favorable cougar habitat. However, the impacts of forest management practices, and subsequent human recreational activities, on cougar habitat use are poorly understood.

Large acreages of mature and 2nd growth forest are harvested annually in Douglas County, which may adversely impact cougar habitats via accelerated rates of habitat alteration, disturbance related to harvest activities, forest road construction and use, and increased human access to once remote areas of cougar habitat; a direct impact of which is an increased probability of human-induced mortality. These potentially conflicting influences of forest management on cougar habitat suitability and use have not been evaluated. Such relationships must be addressed for informed management of cougars habitats affected by forest management.

This research was an attempt to evaluate the impacts of habitat alterations and human perturbations on cougar habitat use. The frequent occurrence of forest alterations and disturbances experienced by Douglas County's cougar populations, and their higher than average densities, provided an excellent opportunity to investigate interactions between human activity and cougar habitat use in a managed forest. The study evaluated cougar use (or avoidance) of habitats altered by forest management practices, and assessed the association of human disturbances with habitat use by cougars. The research's primary goal was to relate habitat alterations and human disturbance to cougar habitat use in the west side of the Cascade Range. This goal was achieved through the completion of four objectives:

1) determine home ranges, movements, and habitat use of cougars in the North Umpqua River drainage for the period of November, 1985 to January, 1988;

2) define cougar habitats within the study area based on broad classifications of forest stand age classes;

3) characterize human disturbance within the study

area; and

4) describe the home range, habitat use, and movement patterns of cougars, and test whether habitat use was independent of habitat availability and human disturbance.

This thesis, written in journal format, contains three papers, each constituting a separate chapter. The second chapter presents home range data compiled through the use of radio telemetry. Home range and core area sizes, juxtaposition of adjoining cougar home ranges, and the displacement of juvenile cougars are reported. The third chapter describes habitat use by cougars, and tests the use of different habitat types in relation to their availability. The last chapter addresses the study's primary goal, that of investigating the relationship between human disturbances and habitat alterations and cougar use of impacted habitats within managed forests.

STUDY AREA

The study area, located on the west side of the Cascade Range in southwest Oregon, comprised approximately 2250 square kilometers (km^2) in the upper North Umpqua River drainage (Figure 1.1). The area was located in the northern portions of the vegetative zone defined by Franklin and Dyrness (1973) as mixed conifer (<u>Pinus</u>-<u>Pseudotsuga-</u> -<u>Libocedrus</u>-<u>Abies</u>). Habitats were dominated by subclimax

Douglas Fir (Pseudotsuga menziesii), intermixed with western red cedar (Thuja plicata), hemlock (Tsuga heterophylla), sugar pine (Pinus lambertiana), and white fir (Abies concolor) (Franklin and Dyrness 1973). Other typical tree species included big leaf maple (Acer macrophyllum), pacific madrone (Arbutus menziesii), western white pine (Pinus monticola), mountain hemlock (Tsuga mertensiana), and golden chinquapin (Castanopsis chrysophylla) (Franklin and Dyrness 1973).

Precipitation averaged 120 centimeters annually, with less than 6 percent falling during summer months (Franklin and Dyrness 1973). Temperatures ranged from a winter average of 2 degrees C, to a summer average of over 30 degrees C (Franklin and Dyrness 1973). Elevations increased from west to east, and ranged from 500 to 2000 meters. Riparian areas (all orders of streams, rivers, and ponds) were extensive, and remained consistent from west to east averaging over 1 km/km^2 of length (Figure 1.2).

The study area was chosen because of high estimated cougar population densities, coupled with high degrees of habitat alterations and human disturbances. Habitats within the study area have been drastically altered due to forest management activities. Based on analysis of approximately 1500 randomly generated Universal Transverse Mercator (UTM) coordinates, over 48 percent of the area had experienced previous harvest. Associated forest road system densities

Figure 1.1: Study area location: North Umpqua River Drainage in southwest Oregon

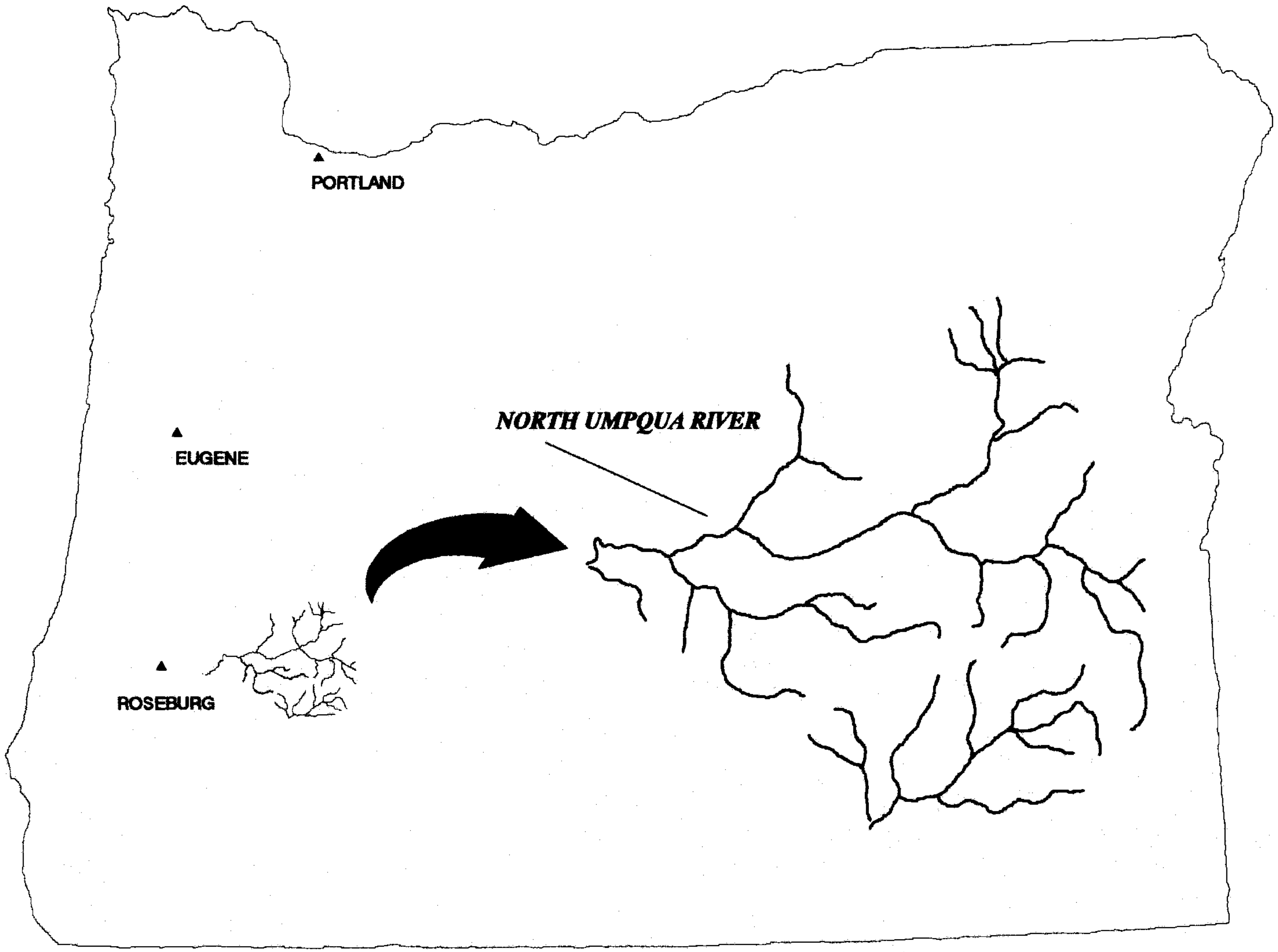


Figure 1.1

were also high, ranging west to east from over 2.5 km/km^2 to 1.6 km/km^2 (Figure 1.2).

Figure 1.2: Mean length (km) of forest roads and riparian areas per square kilometer for west to east 5000m north to south strips.

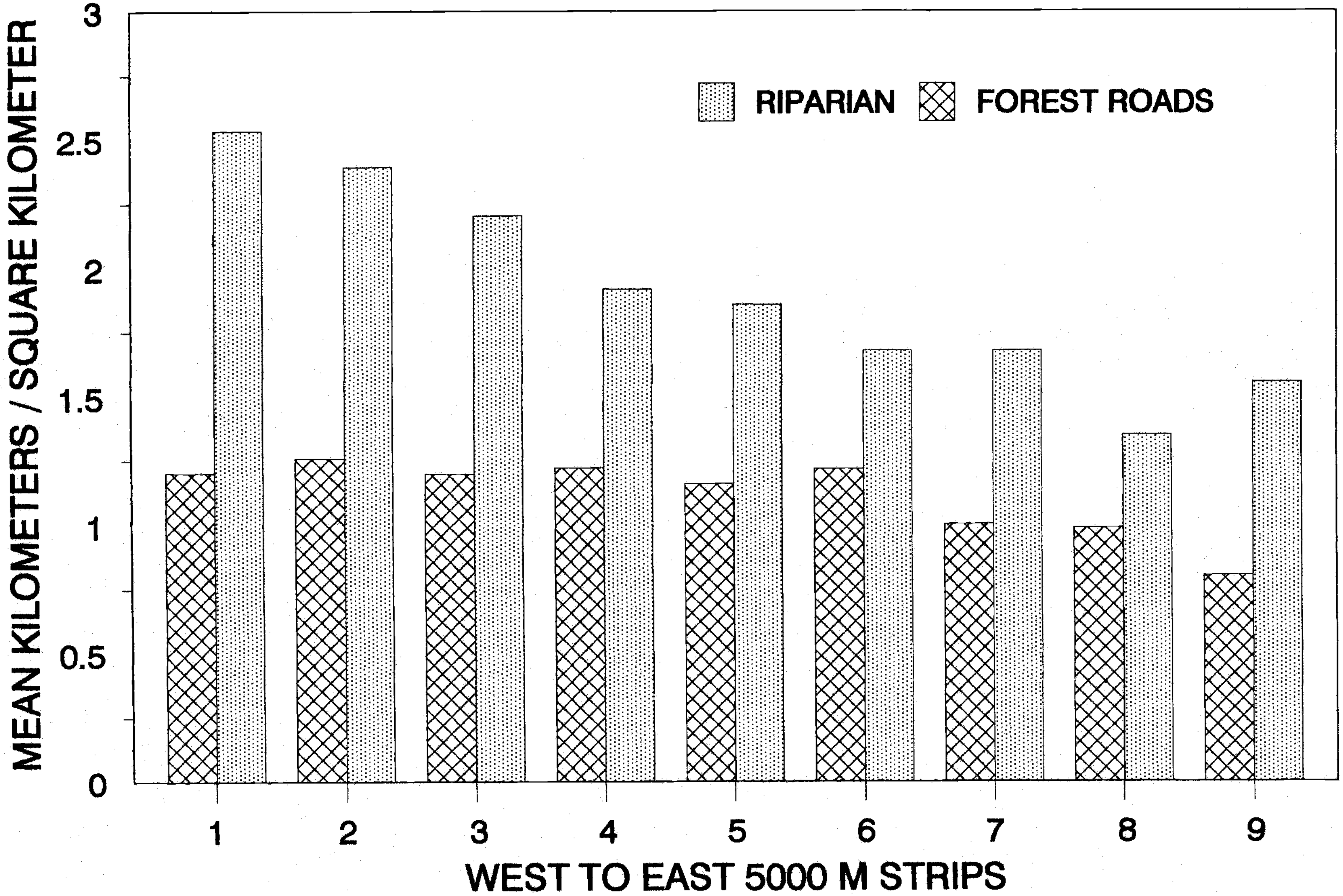

MEAN KILOMETERS / SQUARE KILOMETER
3
2.5
2
1.5
1
0.5
0
RIPARIAN
FOREST ROADS
1
2
3
4
5
6
7
8
9
WEST TO EAST 5000 M STRIPS

Figure 1.2

CHARACTERISTICS OF COUGAR HOME RANGE

Before the advent of radio telemetry technology, inferences concerning territorial behavior and social structure were restricted to observational data (Young and Goldman 1946). Hornocker (1969) and Seidensticker et al. (1973) conducted the first quantitative analysis of cougar home range use and territoriality of an unexploited cougar population in the Idaho Primitive Area. They employed mark and recapture methods and radio telemetry over a period of several years, and derived estimations of home range areas, juxtaposition of adjoining cougar home ranges, population density, and daily/seasonal activity patterns. These estimates were used to examine home range in terms of spatial patterns of land tenure, interactions between individuals, and as approximators of population density Seidensticker et al. (1973). Home range size and juxtaposition for unexploited and exploited cougar populations have been reported for Arizona (Shaw 1980), California (Sitton 1977, Kutilek et al. 1980, Neal et al. 1987), Idaho (Seidensticker et al. 1973, Hornocker 1969), Nevada (Ashman et al. 1983), New Mexico (Bavin 1976, Bavin 1978), Texas (McBride 1976), Utah (Lindzey 1981, Hemker et al. 1984), and Wyoming (Logan et al. 1986).

For western Oregon, there is no information concerning home range parameters, including size, descriptions of core areas, juxtaposition among individuals, and displacement of juvenile cougars. This research provides the first documentation of fundamental aspects of cougar social organization (home range size, juxtaposition, core area descriptions, and displacement of juveniles).

Since 1969, the Oregon Department of Fish and Wildlife (ODFW) has managed cougars as big game animals, but has had little information upon which to base management decisions. This research adds data useful in the management of cougars, including field checks of estimated cougar population densities, and potentials of juvenile immigration or emigration on the west side of the Cascade Range. Home range and core area size, juxtaposition, and displacement of juvenile cougars in southwest Oregon are reported.

METHODS

Capture

Cougars were captured with the aid of local houndsmen. Capture activities were restricted to daylight hours, and effort was made to capture cougars throughout the study area. Cougar tracks were scented by hounds from pickup trucks driven in areas likely occupied by cougars, or located visually when weather conditions created a favorable tracking medium. Hounds were released on scented or visual tracks, and followed by vehicle on forest road systems.

Treed cougars were approached on foot from the nearest position attainable on forest roads. Cougars judged too young for the study were left in trees; animals large enough, but in an unacceptable tree location, or an inaccessible location within the tree, were forced to leave the tree. Hounds then re-treed the animal in another tree or location. These steps were repeated until the animal was in an acceptable situation for immobilization.

A combination of ketamine hydrochloride (Ketaset) and xylazine hydrochloride (Rompum) was used to immobilize cougars. Both drug concentrations were 100mg/cc; dosage rates approximated a 6:1 mg mix of ketamine and xylazine hydrochloride per pound of estimated weight. Drugs were delivered to the animal by Chap-Chur darts in the upper hind quarter region. Darted cougars were forced from trees before the drugs took affect, and were relocated with restrained hounds. Degree of immobilization was estimated; if required, additional ketamine hydrochloride was administered.

Immobilized animals were fitted with a radio collar manufactured by Telonics, Inc., following the guidelines outlined in Seidensticker et al. (1970). Age was estimated utilizing the general condition and wear of the cougar's teeth (Ashman et al. 1983).

Data Collection

Data were collected on a randomized schedule, with locations obtained from the ground and air. A period of 1 to 3 days between locations was maintained to ensure independence of data points (Swihart and Slade 1985). Ground telemetry locations were determined from the use of a hand held yagi antenna and portable receiver. Locations from which bearings were taken were plotted on USGS topographic maps. These locations were converted to UTM coordinates through the use of Hitachi and GTCO digitizer pads and supporting software and matched to bearing data. The Andrews estimator of signal source was employed through available software to determine UTM coordinates and error ellipses of animal locations (White and Garrott 1990). Data were also collected from fixed wing aircraft equipped with yagi antennae attached to each wing strut. Longitude and latitude coordinates of animal locations were determined with the aircraft's LORAN navigational system. Aerial locations were converted to UTM coordinates through the application of available software. Error estimations for each method of data collection were also developed (see Appendix A for aerial and ground telemetry error estimations). All locations were coded to indicate habitat type, study animal, date, and time of day, and entered into database software.

Home Range Analyses

Discussions in this paper apply the definitions of home range put forward by Seidensticker et al. (1973). Home range analysis was performed only on data collected from resident adults. The study area was divided into 65, 25 km^2 UTM coordinate system blocks. Home range and core areas for each animal were derived utilizing available software. The minimum convex polygon method was employed in determination of home range sizes. Core areas were defined as that portion of an animal's home range which included 50 percent of the telemetry locations, and were developed for each resident animal using harmonic mean analyses (Dixon and Chapman 1980). Juxtapositions of animal home ranges were described by mapping home ranges using the UTM coordinate system and plotting software. Displacements of juvenile and transient cougars were documented by aerial telemetry locations, and plotted using the methods described above.

RESULTS

Capture

Fifteen cougar were treed; 12 in 1985-86, with the remainder in 1986-87. Of these animals, 10 were immobilized and fitted with radio collars, 7 during 1985-86 and 3 during 1986-87. An average of over 30 days hunting was required for each cougar captured. Animals were identified by sex and capture sequence (e.g. female 1, female 2, female 3, female 4, male 5, female 6, female 7, female 8, male 9, male 10). Female 1 had at least one kitten at time of capture.

Female 8 had at least one yearling (male 10) in its vicinity at capture, and had at least one other kitten (as confirmed by tracks and movements) during monitoring. Female 7 was the offspring of female 4.

Mortality/Losses

Of the 10 cougars captured, only female 3 was confirmed alive at the end of the two-year sampling period. Two females (female 4 and female 6) suffered capture-related mortalities. Male 5 was legally taken during the 1986-87 cougar season. Female 1 and female 8 were illegal kills confirmed by examination of skulls and personal communications with local houndsmen. Female 2's radio collar was found, with circumstances of its location and date of discovery suggestive of poaching. Male 10 was killed by some type of motor vehicle. Females 3 and 7 displaced out of the study area. Male 9 disappeared suddenly, and was believed to have been poached.

Data Collection

Over 300 telemetry locations were collected from 8 radio collared cougars during the period November, 1985 through January, 1987 (Table 2.1). Of these 8 animals, 5 were resident adults (male 5, male 9, female 1, female 2, female 8), 2 were transient (female 3, female 7), and 1 was juvenile (male 10). Three resident cougars (male 5, female 1, female 2) were collared and monitored during 1985-86, with the remainder of the resident adults (male 9, female 8) captured and monitored in 1986-87. Sufficient locations were obtained from all resident animals for habitat and home range analyses. Number of telemetry locations varied among resident animals, ranging from 55 to 82.

Home Range and Core Area Sizes

Female 1 exhibited a home range size of 165.8 km^2, female 2 182.0 km^2, and female 8 111.4 km^2. Pooled, female home range size averaged 153.1 km^2. Male home range sizes were substantially larger; male 5 utilized 524.5 km^2 and male 9 562.4 km^2, which resulted in an average male home range of 543.5 km^2. Lack of sufficient sampling during winter seasons prevented evaluation of seasonal home range size. However, cursorial examination of radio-locations for each cougar suggested that there were no seasonal shifts in home range locations.

Core areas for females 1, 2, and 8 were 19.5 km^2, 33.2 km^2, and 12.5 km^2 respectively. Mean female core areas averaged 21.7 km^2. As with home ranges, core areas of males were substantially larger and averaged 96.9 km^2 (111.6 km^2 for male 5 and 82.1 km^2 for male 9). Female 1's core area represented 11.8 percent of the total home range, female 2's 18.2 percent, and female 8's 11.2 percent. Female core areas averaged 13.7 percent of their home range. The core area for male 5 comprised 21.3 percent of that animal's home range, while male 9's core area represented 14.6 percent (an average of 17.9 percent).

Table 2.1: Cougars captured, active monitoring period, number of loci, percent day versus night, location type, and number of continuous monitoring periods.

ANIMAL ID	MONITORING PERIOD	TOTAL LOCATIONS	PERCENT DAY/NIGHT	GROUND/AERIAL/MISC*	NUMBER CMP'S**
FEMALE 1	11/20/85 - 11/27/86	*60*	57/43	37/20/3	3
FEMALE 2	11/27/85 - 11/27/86	*61*	57/43	36/20/5	2
FEMALE 3	03/12/86 - 07/07/87	*27*	100/0	00/24/3	0
MALE 5	04/30/86 - 11/09/86	*55*	65/35	32/18/5	3
FEMALE 7	05/29/86 - 11/27/86	*12*	100/0	00/12/0	0
FEMALE 8	01/11/87 - 10/28/87	*82*	51/49	67/08/7	5
MALE 9	02/22/87 - 11/20/87	*56*	64/36	47/06/3	3
MALE 10	03/21/87 - 04/07/87	*06*	100/0	02/04/0	0

* CMP, verified track, sighting, recapture, kill location

** Continuous monitoring periods

Table 2.1

Home Range/Core Area Overlaps

There was considerable variability in overlap of home ranges and core areas. Female home ranges bordered one another with a minimal amount of overlap (Figures 2.1-2.2). Home range of male 5 overlapped considerably with that of female 2 (Figure 2.1). Home range of male 9 overlapped substantially with the home range of male 5, which was legally killed during 1986 (Figures 2.1-2.2). Home range of male 9 did not overlap with that of female 8, the only other animal still collared during the same time period (Figure 2.2). Core areas never overlapped, regardless of cougar sex or year of data collection (Figures 2.1-2.2).

Movements of Transients

Two transient females (female 3, female 7) exhibited the cougar's ability to traverse large distances. Both females were collared in the study area; female 3 moved a straight line distance of over 60 km to the northwest, and was last reported crossed west of an interstate highway. Female 7 traveled over 70 km to the northeast, crossing over to the eastern slopes of the Cascade Mountain Range. Male 10, a yearling male, presumably forced to leave its mother's home range, also exhibited this movement pattern until its vehicular related mortality.

Figure 2.1: Juxtaposition of home ranges and core areas (shaded) for 1986 study animals (females = solid lines, males = dashed lines).

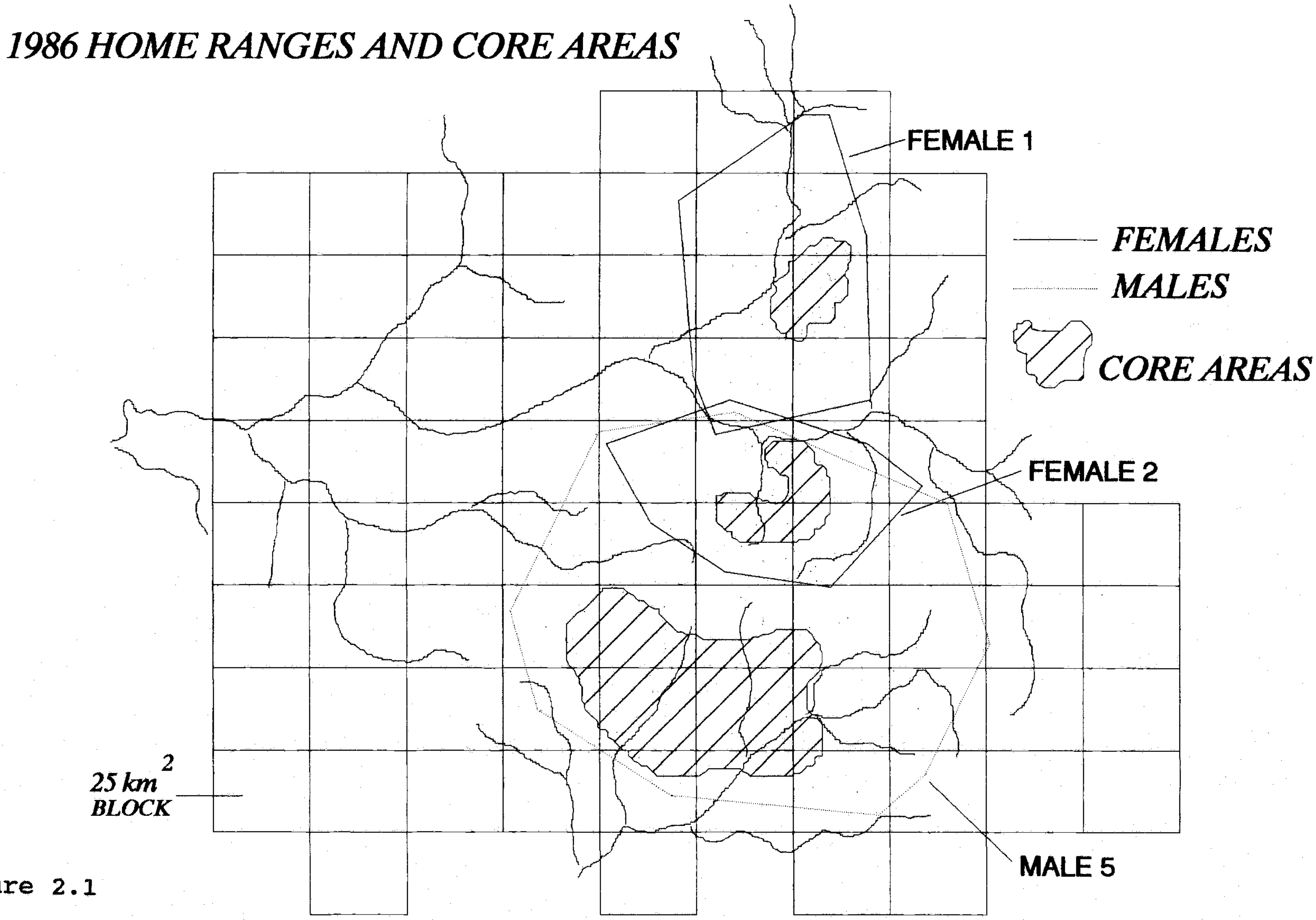

1986 HOME RANGES AND CORE AREAS
FEMALE 1
FEMALES
MALES
CORE AREAS
FEMALE 2
MALE 5
25 km²
BLOCK

Figure 2.1

Figure 2.2: Juxtaposition of home ranges and core areas (shaded) for 1987 study animals (females = solid lines, males = dashed lines).

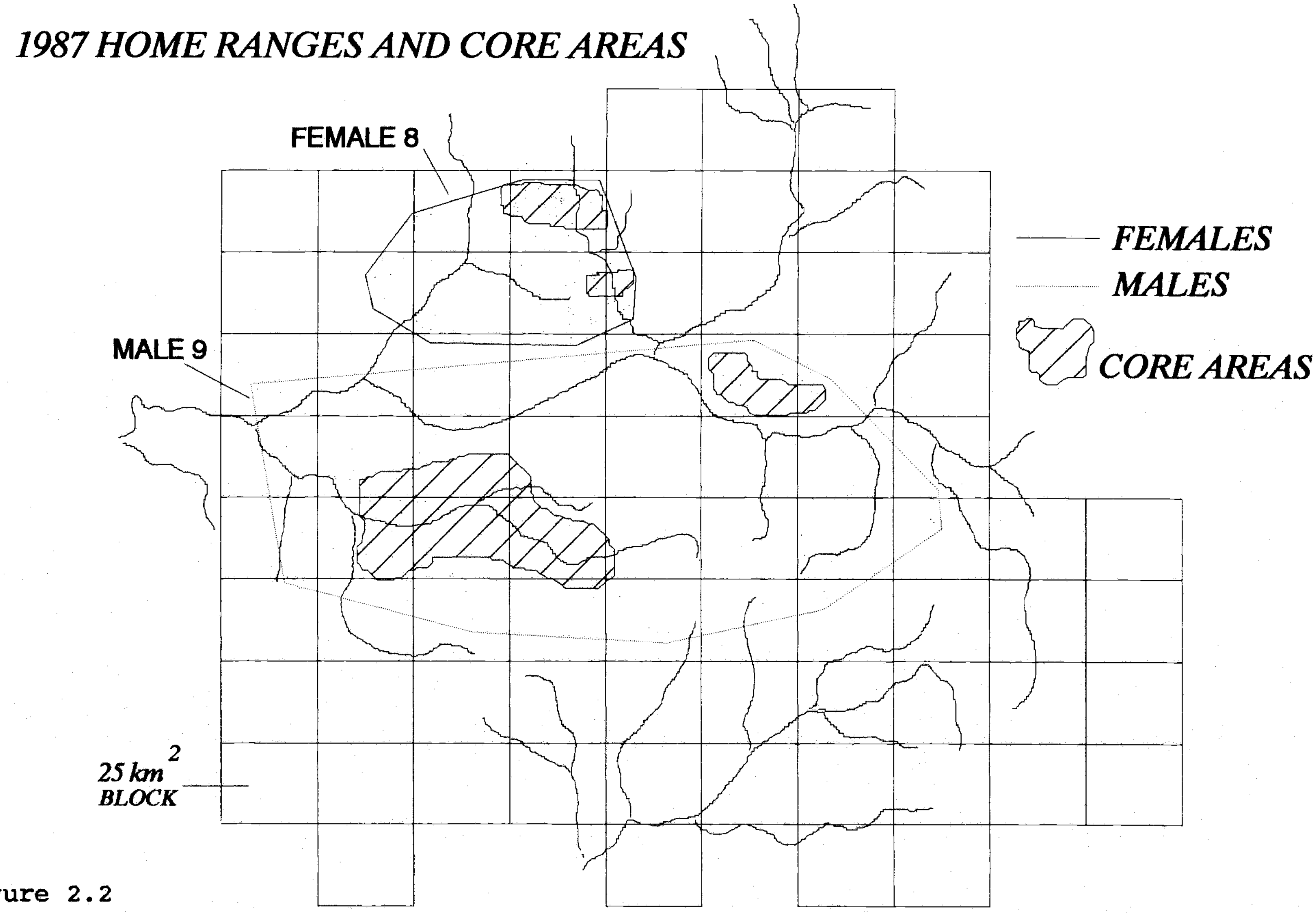

1987 HOME RANGES AND CORE AREAS
FEMALE 8
MALE 9
FEMALES
MALES
CORE AREAS
25 km²
BLOCK

Figure 2.2

DISCUSSION

The term home range has been utilized widely in the literature concerning cougar social organization, but has rarely been defined (Anderson 1983a). The models used to determine home range areas are seldom standardized among studies, making direct comparisons inappropriate. Indeed, rarely are the models or the number of data points used presented (Anderson 1983a). Anderson (1983a) noted that of the 7 states reporting home range information, only Seidensticker et al. (1973) described methods used to compute home range. Additionally, the assumptions of a particular home range model in many instances are violated, making the estimate meaningless (White and Garrott 1990). Unequal sample sizes also make comparisons difficult, especially if the model is sensitive to sample size (White and Garrott 1990). There have also been suggestions that factors such as environment and other circumstances determine the type of social structure exhibited (Seidensticker et al. 1973, Leyhausen 1965). Despite these concerns, several generalities concerning cougar home range size can be drawn in comparison to other studies.

Comparisons of home range area among study animals similar to the ones reported herein have been documented in several studies. Hornocker (1969) and Seidensticker et al. (1973) found that male home range sizes tended to be substantially larger than female areas. Ashman et al. (1983) also reported larger male home range areas than females for exploited and unexploited cougar populations in Nevada, as did Hemker et al. (1984) for cougars in Utah. Anderson (1983a) summarized data of cougar home range size and indicated that the same pattern of relative size difference between sexes was present in Arizona, New Mexico, California, Utah, and Texas. He also suggested that large differences in home range areas may result from differences in habitats, with the largest home range being reported in isolated mountain ranges surrounded by deserts of eastern Nevada, west Texas, and south-central Utah.

There exist no specific data concerning the size of core areas, or their proportion of the total home range area. Hornocker (1969) and Seidensticker et al. (1973) observed that over 70 percent of radio telemetry locations were obtained in less than 50 percent of the study area. These authors suggested that aggregations of cougars were associated with seasonal increases in prey densities.

Home range overlaps reported here also agree with other published accounts. The pattern of male home ranges overlapping one or more female home ranges has been documented in Idaho (Hornocker 1969, Seidensticker et al. 1973), Nevada (Ashman et al. 1983), and other states (Lindzey 1981, McBride 1976, Sitton 1977, Hemker et al. 1984). Additionally, overlap between female home ranges has been reported by the same authors. Overlap between females in this study appeared less pronounced than in other areas of the country (Hemker et al. 1984, Logan et al. 1986, Neal et al. 1987). This may be due in part to differences in sampling intensity, population structure, or resource base. Overlap of male home ranges was not examined due to male 5's sport harvest: observation periods for the 2 males did not overlap. However, some insight into cougar social structure might be gained when examining the re-establishment of male 9's home range over a substantial portion of male 5's former range. Male 9 appeared to be actively establishing a home range during the monitoring period. This animal was able to establish in male 5's former range suggesting the vacant space was not annexed by neighboring and established males.

Dispersals of the two transient animals (female 3 and female 7) follow observational reports of the cougar's ability to travel long distances and over varied terrain. Young and Goldman (1946) mentioned cougars traveling large distances overnight (approximately 40 km) and over longer periods (120 km over 1 year). Hornocker (1970) stated four young cougar traveled an average of 85 km from the point of capture. Dewar (1976) also noted that several transient cougars were killed over 160 km from capture locations. Hemker et al. (1984) reported 3 juveniles dispersing 35-120 km.

Management Implications

Although knowledge of social aspects of cougar biology does not constitute all the data required by biologists to make informed management decisions, it does provide important information useful in cougar management. Until statistically valid data are obtained for population densities and recruitment rates of cougars in western Oregon, home range and core area size can provide a preliminary check of population densities estimates. Harcombe's (1976) estimated densities by management unit ranged from 25 to 187 square miles per cougar; however, the author did not indicate any basis for these estimates. The Oregon Department of Fish and Wildlife (ODFW) reported 1800 cougar statewide in 1987, with 1100 in western Oregon. They also reported approximately 45,000 square miles of cougar habitat (ODFW 1987). This estimate results in an average of approximately 25 square miles per cougar state wide. This figure would be expected to decrease in the study area, since this portion of the state is said to support above average cougar densities (ODFW 1987).

Based on the home range and core area values reported herein, this figure almost certainly underestimates the amount of area required for home range in the study area. Additionally, the establishment of male 9's home range suggests population densities are not exceeding the resource base since the area did not appear to be immediately annexed by adjacent animals, in contrast to results reported by Neal et al. (1987) in California.

ODFW maintains that the highest population densities in western Oregon exist primarily on the west side of the south Cascades (1987). The South Cascade harvest unit receives the greatest number of tags, and accounts for the majority of harvested cougar in western Oregon (ODFW 1987, ODFW harvest statistics). The study area constituted approximately the northern third of the harvest unit. If the home range characteristics reported here are consistent through out the harvest unit, the estimates of ODFW concerning cougar density may be inflated. Since the estimate of density is the primary basis for harvest allowances, there exists the potential of over harvest in the primary cougar population of western Oregon.

Harvest impacts the social structure of cougar populations, and thereby may affect recruitment rates and population densities. The research record suggests that the social organization of cougar populations are severely disrupted when populations are exploited, especially when resident females are harvested (Hornocker 1969, Hornocker 1970, Seidensticker et al. 1973). Female cougars will not breed unless they have an established home range; however, transient males are able to mate with resident females (Anderson 1983a, Hornocker 1969, Hornocker 1971, Seidensticker et al. 1973). Because of this, consistent removal of resident females may reduce, over a period of years, the ability of the population to support harvest (Hornocker 1971). Consistent removal of resident females would create a lag time in which female transients must locate and establish home ranges and become breeding members of the population. Lag times increase if adjacent population densities are low, since resident adults removed from a local population are generally replaced by other transient cougars, rather than young from the same population (Hornocker 1971, Hemker et al. 1984, Logan et al. 1986). If an area is over harvested, and if the over harvest is maintained over a period of time, then it is inevitable that population numbers will decline, both in the harvested population and adjacent populations (Hornocker 1971).

There exists a potential for over harvest in cougar populations in Oregon, as evidenced by the rapid decline of cougars in the three decades before they were protected (ODFW 1987). The cougar population in the southern Cascades may be at an increased risk of over harvest for several reasons. As reported by ODFW, the south Cascade region consists of an area of high cougar population densities surrounded by areas of lower densities (ODFW 1987). Since sport harvest began in the early 1970's, no effort has been made to regulate harvest by sex and/or age. As a result, the majority of cougars harvested are resident females or transients (Trainer et al. 1988, ODFW 1987, ODFW harvest statistics). The ODFW maintains that cougar populations are increasing in southwest Oregon and can support increased harvest (ODFW 1987). The increased number of tags for the South Cascade harvest unit has been justified with unsubstantiated population estimates which may be inflated. Indeed, the effort required in this study to capture cougars and the discrepancies in area requirements contradicts the belief that cougar populations are high. As evidence of heavy harvest, there has been a decline in the estimated age of cougars killed during seasons (ODFW harvest statistics, Trainer et al. 1988).

COUGAR HABITAT USE

Early telemetry studies conducted by Hornocker (1969; 1970) and Seidensticker et al. (1973) discussed structural components of cougar habitat in relation to the cougar's primary prey species. Seidensticker et al. (1973) suggested that a vegetation-terrain/prey abundance-vulnerability complex constituted an important characteristic of productive cougar habitat. Later research by Anderson (1983b), Currier et al. (1977), and Logan and Irwin (1985) supported the importance of available stalking cover in cougar habitats. Other studies that addressed cougar habitat use commonly limited discussions of the structural components of habitat to their implied use in predation by cougars (Robinette et al. 1959, Ashman 1975, Berg et al. 1983, Ackerman et al. 1984). Few studies exist in the literature of cougar use of other habitat components such as riparian areas and topographic features.

Although it is commonly accepted that cougar habitat is synonymous with deer habitat, few quantified comparisons of habitat use with availability exist as a test of this concept. The same is true of movement patterns by cougars in relation to different age class structure and species composition of forest stands, riparian areas, and topographic features. Logan and Irwin (1985) reported cougar use of habitat relative to the availability of different habitat types in Wyoming. They demonstrated that cougars exhibit preferences for forested habitats, particularly stands possessing certain structural characteristics and species composition; and suggested that cougars selected for habitats that provided vegetative or topographic cover advantageous to stalking.

Investigation of habitat use by cougars in western Oregon is limited to subjective observations of ODFW biologists. The ODFW Cougar Management Plan (1987) reported 44,740 square miles as "cougar habitat", but did not indicate location, vegetative/age class classification, or spatial distributions of these habitats. Harcombe (1976) theorized that human disturbance and lack of old growth forests limited cougar populations in some areas of western Oregon, despite the presence of an adequate prey base. However, no data existed with which to support his contention.

The purpose of this study was to examine habitat use by cougars in southwestern Oregon. This area supports one of the highest estimated cougar densities in the state, an indication that it provides structural and vegetative composition characteristics that create favorable cougar habitat. Use of available habitat classes, and indications of use or avoidance of specific stand age classes, riparian areas, and topographic elevations are evaluated. Movement patterns within home ranges in relation to topography and riparian areas are also presented.

METHODS

[To reduce redundancy, methods and results which describe the capture, immobilization, number of cougar treed and radio collared, and telemetry data collection can be found in the methods and results sections of Chapter Two.]

Data Collection

Telemetry data were collected as independent and sequential locations. Independent data were collected on a randomized schedule, with locations obtained from the ground and air. Ground telemetry locations were determined from the use of a hand held yagi antenna and portable receiver. Data were also collected from fixed wing aircraft equipped with yagi antennae attached to each wing strut. Longitude and latitude coordinates of animal locations were determined with the aircraft's LORAN navigational system. Sequential locations were collected from the ground, and were obtained every 1 to 2 hours over a period of 24 to 36 hours. A minimum of 2 continuous monitoring periods (CMP) were collected for each animal. Independent and sequential telemetry locations were developed as described in Chapter Two.

Habitat Classification

The study area was divided into 65, 25 km^2 UTM coordinate system blocks. A FORTRAN program was written that generated 25 random UTM northing and easting pairs for each 25 km^2 block (Press et al. 1986). Independent and random data points were classed by vegetative and age class composition; minimum distances to riparian areas were also determined. Habitat classifications were based on five of the categories presented in Brown et al. (1985) (e.g. recent clearcut, brush/shrub, open pole/sapling, closed pole/small sawtimber, mature), and were obtained through interpretation of satellite imagery.

Three band composite 1:100000 scale photography of the study area was acquired for July 1986 from Spot Image Corporation. A UTM grid for the satellite photographs, developed from 1:100000 scale Bureau of Land Management (BLM) planimetric maps, was scribed onto the imagery. Overlays of randomly located and actual digitized telemetry locations were produced on 1mm Vellum grids for each 25 km^2 block at the appropriate scale. Classification of the data point was confirmed using NHAP 1:60000 infra-red aerial photography. Proportions of random and actual data points were developed for each habitat category by individual animal, as averages by sex, and as pooled averages. In addition, proportions of random and actual data points classified as either edge or non-edge were computed.

Distance Measures to Riparian Areas

Riparian areas for each 25 km^2 were digitized, and combined with digital locational data for each animal. A FORTRAN program was written which calculated from each random and actual telemetry location the minimum distance to riparian areas. Averages for random and actual distances were calculated for individual animals, as pooled averages by sex, and as overall averages. Additionally, occurrences of random and actual locations were computed in five consecutive 1000 meter bands from the riparian areas in the same manner.

Statistical Analysis

Statistical analysis of habitat use followed the procedures outlined by Marcum and Loftsgaarden (1980). A FORTRAN program was developed to test cougar habitat use against availability. Chi-square analysis was performed to test the null hypothesis that cougar use of each habitat category was in proportion to its occurrence within the study area. If differences existed, simultaneous confidence intervals were then calculated to determine use of each habitat class in proportion to availability.

T-tests were used to test the hypothesis that no statistical differences existed between mean actual and random distances to riparian areas. Because of unequal sample size between actual and random locations, pooled variances were utilized in all tests. Chi square analyses were performed to determine if number of actual occurrences differed significantly from random within each of five 1000 meter band.

Movement Patterns

Independent and continuous monitoring periods (CMP's) were utilized to describe movement patterns within each animal's home range. Independent locations collected over many months were plotted sequentially to determine gross movement patterns within the animal's home range. Straight line distances were determined between successive locations, and calculated in terms of distances traveled per day. T-tests were performed to determine if distances traveled varied between groups pooled by sex.

For CMP's, digital elevation models (DEM) from 1:31000 black and white aerial photography were developed using a Carto AP190 analytical stereo plotter. The UTM coordinates of the movements were incorporated into the DEM's, and described in relation to topographic relief and riparian areas. Straight line distances for each animal's CMP were determined between successive locations, and calculated in terms of distances traveled per unit of time and time of day (dawn, dusk, day, night). T-tests were performed to determine if distances traveled varied among time of day between groups pooled by sex.

RESULTS

Habitat Use

Cougars utilized the five habitats disproportionately to their occurrence ($P<0.005$) when locations were pooled for all cougars and by sex classes (Table 3.1). Individually, four of the five cougars utilized habitats significantly differently from rates of occurrence although at lower significance levels than for pooled locations ($P<0.10$, $P<0.025$). Only one animal (male 9) exhibited no preference among habitat types. Neither pooled nor individual comparisons of cougar locations with occurrence of habitat edges indicated a preference or avoidance of this type (Table 3.1).

Habitat use: Recently-harvested areas. - Simultaneous confidence interval testing indicated that recently-harvested areas (stand condition one) were selected against when cougar locations were pooled across all individuals, by sex, and by individual cougars exhibiting differential use of habitat types (Table 3.1).

Habitat use: shrub/brush. - Use of this habitat by all cougars pooled, and for all females pooled was in proportion to availability (Table 3.1). However, this habitat was utilized significantly less in proportion to availability when locations were pooled across males. Results were mixed when locations of individual animals were compared with occurrence of this habitat. Female 1 and female 8 used this habitat in proportion to its availability. Female 2 and male 5 utilized this habitat significantly less in

Table 3.1: Habitat use of five habitat classes and edge for individual, pooled by sex, and all cougars combined.

	FEMALE 1	FEMALE 2	FEMALE 8	MALE 5	MALE 9	ALL FEMALES	ALL MALES	ALL ANIMALS
EDGE vs NON-EDGE	NS	NS	NS	NS	NS	NS	NS	NS
LEVEL OF SIGNIFICANCE	P<0.025	P<0.10	P<0.10	P<0.10	NS	P<0.005	P<0.05	P<0.005
RECENT CLEARCUT	SL	SL	SL	SL	NS	SL	SL	SL
BRUSH / SHRUB	IP	SL	IP	SL	NS	IP	SL	IP
OPEN POLE / SAPLING	SL	IP	IP	SL	NS	SL	IP	IP
CLOSED POLE / SMALL SAW	IP	IP	IP	IP	NS	IP	IP	IP
MATURE / OVER MATURE	SM	SM	IP	IP	NS	SM	IP	SM

SL = SIGNIFICANTLY LESS
SM = SIGNIFICANTLY MORE
IP = IN PROPORTION

Table 3.1

proportion to availability.

Habitat use: open pole-sapling/small sawtimber. - This habitat was utilized in proportion to availability by all cougars pooled and by all males (Table 3.1). Pooled females under-utilized this habitat. Use by individual cougars also varied: female 2, female 8, and male 5 utilized this habitat in proportion to its availability; male 9 avoided this habitat.

Habitat use: closed pole/sapling. - All combinations of cougars, pooled and unpooled, utilized this habitat in proportion to availability (Table 3.1).

Habitat use: mature/over mature. - This habitat was utilized significantly more in proportion to availability by all cougars pooled and by females pooled (Table 3.1). When males were pooled their use of this habitat was in proportion to availability. Taken individually, none of the animals indicated an under use of this habitat. Female 1 and female 2 exhibited significantly more use in proportion to availability. Female 8 and male 5 utilized the habitat in proportion to availability.

Distance Measures

Riparian Areas. - Mean distance to riparian areas for all cougar locations pooled (247.3m) was significantly less ($P<0.001$) than mean distances for random locations (289.2m) (Table 3.2). When pooled by sex, females exhibited a similar result (P 0.009, mean cougar distance = 289.2m, mean

Table 3.2: T-test values for significance of differences between actual and random distances to riparian areas for individual cougars, pooled by sex, and all cougars combined (top number = t-value; bottom number = significance level).

RIPARIAN AREAS	
FEMALE1	T = -1.459 P = 0.145
FEMALE2	T = -1.163 P = 0.245
FEMALE8	T = -1.843 P = 0.066 *
MALE5	T = -1.275 P = 0.203
MALE9	T = -0.497 P = 0.619
ALL FEMALES	T = -2.600 P = 0.009 *
ALL MALES	T = -1.227 P = 0.220
ALL ANIMALS	T = -3.267 P = 0.001 *

Table 3.2

random distance = 272.5m), whereas males exhibited no difference. Individually, all animals except female 8 exhibited no significant differences in distance to riparian areas from random locations. Female 8 was farther, on average, from riparian areas (271.2m) than random locations (229.8m)($P<0.066$).

Chi-square analyses indicated that there were no significant differences between the proportions of cougar versus random locations among five consecutive 1000 meter bands (zones 1-5) from riparian areas for pooled and individual cougar locations.

Movement Patterns

Independent Locations. - In general, cougars tended to move through their respective home ranges in a circular or zig-zag pattern, utilizing an area, then moving to another portion of the home range (Figures 3.1-3.5). This pattern continued until the animal covered the majority of their home range. Average straight line distances traveled per day were highly variable. All animals pooled traveled an average 1456.9m per day (standard deviation = 1606.7m, maximum = 11236.8m, minimum = 18.7m). Average straight line distances traveled by females (mean = 1175.5m, sd = 1507.2m, maximum = 11236.8, minimum = 18.7) was not significantly different than that for males (mean = 1971.8m, sd = 1654.9m, maximum = 6992.0m, minimum = 26.5m).

Continuous Monitoring Periods. - Cougars used riparian

Figure 3.1: Sequential locations of female 1; numbers indicate location sequence.

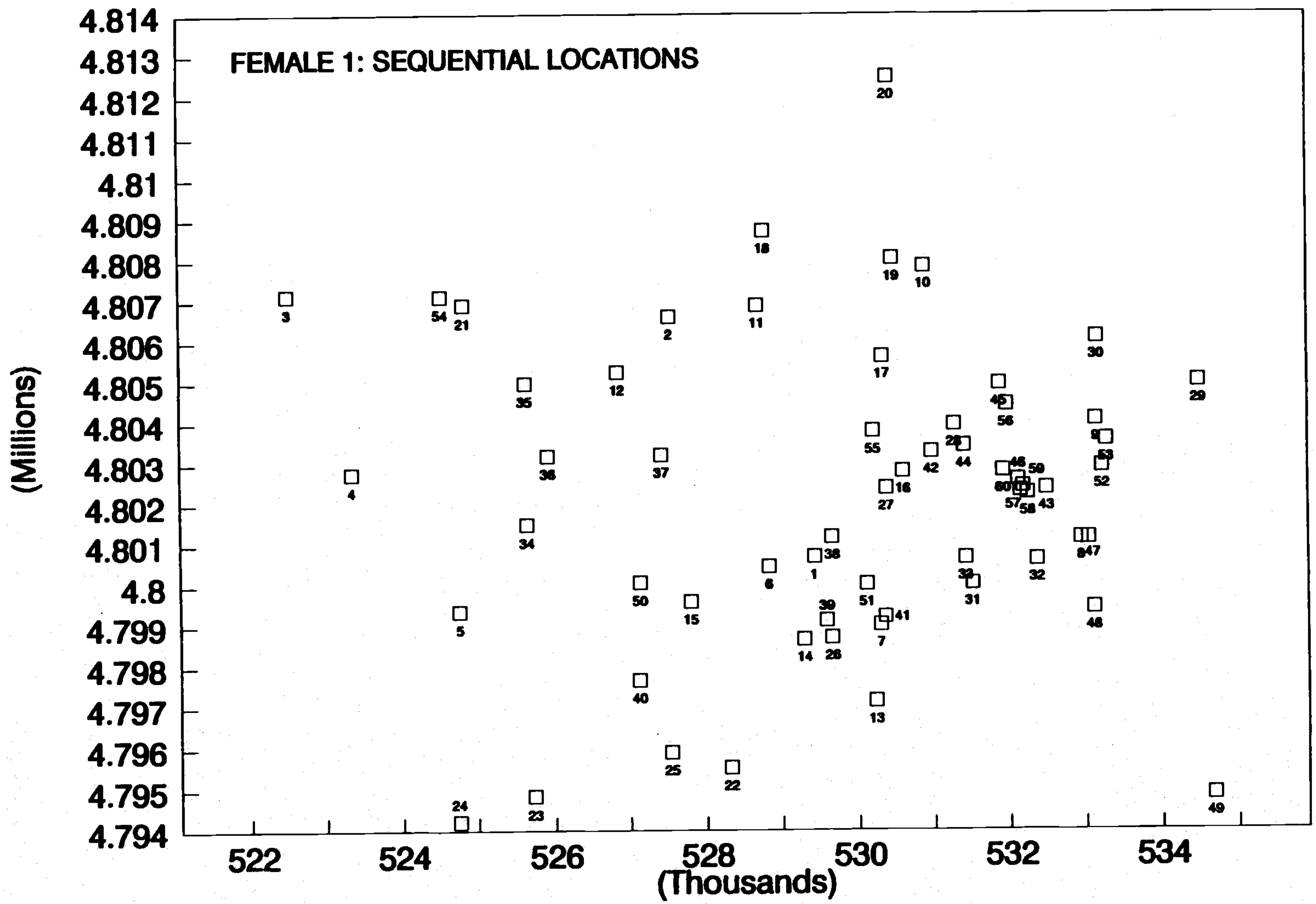

FEMALE 1: SEQUENTIAL LOCATIONS
(Millions)
4.814
4.813
4.812
4.811
4.81
4.809
4.808
4.807
4.806
4.805
4.804
4.803
4.802
4.801
4.8
4.799
4.798
4.797
4.796
4.795
4.794
522
524
526
528
530
532
534
(Thousands)

Figure 3.1

Figure 3.2: Sequential locations of female 2; numbers indicate location sequence.

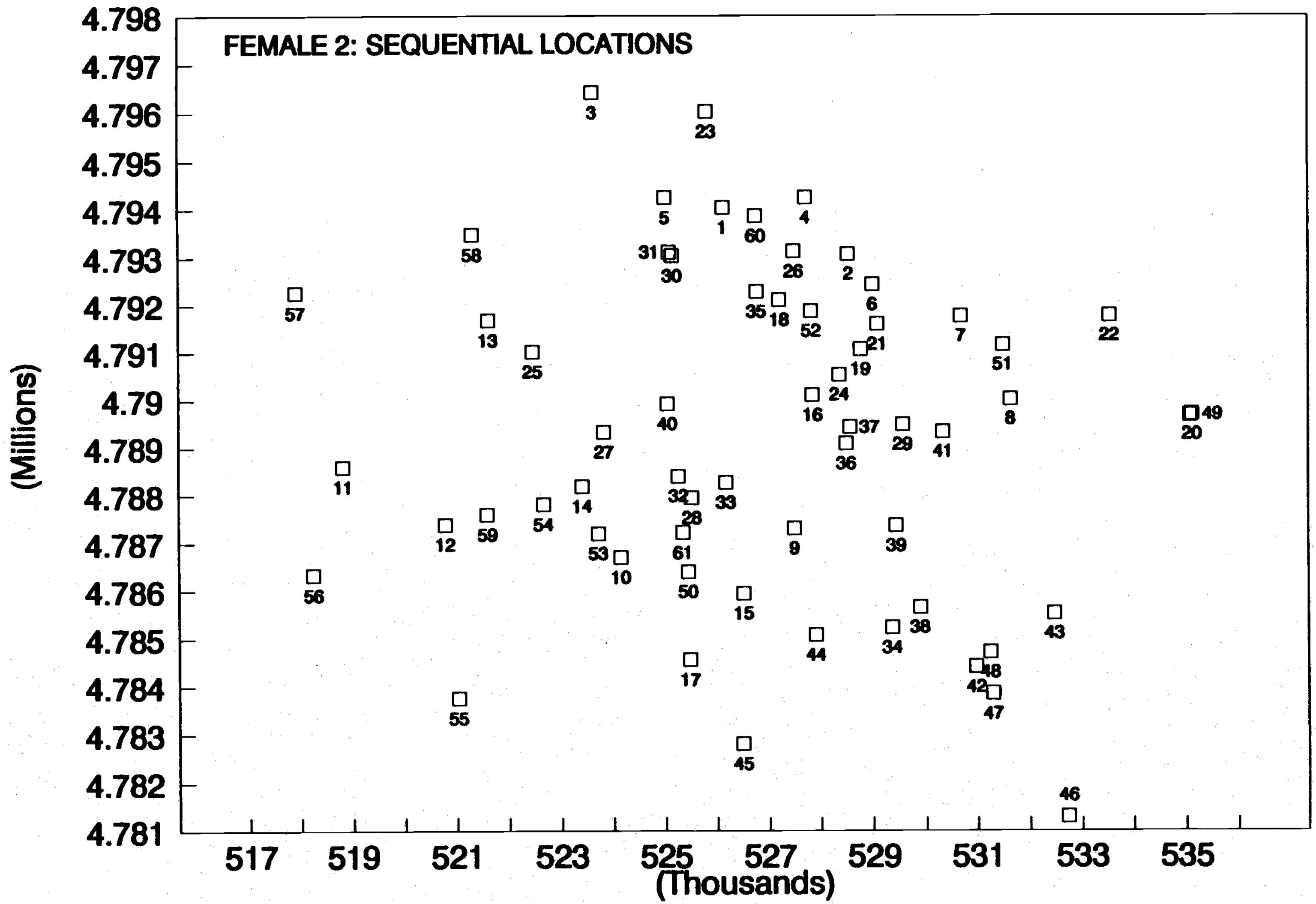

FEMALE 2: SEQUENTIAL LOCATIONS
4.798
4.797
4.796
4.795
4.794
4.793
4.792
4.791
4.79
4.789
4.788
4.787
4.786
4.785
4.784
4.783
4.782
4.781
(Millions)
517
519
521
523
525
527
529
531
533
535
(Thousands)
3
23
5
1
60
4
58
31
30
26
2
6
57
35
18
52
13
21
7
22
51
25
19
24
16
8
49
20
40
37
29
41
27
36
11
32
33
14
28
54
59
12
39
9
53
61
10
56
50
15
38
43
34
44
48
17
42
47
55
45
46

Figure 3.2

Figure 3.3: Sequential locations of female 8; numbers indicate location sequence.

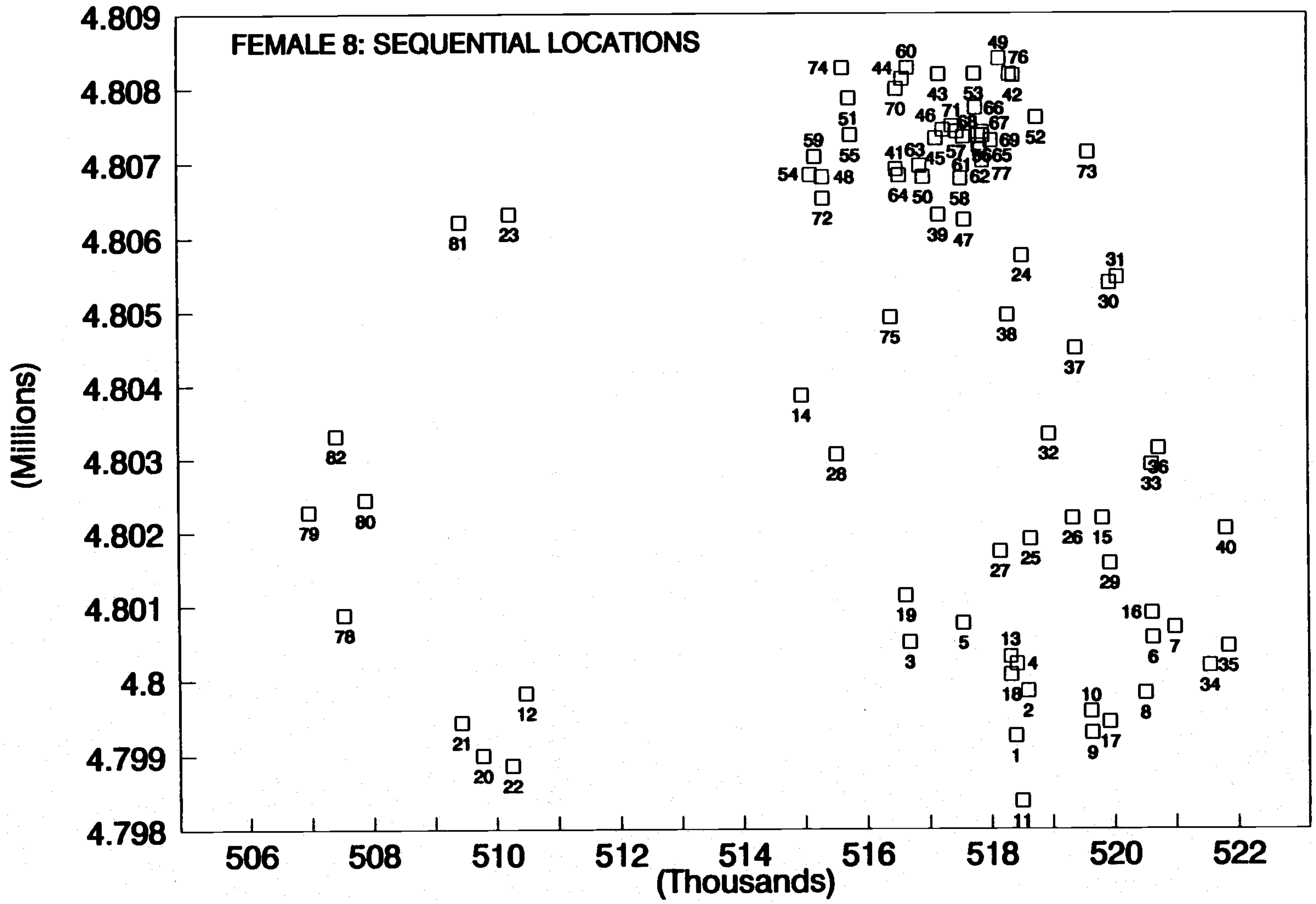

FEMALE 8: SEQUENTIAL LOCATIONS
4.809
4.808
4.807
4.806
4.805
4.804
4.803
4.802
4.801
4.8
4.799
4.798
(Millions)
506
508
510
512
514
516
518
520
522
(Thousands)

Figure 3.3

Figure 3.4: Sequential locations of male 5; numbers indicate location sequence.

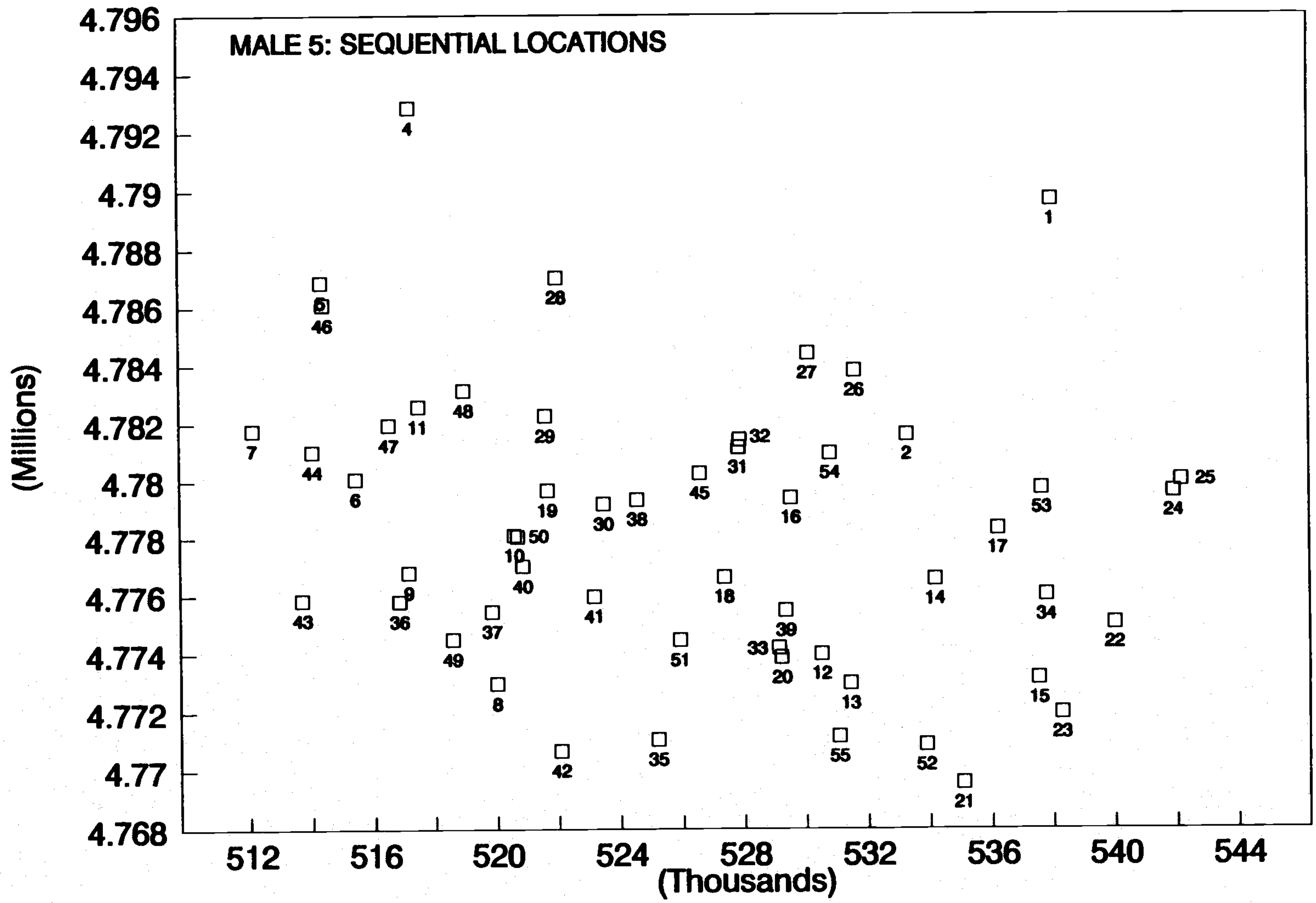

MALE 5: SEQUENTIAL LOCATIONS
4.796
4.794
4.792
4.79
4.788
4.786
4.784
4.782
4.78
4.778
4.776
4.774
4.772
4.77
4.768
(Millions)
512
516
520
524
528
532
536
540
544
(Thousands)
4
1
28
5
46
27
26
48
11
47
29
32
7
44
31
2
54
45
6
53
25
24
19
30
38
16
50
10
17
9
40
18
14
43
36
41
34
39
37
22
49
51
33
12
20
8
13
15
23
42
35
55
52
21

Figure 3.4

Figure 3.5: Sequential locations of male 9; numbers indicate location sequence.

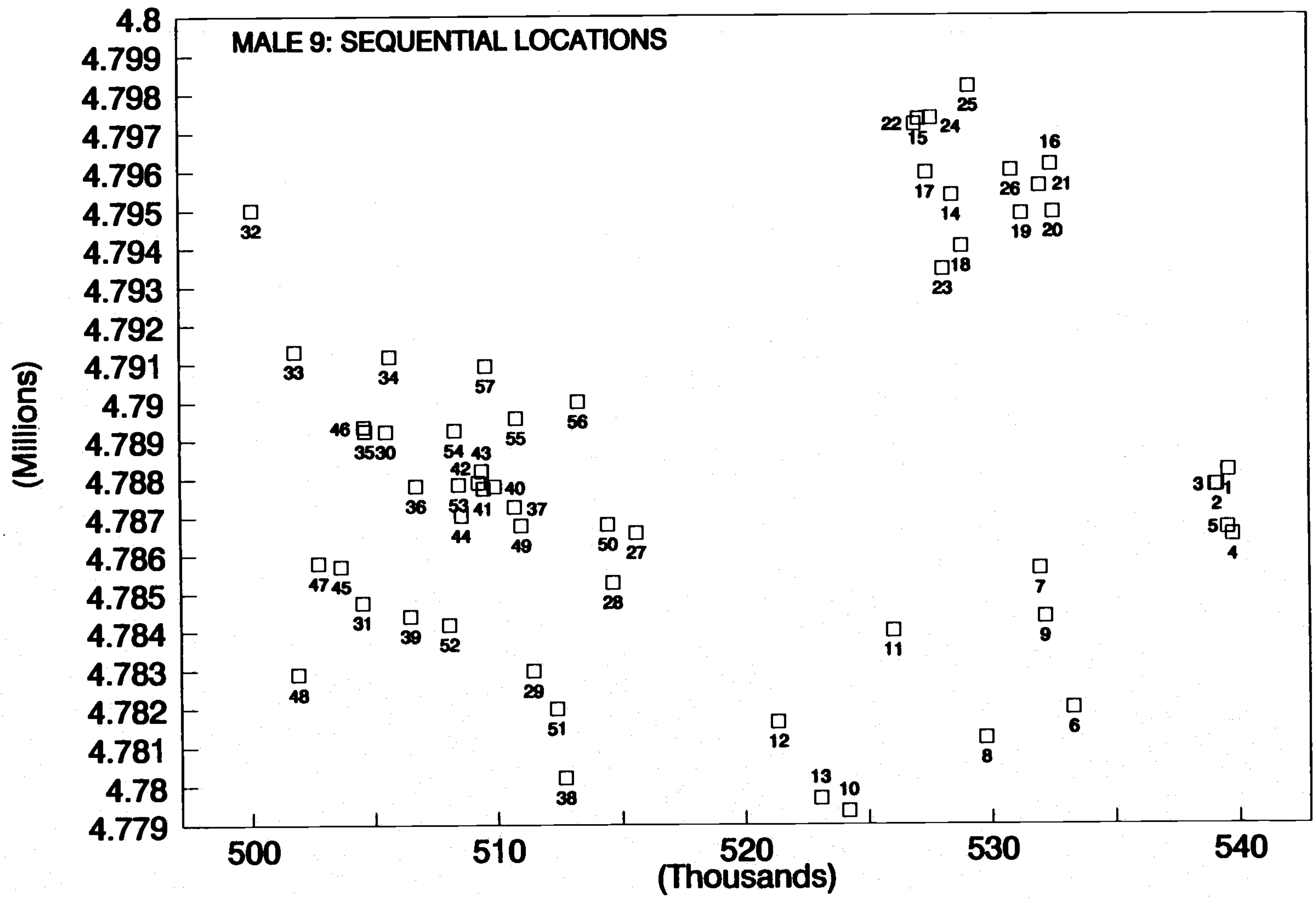

MALE 9: SEQUENTIAL LOCATIONS
(Millions)
4.8
4.799
4.798
4.797
4.796
4.795
4.794
4.793
4.792
4.791
4.79
4.789
4.788
4.787
4.786
4.785
4.784
4.783
4.782
4.781
4.78
4.779
500
510
520
530
540
(Thousands)

Figure 3.5

areas extensively to travel within their home ranges. Continuous monitoring periods indicate this pattern of movement regardless of sex. Figure 3.6 demonstrates a typical monitoring period in which riparian areas are utilized during movements. Movement associated with riparian areas was found in the majority of CMP's (Appendix B). Riparian areas were utilized in both slope directions, and during all weather conditions (Appendix B).

Cougars also utilized topographical relief within home ranges. Topographic convexities (i.e. ridge tops) and concavities (i.e. primarily riparian areas) were utilized apparently as travel corridors when moving to another portion of the animal's home range. Figure 3.7 exhibits female 8's use of topography in a partial CMP. Other examples of topographic use are in Appendix B.

Pooled by sex and time of day, distances traveled per hour by females (mean = 495.3m, sd = 466.7m, maximum = 2500.7m, minimum = 3.5m) were significantly ($P<0.01$) larger than that of males (mean = 306.7m, sd = 327.7m, maximum = 2013.4m, minimum = 3.3m). When pooled by sex only, females (mean = 620.1m, sd = 473.0m, maximum = 1777.5m, minimum = 21.6m) traveled significantly more ($P<0.01$) during the night than did males (mean = 251.9m, sd = 381.9m, maximum = 2013.4m, minimum = 3.3m). The same was true of travel during dusk ($P<0.05$, females: mean = 597.4m, sd = 479.8m, maximum = 1598.0m, minimum = 73.1m, males: mean = 178.2m, sd

Figure 3.6: Example of riparian zone (bolded) use by female 1 (military times and ellipses of loci are shown).

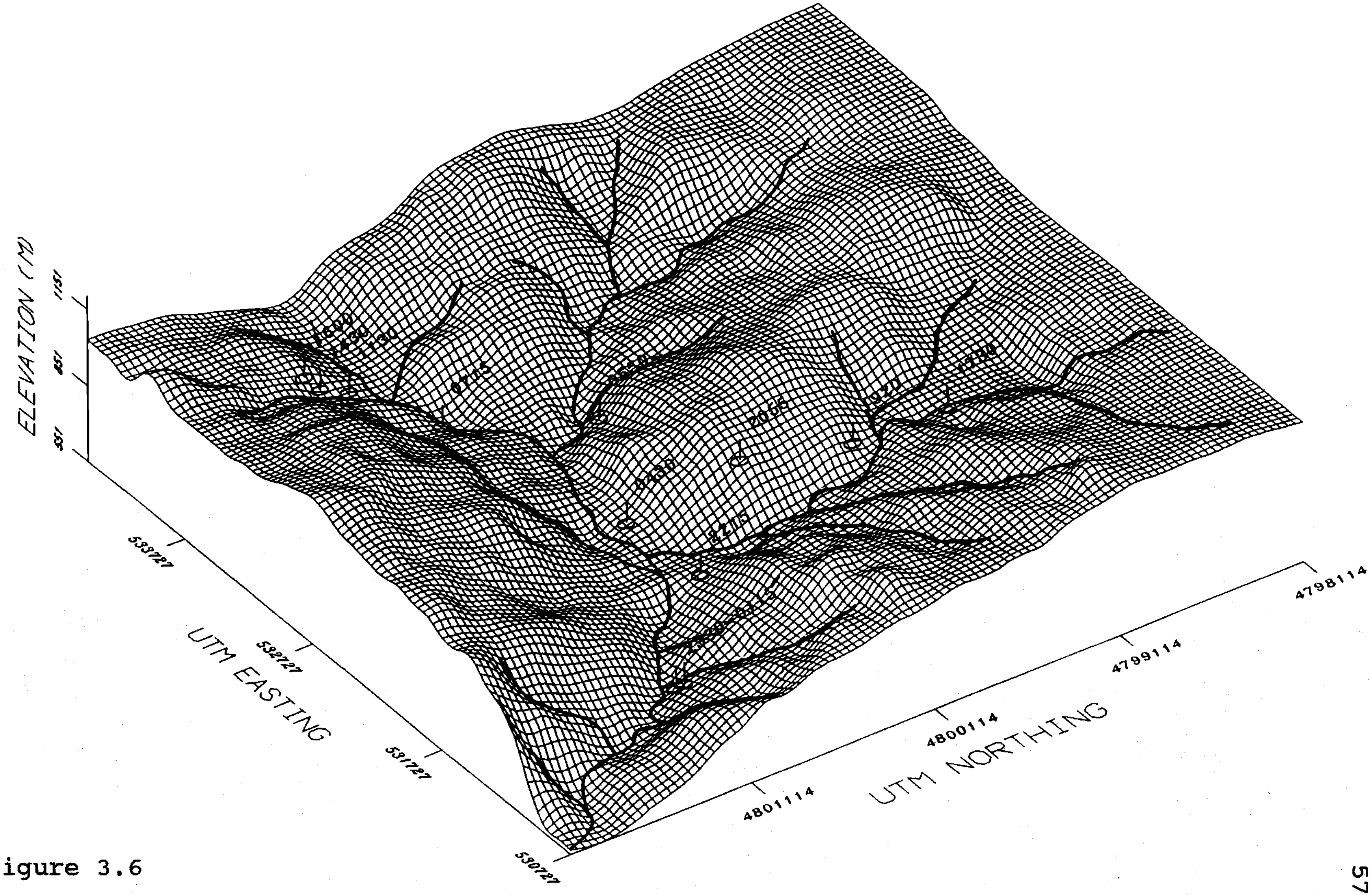

ELEVATION (M)
1151
851
351
UTM EASTING
533727
532727
531727
530727
UTM NORTHING
4801114
4800114
4799114
4798114

Figure 3.6

Figure 3.7: Example of movement utilizing topographic relief for a partial CMP for female 8 (military times and ellipses of loci are shown).

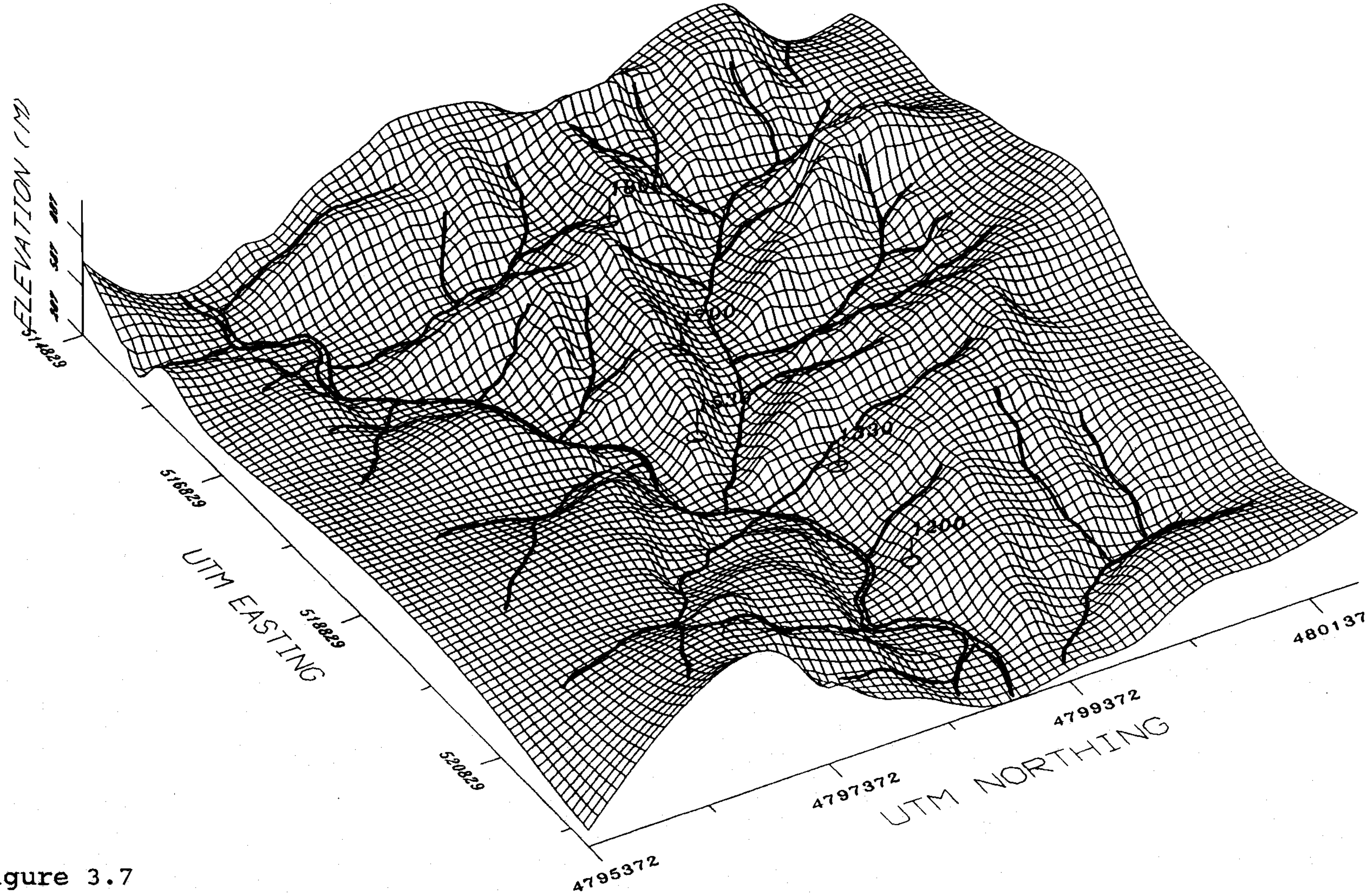

ELEVATION (M)
516829
518829
520829
UTM EASTING
4795372
4797372
4799372
4801372
UTM NORTHING
1200

Figure 3.7

= 139.5m, maximum = 418.2m, minimum = 37.9m). Distances traveled during day and dawn were not significant between sexes. When distances traveled per hour by time of day were tested against pooled averages, no significant differences were observed for all animals and all males pooled. All females pooled traveled significantly less ($P<0.05$) during the day (mean = 327.5m, sd = 299.8m, maximum = 1294.7m, minimum = 3.5m) than over all time periods (mean = 495.3m, sd = 466.7m, maximum = 2500.7m, minimum = 3.5m).

DISCUSSION

Habitat Use

Cougar use of the five habitats was disproportionate to occurrence indicating there were structural components present in some stands (absent in others) that combined to produce differences selected for or against by cougar. The data presented support the vegetation-terrain/prey abundance-vulnerability complex of productive cougar habitat put forth by Seidensticker et al. (1973). Results were also similar to those in Wyoming where cougars exhibit preferences for forested habitats, particularly stands possessing certain structural characteristics and species compositions (Logan and Irwin, 1985). Other studies have also supported the importance of stalking cover in cougar habitat, and the implied use of structural components in predation by cougars (Robinette et al. 1959, Ashman 1975, Berg et al. 1983, Ackerman et al. 1984, Currier et al. 1977, Anderson 1983b).

Individually, animals that exhibited disproportionate use among habitat types selected against recent clearcuts, presumably due to a lack of vegetative cover. Shrub/brush and open pole/sapling stages were utilized either significantly less or in proportion to availability. These varied results may be indicative of the interrelationship between seral stage, stalking cover, and prey abundance and/or vulnerability. In some instances there existed enough cover in these stages that precluded avoidance by cougars, and/or increased abundance and vulnerability of prey. Closed pole/small sawtimber stands were utilized in proportion to availability for all animals. This suggested structural components of the stand condition provided thermal and travel cover, but not enough stalking cover and/or prey abundance/vulnerability to be preferred. This habitat class is typified by the term "conifer desert", under whose closed canopy little else successfully competes. This would provide thermal cover but little food for prey populations.

Mature and over mature stands were utilized significantly more or in proportion to availability. The same interrelationship between prey and cover can be inferred, except in the selection for, rather than against, the habitat type. Mature and over mature stands typically had greater vertical and horizontal heterogeneity than closed pole/small sawtimber stands, and more stalking cover than earlier seral stages. Additionally, the landscape pattern of staggered clearcuts provides ample food sources for deer within a short distance to these types of stands.

Only one animal (male 9) exhibited no preference among habitat types. This may have resulted from the animal's apparent active establishment of a home range. An animal establishing a home range will tend to move about the home range to a greater extent in an effort to mark and test territorial limits. Given the landscape patterns of the western Cascades, there is more probability of showing no preference of habitat types as home range is established. Van Dyke et al. (1986a) also reported that younger animals were more likely to be associated with recently clearcut areas.

Riparian Area Use

Although t-test results reported significant differences between mean cougar and random distances to riparian areas, the absolute difference between the two means was less than 35m on average. Because this distance was smaller than triangulation error estimations (57.3m triangulation, 0.4-0.5 ha area: Appendix A), differences identified as being statistically significant are not within the level of discrimination afforded by telemetry. It is also questionable whether a difference of 35m is biologically significant. Finally, the differences detected by t-tests in mean distances for female 8, all females pooled, and all animals pooled to riparian areas were not identified within 1,000m interval distances by chi-square analyses. This suggests that while cougars may as a group be found closer to riparian areas than expected, there exists no identified preferred interval distance. The first 1,000m interval would have contained more cougar locations than expected if they were preferentially using riparian areas. The large number of riparian areas in close proximity to each other area may also have contributed to the lack of large differences between actual and random distances. The probability of being close to a riparian area increases as the number of riparian areas increases; past a certain density, moving away from one riparian areas will result in approaching another.

Movement Patterns

Continuous Monitoring Periods. - The use of, but perhaps not selection for (because of their ubiquity), riparian areas by cougars is clearly demonstrated in the majority of the continuous monitoring periods. Cougars utilized concavities in topography (primarily riparian) apparently for many reasons. These include use of travel corridors between and within drainages, selection for modified microclimates during periods of summer heat, use for temporary rest during periods of movements, escape from pursuing hounds, and avoidance of human interactions. Because of forest protection statutes, the riparian areas were also associated most commonly with mature and over mature stands, a habitat type that was selected for by cougars.

Independent Locations. - Sequential independent locations demonstrated circular and zig-zag patterns of home range use as reported elsewhere in the literature (Hornocker 1969, Seidensticker et al. 1973). Average distances travelled per day undoubtably underestimated actual distances traversed. Seidensticker et al. (1973) described extensive zig-zag movements of cougars, demonstrating that they traveled farther than straight line distances would indicate. However, sequential distance traveled might be applied to some type of index to energy expenditures (White and Garrott 1990). Specifically, females would require traveling greater distances to fulfill energy requirements of young they were caring for as well as themselves, while males need only to satisfy their own energy requirements. A pattern of travel supporting this contention was apparent in this study: females travelled greater distances than males during night and dusk when hunting to support kits occurs. Conversely, females would tend to move less during the day, when caring (exclusive of hunting) for young.

Management Implications

On a landscape level, forest management in the study area has produced a mosaic of habitat classes. The continual set-back of succession and the interspersion of seral stages benefit prey populations (primarily deer). Western Oregon deer populations are at their highest levels since being managed by state organizations (pers. commun. ODFW district biologists). From purely a prey base view, habitat alterations produced by forest management in the study area have created productive cougar habitat. Indeed, in the majority of western states supporting cougar populations, management of cougar habitat, by default, results from the habitat management of prey populations for sport harvest (Anderson 1983a).

However, this does not imply that unrestricted timber harvest will continually benefit cougar populations. Of primary importance is the maintenance of adequate stalking cover. An associated concern is the resultant fragmentation of habitats to the point where travel within an animal's home range dictates movement through areas of little or no cover. This may increase the probability of under use of habitats, even though substantial prey populations exist. Finally, impacts of human activities and encroachment resulting from timber management on cougar habitat use must be considered.

HUMAN DISTURBANCE AND COUGAR HABITAT USE

Western North America has undergone profound habitat alterations since the turn of the century. The forested landscapes which support cougar populations have experienced extensive change, primarily as a consequence of forest management. Only a small percentage of the areas occupied by cougars in forested habitats are in a pristine state (Anderson 1983a).

In the Pacific Northwest, intensive forest management has reverted late successional stages to early, and accelerated the rate of seral change. The resultant mosaic of timber stands of differing age classes, especially on federal lands, has produced substantial increases in deer populations. In general, the most productive deer habitats in western North America are characterized by timber stand age class diversity. Cougars invariably utilize habitats which produce deer, their major prey species (Anderson 1983a); therefore, productive deer habitat has been assumed to define productive cougar habitat.

However, cougars in managed forests are potentially impacted by habitat alterations, human disturbances, human access to once remote areas, and vulnerability to human-induced mortality. Loss of suitable habitat, unrestricted cougar harvest, and increased human accessibility into cougar habitats have been implicated in the cougar's rapid decline over its former range. However, the impacts of habitat alterations and human disturbances on cougar habitat use are virtually undocumented. Only one published study has addressed cougar responses to the alterations and disturbances associated with forest management (Van Dyke et al. 1986a).

In western Oregon, intensive forest management has drastically changed the proportional and spatial relationships of successional stages on forest lands. Human disturbance (harvest activities, road construction and use, and habitat alterations) increased significantly as a direct consequence of forest management conducted on commercial and public timber lands. The potential impacts of human-induced disturbance (displacement from habitat, higher mortality rates) on cougars may also increase. The impacts of the interaction between cougars and human activities in Oregon can only gain in importance as human recreational and commercial use of forest lands increases.

The purpose of this study was to examine how habitat alterations and human disturbances impacted cougar habitat use in the west side of the Cascade Range of Oregon. The research evaluated cougar use (or avoidance) of habitats altered by forest management practices, and assessed associations of human disturbances (forest management activities, road system densities and use, recreational use) with the habitat use of an exploited cougar population in a managed forest.

METHODS

[To reduce redundancy, methods which describe the capture, immobilization, number of cougar treed and radio collared, and telemetry data collection can be found in Chapter Two's method section.]

Data Collection

Telemetry data were collected as independent and sequential locations. Independent data were collected on a randomized schedule, with locations obtained from the ground and air. Ground telemetry locations were determined from the use of a hand held yagi antenna and portable receiver. Data were also collected from fixed wing aircraft equipped with yagi antennae attached to each wing strut. Longitude and latitude coordinates of animal locations were determined with the aircraft's LORAN navigational system. Sequential locations were collected from the ground, and were spaced over a period of 24 to 36 hours. A minimum of 2 continuous monitoring periods (CMP) were collected for each animal.

The study area was divided into 65 square 5000 meter UTM (Zone 10) coordinate system blocks. A FORTRAN program was written that generated 25 random UTM northing and easting pairs for each 25 km^2 block. Independent and sequential locations were developed as described in Chapter

Two.

Classifications of Human Disturbance

Human disturbances were classified as on-going forest management activities, including final timber harvest, and commercial and pre-commercial thinning. Location, date, and type of activity were obtained from U.S. Forest Service (USFS) total resource inventory (TRI) files, Bureau of Land Management (BLM) activity records, and Oregon Department of Forest Protection (ODFP) information files. Activities occurring during 1986 and 1987 were located, typed, and plotted on USGS and USFS topographic maps, and then digitized relative to their respective 5000 meter UTM blocks.

Another primary category of human perturbations examined was the forest road system. This system's impact was investigated in relation to road location, type, and densities, active construction, commercial use, and recreational use. Road systems for each 25 km^2 block were classified into 4 road types (paved, arterial, feeder, and spur). Road systems were digitized for each 5000 meter UTM block from USGS and USFS road maps, and typed according to category.

Other categories of human disturbance included riparian area campgrounds and permanent residences or ranches. These areas were determined from USGS, BLM, or USFS topographic maps, classified to type, and digitized within their respective 25 km^2 block.

Distance Measures to Human Disturbances

Independent telemetry and random test locations were combined with each category of human disturbance in digital form. A FORTRAN program was developed to determine minimum distances to each disturbance type. For forest management activities, a minimum distance for each data point (random or actual) was calculated for every disturbance. Therefore, any one data point could potentially have several minimum distances associated with it for human disturbances. The categories of riparian area campgrounds and permanent residences or ranches were analyzed in the same manner. All categories of activities were included in nearest distance measures if telemetry locations were within 5000 meters of activity and occurred during the period of activity. Impacts of road systems were analyzed by type of road and all types pooled, with only one nearest distance measure being performed for any data point within 5000 meters. Averages of all categories of human disturbance for random and actual distances were calculated for individual animals, as pooled averages by sex, and as overall averages. Additionally, occurrences of random and actual locations were computed in five consecutive 1000 meter bands from all categories of human disturbances in the same manner.

Statistical Analysis

T-tests were conducted to determine if statistical differences existed between mean actual and random distances to disturbance type. Because of unequal sample size between actual and random locations, pooled variances were utilized in all tests. A FORTRAN program was developed which performed chi square analyses to determine if number of actual occurrences differed significantly from random within each of five 1000 meter band from the perturbation.

Movement Patterns Relative to Human Disturbances

Continuous monitoring periods (CMP) were conducted during peak levels of human activity (opening days of hunting seasons, ongoing forest management activities, holidays), and during periods when human activities were at or below normal levels (mid-week, forest road closures). Digital elevation models (DEMs) were developed as described in Chapter Three. The UTM coordinates of the CMP's were incorporated into the DEM's, and described in relation to all categories of human perturbations presumed to have a direct impact on cougar habitat use. CMP's conducted during higher levels of human activities were compared to those conducted during lower levels of activity. Cougar movement patterns were described visually, and contrasted to determine if cougars actively avoided habitats impacted by these human perturbations. Straight line distances for each animal's CMP were determined between successive locations, and calculated in terms of distances traveled per unit of time and time of day (dusk, dawn, day, night). T-tests were performed to determine if distances traveled varied among time of day and levels of disturbance between groups pooled by sex.

RESULTS

Distance and Occurrence Measures

<u>Harvest Activities</u>. - When pooled, females and males exhibited significant (P<0.051 and P<0.026 respectively) differences between mean and random distances, while all animals pooled produced no significant differences (Table 4.1). Mean actual distances for all females were slightly larger (3082.1m) than mean random distances (3051.6m). Mean actual distances for all males were smaller (3061.7m) than mean random distances (3121.0m). Individually, male 5, female 1, and female 8 exhibited no significant differences between actual and random distances. Female 2 had significantly (P<0.009) smaller mean random (3059.6m) distances than mean actual (3146.5m) distances. Male 9 showed significantly (P<0.023) smaller mean actual (3013.5m) distances than mean random (3108.1m) distances.

Significant (P<0.005) differences were indicated from chi square analyses between zones for all animals pooled (Table 4.2). Simultaneous confidence intervals indicated that zone 1 had significantly more actual than random locations, while zones 2, 3, 4, and 5 exhibited no

Table 4.1: T-test values and significance levels of differences between actual and random distances to campgrounds, permanent residences, harvest activities, forest road system, and riparian areas.

	CAMP GROUNDS	*PERMANENT RESIDENCES*	*HARVEST ACTIVITIES*	*ALL ROAD TYPES*	*PAVED ROADS*	*ARTERIAL ROADS*	*FEEDER ROADS*
FEMALE1	1.587	3.369	0.934	-0.551	0.766	0.965	-2.434
	0.113	* 0.001	0.351	0.582	0.444	0.335	0.150
FEMALE2	2.376	2.775	2.607	0.141	0.985	-1.523	-0.309
	* 0.018	* 0.006	* 0.009	0.888	0.326	0.128	0.757
FEMALE8	-0.617	1.579	-0.402	-2.129	-4.804	-2.930	-2.351
	0.538	0.115	0.687	* 0.034	* 0.000	* 0.004	0.019
MALE5	0.028	-0.279	-1.006	-0.012	0.230	-1.712	0.642
	0.978	0.781	0.314	0.991	0.819	* 0.087	0.521
MALE9	-0.647	1.717	-2.273	-0.287	-1.855	0.471	0.376
	0.518	* 0.086	* 0.023	0.774	* 0.064	0.638	0.707
ALL FEMALE	1.775	4.403	1.950	-1.752	-2.353	-2.330	-3.197
	0.076	* 0.000	* 0.051	* 0.080	* 0.019	* 0.020	0.001
ALL MALE	-0.504	1.267	-2.232	-0.190	-1.362	-0.920	0.735
	0.614	0.205	* 0.026	0.849	0.174	0.357	0.462
ALL ANIMAL	0.917	3.967	-0.697	-1.990	-3.426	-3.093	-2.152
	0.359	* 0.000	0.486	* 0.047	* 0.001	* 0.002	0.031

Table 4.1

Table 4.2: Significance of differences between proportion of actual and random locations falling within successive 1000m bands from camp grounds, permanent residences, harvest activities, and roads for all cougars and cougars pooled by sex.

	CAMP GROUNDS	PERMANENT RESIDENCES	HARVEST ACTIVTIES	ALL ROAD TYPES	PAVED ROADS	ARTERIAL ROADS	FEEDER ROADS	SPUR ROADS
ALL FEMALES	P<0.05	NS	NS	NS	P<0.10	NS	NS	P<0.10
{0-1000}	IP				IP			IP
{1001-2000}	IP				IP			IP
{20001-3000}	IP				IP			IP
{3001-4000}	IP				IP			SL
{4001-5000}	IP				SL			IP
ALL MALES	NS	P<0.025	P<0.005	NS	NS	NS	NS	NS
{0-1000}		SL	SM					
{1001-2000}		IP	IP					
{20001-3000}		IP	IP					
{3001-4000}		IP	IP					
{4001-5000}		IP	IP					
ALL ANIMALS	P<0.025	NS	P<0.005	P<0.025	P<0.005	P<0.025	NS	P<0.025
{0-1000}	IP		SM	SM	IP	SM		IP
{1001-2000}	SM		IP	SL	IP	IP		IP
{20001-3000}	IP		IP	SL	IP	SL		IP
{3001-4000}	IP		IP	SL	IP	SL		IP
{4001-5000}	IP		IP	IP	SL	IP		SL

Table 4.2

differences between number of actual and random locations. There were no differences among zones when females were pooled. When males were pooled zone 1 had more actual points than expected. The remaining zones exhibited no difference between the number of actual and random locations. Individually, female 2, female 8, and male 5 produced no significant differences among zones. Female 1 and male 9 indicated significant differences among zones. For male 9 and female 1, zone 5 had fewer actual locations than expected, while the remaining zones exhibited no differences between the number of actual and random locations (Table 4.3).

All Road Types. - Mean cougar distance (240.1m) to all road types for all animals pooled was significantly less ($P<0.047$) than mean random distance (280.7m) (Table 4.1). Results pooled by sex varied. Pooled males exhibited no significant difference in mean distances, while females were located significantly ($P<0.08$) closer (204.9m) to roads than were random locations (238.4m). Individually, all animals except female 8 exhibited no significant differences in actual versus random mean distances to roads. Female 8 was significantly ($P<0.034$) closer to roads (149.4m) than random locations (214.9m).

Chi-square analysis of data from all cougars pooled revealed significant differences ($P<0.025$) of cougar use among zones (Table 4.2). Simultaneous confidence intervals

Table 4.3: Significance of differences between proportion of actual and random locations falling within successive 1000m bands from camp grounds, permanent residences, harvest activities, and roads for individual cougars

	CAMP GROUNDS	PERMANENT RESIDENCES	HARVEST ACTIVITIES	ALL ROAD TYPES	PAVED ROADS	ARTERIAL ROADS	FEEDER ROADS	SPUR ROADS
FEMALE1	NS	P<0.01	P<0.005	NS	P<0.005	NS	NS	NS
{0-1000}		IP	IP		IP			
{1001-2000}		SM	IP		IP			
{20001-3000}		IP	IP		IP			
{3001-4000}		IP	IP		IP			
{4001-5000}		IP	IP		SL			
FEMALE2	P<0.025	NS	NS	NS	NS	NS	NS	P<0.10
{0-1000}	IP							IP
{1001-2000}	IP							IP
{20001-3000}	IP							IP
{3001-4000}	IP							SL
{4001-5000}	IP							IP
FEMALE8	NS	P<0.025	NS	NS	P<0.005	NS	NS	P<0.005
{0-1000}		IP			SM			IP
{1001-2000}		SM			IP			SM
{20001-3000}		IP			IP			SL
{3001-4000}		IP			SL			SL
{4001-5000}		IP			SL			IP
MALE5	NS	NS	NS	NS	NS	NS	NS	NS
{0-1000}								
{1001-2000}								
{20001-3000}								
{3001-4000}								
{4001-5000}								
MALE9	NS	P<0.01	P<0.005	NS	NS	NS	NS	NS
{0-1000}		SL	IP					
{1001-2000}		IP	IP					
{20001-3000}		IP	IP					
{3001-4000}		IP	IP					
{4001-5000}		IP	SL					

Table 4.3

indicated that zone 1 had significantly more cougar than random locations, while zones 2, 3, and 4 had significantly fewer cougar locations than random. There were no significant differences between cougar and random locations within Zone 5. When cougar locations were pooled by sex, or evaluated individually, there were no significant differences between cougar and random proportions of locations within any of the zones (Tables 4.2, 4.3).

Paved Roads. - Mean distance to paved roads for all cougar locations pooled (1948.2m) was significantly ($P<0.001$) shorter than random (2278.1m) (Table 4.1). Mean distance to paved roads for pooled males was not significantly different from random, whereas mean distance for pooled females (1846.6m) was significantly ($P<0.019$) smaller than random (2121.29 m). Individually, female 8 and male 9 were significantly closer ($P<0.000$ and $P<0.064$ respectively) to paved roads, whereas females 1 and 2 and male 5 were neither closer to nor farther from paved roads than random locations (Table 4.1).

Chi-square analysis revealed that there were significant ($P<0.005$) differences of proportions of locations within 1,000m zones between pooled locations of all cougars and random locations (Table 4.2). Zone 5 had significantly fewer cougar locations than random and the remaining zones exhibited no differences between proportions of cougar and random locations. Proportions of pooled male locations in 1,000m bands were not significantly different from random locations, whereas proportions of pooled female locations were significantly fewer than random in zone 5. Two individual females exhibited use of zones different from random. Female 1 used zone 5 proportionally less than random, and female 8 had proportionally more locations in zone 1 and proportionally less in zones 4 and 5 than random (Table 4.3).

Arterial Roads. - Mean distance to arterial roads for all cougar locations pooled (491.4m) was significantly less ($P<0.002$) than mean random distance (605.6m) (Table 4.1). Mean distance of pooled males was not significantly different from mean random distance, whereas pooled mean distance for females (425.9m) was significantly ($P<0.02$) shorter that mean random distance to arterial roads (511.5m). For some individual cougars, mean distances to arterial roads were significantly different than mean random distances. Male 5 (actual = 564.0m, random = 744.9m) and female 8 (actual = 298.9m, random = 430.9m) showed significantly smaller mean actual distances ($P<0.087$ and $P<0.004$ respectively), while differences between means for females 1, female 2, and male 9 were insignificant.

Chi-square analysis of proportion of points from all animals pooled exhibited a significant difference ($P<0.025$) among zones (Table 4.2). Simultaneous confidence intervals indicated that zone 1 had significantly more actual than random locations, while zones 3 and 4 had significantly fewer actual locations. Zone 2 exhibited no significant differences between number of actual and random locations. When pooled by sex, or by individual animals, no significant differences were apparent among zones (Tables 4.2, 4.3).

Feeder Roads. - All animals pooled produced significantly smaller ($P<0.031$) mean actual distances (431.4m) than mean random distances (487.9m) (Table 4.1). All males pooled indicated no significant difference in mean distances, while females exhibited a significant ($P<0.001$) difference between actual and random distances (377.9m and 475.2m respectively). Individually, only female 8 showed significant differences ($P<0.019$) (actual = 316.8m, random = 432.8m), while differences between means for the remaining animals were insignificant.

Chi-square analyses indicated no significant differences between the number of actual versus random locations among zones from feeder roads (Tables 4.2, 4.3). The lack of significance was constant regardless of grouping or individual.

Spur Roads. - Mean distances to spur roads between actual and random locations for all groupings (all animals, males, and females pooled) were insignificant (Table 4.1). Individually, mean distances for every animal also exhibited no significant differences.

Significant differences ($P<0.025$) were present between zones when all animals were pooled (Table 4.2). Analyses indicated zone 5 had fewer actual locations than expected, while the remaining zones exhibited the no difference between the number of actual and random locations. When pooled by sex, males showed no significant differences among zones (Table 4.2). When pooled by sex, females demonstrated significant differences among zones, with zone 4 having fewer actual points than expected. The remaining zones showed no difference between the number of actual and random locations among zones. Individually, female 1, male 5, and male 9 produced no significant differences among zones. Female 2 and female 8 indicated significant differences among zones. For female 2, zones 1 through 3 and 5 exhibited no differences between the number of actual and random locations, while zone 4 had fewer actual locations than expected (Table 4.3). Female 8 showed more actual locations in zone 2 than expected, with zones 1 and 5 indicating no differences in numbers. Zones 3 and 4 produced fewer actual locations than expected.

Camp Grounds. - Mean actual distances to camp grounds for all animals and all males pooled exhibited no significant difference from mean random distances (Table 4.1). Analysis of all females indicated a significantly ($P<0.076$) smaller mean random distance (3249.7m) than mean actual distance (3357.9m). Individually, only female 2 exhibited a significant difference between actual (3491.7m) and random (3194.9m) means. No other animal exhibited a significant difference between actual and random means.

Chi square analyses demonstrated significant differences ($P<0.025$) between zones when all animals were pooled (Table 4.2). Zone 2 had more actual locations than expected, while the remaining zones exhibited no difference between the number of actual and random locations (Table 4.2). When pooled by sex, males showed no significant differences among zones (Table 4.2). Females resulted in significant differences among zones, with zone 5 having fewer actual points than expected. The remaining zones showed no difference between the number of actual and random locations among zones. Individually only female 2 indicated differences among zones (Table 4.3). Zones 1 through 3 and 5 exhibited no differences between the number of actual and random locations, while zone 4 had fewer actual locations than expected.

Permanent Residences. - All animals pooled produced significantly ($P< 0.001$) smaller mean random distances (3302.9m) than mean actual distances (3024.8m) (Table 4.1). All males pooled indicated no significant difference in mean distances, while females exhibited a significant ($P<0.001$) difference between actual (3372.3m) and random (2929.7m) distances. Individually, female 1, female 2, and male 9 showed significantly smaller mean random differences ($P<0.001$, $P<0.006$, and $P<0.086$ respectively), while differences between means for female 8 and male 5 were insignificant.

Chi square analyses indicated no significant differences between zones when all animals or females were pooled (Table 4.2). Pooled males resulted in significant (P<0.025) differences among zones. Zone 1 had fewer actual points than expected; the remaining zones showed no difference between the number of actual and random locations among zones. Individually, female 2, and male 9 produced no significant differences among zones. Female 1, female 8, and male 9 indicated significant differences among zones. For female 1, zone 2 had more actual locations than expected, while the remaining zones exhibited no differences between the number of actual and random locations (Table 4.3). Female 8 showed more actual locations in zone 2 than expected, with zones 1, and 3 through 5 indicating no differences in numbers. Male 9 exhibited less actual points in zone 1, while all other zones indicating no difference.

Movement Patterns

Continuous Monitoring Periods. - Cougars utilized areas of their home ranges during high levels of human activities in the same manner as during low levels of human disturbances. Continuous monitoring periods demonstrated cougar movements with apparent disregard to commercial use of forest road systems, harvest activities, recreational use of road systems, camp grounds, and permanent residences

(Appendix B). Figures 4.1-4.2 demonstrate female 8's movement patterns during a period of high disturbance (opening day of deer season) and one of low disturbance (forest closure in effect due to fire hazard). In both instances, movements were quite similar in relation to crossing active roads and travelling in proximity to active riparian area camp grounds. Figures 4.3 - 4.4 demonstrate cougar movements in relation to ongoing harvest activities, while Figures 4.5 - 4.6 exhibit movements in relation to active camp grounds and permanent residences. Additional examples are presented in Appendix B.

No significant differences were detected in mean distances travelled per hour between CMP's conducted during high versus low levels of disturbance. This was true regardless of pooled combination.

DISCUSSION

Distance Measures to Human Disturbances

Avoidance of ongoing harvest activities was not demonstrated by t-tests. Mean actual distances were smaller for all males pooled, and within telemetry error estimations for all females pooled. Pooling all animals produced no significant differences between random and actual mean distances. Individually, a similar pattern was displayed. Chi square analysis also indicated no active avoidance of

Figure 4.1: Continuous monitoring period of female 8 during opening of black tail deer season (high disturbance level) (shaded = active harvest areas, solid circles = active camp grounds, solid squares = permanent residences).

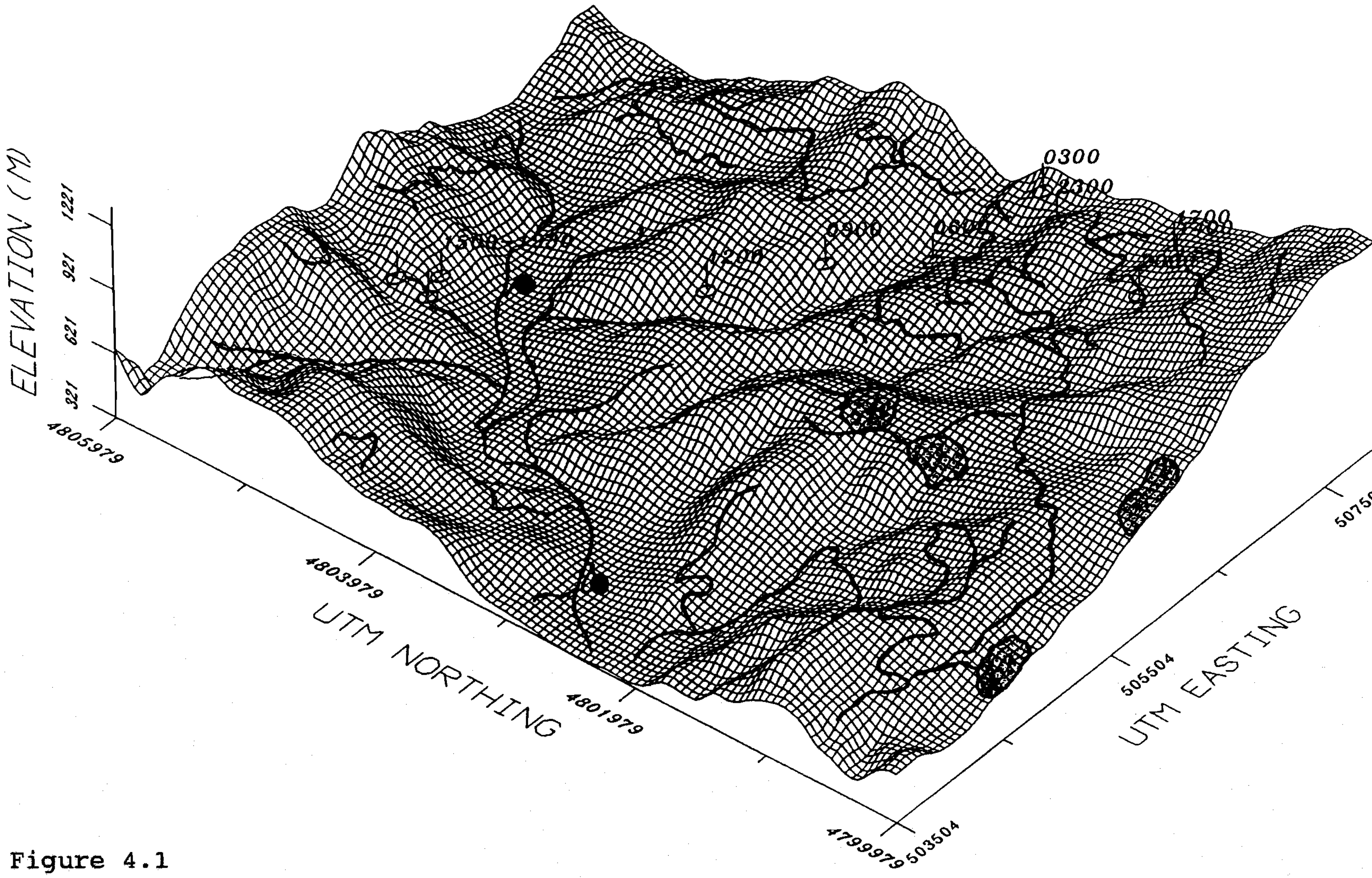

ELEVATION (M)
321
621
921
1221
4805979
4803979
4801979
4799979
UTM NORTHING
503504
505504
507504
UTM EASTING
0300
2300
1700
0900
1200

Figure 4.1

Figure 4.2: Continuous monitoring period of female 8 during forest closure due to fire hazard (low disturbance level). (shaded = active harvest areas, solid circles = active camp grounds, solid squares = permanent residences).

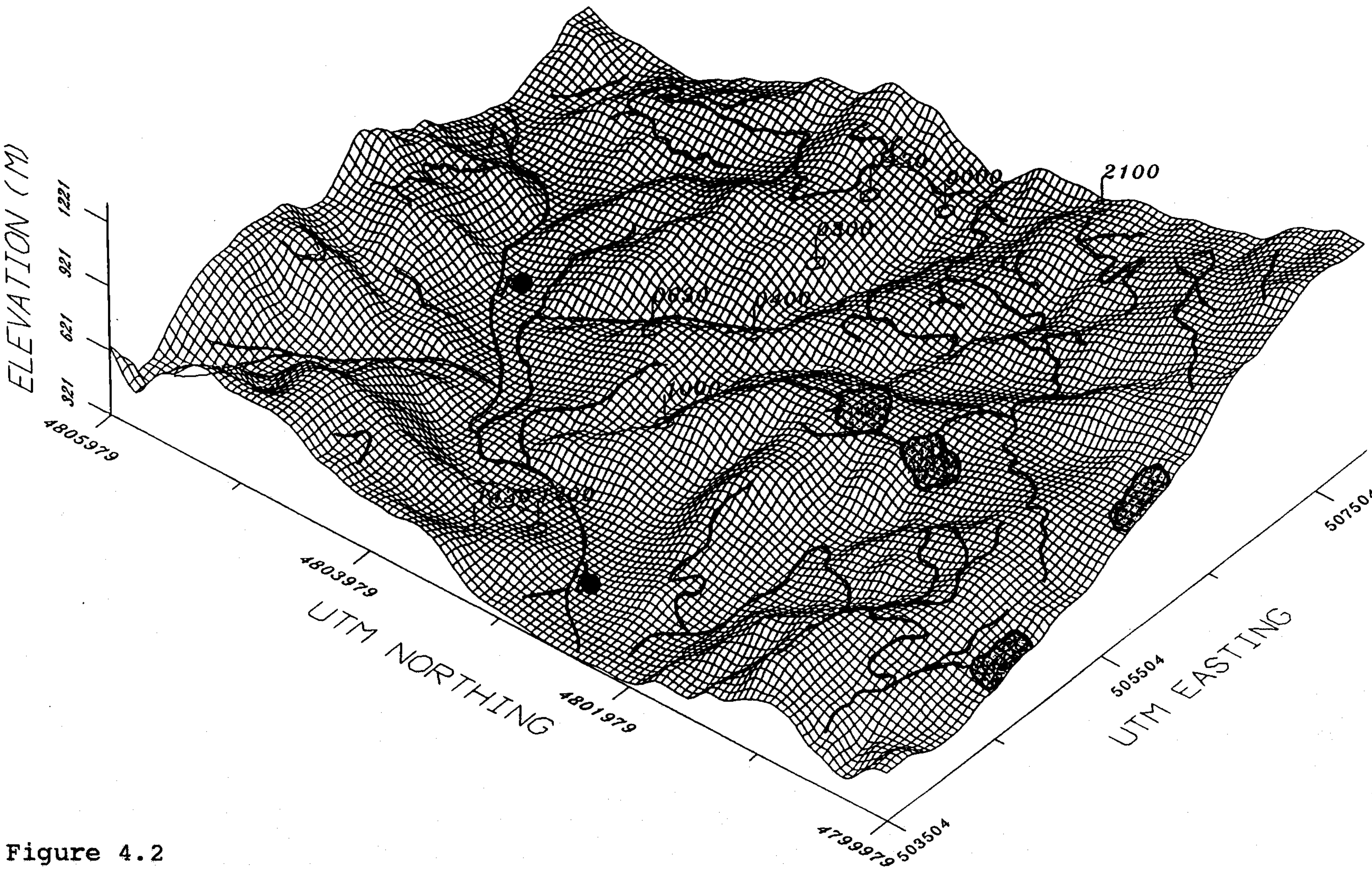

ELEVATION (M)
1221
921
621
321
4805979
4803979
4801979
4799979
UTM NORTHING
503504
505504
507504
UTM EASTING
2100

Figure 4.2

Figure 4.3: CMP of female 1 during human disturbances (shaded = active harvest areas, solid circles = active camp grounds, solid squares = permanent residences).

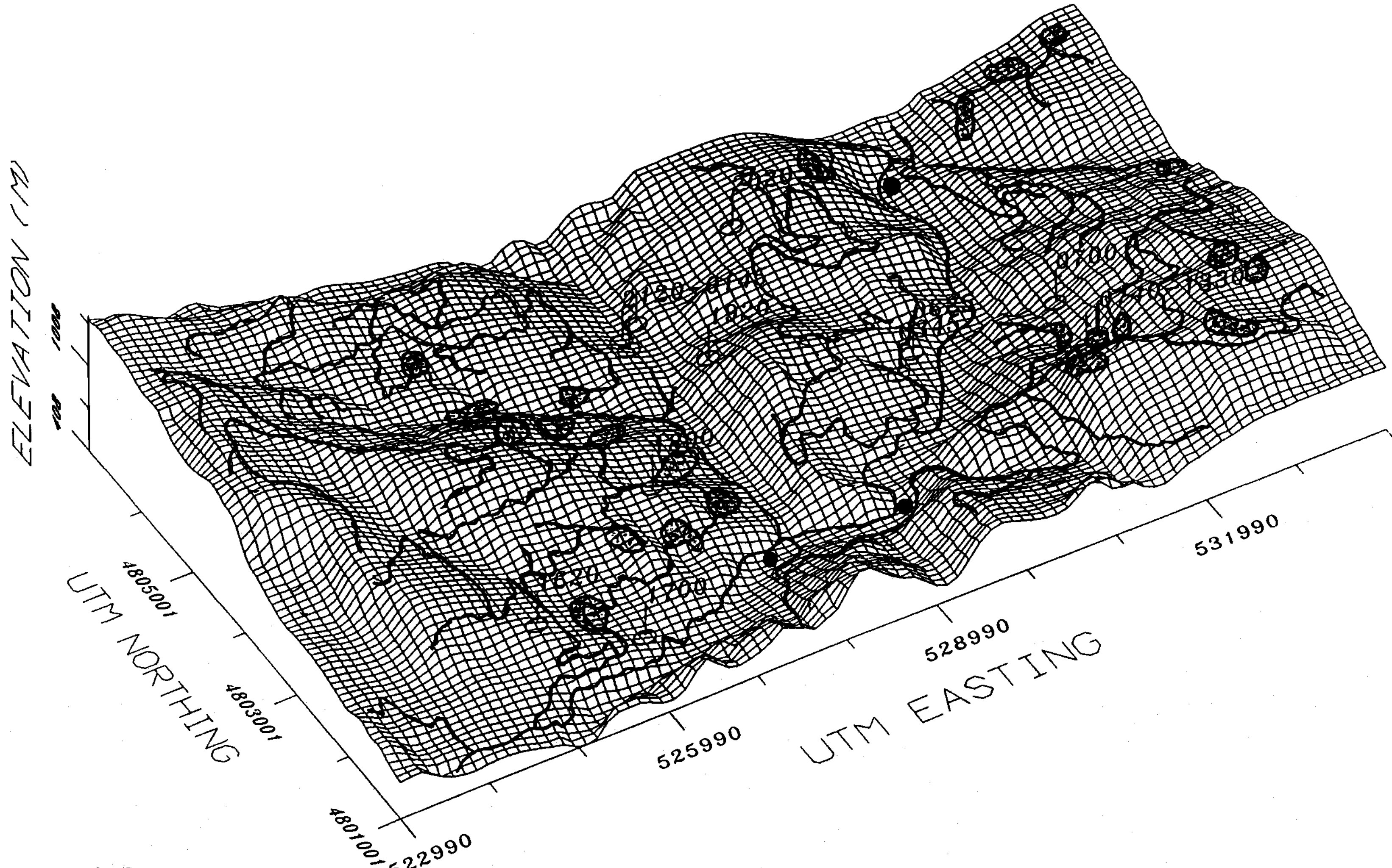
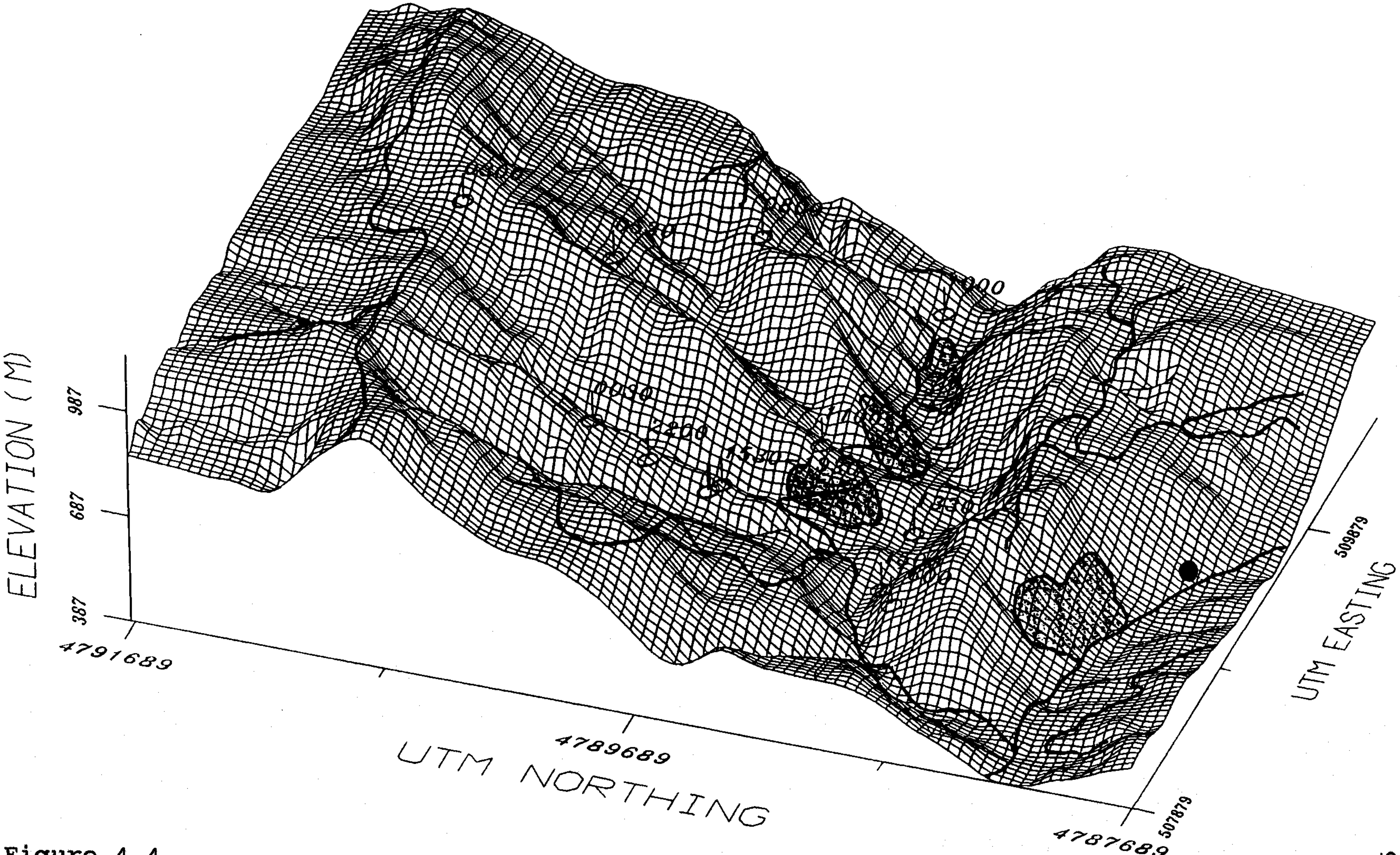

ELEVATION (M)
UTM NORTHING
4805001
4803001
4801001
UTM EASTING
522990
525990
528990
531990

Figure 4.3

Figure 4.4: CMP of male 9 during human disturbances (shaded = active harvest areas, solid circles = active camp grounds, solid squares = permanent residences).



ELEVATION (M)
987
687
387
4791689
4789689
4787689
UTM NORTHING
509879
507879
UTM EASTING

Figure 4.4

Figure 4.5: CMP of female 1 during human disturbances (shaded = active harvest areas, solid circles = active camp grounds, solid squares = permanent residences).

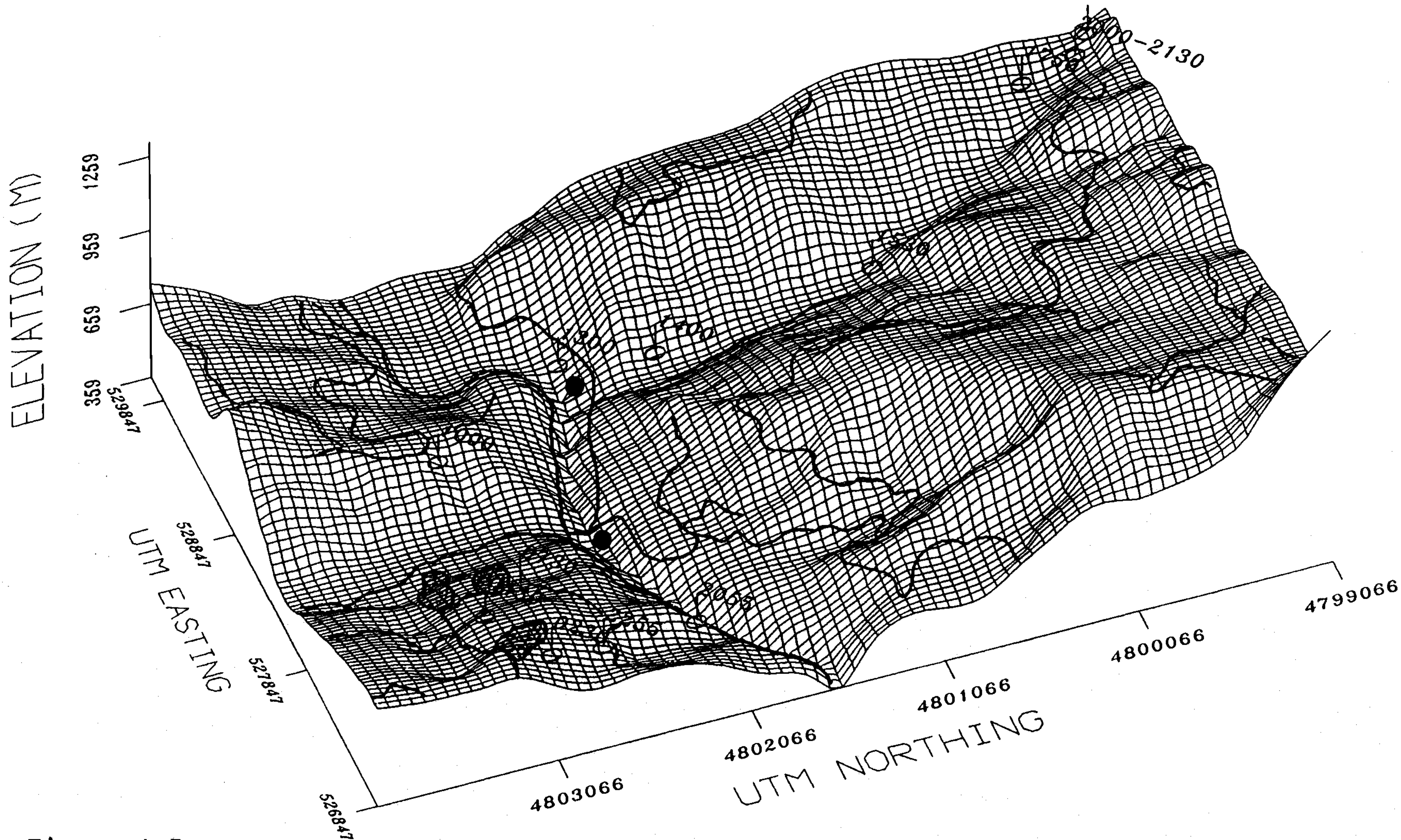

ELEVATION (M)
359
659
959
1259
UTM EASTING
529847
528847
527847
526847
UTM NORTHING
4803066
4802066
4801066
4800066
4799066

Figure 4.5

Figure 4.6: CMP of male 9 during human disturbances (shaded = active harvest areas, solid circles = active camp grounds, solid squares = permanent residences).

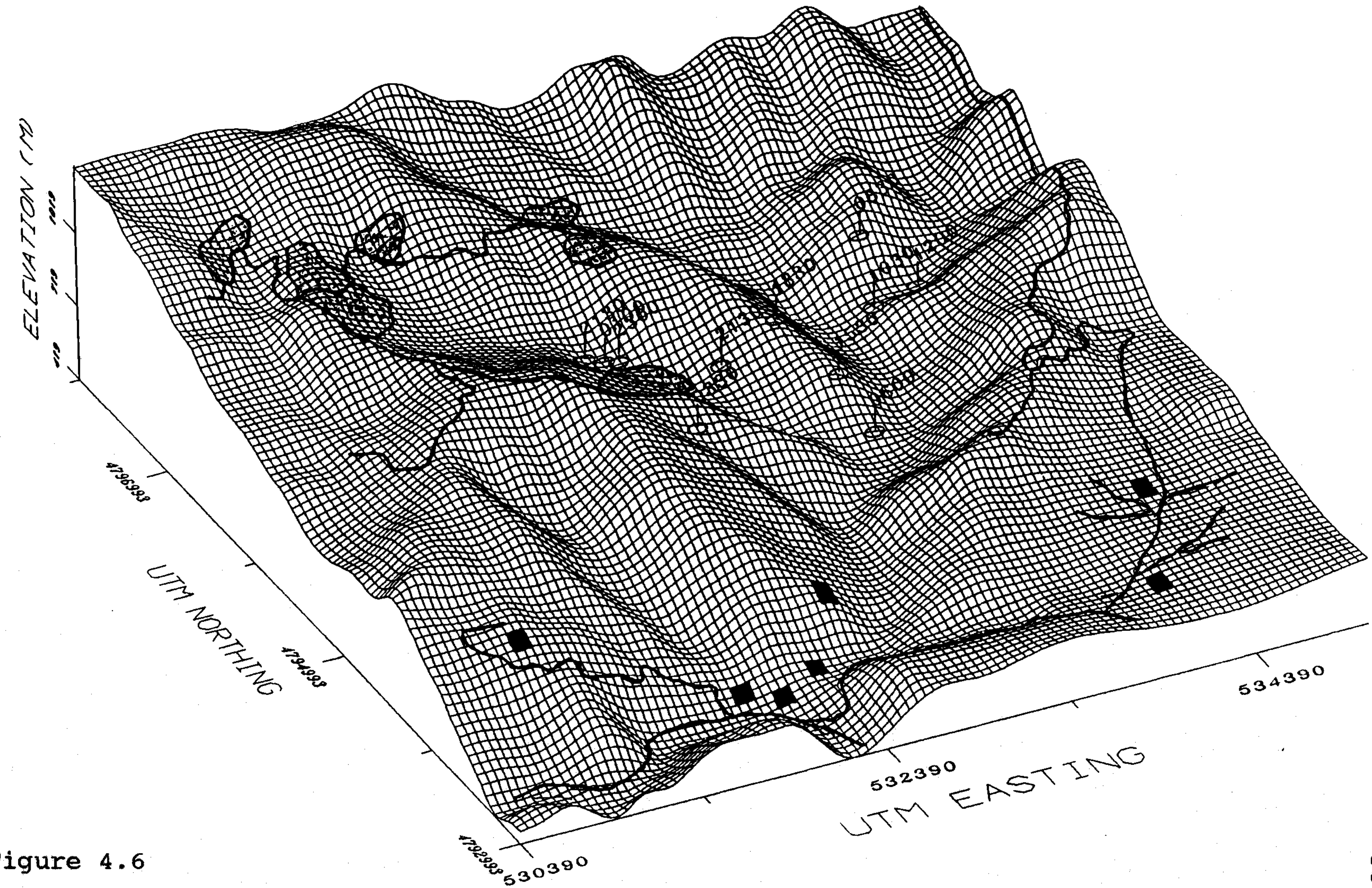

ELEVATION (M)
UTM NORTHING
4796993
4794993
4792993
UTM EASTING
530390
532390
534390

Figure 4.6

ongoing harvest activities. When significant differences were detected between number of actual and random points in 1000m zones zone 1 consistently had more actual points than expected. This zone would be expected to have significantly fewer actual points than random if avoidance of harvesting was exhibited by cougars.

Only one other published study has addressed cougar habitat use in relation to human disturbances (Van Dyke et al. 1986a). Results reported here contradict those results. Van Dyke et al. (1986a) reported that resident cougars were rarely found in or near logged sites, and that avoidance was active for up to 6 years following the disturbance. Habitat analyses support this concept of under-utilization of recently clearcut areas, however distance measure tests indicated no pattern of active avoidance. Van Dyke et al. (1986a) utilized preference-avoidance for "harvest zones" based only on whether cougars were located in, within 1 km, or not in active or inactive harvest zones. I hypothesize that an additional reason for the contradictory results between Van Dyke et al. (1986a) and this study is difference in study area vegetation, particularly as related to stalking cover. Cougars in western Oregon apparently have enough available cover to utilize habitats in immediate proximity to active harvest sites. Indeed, one would anticipate results similar to those presented by Van Dyke et al. (1986a) had the study area been located farther south where vegetation types change to the typical conifer associations of northern California, or in eastern Oregon, where vegetation types and topography are radically different. The high degree of understory vegetation in western Oregon may be a primary habitat feature which affords cougars access to the majority of a cougar's home range at the current levels of human disturbances.

Distance Measures to Road Systems

Cougars demonstrated the same statistical pattern of non avoidance in relation to road systems as with harvest activities. T-tests indicated that mean distances for all cougars locations pooled were consistently less than random distances. Chi square analyses supported the t-test results, that cougars were significantly closer to roads that expected.

Again, results reported here contradict those previously published (Van Dyke 1983, Van Dyke et al. (1986a), Van Dyke et al. (1986b) that cougars usually resided in areas with lower than average road densities. In addition to differences in vegetation previously discussed, road densities in Oregon approach 6-10 times the values reported in Van Dyke et al. (1986b). This may result in cougars being forced into crossing road systems to make use of major portions of their home ranges.

Distance Measures to Camp Grounds and Permanent Residences

Statistically, tests of distance measures to camp grounds and permanent residence are suggestive of avoidance. Mean random distances are generally less than mean actual distances. Chi square results were not as consistent; there existed differences among zones between number of expected and observed locations, however simultaneous confidence intervals generally indicated significantly more or fewer actual locations only in the last 3 zones, male 9 and all males pooled being the exceptions.

These results agree with Van Dyke et al. (1986a, 1986b) in that areas of permanent residences are actively avoided. However, the placement of camp grounds, permanent residences, and cougar home ranges within the study area may have influenced the distance estimates. The home range boundaries of these animals tended to be defined by a topographic feature, the most predominant were large rivers and numerous drainages. Camp grounds are invariably placed along riparian areas; consequently the majority of campgrounds in the study area are located along the outer boundaries of the study animal's home ranges. By definition, these areas would be less used in relation to the other areas of the home range. Small sample sizes may preclude any certainty when commenting on habitat use and distance measures to features on the extremes of an animal's home range.

Movement Patterns

Results from the continuous monitoring periods strongly reinforce the significant findings that cougars in western Oregon, at the levels of disturbance experienced in the study area, do not under-utilize habitat in close proximity to human activity nor do they actively avoid human disturbances. CMP's conducted during periods of high disturbance were similar to CMP's conducted during low disturbance periods. Cougars moved through their home ranges in close proximity to active harvest, vehicular traffic, active campgrounds, and permanent residences.

Results are contrary to those reported by Van Dyke et al. (1986a,b). Those authors reported that human activity, increased road densities, and associated increases in human access contribute to avoidance by cougars. Movement data do not suggest that these patterns are present in western Oregon, most probably a function of high availability of cover. Additionally, Van Dyke et al.'s (1986b) contention that a cougar's ability to adjust its activity pattern may be an important behavioral compensation for dealing with human disturbances is a valid conclusion. This may be demonstrated by the increase in distances traveled by females during the night and dusk time periods. However, no significant differences in distances travelled per hour were found between CMP's conducted during high and low levels of disturbances.

Management Implications

At the levels of human disturbance and habitat alteration experienced in the study area, statistical tests and observational data suggested no under-utilization of impacted habitats by cougars . However, it would be erroneous to equate these results with humans having no impact on cougar populations. Cougars in managed forests are potentially impacted by increased habitat alteration, human disturbance, access to once remote areas, and vulnerability to human induced mortality.

The primary impact of human activities and access on cougar populations in this study was human induced mortality. Of the 8 animals successfully collared, only one was confirmed alive at the end of the study. Human induced mortalities were confirmed in 3 animals, and suspected in 3 others. Similar rates of human induced mortalities were reported in Washington state (pers. commun. WA. Dept. Nat. Res. Biol. D. Brittell).

In addition to the negative impact on cougar social structure outlined in Chapter 2, populations in southwest Oregon may be adversely impacted by the current levels of human induced mortalities for several reasons. These include a high level of legal harvest supported by ODFW biologists, an unknown amount of illegal mortality, unknown population parameters such as recruitment and mortality rates, extensive forest road systems into once inaccessible areas, and pressure from ranchers in the area to alleviate sheep depredations.

Cougar densities in the study area may be overestimated because they were generated from an cervid population model untested for cougar populations (ODFW 1987, ODFW harvest statistics). The estimates derived by the ODFW from a general cervid model may be inflated due to the primary assumption of the model that recruitment into cougar populations equals mortality (ODFW 1987, ODFW harvest statistics). Certainly, this assumption cannot remain valid for cougar populations over all levels of mortality (Sheriff 1987). Additionally, the fact that cougar populations tend to be regulated more by territoriality than a herbivore may result in substantially different population dynamics (Fowler, 1981).

Illegal kills of cougars (both for harvest and preventing depredation) constitute a large source of mortality; it is estimated to equal or exceed the numbers harvested legally (pers. commun. Oregon State Police). In this study, confirmed illegal mortalities accounted for at least 35 percent of the mortality, a figure consistent with the levels experienced in Washington (pers. commun. WA. Dept. Nat. Res. Biol. D. Brittell). Illegal harvest, coupled with sport hunting, may be additive in nature and disrupt cougar social structures, reduce population densities, and inhibit a population's ability to respond to harvest. Considering the ODFW have no valid estimations of population densities, recruitment rates, or total mortality rates, the combined impact of these mortality sources could be substantial and detrimental.

The road densities in the study area precluded movements of cougars without necessitating a crossing. When a cougar crossed a road, the chance of its being successfully hunted (legally or illegally) increased dramatically. The likelihood of harvest is increased, not only for the time of immediate association with the road, but up to 2 days afterward, depending on weather conditions, tracking medium, and quality of hound. Coupled with high numbers of tags and illegal mortalities, the impact on cougar populations is a substantial increase in the probability of human induced mortality.

The number of damage complaints against cougars has been used as an indicator of population status (ODFW 1987). The ODFW consistently insist that cougar populations on public lands are increasing because of the increases in damage complaints on private lands (ODFW 1987). However, in light of this research's findings that cougars in western Oregon apparently have enough cover available to them to utilize habitats impacted by humans, the number of damage complaints as an indicator of population status may not be valid. The ranches are typically located in the private lands in the foothills of the Cascades. These lands tend to have higher than average prey populations due to the restrictive nature of landowners, the majority disallowing hunting on their lands. The habitats are also interspersed with forested stands, and provide ideal cougar habitat. It is my speculation that high rates of damage complaints result from cougars resident to the privately owned lands. Sport hunting of cougars is restricted almost exclusively to public lands. Therefore, the ODFW policy of increasing tags will do little to alleviate damage complaints, as evidenced by the continual increase in damage complaints (ODFW 1987). This contradiction has not been addressed by ODFW biologists who have supported a limited number of special hunts, but with no reduction in the number of tags issued during the regular season (ODFW 1987, ODFW harvest statistics).

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APPENDICES

APPENDIX A: TELEMETRY ERROR ESTIMATIONS

Telemetry errors were determined in two manners. First, transmitters were placed in known locations throughout the study area. Efforts were made to utilize all possible situations encountered during actual telemetry activities. Bearings were taken from known locations, and converted into UTM coordinates utilizing digitizing software and hardware. These "tower locations" were input into available software which utilized the Andrews estimator to calculate X and Y UTM coordinates for the telemetry locations. Transmitter locations were converted into UTM coordinates in a similar manner. Distances between transmitter and radio telemetry locations were calculated, and averaged to gain an estimate concerning the average distance a telemetry location could be expected to off from actual locations. Based on an average of 20 ground locations, mean straight line distance errors were 57.3m. Aerial locations were less precise, with an average of 74.5m.

The second method was to utilize available software to determine UTM coordinates and associated error ellipses. The Andrews estimator was employed because it is more sensitive to reflected signals, and provides lower distances to true from estimated locations than the MLE or Huber estimators (White and Garrott, 1990). As discussed in White and Garrott (1990), mean distance between estimated transmitter locations and true locations increase dramatically when error ellipses are greater than 0.6 hectares. Therefore, an error ellipse of 0.6 hectares was utilized as an upper limit in determining valid telemetry locations. The following are mean error ellipses areas for each of the 5 resident adults:

	mean	standard deviation
female 1	0.464615	0.128197
female 2	0.508228	0.109967
female 8	0.492259	0.097111
male 5	0.540092	0.079249
male 9	0.465751	0.138026

APPENDIX B: CONTINUOUS MONITORING PERIODS

Riparian Area Use:

Female 1, CMP1	116
Female 1, CMP2	117
Female 1, CMP3	118
Female 2, CMP1	119
Female 2, CMP2	120
Female 8, CMP1	121
Female 8, CMP2	122
Female 8, CMP3	123
Female 8, CMP4	124
Female 8, CMP5	125
Male 5, CMP1	126
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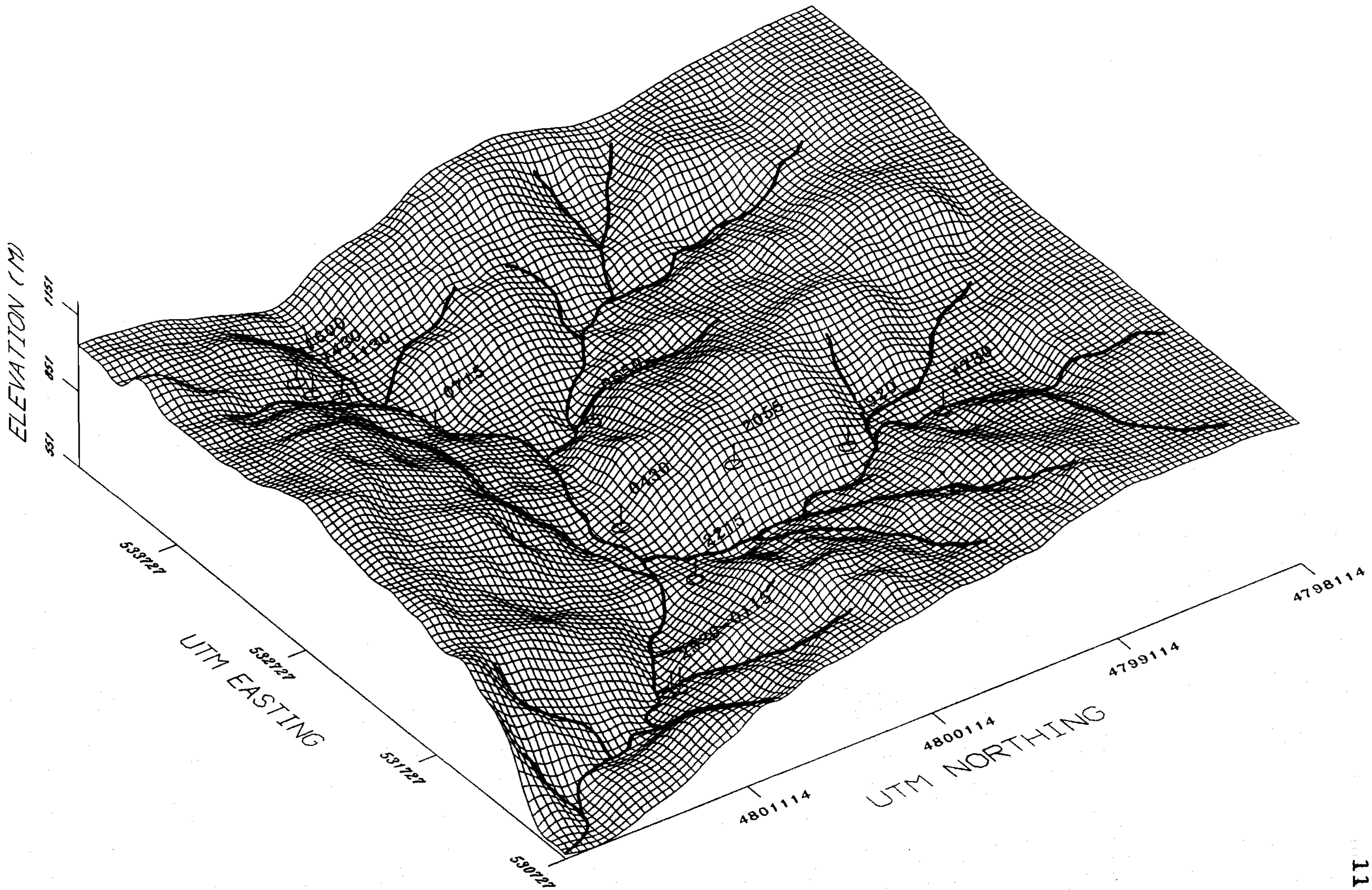
Male 9, CMP2	130
Male 9, CMP3	131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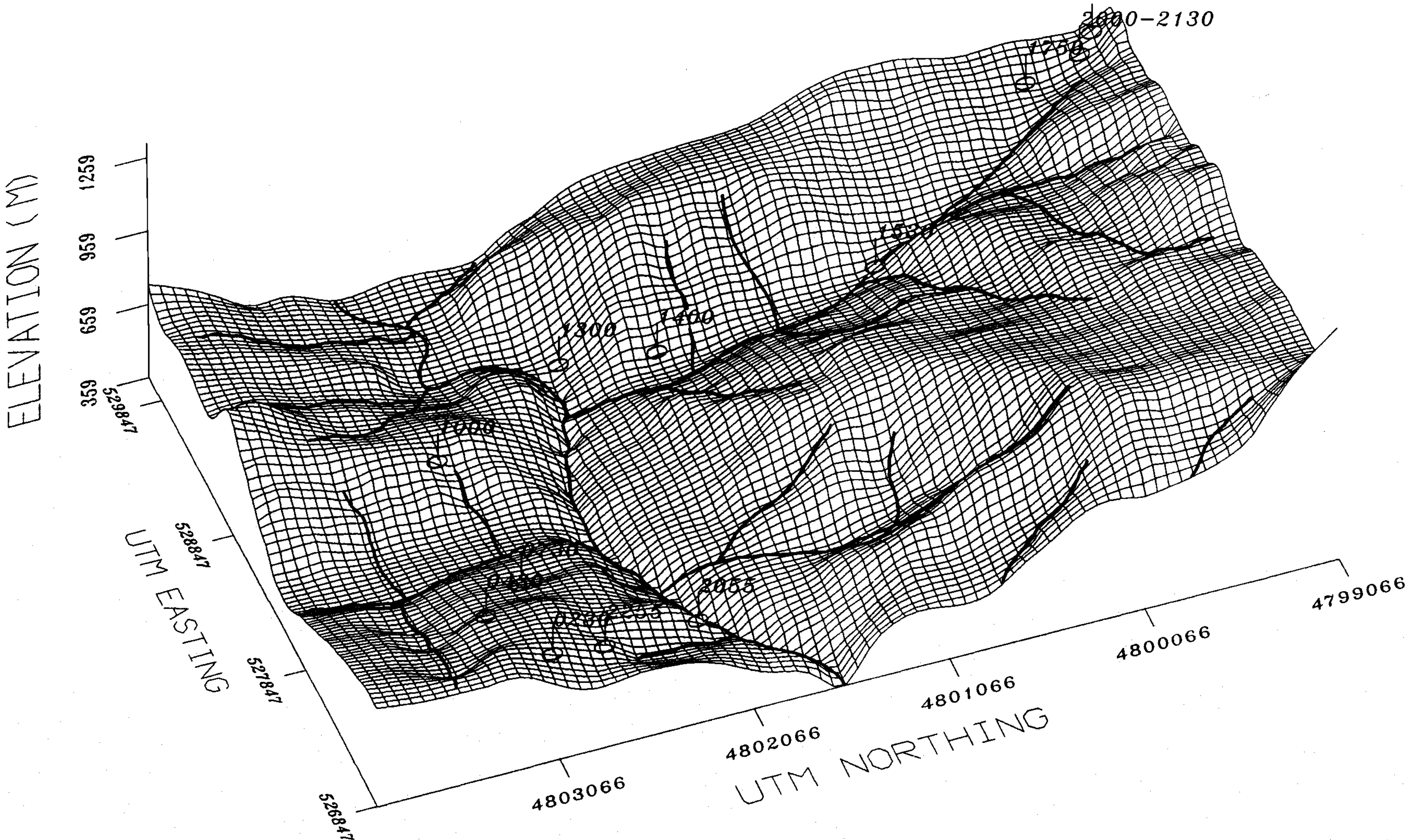
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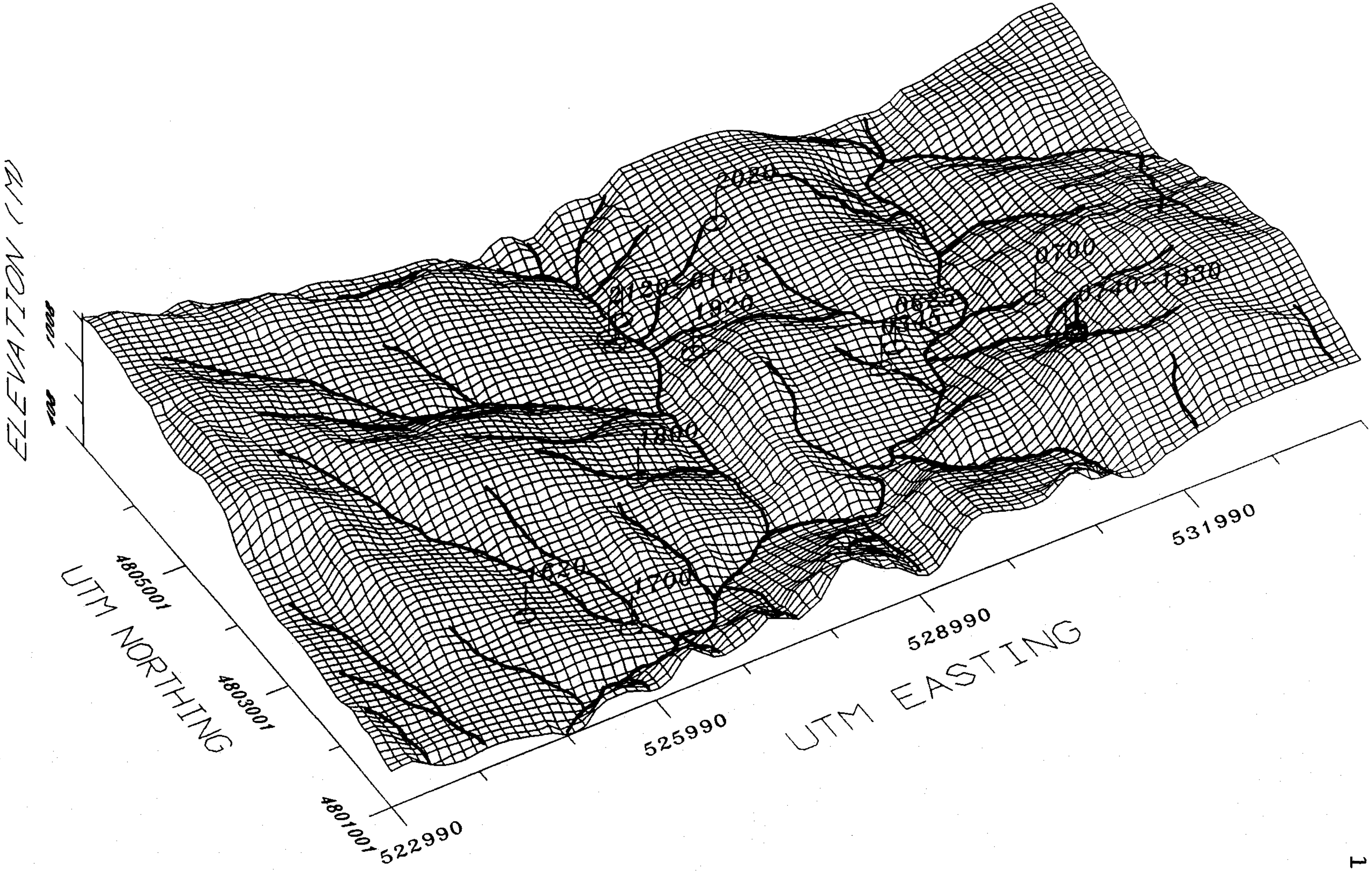
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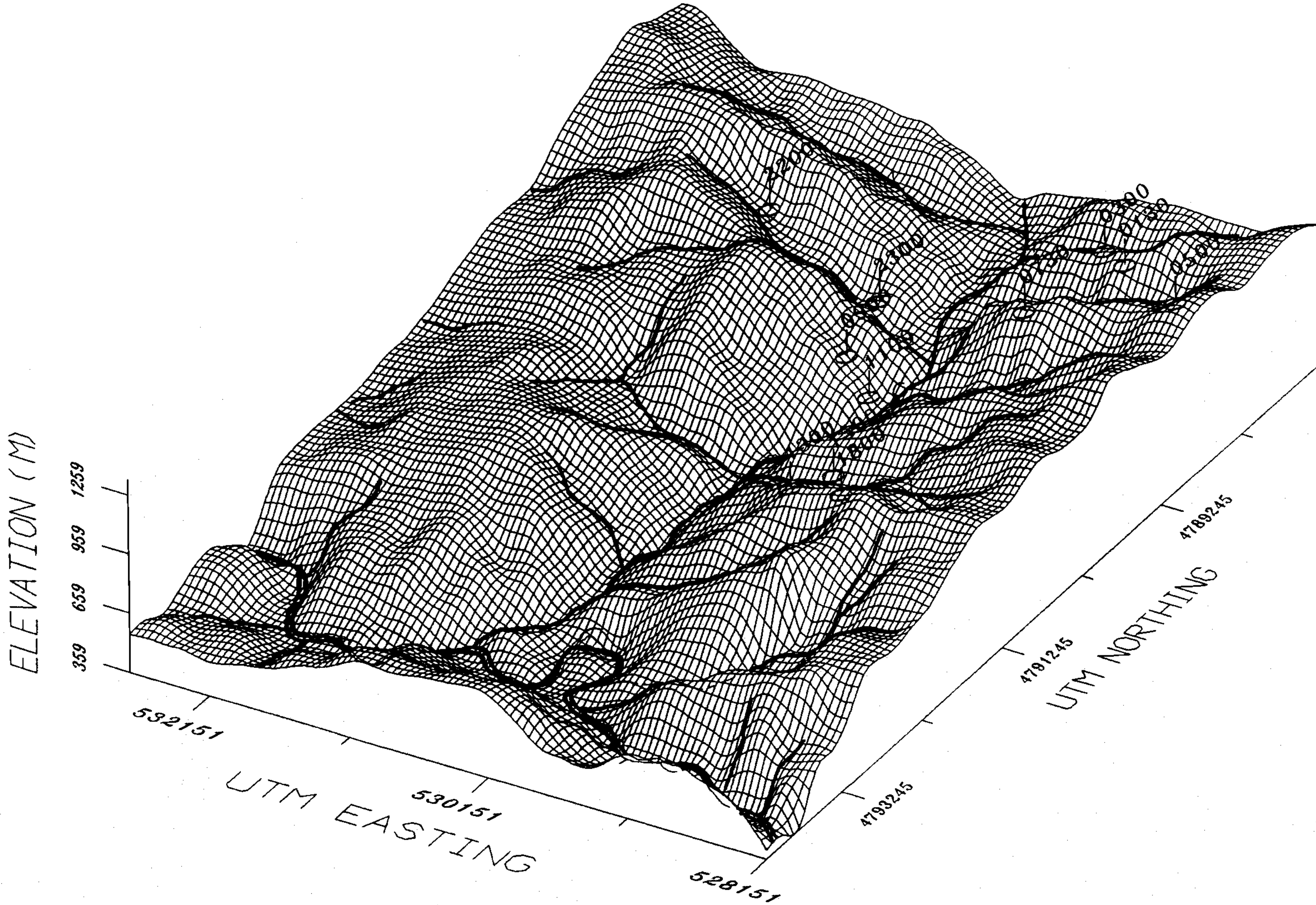
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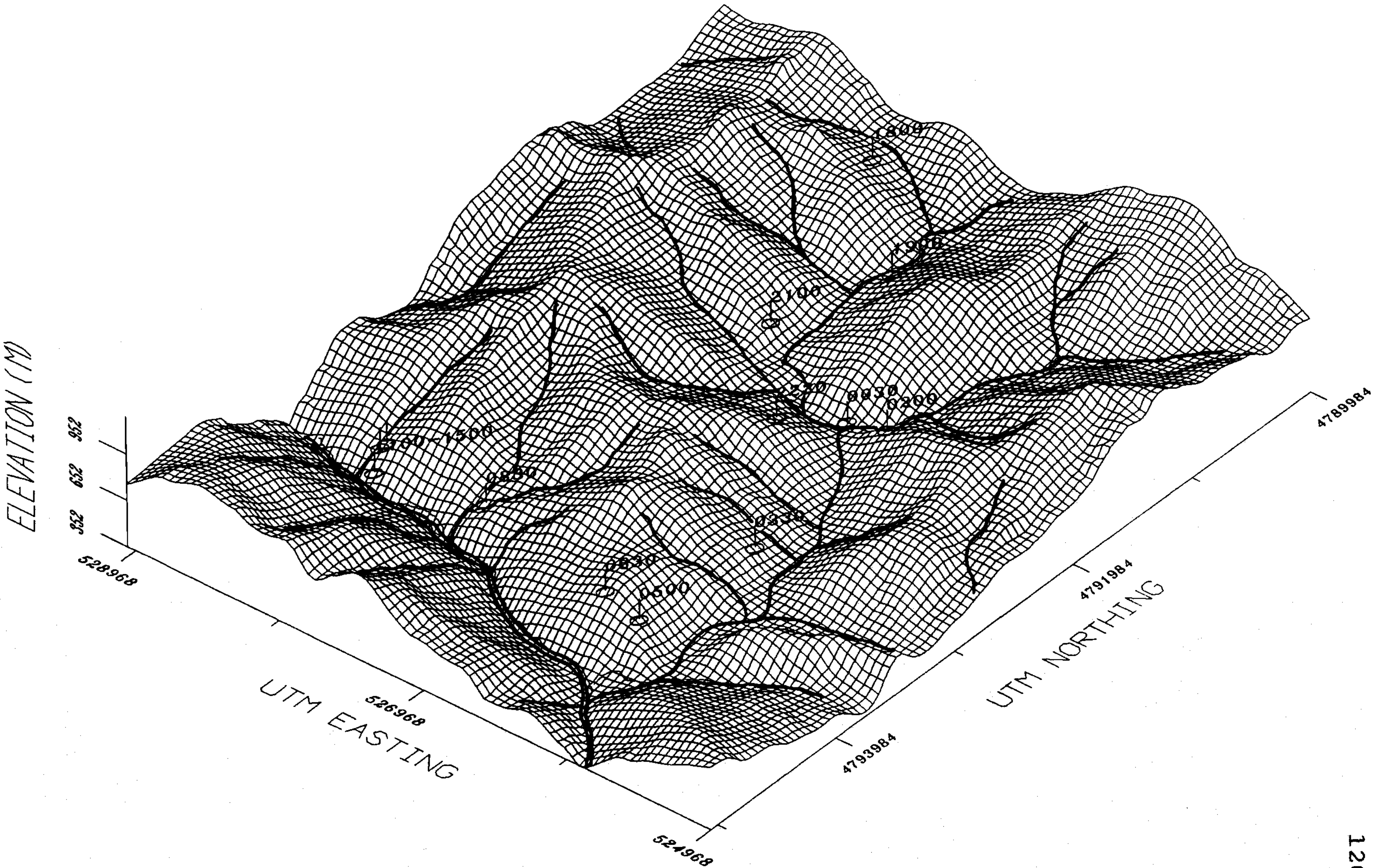
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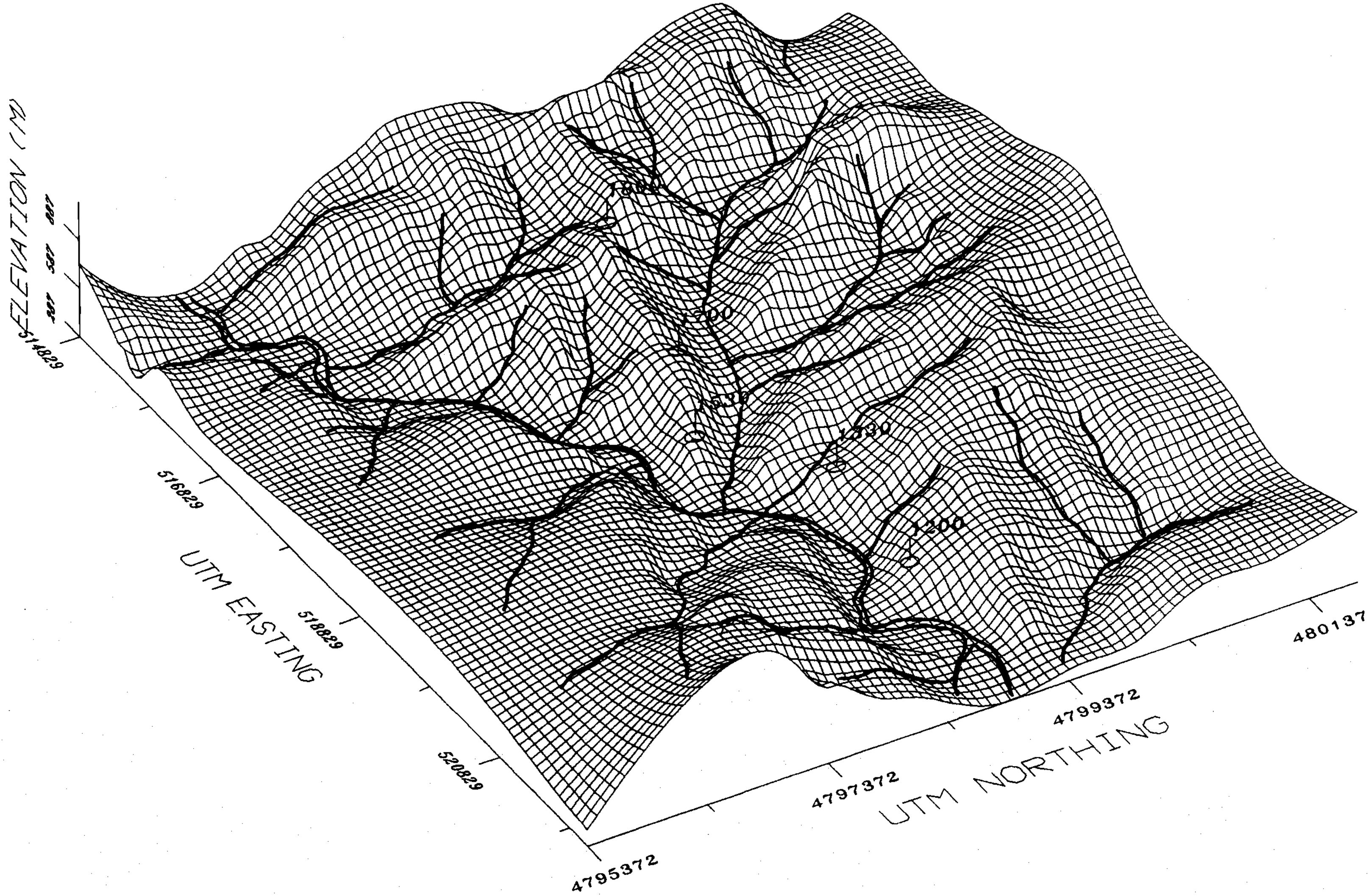
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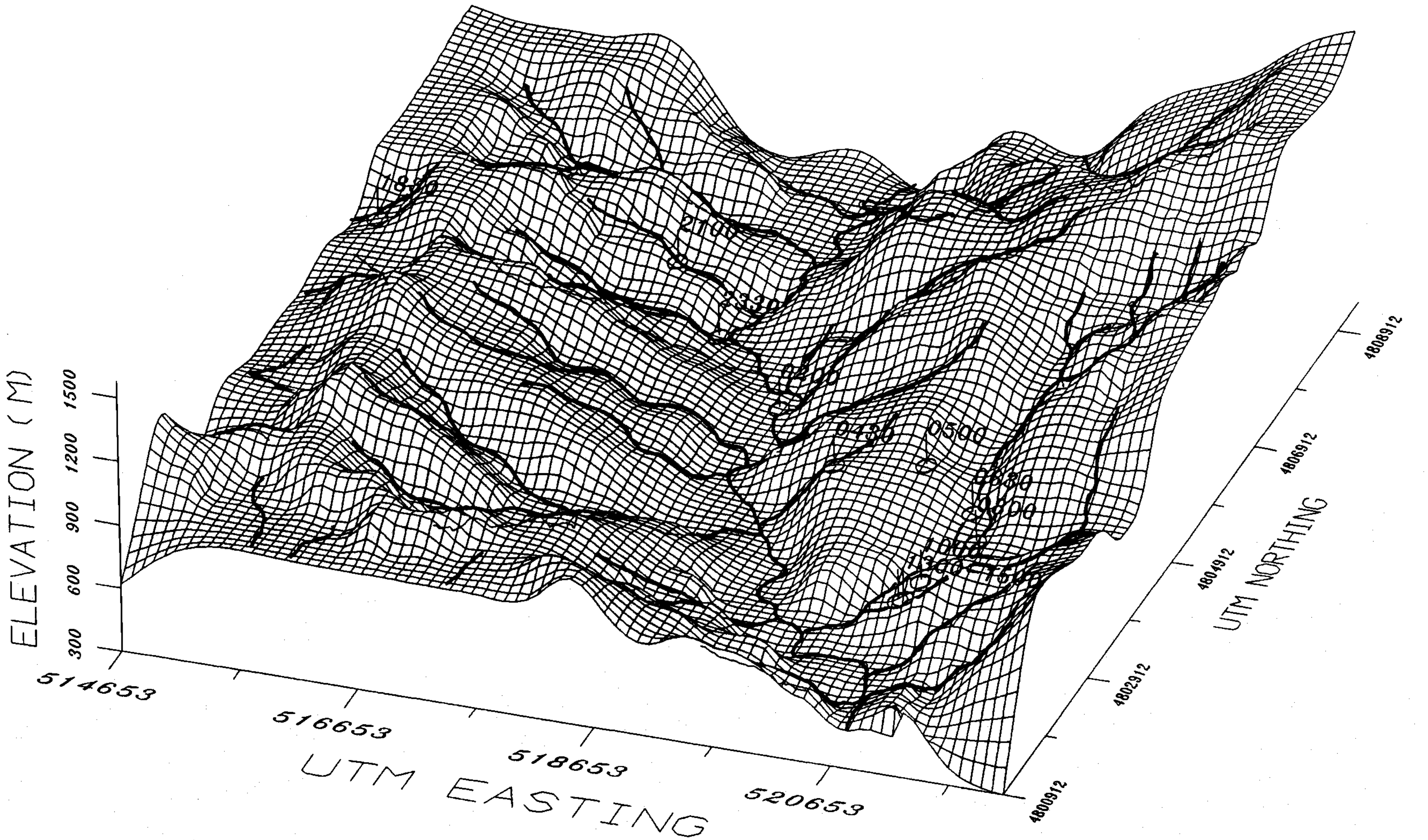
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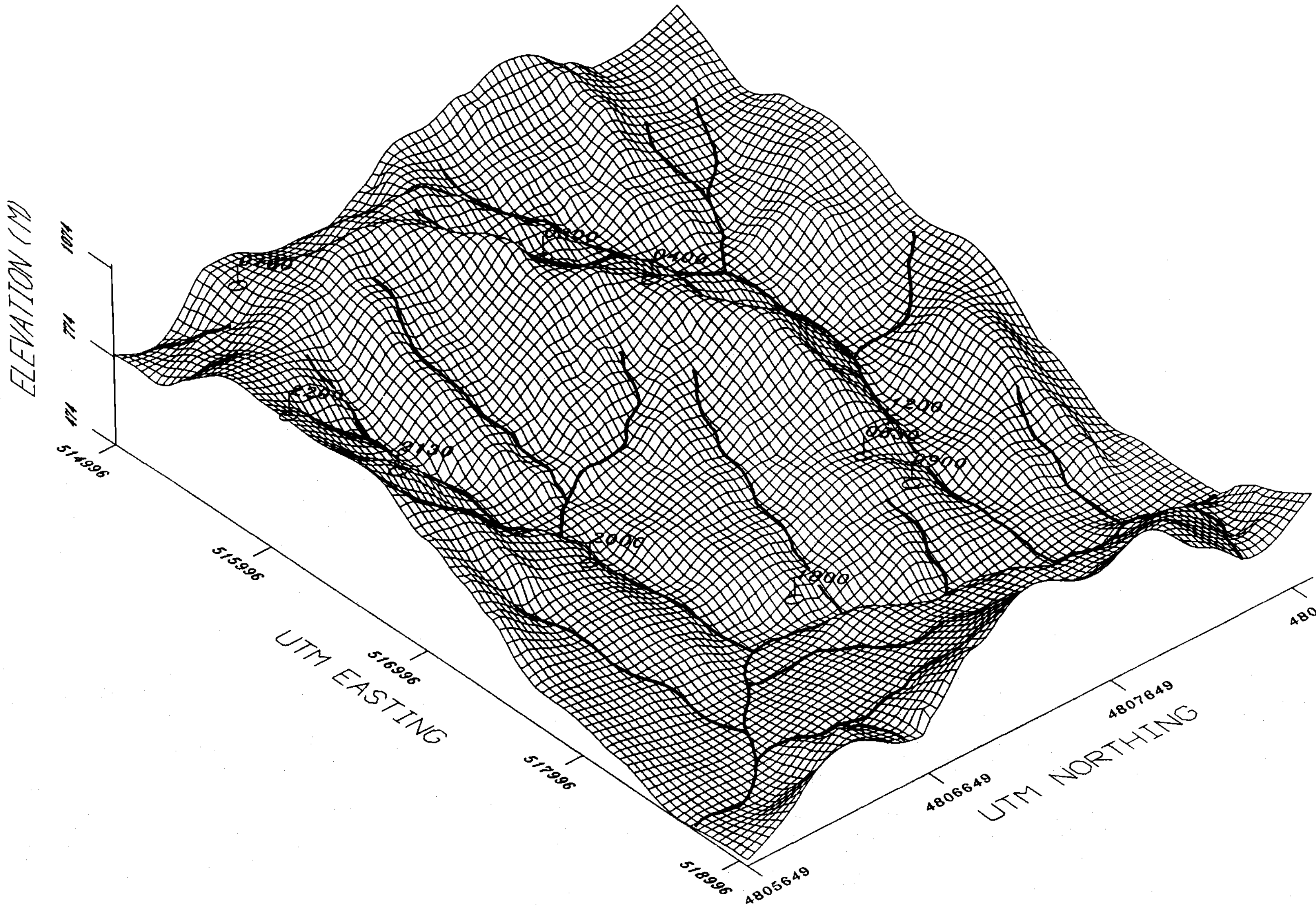
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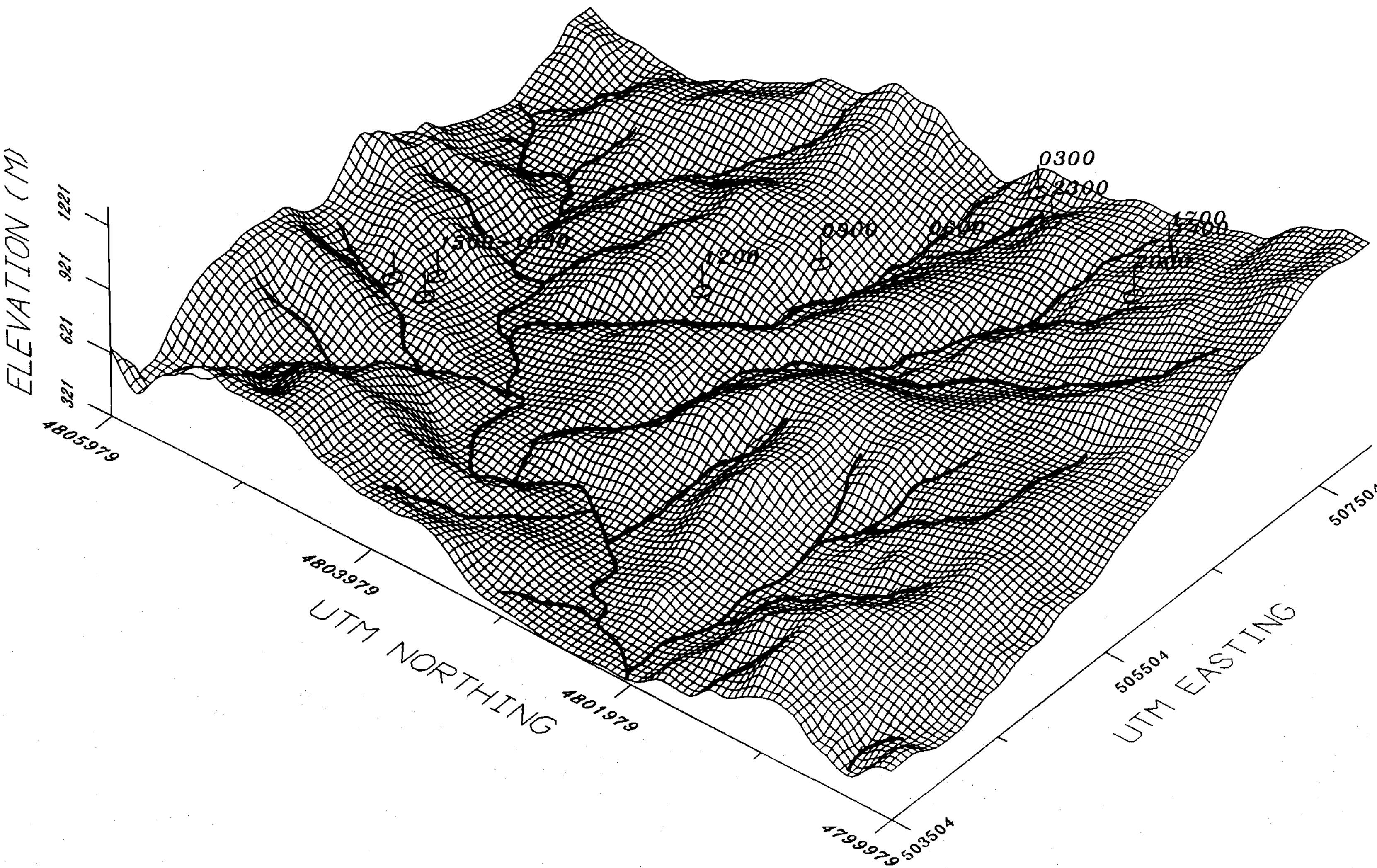

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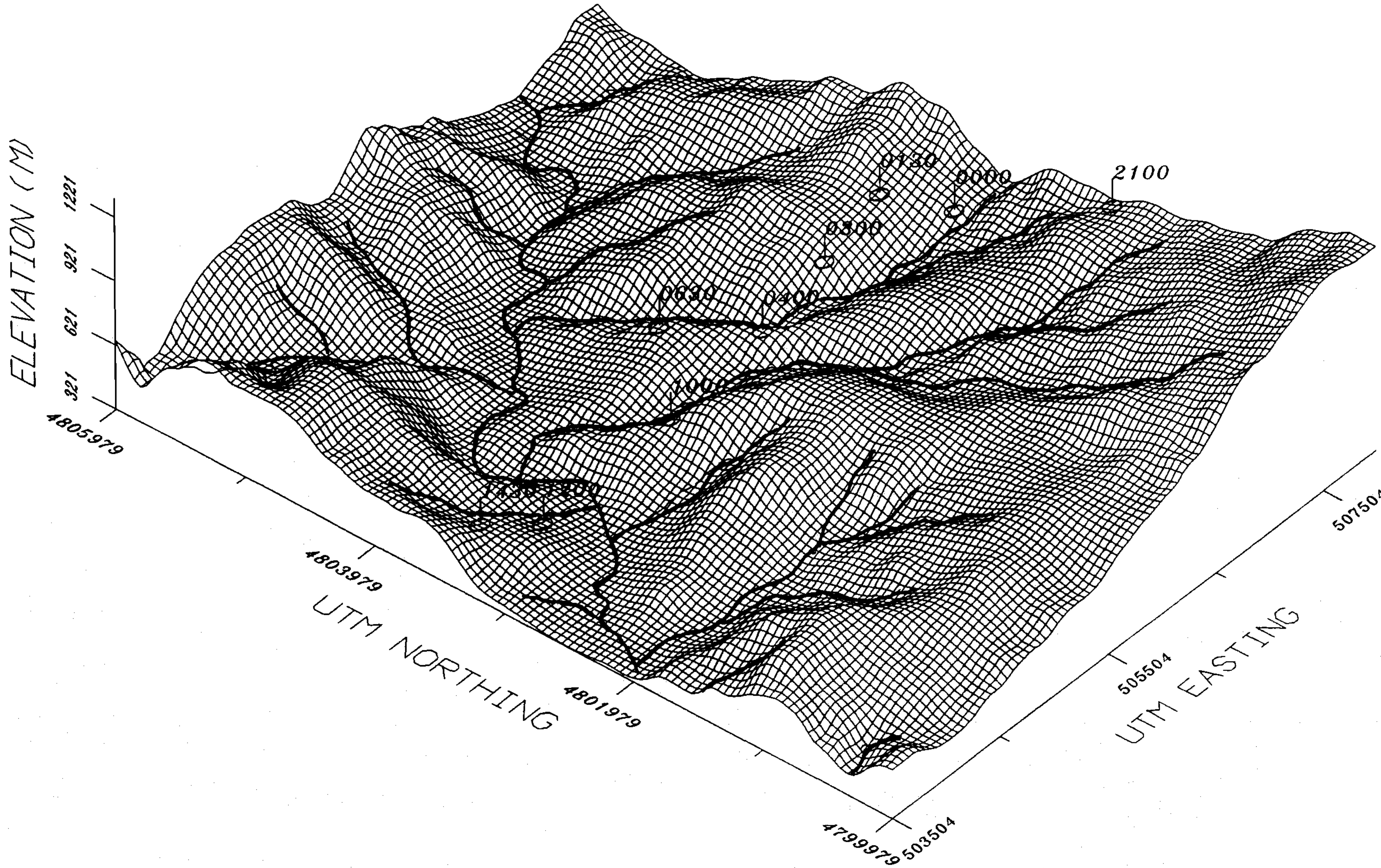

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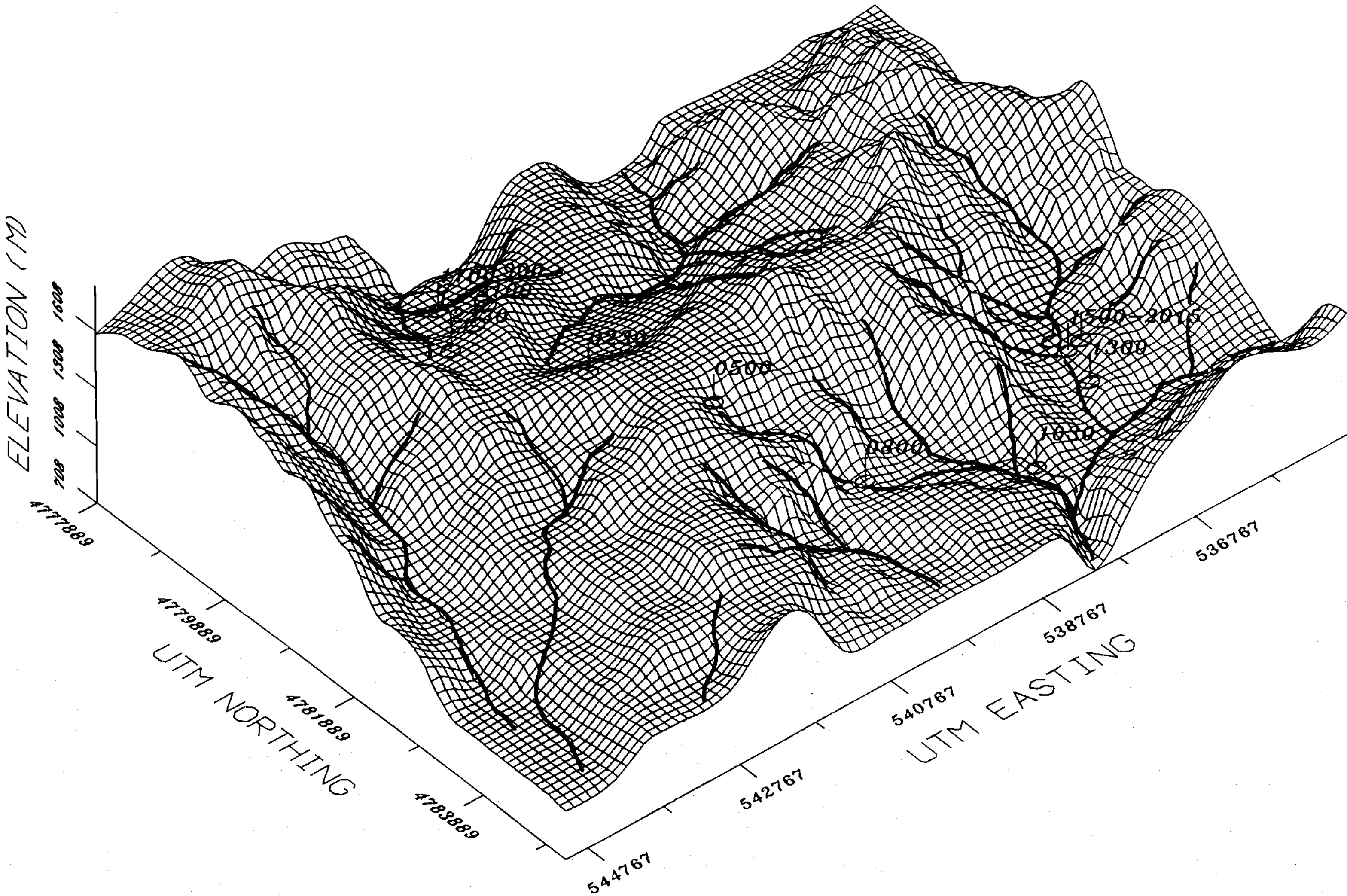

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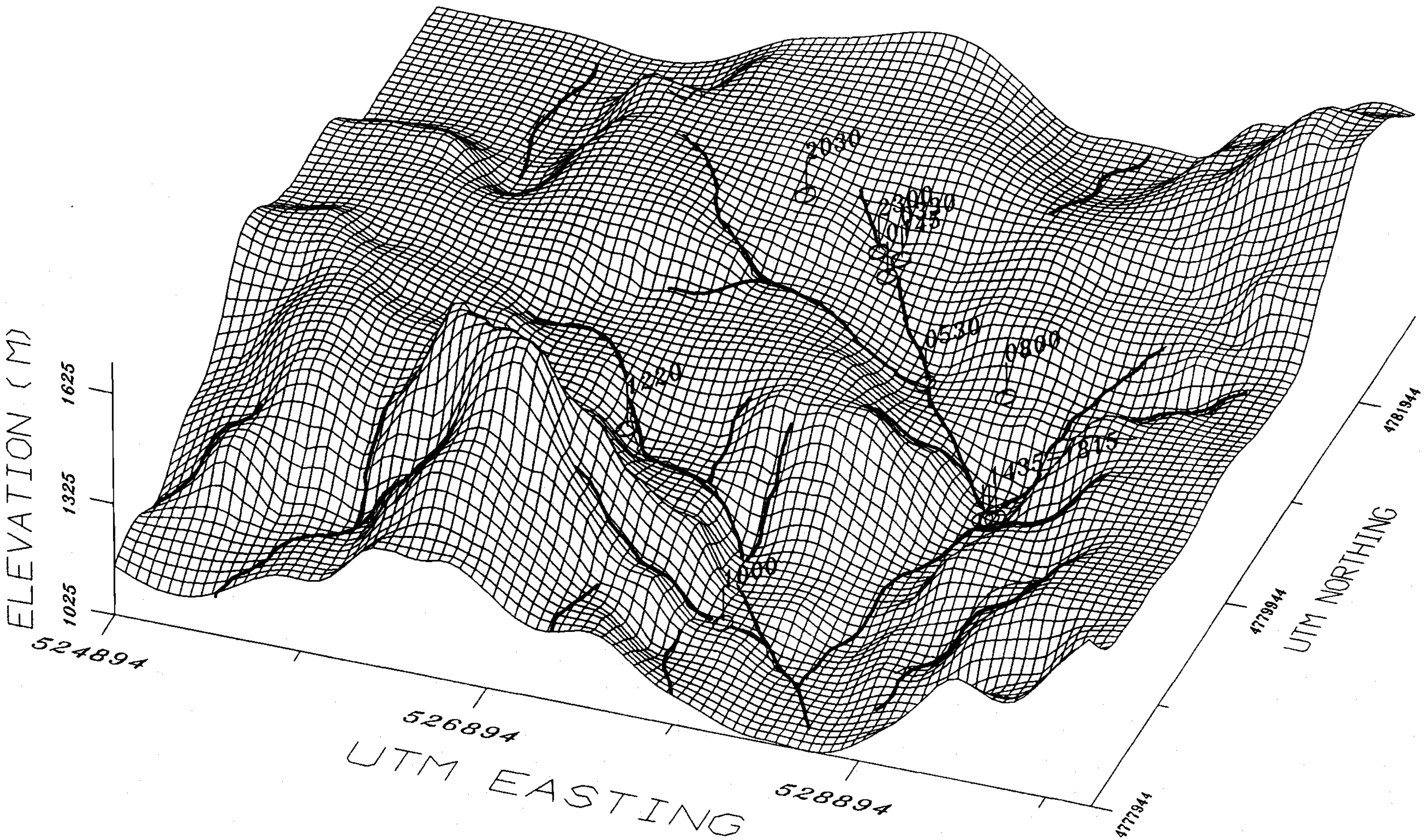

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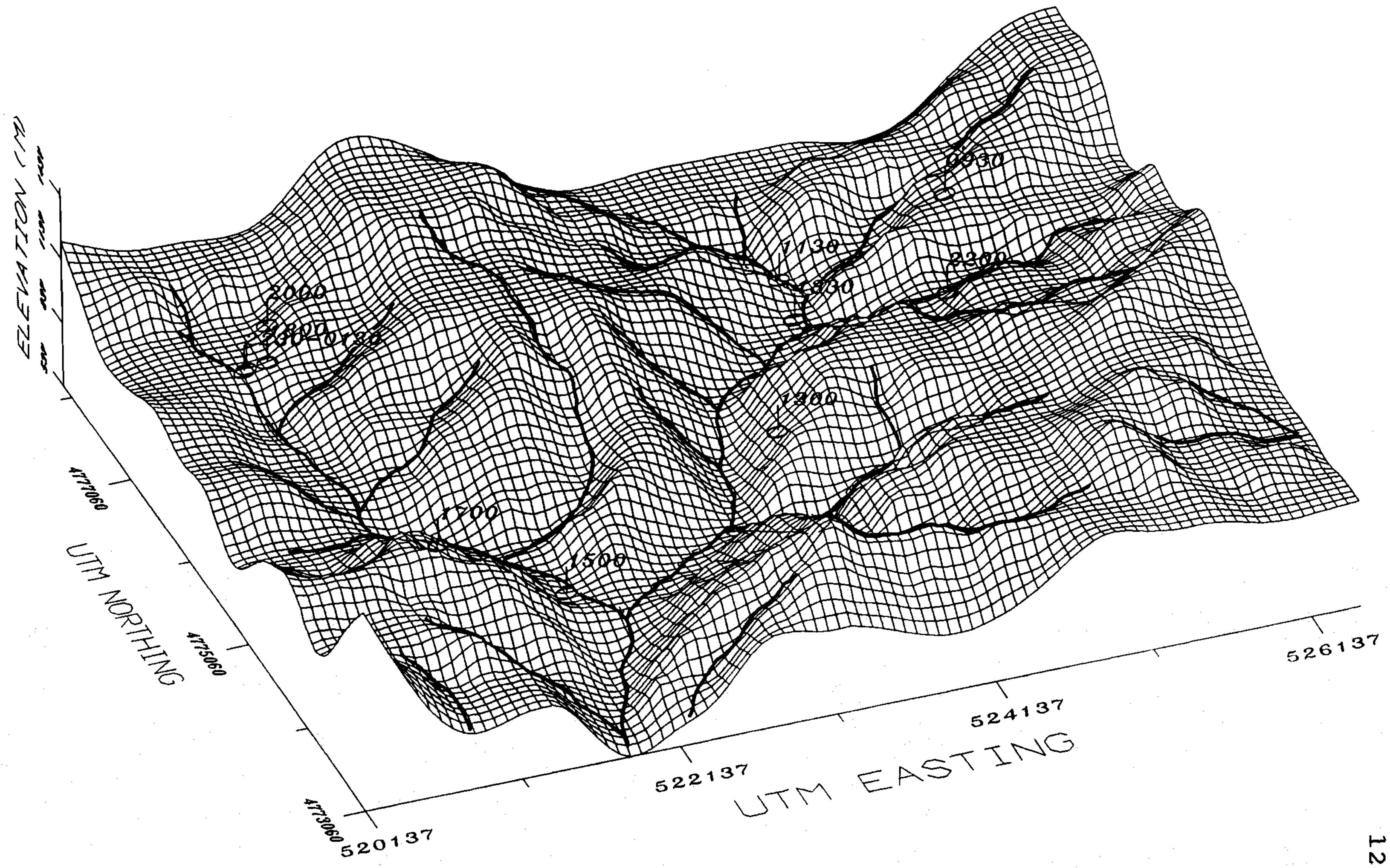
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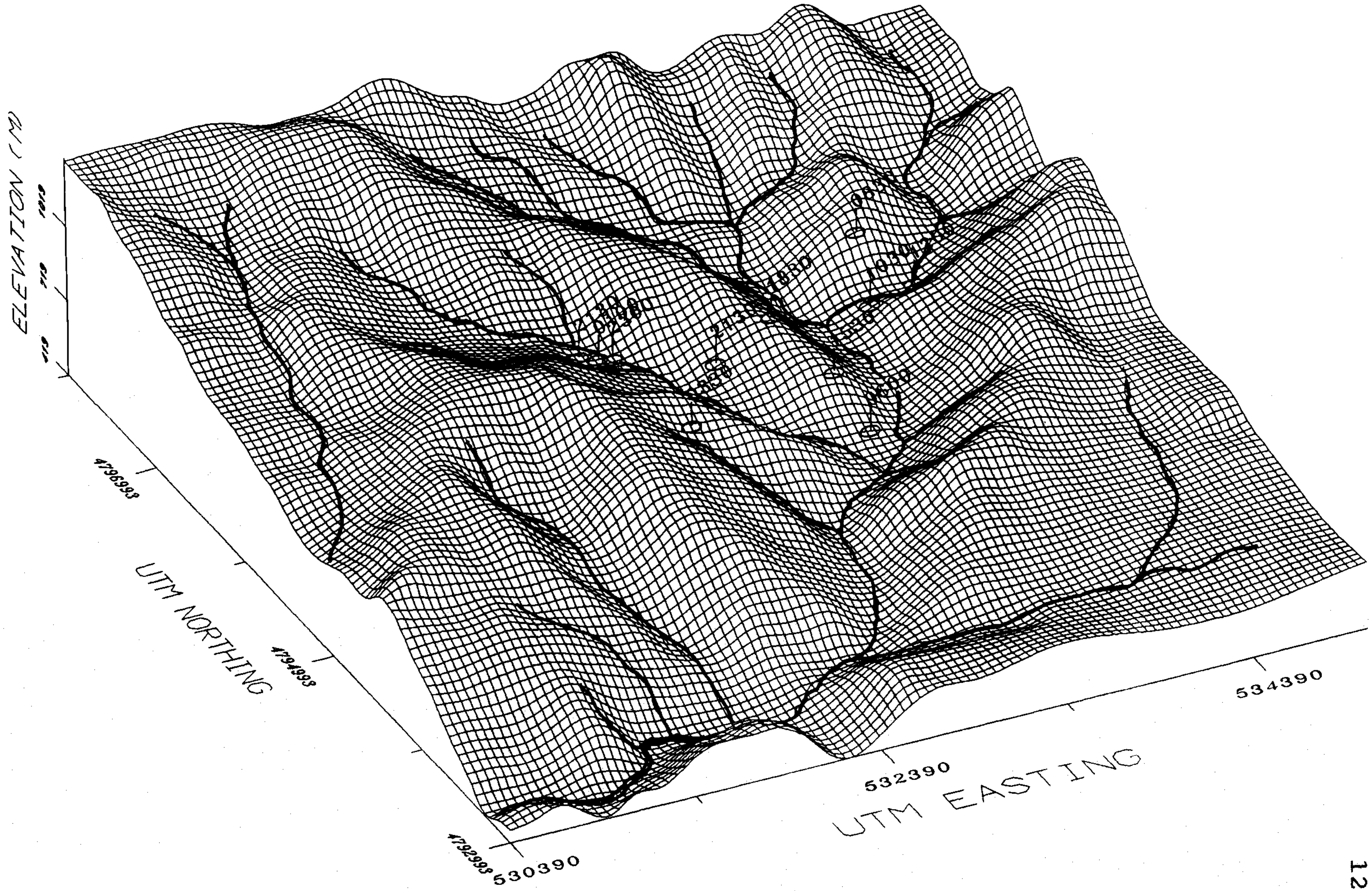
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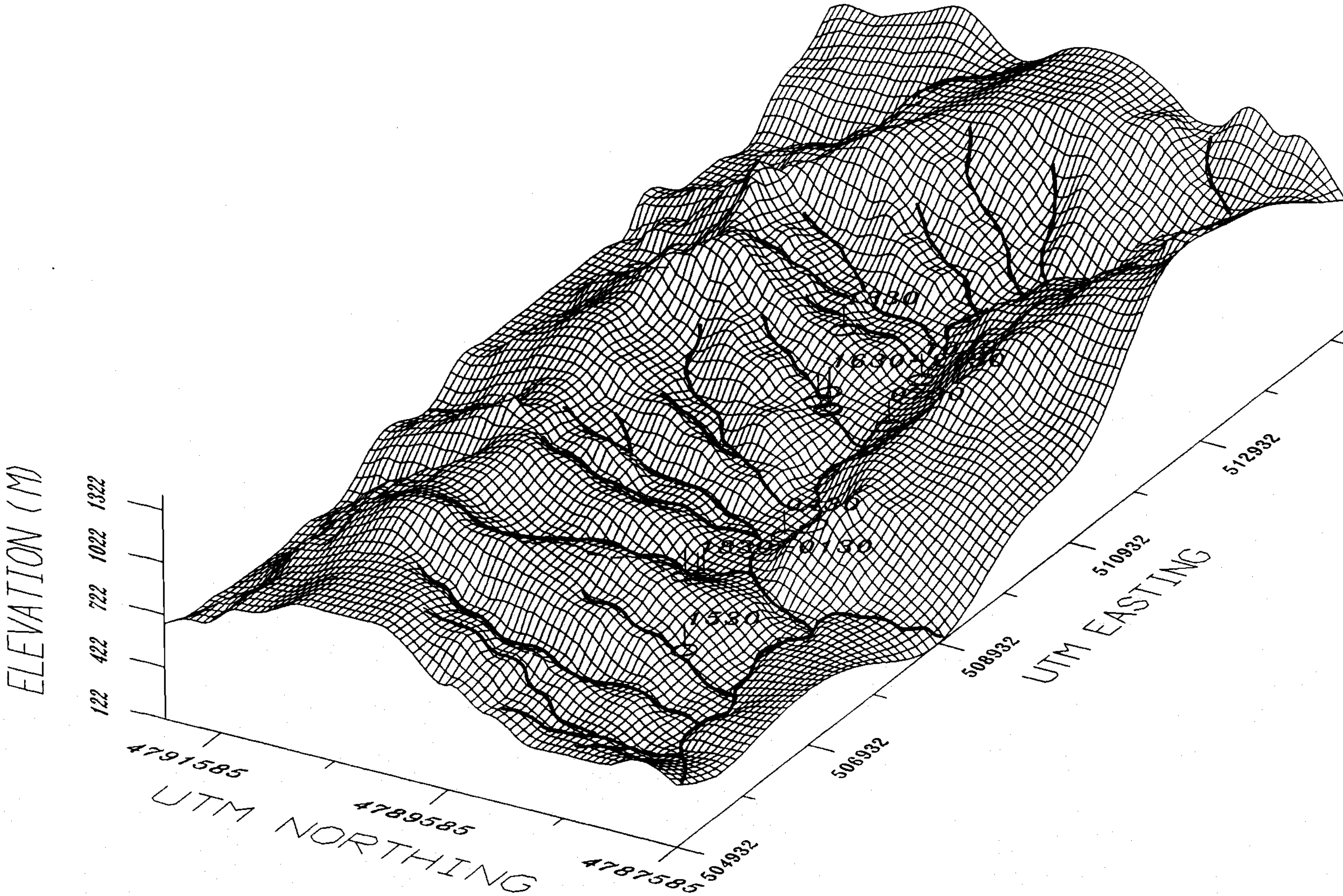
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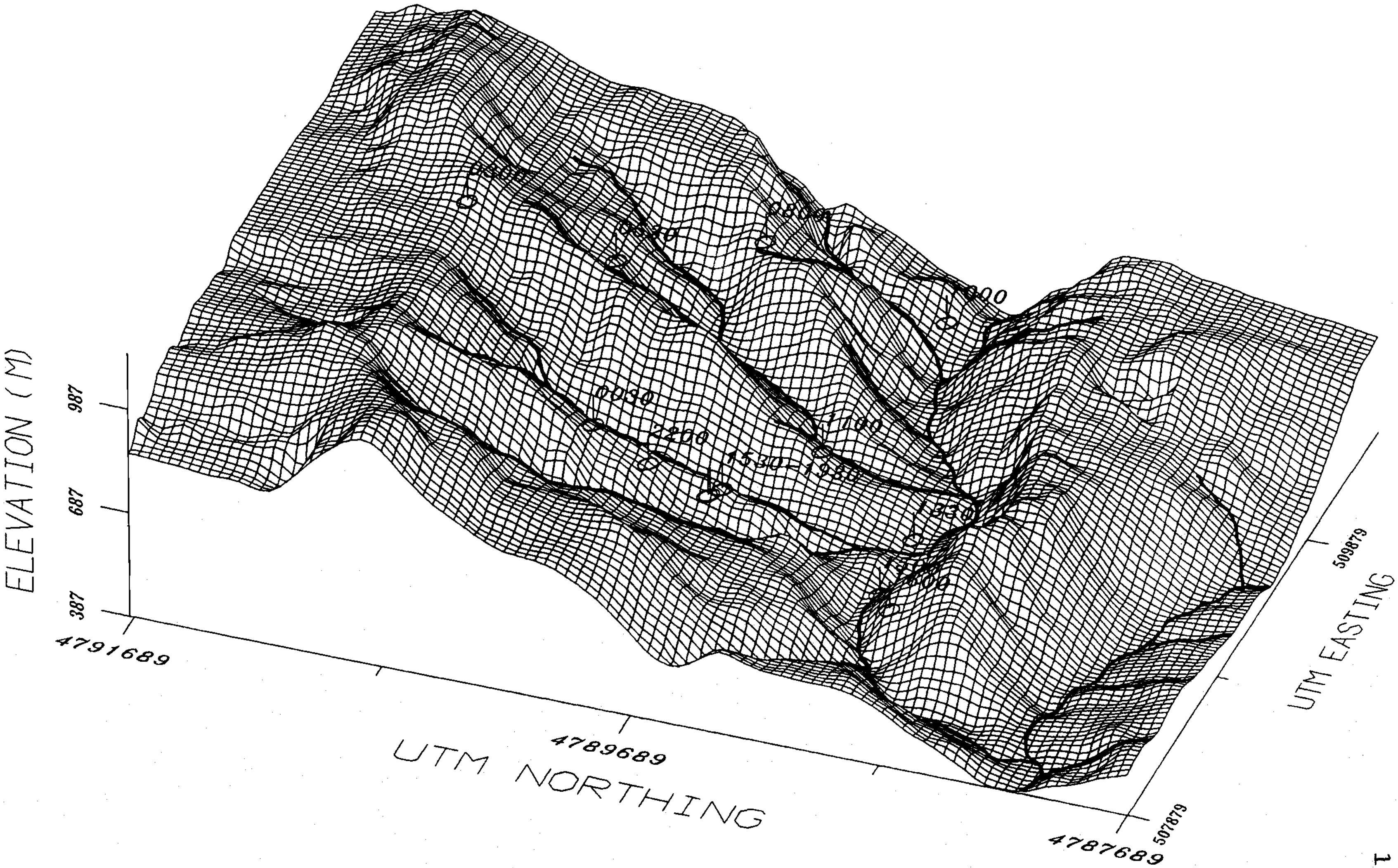
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Road Systems:

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Female 1, CMP3	135
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Female 2, CMP2	137
Female 8, CMP1	138
Female 8, CMP2	139
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Female 8, CMP4	141
Female 8, CMP5	142
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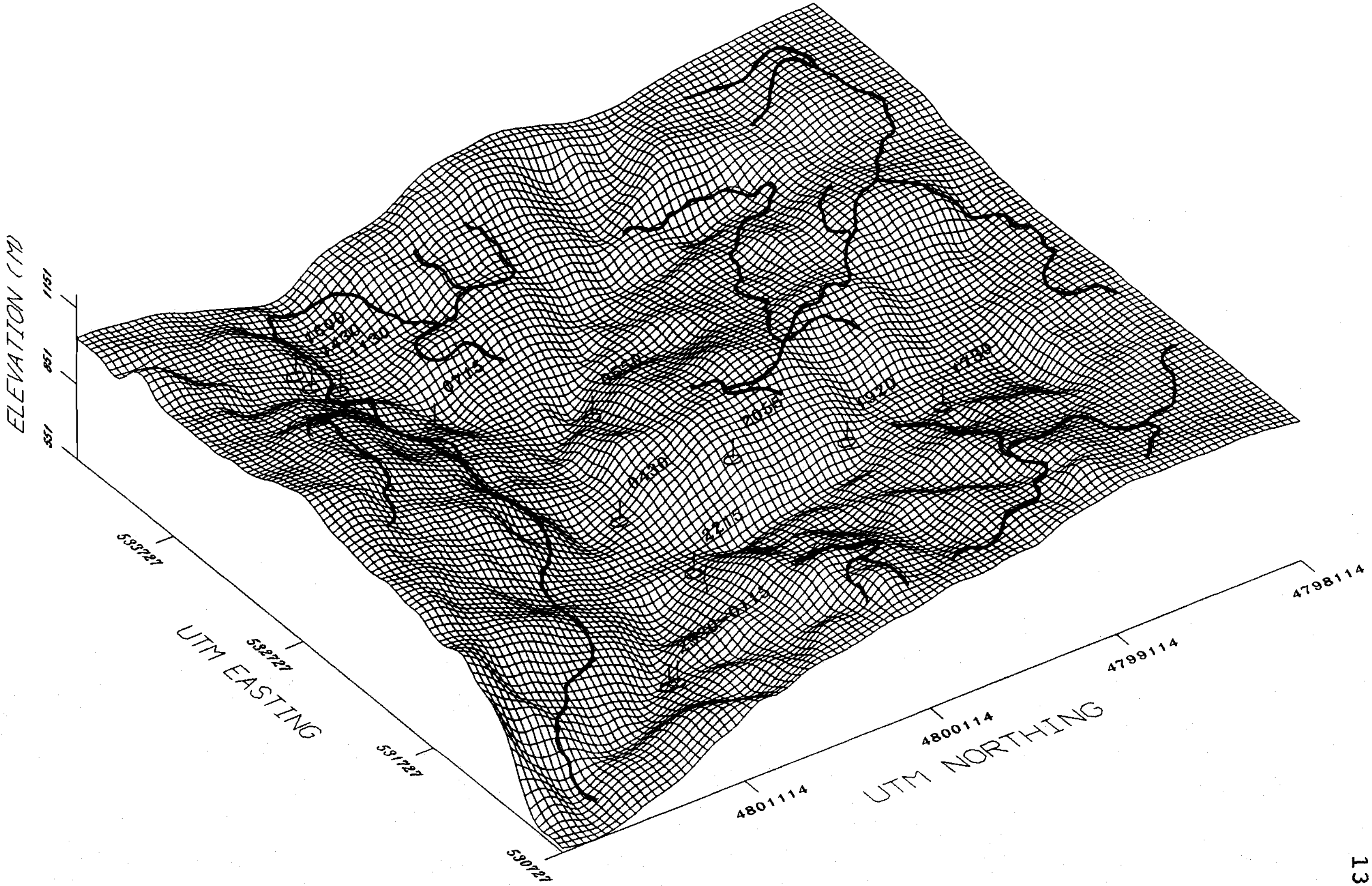
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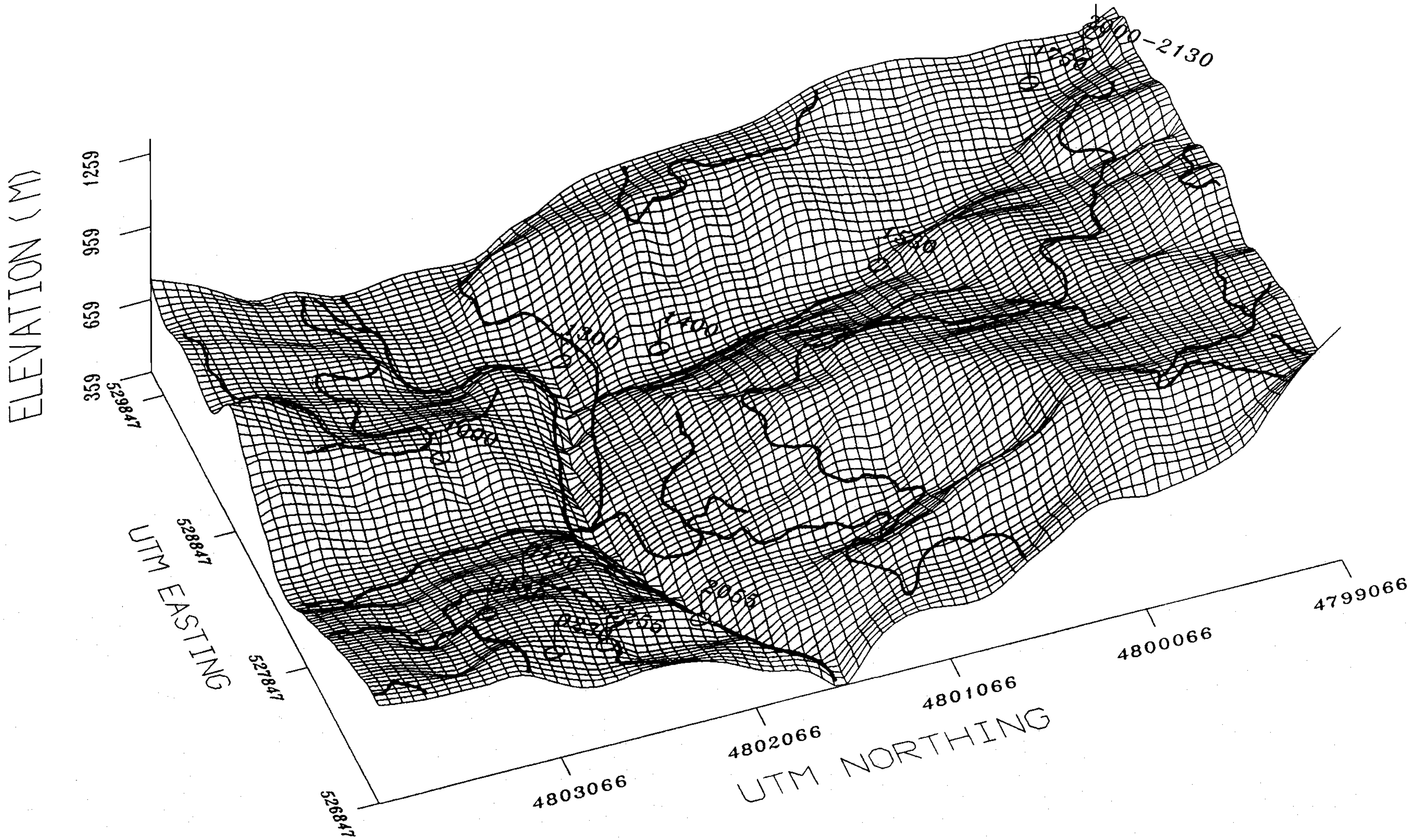
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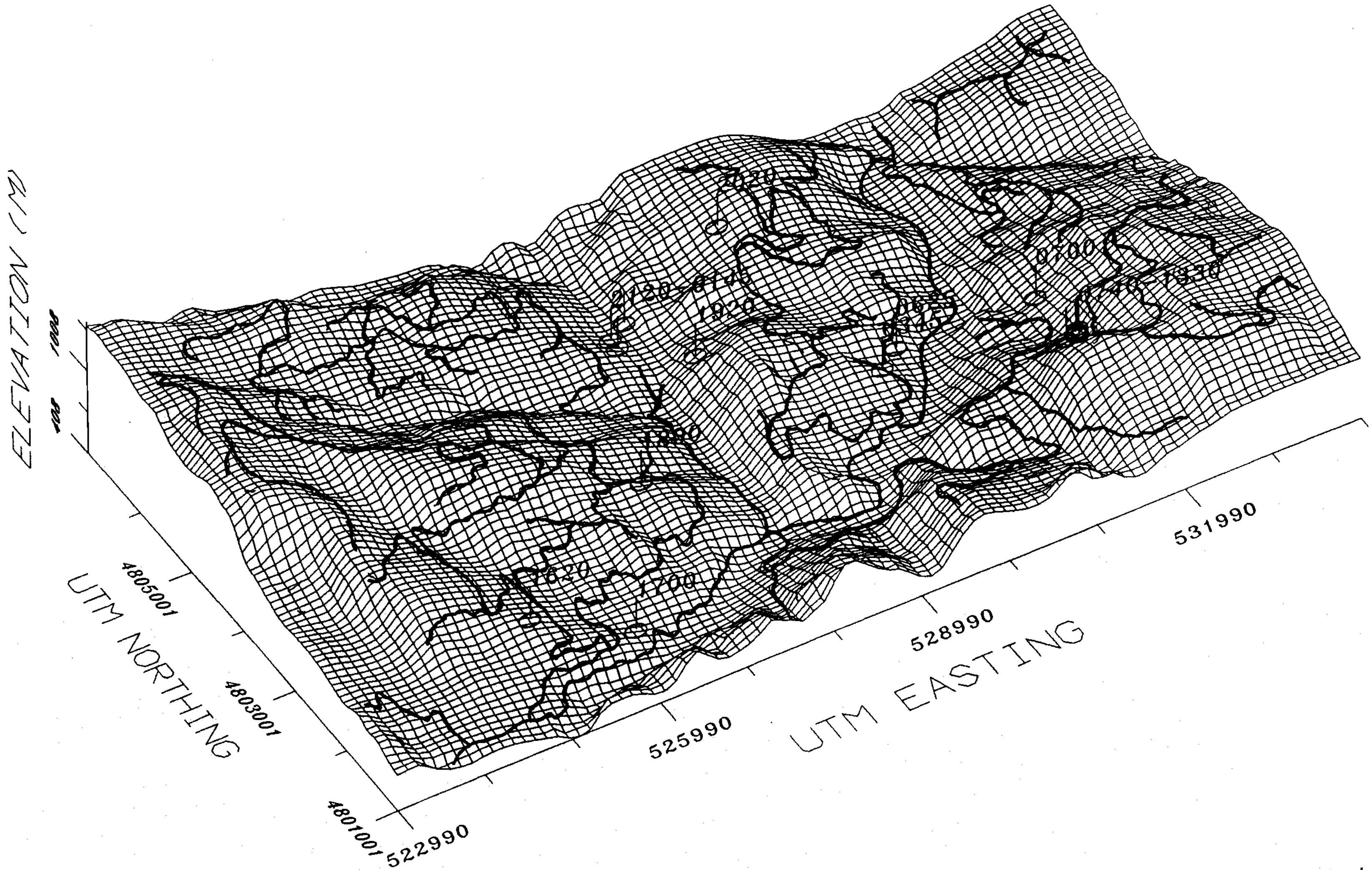
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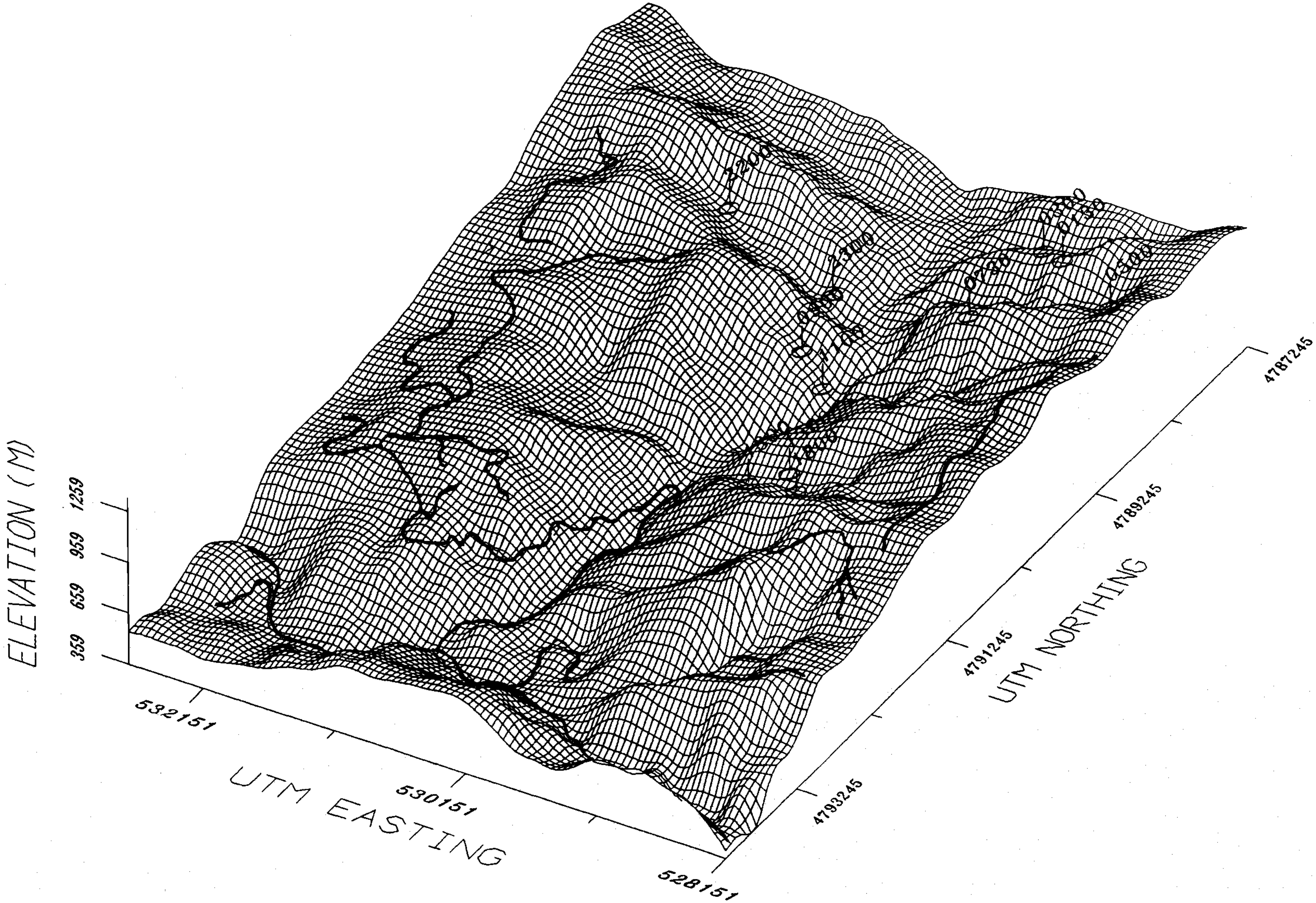
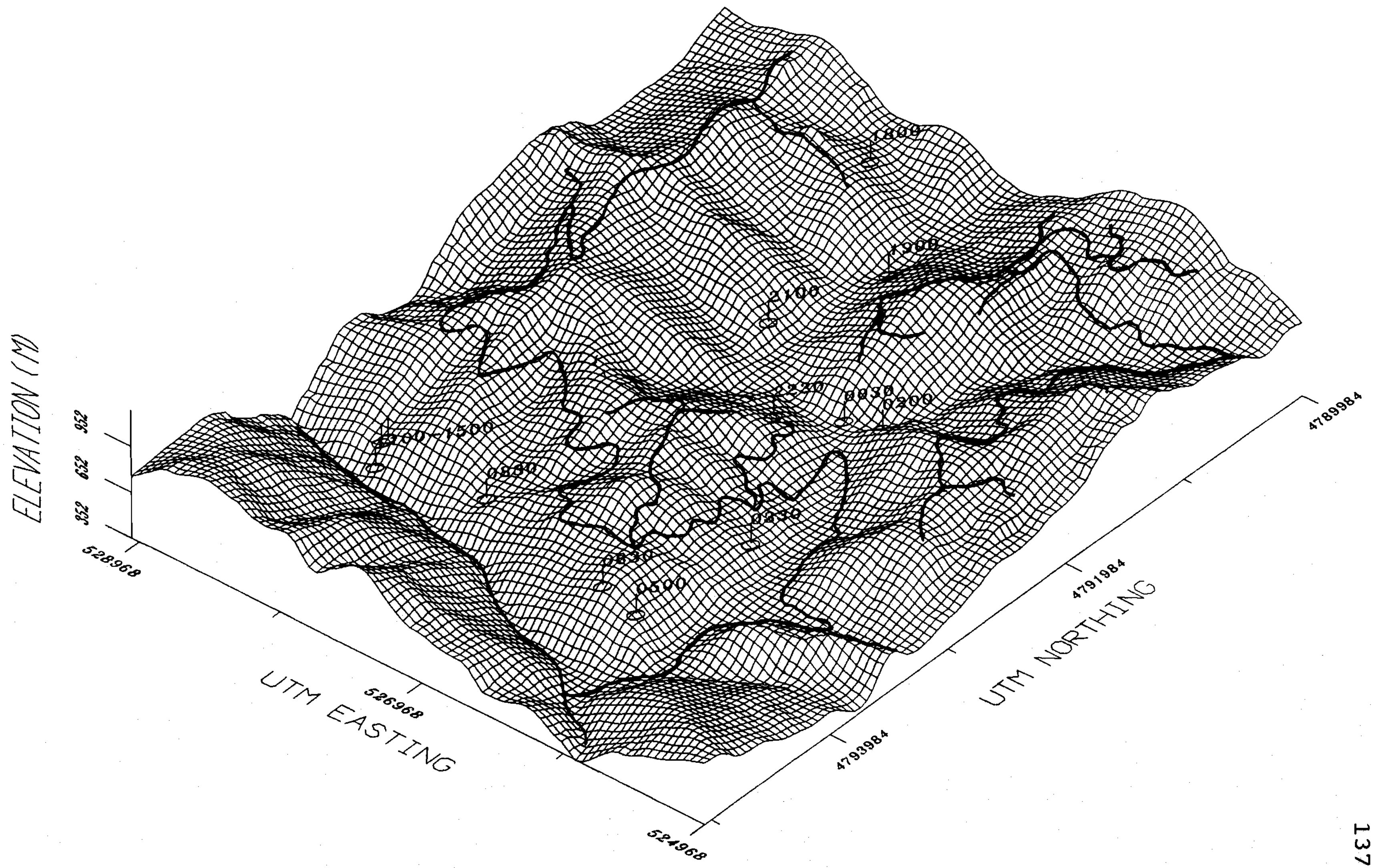
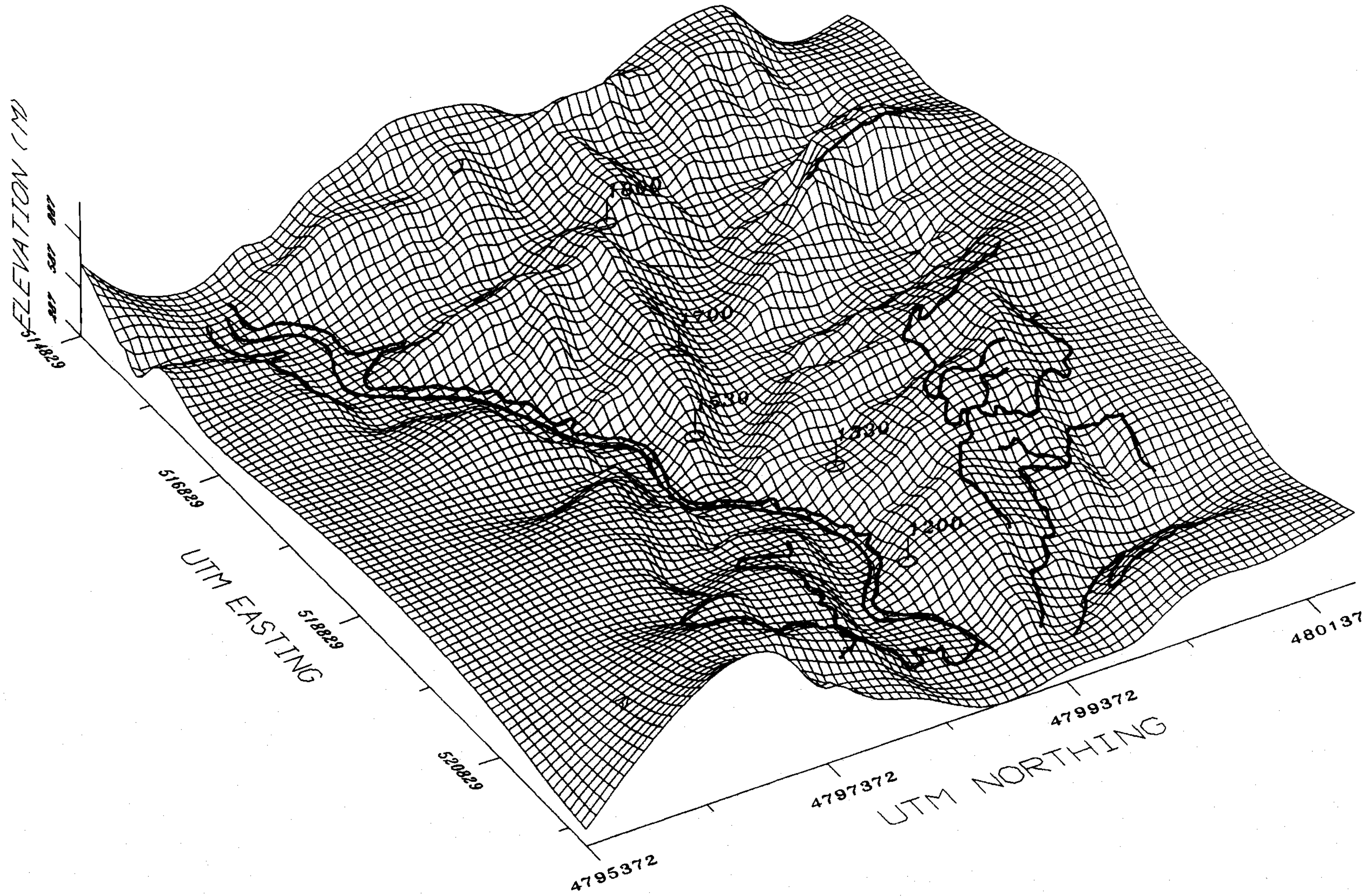
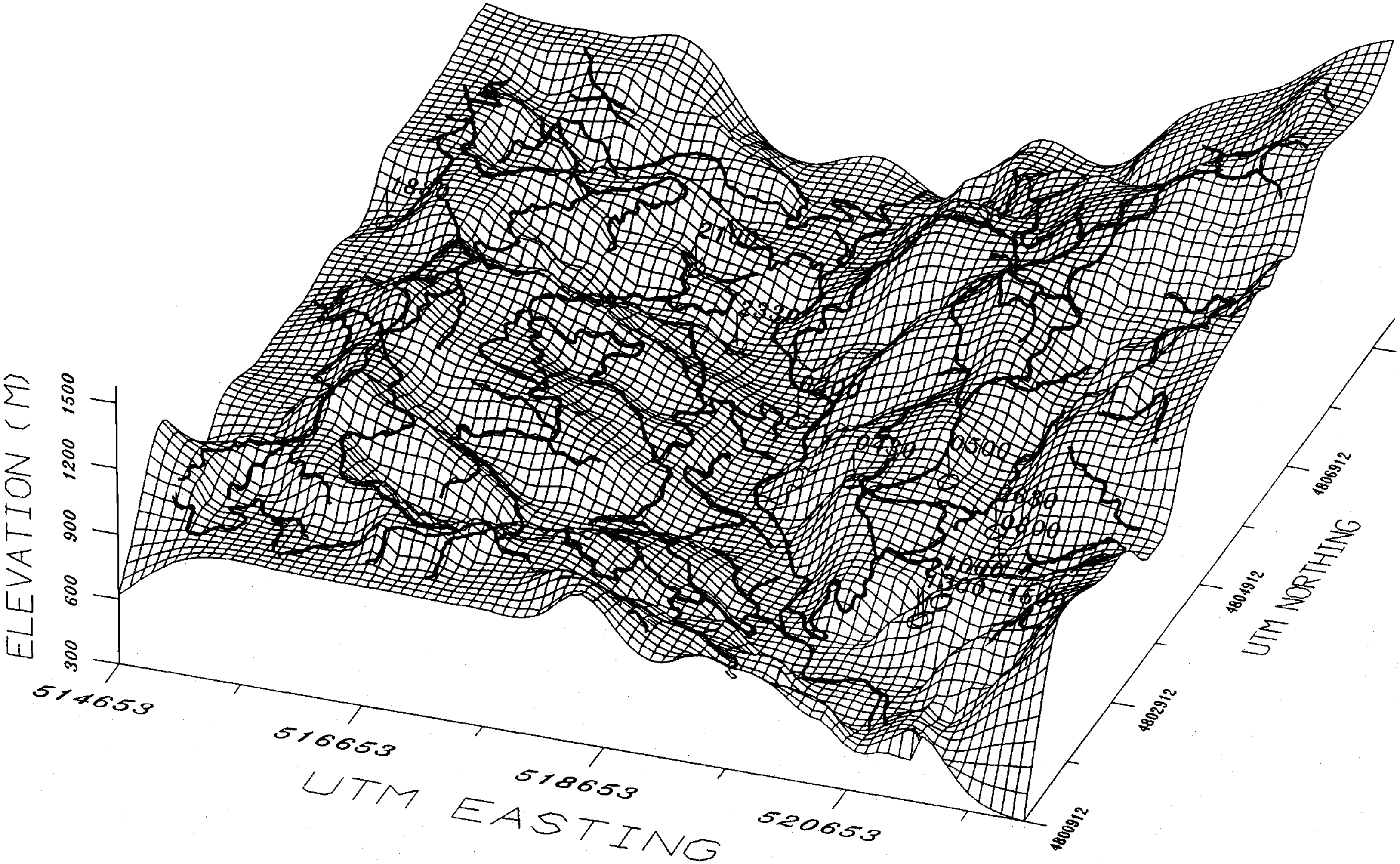
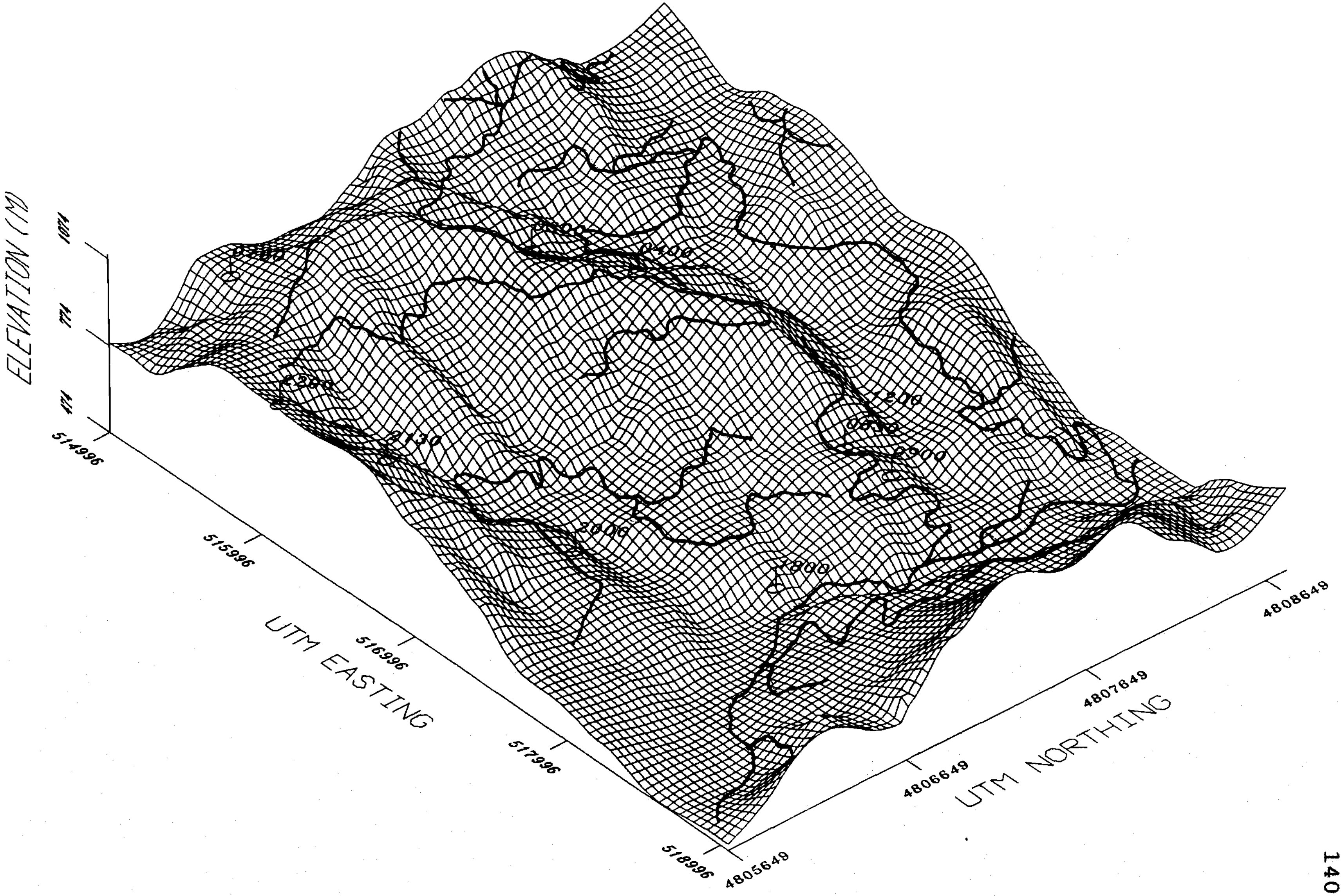
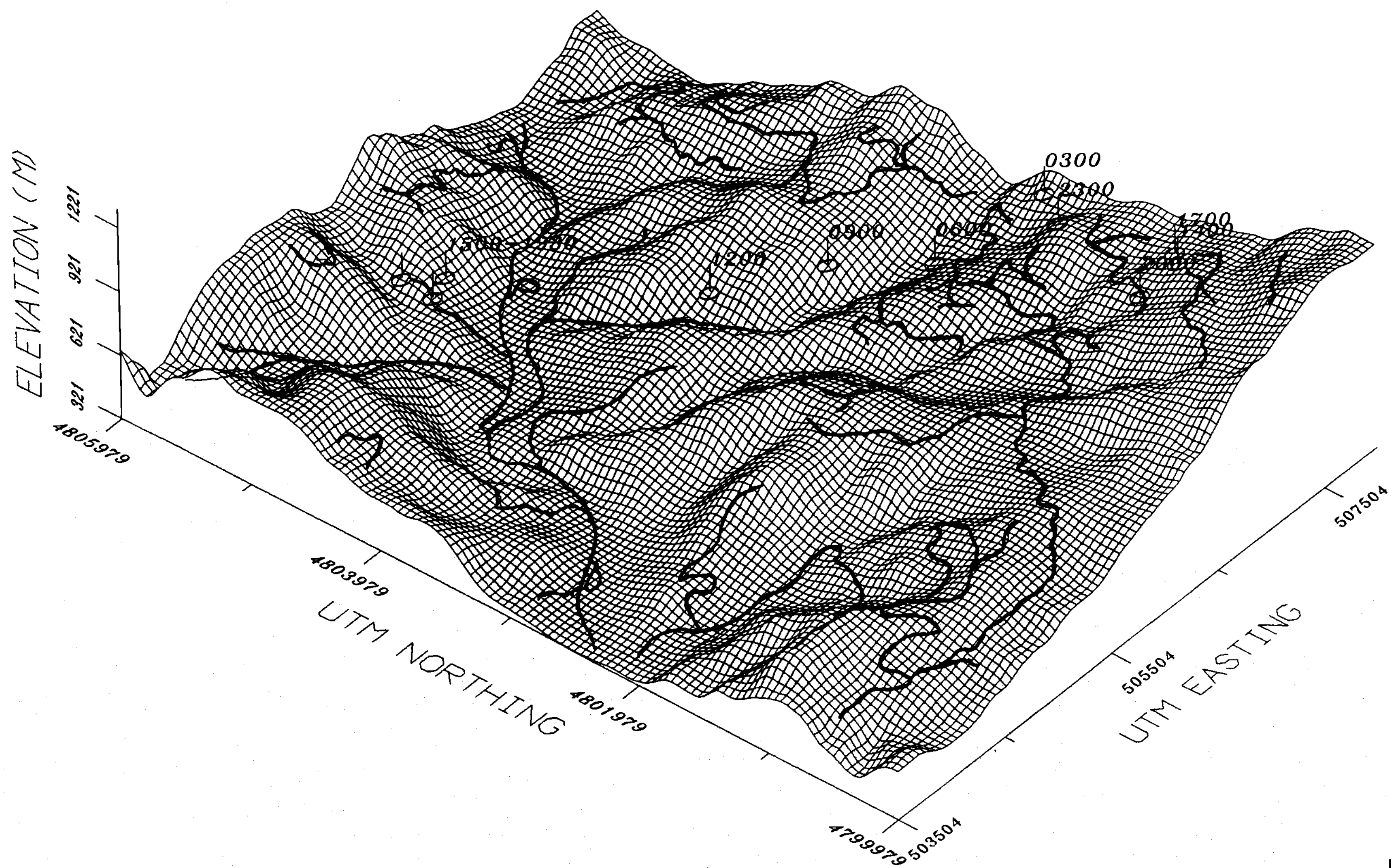

ELEVATION (M)
359
659
959
1259
532151
530151
528151
UTM EASTING
4793245
4791245
4789245
4787245
UTM NORTHING

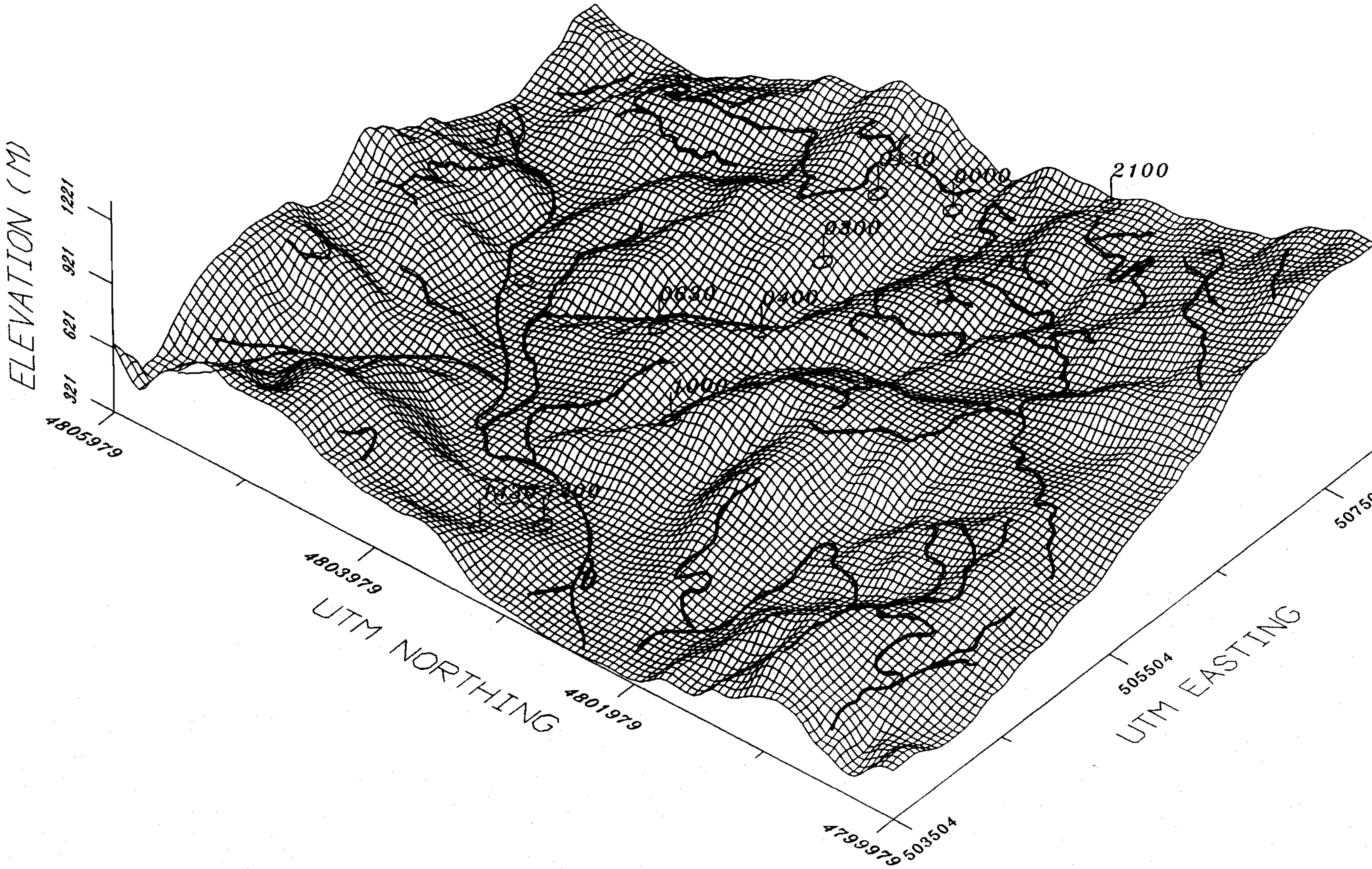

ELEVATION (M)
352
652
952
528968
526968
524968
UTM EASTING
4793984
4791984
4789984
UTM NORTHING

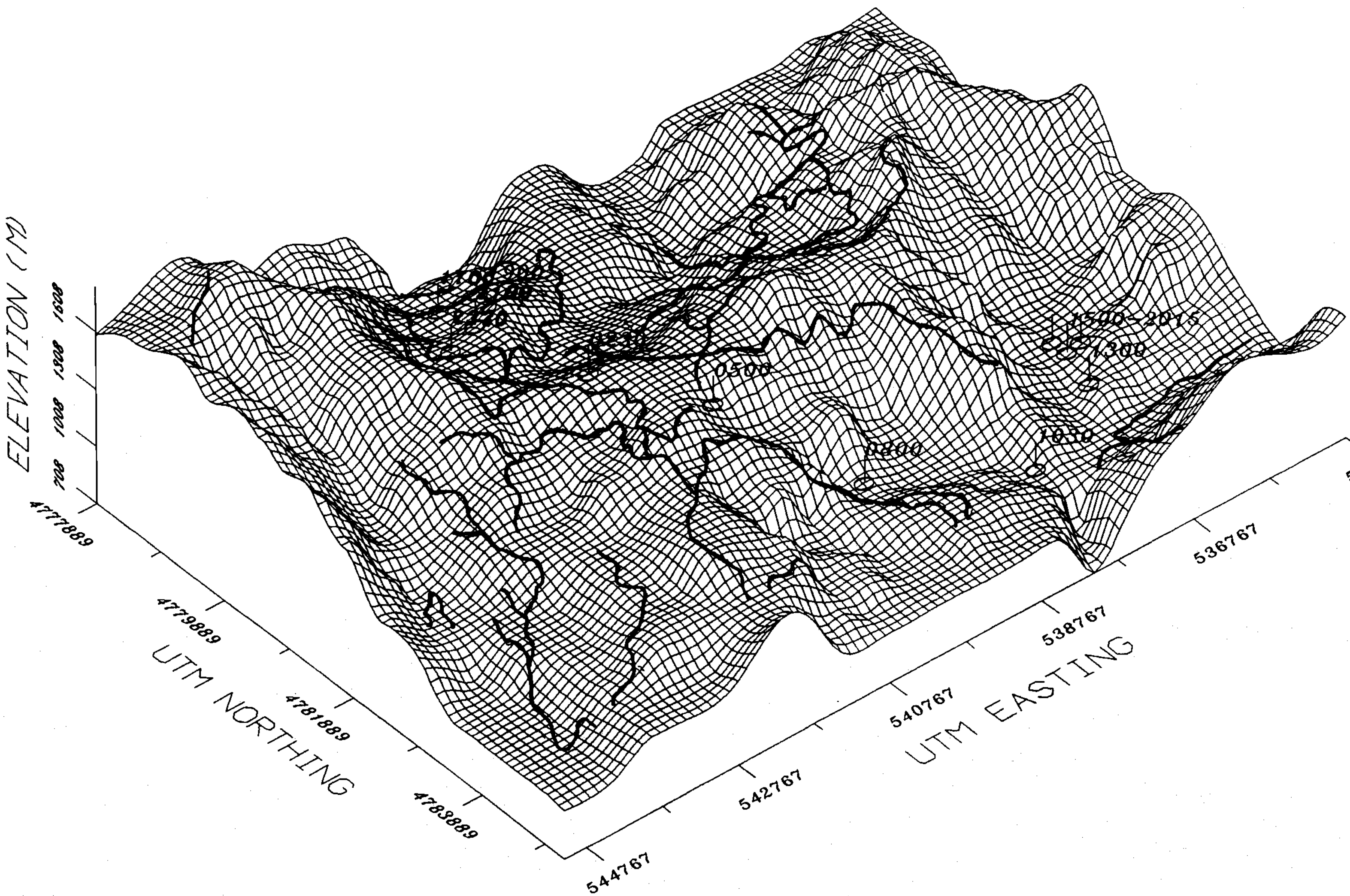

ELEVATION (M)
514829
516829
518829
520829
UTM EASTING
4795372
4797372
4799372
4801372
UTM NORTHING
1800
1700
1520
1330
1200

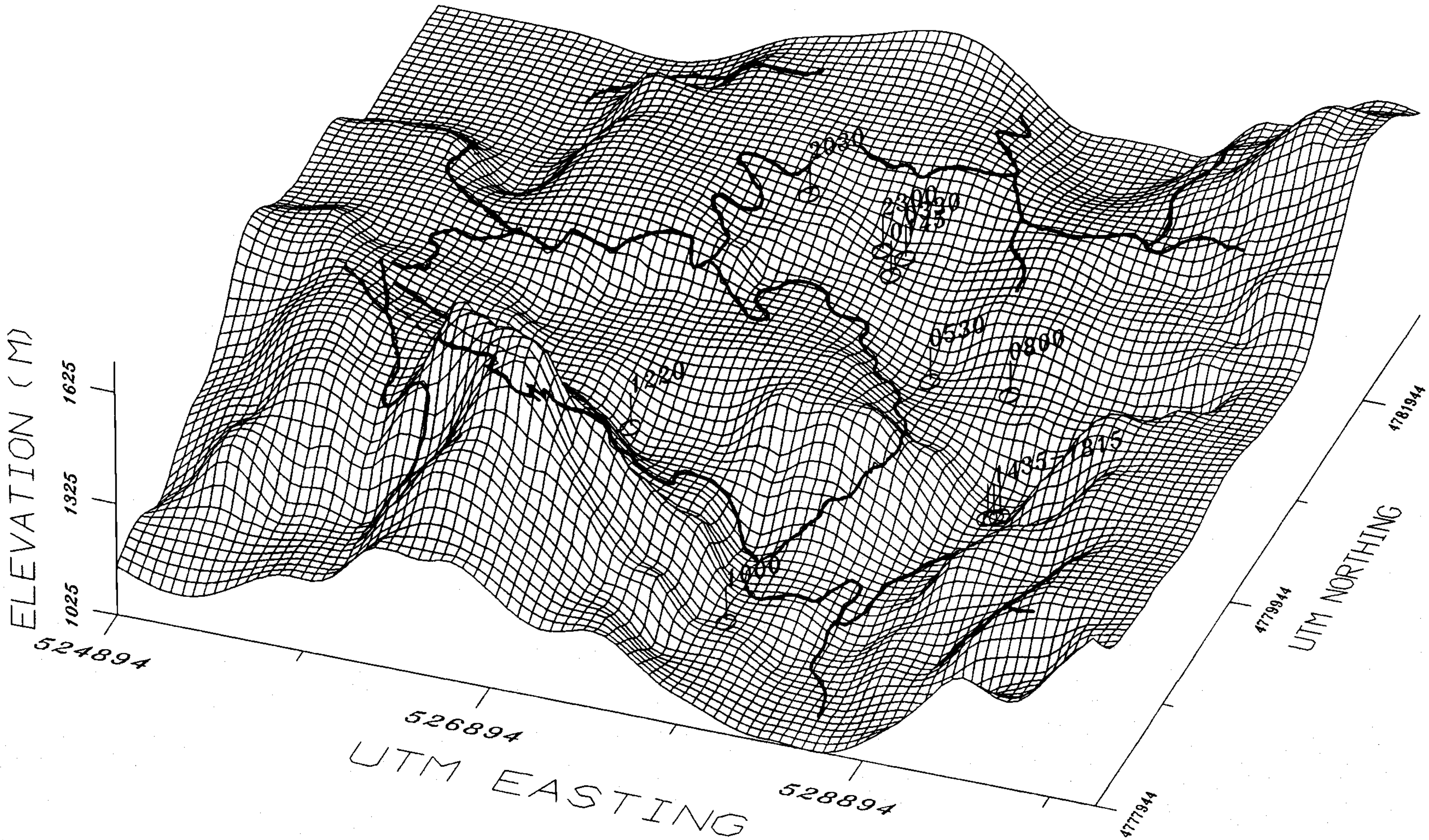

ELEVATION (M)
300
600
900
1200
1500
514653
516653
518653
520653
UTM EASTING
4800912
4802912
4804912
4806912
4808912
UTM NORTHING

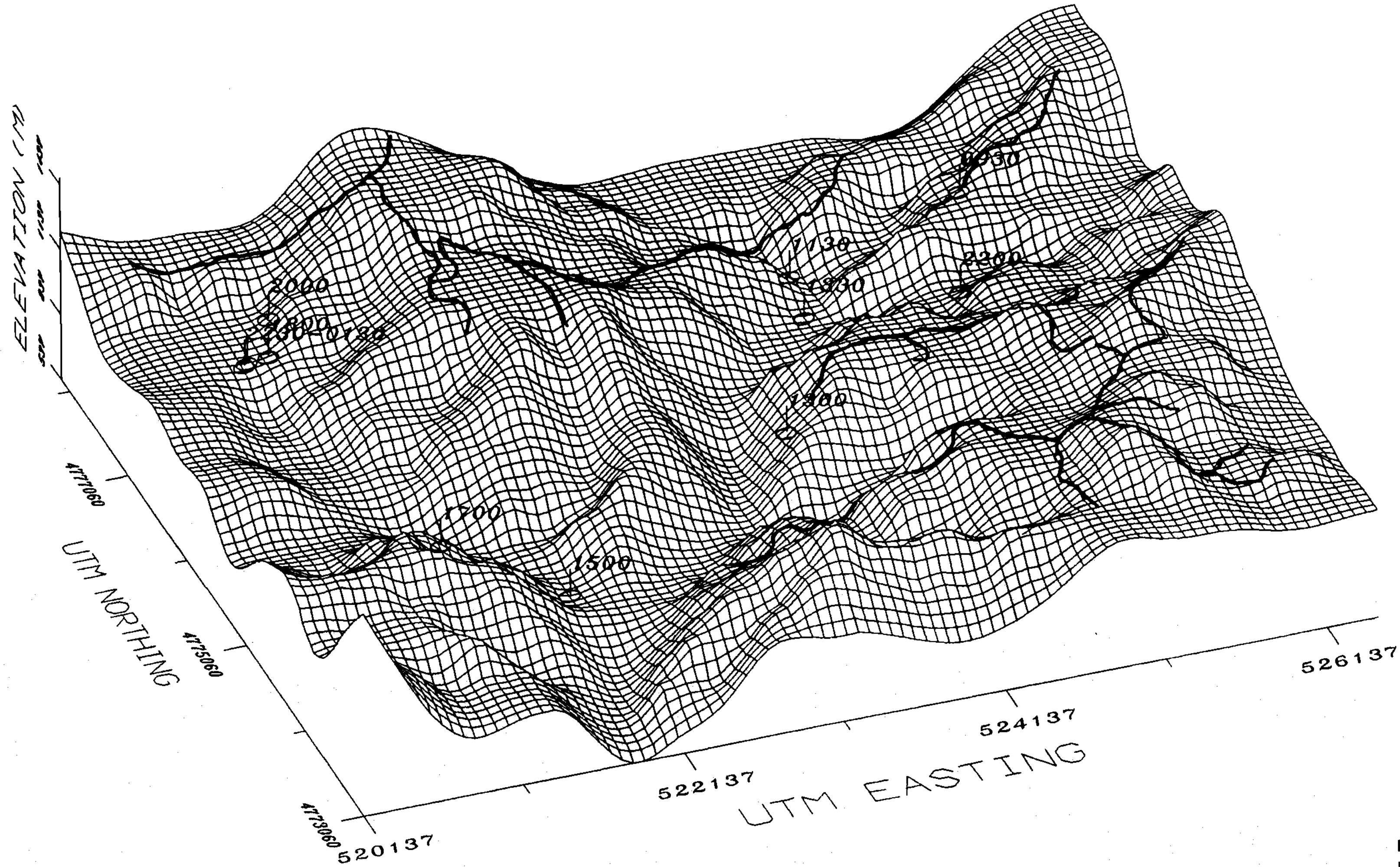

ELEVATION (M)
474
774
1074
514996
515996
516996
517996
518996
UTM EASTING
4805649
4806649
4807649
4808649
UTM NORTHING

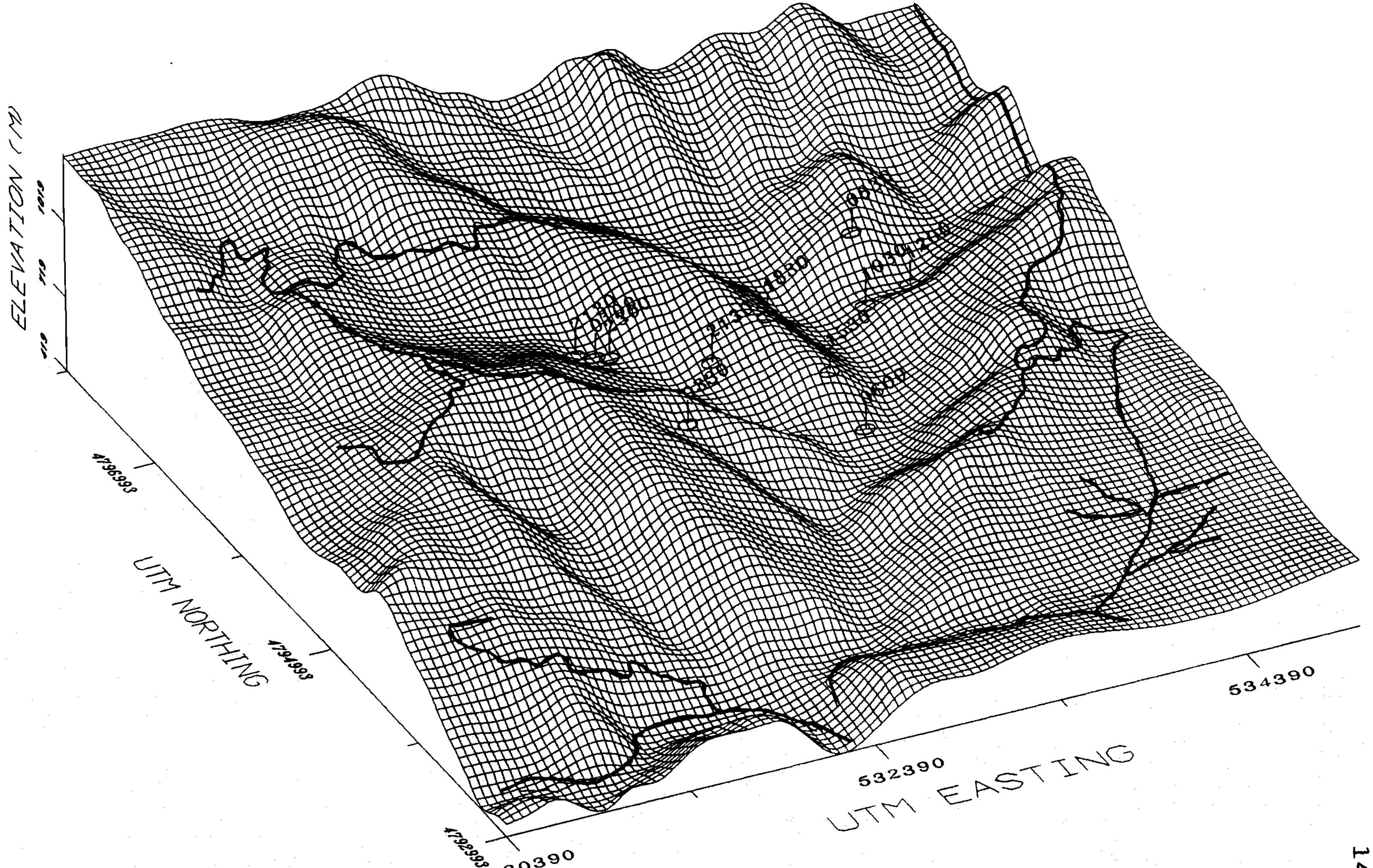

ELEVATION (M)
321
621
921
1221
4805979
4803979
4801979
4799979
UTM NORTHING
503504
505504
507504
UTM EASTING
0300
2300
0500
1200
1700


ELEVATION (M)
1221
921
621
321
4805979
4803979
4801979
4799979
UTM NORTHING
503504
505504
507504
UTM EASTING
2100
0000
0300
0630
0400


ELEVATION (M)
708
1008
1308
1608
UTM NORTHING
4777889
4779889
4781889
4783889
UTM EASTING
544767
542767
540767
538767
536767
534767


ELEVATION (M)
1025
1325
1625
524894
526894
528894
UTM EASTING
4777944
4779944
4781944
UTM NORTHING
2030
2300
0530
0800
1220
1000
1435
1815


ELEVATION (M)
UTM NORTHING
UTM EASTING
520137
522137
524137
526137
4773060
4775060
4777060
2000
2200
1130
1700
1500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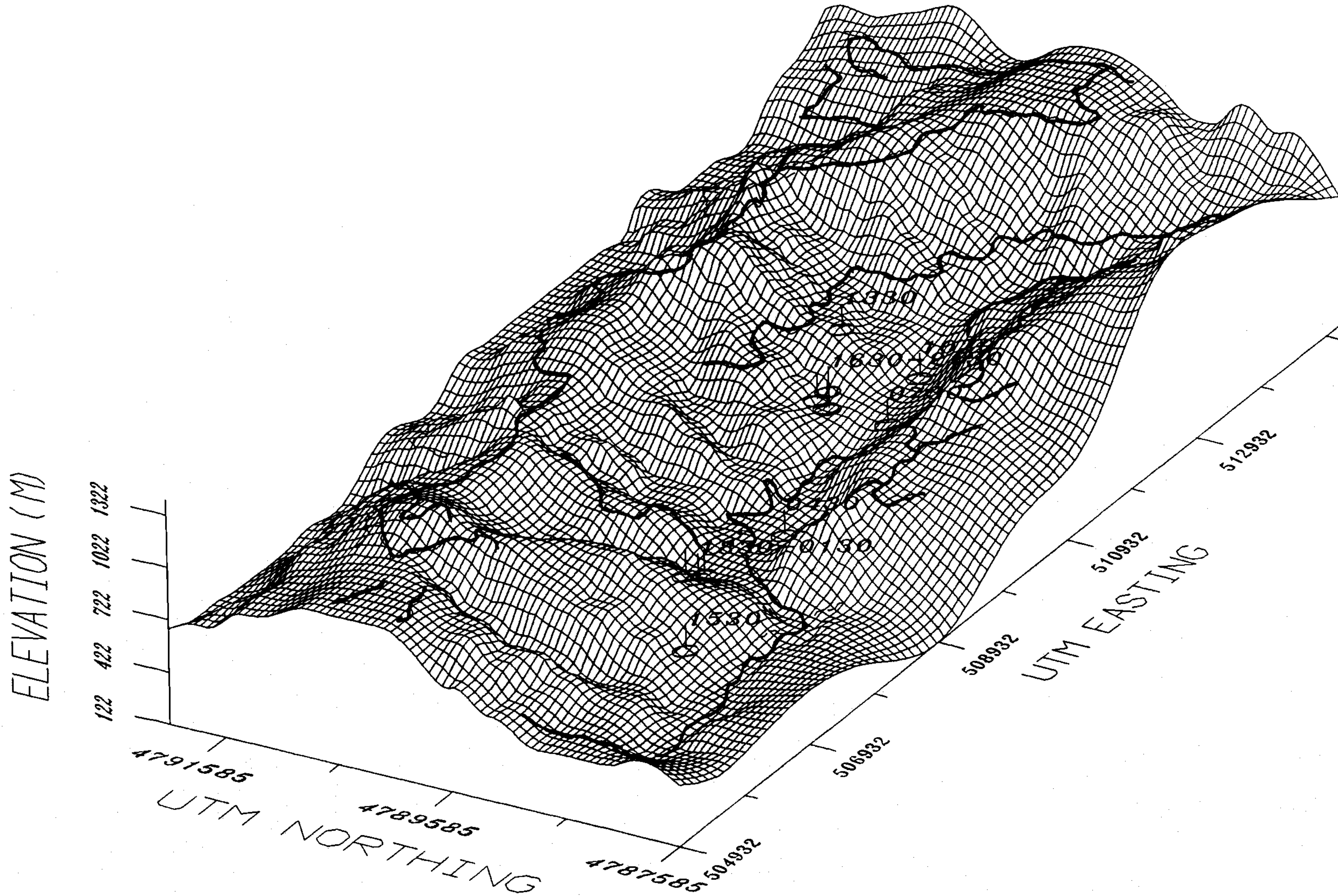
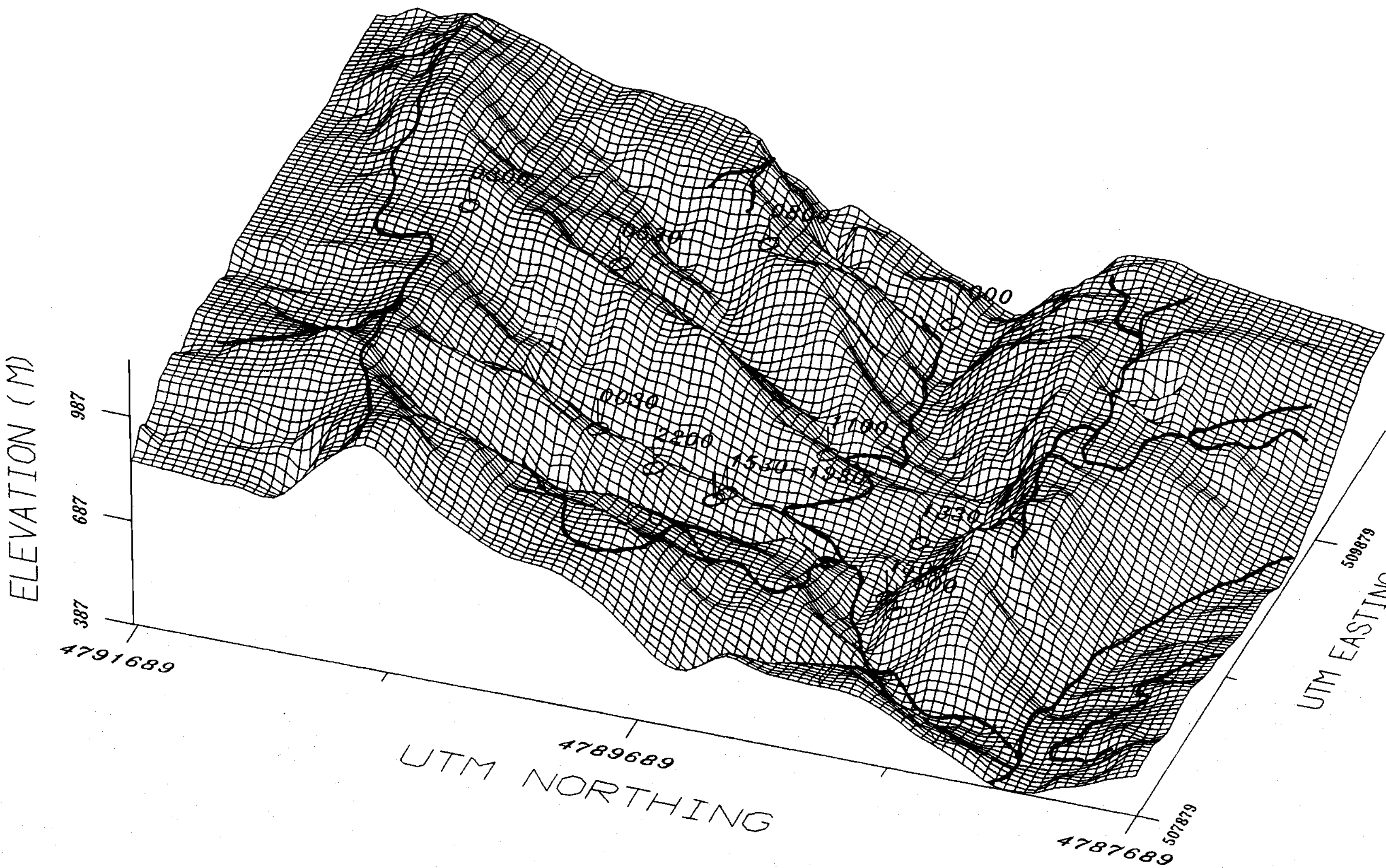
UTM NORTHING
4796993
4794993
4792993
UTM EASTING
530390
532390
534390


ELEVATION (M)
122
422
722
1022
1322
UTM NORTHING
4791585
4789585
4787585
UTM EASTING
504932
506932
508932
510932
512932
514932


ELEVATION (M)
987
687
387
4791689
4789689
4787689
UTM NORTHING
507879
509879
UTM EASTING

Human Disturbances:

Female 1, CMP1 150

Female 1, CMP2 151

Female 1, CMP3 152

Female 2, CMP1 153

Female 2, CMP2 154

Female 8, CMP1 155

Female 8, CMP2 156

Female 8, CMP3 157

Female 8, CMP4 158

Female 8, CMP5 159

Male 5, CMP1 160

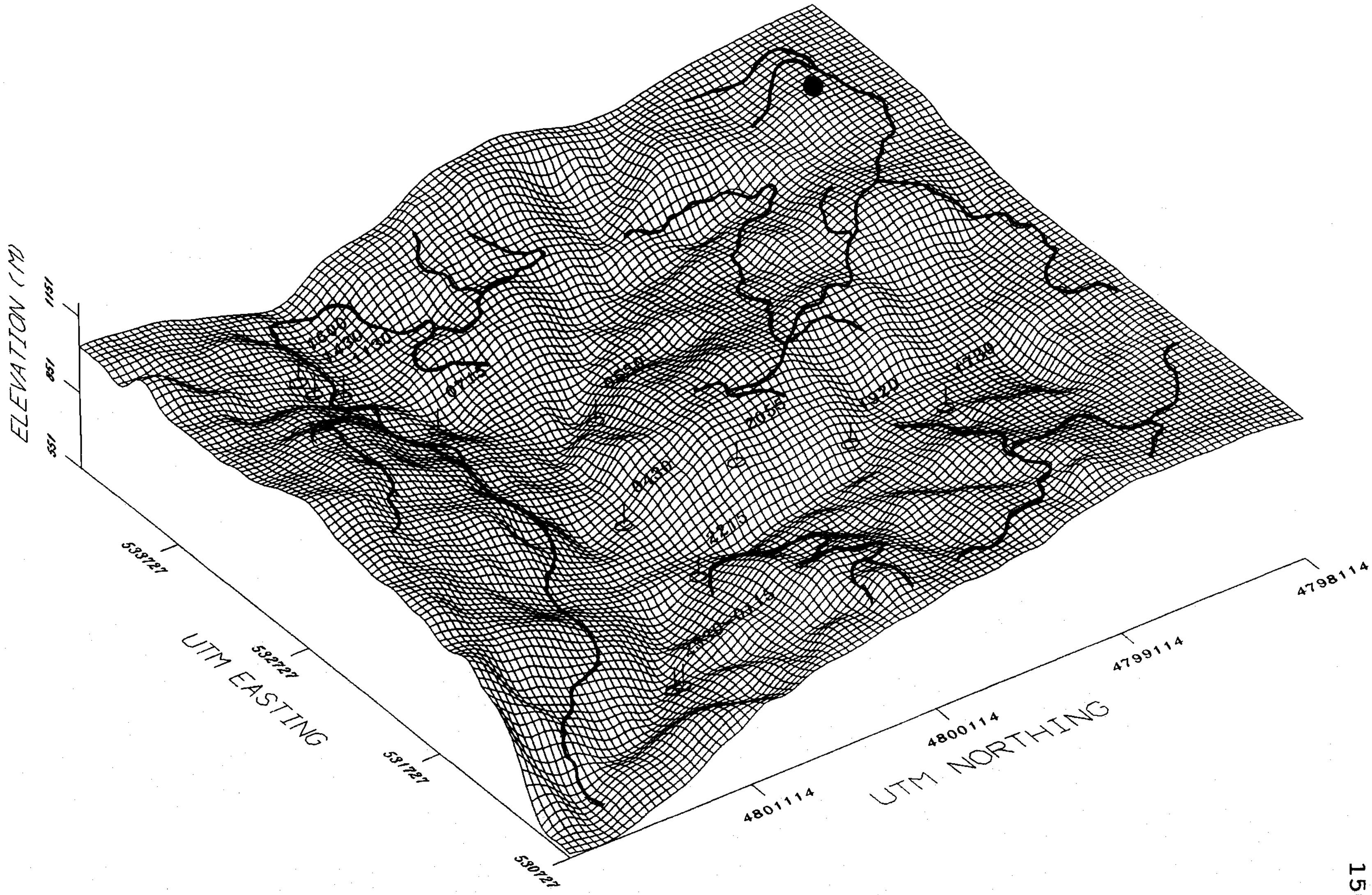
Male 5, CMP2 161

Male 5, CMP3 162

Male 9, CMP1 163

Male 9, CMP2 164

Male 9, CMP3 165


ELEVATION (M)
1151
851
551
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532727
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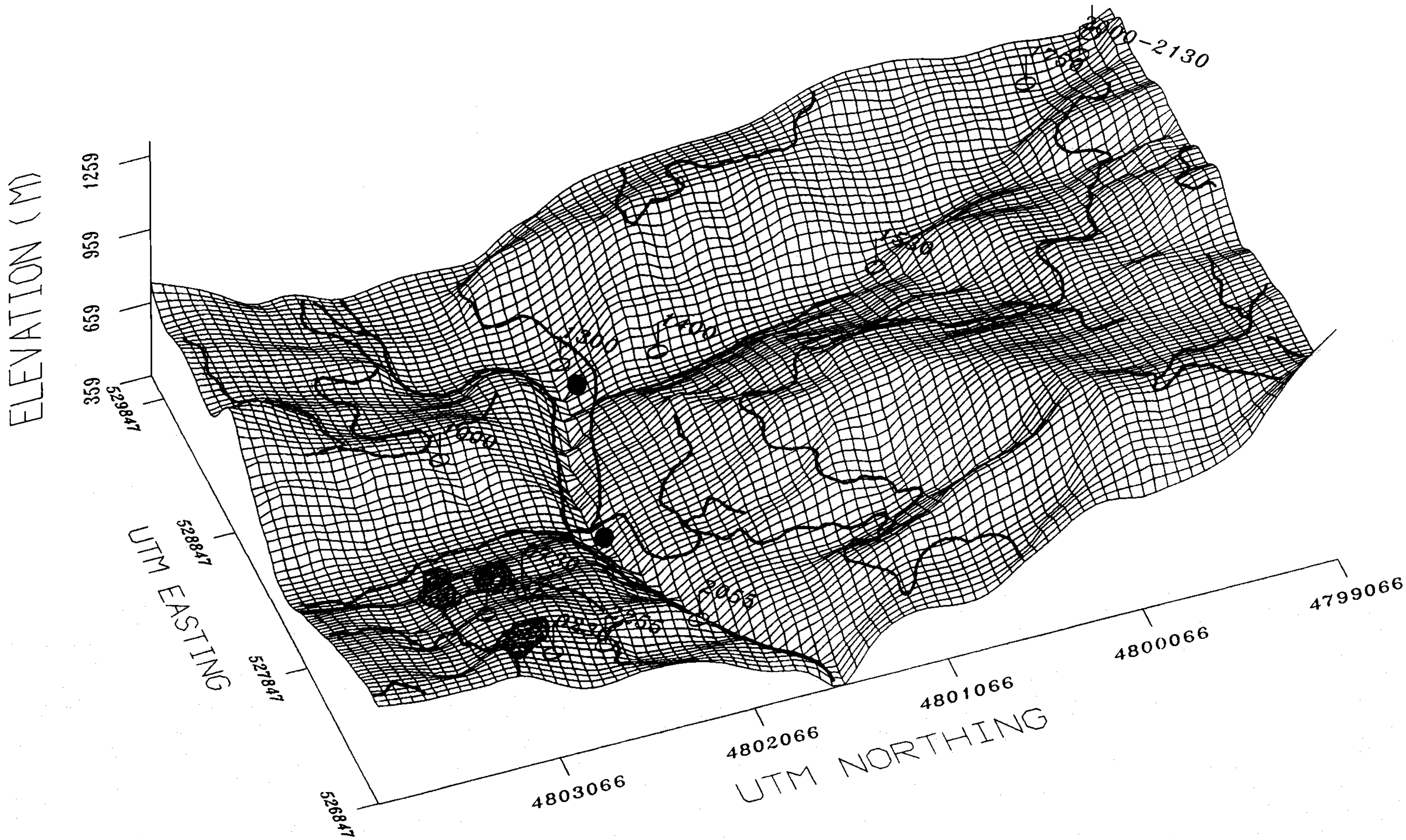
4800114
4799114
4798114


ELEVATION (M)
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659
959
1259
UTM EASTING
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527847
526847
UTM NORTHING
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4802066
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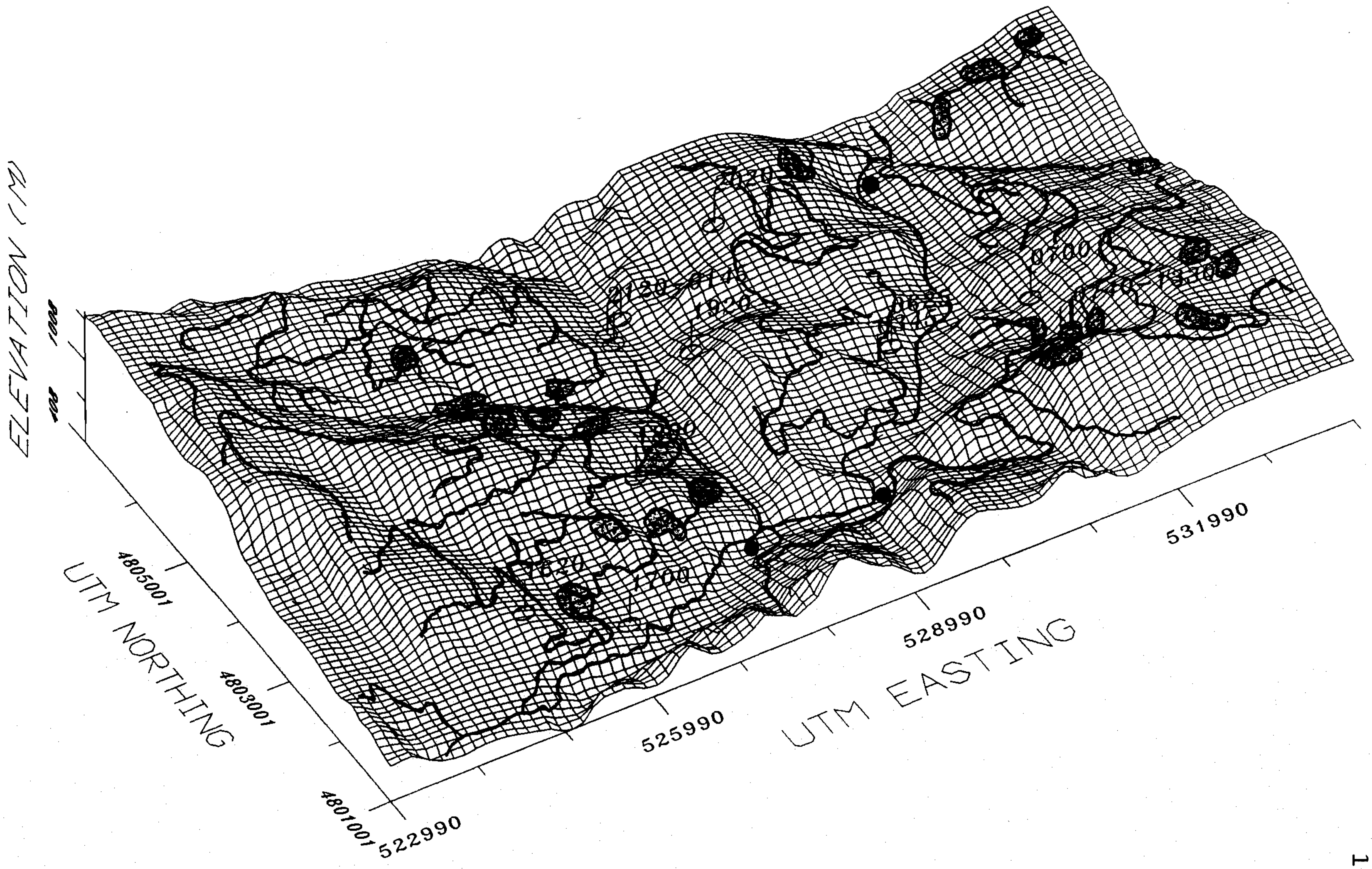
4799066
2000-2130


ELEVATION (M)
UTM NORTHING
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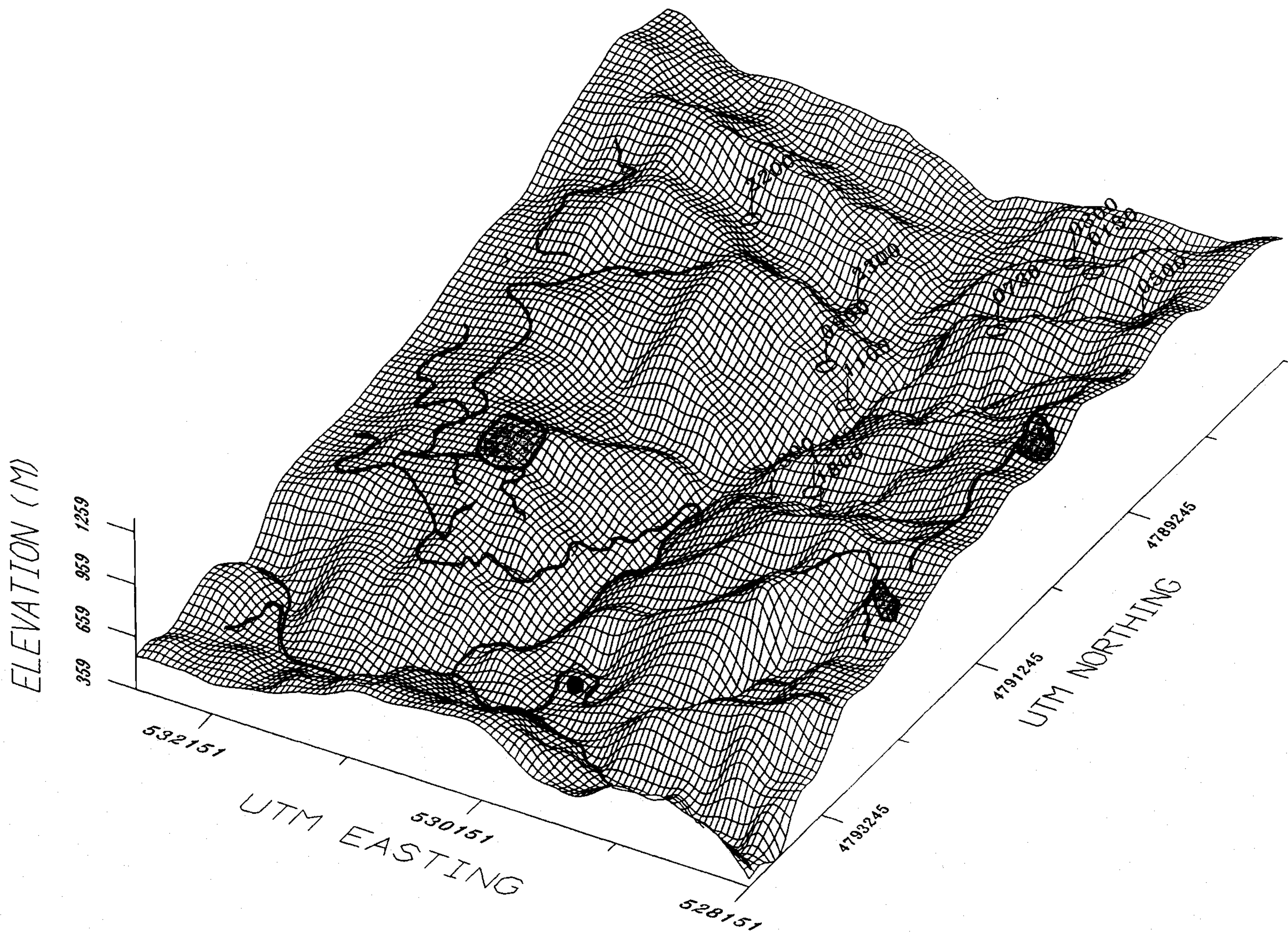
4803001
4801001
UTM EASTING
522990
525990
528990
531990


ELEVATION (M)
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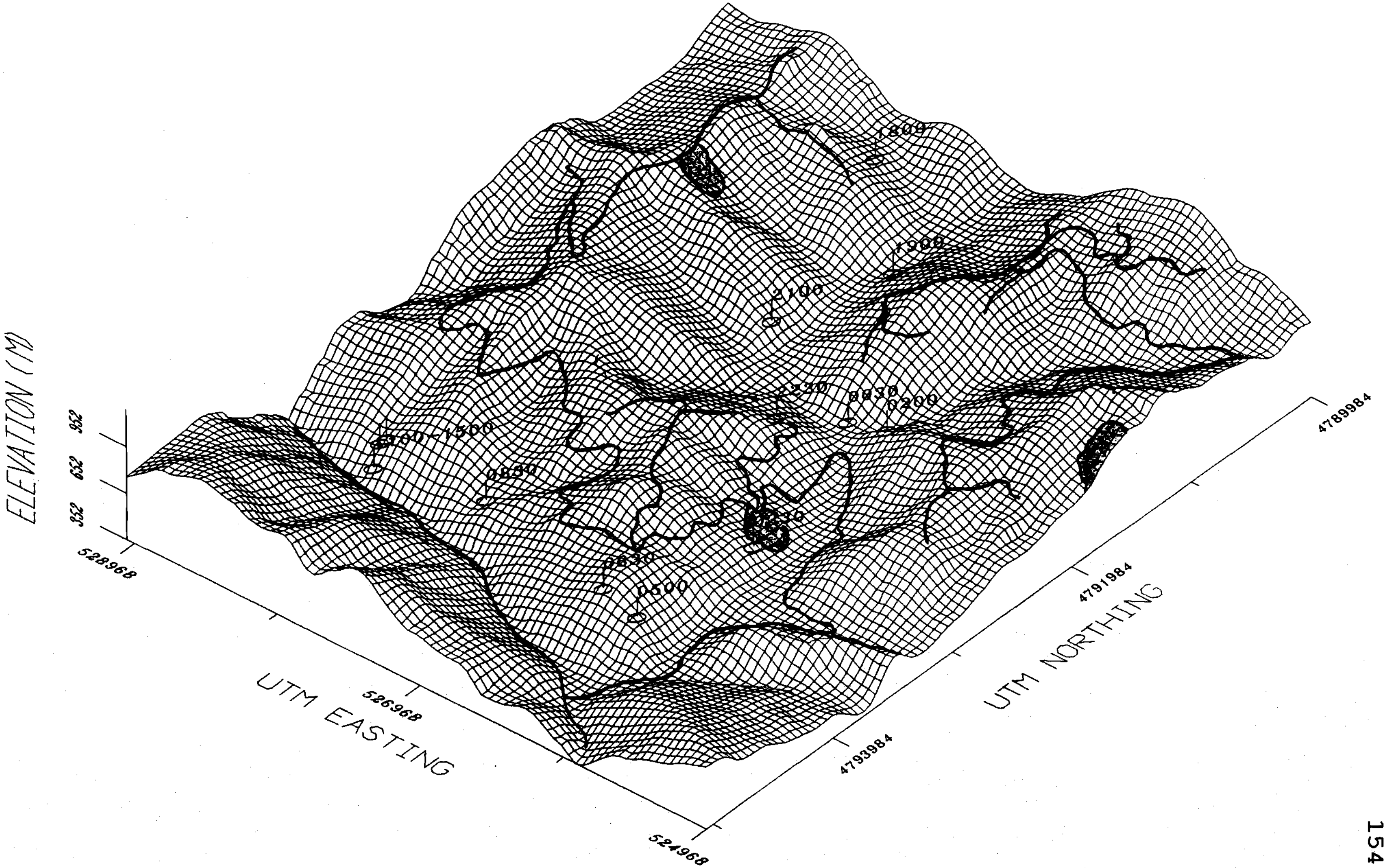
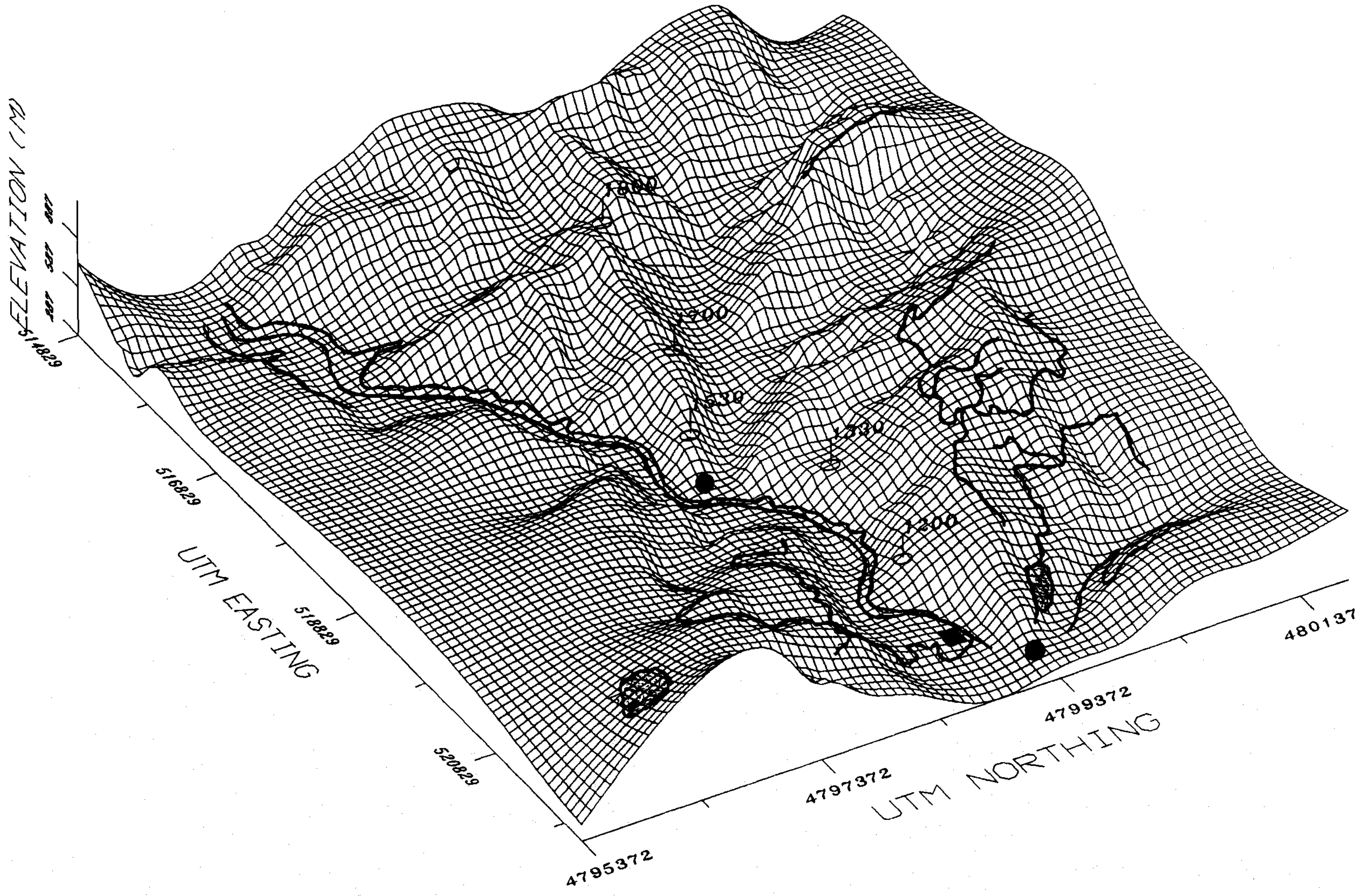
659
959
1259
532151
530151
528151
UTM EASTING
4793245
4791245
4789245
4787245
UTM NORTHING


ELEVATION (M)
352
652
952
528968
526968
524968
UTM EASTING
4793984
4791984
4789984
UTM NORTHING
1800
1900
2100
2230
0830
0200
1500
0800
0500



ELEVATION (M)
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516829
518829
520829
UTM EASTING
4795372
4797372
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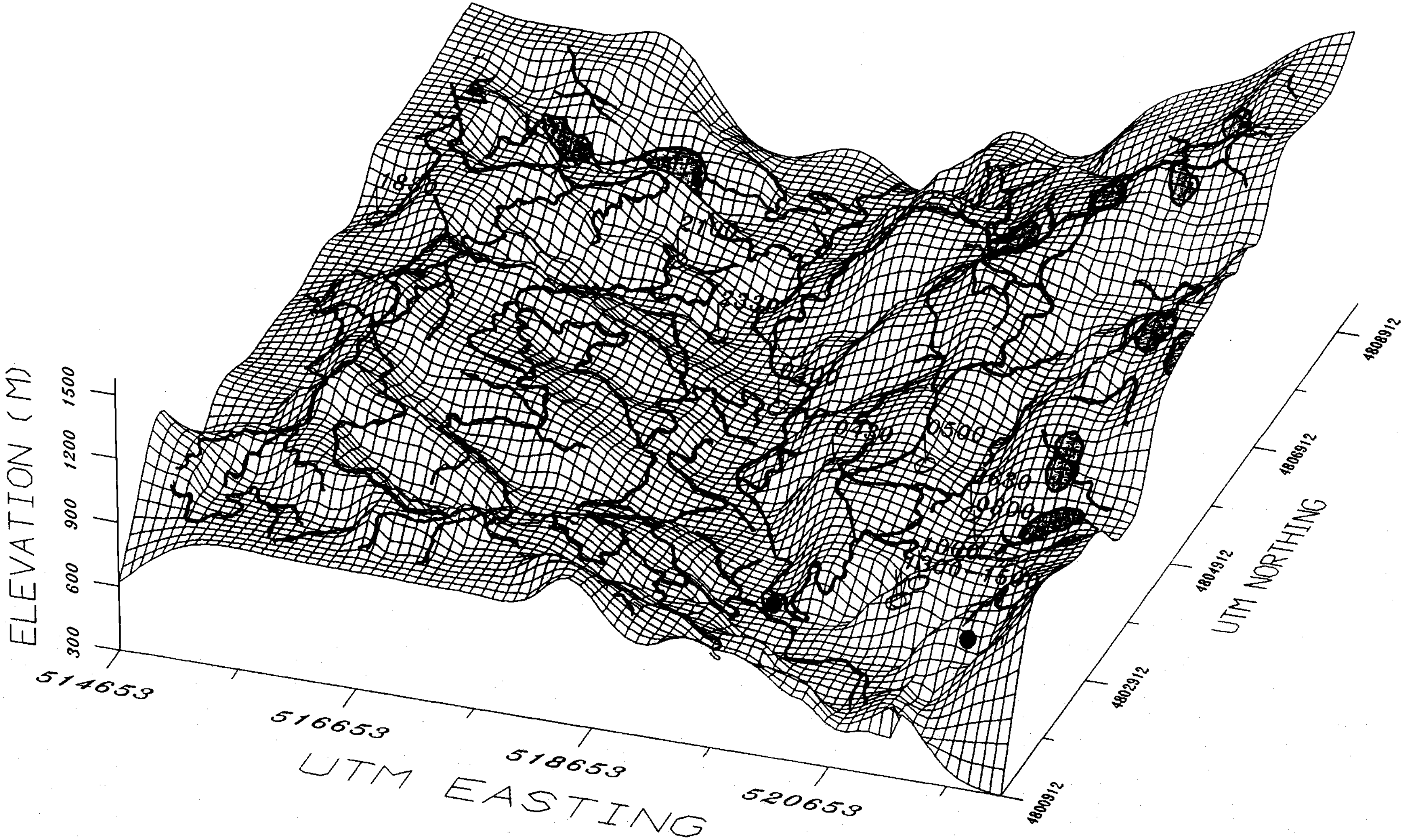
4801372
UTM NORTHING
1200



ELEVATION (M)
300
600
900
1200
1500
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518653
520653
UTM EASTING
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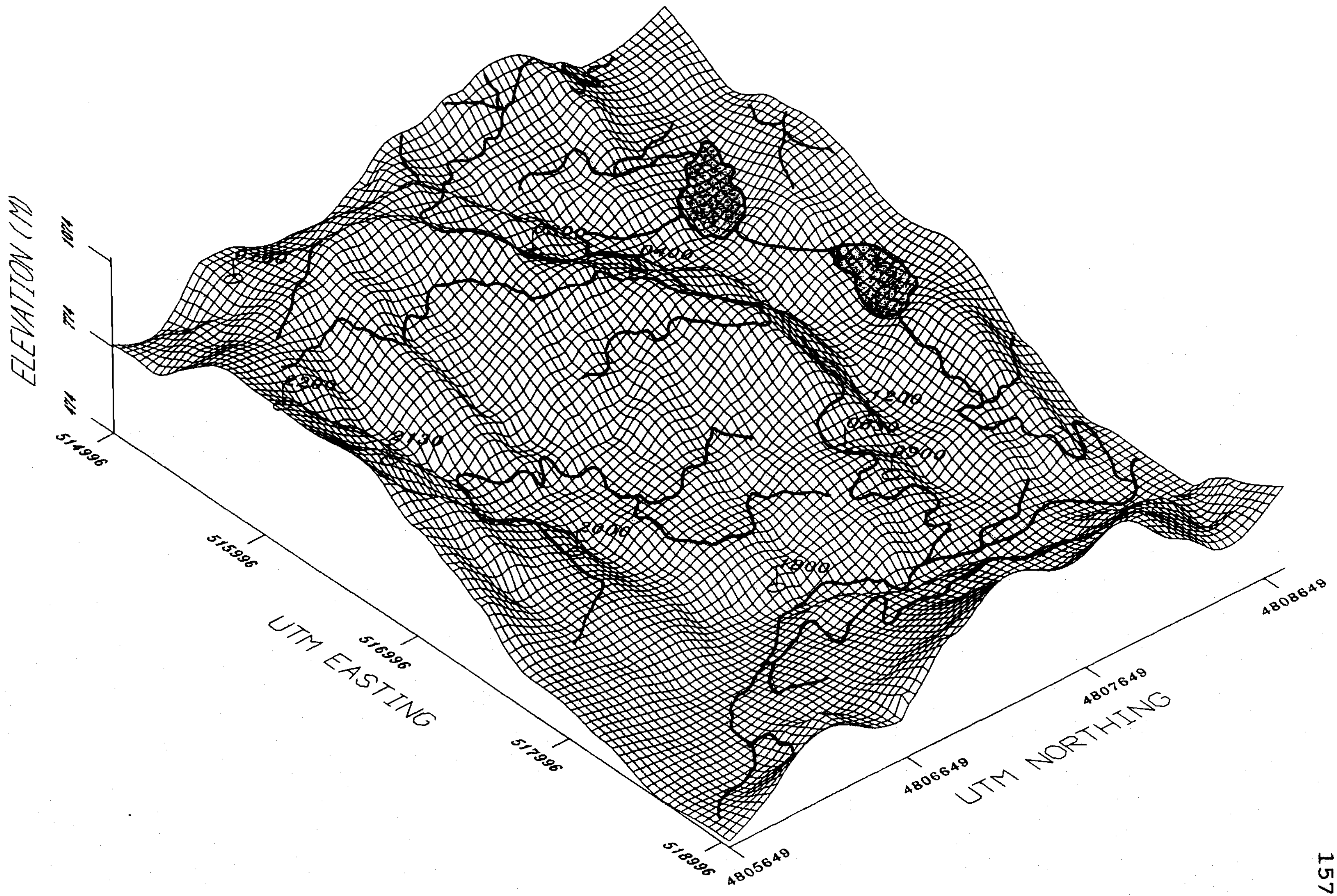
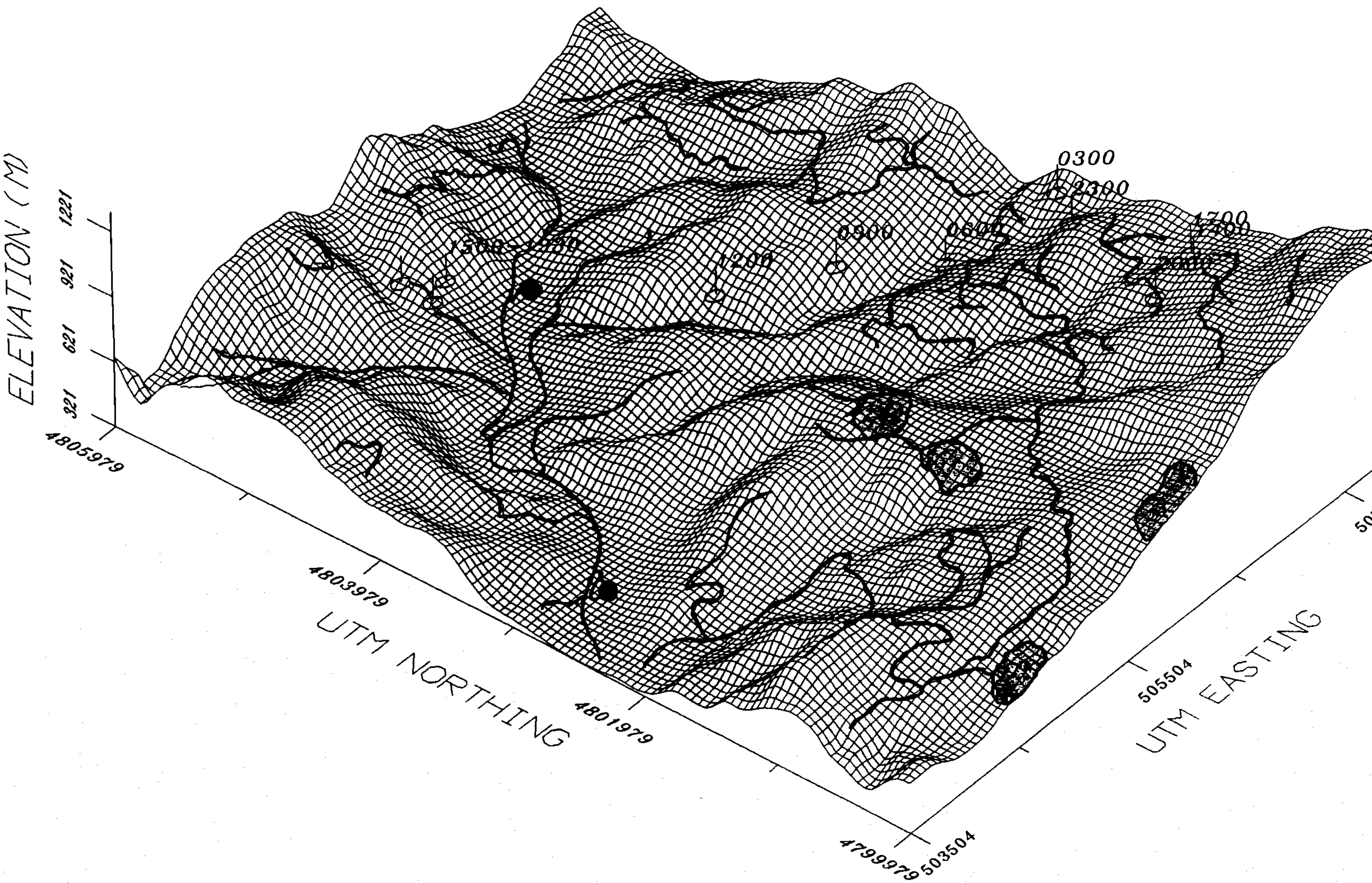
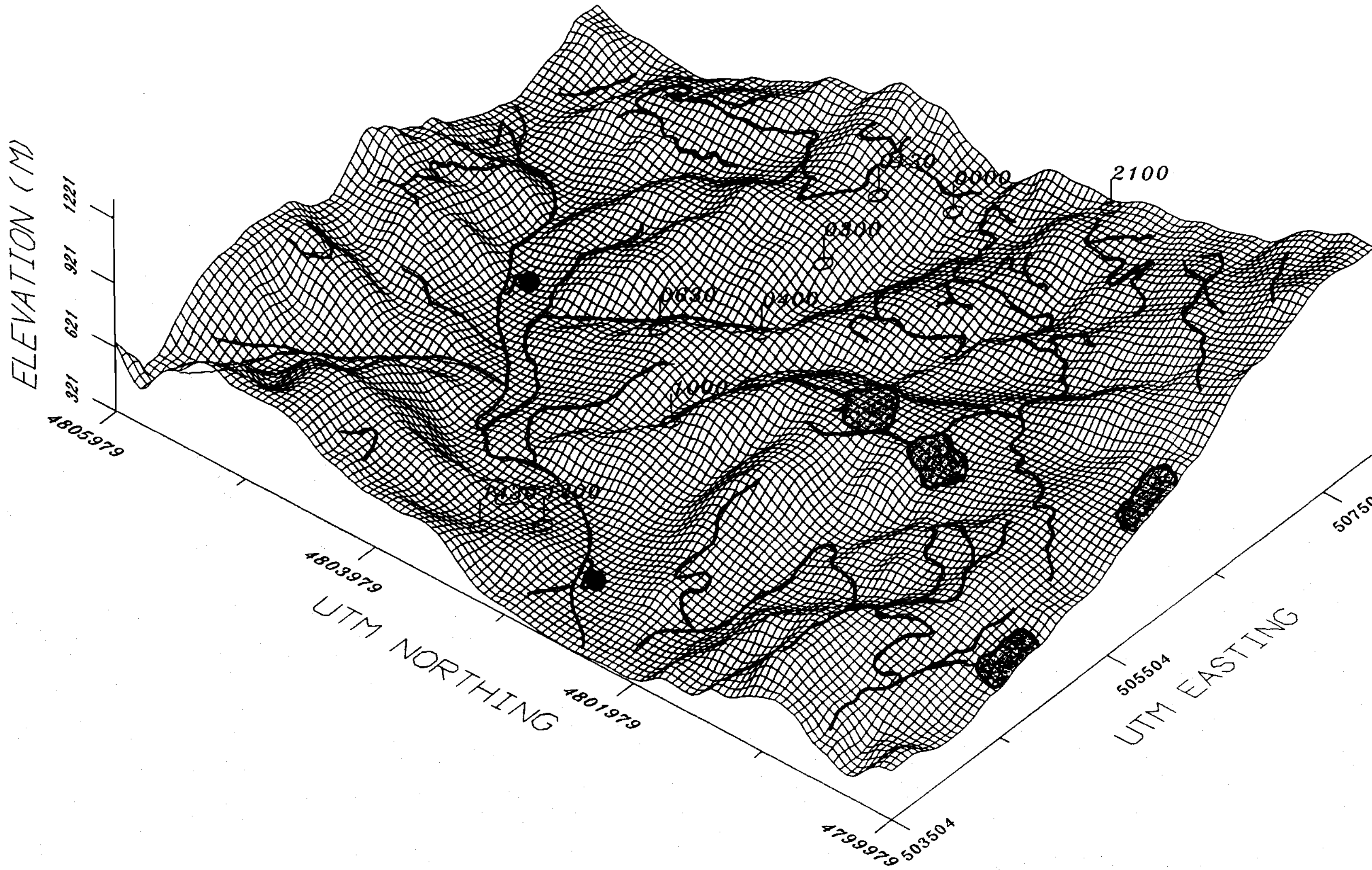
4804912
4806912
4808912
UTM NORTHING



ELEVAITON (M)
1074
774
474
514996
515996
516996
517996
518996
UTM EASTING
4805649
4806649
4807649
4808649
UTM NORTHING


ELEVATION (M)
321
621
921
1221
4805979
4803979
4801979
4799979
UTM NORTHING
503504
505504
507504
UTM EASTING
0300
2300
1700
0900
0600
1200


ELEVATION (M)
321
621
921
1221
4805979
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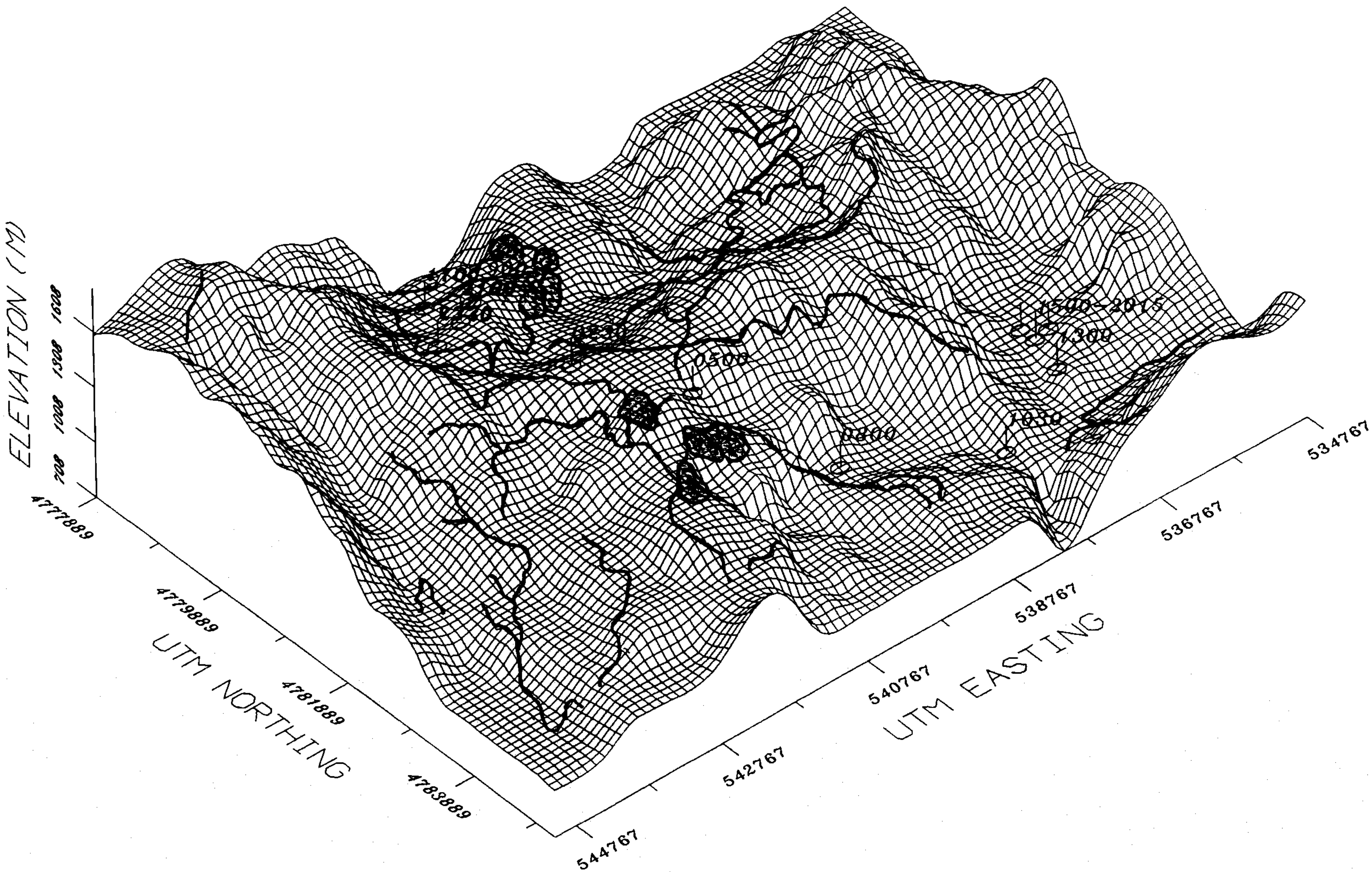
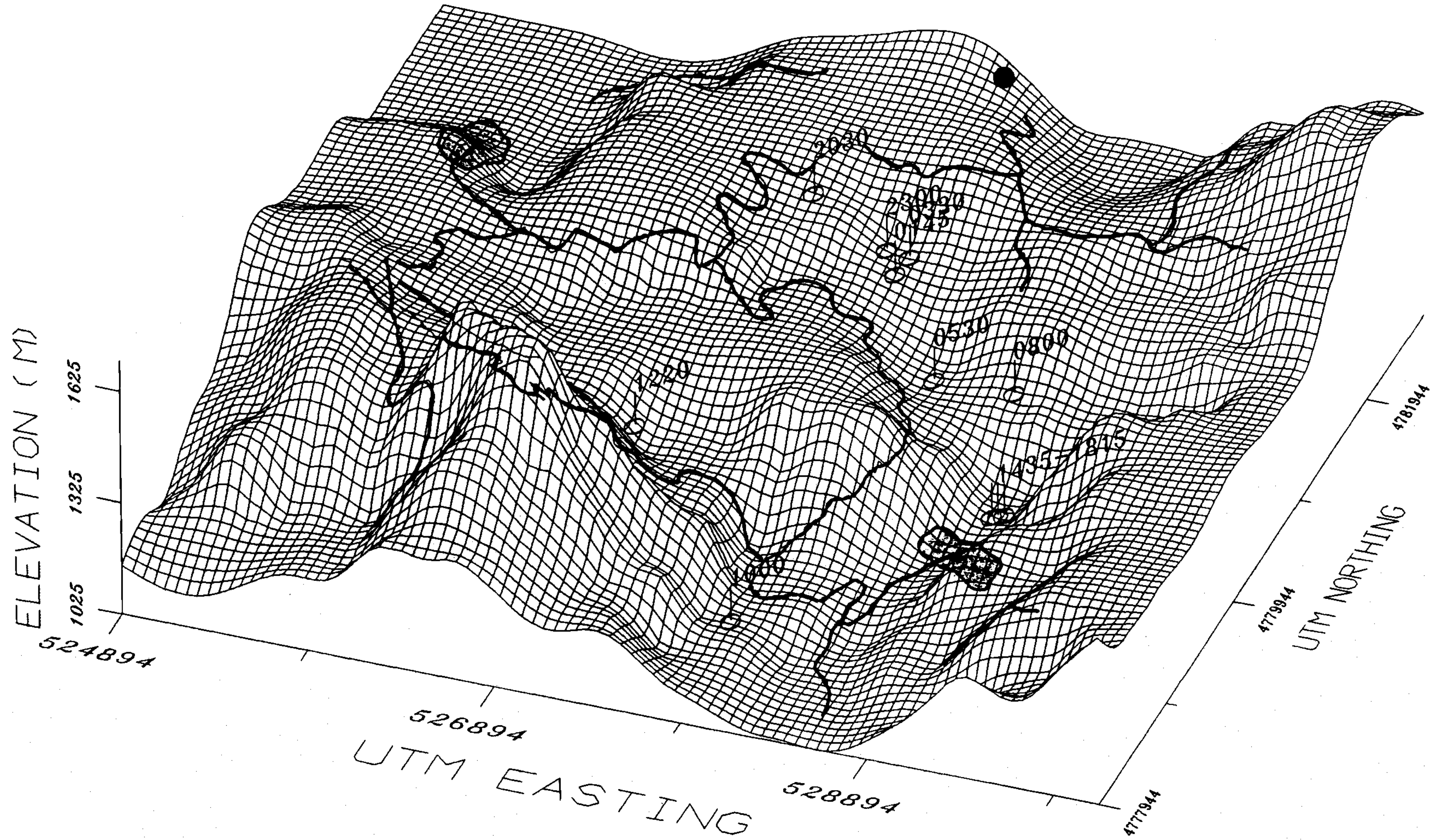
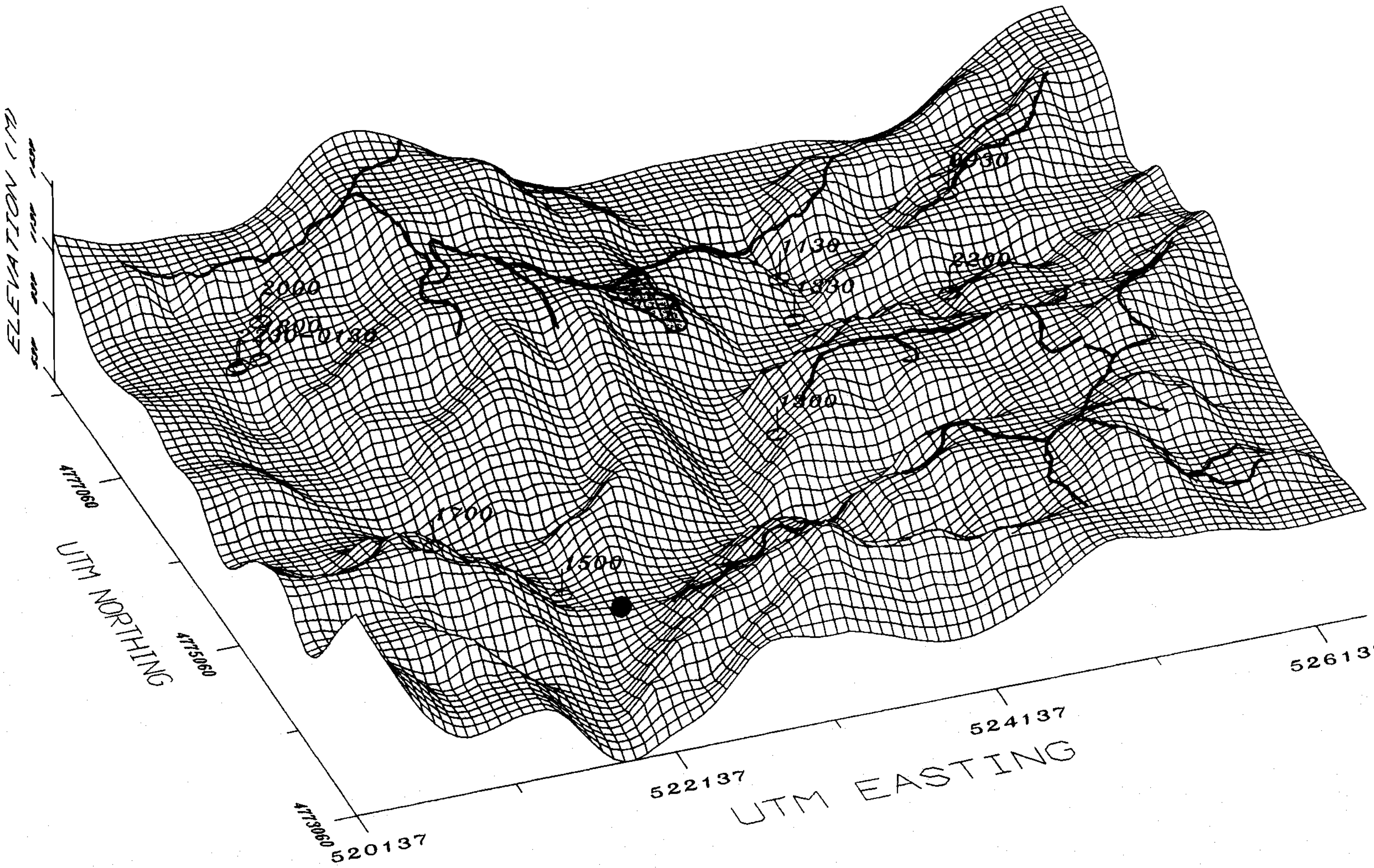
UTM NORTHING
503504
505504
507504
UTM EASTING
2100
0630
0400
0300
0000


ELEVATION (M)
708
1008
1308
1608
4777889
4779889
4781889
4783889
UTM NORTHING
544767
542767
540767
538767
536767
534767
UTM EASTING
0500
0900
1030
1300
1500-2075


ELEVATION (M)
1625
1325
1025
524894
526894
528894
UTM EASTING
4777944
4779944
4781944
UTM NORTHING
2030
0530
0800
1220
1000


ELEVATION (M)
UTM NORTHING
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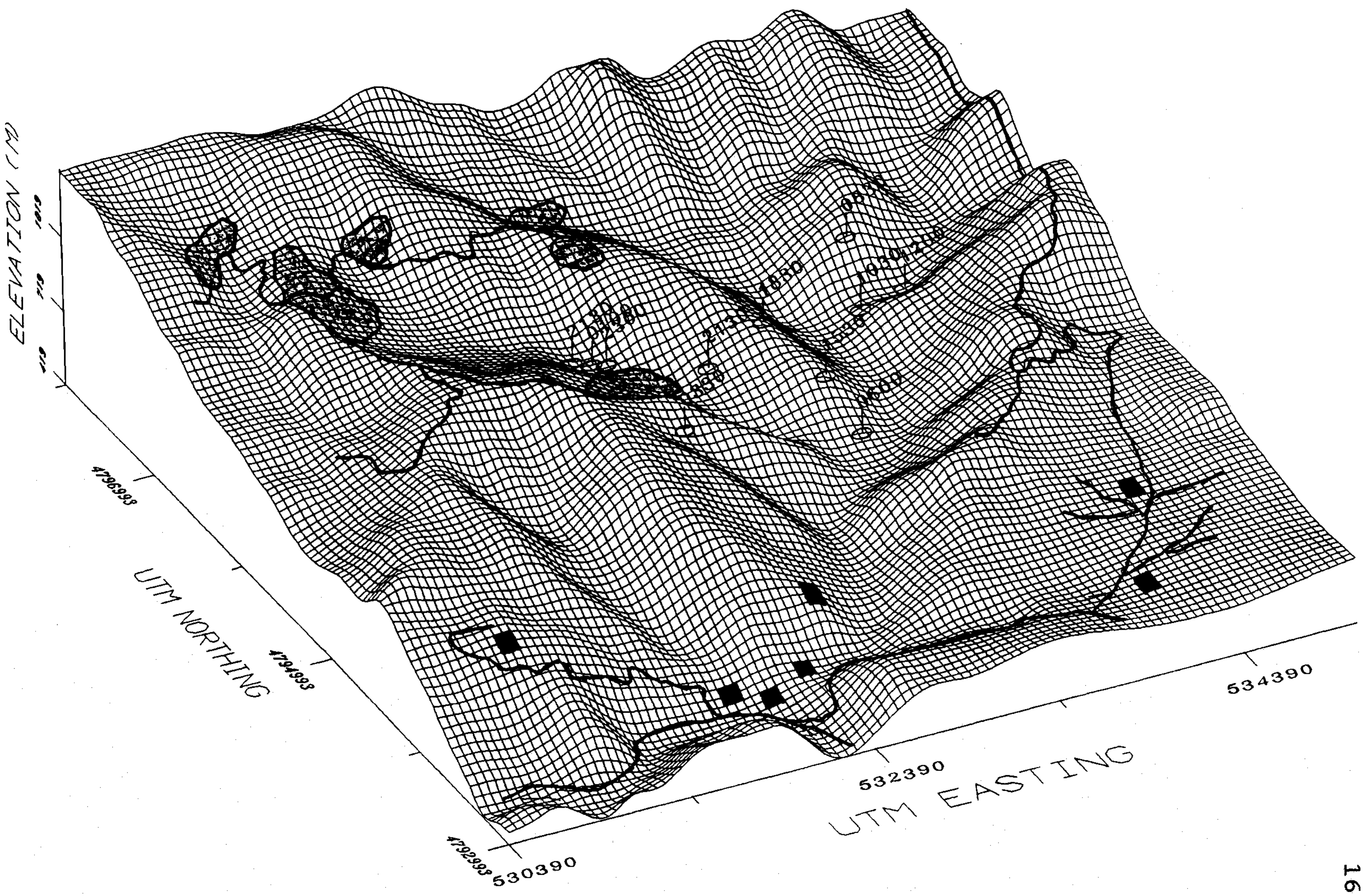
4773060
UTM EASTING
520137
522137
524137
526137
2000
1700
1500
1130
2200



ELEVATION (M)
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4792993
UTM EASTING
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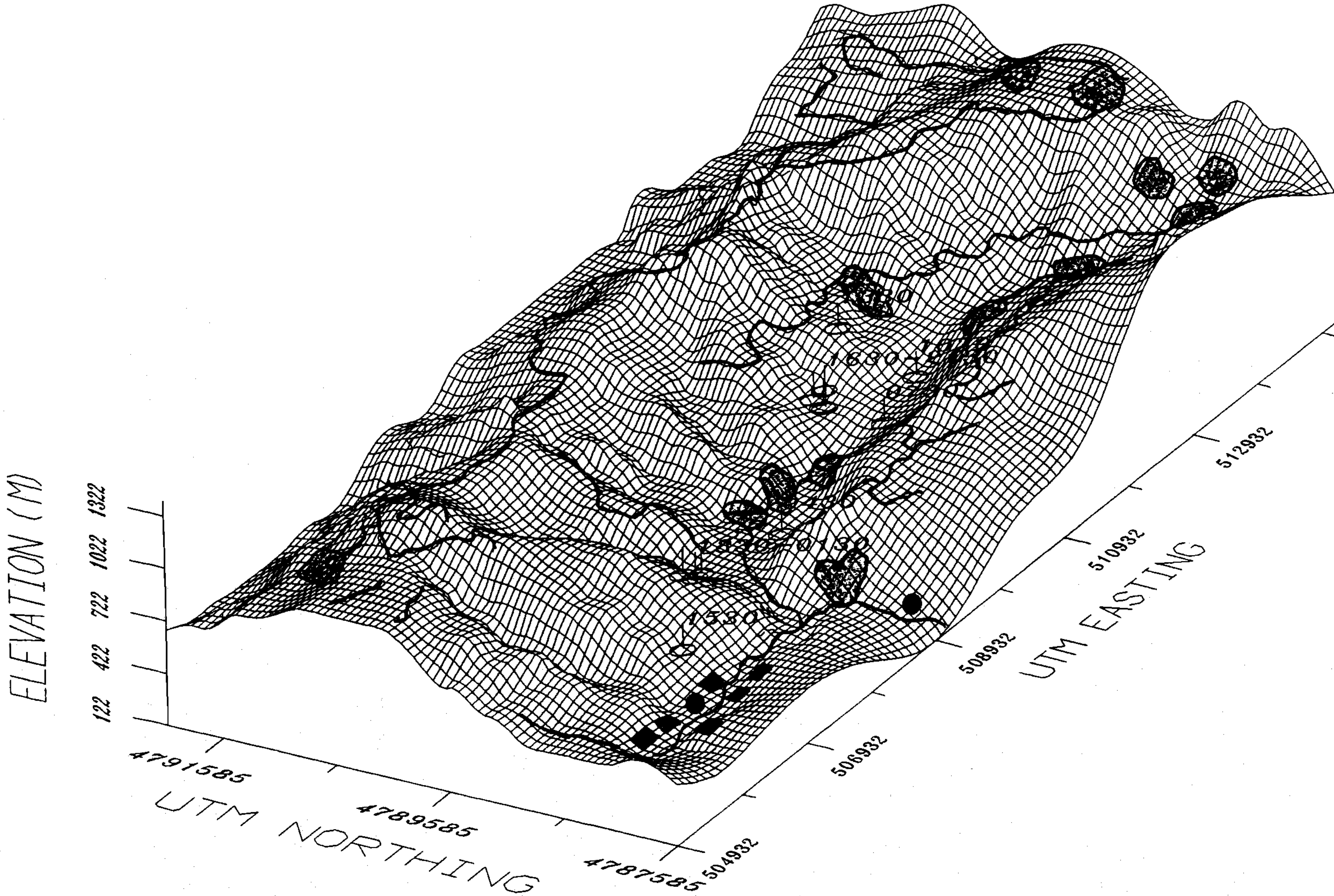
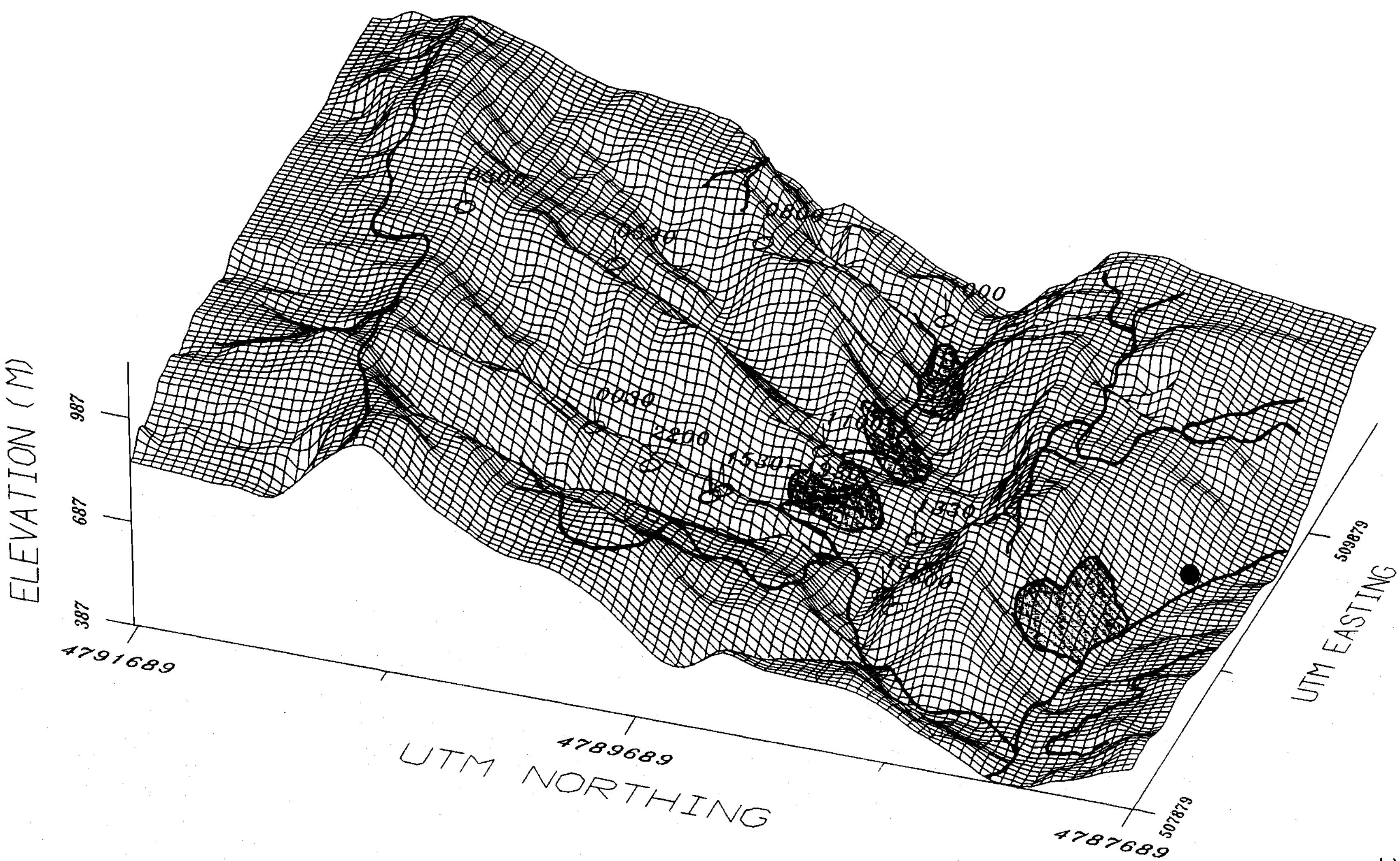

ELEVATION (M)
122
422
722
1022
1322
UTM NORTHING
4791585
4789585
4787585
UTM EASTING
504932
506932
508932
510932
512932
514932


ELEVATION (M)
987
687
387
4791689
4789689
4787689
UTM NORTHING
UTM EASTING
509879
507879