GARY S. RASMUSSEN & ASSOCIATES, INC. / *ENGINEERING GEOLOGY*

1811 COMMERCENTER WEST • SAN BERNARDINO, CALIFORNIA 92408 • (714) 888-2422 • 825-9052 • FAX 888-6806

PRELIMINARY ENGINEERING GEOLOGY INVESTIGATION
PARADISE HILLS DEVELOPMENT
APPROXIMATELY 410 ACRES
BADGER CANYON AND VICINITY
SAN BERNARDINO, CALIFORNIA

October 4, 1990

Project No. 2776

Prepared For

Aradi, Inc.
1875 Century Park East, Suite 1880
Los Angeles, California 90067

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1875 Century Park East, Suite 1880
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Project No. 2776

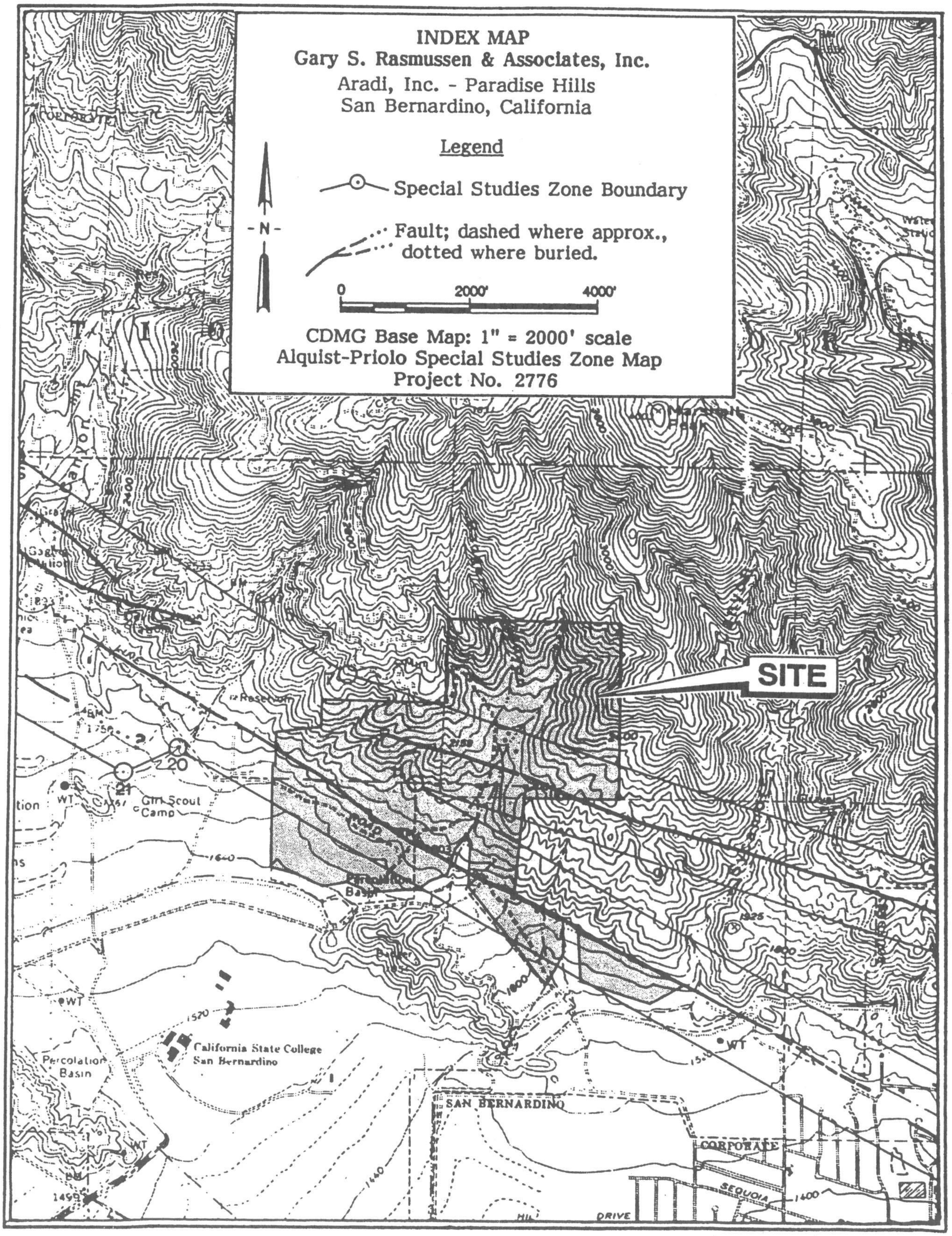
Attention: Steve Dallman

Subject: **Preliminary Engineering Geology Investigation of the Proposed Paradise Hills Development, Approximately 410 Acres, Badger Canyon and Vicinity, San Bernardino, California.**

A preliminary engineering geology investigation of the proposed Paradise Hills Development has been conducted in accordance with your request. The purpose of our investigation was to relate general geologic conditions of the site to future residential development. An undated 200-scale topographic map, prepared by J.F. Davidson Associates, Inc., was used in our investigation. The approximate location of the site is shown on the index map on page 2.

We understand that the site is to be developed with approximately 500 single-family residences. No grading plans were available at the time of our investigation; however, existing site topography suggests that significant cut and fill slopes may be required for development of the site. We understand that the flatter portions of the site will be developed with structures and that the steeper hillside areas will remain as open space.

Most of the site lies within an Alquist-Priolo Special Studies Zone designated by the State of California to include traces of suspected active faulting associated with the San Andreas fault. The main trace of the San Andreas fault traverses the southwest portion of the site. Prior to placement of human occupancy structures within the Alquist-Priolo Special Studies Zone, a subsurface investigation will need to be conducted so that setbacks for placement of human occupancy structures can be recommended. This investigation was not intended to satisfy the requirements of the Alquist-Priolo Special Studies Zones Act. The purpose of our investigation was


INDEX MAP
Gary S. Rasmussen & Associates, Inc.
Aradi, Inc. - Paradise Hills
San Bernardino, California
Legend
Special Studies Zone Boundary
Fault; dashed where approx., dotted where buried.
-N-
0
2000'
4000'
CDMG Base Map: 1" = 2000' scale
Alquist-Priolo Special Studies Zone Map
Project No. 2776
SITE
Girl Scout Camp
California State College San Bernardino
Percolation Basin
SAN BERNARDINO
CORPORATE
SEQUOIA
DRIVE
20
21

to provide geologic input for planning purposes and formulating a conceptual design plan for the development.

SITE INVESTIGATION

A geologic field reconnaissance and geologic mapping of the site were conducted during August and September, 1990. The geologic map is included as Plate 1. In addition, our investigation included review of stereoscopic aerial photographs flown in 1930, 1953, 1971, 1972, 1978 and 1990; review of pertinent geologic literature and maps, including reports in our files on nearby projects; and review of significant seismic information, including historic seismic activity. A list of aerial photographs reviewed and references cited in this report is included as Enclosure 3.

SITE DESCRIPTION

The approximately 410-acre site is located within the southwestern foothills of the San Bernardino Mountains in the northwestern portion of the City of San Bernardino, California. The site includes the SW¼ of Section 4 and portions of Sections 5, 8, and 9 of T1N, R4W, SBB&M. The site includes the lower portion of Badger Canyon and the immediate vicinity. Vacant land borders the site on the north and east. Flood control facilities, including a concrete-lined channel, flood control berms and percolation basins, border the site on the south. A ranch exists immediately west of the site. At the time of our investigation, on-site vegetation generally consisted of a light to moderate growth of brush. Relatively dense vegetation consisting of trees, vines, and poison oak existed in the Badger Canyon drainage bottom and associated with some of the numerous springs on the site.

Site topography varies from relatively flat in the southwest portion of the site to relatively steep, mountainous areas in the north portion of the site. Overall, the southwest portion of the site slopes toward the southwest at a rate of approximately 20 percent. The central portion of the site is characterized by rolling bedrock hills and an overall slope to the southwest of approximately 25 to 50 percent. The relatively steep mountainous area in the north portion of the site is characterized by slopes that are generally steeper than 50 percent. Much of the north portion of the site is too steep for development and we understand that most of this area will remain undeveloped. However, the Badger Canyon drainage bottom is relatively flat in the north portion of the site and is conducive for development.

Review of the aerial photographs suggests that portions of the Badger Canyon drainage area and the relatively flat southwest portion of the site have been used for agricultural purposes in the past, starting before 1930. Remnants of a previous development were observed in the Badger Canyon drainage in the northeast portion of the site, including numerous graded cut and fill pads, concrete slabs, structure remnants and a swimming pool. Two small concrete-lined reservoirs are also associated with this facility. We understand that this facility was previously utilized as a recreational camp. Remnants of a single-family residence and outbuildings were observed in the southern portion of the site. Structure remnants were also observed in the extreme western portion of the site. The California Aqueduct traverses the southwestern portion of the site in a southeast-northwest direction. Several access structures associated with the aqueduct exist on the site.

SITE GEOLOGY

The site is located along the northeast margin of the San Bernardino Valley in the foothills of the San Bernardino Mountains. The foothills of the San Bernardino Mountains, immediately north of the San Bernardino Valley, are a complex tectonic zone cut by numerous faults separating vastly different lithologies. The San Andreas fault has formed a major structural break between the San Bernardino Mountains and the San Bernardino Valley, and the San Bernardino Mountains have been uplifted along its trace.

Several discontinuous but relatively planar geomorphic surfaces characterize the central portion of the site. These surfaces may represent former levels of the San Bernardino Valley. The surfaces may have been uplifted relative to the current valley bottom by recurrent movement along the San Andreas fault, which traverses the southwest portion of the site.

Geologic mapping of the site was conducted at a scale of 1 inch equals 200 feet, and a preliminary geologic map is included as Plate 1. Our geologic mapping revealed that much of the site is characterized by relatively complex geology that includes several different rock types and significant geologic structures such as faults and large landslides. Detailed geologic mapping of the site was beyond the scope of this investigation. Detailed large-scale geologic mapping in the bedrock areas may be necessary based on review of development plans.

Most of the hillside portions of the site are underlain by granitic bedrock shown as "gr" on Plate 1. This unit includes granitic rock types of several different compositions. The granitic rocks are pink, yellow and brown in color and are generally highly weathered. The granitic rocks generally occur southwest of an unnamed fault that traverses the central portion of the site.

Marble mapped as "m" exists northeast of the granitic rock. The marble is primarily gray and coarse-grained with well-developed foliation. It is not known whether the foliation in the marble is parallel to relict bedding, as no sedimentary structures or fossils were observed in it. The marble generally occurs along the northeast side of the unnamed fault. The marble terrane on and in the vicinity of the site is extensive but has apparently not been identified during previous regional mapping (Morton, 1974; Morton and Miller, 1975; Miller, 1979).

Regional geologic mapping by Morton and Miller (1975) and Miller (1979) showed bedrock consisting of the Potato Sandstone in the southeast portion of the site. However, the only bedrock type observed in the southeast portion of the site during the geologic field reconnaissance was granitic rock.

Older alluvial materials of probable Pleistocene age were identified at several locations on the site. These materials were mapped as "Qoa". The older alluvial materials consist of firm to dense gravel, sand and silty sand. These materials are associated with slightly to highly dissected geomorphic surfaces that are not in equilibrium with current drainage patterns. The older alluvium is suspected to encompass a range of ages from late Pleistocene to possibly mid Pleistocene. Many of the exposures of older alluvium on the site are the result of faulting along the south branch of the San Andreas fault zone. The older alluvium may be deformed in the immediate vicinity of on-site faulting.

Relatively fine-grained younger alluvium of suspected mid to late Holocene age was mapped as "Qya_1". This younger alluvial unit consists of silty sand and sand that has accumulated behind hills and shutter ridges associated with the south branch of the San Andreas fault zone. The map unit Qya_1 is designated only along the northeast side of the south branch of the San Andreas fault.

Younger alluvial materials mapped as "Qya_2" are associated with the Badger Canyon drainage and smaller, active drainages across much of the site. These materials consist of relatively coarse-grained sand, silty sand and gravel.

Numerous areas of fill were observed on the site during our geologic mapping. The fill areas are primarily associated with dirt roadways, flood control structures adjacent to the site, and with the graded pads associated with the former recreational camp in Badger Canyon. Areas of larger and more obvious fills were mapped as "f". Other significant fills are expected to exist on the site. A significant amount of backfill is expected to exist on the site associated with the buried California

Aqueduct. The aqueduct backfill is not shown on the geologic map. An evaluation of the extent of the on-site fill and its significance to the proposed development falls under the purview the project geotechnical engineer.

SEISMIC SETTING

On-Site Faulting

The most important fault to the site from a seismic shaking and ground rupture standpoint is the active south branch of the San Andreas fault, which traverses the southwestern portion of the site. The location of the main, active trace of the San Andreas fault on the site and in the San Bernardino Valley is evidenced by vegetation lineaments, fault scarps, springs, linear ridges, shutter ridges and offset drainages. Although the San Andreas fault is characterized overall by right-lateral, strike-slip movement, the San Bernardino Mountains have been uplifted along its trace. Review of the aerial photographs and geologic field reconnaissance indicates that many of these fault features on the site are youthful and have undergone little modification. This suggests that ground rupture along the south branch has occurred within the past few hundred years.

The north branch of the San Andreas fault is an older trace of the San Andreas fault, located northeast of the main, active trace of the San Andreas fault. Although the north branch of the San Andreas fault is not shown on the Alquist-Priolo Special Studies Zones Map of the San Bernardino North quadrangle (index map), the north branch was shown in the southwest portion of the site by Miller (1979). Suspected faulting associated with the north branch of the San Andreas fault as shown by Miller was observed during the geologic field reconnaissance and is shown on Plate 1. The north branch as it traverses the site appears to consist of several discontinuous bedrock faults that are considered to be potentially active. Potentially active faults are considered to be a hazard to structures unless they can be shown to be inactive.

No evidence of active faulting associated with these features was observed during our investigation.

A significant, unnamed northwest-trending fault traverses the central portion of the site. This fault apparently forms the boundary between the marble terrane in the northeast portion of the site and the granitic terrane in the southwest portion of the site. This fault is exposed in a road cut along the west margin of Badger Canyon, where it juxtaposes older alluvium against bedrock. The exposed fault zone is at least 20 to 30 feet in width. As observed in the exposure, the fault appears to dip steeply towards the southwest, but its expression on the aerial photographs suggests that it dips steeply towards the north as it traverses the site. In the northwest portion of the site, the fault appears to be buried beneath erosional remnants of older alluvium. The possible presence of unfaulted older alluvium over the fault suggests that it is inactive. In addition, no geomorphic evidence of activity associated with this fault was observed during the geologic mapping or on the aerial photographs reviewed. However, this fault is included within an Alquist-Priolo Special Studies Zone (index map) and is considered to be potentially active. The state of activity of this fault is not known.

A northwest-trending aerial photograph lineament in bedrock in the western portion of the site was observed on the aerial photographs reviewed. This lineament may represent potentially active faulting and may be associated with the north branch of the San Andreas fault.

Other Faults

The northwest-trending San Jacinto fault, located approximately 4 miles southwest of the site is considered to be the most active fault in southern California (Allen *et al.*, 1965). Trenching in very young alluvium across the San Jacinto fault has confirmed very recent episodes of fault rupture. The San Jacinto fault is characterized by right-lateral, strike-slip movement.

The Glen Helen fault is a northwest-trending strike-slip fault which is parallel and northeast of the San Jacinto fault. The youthful geomorphic appearance of the Glen Helen fault in the vicinity of Glen Helen Regional Park indicates that this fault is an active fault. The apparent lack of youthful fault geomorphology along the northernmost segment of the San Jacinto fault as it enters the San Gabriel Mountains suggests that the Glen Helen fault may represent the active trace of the San Jacinto fault at this location as an *en echelon* segment between the San Jacinto and San Andreas faults. The Glen Helen fault may help transfer motion from the San Jacinto fault to the San Andreas fault. The Glen Helen fault is located approximately 4 miles west of the site.

The Cucamonga fault is an east-trending fault located approximately 7 miles west of the site. This fault zone is characterized by reverse movement. The Cucamonga fault zone is the eastward extension of the Sierra Madre fault zone, which was responsible for the Richter magnitude 6.4 earthquake of 1971 in the San Fernando Valley.

A summary of significant faults and their distances from the site is presented in the following table:

FAULT	DISTANCE (MILES)	DIRECTION
San Andreas (south branch)	on-site	
San Andreas (north branch)	on-site	
Unnamed, northwest-trending	on-site	
San Jacinto	4	Southwest
Glen Helen	4	West
Cucamonga	7	West

Other active or potentially active faults are located within the general region, such as the Cleghorn, Chicken Hill and Western Heights faults, but because of their greater distance from the site and/or lower expected maximum probable earthquake, they are less important to the site.

SEISMIC HISTORY

The accuracy of locating earthquake epicenters is not always sufficient to determine which fault they are associated with. Estimates of magnitude and epicenter locations for earthquakes prior to implementation of recording instruments were based on descriptions of the earthquakes by individuals in different areas. Seismic instrumentation did not become available until about 1932, and these earlier instruments were imprecise. The earthquake locations shown on Enclosure 2 are either based on instrument locations or by analysis of isoseismal contouring.

No large earthquakes have occurred along the San Andreas fault in the southern California area in recent time. The last major earthquake along it in this area was the great earthquake of 1857, which was centered at Fort Tejon, north of Gorman. This fault has a pattern of almost no movement for long periods of time (131 years, Sieh, 1984), followed by a sudden release of energy. The Fort Tejon earthquake had an estimated Richter magnitude greater than 8.0, comparable to the 1906 San Francisco earthquake (Wood, 1955). In 1948, an earthquake of Richter magnitude 6.5 occurred along the Mission Creek fault (north branch of the San Andreas fault) in the Desert Hot Springs area. An earthquake of Richter magnitude 5.9 occurred along the Banning fault (south branch of the San Andreas fault) in the North Palm Springs area in 1986, which resulted in surface ground rupture. Other, smaller earthquakes have occurred along the San Andreas fault northwest and southeast of these two locations.

The San Jacinto fault has been the most seismically active fault in southern California (Allen *et al.*, 1965). Between 1899 and 1990, eight earthquakes of Richter magnitude 6.0 or greater have occurred somewhere along the San Jacinto fault between the San Gabriel Mountains and Mexico (Lamar *et al.*, 1973; Kahle *et al.*, 1988).

A summary of the dates of these earthquakes, their approximate locations, and their estimated Richter magnitude is presented in the following table:

DATE	LOCATION	RICHTER MAGNITUDE
December 25, 1899	San Jacinto Valley	(estimated) 7.1
April 21, 1918	San Jacinto Valley	(estimated) 6.8
July 22, 1923	South of Loma Linda	(estimated) 6.3
March 25, 1937	Southeast of Anza	6.0
October 21, 1942	Southeast of Borrego	6.5
March 19, 1954	East of Borrego	6.2
April 9, 1968	Borrego Mountain	6.5
November 24, 1987	Superstition Hills	6.6

Since 1899, earthquakes on the San Jacinto fault of Richter magnitude 6.0 or greater have occurred every 5 to 19 years. The earthquakes in 1899, 1918 and 1923 occurred along the northern portion of the San Jacinto fault; the earthquake in 1937 occurred along the middle reach of the San Jacinto fault; and the earthquakes in 1942, 1954, 1968 and 1987 occurred along the southern portion of the San Jacinto fault (Lamar *et al.*, 1973; Kahle *et al.*, 1988).

Documented evidence for large earthquakes along the Cucamonga fault has only recently been found. This fault is part of the Sierra Madre-Cucamonga fault system which did move in the 1971 San Fernando earthquake with a Richter magnitude of 6.4. Investigations by the U.S. Geological Survey have uncovered evidence of Holocene activity along the Cucamonga fault (Matti *et al.*, 1982; Morton and Matti, 1987).

No significant earthquakes are known to have occurred during historic time along the Glen Helen fault.

SEISMIC ANALYSIS

The most important fault to the site from a seismic shaking and ground rupture standpoint is the south branch of the San Andreas fault, located on the site. Significant earthquakes and possible surface ground rupture affecting the site may occur along the south branch of the San Andreas fault during the life of the proposed structures.

Recurrence intervals for maximum probable earthquakes cannot yet be precisely determined from a statistical standpoint, because recorded information on seismic activity does not encompass a sufficient span of time. However, based on information available at this time, it is our opinion that a maximum probable earthquake of Richter magnitude 7.5 along the San Andreas fault may occur. Large earthquakes could occur on other faults in the general area or on the site, but because of their greater distance and/or lower probability of occurrence, they are less important to the site from a seismic shaking standpoint.

Campbell (1987) presented data that showed a relationship between the distance from a causative fault and peak horizontal ground accelerations on alluvium. Based on the data of Campbell for a Richter magnitude 7.5 earthquake along the San Andreas fault, which traverses the southwest portion of the site, a maximum ground acceleration on alluvium at the site would be 0.66g.

Seed and Idriss (1983) have shown that maximum accelerations recorded on bedrock are typically slightly less than maximum accelerations recorded on alluvium. Utilizing the data of Seed and Idriss, the maximum peak acceleration on bedrock at the site would be approximately 0.71g.

Amplification of earthquake ground motions has been reported at sites underlain by thin soils (less than 30 to 60 feet thick) relative to ground motions measured at thick soil sites. Therefore, peak horizontal ground accelerations could be higher on alluvium adjacent to the bedrock areas.

These accelerations should not be used as design values for insertion in the Uniform Building Code formula; rather, they should be considered as an aid in the evaluation of the structural design of the residential structures to be placed on the site.

SLOPE STABILITY

Several large landslides (deep-seated slope failures) and debris flows (shallow failures) exist on and adjacent to the site. The approximate locations of the slope failures identified during the geologic mapping are shown on Plate 1. The landslides and debris flows shown on Plate 1 are geomorphically expressed in the field and/or on the aerial photographs, and should be considered to be the minimum number of slope failures on the site. Additional, older slope failures with little or no geomorphic expression may be exposed during grading. Human occupancy structures should not be placed on or immediately adjacent to any of the landslides or debris flows shown on Plate 1, unless they are evaluated by the engineering geologist and recommendations are made for stabilization or removal of them if necessary.

Debris flows are shallow-seated failures that generally only involve failure of the surficial soils. Most of the debris flows on the site are associated with soil mantles developed on very steep bedrock slopes. The debris flows are probably best mitigated by removal during grading.

Due to their relatively large size, deep-seated landslides can be much more difficult to mitigate than debris flows. Where mitigation of the hazard of the landsliding cannot be accomplished by avoidance, it is typically accomplished by removal of the landslide, stabilization of the landslide with a buttress fill, or a combination of these two.

Large, deep-seated bedrock landsliding is suspected to exist in the northwest portion of the site (Plate 1). Two general types of large-scale landslides are shown on Plate 1. Older, highly incised and dissected landslides are shown as landslide debris (Qls). Younger, relatively intact landslides are delineated by arrows showing the inferred direction of movement.

Evidence for older landsliding includes an apparently continuous, north-dipping brecciated contact that appears to place marble bedrock over granitic bedrock. This brecciated contact is at least 20 feet thick and its approximate location is shown on Plate 1. Morton and Miller (1976) showed large landsliding associated with this contact. The contact is coincident with several existing springs, and inspection of the contact area revealed tufa deposits and small cavities that are suggestive of past spring activity along the contact. Some of the spring activity may also be related to the ground-water barrier effect of the unnamed northwest-trending fault that traverses the central portion of the site. This fault apparently offsets a portion of the older landsliding and appears to be buried beneath some of the landsliding. Therefore, at least two episodes of older bedrock landsliding are suspected to exist, based on contact relationships between the landsliding and the fault.

The older bedrock landsliding on the site (mapped as Qls) is moderately to highly incised and probably occurred during Pleistocene time. The climatic and topographic conditions that may have triggered this older landsliding no longer exist. Therefore, it is unlikely that reactivation of the Pleistocene-age landsliding on the site will occur during the lifetime of the proposed development. However, the landslide material consists of shattered and deformed bedrock that may be unstable when it is exposed in cut slopes. Therefore, the hazard of the landsliding to the proposed development should be evaluated by the engineering geologist based on review of the grading plan. Depending on the extent of the proposed grading, a subsurface investigation of the landsliding may be recommended. For overall planning purposes, cut slopes in Qls should be no steeper than 2:1 (horizontal to vertical).

The younger landsliding includes a relatively large, southeast-failing landslide that is characterized by a well-developed reddish-brown argillic soil horizon. This landslide is moderately incised and is suspected to be late Pleistocene in age. Depending on the extent of grading, the younger landsliding may be capable of renewed movement during the lifetime of the proposed development.

GROUND WATER

The San Andreas fault forms a subsurface barrier to the south flow of ground water in the area. The static ground-water table on the northeast side of the fault is commonly within 20 feet of the surface; whereas, on the southwest side of the fault, ground water is much deeper. As a result of the ground-water barrier effect of the San Andreas fault, springs and seeps occur along the fault in the San Bernardino Valley. Several springs and seeps were observed associated with the south branch of the San Andreas fault and with the other northwest-trending faults mapped on the site. The spring areas delineated on Plate 1 reflect areas of dense vegetation and do not necessarily indicate areas of surface water flow. However, all of the spring areas shown on Plate 1 are expected to be associated with shallow subsurface ground water and possible surface flow.

A small flow of surface water was observed within the Badger Canyon drainage on the site during our geologic mapping. The presence of surface water during the dry summer months and the drought of the last few years suggests that a surface flow within the drainage occurs throughout most or all of the year. Depth to ground-water data are not available from wells in the general area of the site (California Department of Water Resources, 1987; City of San Bernardino, 1990). However, the surface flow within the Badger Canyon drainage suggests that shallow ground water (less than 30 feet deep) may exist throughout much of the drainage area northeast of the south branch of the San Andreas fault. The ground water northeast of the fault may be perched on bedrock. A significant potential for liquefaction may exist in the younger alluvial areas in Badger Canyon northeast of the fault.

Shallow ground water is expected within some of the on-site drainage areas. Significant fills placed within on-site drainages may require subdrains. Subdrains or horizontal drains may also be recommended in cut areas where shallow ground water exists or has occurred in the past.

The depth to static ground water on the site southwest of the south branch of the San Andreas fault is not known but is expected to be deeper than on the northeast side of the fault. Although shallow, static ground water southwest of the fault on the site is not expected, the liquefaction potential in the low-lying younger alluvial areas on the site should be evaluated by the project geotechnical engineer when development plans are better known.

FLOODING

The site does not lie within an area designated as being a potential flood area on the Health and Safety Map of the San Bernardino County General Plan (1979). Evidence of recent flooding and erosion associated with flows within the Badger Canyon drainage was observed during the geologic field reconnaissance and on the aerial photographs reviewed. Many of the on-site drainages are expected to contain water during periods of intense precipitation. An evaluation of the hazard of flooding to the site falls under the purview of the project engineer.

No large water storage reservoirs are located topographically higher than the site. However, the California Aqueduct traverses the southwestern portion of the site.

Some potential for seismically induced flooding of the southwest portion of the site exists should the pipeline fail on the site during a large earthquake.

CONCLUSIONS

Development of the site with residential structures appears feasible from a geologic standpoint. Geologic hazards and concerns to the site include active and potentially active faulting through the site, seismic shaking, landsliding, and shallow ground water.

The site is traversed by several faults including the north and south branches of the San Andreas fault and several unnamed faults. Except for the south branch of the San Andreas fault, no evidence of active faulting was observed on the site. Severe seismic shaking and possible surface rupture of the south branch of the San Andreas fault is expected during the lifetime of the proposed development.

Large bedrock landslides were observed in the northwest portion of the site. These bedrock landslides are considered to be at least late Pleistocene in age. Due to the degree of incision and modification and the absence of the climatic and topographic conditions that may have caused the landsliding, the landslide debris (Qls) is probably not capable of large-scale movement during the lifetime of the proposed structures. However, Qls is expected to contain shattered and deformed bedrock that may be unstable when exposed in cut slopes. The younger landsliding (delineated with arrows) may be capable of renewed movement during the lifetime of the proposed structures, depending on the extent of grading.

Several large debris flows (surficial failures) were observed on the site. The debris flows are primarily associated with steep slopes.

Severe seismic shaking of the site can be expected within the next 100 years.

Shallow, perched ground water (less than 30 feet deep) is expected within the younger alluvial materials in the Badger Canyon drainage northeast of the south branch of the San Andreas fault. Therefore, a potential for liquefaction may exist beneath these younger alluvial materials. Shallow, static ground water is not expected on the site southwest of the San Andreas fault.

Numerous springs were identified on the site during this investigation. Shallow ground water and possible surface flow is expected associated with the springs. Shallow, perched ground water is expected within on-site drainages located northeast of the south branch of the San Andreas fault. Fills placed within on-site drainages may require subdrains. Subdrains or horizontal drains may be recommended in cut areas where shallow ground water exists or has occurred in the past.

No large bodies of water at higher elevations than the site were observed in the immediate area. However, some potential for seismically induced flooding of the southwest portion of the site exists should the California Aqueduct fail during a large earthquake.

Most of the on-site drainages are expected to contain water during periods of intense precipitation. An evaluation of the hazard of flooding to the site falls under the purview of the project engineer.

RECOMMENDATIONS

A subsurface investigation of the portion of the site that is to be developed that lies within the Alquist-Priolo Special Studies Zone should be conducted prior to placement of human occupancy structures. The subsurface investigation will be required to establish the state of activity and width of faulting associated with the on-site faults.

Bedrock geology on the site is relatively complex. Detailed geologic mapping of the site was beyond the scope of this investigation. Detailed large-scale mapping of the bedrock areas may be recommended by the engineering geologist based on review of development and grading plans.

The older landslide debris (Qls) is probably not capable of large-scale movement and, therefore, development is probably feasible. Any proposed development in Qls should be evaluated prior to and during grading. Human occupancy structures should not be placed on or near any of the other landslides or debris flows shown on Plate 1 unless review of the grading plans by the engineering geologist indicates that slope failures will not be adversely affected by grading or will be removed or stabilized during grading. A subsurface investigation of on-site landslides may be recommended based on review of the grading plans.

The potential for seismically induced flooding of the site, the potential for flooding within the major drainages and the adequacy of the existing flood control measures in the area should be evaluated by the project engineer.

The alluvial material on-site is moderately to highly susceptible to erosion; therefore, cut and fill slopes should be planted as soon as possible to prevent erosion.

Positive drainage of the site should be provided, and water should not be allowed to pond behind or flow over any cut or fill slopes. Where water is collected in a common area and discharged, protection of the native soils should be provided, as the native soils are moderately to highly susceptible to erosion by running water.

A detailed evaluation of the site-specific liquefaction potential should be conducted by the geotechnical engineer.

The maximum inclination of all cut slopes within granitic bedrock should be 1 3/4 horizontal to 1 vertical up to a maximum height of 30 feet. The maximum inclination of cut slopes within competent marble bedrock should be 1 1/2 horizontal to 1 vertical up to a maximum height of 30 feet. Steeper cut slopes within the bedrock may be feasible, depending on the degree of bedrock weathering and the orientation of foliation within the marble.

For planning purposes, cut slopes within Qls should be 2 horizontal to 1 vertical or flatter up to a maximum height of 30 feet. All proposed grading in the landslide areas should be evaluated by the engineering geologist prior to any grading.

The maximum inclination of all cut slopes within alluvial materials should be 2 horizontal to 1 vertical up to a maximum height of 30 feet.

Any cut slopes which could intercept slope runoff and are greater than 15 feet in height should be provided with a concrete-lined "V" ditch above the top of the cut slope to protect the slope from erosion. Cut slopes to be higher than 30 feet should be evaluated individually by the engineering geologist. All cut slopes 30 feet or greater in height should have terraces in accordance with the Uniform Building Code.

We recommend a minimum setback for human occupancy structures from the top of natural steep slopes should be a horizontal distance of at least 10 feet or the horizontal distance calculated by extending a 2:1 (horizontal to vertical) plane, extending upward from the toe of the steep slope, whichever is greatest.

For planning purposes, structures to be placed at the base of steep slopes should be set back from the toe of the slopes at least a horizontal distance equal to 1/2 the slope height up to a maximum distance of 15 feet. Each slope and setback should be individually evaluated during review of the grading plan.

The grading plan for the site should be reviewed and approved by an engineering geologist prior to any grading.

Grading of the site should be evaluated by the engineering geologist by in-grading inspections.

Small cavities in the marble debris (Qls_m) were observed during the geologic mapping. Although large cavities are not expected, the presence of any cavities in the marble should be evaluated by the engineering geologist during grading.

A seismic refraction survey could better evaluate the rippability characteristics of the bedrock within selected areas of the site. This would indicate the approximate rippability of the bedrock materials at various depths. The need for a seismic refraction survey should be evaluated by the engineering geologist during review of the grading plan. The need will be dependent upon the extent of grading proposed within the bedrock areas.

Respectfully submitted,

GARY S. RASMUSSEN & ASSOCIATES, INC.

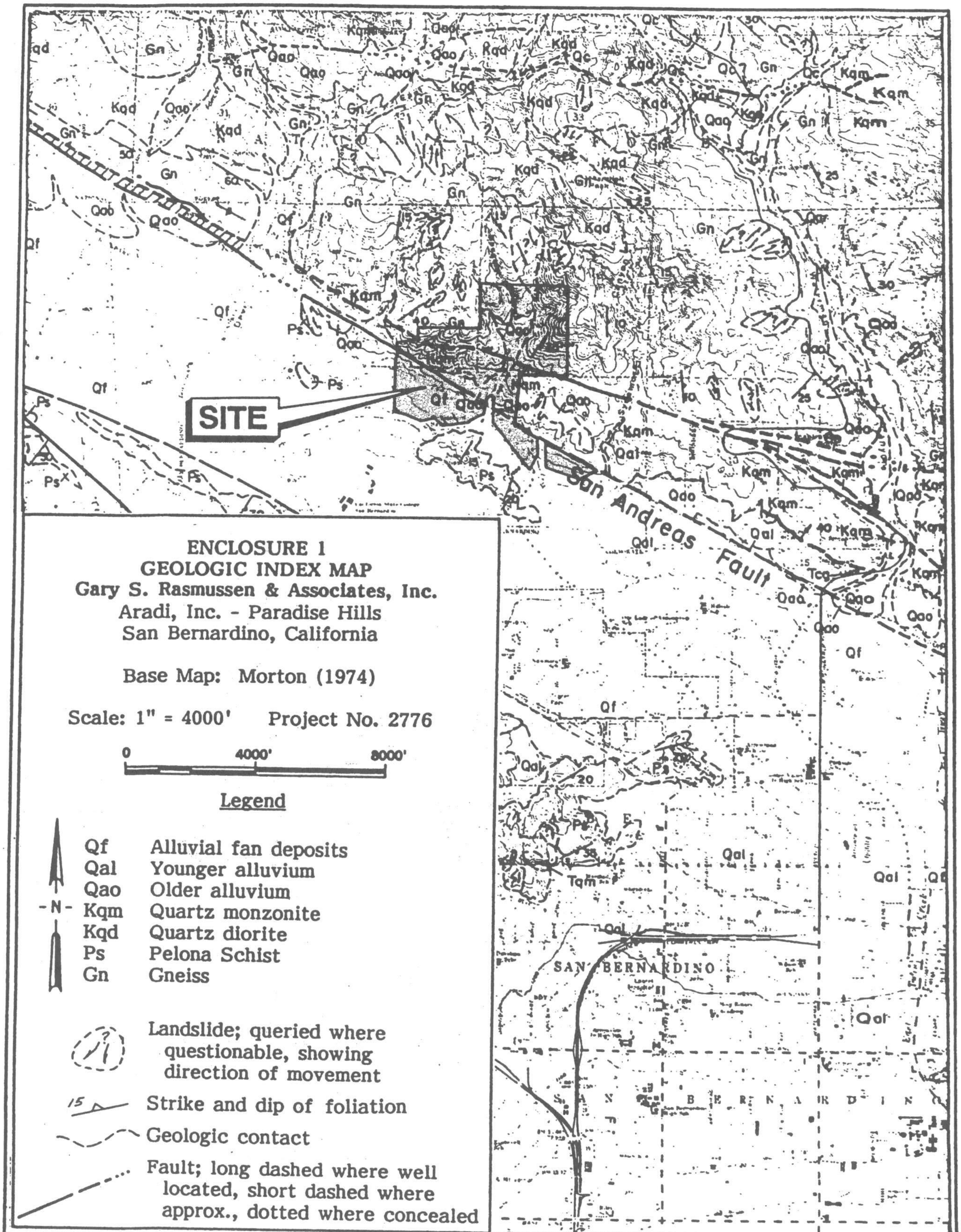
Jay J. Martin
Engineering Geologist, EG 1529

JJM/pg

Enclosure 1: Geologic Index Map
Enclosure 2: Earthquake Epicenter Map
Enclosure 3: References

Plate 1: Preliminary Geologic Map

Distribution: J.F. Davidson Associates (5)
Aradi, Inc. (2)



ENCLOSURE 1
GEOLOGIC INDEX MAP
Gary S. Rasmussen & Associates, Inc.
Aradi, Inc. - Paradise Hills
San Bernardino, California

Base Map: Morton (1974)

Scale: 1" = 4000' Project No. 2776

ENCLOSURE 2
EARTHQUAKE EPICENTER MAP
Gary S. Rasmussen & Associates, Inc.
Aradi, Inc. - Paradise Hills
San Bernardino, California

Legend

Fault

Maximum reported intensity
(prior to 1930's)

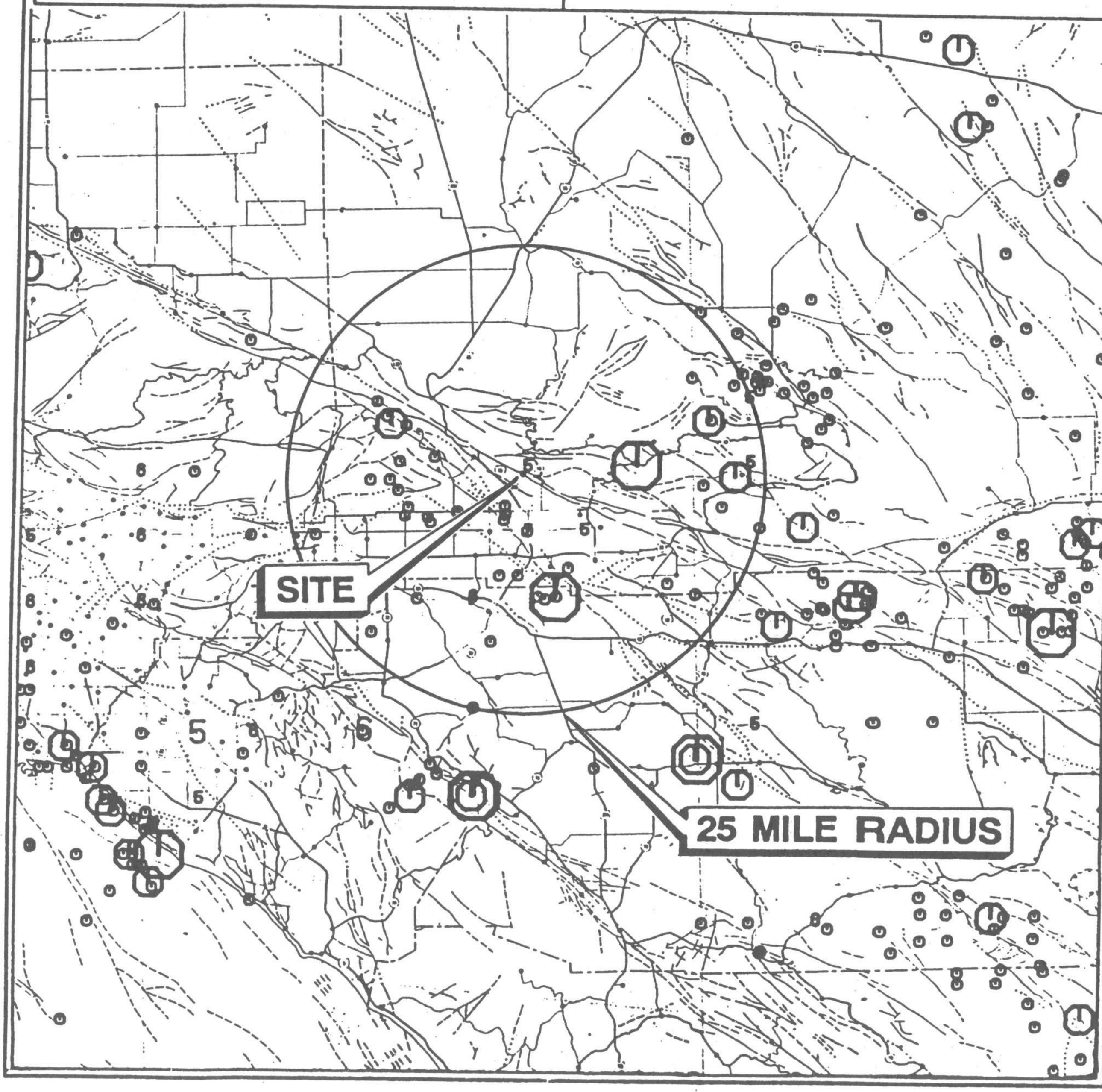
RICHTER MAGNITUDE

.... 4.0 – 4.9
.... 5.0 – 5.9
.... 6.0 – 6.9

-N-

Base: Real, *et. al.,* 1978
Earthquake Epicenter Map
of California; 1900 - 1974
Scale: 1" = approx. 16 mi.

Project No. 2776



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