MINERAL LAND CLASSIFICATION: AGGREGATE MATERIALS IN THE SAN FRANCISCO–MONTEREY BAY AREA

1987

CALIFORNIA DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY

SPECIAL REPORT 146

Part III

Classification of
Aggregate Resource Areas

**NORTH SAN FRANCISCO BAY
PRODUCTION–CONSUMPTION REGION**

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SPECIAL REPORT 146

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1987

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FOREWORD

Special Report 146, "Mineral Land Classification of the San Francisco-Monterey Bay Area," is the first analysis of mineral resources in the San Francisco-Monterey Bay area to be developed by the California Department of Conservation's Division of Mines and Geology under the authority of the Surface Mining and Reclamation Act of 1975 (SMARA). This classification is provided to the State Mining and Geology Board for transmittal to the local governments which regulate land use in this region, and for consideration of areas, if any, to be designated as regionally significant. SMARA was enacted by the State Legislature to assure mineral resource conservation and adequate mined land reclamation.

The Mining and Geology Board adopted Guidelines in June 1978 to be employed by the Division in its mineral resource classification. This report was prepared in conformance with those directives. The undertaking is of great importance in economic geology, because it deals with very specific mineral resource conservation issues in areas of intensive competing land use.

State Geologist
James F. Davis

PREFACE

Data presented in this report is accurate as of January 1983, at which time a preprint version of the report was circulated to lead agencies and made available to the public. Changes in reserves resulting from either the premature closure of mines active in 1983, or the permitting of new mines since that time, may have impacted forecasted depletion dates for the three production-consumption regions studied. However, the material presented and the fundamental conclusions of the report remain valid and useful.

David J. Beeby
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EXECUTIVE SUMMARY
(PART III)

The San Francisco-Monterey Bay area, with its population of over six million people, is the largest urbanized area in northern California. This region includes twelve counties that border on San Francisco or Monterey bays. Although substantial portions of the region have been developed, urbanization is still occurring at a rapid rate.

In any urban development it is important that land-use decisions are made with full recognition of the natural resources of the area. Mineral resources, including aggregate, are limited within a given region. The object of this report is to convey information concerning the aggregate resources of the region and the expected needs of the region for such resources in the coming decades. For many years, the San Francisco-Monterey Bay area has been fortunate because adequate quantities of low-cost aggregate materials have been available locally. However, as more and more areas become urbanized, suitable sand, gravel, and stone deposits are being lost through urban development and are being diminished yearly by mining.

The principal objective of this project is to classify land in the San Francisco-Monterey Bay area into Mineral Resource Zones (MRZs) based on guidelines adopted by the California State Mining and Geology Board. This classification project will assist the Board in designating lands that contain valuable mineral resources, as mandated by the Surface Mining and Reclamation Act of 1975. The objective of the classification and designation process is to insure through appropriate lead agency policies and procedures that mineral deposits of statewide or regional significance are considered for availability when needed.

The Division of Mines and Geology has classified urbanizing lands within the North San Francisco Bay Production-Consumption (P-C) Region according to the presence or absence of significant sand, gravel, or stone deposits that are suitable as sources of aggregate. If a deposit contained more than $ 5 million worth of material suitable for at least subbase aggregate, the deposit was classified MRZ-2. In the San Francisco-Monterey Bay area, classification was done with regard to the suitability of the underlying material for use as asphaltic concrete aggregate, road base, or subbase material, in addition to its use as Portland cement concrete (P.C.C.) aggregate. This classification project stands in contrast to the various P-C region studies underway in southern California, where only P.C.C.-grade deposits were classified. This different approach is appropriate in the San Francisco-Monterey Bay area for two reasons:

1. In the Los Angeles Basin almost all aggregate production is from deposits which meet P.C.C. specifications. The Bay area, in contrast, is not blessed with such large amounts of high quality sand and gravel and about half the production comes from deposits which are not of P.C.C. quality. To accommodate this difference, all deposits in the Bay area containing suitable material for aggregate commodities higher than fill quality have been classified. Each deposit has been identified on the basis of sales records or test data as to its highest use.

2. The Los Angeles Basin aggregate production is dominated by alluvial sand and gravel deposits with very little crushed stone production. The Bay area is much more dependent on crushed stone quarries (many of which do not meet P.C.C. specifications) to satisfy its aggregate demands. Therefore, crushed stone deposits have been segregated from sand and gravel deposits in the San Francisco reports.

The land classification within the North San Francisco Bay P-C Region is presented in the form of Mineral Resource Zones on 38 U.S. Geological Survey topographic quadrangles that accompany this report (Plates 3.5–3.41a). Mineral resource zones were established on the basis of a sand, gravel, and stone resource appraisal which included the following actions: a study of pertinent geologic reports and maps; field investigations and sampling at outcrops and active and inactive pits and quarries; and an analysis of water-well logs and drill records. Twenty-five areas were determined to contain significant aggregate deposits and were classified MRZ-2. In addition, there were 112 areas that contained mineral resources, but their significance could not be evaluated from available data; these areas were classified MRZ-3.

In order to organize the volume calculations of the aggregate resources, the State Geologist has utilized the concept of "sectors" to identify those MRZ-2 areas that have not been urbanized. The geometrical configuration of the deposit in each sector is fairly uniform, so that tonnage of the mineral resource present can be calculated with some reliability. Thus, for example, sector boundaries would be established between that part of a natural deposit formed on a fan, and that part within the confines of an adjacent modern stream channel and its floodplain. The sector concept is used for the convenience of arraying resource information, and is intended to convey accurate information regarding the locations and approximate tonnage of resources found in nonurbanized areas.

In the North San Francisco Bay P-C Region, 25 MRZ-2 areas with existing land uses that are compatible with mining qualify as sectors; they contain a total of 2.4 billion tons of resources. The sectors are described in detail in this report, and are shown on Plates 3.42–3.65. One sector encompasses the unimproved portions of a dedicated park. It is recognized that dedicated parklands have special status as opposed to other current uses of sectorized land, consequently the resources within parks have been sectorized separately and the quantifications of those resources are presented separately in the tables. The quantification of resources within park sectors is expressed to a lower degree of accuracy rather than the higher level of accuracy reflected in the resource calculations for other sectors.

The North San Francisco Bay P-C Region is dependent upon aggregate from both crushed stone and alluvial deposits. Because these two commodities are not entirely interchangeable, resource and reserve totals for each type have been identified separately.

Reserves are aggregate materials that a company owns or controls, and for which it has a valid mining permit; *resources* are the total amount of available aggregate within the sector, including any reserves. The estimated resources within the 6 sand and gravel sectors amount to 908 million tons, of which 108 million tons are classified as reserves available for mining as of the end of 1980. The estimated crushed stone resources within the remaining 19 sectors amount to 1.4 billion tons, of which 432 million tons are classified as reserves available for mining as of the end of 1980.

The total projected aggregate consumption through the year 2030 is estimated to be 478 million tons, of which at least 24 percent (115 million tons) must be of P.C.C. quality. Of the projected total demand, 540 million tons (113 percent) were available for mining at the end of 1980. Unless additional resources are permitted for mining or alternative resources are utilized, existing reserves will be depleted in 49 years (2036). To make the projections, production records and population figures were correlated for the past 28 years (1953-1980) to obtain an average per capita rate. The derived rate of 8.8 tons per year was used along with population projections to make the estimate of total consumption.

The average annual per capita consumption rate for the North San Francisco Bay P-C Region may decrease, at a more or less steady rate, as the area becomes more urbanized until a steady state (urban maturity) is reached. Should unforeseen events occur, such as massive urban renewal, disaster reconstruction, or major recession, the per capita consumption rate could change significantly. The presence of several major active fault systems within the North San Francisco Bay P-C Region increases the chance for a damaging earthquake and the need for subsequent extensive reconstruction afterwards.

Alternative sources of aggregate, in addition to those deposits classified MRZ-2 and MRZ-3, occur in areas within the North San Francisco Bay P-C Region, and in adjacent P-C regions. Some potential deposits lie outside the OPR urbanizing boundaries, but still within the P-C region boundaries. Included within the group of potential resources are the extensions of several deposits classified MRZ-2 or MRZ-3. In addition, sand and fine gravel occur in bars on the floor of San Francisco Bay between the Golden Gate Bar and the confluence of the Sacramento and San Joaquin rivers. Except for the aggregate resources in adjacent P-C regions and marine sand deposits, too little is known about the physical and chemical qualities of most of the alternative sources to permit even crude resource estimates.

If additional aggregate is needed in the North San Francisco Bay P-C Region on a short-term basis, the most readily available material is located in the neighboring regions — South San Francisco Bay, Monterey Bay, and Sacramento-Fairfield P-C regions. On a short-term basis the active producers in these P-C regions can send large amounts of aggregate into the North San Francisco Bay P-C Region, but the delivered price per ton would be greatly increased by inflated transportation costs and by any supply-demand conflicts. The long-term (50-year) resource picture is more uncertain. The South San Francisco Bay P-C Region is projected to have a substantial deficit of aggregate, while the Monterey Bay P-C Region appears to have a surplus of material. Projected aggregate needs and available supplies in the Sacramento-Fairfield P-C Region are currently being studied.

As with many forecasts of economic activity, the forecasts in this report should not be viewed as offering unqualified predictions of how the future will unfold. The forecasts of this report are based upon assumptions concerning the accuracy of the basic data, and the continuation of the development trends of the past three decades into the five decades ahead.

Assuming, however, the correctness of our forecasts for the consumption of aggregate, the following conclusions were reached:

- The anticipated consumption of aggregate resources in the P-C region to the year 2030 is forecast to be 478 million tons, of which approximately 24 percent or 115 million tons must be of P.C.C. quality.
- Unless additional resources are permitted for mining, or alternative resources are utilized, total existing reserves (both P.C.C. and non-P.C.C. aggregate) would be depleted within 49 years (2036). About 540 million tons of permitted aggregate reserves exist in the P-C region. About 20 percent of the permitted reserves are sand and gravel, and 80 percent are crushed stone. In total, the 540 million tons amount to 113 percent of the anticipated consumption during the next 50 years.
- Of the 540 million tons of permitted reserves, about 100 million tons are suitable for use as P.C.C. aggregate. This amounts to 97 percent of the anticipated consumption during the next 50 years.
- The expected longevity of the existing reserves is based upon the assumption that mining of these reserves will continue to be permitted until the reserves are depleted.
- P.C.C. reserves, because of their higher quality specifications will be the most difficult to replace as existing permitted deposits are depleted.
- Of 15 stratigraphic/lithologic units suitable for aggregate in the P-C region, only 4 are suitable for P.C.C. aggregate. Only two of these units (Quaternary Alluvium and Novato Conglomerate) are sources of sand and gravel. This contrasts markedly with other P-C regions examined to date, where P.C.C. sand and gravel can be extracted from several older sedimentary formations as well as from modern stream deposits.
- A total of 2.4 billion tons of aggregate resources (including reserves) have been identified within the North San Francisco Bay P-C Region. Of this total, 31 million tons are on parklands. Nine-tenths of a billion tons of sand and gravel and 1.4 billion tons of crushed stone compose the 2.4 billion tons of resources.
- If all of the reserves suitable for P.C.C. aggregate are utilized only for that purpose, P.C.C.-grade reserves would be depleted in about 45 years. However, we can expect that some of the production from these reserves will be used for non-P.C.C. applications, consequently, the expected exhaustion of these reserves will occur considerably earlier.
- Most of the high quality P.C.C. resources are present in two sectors in the Russian River area. These also constitute the main source of sand and gravel in the P-C region. These two sectors contain 21 parcels that contain a total of about 854 million tons of sand and gravel resources.
- Of 34 aggregate production sites in the North San Francisco Bay P-C Region, 14 contain sand and gravel resources and 20 contain crushed-stone resources.

SPECIAL REPORT 146

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Part III

Classification Of Aggregate Resource Areas North San Francisco Bay Production-Consumption Region

INTRODUCTION

The Division of Mines and Geology (DMG) has classified urbanizing lands within the North San Francisco Bay Production-Consumption (P-C) Region according to the presence or absence of significant sand, gravel, or stone deposits that are suitable as sources of aggregate. The land classification is presented in the form of Mineral Resource Zones (MRZs)—as described in Part I of this report—on 38 U.S. Geological Survey topographic quadrangles that accompany this report (Plates 3.5–3.41a). Twenty-five areas are classified MRZ-2 (they contain significant aggregate deposits). Twenty-five resource sectors containing a total of 2.4 billion tons of resources have been identified within the MRZ-2 areas. The sectors are described in detail in this report, and are shown on 24 additional topographic quadrangles.

Based on population records and projections and aggregate production records, the North San Francisco Bay P-C Region will need 478 million tons of aggregate during the next 50 years. Of this projected demand, 540 million tons (113 percent) were available for mining at the end of 1980.

Several alternative sources of aggregate for this P-C region are discussed. Similar studies have been completed for the South San Francisco Bay and Monterey Bay P-C regions (Parts II and IV) and pertinent data are included herein for comparison.

To assist the reader, the following "road map" through this report will be helpful. The classification process, which is described more fully in Special Report 146, Part I, occurs in seven separate but interrelated steps. Steps 1 and 2 in the following list are described in Part I, but are restated merely for completeness. Steps 3 through 7 form the bulk of this report (Part III) and are described sequentially. Resource information is integrated in Table 3.6 and described on a sector-by-sector basis on pages 10 through 21.

These are the steps:

1. *Determination of Production—Consumption (P-C) Region Boundaries:* In this step, active aggregate operations are identified (Production) and the market area they serve is determined (Consumption).

2. *Determination of Modified OPR Boundaries Within the P-C Region:* Only those portions of the P-C Region that are urbanized or urbanizing (based on determination by the State Office of Planning and Research, as modified by local lead agencies) are classified for their aggregate content. Other areas may be classified with the approval of the State Mining and Geology Board (SMGB). This step determines which areas should be classified.

3. *Establishment of Mineral Resource Zones (MRZs):* This step includes a geologic appraisal for aggregate deposits of all land within the modified OPR boundaries.

4. *Determination of Sectors:* Only those portions of land classified MRZ-2 (in Step 3) that have current land uses considered to be compatible with mining are considered to be available as future resources for the P-C region. This step utilizes intensive field checking to make that determination.

5. *Calculation of Resource Volumes Within Sectors:* In this step, careful analysis of site-specific conditions is utilized to calculate total volumes of aggregate reserves and resources within each sector.

6. *Forecasting:* In this step, anticipated aggregate demand in the P-C region for the next 50 years is determined. This is done by correlating historic population and aggregate production data for the past 28 years to calculate an annual per capita consumption rate. This figure is used with projected population figures in the area to determine anticipated aggregate demand. Results of this analysis are compared with total volumes of permitted aggregate reserves in the P-C region.

7. *Alternative Resources:* A variety of potential alternative sources of aggregate are evaluated in this final step of the classification process.

ESTABLISHMENT OF MINERAL RESOURCE ZONES

Mineral resource zones within the North San Francisco Bay P-C Region were established on the basis of a sand, gravel, and stone resource appraisal which included the following actions: a study of pertinent geologic reports and maps; field investigations and sampling at outcrops and active and inactive pits and quarries; analysis of water-well logs and drill records. Twenty-five areas were classified MRZ-2 (see below for a description of MRZ terminology). In addition, there were 112 areas that contained mineral resources, but did not possess all the qualifications for classification as MRZ-2; these areas were classified MRZ-3.

Due to the large amount of area classified in this report—portions of 38 quadrangles—the field and office work extended over a 4-year period. Field work was done during the following months: Marin County—August 1980, October 1980; Napa County—May 1980, August 1980; Sonoma County—February 1980, August 1980, May 1981; Solano County—August 1980. Selected areas within these counties were revisited in August 1982, May 1983. and October 1984.

Plates 3.5–3.41a are 1:48,000 scale copies of U.S. Geological Survey 7.5-minute topographic quadrangles that cover the urbanizing portions of the North San Francisco P-C Region. Refer to Plate 1.1 (in Part I) or Table 3.1 for an index to quadrangles classified in the P-C region. A list of possible lead agencies and other affected agencies within the P-C region is presented in Table 3.2.

Areas Classified MRZ-1

Areas classified MRZ-1 are "areas where adequate information indicates that no significant mineral deposits are present, or where it is judged that little likelihood exists for their presence" (see Part I, Appendix A-3, page 25). The areas in the North San Francisco Bay P-C Region that have been classified MRZ-1 are underlain by Quaternary alluvial material judged to contain too much clay and silt for use as aggregate. The data used in evaluating these areas included available water-well logs and the best-available geologic and soil maps.

Areas Classified MRZ-2

Twenty-five areas within the North San Francisco Bay P-C Region are classified MRZ-2 (Plates 3.1–3.3, and 3.5–3.41a). These are "areas where adequate information indicates that significant deposits are present, or where it is judged that a high likelihood for their presence exists" (see Part I, Appendix A-3, p. 25)

The guidelines set forth two requirements to be used to determine if land should be classified MRZ-2:

1. The deposit must be composed of material that is suitable as a marketable commodity.
2. The deposit must meet threshold value. The projected value (gross selling price) of the deposit, based on the value of the first marketable product must be at least $5 million (1978 dollars).

Although not specified in the guidelines, the following criteria were applied to each deposit to test its suitability for inclusion in a MRZ-2 zone:

A. The presence of an operating quarry within the deposit is considered proof that condition 1 has been met.

B. An average value of $2.00 per ton (all aggregate types) and a conversion factor of 2,500 tons per acre-foot of material (0.065 tons per cubic foot with 10 percent waste) requires a minimum amount of 1000 acre-feet of material within the deposit, exclusive of overburden and fill material, to meet suggested threshold value.

C. A deposit of aggregate material must have an overburden-to-ore ratio of less than 1 to 1 in order for mining to be economic at the present time.

Specific criteria are discussed in the section "Estimated Aggregate Resources of the North San Francisco Bay P-C Region".

In the San Francisco-Monterey Bay area, classification was done with regard to the suitability of the underlying material for use as asphaltic concrete aggregate, roadbase, or subbase material, in addition to its use as Portland cement concrete (P.C.C.) aggregate. If a deposit contained more than $5 million worth of material suitable for at least subbase aggregate, the deposit was classified MRZ-2. This classification project stands in contrast to the various P-C region studies underway in southern California, where only the P.C.C.-grade deposits were classified. This different approach is appropriate in the San Francisco-Monterey Bay area for two reasons:

1. In the Los Angeles Basin almost all aggregate production is from deposits which meet P.C.C. specifications. The Bay area, in contrast, is not blessed with such large amounts of high quality sand and gravel, and about half the production comes from deposits which are not of P.C.C. quality. To accommodate this difference, all deposits in the Bay area containing suitable material for aggregate commodities higher than fill quality have been classified. Each deposit has been identified on the basis of sales records or test data as to its highest use.
2. The Los Angeles Basin aggregate production is dominated by alluvial sand and gravel deposits with very little crushed stone production. The Bay area is much more dependent on crushed stone quarries (many of which do not meet P.C.C. specifications) to satisfy its aggregate demands. Therefore, crushed stone deposits have been segregated from sand and gravel deposits in the San Francisco reports.

Only two sand and gravel deposits are within the OPR areas of the North San Francisco Bay P-C Region. The stream channel of Sonoma Creek between Glen Ellen and Schellville (Sonoma County) is classified MRZ-2. Near Black Point in Marin County, portions of the Novato Conglomerate have been classified MRZ-2. However, approximately 90 percent of this deposit underlies already urbanized land. Such areas are considered unavailable as sources for aggregate because they occur in areas presently committed to uses that preclude the extraction of aggregate (see "Calculation of Available Resources" in Part I, p. 9).

Nineteen areas within the North San Francisco Bay P-C Region have been classified MRZ-2 due to the presence of large amounts of stone suitable for use as crushed stone. In Marin County, Sonoma Volcanics and Franciscan Complex sandstone (graywacke), and greenstone are the principle rock types. Greenstone and graywacke of the Franciscan Complex form the deposit classified MRZ-2 in western Solano County at Sulphur Springs Mountain. An active quarry is located in the only MRZ-2 deposit in Napa County. This deposit consists of basalt, rhyolite, and tuff of the Sonoma Volcanics, and extends into portions of four quadrangles. Twelve rock deposits are classified MRZ-2 in Sonoma County. At Petaluma a large deposit of Sonoma Volcanics basalt is quarried for asphaltic concrete aggregate, and a smaller deposit of Franciscan Complex rocks is quarried for roadbase aggregate. West of Healdsburg, greenstone of the Franciscan complex is mined for roadbase. Basalt, tuff, and related sedimentary rocks of the Sonoma Volcanics, in addition to sand and pebbly sand of the Petaluma Formation, are quarried for subbase, drain rock, and fill material near Stony Point, Petaluma, and north of Sears Point. Near Glen Ellen, rhyolite and tuff of the Sonoma Volcanics are quarried for subbase, drain rock, and fill material. Also near Glen Ellen, rhyolite and tuff of the Sonoma Volcanics are quarried for flagstone and roadbase. East of Mark West Springs, pillow basalt of the Franciscan complex is quarried for roadbase and fill. Some of these areas are unavailable for mining, because they occur in areas presently urbanized or committed to uses that preclude the extraction of aggregate.

Table 3.1 List of U.S. Geological Survey 7.5-minute and 15-minute quadrangles classified in the North San Francisco Bay P-C Region. Plates 3.5–3.41a show the classification in these quadrangles.

MARIN COUNTY	PLATE
Bolinas	3.5
Inverness	3.7
Novato	3.8
Petaluma Point	3.9
Petaluma River	3.10
Point Bonita	3.11
San Francisco North	3.12
San Geronimo	3.13
San Quentin	3.14
San Rafael	3.15

NAPA COUNTY	PLATE
Cordelia	3.16
Cuttings Wharf	3.17
Mount George	3.18
Napa	3.19

WESTERN SOLANO COUNTY	PLATE
Benicia	3.20
Cordelia	3.16
Cuttings Wharf	3.17
Fairfield South	3.21
Mare Island	3.22
Mount George	3.18
Napa	3.19
Port Chicago	3.23

SONOMA COUNTY	PLATE
Asti	3.36
Bodega Head	3.24
Camp Meeker	3.6
Cloverdale	3.37
Cotati	3.25
Duncan Mills	3.26
Geyserville	3.38
Glen Ellen	3.27
Guerneville	3.39
Healdsburg	3.40
Jimtown	3.41
Kenwood	3.28
Mark West Springs	3.41a
Petaluma	3.29
Petaluma River	3.10
Santa Rosa	3.30
Sears Point	3.31
Sebastopol	3.32
Sonoma	3.33
Stewarts Point	3.34
Two Rock	3.35

Table 3.2 List of lead agencies (county and incorporated city governments) and other affected agencies (special districts, State and U.S. Government agencies) located within the North San Francisco Bay P-C Region. Agencies with active aggregate operations within their jurisdictional boundaries are denoted by asterisks (*). Agencies that have land classified MRZ-2 within their jurisdiction are denoted by plus signs (+).

MARIN COUNTY

*+Marin County
Belvedere
Corte Madera
Fairfax
Larkspur
Mill Valley
Novato
Ross
San Anselmo
San Rafael
Sausalito
Tiburon
US Department of Defense
US Department of the Interior
US Army
US Navy
US Coast Guard
State of California
*Bay Conservation and Development Commission

NAPA COUNTY

*+Napa County
Calistoga
Napa
Saint Helena
Yountville
State of California
*Bay Conservation and Development Commission

SOLANO COUNTY

*+Solano County
Benicia
Vallejo
US Navy
State of California
*Bay Conservation and Development Commission

SONOMA COUNTY

*+Sonoma County
*+Cloverdale
Cotati
+Healdsburg
+Petaluma
Rohnert Park
Santa Rosa
Sebastopol
+Sonoma
State of California
*Bay Conservation and Development Commission

The other MRZ-2 areas that lie outside of the OPR urbanizing boundaries are located in four areas of Sonoma County. Along the Russian River from north of Cloverdale to the vicinity of the Wohler Bridge, near Mirabel Heights and along the lower 15 miles of Dry Creek are extensive deposits of sand and gravel which supply the high quality aggregate for most of the North San Francisco Bay P-C Region. Two smaller stream deposits of sand and gravel are found in Austin Creek and Gualala River, also in Sonoma County.

As explained in Part I under the heading "Concept of Sectors", the State Geologist has identified as resource sectors those MRZ-2 areas with existing land uses that are compatible with mining (Part I, p. 9 and Appendix A-5, p. 41). In the North San Francisco Bay P-C Region, 25 areas qualify as sectors; they contain sand and gravel, or stone suitable for aggregate. Table 3.3 lists the geologic units and formations underlying the resource sectors, and shows which sectors contain material that may be suitable for Portland cement concrete aggregate. Detailed descriptions of the individual sectors are included below in the section "Estimated Aggregate Resources of the North San Francisco Bay P-C Region". The identification of resource sectors has been done to inform lead agencies and others of resources that could be made available for mining by virtue of the present, generally undeveloped status of the land. It is recognized that dedicated parklands have special status as opposed to other current uses of sectorized land, consequently the resources within parks have been sectorized separately and the quantification of those resources are presented separately in the tables. The quantification of resources within park sectors are expressed to a lower degree of accuracy rather than to the higher level of accuracy reflected in the resource calculations for other sectors. The sectorization of any area is not an advocacy of mining in that area.

Areas Classified MRZ-3

One hundred twelve (112) areas in the North San Francisco Bay P-C Region have been classified MRZ-3 (Plates 3.1–3.3, and 3.5–3.41). Areas classified MRZ-3 contain mineral deposits, but their significance cannot be evaluated from available data (see Part I, Appendix A-3, p. 25). Geologic units and formations underlying areas classified MRZ-3 are given in Table 3.4. A summary of MRZ-3 areas, by county and by quadrangle, is presented in Appendix B of this report (p. 49).

MRZ-3 areas located in valleys are generally underlain by Quaternary alluvial deposits containing sand and gravel, but resource calculations cannot be made due to inadquate subsurface data (either the well-log data is unavailable or the available data is inconclusive). An area will be classified MRZ-3 if, based upon well-log data, sand and gravel are present that do not meet the criteria for MRZ-2 listed above. MRZ-3 areas in hilly or mountainous terrain are generally underlain by Tertiary sedimentary or volcanic rocks, or by Mesozoic sedimentary, volcanic, or metamorphic basement rocks. Many of these areas are classified as such due to the lack of outcrops or accessible areas for field examination.

Areas Classified MRZ-4

Areas where available information is inadequate for assignment to any other MRZ category are classified MRZ-4 (Part I, Appendix A-3, p. 25). In the North San Francisco Bay P-C Region, all MRZ-4 areas are located in hilly or mountainous terrain underlain by Tertiary-age sedimentary or volcanic rocks, or Jurassic-Cretaceous sedimentary, igneous, or metamorphic rocks. The areas often are poorly mapped, have poor accessibility, and may be underlain by rock units that have never been quarried for aggregate.

Areas Classified SZ

In addition to Mineral Resource Zones, the State Mining and Geology Board has established Scientific Resource Zones (SZ, see Part I, Appendix A-3, p. 25). These are areas that contain unique or rare occurrences of rocks, minerals, or fossils of outstanding scientific significance.

Such an area occurs on the northern end of Tiburon Peninsula, within the OPR urbanizing boundaries. This area, known as the Ring Mountain area, is "an important and famous geological locality. The rare, colorful, and enigmatic metamorphic rocks that occur there have been studied by geologists and mineralogists for many decades, but their origins are still not fully understood. This area should be preserved in its present condition for further study and as a natural geologic exhibit" (Rice, Smith, and Strand, 1976, p. 5).

The Ring Mountain area has been classified SZ, and a description of the area is included with the present study.

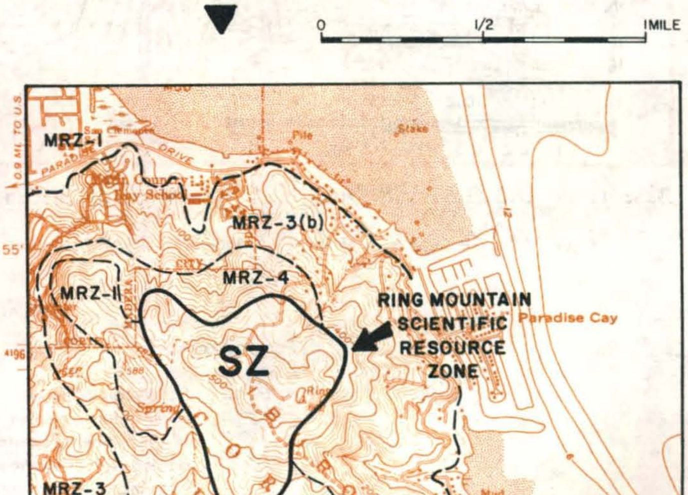
Table 3.3 Geologic units underlying resource sectors within the North San Francisco P-C Region. Those deposits chosen as sectors are identified by the letters A–Y. Present or potential sources of Portland cement concrete aggregate are identified with an asterisk (*). Geologic units shown without an asterisk are potential sources of non-P.C.C. aggregate.

GEOLOGIC UNIT / QUADRANGLE	QUATERNARY ALLUVIUM*	NOVATO CONGLOMERATE*	SONOMA VOLCANICS ANDESITE AND BASALT	SAINT HELENA RHYOLITE	FRANCISCAN COMPLEX UNDIFFERENTIATED	FRANCISCAN COMPLEX GREENSTONE*	FRANCISCAN COMPLEX SANDSTONE*	FRANCISCAN COMPLEX SERPENTINITE
Asti	A							
Cloverdale	A							
Geyserville	A B							
Jimtown	A B							
Guerneville	B					Y		
Healdsburg	B							
Glen Ellen	C			K				
Sears Point	C		X					
Sonoma	C			K				
Novato		D						
Petaluma River		D	E J S V		R			
Cotati			F					
Benicia					G	G	G	
Cuttings Wharf			H					
Mount George			H					
Napa			H					
San Quentin							I	
Kenwood				K				
Inverness					L			M
Camp Meeker					N O P			
Bodega Head							Q	
Duncans Mills	T						T	
Stewarts Point	U							
Mark West Springs					W			

Table 3.4 Geologic units underlying areas classified MRZ-3 within the North San Francisco Bay P-C Region.

Quadrangle \ Geologic Unit	Quaternary Alluvium	Sonoma Volcanics andesite and basalt	Sonoma Volcanics intrusive complex	Sonoma Volcanics rhyolite	Novato Conglomerate	Domengine Formation	Unnamed Formation of Sims	Briones Formation sandstone	Merced Formation sandstone	Franciscan Complex chert	Franciscan Complex greenstone	Franciscan Complex sandstone	Franciscan Complex metamorphics
Bolinas											X		
Novato		X									X	X	
Petaluma Point					X							X	
Petaluma River		X											
Point Bonita										X			
San Francisco North										X	X		X
San Geronimo											X	X	
San Quentin												X	X
San Rafael										X	X	X	
Cordelia		X				X		X				X	
Cuttings Wharf		X				X	X	X					
Mount George		X											
Napa		X	X			X							
Benicia												X	
Cotati		X											
Glen Ellen		X											
Kenwood		X		X									
Petaluma		X											
Santa Rosa	X	X											
Sebastopol									X				
Sonoma	X	X		X									
Two Rock									X				
Asti	X												
Cloverdale	X												
Geyserville	X	X											
Guerneville	X												
Jimtown	X	X									X		
Healdsburg	X												

Figure 3.1 Map of the southwestern corner of Plate 3.14, the San Quentin Quadrangle, showing the location of the Ring Mountain Scientific Resource Zone.



Base from U.S.G.S. San Quentin 7 1/2-Minute Quadrangle

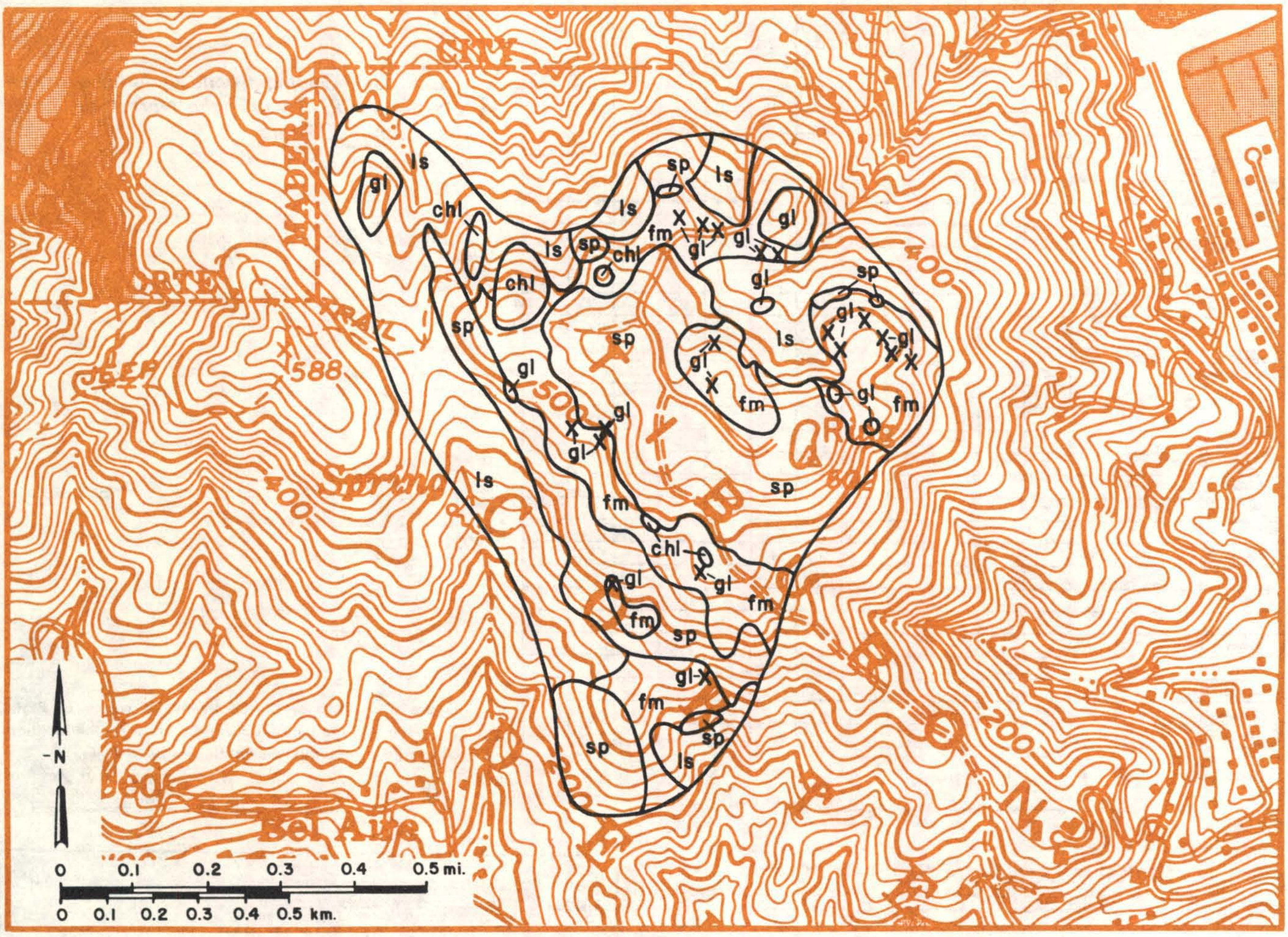
RING MOUNTAIN SCIENTIFIC RESOURCE ZONE

The Ring Mountain Scientific Resource Zone consists of approximately 190 acres of land on the north end of Tiburon Peninsula. Ring benchmark (Elevation 602 feet) lies near the east central edge of the area and is the highest point on Tiburon Peninsula. Figure 3.1 (the southwestern corner of the San Quentin Quadrangle, Plate 3.14) shows the location of the Ring Mountain Scientific Resource Zone. The detailed geology of the area is shown on Figure 3.2.

The Ring Mountain area was mapped by Rice and Smith (1976, Plate 1E) and described in an open-file report prepared in cooperation with Marin County and a number of cities and towns in southern Marin County (Rice, Smith, and Strand, 1976, p. 50–53). The following description of the area is quoted from that report:

> In general, the Tiburon Peninsula appears to be made up of a series of superimposed, thrust-fault slices of diverse rock sequences, the youngest rocks at the bottom and the older ones above.
>
> Well-stratified sandstones and shales are exposed in many road cuts along Paradise Drive and Tiburon Boulevard northwest of their intersections with Trestle Glen Boulevard, and also in wave-cut cliffs along much of the northeast shore of the peninsula. As revealed in good exposures, sequences of these sedimentary rocks range from predominantly sandstone in beds a few inches to a

122°30'
37°55'



Base from U.S.G.S. San Quentin 7 1/2-Minute Quadrangle

Figure 3.2 Geologic map of the Ring Mountain Scientific Resource Zone. Geology and explanation from Rice and Smith, 1976, Plate 1E.

EXPLANATION

fm = *Franciscan Melange.* A tectonic mixture consisting of small to large masses of resistant rock types, principally of sandstone, greenstone, chert, and serpentine, but including various exotic metamorphic rock types embedded in a matrix of pervasively sheared or pulverized rock material. Masses too small to delineate at map scale are indicated by the symbol "x".

chl = *Chlorite schist.* A dull green schistose rock composed principally of chlorite, commonly containing veins of tremolite.

gl = *Metamorphic rock.* Chiefly dense, coarsely crystalline, dark-bluish glaucophane-bearing schists or gneisses and dark-green eclogite.

sp = *Serpentine.* Pale green to dark-green, fine-grained metamorphic rocks composed almost entirely of the magnesium silicate minerals lizardite and chrysotile.

ls = *Landslide*

few feet thick, and with little or no shale, to alternating, graded, thin beds of sandstone and shale, each bed an inch to a few inches thick. Bedding is characteristically steeply dipping, and the graded beds commonly reveal tight, overturned folding. These are unmetamorphosed sedimentary rocks, formed from sand and mud deposited in a deep ocean environment, and probably of Late Cretaceous age (about 80 million years).

In contrast to these rocks that appear to constitute a base for the peninsula, much of the crest area is capped by large sheets of serpentine, a rock of igneous origin that almost certainly originated in the mantle of the earth, beneath the crust on which the sandstones and shales were deposited. Though the serpentine has not been dated, it is perhaps the oldest of the rock sequences on the peninsula, probably more than 150 million years old.

Northwest of Trestle Glen Boulevard, the sheets of serpentine that cap the two crests in the Ring Mountain area are separated from the underlying sandstones and shales by a thick zone composed principally of intensely sheared Franciscan melange matrix. The melange represents an ancient fault zone, a clue to the mechanisms whereby the serpentine, from beneath the crust of the earth, was thrust over sedimentary rocks deposited on the surface of the crust.

Scattered on the ridge in the Ring Mountain area, in places on the serpentine but for the most part downslope from it within melange and landslide areas, are many prominent, dark-colored monuments and blocky masses of various unusual and weather-resistant metamorphic rock types that help make this area unique and famous as a geologic locality. Generally speaking, each of these monolithic masses has a different fabric and assemblage minerals than its nearest neighbors. Most of them are coarse-grained, massive to schistose rock types that include eclogites, hornblende-garnet amphibolites, glaucophane-garnet schists, stilpnomelane-riebeckite-quartz schists, chlorite schists, and actinolite schists. Some are of such unusual mineral composition and massive texture that none of the standard rock names apply to them. The petrology and mineralogy of the metamorphic rocks in this area have been studied in considerable detail by Dudley (1967).

These exotic metamorphic rock masses, ranging in size from less than a foot to many tens of feet, are or were embedded in the weak, sheared matrix of the melange or in the serpentine. Some have simply been partially exposed by erosion of the weak rock material that enclosed them, for they appear to be in place, partially embedded. Others have been left behind by erosion as loose rock masses on the surface, and many have been transported downslope by landslides, in places as far as the bay.

They are clearly isolated tectonic fragments, delivered from a disrupted source or sources unknown, but presumably at great depths as revealed by the presence in them of the mineral lawsonite, and transported to the present locality by the same thrust faulting mechanisms that brought the serpentine here. No coherent outcrop areas of such rocks are known anywhere on the surface of the earth. Their origins remain an enigma, even though studied over many decades by many geologists and mineralogists.

Most, perhaps all, of the rare and unusual rock types found in this area have been found in similarly disrupted zones at one or more other localities in the world. To the best of our knowledge, however, the rich assortment of them in the Ring Mountain area is not duplicated anywhere else . . .

This area caught the attention of many mineralogists in the 1890s, when a newly discovered mineral, named lawsonite, was first described (Ransome, 1895) from a large, picturesque outcrop of metamorphic rock that used to dominate the landscape where Reed Ranch Road presently ends. That outcrop was destroyed by blasting and bulldozing in 1964 in preparation of a subdivision (Rice, 1964).

Lawsonite was subsequently found to be one of the significant metamorphic indicator minerals, indicating that metamorphism (recrystallization of the rock) had occurred under conditions of great pressures (equivalent to as much as 20 miles of burial), but at relatively low temperatures (less than about 400 degrees centigrade, well below the melting point of the rock).

Following the initial discovery of lawsonite, other relatively rare minerals and rock types were found in the vicinity of Ring Mountain (the local name for the northern crest area of Tiburon Peninsula), and the area has been visited and studied by numerous geologists and mineralogists.

As an interesting sidelight on these rocks, a few years ago the face of one of the large blocks of metamorphic rocks in the Ring Mountain area was found to have many ancient petroglyphs carved on it (Hotz and Clewlow, 1974), the first petroglyphs reported in the Bay area by archaeologists. The carvings are in chlorite schists, a very soft rock, but one with great resistance to weathering processes that decompose most common rock types. Since that discovery, many other petroglyphs have been found in the Ring Mountain area, all carved in similar chlorite schists. . .

References named above are found in the Reference Section at the end of this report (p. 37).

EVALUATION OF AGGREGATE RESOURCES IN THE NORTH SAN FRANCISCO BAY P-C REGION

Data Base

In order for any appraisal of a resource to have credibility, the basis for that appraisal must be described. If the data base is weak, the resource appraisal must indicate this fact; conversely, if it is strong, this should also be noted. Terminology used to reflect the confidence level of the data base for this project have been adapted from the U.S. Geological Survey Circular 831 (Appendix A of this report—p. 39). For this project, *reserves* represent tested material determined to be acceptable for commercial use, that exists within properties owned or leased by an aggregate producing company, and for which permission allowing mining and processing has been granted by the proper authorities. *Resources* include *reserves* as well as all similar potentially usable aggregate materials which may be mined in the future, but for which no permit allowing mining has been granted, or for which marketability has not been established.

Factors Considered in Calculation of Resources

The resource estimates given here are limited to those resources present in nonurbanized portions of the areas designated by the Office of Planning and Research (OPR) as subject to urbanization within the near future (1990) as modified for this study by available information from county or city planning departments (Plates 3.5–3.41a), and include the Russian River and Dry Creek sand and gravel production areas and other significant aggregate operations.

Twenty-five areas were chosen as resource sectors during the course of this study. The sectors are identified on 24 sector maps (Plates 3.42–3.65), which are 1:48,000 scale editions of the U.S. Geological Survey quadrangles in which the sectors are located. The sectors are identified by the letters A through Y on the sector maps, in Tables 3.5 and 3.6, and in the sector descriptions below. Reserves and resources within the sectors are shown in Table 3.6.

Parameters used in determining locations and volumes of resources within the 25 sectors included the following items:

1. The most detailed geologic and topographic maps available were used for classification. Published and unpublished reports were used to locate and identify active and inactive quarries within the P-C region.

2. An operating quarry was considered sufficient evidence that commercial-quality aggregate was present in the deposit.

3. All areas classified MRZ-2 and MRZ-3 were field-checked, and found to contain material similar to that occuring in active quarries. Material suitable only for fill was not classified MRZ-2.

4. The lateral and vertical distribution of the resource was determined on the basis of geologic projections from sample sites at quarries and outcrops, and on the basis of an understanding of the geological processes responsible for the formation of the deposit. The resource evaluation of the sand and gravel deposits are based in part on analyses of several thousand water-well logs. The logs describe the types of earth materials (clay, silt, sand, gravel) and bedrock encountered at various depths, as interpreted by the well driller (who may have had little or no training in earth sciences). The quality of the descriptions range from bad to very good. Many water-well logs were unsuitable because of the incomplete descriptions of the earth materials encountered in the well. In some instances the location of the well was vague. Only well logs that contain acceptable descriptions and locations were used in this study.

5. Resource estimates for those deposits chosen as sectors are based on measurements of volumes made from base maps enlarged to scales of 1:6,000 or 1:12,000. Tonnage conversion factors are based on density tests of samples from the sectors or from quarries with material similar to the sector material. Reserve figures for areas outside O P R boundaries were based on published data (Sonoma County Planning Department).

Included within the boundaries of many sectors are active commercial aggregate operations. Reserve and resource calculations were done in 1977 for most significant quarries or sand pits in the four counties, as part of a study of the aggregate industry in the San Francisco-Monterey Bay Region (Chesterman and Manson, 1983). These calculations were revised to 1980, the year of the most recent available production statistics to accomodate resource depletion and other factors. County totals of commercial reserves and resources in the 3 P-C regions are included in Tables 3.6, 3.13, and 3.14 for comparison with the resources available in the sectors.

Parameters used by Chesterman and Manson (1983) in making their calculations, largely of demonstrated reserves (see Appendix A), are site specific and reflect all conditions listed in the mine's use permit. These parameters may include some or all of the following items:

1. Setbacks of excavation areas from property lines range from 0 to 105 feet. Minimum setbacks usually occur when the excavation area is adjacent to other producers. Maximum setbacks are delineated along public roads.

2. Pit wall slopes are usually required to have a horizontal-to-vertical ratio of less than or equal to 1:1, 1.5:1, or 2:1. Quarry walls usually are required to be benched at specific vertical intervals and may have sloped connecting walls. When benching is required, the width of the bench, if specified, often is approximately equal to one-half the vertical interval. This design results in an approximate slope of 63°. Occasionally, benches are forbidden and a smooth wall with a 2:1 or 3:1 slope is specified in the use permit.

3. Maximum pit depth or minimum quarry floor elevation is indicated in many use permits. Depths of excavation range from 40 to 120 feet below ground surface.

4. Densities of the in-place material vary considerably between individual deposits and from one rock type to another. Where aggregate is composed of sediments derived from the Franciscan Complex (as in the Russian River Production District) a factor of 14.50 cubic feet per ton (0.069 tons per cubic foot) is used in reserve calculations. This factor is derived from data supplied by producers in the Livermore-Amador Valley.

The specific gravities of rock samples from individual quarries range from 2.13 to 2.70, yielding individual conversion factors from 0.06 to 0.08 tons per cubic foot.

5. Waste factors vary from plant to plant, and considerable variation within a deposit often is shown by detailed sampling. Most sand and gravel plants have waste factors that range from 5 to 15 percent of gross tonnage. The rock quarries usually have no waste because the low grade material is sold for fill or topsoil.

Table 3.5 Resource sectors in the North San Francisco Bay P-C Region.

QUADRANGLE	CLASSI-FICATION	SECTOR	REFER-ENCE IN TEXT
Asti Quadrangle	MRZ-2(a)	A	p. 11
Cloverdale Quadrangle	MRZ-2(a)		
Geyserville Quadrangle	MRZ-2(a)		
Jimtown Quadrangle	MRZ-2(a)		
Geyserville Quadrangle	MRZ-2(b)	B	p. 12
Guerneville Quadrangle	MRZ-2(a),(b)		
Healdsburg Quadrangle	MRZ-2(a),(b)		
Glen Ellen Quadrangle	MRZ-2(a)	C	p. 13
Sears Point Quadrangle	MRZ-2(a)		
Sonoma Quadrangle	MRZ-2(a)		
Novato Quadrangle	MRZ-2(a)	D	p. 13
Petaluma River Quadrangle	MRZ-2(c)		
Petaluma River Quadrangle	MRZ-2(a)	E	p. 14
Cotati Quadrangle	MRZ-2(a)	F	p. 14
Benicia Quadrangle	MRZ-2(a)	G	p. 14
Cuttings Wharf Quadrangle	MRZ-2(a)	H	p. 16
Mount George Quadrangle	MRZ-2(a)		
Napa Quadrangle	MRZ-2(a)		
San Quentin Quadrangle	MRZ-2(a)	I	p. 16
Petaluma River Quadrangle	MRZ-2(b)	J	p. 17
Glen Ellen Quadrangle	MRZ-2(b)	K	p. 17
Kenwood Quadrangle	MRZ-2(a)		
Sonoma Quadrangle	MRZ-2(b)		
Inverness Quadrangle	MRZ-2(a)	L	p. 18
Petaluma River Quadrangle	MRZ-2(f)	M	p. 18
Camp Meeker Quadrangle	MRZ-2(b)	N	p. 18
Camp Meeker Quadrangle	MRZ-2(a)	O	p. 18
Camp Meeker Quadrangle	MRZ-2(c)	P	p. 19
Bodega Head Quadrangle	MRZ-2(a)	Q	p. 19
Petaluma River Quadrangle	MRZ-2(d)	R	p. 19
Petaluma River Quadrangle	MRZ-2(e)	S	p. 19
Duncans Mills Quadrangle	MRZ-2(a)	T	p. 19
Stewarts Point Quadrangle	MRZ-2(a)	U	p. 20
Petaluma River Quadrangle	MRZ-2(b)	V	p. 20
Mark West Springs Quadrangle	MRZ-2(a)	W	p. 20
Sears Point Quadrangle	MRZ-2(b)	X	p. 20
Guerneville Quadrangle	MRZ-2(c)	Y	p. 20

ESTIMATED AGGREGATE RESOURCES OF THE NORTH SAN FRANCISCO BAY P-C REGION

The available aggregate resources within the urbanizing portions of the North San Francisco Bay P-C Region are summarized by county and by sector in Table 3.6. The table identifies the sectors and lists the amounts of available aggregate within the sectors. In addition, Table 3.6 lists the amount of sand and gravel or stone reserves controlled by commercial aggregate companies within the four counties of this P-C region. In Table 3.6, *reserves* are aggregate materials that a company owns or controls, and for which it has a valid mining permit; *resources* are the total amount of available aggregate within the sector. Unless noted otherwise, all resources are of the inferred category as described in Appendix A of this report (p. 39).

The estimated resources within the 6 sand and gravel sectors amount to more than 908 million tons, of which approximately 108 million tons qualify as reserves available for mining at the end of 1980. The sand and gravel sectors are distributed as follows: Marin County has 29 million tons of Novato Conglomerate; Sonoma County has more than 879 million tons of Quaternary alluvium.

The estimated resources within the 19 crushed stone sectors amount to more than 1,449 million tons, of which approximately 432 million tons qualify as reserves available for mining at the end of 1980. Stone resources within the P-C region are distributed as follows: Marin County contains more than 39 million tons of Franciscan Complex sandstone and Sonoma Volcanics andesite; Napa County has 641 million tons of Sonoma Volcanics rhyolite, andesite, basalt, and tuff; western Solano County contains 413 million tons of Franciscan Complex greenstone, sandstone, and silica-carbonate rocks; Sonoma County has more than 330 million tons of basalt and rhyolite from the Sonoma Volcanics.

The estimated P.C.C.-grade aggregate resources (from both crushed stone and sand and gravel deposits) within all sectors amount to more than 883 million tons, of which approximately 112 million tons qualify as reserves available for mining at the end of 1980 (see Table 3.7). P.C.C. aggregate for the P-C region is obtained from three sources: the Russian River Production District, and stone quarries of Syar Industries and Basalt Rock Company. Sand and gravel obtained from the production district supplies the bulk of the demand for P.C.C. aggregate in the North San Francisco Bay P-C Region. The deposits within the production district consist of stream channel and flood-plain material, which form aquifers in the valleys along the Russian River.

Sand and Gravel Resources

In the North San Francisco Bay P-C Region, sand and gravel production, and sand and gravel resource sectors are restricted to three counties: Marin, Napa, and Sonoma. The principal sand and gravel production occurs in two areas—the Alexander Valley and Middle Reach of the Russian River—both in Sonoma County and both outside of the OPR urbanizing areas (see Figure 3.3). Relatively minor production occurs near Point Reyes Station (Marin County), and near the cities of Sonoma and Napa. Sand is dredged from marine deposits in the San Francisco Bay and the Carquinez Strait.

Table 3.6 Reserves and resources within sectors in the North San Francisco Bay P-C Region. The reserves (calculated through 1980) are material that commercial aggregate companies control, and for which the companies have valid mining permits. Resources include the reserves and any other material within the sector.

COUNTY	SECTOR	SAND AND GRAVEL AMOUNT (millions of tons) Reserves	SAND AND GRAVEL AMOUNT (millions of tons) Resources	CRUSHED STONE AMOUNT (millions of tons) Reserves	CRUSHED STONE AMOUNT (millions of tons) Resources
Marin	D		29		
	I			*	*
	J				8
	L			*	*
	M			*	*
Marin Subtotal			29	*	8+
Parklands	V				31
Parklands Subtotal					31
MARIN COUNTY TOTAL			29	*	39+
Western Solano	G			*	413
SOLANO COUNTY TOTAL				*	413
Napa	H			*	641
NAPA COUNTY TOTAL				*	641
Sonoma	A	*	449		
	B	*	405		
	C	*	25		
	E			*	*
	F			*	*
	K			*	151
	N			*	*
	O			*	*
	P			*	*
	Q			*	*
	R			*	*
	S			*	*
	T	*	*	*	*
	U	*	*		
	W			*	*
	X			*	*
	Y			*	*
SONOMA COUNTY TOTAL		108#	879+	180#	330#
P-C REGION TOTAL		108#	908+	432#	1,449#

TOTAL RESERVES IN NORTH SAN FRANCISCO BAY P-C REGION = 540 MILLION TONS
TOTAL RESOURCES IN NORTH SAN FRANCISCO BAY P-C REGION = 2.4 BILLION TONS

* Proprietary data
\# Includes combined proprietary data

Table 3.7 Sectors that contain proven P.C.C.-grade aggregate, their resources, and any reserves that may exist within their boundaries.

SECTOR	MATERIAL	RESOURCES (Million tons)	RESERVES (Million tons)
A	S & G	449	*
B	S & G	405	*
D	S & G	29	-
G	Stone	?	*
I	Stone	*	*
U	S & G	*	*
Total		883+	112+

* Proprietary

SECTOR A: QUATERNARY ALLUVIUM - ALEXANDER VALLEY

Plate 3.36	Asti Quadrangle	MRZ-2(a)	Sector Plate 3.42 *
Plate 3.37	Cloverdale Quadrangle	MRZ-2(a)	Sector Plate 3.43
Plate 3.38	Geyserville Quadrangle	MRZ-2(a)	Sector Plate 3.44
Plate 3.41	Jimtown Quadrangle	MRZ-2(a)	Sector Plate 3.45

Resource Sector A is in Alexander Valley, Sonoma County. The sector extends southeast along the Russian River from about 1 mile north of Cloverdale to 3.5 miles southeast of Jimtown—a total distance of more than 20 miles. A comparison of topographic maps, water-well logs, and soil survey maps (Miller, 1972) shows that most of the sand and gravel deposits occur within four soil mapping units: (1) Riverwash—this consists of very recent deposits of gravel, sand, and silt; (2) Alluvial land, sandy—this unit contains soil underlain by sand and gravel deposits along streams; (3) Cortina very gravelly loam; and (4) Cortina very gravelly sandy loam. Sand and gravel is currently mined from gravel bars at a number of sites in Sector A. Available water-well logs indicate that the commercial-grade sand and gravel extend to depths of 50–55 feet at the south end of the sector near Jimtown. Well logs were not available for the northern end of the sector, so an average thickness of 40 feet was chosen for the sand and gravel resources in Sector A. Several commercial aggregate operations are active in Sector A, but due to the large amount of reserves controlled by one company, reserve data is not shown here but is included with data from other sectors in Table 3.6.

Sand and gravel resources for Sector A are given in the table at the end of this section. They were calculated be determining the volume of a horizontal prism, beginning below the overburden (at the top of the aquifer) downward to the base of the deposit. This technique was used in all alluvial deposits. Factors used (which include both factual data and assumptions in this and all subsequent sector tonnage calculations) in calculating resources included the following items:

1. Resource material is Quaternary sand and gravel beneath the following U.S.D.A. soil units: Riverwash, Alluvial land, sandy, Cortina very gravelly loam, and Cortina very gravelly sandy loam.
2. All sand and gravel present is suitable for P.C.C. aggregate.
3. Waste is 10 percent of the total material.
4. Overburden (soil) is assumed to be no more than 10 feet thick. Sand and gravel is assumed to exist from 10 feet to 50 feet beneath the surface of Sector A. It is assumed that overburden has been stripped prior to the calculation of resources. Resource totals, therefore, do not include overburden.
5. Wall slopes above the aquifer and within the deposit were not considered in the calculations.
6. Ground-water table ranges from 0 to 30 feet beneath the surface. Dredging can be economic at depths of at least 50 feet.
7. A conversion factor of 14.50 cubic feet per ton of material was used in calculating resources. This factor is based on detailed calculations for sediments derived from rocks of the Franciscan Complex in the Livermore-Amador Valley (Alameda County) during a previous aggregate study (Chesterman and Manson, 1983).
8. Base maps used in calculating resources were 4:1 enlargements of the Asti, Cloverdale, Geyserville, and Jimtown 7.5-minute quadrangles (1959, 1960, 1955, and 1955, respectively). No allowance was made for material removed by stream erosion or mining since it is insignificant in comparison to the total resource.

* Resource sectors have not been labeled as such on the 38 quadrangles (Plates 3.5 through 3.41a) that accompany this report. Instead, they are individually identified under each heading in the text, in Table 3.5 and 3.6, and on individual sector maps (Plates 3.42 through 3.65). For example, Sector A-1 is within the area identified by the symbol MRZ-2(a) on Plate 3.36 and within the area designated 'Sector A-1' on Plate 3.42. Many of the resource sectors do not occupy the entire area classified MRZ-2 due to some restrictions caused by urbanization.

RESOURCES - SECTOR A

SECTOR	AREA (acres)	X	DEPTH (feet)	X	CONVERSION FACTORS	=	TONNAGE (to nearest 10,000 tons)
A-1							
A-1	306.07	X	40	X	(43,560)(.90) / 14.50	=	33,100,000
A-2							
A-2(a)	301.54	X	40	X	(43,560)(.90) / 14.50	=	32,610,000
A-2(b)	554.41	X	40	X	"	=	59,960,000
A-2(c)	384.24	X	40	X	"	=	41,550,000
A-2(d)	901.11	X	40	X	"	=	97,450,000
					Total	=	231,570,000
A-3							
A-3(a)	365.70	X	40	X	(43,560)(.90) / 14.50	=	39,550,000
A-3(b)	506.26	X	40	X	"	=	54,750,000
A-3(c)	426.88	X	40	X	"	=	46,170,000
					Total	=	140,470,000
A-4							
A-4(a)	139.81	X	40	X	(43,560)(.90) / 14.50	=	15,120,000
A-4(b)	267.96	X	40	X	"	=	28,980,000
					Total	=	44,100,000
					Sector A Total	=	449,240,000

RESOURCES SECTOR A (continued)

TOTAL RESOURCES - SECTOR A =
449 MILLION TONS (ALL P.C.C. GRADE)
TOTAL RESERVES - SECTOR A =
(PROPRIETARY DATA)

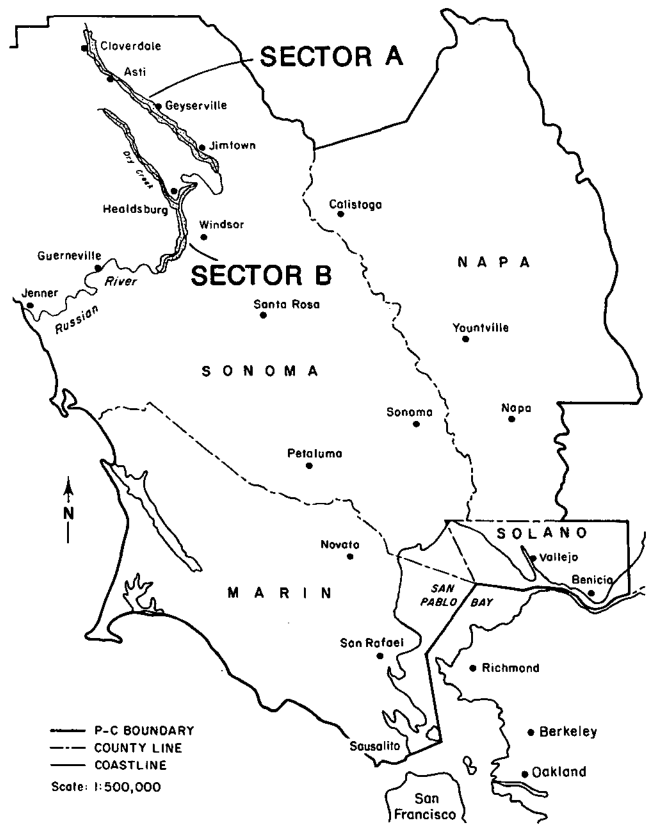


Figure 3.3 Map of the North San Francisco Bay P-C Region showing the location of the Russian River and Dry Creek sand and gravel production areas (Sectors A and B).

SECTOR B: QUATERNARY ALLUVIUM - RUSSIAN RIVER AND DRY CREEK

Plate 3.38	Geyserville Quadrangle	MRZ-2(b)	Sector Plate 3.44
Plate 3.39	Guerneville Quadrangle	MRZ-2(a),(b)	Sector Plate 3.46
Plate 3.40	Healdsburg Quadrangle	MRZ-2(a),(b)	Sector Plate 3.47

Resource Sector B includes the Middle Reach of the Russian River (Sectors B-1 and B-2) and Dry Creek (Sectors B-3 and B-4). Sectors B-1 and B-2 encompass the sand and gravel deposits along the Middle Reach of the Russian River, from approximately 1000 feet south of the Wohler Road bridge to where the river narrows, approximately a mile east of Healdsburg. Available water-well logs indicate that the sand and gravel extend to depths of up to 80 feet beneath the following soil units: Riverwash; Alluvial land, sandy; Cortina very gravelly loam; and Cortina very gravelly sandy loam. Sectors B-3 and B-4 are located in the drainage of lower Dry Creek from a point about 2000 feet west of the confluence of Dry Creek and the Russian River to near School House Creek, a distance of about 15 miles. Available well logs indicate that sand and gravel extend to a depth of about 35 feet beneath the four soil units mentioned above. Several aggregate operations are active in Sector B. Data on reserves cannot be disclosed here for proprietary reasons, but are included with data from other sectors in Table 3.6.

Resources of sand and gravel in Sector B are given in the table below. Factors used in calculating resources included the following items:

1. Resource material is Quaternary alluvium beneath the four soil units (Riverwash; Alluvial land, sandy; Cortina very gravelly loam; Cortina very gravelly sandy loam). The sand and gravel present is suitable for P.C.C. aggregate.
2. Waste is assumed to be 10 percent of the total material.
3. Overburden (soil) is assumed to be 10 feet thick. Sand and gravel is assumed to be from 10 feet to 45 feet below ground surface in Sectors B-3 and B-4, and from 10 feet to 70 feet below ground surface in Sectors B-1 and B-2.
4. Wall slopes were not considered in the calculations.
5. Ground-water table ranges from 0 to 30 feet beneath the surface. Dredging of material is economic at depths of at least 50 feet.
6. A conversion factor of 14.50 cubic feet per ton of material was used in resource calculations, due to the similarity of the resource material to that in Sector A.
7. Base maps used in resource calculations were 4:1 enlargements of the Geyserville, Guerneville, and the Healdsburg 7.5-minute quadrangles (1955). No allowance is made for river erosion. Approximately 22 million tons have been mined from terrace pits as of 1978; this figure has been subtracted from the sector totals.

RESOURCES - SECTOR B

SECTOR	AREA (acres)	X	DEPTH (feet)	X	CONVERSION FACTORS	=	TONNAGE (to nearest 10,000 tons)
B-1							
B-1	120.18	X	60	X	(43,560)(.90) / 14.50	=	19,500,000
B-2							
B-2(a)	463.67	X	60	X	(43,560)(.90) / 14.50	=	93,340,000
B-2(b)	618.46	X	60	X	"	=	100,330,000
B-2(c)	577.88	X	60	X	"	=	106,110,000
B-2(d)	188.30	X	60	X	"	=	30,550,000
					Total	=	330,330,000
B-3							
B-3	212.92	X	35	X	(43,560)(.90) / 14.50	=	20,150,000
B-4							
B-4(a)	175.73	X	35	X	(43,560)(.90) / 14.50	=	16,630,000
B-4(b)	165.58	X	35	X	"	=	15,670,000
B-4(c)	72.83	X	35	X	"	=	6,890,000

RESOURCES – SECTOR B (continued)

CONTOUR ELEVATION	AREA (acres)	X	AVERAGE AREA (acres)	X	CONVERSION FACTORS	=	TONNAGE (to nearest 10,000 tons)
B-4(d)	97.74	X	35	X	(43,560)(.90) / 14.50	=	9,250,000
B-4(e)	90.79	X	35	X	"	=	8,590,000
					Total	=	57,030,000
					Sector B Total	=	427,010,000
					Minus production from terrace pits	-	22,000,000
					Remaining Resources	=	405,010,000

TOTAL RESOURCES - SECTOR B =
405 MILLION TONS (ALL P.C.C. GRADE)
TOTAL RESERVES - SECTOR B =
(PROPRIETARY DATA)

SECTOR C: QUATERNARY ALLUVIUM - SONOMA CREEK

Plate 3.27	Glen Ellen Quadrangle	MRZ-2(a)	Sector Plate 3.48
Plate 3.31	Sears Point Quadrangle	MRZ-2(a)	Sector Plate 3.49
Plate 3.33	Sonoma Quadrangle	MRZ-2(a)	Sector Plate 3.50

Resource Sector C extends southward from the Glen Ellen Quadrangle into the Sonoma and Sears Point quadrangles. The sector boundaries are approximately those of "Riverwash" as drawn by Miller (1972, sheets 91, 99, 100, 108). According to Goldman (1974, p. 49), the deposit reaches a maximum depth of 60 feet. Honke and Ver Planck (1950, p. 110) state that the material within the deposit consists predominently of andesite and basalt, with minor olivine basalt, vesicular lava, chert, and rhyolite. No test data is available concerning the suitability of this material for P.C.C. aggregate.

Resources in Sector C are given in the table below. Factors used in calculating resources included the following items:

1. The aggregate material is Quaternary alluvium in Sonoma Creek within the boundaries drawn by Miller (1972) for "Riverwash."
2. The sand and gravel is suitable for asphaltic concrete aggregate and perhaps P.C.C. aggregate.
3. Waste (silt and clay) is assumed to form 10 percent of the material.
4. Overburden is assumed to be negligible.
5. Wall slopes are not considered in resource calculations.
6. Average thickness of material is assumed to be 20 feet.
7. Ground water will not hinder mining operations during the summer low-water period.
8. A conversion factor of 14.50 cubic feet of material per ton was used.
9. Base maps for resource calculations are 4:1 enlargements of the Glen Ellen, Sears Point, and Sonoma 7.5-minute quadrangles (1980, 1968, and 1980, respectively).

RESOURCES – SECTOR C

SECTOR	AREA (acres)	X	DEPTH (feet)	X	CONVERSION FACTORS	=	TONNAGE (to nearest 10,000 tons)
C-1							
C-1	34.49	X	20	X	(43,560)(.90) / 14.50	=	1,870,000
C-2							
C-2(a)	48.09	X	20	X	(43,560)(.90) / 14.50	=	2,600,000
C-2(b)	69.85	X	20	X	"	=	3,780,000
					Total	=	6,380,000
C-3							
C-3	28.35	X	20	X	(43,560)(.90) / 14.50	=	1,530,000
C-4							
C-4	136.88	X	20	X	(43,560)(.90) / 14.50	=	7,400,000
C-5							
C-5	36.10	X	20	X	(43,560)(.90) / 14.50	=	1,950,000
C-6							
C-6	106.81	X	20	X	(43,560)(.90) / 14.50	=	5,780,000
					Sector C Total	=	24,910,000

TOTAL RESOURCES - SECTOR C =
25 MILLION TONS (ALL ASPHALTIC AGGREGATE GRADE)
TOTAL RESERVES - SECTOR C =
(PROPRIETARY DATA)

SECTOR D: NOVATO CONGLOMERATE - BLACK POINT

Plate 3.8	Novato Quadrangle	MRZ-2(a)	Sector Plate 3.51
Plate 3.10	Petaluma River Quadrangle	MRZ-2(c)	Sector Plate 3.52

Sector D is near Black Point (Marin County) and consists of two portions of a prominent ridge that is underlain by Novato Conglomerate, a thick accumulation of well-rounded pebbles, cobbles, and boulders in a well-cemented sandy matrix. Most of the coarse material is rhyolite or black chert. Sand and gravel suitable for P.C.C. aggregate formerly was produced at a quarry at the southern end of the ridge. The high degree of weathering in the deposit required the thorough washing of the aggregate (Ver Planck, 1955, p. 239). Field reconnaisance of the ridge indicates that the appearance of the material is uniform throughout the deposit, and that the deposit is urbanized except for two areas, one at each end. The northern area is Sector D-1, and the southern area is Sector D-2.

Resource calculations for Sector D are given in the table. Factors used in calculating resources included the following items:

1. The resource material is sand and gravel of the Novato Conglomerate.

2. The aggregate, when washed, is suitable for P.C.C. aggregate.

3. Waste is estimated to be at least 20 percent.

4. Thickness of overburden is not considered, since weathering appears to be uniform throughout the material, and topsoil can be sold for soil or fill material.

5. Wall slopes would have a ratio of 2:1 (horizontal to vertical), and the quarry would have a minimum elevation of 40 feet.

6. Ground water is not expected to pose a problem to quarry operations.

7. A conversion factor of 14.50 cubic feet of material per ton was used in calculating resources. This factor is derived from data supplied by producers in the Livermore-Amador Valley (Alameda County), and is used for sediments derived from the Franciscan Complex. The basalt and chert in the Novato Conglomerate has a density of at least 2.65 when fresh; this density is equivalent to a factor of 12.1 cubic feet per ton, with no allowance for weathered material or pore space within the conglomerate. The only way to obtain an accurate figure is to perform density tests on samples of the conglomerate.

8. Base maps for resource calculations are 4:1 enlargements of the Novato and the Petaluma River 7.5-minute quadrangles (1980). No allowance is made for material mined since the maps were released.

RESOURCES - SECTOR D

CONTOUR ELEVATION	AREA (acres)	X	AVERAGE AREA (acres)	X	CONVERSION FACTORS	=	TONNAGE (to nearest 10,000 tons)
SECTOR D-1							
200	12.57						
		—	26.95	X	(40)(43,560)(.80) / 14.50	=	2,590,000
160	41.32						
		—	59.14	X	"	=	5,690,000
120	76.96						
		—	106.00	X	"	=	10,190,000
80	135.04						
					Total	=	18,470,000
SECTOR D-2							
160	4.65						
		—	16.33	X	(40)(43,560)(.80) / 14.50	=	1,570,000
120	28.01						
		—	31.86	X	"	=	3,060,000
80	35.70						
		—	62.47	X	"	=	6,010,000
40	89.24						
					Total	=	10,640,000

TOTAL RESOURCES - SECTOR D =
29 MILLION TONS (ALL P.C.C. GRADE)
TOTAL RESERVES - SECTOR D =
0 TONS

Crushed Stone Resources

In the North San Francisco Bay P-C Region, crushed stone production and resources are found in all four counties. As shown in the following sector descriptions, there are more stone resources available in this P-C Region than sand and gravel resources. There are no large production districts for crushed stone, but there are instead numerous small groups and scattered isolated producers.

SECTOR E: SONOMA VOLCANICS BASALT - PETALUMA HILL

Plate 3.10 Petaluma River Quadrangle MRZ-2(a) Sector Plate 3.52

This basalt deposit has been quarried for paving blocks or crushed stone for over a century. The quarry is currently operated by Quarry Products, Inc., and supplies asphaltic concrete aggregate and roadbase material. Because the entire deposit is controlled by a single operator, proprietary data on reserves cannot be released, but are included with data from other producers in Table 3.6.

TOTAL RESOURCES - SECTOR E =
(PROPRIETARY DATA, MIXED NON-P.C.C. GRADE)
TOTAL RESERVES - SECTOR E =
(PROPRIETARY DATA)

SECTOR F: SONOMA VOLCANICS BASALT AND PETALUMA FORMATION SAND - STONY POINT

Plate 3.25 Cotati Quadrangle MRZ-2(a) Sector Plate 3.53

Basalt and weathered volcanic material of the Sonoma Volcanics group are quarried for subbase, drain rock, and fill material at the Stony Point Quarry in Sonoma County. In addition, overburden (which consists of sand and pebbly gravel of the Petaluma Formation) is stripped off and sold for fill.

Resources in Sector F are proprietary and are included in with data from other producers in Table 3.6.

TOTAL RESOURCES - SECTOR F =
(PROPRIETARY DATA, MIXED NON-ASPHALTIC GRADE)
TOTAL RESERVES - SECTOR F =
(PROPRIETARY DATA)

SECTOR G: FRANCISCAN COMPLEX - SULPHUR SPRINGS MOUNTAIN

Plate 3.20 Benicia Quadrangle MRZ-2(a) Sector Plate 3.54

Sector G lies at the southern end of Sulphur Springs Mountain (Solano County), just south of Blue Rock Springs Park, and is divided into 3 subsectors (Sectors G-1, G-2, and G-3). The Lake Herman Quarry of Syar Industries covers most of the northern end of the sector, and the W.E. Martin Quarry (Solano Excavators) is at the southwestern edge of the sector. The rocks underlying Sector G consist principally of metamorphosed graywacke and greenstone of the Franciscan Complex, with some shale and chert. Several localities within Sector G contain iron-stained silicified metavolcanic dike rocks that have been brecciated and hydrothermally altered. Mercury mineralization (cinnabar and metacinnabar) occurs along fault planes and in fractures in the brecciated rocks. Since only two companies have quarries in Sector G, reserve data is not disclosed here but is included with data from other sectors in Table 3.6.

Resources within Sector G are given in the table below. Factors used in calculating resources included the following items:

1. Resource material is Franciscan Complex graywacke, greenstone, chert, shale, and silicified dike rocks.
2. Some of the rock, especially the graywacke and greenstone, is suitable for asphaltic concrete aggregate, and P.C.C. aggregate.
3. No allowance is made for overburden or waste, since low-quality material is believed to form a small amount of the total resource.
4. Minimum quarry elevation would be 280 feet, with a bench in Sector G-3 at elevation 400.
5. Wall slopes would have a 2:1 ratio (horizontal to vertical).
6. Ground water could pose a problem for quarry operations with regard to both quantity and quality (i.e., "Sulphur Springs Mountain"). Drainage occurs at a mercury mine adit on the east side of the Syar Industries property.
7. A conversion factor of 11.90 cubic feet of material per ton was used in calculating tonnages. This factor is based on density tests performed on samples from the Syar Industries Quarry.
8. The base map used in resource calculations was a 4:1 enlargement of the Benicia 7.5-Minute Quadrangle (1968). No allowance is made for material mined since the maps were released, since it is believed to be an insignificant amount compared to the total resources available in Sector G.

RESOURCES - SECTOR G

CONTOUR ELEVATION	AREA (acres)	X	AVERAGE AREA (acres)	X	CONVERSION FACTORS	=	TONNAGE (to nearest 10,000 tons)
SECTOR G-1							
920	2.12						
		—	3.33	X	(40)(43,560) / 11.90	=	490,000
880	4.53						
		—	6.26	X	"	=	920,000
840	7.98						
		—	9.88	X	"	=	1,450,000
800	11.77						
		—	11.80	X	"	=	1,730,000
760	11.82						
		—	11.85	X	"	=	1,740,000
720	11.88						
		—	11.85	X	"	=	1,740,000
680	11.82						
		—	11.77	X	"	=	1,720,000
640	11.71						
		—	11.74	X	"	=	1,720,000
600	11.77						
		—	12.11	X	"	=	1,770,000
560	12.45						
		—	15.41	X	"	=	2,260,000
520	18.37						

RESOURCES - SECTOR G (continued)

CONTOUR ELEVATION	AREA (acres)	X	AVERAGE AREA (acres)	X	CONVERSION FACTORS	=	TONNAGE (to nearest 10,000 tons)
520	18.37						
		—	22.30	X	(40)(43,560) / 11.90	=	3,270,000
480	26.23						
		—	29.93	X	"	=	4,380,000
440	33.63						
		—	36.07	X	"	=	5,280,000
400	38.51						
		—	43.25	X	"	=	6,330,000
360	47.98						
		—	49.96	X	"	=	7,320,000
320	51.94						
		—	59.66	X	"	=	8,740,000
280	67.38						
					Total	=	50,860,000
SECTOR G-2							
720	.92						
		—	1.70	X	(40)(43,560) / 11.90	=	250,000
680	2.47						
		—	3.22	X	"	=	470,000
640	3.96						
		—	4.68	X	"	=	680,000
600	5.39						
		—	6.80	X	"	=	1,000,000
560	8.21						
		—	10.39	X	"	=	1,520,000
520	12.57						
		—	14.41	X	"	=	2,110,000
480	16.24						
		—	17.94	X	"	=	2,630,000
440	19.63						
		—	22.79	X	"	=	3,340,000
400	25.94						
					Total	=	12,000,000
SECTOR G-3							
920	1.38						
		—	4.08	X	(40)(43,560) / 11.90	=	600,000
880	6.77						
		—	14.21	X	"	=	2,080,000
840	21.64						
		—	27.29	X	"	=	4,000,000
800	32.94						
		—	43.22	X	"	=	6,330,000
760	53.49						
		—	65.43	X	"	=	9,580,000
720	77.36						
		—	88.36	X	"	=	12,940,000
680	99.35						
		—	110.74	X	"	=	16,210,000
640	122.13						
		—	133.75	X	"	=	19,580,000
600	145.37						
		—	161.21	X	"	=	23,600,000
560	177.05						
		—	191.26	X	"	=	28,000,000
520	205.46						
		—	220.44	X	"	=	32,280,000
480	235.42						
		—	250.40	X	"	=	36,660,000
440	265.38						
		—	282.31	X	"	=	41,340,000
400	299.24						
Bench							
400	274.10						
		—	273.53	X	"	=	40,050,000
360	272.96						
		—	268.34	X	"	=	39,290,000
320	263.72						
		—	257.18	X	"	=	37,660,000
280	250.63						
					Total	=	350,200,000

TOTAL RESOURCES - SECTOR G =
413 MILLION TONS (MIXED AGGREGATE GRADES)
TOTAL RESERVES - SECTOR G =
(PROPRIETARY DATA)

SECTOR H: SONOMA VOLCANICS - NAPA STATE HOSPITAL

Plate 3.17	Cuttings Wharf Quadrangle	MRZ-2(a)	Sector Plate 3.55
Plate 3.18	Mount George Quadrangle	MRZ-2(a)	Sector Plate 3.56
Plate 3.19	Napa Quadrangle	MRZ-2(a)	Sector Plate 3.57

Sector H encompasses a large deposit of Sonoma Volcanics rhyolite, andesite, basalt, perlitic rhyolite, and tuff situated at the common corner of the three quadrangles listed above. A portion of the deposit within the Napa and Mount George quadrangles, on the grounds of the Napa State Hospital, has been quarried since the turn of the century. Basalt Rock Company has operated a quarry here for several decades. Much of the aggregate is suitable for asphaltic concrete, while other material can be used for roadbase aggregate. Since only one company has a quarry in Sector H, reserve data is proprietary and cannot be shown here, but is included with data from other companies in Table 3.6.

Resource calculations for Sector H are given in the table below. Factors used in calculating resources included the following items:

1. Crushed stone resources consist of rhyolite, andesite, basalt, perlitic rhyolite, and tuff of the Sonoma Volcanics.

2. The basalt is suitable for asphaltic concrete aggregate, while other material can be used for roadbase or subbase aggregate or fill.

3. No allowance was made for overburden or waste, since the percentage of low-quality material is not known.

4. Wall slopes would have a ratio of 2:1 (horizontal to vertical).

5. Minimum quarry elevation would be 100 feet.

6. Ground water is not expected to pose a problem to mining.

7. A conversion factor of 11.56 cubic feet of material per ton was used. This factor is based on density tests of samples from Sector H. The exact proportions of rhyolite, basalt, andesite, and tuff are unknown, so an exact conversion factor cannot be determined.

8. Base maps used in calculating resources are 4:1 enlargements of the Cuttings Wharf, Mount George, and Napa 7.5-minute quadrangles (editions of 1981, 1968, and 1973, respectively). An allowance of 60 million tons is made for material mined since the maps were released.

RESOURCES - SECTOR H

CONTOUR ELEVATION	AREA (acres)		X	AVERAGE AREA (acres)	X	CONVERSION FACTORS	=	TONNAGE (to nearest 10,000 tons)
780	.34							
		—		.40	x	(20)(43,560) / 11.56	=	30,000
760	.46							
		—		.78	x	"	=	60,000
740	1.09							
		—		1.52	x	"	=	110,000
720	1.95							

RESOURCES - SECTOR H (continued)

CONTOUR ELEVATION	AREA (acres)		X	AVERAGE AREA (acres)	X	CONVERSION FACTORS	=	TONNAGE (to nearest 10,000 tons)
720	1.95							
		—		3.70	x	(20)(43,560) / 11.56	=	280,000
700	5.45							
		—		7.35	x	"	=	550,000
680	9.24							
		—		11.48	x	"	=	870,000
660	13.72							
		—		16.42	x	"	=	1,240,000
640	19.11							
		—		21.01	x	"	=	1,580,000
620	22.90							
		—		26.12	x	"	=	1,970,000
600	29.33							
		—		33.46	x	"	=	2,520,000
580	37.59							
		—		42.62	x	"	=	3,210,000
560	47.64							
		—		54.87	x	"	=	4,140,000
540	62.10							
		—		69.99	x	"	=	5,270,000
520	77.88							
		—		86.61	x	"	=	6,530,000
500	95.33							
		—		105.35	x	"	=	7,940,000
480	115.36							
		—		127.01	x	"	=	9,570,000
460	138.66							
		—		151.80	x	"	=	11,440,000
440	164.94							
		—		180.93	x	"	=	13,640,000
420	196.91							
		—		212.07	x	"	=	15,980,000
400	227.22							
		—		247.77	x	"	=	18,670,000
380	268.31							
		—		291.99	x	"	=	22,000,000
360	315.66							
		—		338.90	x	"	=	25,540,000
340	362.14							
		—		389.92	x	"	=	29,390,000
320	417.70							
		—		440.77	x	"	=	33,220,000
300	463.84							
		—		482.24	x	"	=	36,340,000
280	500.63							
		—		517.86	x	"	=	39,030,000
260	535.07							
		—		551.60	x	"	=	41,570,000
240	568.12							
		—		585.80	x	"	=	44,150,000
220	603.48							
		—		621.65	x	"	=	46,850,000
200	639.81							
		—		657.95	x	"	=	49,580,000
180	676.08							
		—		695.51	x	"	=	52,420,000
160	714.93							
		—		735.08	x	"	=	55,400,000
140	755.22							
		—		775.45	x	"	=	58,440,000
120	795.68							
		—		812.39	x	"	=	61,220,000
100	829.09							
						Total	=	700,750,000
				Minus Material Already Mined (estimate)				-60,000,000
						Remaining Resources		640,750,000

TOTAL RESOURCES - SECTOR H =
641 MILLION TONS (MIXED NON-P.C.C. GRADES)
TOTAL RESERVES - SECTOR H =
(PROPRIETARY DATA)

SECTOR I: FRANCISCAN COMPLEX SANDSTONE - SAN PEDRO HILL

Plate 3.14	San Quentin Quadrangle	MRZ-2(a)	Sector Plate 3.58

Crushed stone suitable for P.C.C. aggregate and riprap has been quarried from San Pedro Hill (Marin County) since the turn of the century. Basalt Rock Company currently operates a quarry at this site. Resource material is a hard, slightly metamorphosed sandstone of the Franciscan Complex, with interbedded black shale. The northern boundary of the MRZ-2 zone is drawn where detailed mapping by Rice and others (1976, Plate 1C) shows that shale becomes the predominant rock type. The shale deposits have been developed by several quarries, which supply material for bricks, tile, and lightweight aggregate.

Resource data for Sector I is proprietary. It is included with data for other companies in Table 3.6.

TOTAL RESOURCES - SECTOR I =
(PROPRIETARY DATA, MIXED AGGREGATE GRADES)
TOTAL RESERVES - SECTOR I =
(PROPRIETARY DATA)

SECTOR J: SONOMA VOLCANICS ANDESITE - BURDELL MOUNTAIN

Plate 3.10 Petaluma River Quadrangle MRZ-2(b) Sector Plate 3.52

This sector is underlain by a large block of andesite, which occurs within landslide debris on the east end of Burdell Mountain (Marin County), and is the largest of several such blocks that have moved downhill from the lava-capped crest. According to Ver Planck (1955, p. 242–243), seismic tests indicate that the block of andesite is 200 feet thick. Smaller blocks of andesite have been classifed MRZ-3. The andesite is suitable for asphaltic concrete aggregate. A processing plant was set up at this site in 1954 for the production of crushed stone, but is no longer active.

Resources in Sector J are given in the table below. Factors used in calculating resources included the following items:

1. The resource sector contains andesite of the Sonoma Volcanics, and is limited to the area shown as "disturbed ground" on the 1980 photo - revised edition of the Petaluma River Quadrangle.

2. The andesite is suitable for asphaltic concrete aggregate or roadbase material.

3. No allowance is made for overburden or waste, since the amount of low-grade material is not known.

4. Wall slopes would have a ratio of 2:1 (horizontal to vertical).

5. Minimum quarry elevation would be 240 feet.

6. Ground water is not expected to pose a problem to mining.

7. A conversion factor of 11.90 cubic feet of material per ton is used in calculating resources. This factor is based on density tests on samples from Sector J, and assumes that the andesite block is homogenous throughout its extent.

8. Base map for resource calculations is a 4:1 enlargement of the 1980 edition of the Petaluma River 7.5-Minute Quadrangle. An allowance of 7.1 million tons is made for material mined since the first edition of the map was prepared.

RESOURCES - SECTOR J

CONTOUR ELEVATION	AREA (acres)	X	AVERAGE AREA (acres)	X	CONVERSION FACTORS	=	TONNAGE (to nearest 10,000 tons)
520	8.95						
		—	9.59	X	(40)(43,560) / 11.90	=	1,400,000
480	10.22						
		—	10.71	X	"	=	1,570,000
440	11.19						
		—	11.42	X	"	=	1,670,000
400	11.65						
		—	14.47	X	"	=	2,120,000
360	17.28						
		—	18.26	X	"	=	2,670,000
320	19.23						
		—	19.63	X	"	=	2,870,000
280	20.03						
		—	19.11	X	"	=	2,800,000
240	18.19						
					Total		15,100,000
			Minus material already mined (estimate)				-7,100,000
					Remaining resources		8,000,000

TOTAL RESOURCES - SECTOR J =
8 MILLION TONS (MIXED NON-P.C.C. GRADES)
TOTAL RESERVES - SECTOR J =
0 TONS

SECTOR K: SAINT HELENA RHYOLITE - NUNS CANYON

Plate 3.27	Glen Ellen Quadrangle	MRZ-2(b)	Sector Plate 3.48
Plate 3.28	Kenwood Quadrangle	MRZ-2(a)	Sector Plate 3.59
Plate 3.33	Sonoma Quadrangle	MRZ-2(b)	Sector Plate 3.50

The extensive mass of riebeckite rhyolite and volcanic tuff is part of the Saint Helena Rhyolite member of the Sonoma Volcanics, and covers portions of three quadrangles. Several quarries within the sector have provided decorative stone, flagstone, paving blocks, and roadbase material during this century. At present, two companies are active; the Nuns Canyon Quarry and Trinity Quarry, Inc., which share the same site. Waste material from flagstone and decorative stone operations is sold for roadbase aggregate.

Resources within Sector K are given in the table below. Factors used in calculating resources included the following items:

1. Resource material is rhyolite and tuff of the Saint Helena Rhyolite member of the Sonoma Volcanics.

2. Material within the sector is suitable for asphaltic concrete aggregate, roadbase aggregate, or fill material.

3. No allowance is made for overburden or waste, since the percentage of low quality material is not known.

4. Quarry walls would have slopes of 2:1 (horizontal to vertical).

5. Minimum quarry elevation would be 400 feet.

6. Ground water is not expected to pose a problem to mining.

7. A conversion factor of 14.21 cubic feet of material per ton was used in resource calculations. This factor is

based on density tests of samples of rhyolite from Sector K, and assumes uniformity of the material within the deposit.

8. Base maps for resource calculations are 4:1 enlargements of the Glen Ellen, Kenwood, and Sonoma 7.5-minute quadrangles (1980). No allowance is made for material mined since the maps were issued, since mined material is an insignificant amount of the total resource.

RESOURCES – SECTOR K

CONTOUR ELEVATION	AREA (acres)	X	AVERAGE AREA (acres)	X	CONVERSION FACTORS	=	TONNAGE (to nearest 10,000 tons)
760	3.44						
		—	10.22	X	(40)(43,560) / 14.21	=	1,250,000
720	16.99						
		—	28.27	X	"	=	3,470,000
680	39.54						
		—	51.54	X	"	=	6,320,000
640	63.53						
		—	80.95	X	"	=	9,930,000
600	98.37						
		—	118.43	X	"	=	14,520,000
560	138.49						
		—	158.46	X	"	=	19,430,000
520	178.43						
		—	207.19	X	"	=	25,400,000
480	235.94						
		—	259.01	X	"	=	31,760,000
440	282.08						
		—	315.66	X	"	=	38,700,000
400	349.23						
					Total	=	150,780,000

TOTAL RESOURCES - SECTOR K =
151 MILLION TONS (ALL ROADBASE GRADE)
TOTAL RESERVES - SECTOR K =
(PROPRIETARY DATA)

Resource Sectors Outside of the Urbanizing Areas

In the North San Francisco Bay P-C Region there are ten significant quarries that lie outside of the OPR urbanizing areas, in addition to the operations in the Russian River Production District. Since their production has been included in reserve projections for the P-C Region, and these quarries meet threshold value, they have been included as sectors and are described below.

SECTOR L: FRANCISCAN COMPLEX - BORELLO QUARRY

Plate 3.7 Inverness Quadrangle MRZ-2(a) Sector Plate 3.60

This sector, consisting of approximately 900 acres, is situated in Millerton Gulch, about 0.9 miles northeast of Highway 1, and 1.1 miles east of Tomales Bay. The quarry has been in operation since the late 1950s, and is owned by R.A. Borello Tractor Rentals. The quarry area is underlain by sandstone, shale, greenstone, chert, and pillow lavas of the Franciscan Complex. Reserve material is the greenstone and pillow lavas, and the crushed material is sold for roadbase material and drain rock.

Reserve data for the Borello Quarry is proprietary and cannot be released here, but is included with that of other quarries in Table 3.6.

TOTAL RESOURCES - SECTOR L =
(PROPRIETARY DATA, ALL ROADBASE GRADE)
TOTAL RESERVES - SECTOR L =
(PROPRIETARY DATA)

SECTOR M: FRANCISCAN COMPLEX SERPENTINITE - GHILOTTI QUARRY

Plate 3.10 Petaluma River Quadrangle MRZ-2(f) Sector Plate 3.52

This sector contains approximately 50 acres and is located at the upper end of Bowman Canyon, on the southwest slope of Burdell Mountain, about 3 miles from the center of Novato. The quarry was opened in 1965, and is operated by Ghilotti Brothers, Inc. The resource material in the quarry is serpentinite of the Franciscan Complex, and is suitable for subbase material. The rock is highly fractured and sheared, and is dark green to grayish-green in color.

Due to the proprietary nature of the reserve data, the available amount of material cannot be released here, but is included along with data from other companies in Table 3.6.

TOTAL RESOURCES - SECTOR M =
(PROPRIETARY DATA, ALL SUBBASE GRADE)
TOTAL RESERVES - SECTOR M =
(PROPRIETARY DATA)

SECTOR N: FRANCISCAN COMPLEX - BLUE ROCK COMPANY QUARRY

Plate 3.6 Camp Meeker Quadrangle MRZ-2(b) Sector Plate 3.61

Sector N contains approximately 31 acres, and is situated on the south side of Highway 116, 1 mile west of Forestville (Sonoma County). The quarry is on the north slope of a hill along the west side of Green Valley Creek, a tributary of the Russian River. The material is siltstone and metasiltstone of the Franciscan Complex. The siltstone is bluish-gray in color, platy, and not suitable for uses other than fill. The metasiltstone, which is suitable for subbase aggregate, is dark gray to light bluish-gray, hard, and overlies the siltstone on a gradational contact.

Estimates of available aggregate are not presented here, since reserve data are proprietary but are included with that of other quarries in Table 3.6.

TOTAL RESOURCES - SECTOR N =
(PROPRIETARY DATA, ALL SUBBASE GRADE)
TOTAL RESERVES - SECTOR N =
(PROPRIETARY DATA)

SECTOR O: FRANCISCAN COMPLEX - CANYON ROCK COMPANY QUARRY

Plate 3.6 Camp Meeker Quadrangle MRZ-2(a) Sector Plate 3.61

This sector contains 85 acres located on the west side of Green Valley Creek, 1 mile west of Forestville on the north side of Highway 116. The sector is situated on the east side of a hill

300 feet high, and is underlain by siltstone and metasiltstone of the Franciscan Complex, similar to the material in Sector N above. The rock is not durable enough to serve as other than subbase and fill material.

Estimates of available aggregate are not presented here, since reserve data are proprietary but are included with that of other quarries in Table 3.6.

TOTAL RESOURCES - SECTOR O =
(PROPRIETARY DATA, ALL SUBBASE GRADE)
TOTAL RESERVES - SECTOR O =
(PROPRIETARY DATA)

SECTOR P: FRANCISCAN COMPLEX - GREEN VALLEY QUARRY

Plate 3.6 Camp Meeker Quadrangle MRZ-2(c) Sector Plate 3.61

This sector contains about 70 acres, and is located approximately 500 feet west of Green Valley Road (Sonoma County) on a private road that leads to the Mount Gilead Bible Conference Grounds. The quarry has been in continuous operation since 1935. The sector is underlain by two different types of rock belonging to the Franciscan Complex: interbedded siltstone and shale, and a massive, indurated mudstone. Rock from the quarry is used for roadbase and fill. Data concerning aggregate reserves are not presented here, since reserve data are proprietary, but are included with that of other quarries in Table 3.6.

TOTAL RESOURCES - SECTOR P =
(PROPRIETARY DATA, ALL ROADBASE GRADE)
TOTAL RESERVES - SECTOR P =
(PROPRIETARY DATA)

SECTOR Q: FRANCISCAN COMPLEX - HAGEMANN QUARRY

Plate 3.24 Bodega Head Quadrangle MRZ-2(a) Sector Plate 3.62

The Hagemann Quarry is located about 2.5 miles east of Bodega Bay on Highway 1. The sector covers approximately 26 acres. Quarry rock consists of massive, fine-grained Franciscan Complex sandstone, and is sold primarily for roadbase, although it may be suitable for asphaltic concrete aggregate.

Reserve data is not released here, since it is proprietary, but is included with data from other producers in Table 3.6.

TOTAL RESOURCES - SECTOR Q =
(PROPRIETARY DATA, ALL ROADBASE GRADE)
TOTAL RESERVES - SECTOR Q =
(PROPRIETARY DATA)

SECTOR R: FRANCISCAN COMPLEX - HARTMAN QUARRY

Plate 3.10 Petaluma River Quadrangle MRZ-2(d) Sector Plate 3.52

This sector contains about 9.5 acres located southeast of Petaluma on Lakeville Road (Highway 116), near the intersection of Lakeville Road and Stage Gulch Road. The quarry is owned and operated by Ghilotti Brothers Construction Company, and supplies roadbase and fill. The sector is underlain by greenstone, schist, interbedded chert and shale, and interbedded sandstone and shale of the Franciscan Complex.

Estimates of available aggregate are not presented here, since reserve data are proprietary, but are included with that of other quarries in Table 3.6.

TOTAL RESOURCES - SECTOR R =
(PROPRIETARY DATA, ALL ROADBASE GRADE)
TOTAL RESERVES - SECTOR R =
(PROPRIETARY DATA)

SECTOR S: SONOMA VOLCANICS - STAGE GULCH QUARRY

Plate 3.10 Petaluma River Quadrangle MRZ-2(e) Sector Plate 3.52

The Stage Gulch Quarry occupies approximately 50 acres, and is situated off Stage Gulch Road (Highway 116), about 7 miles southeast of Petaluma. The quarry has been operated intermittently since the early 1940s, and produces roadbase and fill. The sector is underlain by basalt and agglomerate of the Sonoma Volcanics, interbedded with tuffaceous sediments of the Petaluma Formation.

Data concerning aggregate reserves are not presented here, since reserve data are proprietary, but are included with that of other quarries in Table 3.6.

TOTAL RESOURCES - SECTOR S =
(PROPRIETARY DATA, ALL ROADBASE GRADE)
TOTAL RESERVES - SECTOR S =
(PROPRIETARY DATA)

SECTOR T: FRANCISCAN COMPLEX SANDSTONE AND HOLOCENE STREAM CHANNEL DEPOSIT - BOHAN AND CANELIS QUARRY

Plate 3.26 Duncans Mills Quadrangle MRZ-2(a) Sector Plate 3.63

This 35-acre sector is located 3 miles east of Duncans Mills, about one-half mile north of Highway 116 on Austin Creek Road. Bohan and Canelis operate two separate deposits: a stream channel sand and gravel deposit, and a quarry underlain by fractured, fine-grained sandstone of the Franciscan Complex. The sandstone is sold for roadbase and fill, but may be suitable for asphaltic concrete aggregate. The sand and gravel is suitable for asphaltic concrete aggregate, and may be suitable for P.C.C. aggregate.

Estimates of available aggregate are not presented here, since reserve data are proprietary, but are included with that of other quarries in Table 3.6.

TOTAL RESOURCES - SECTOR T =
(PROPRIETARY DATA, MIXED AGGREGATE GRADES)
TOTAL RESERVES - SECTOR T =
(PROPRIETARY DATA)

SECTOR U: HOLOCENE SAND AND GRAVEL - GUALALA READY-MIX COMPANY DEPOSIT

Plate 3.34 Stewarts Point Quadrangle MRZ-2(a) Sector Plate 3.64

The sector is located at the confluence of the South Fork and Wheatfield Fork of the Gualala River, about one-quarter mile off the Annapolis Road. Gravel bar skimming in the channel began in 1971, and has continued seasonally since then. The sand and gravel is suitable for P.C.C. aggregate.

Data concerning aggregate reserves are not presented here, since reserve data are proprietary, but are included with that of other companies in Table 3.6.

TOTAL RESOURCES - SECTOR U =
(PROPRIETARY DATA, ALL P.C.C. GRADE)
TOTAL RESERVES - SECTOR U =
(PROPRIETARY DATA)

SECTOR W: FRANCISCAN COMPLEX PILLOW BASALTS - MARK WEST SHALE PIT

Plate 3.41a Mark West Springs Quad. MRZ-2(a) Sector Plate 3.65

This 65-acre sector is located on the north side of Porter Creek Road, immediately west of the Petrified Forest. The quarry is underlain by a fine-grained, blue-green pillow basalt of the Franciscan Complex. The near-surface rock is weathered to a red-brown and is used for road subbase. The fresh rock is suitable for roadbase.

Estimates of available reserves of aggregate are not presented here, since reserve data are proprietary, but are included with that of other quarries in Table 3.6.

TOTAL RESOURCES - SECTOR W =
(PROPRIETARY DATA, SUBBASE AND ROADBASE GRADE)
TOTAL RESERVES - SECTOR W =
(PROPRIETARY DATA)

SECTOR X: SONOMA VOLCANICS ANDESITE - SONOMA ROCK COMPANY DEPOSIT

Plate 3.31 Sears Point Quadrangle MRZ-2(b) Sector Plate 3.49

The sector is located on the east side of Highway 121, about 7 miles south of Sonoma. Quarrying of aggregate began here in 1906 but the quarry has been a major producer only since 1973. Roadbase aggregate is produced by crushing the andesite of the Sonoma Volcanics which overlies Franciscan sandstone and shale.

Data concerning aggregate reserves are not presented here, since reserve data are proprietary, but are included with that of other quarries in Table 3.6.

TOTAL RESOURCES - SECTOR X =
(PROPRIETARY DATA, ALL ROADBASE GRADE)
TOTAL RESERVES - SECTOR X =
(PROPRIETARY DATA)

SECTOR Y: FRANCISCAN COMPLEX - INMAN SHALE PIT

Plate 3.39 Guerneville Quadrangle MRZ-2(c) Sector Plate 3.46

The Inman Shale Quarry occupies approximately 28 acres, and is located on the north side of Wallace Creek Road, about 2 miles west of Healdsburg. The quarry has been in operation since the early 1940s. A very fine-grained shale of the Franciscan Complex is quarried for roadbase aggregate.

Data concerning aggregate reserves are not presented here, since reserve data are proprietary, but are included with that of other quarries in Table 3.6.

TOTAL RESOURCES - SECTOR Y =
(PROPRIETARY DATA, ALL ROADBASE GRADE)
TOTAL RESERVES - SECTOR Y =
(PROPRIETARY DATA)

Resource Sectors Within Parks

It is recognized that dedicated parklands have special status as opposed to other current uses of sectorized land, consequently the resources within parks have been sectorized separately below, and the quantification of those resources are presented separately in the tables. The quantification of resources within park sectors are expressed to a lower degree of accuracy rather than to the higher level of accuracy reflected in the previous sections.

SECTOR V: SONOMA VOLCANICS ANDESITE - BURDELL MOUNTAIN OPEN SPACE PRESERVE

Plate 3.10 Petaluma River Quadrangle MRZ-2(b) Sector Plate 3.52

This sector is located adjacent to Sector J on Burdell Mountain and is part of the Burdell Mountain Open Space Preserve. The sector includes an area of about 80 acres which is underlain by a large block of hard, dense andesite suitable for asphaltic concrete aggregate.

Resources in Sector V are presented in the table below. Factors used in calculating resources including the following items:

1. The resource sector contains andesite of the Sonoma Volcanics.
2. The andesite is suitable for asphaltic concrete aggregate or roadbase material.
3. No allowance is made for overburden or waste, since the percentage of low-grade material is not known.
4. Wall slopes would have a ratio of 2:1 (horizontal to vertical).
5. Minimum quarry elevation would be 280 feet.
6. Ground water is not expected to pose a problem to mining.
7. A conversion factor of 11.90 cubic feet of material per ton is used in calculating resources. This factor is based

on density tests on samples from Sector J, and assumes that the andesite block is uniform in composition.

8. Base map for resource calculations is the 1980 edition of the Petaluma River 7.5- Minute Quadrangle.

RESOURCES – SECTOR V

CONTOUR ELEVATION	AREA (acres)	X	AVERAGE AREA (acres)	X	CONVERSION FACTORS	=	TONNAGE (to nearest 100,000 tons)
560	3.27				(40)(43,560)	=	1,400,000
		—	9.44	X	11.90		
520	15.61						
		—	22.33	X	"	=	3,300,000
480	29.04						
		—	30.94	X	"	=	4,500,000
440	32.83						
		—	34.04	X	"	=	5,000,000
400	35.24						
		—	36.56	X	"	=	5,400,000
360	37.88						
		—	39.35	X	"	=	5,800,000
320	40.81						
		—	39.75	X	"	=	5,800,000
280	38.68						
					Total	=	31,100,000

TOTAL RESOURCES - SECTOR V =
31 MILLION TONS (MIXED NON-P.C.C. GRADES)
TOTAL RESERVES - SECTOR V =
0 TONS

ESTIMATED 50-YEAR CONSUMPTION OF AGGREGATE

The total projected aggregate consumption through the year 2030 in the North San Francisco Bay P-C Region is estimated to be 478 million tons. This figure was obtained by correlating production records and population data to compute a per capita consumption rate, then using this consumption rate and population projections to make the 50-year estimate. Comparison of the permitted reserves total and the estimated consumption shows that permitted reserves amount to 113 percent of the future consumption. Based upon the per capita use rate, all existing aggregate reserves will be depleted by the year 2036, unless additional resources are permitted for mining or are imported.

Since Portland cement concrete (P.C.C.) is a widely used construction material in our society, it is necessary that suitable aggregate be available in sufficient quantities. According to production statistics for the period 1953–1977, an average of 24 percent of the total aggregate consumed annually in the North San Francisco Bay P-C Region was used in Portland cement concrete or concrete products (Table 3.8). Of this P.C.C. aggregate, crushed stone comprises a minor amount.

The total projected P.C.C.-grade aggregate consumption through the year 2030 in the North San Francisco Bay P-C Region is estimated to be 115 million tons. This is based on an average annual per-capita consumption rate for P.C.C.-grade aggregate of 2.1 tons per person year year (24 percent of total per capita consumption). As shown in Table 3.7, more than 112 million tons of permitted reserves in the Region meet P.C.C. aggregate specifications, which amounts to 97 percent of the anticipated consumption.

If all reserves suitable for use as P.C.C. aggregate are utilized for that purpose, P.C.C.-grade reserves will be depleted in 45 years (2032). However, typical marketing practice in the aggregate industry shows that some of the P.C.C. production will be used for non-P.C.C. applications. It is probable that this practice will continue, and that P.C.C. reserves could be depleted in a shorter time period. P.C.C. reserves, because of their high quality requirements, will be the most difficult to replace as existing permitted deposits are depleted. It is important to realize that new P.C.C. as well as non-P.C.C. resources will need to come into production to meet the 50-year aggregate demands in this P-C Region.

Population Records

Population records were compiled and correlated with aggregate consumption records for the period 1953–1980 for the North San Francisco Bay P-C Region (Figures 3.4 and 3.5, Table 3.9). Records of population and aggregate consumption for this period were compiled for two adjacent regions: South San Francisco Bay and Monterey Bay P-C regions (Figures 3.6–3.10). Population records and projections for the three P-C regions were compiled from publications of the California Department of Finance (no date, 1969, 1977a, 1977b, 1980a, 1980b, 1981, 1982a, 1982b). Population projections for the 10-year period from 2020 to 2030 were extrapolated by DMG staff from the data mentioned above. Population projections for the North San Francisco Bay P-C Region to the year 2030 are given in Table 3.10. Population projections for all three P-C regions to the year 2030 are presented in Figure 3.11.

Table 3.8 Percentage of total aggregate consumed used for Portland cement concrete aggregate in the North San Francisco Bay P-C Region during the period 1953–1977.

NORTH SAN FRANCISCO BAY P-C REGION

Year	P.C.C. AGGREGATE CONSUMED	Total AGGREGATE CONSUMED	P.C.C. AGGREGATE CONSUMED AS A PERCENTAGE OF TOTAL AGGREGATE CONSUMED
1953	377,629	2,438,550	15.5
1954	1,255,240	2,573,521	48.8
1955	115,245	2,161,536	5.3
1956	255,513	5,107,709	5.0
1957	158,588	4,614,768	3.4
1958	364,049	2,681,399	13.6
1959	317,863	2,978,329	10.7
1960	1,014,482	3,450,216	29.4
1961	1,401,182	4,794,380	29.2
1962	1,562,694	4,258,601	36.7
1963	1,311,640	4,283,866	30.6
1964	1,127,000	5,156,157	21.9
1965	1,141,000	5,027,278	22.7
1966	1,029,000	4,512,147	22.8
1967	1,065,374	4,508,884	23.6
1968	1,085,241	4,641,679	23.4
1969	1,109,466	4,745,516	23.4
1970	1,085,488	4,064,338	26.7
1971	869,056	4,460,936	19.5
1972	1,440,427	5,130,327	28.1
1973	1,875,636	6,842,613	27.4
1974	1,632,834	5,360,346	30.5
1975	1,166,185	4,163,455	28.0
1976	1,723,882	4,640,864	37.1
1977	1,645,092	5,475,721	30.0
1978	Not	6,702,047	-
1979	Available	7,021,777	-
1980		6,198,320	-
		Average	23.7%

Per Capita Consumption Rates

The North San Francisco Bay P-C Region had an average per capita consumption rate of 8.8 tons per year during the period 1953–1980 (Table 3.9). Due to the erratic nature of the annual aggregate production (see Figure 3.4), a 3-year moving average of the annual production was used with the annual population data to compute the per capita rates for the North San Francisco Bay P-C Region. The average per capita rate was combined with the population projections for the North San Francisco Bay P-C Region in order to estimate aggregate consumption for the period 1981–2030 (Table 3.11). Similar techniques were used to compute per capita rates for the South San Francisco Bay and Monterey Bay P-C regions, and these per capita rates are discussed below in the section "Aggregate Resources of Adjacent P-C Regions—Estimated Consumption of Aggregate".

Factors Affecting Per Capita Consumption Rates

Per capita consumption of aggregate has varied with time and is different in each P-C region. Several factors, such as changes in urban growth rates with time, relative degrees of urban maturity, and major construction projects (for example, freeways), may account for the variations and differences. Another factor may be possible incompleteness or inaccuracy of the production records compiled by the U.S. Bureau of Mines or of the population data compiled by the California Department of Finance. In addition, very high interest rates, such as existed in California during the period 1980–1982, tend to lower the amount of new construction in an area.

The average annual per capita consumption rate for the North San Francisco Bay P-C Region may decrease, at a more or less steady rate, as the area becomes more urbanized until a steady state (urban maturity*) is reached. Should unforeseen events occur, such as massive urban renewal, disaster reconstruction, or major recession, the per capita consumption rate could change significantly. The presence of several major active fault systems within the North San Francisco Bay P-C Region increases the chance for a damaging earthquake and the need for subsequent extensive reconstruction afterwards (*see* Davis and others, 1982).

ALTERNATIVE SOURCES OF AGGREGATE

Alternative sources of aggregate, in addition to those deposits classified MRZ-2 and MRZ-3, occur in areas within the North San Francisco Bay P-C Region, and in adjacent P-C regions. Some potential resources lie outside the OPR urbanizing boundaries, but still within the P-C region boundaries. Included within the group of potential resources are the extensions of several deposits classified MRZ-2 or MRZ-3. In addition, sand and fine gravel occur in bars on the floor of San Francisco Bay, between the Golden Gate Bar and the confluence of the Sacramento and San Joaquin rivers. Except for the aggregate resources in adjacent P-C regions and marine sand deposits, too little is known about the physical and chemical qualities of most of the alternative sources to permit even crude resource estimates. A general discussion about the potential resources and their occurrences is included in this section.

* Urban maturity is the point in the development of an area at which construction materials are used primarily to maintain what has already been developed rather than to supply further development.

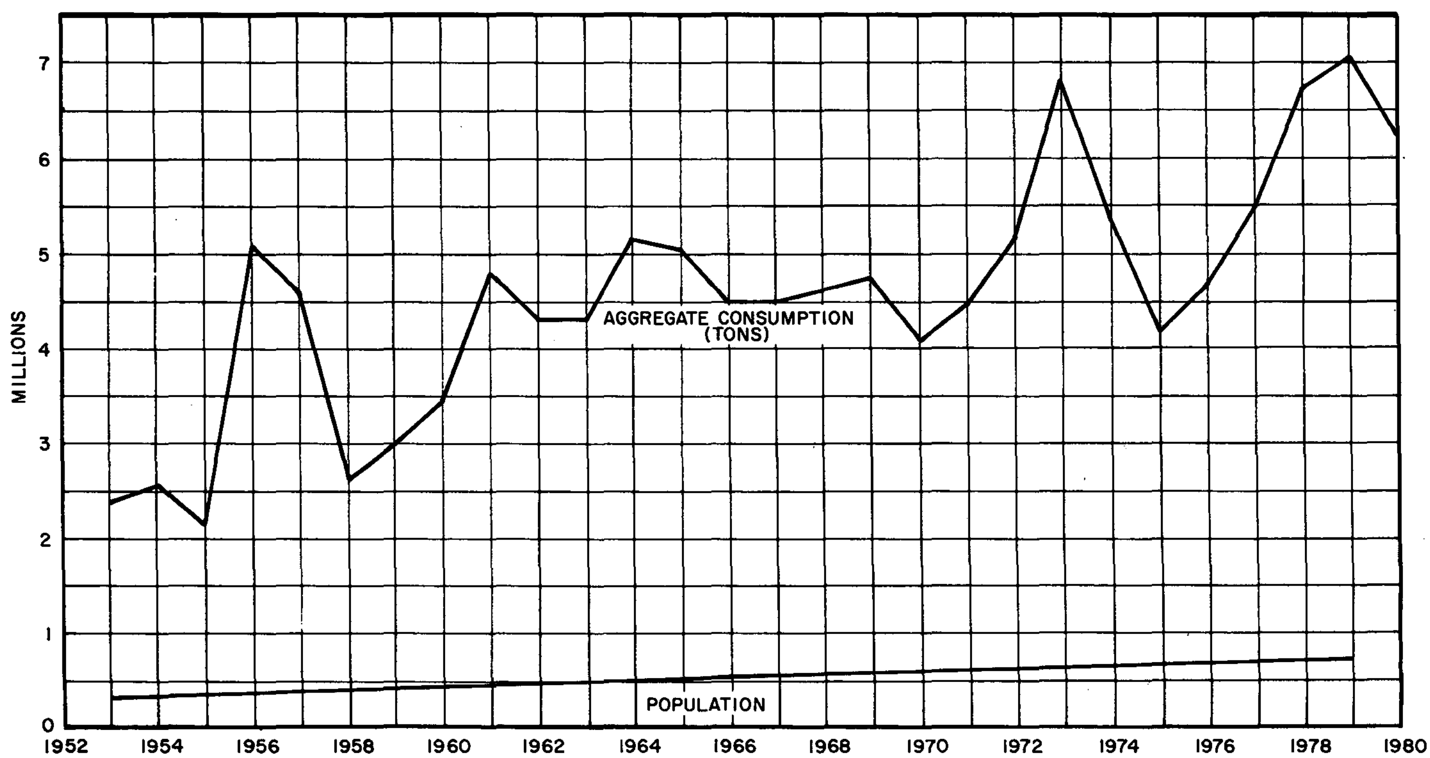


Figure 3.4 North San Francisco Bay P-C Region: population and aggregate consumption records for years 1953–80.

Additional Crushed Stone Resources North San Francisco Bay P-C Region

Basalt, andesite, and rhyolite of the Sonoma Volcanics, graywacke and greenstone of the Franciscan Complex, and Cretaceous conglomerate appear suitable for aggregate. Several deposits have been quarried for aggregate, building stone, or paving blocks. A reconnaissance study of potential quarry sites in Sonoma County was undertaken in 1979 by R. Erickson and three assistants for the Sonoma County Planning Department. Numerous deposits of sandstone, greenstone, and basalt were identified in the resultant report (Erickson and others, 1979b). Some of these deposits may be quarried in the future. Detailed geologic mapping and sampling will be needed to identify those deposits that contain sufficient material for economic operations.

The North San Francisco Bay P-C Region contains several northwest-trending ridges underlain by rocks of the Franciscan Complex and Sonoma Volcanics (Wagner and Bortugno, 1982). Detailed exploration would show where suitable stone deposits exist in the nonurbanized, and therefore unclassified portions of the P-C region.

Marine Sand and Gravel Deposits of the San Francisco Bay Area

Sand and some gravel have been dredged from San Francisco Bay for many years. According to Goldman (1969, p. 22), sand occurs in or immediately adjacent to existing current channels at a number of places between the confluence of the Sacramento and San Joaquin rivers and the western edge of the Golden Gate Bar. The largest area of sand is on the bay floor, between Point San Quentin and the City of San Francisco, but deep water precludes dredging from much of this area. The largest potential source of sand outside of the Golden Gate is on the semicircular Golden Gate Bar. The general distribution of sand is shown on Figure 3.12. Other sand deposits that lie beneath a cover of younger bay mud have been dredged as sources of fill. The bulk of this sand is on the east side of San Francisco Bay between Point Richmond and Bay Farm Island. This sand lens is cut in several places by mud-filled channels and may extend southward beyond Bay Farm Island(Goldman, p. 33). In general, the areas from which sand is being excavated are operated under lease from the State Lands Commission, and are the shoal areas: Point Knox Shoal, southwest of Angel Island; Presidio and Alcatraz shoals, west and southwest of Alcatraz; Southampton Shoal, southwest of Point Richmond; and San Bruno Shoal, east of San Bruno. In 1971 and 1972, E. E. Welday and J. W. Williams of the California Division of Mines and Geology made a geologic reconnaissance of the marine mineral resources of the San Francisco Bay Region. Over 400 samples were collected, and samples that appeared to be of economic importance were analyzed. Welday (1975, p. 23) estimates that nearly one-half billion cubic yards of sand (predominantly medium-grained but with a significant coarse-grained fraction) is accessible to currently operating dredges. If dredging is possible at depths to 100 feet, this tonnage could be increased at least 50 percent. The most valuable deposit is the Point Knox Shoal, as it contains abundant coarse material. This deposit is currently being dredged for P.C.C. sand. An estimate of the offshore sand resources of the San Francisco Bay area is presented in Table 3.12.

Table 3.9 Population, aggregate consumption, and per capita consumption of aggregate in the North San Francisco Bay P-C Region during the period 1953–1980.

YEAR	POPULATION	AGGREGATE CONSUMPTION (Rounded to nearest 1000 Tons)	CONSUMPTION 3-YEAR AVERAGE (Tons)	ANNUAL PER CAPITA CONSUMPTION (Tons)
1953	308,400	2,439.000		
1954	325,100	2,574,000	2,391,000	7.4
1955	342,400	2,162,000	3,280,000	9.6
1956	361,800	5,108,000	3,961,000	10.9
1957	380,200	4,615,000	4,134,000	10.9
1958	396,500	2,681,000	3,424,000	8.6
1959	413,500	2,978,000	3,036,000	7.3
1960	431,000	3,450,000	3,740,000	8.7
1961	444,500	4,794,000	4,167,000	9.4
1962	460,000	4,259,000	4,445,000	9.7
1963	477,200	4,284,000	4,566,000	9.6
1964	495,500	5,156,000	4,822,000	9.7
1965	514,500	5,027,000	4,898,000	9.5
1966	527,200	4,512,000	4,682,000	8.9
1967	540,300	4,509,000	4,554,000	8.4
1968	553,300	4,642,000	4,632,000	8.4
1969	565,900	4,746,000	4,483,000	7.9
1970	571,600	4,064,000	4,423,000	7.7
1971	588,300	4,461,000	4,551,000	7.7
1972	602,800	5,130,000	5,477,000	9.1
1973	617,300	6,843,000	5,777,000	9.4
1974	628,100	5,360,000	5,455,000	8.7
1975	638,600	4,163,000	4,721,000	7.4
1976	654,700	4,641,000	4,760,000	7.3
1977	674,900	5,476,000	5,606,000	8.3
1978	692,700	6,702,000	6,399,000	9.2
1979	700,400	7,021,000	6,640,000	9.5
1980	716,700	6,198,000		

Average annual per capita aggregate consumption 1954–1979 = 8.8 tons.

AGGREGATE RESOURCES OF ADJACENT P-C REGIONS

If additional aggregate is needed in the North San Francisco Bay P-C Region on a short-term basis, the most readily available material is located in the neighboring regions—South San Francisco Bay, Monterey Bay, and Sacramento-Fairfield P-C regions. On a short-term basis the active quarries in these three P-C regions can send large amounts of aggregate into the North San Francisco Bay P-C Region, but the delivered price per ton would be greatly increased by inflated transportation costs and by any supply-demand conflicts (see Tables 1.2, 1.3, and 1.4 in Part I of this report). The long-term (50-year) resource picture is more uncertain. As described in greater detail below, the South San Francisco Bay P-C Region is projected to have a substantial deficit of aggregate, while the Monterey Bay P-C Region appears to have a surplus of material. Projected aggregate needs and available supplies in the Sacramento-Fairfield P-C Region are currently under study.

Resource Estimates

Resource estimates given in this report (Part III) for P-C regions near or adjacent to the North San Francisco Bay P-C Region represent data taken from Parts II and IV of this study. The South San Francisco Bay P-C Region has approximately 6.3 billion tons of aggregate in its resource sectors (1.1 billion tons of sand and gravel, and 5.2 billion tons of stone). At the end of 1980, commercial deposits within the P-C region contained more than 259 million tons of sand and gravel reserves and 293 million tons of crushed stone reserves, for a total of more than 522 million tons. The Monterey Bay P-C Region has approximately 3.1 billion tons of aggregate within its resource sectors (0.7 billion tons of sand and gravel, and 2.4 billion tons of stone). At the end of 1980, commercially controlled deposits within the P-C region contained 195 million tons of sand and gravel reserves and 591 million tons of stone reserves, for a total of 786 million tons. Tables 3.13 and 3.14 list the resource sectors, available tonnages, and commercial reserves for the South San Francisco Bay and Monterey Bay P-C regions.

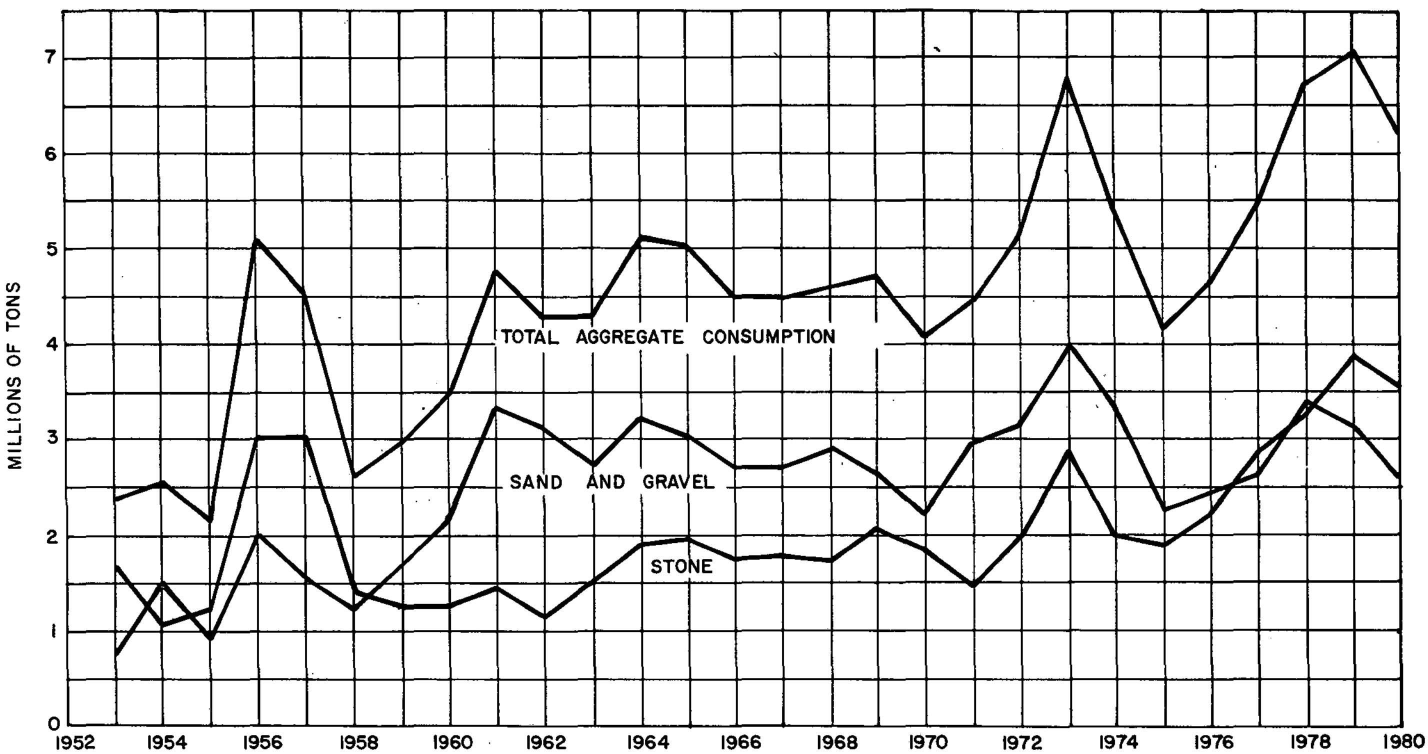


Figure 3.5 North San Francisco Bay P-C Region: sand and gravel, stone, and total aggregate consumption records for years 1953–80.

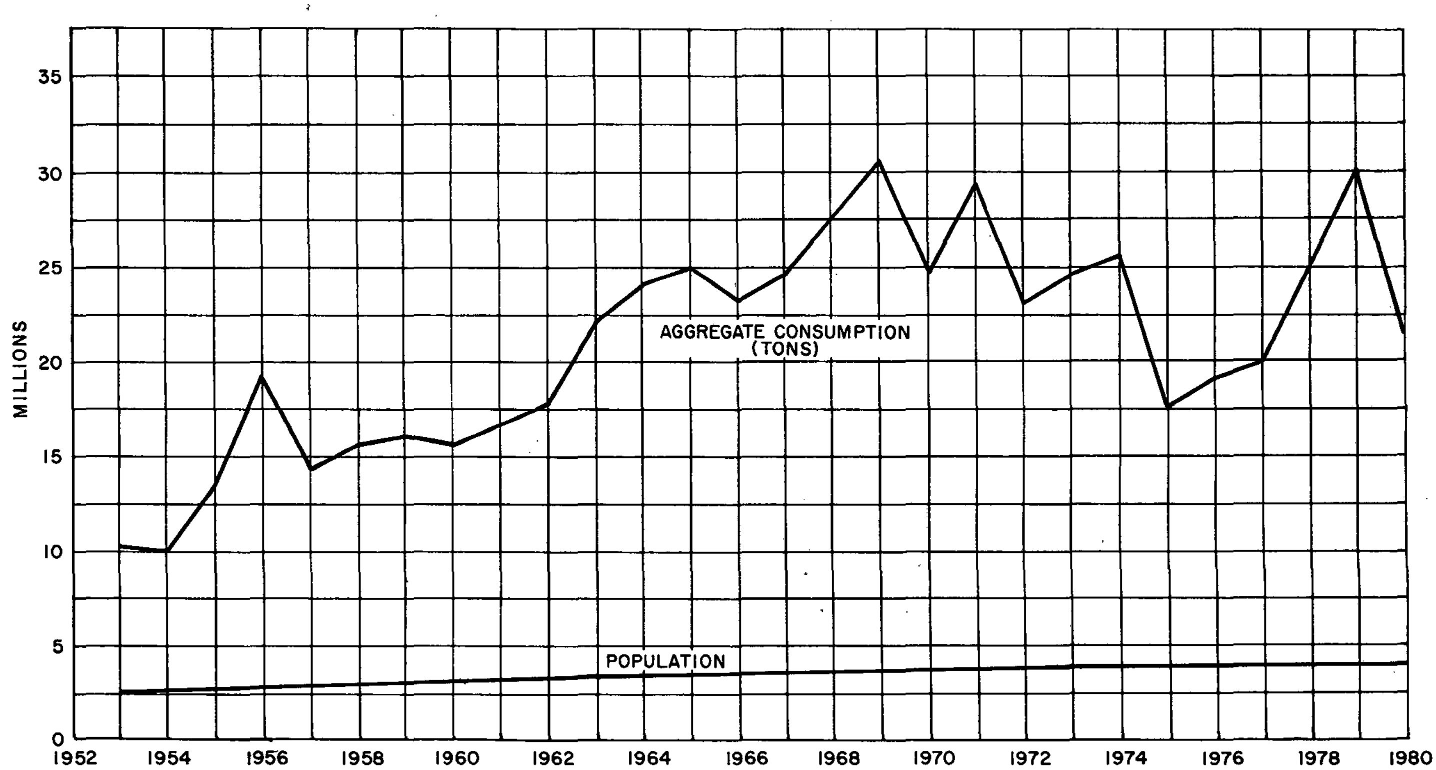


Figure 3.6 South San Francisco Bay P-C Region: population and aggregate consumption records for years 1953–80.

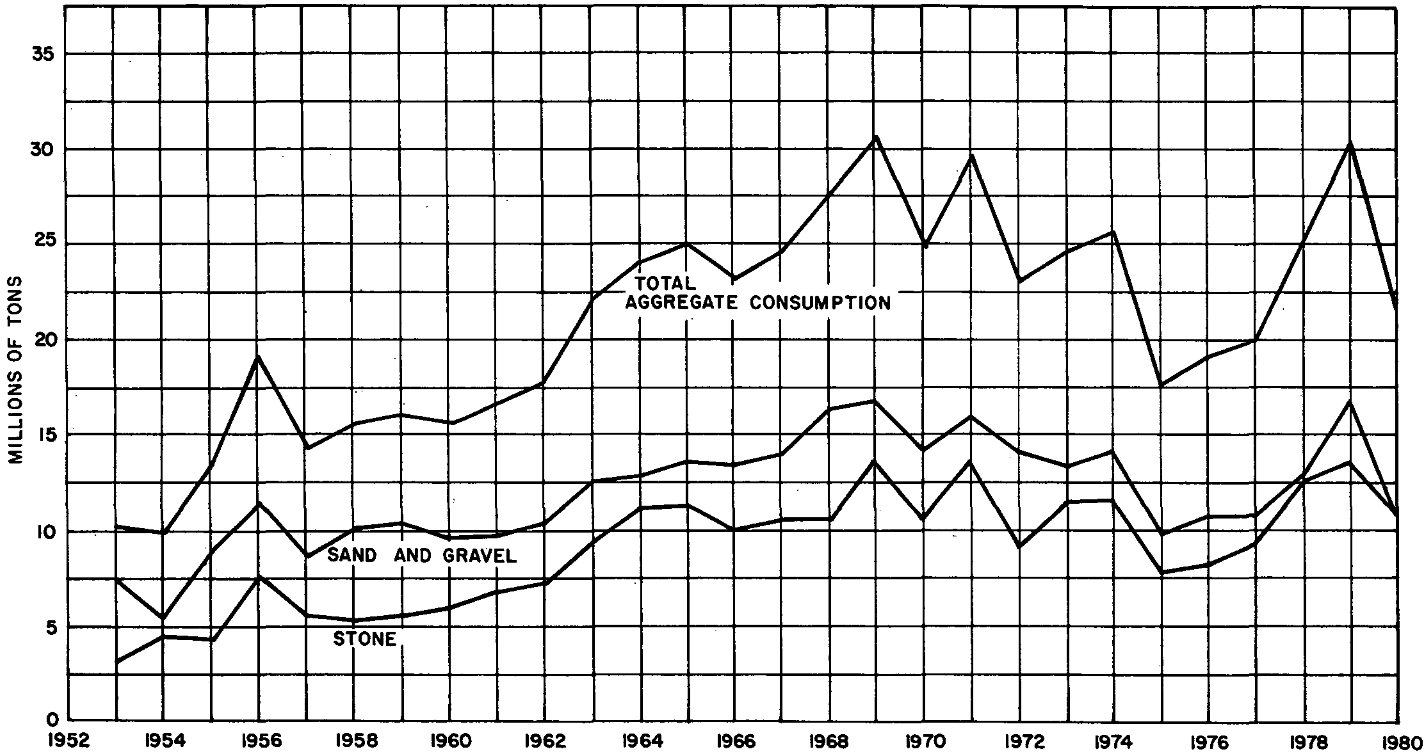


Figure 3.7 South San Francisco Bay P-C Region: sand and gravel, stone, and total aggregate consumption records for years 1953–80.

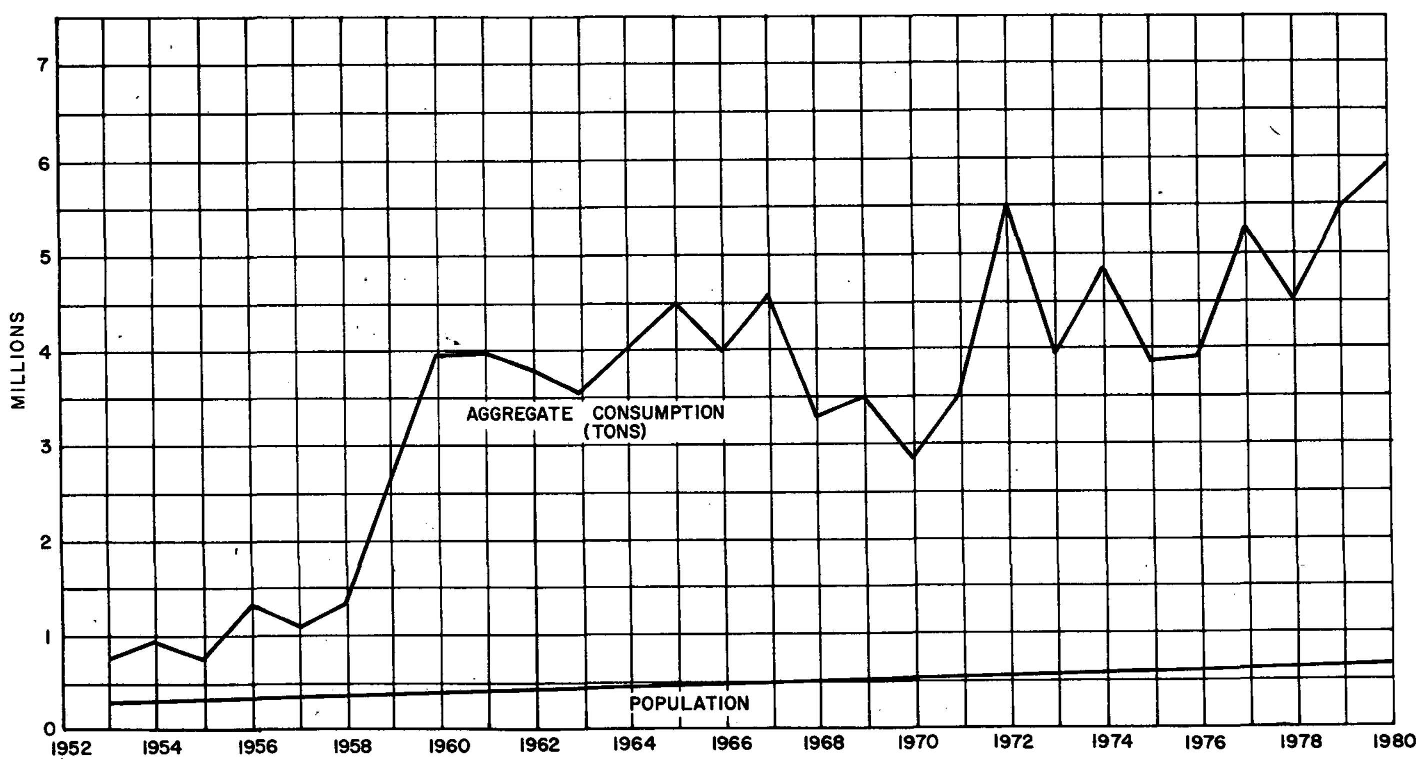


Figure 3.8 Monterey Bay P-C Region: population and aggregate consumption records for years 1953–80.

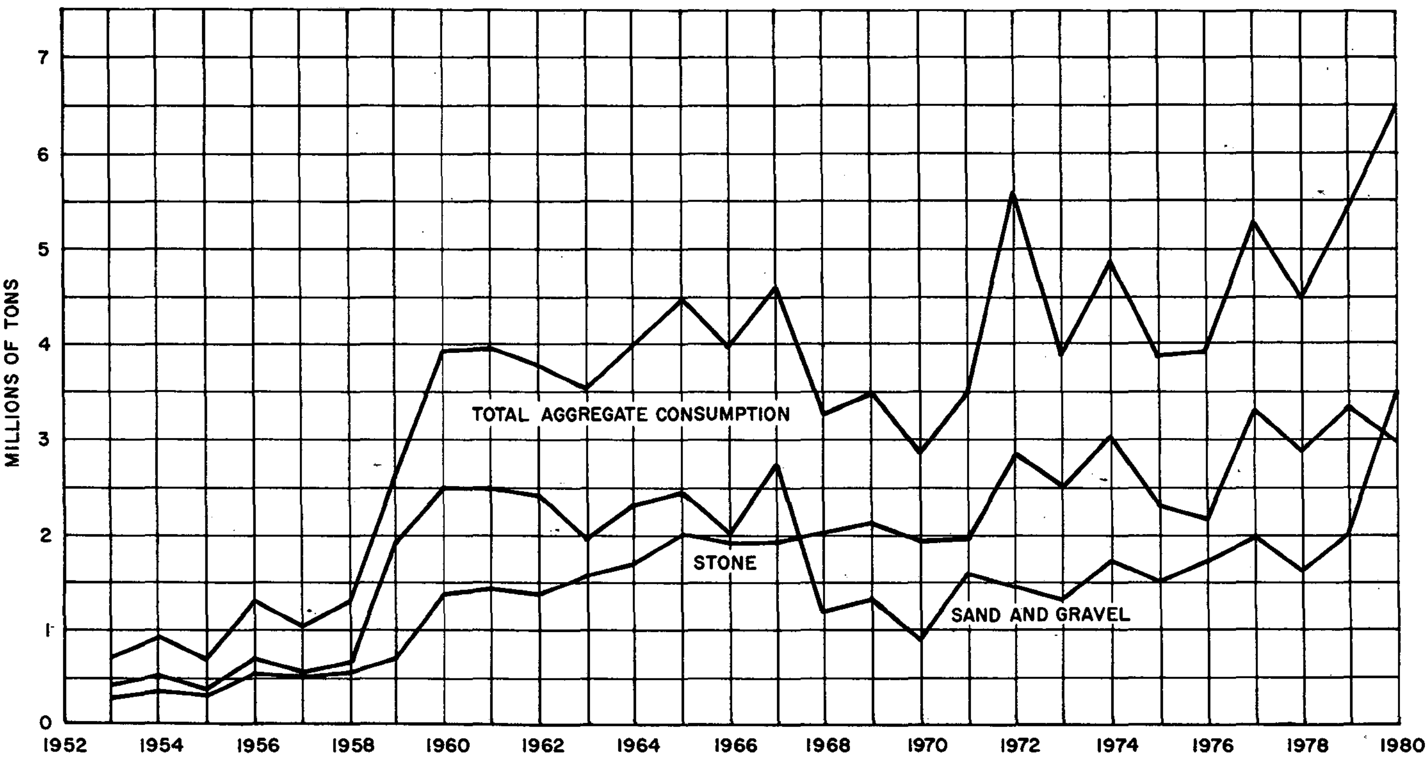


Figure 3.9 Monterey Bay P-C Region: sand and gravel, stone, and total aggregate consumption records for years 1953–80.

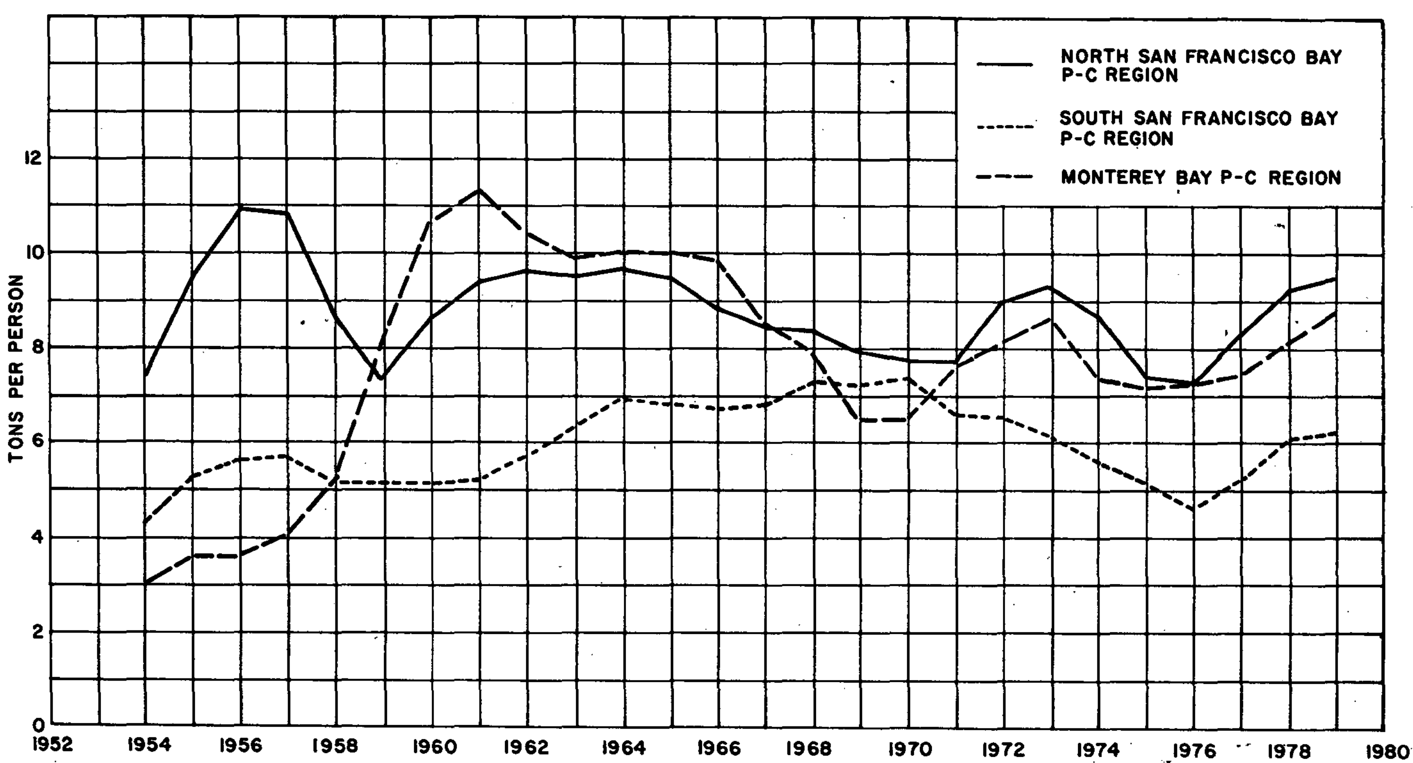


Figure 3.10 Annual per capita consumption of aggregate in the North San Francisco Bay, South San Francisco Bay, and Monterey Bay P-C regions for years 1954–79.

Table 3.10 Population projections, Marin, Napa, Western Solano, and Sonoma counties 1980–2030. Population projected by DMG from data in California Department of Finance (Ibid.) for years 1995 through 2030, inclusive.

NORTH SAN FRANCISCO BAY P-C REGION POPULATION PROJECTIONS

TO YEAR	MARIN	NAPA	SONOMA	WESTERN SOLANO*	TOTAL
1980	222,900	99,100	301,600	93,100	716,700
1985	227,200	102,100	347,600	114,700	791,600
1990	232,000	106,300	387,700	133,500	859,500
1995	247,200	119,300	425,200	148,600	940,300
2000	258,500	131,600	460,600	164,500	1,015,200
2005	267,500	143,500	495,500	181,000	1,087,500
2010	275,800	155,800	530,900	198,200	1,160,700
2015	284,200	168,400	565,900	215,700	1,234,200
2020	291,500	180,800	598,400	232,600	1,303,300
2025	298,800	193,200	630,900	249,600	1,372,500
2030	306,100	205,600	663,400	266,600	1,441,700

*Western Solano County is assumed to constitute 40% of Solano County's total projected population.

Source : California Department of Finance (1977b, and 1981).

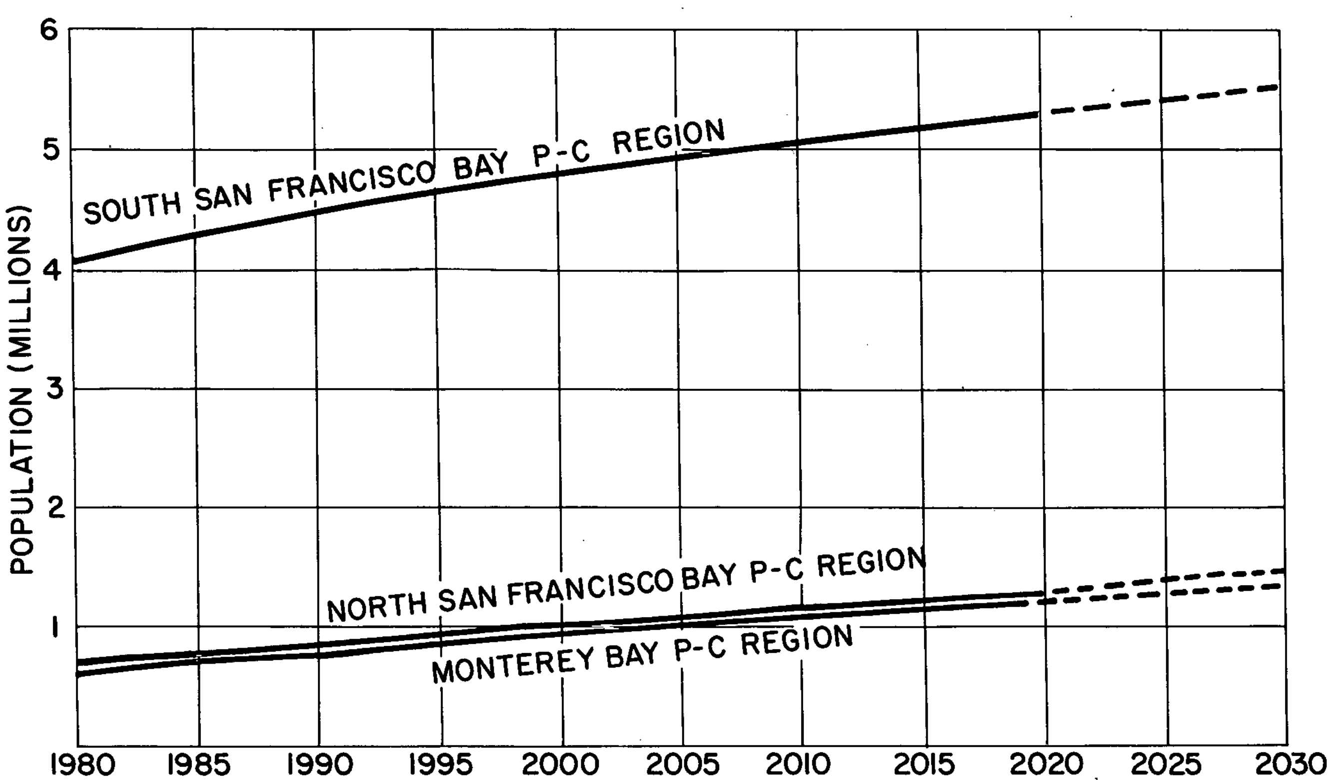


Figure 3.11 Projected populations of the North San Francisco Bay, South San Francisco Bay, and Monterey Bay P-C regions to the year 2030.

Table 3.11 Projected aggregate consumption for the North San Francisco Bay P-C Region, 1981–2030.***

NORTH SAN FRANCISCO BAY P-C REGION PROJECTED AGGREGATE CONSUMPTION (Rounded to nearest 100,000 tons)	
PERIOD	AGGREGATE CONSUMPTION*
1981-1985	33,200,000
1986-1990	36,400,000
1991-1995	39,700,000
1996-2000	43,100,000
2001-2005	46,300,000
2006-2010	49,500,000
2011-2015	52,800,000
2016-2020	55,900,000
2021-2025	59,000,000
2026-2030	62,000,000
50-Year Total	478,000,000

* Aggregate consumption (tons) = population (5-year average) x 5 year per capita consumption

** Projections based on data in Tables 3.9 and 3.10

Table 3.12 Marine sand resources of the San Francisco Bay area. Data from Welday (1975, p. 24). Numbers in parentheses are the equivalent tonnage at 1.5 tons per cubic yard.

LOCATION	VOLUME Million Cubic Yards (Million Tons)	TOTAL Million Cubic Yards (Million Tons)
Vicinity of Rio Vista to Antioch		
Steamboat Slough, Sacramento River	15 (22.5)	
Three Mile Slough to Antioch	40 (60)	55 (82.5)
Antioch to Benicia		
Antioch to Chipps Island	40 (60)	
Chipps Island to Ryer Island	40 (60)	
Ryer Island to Benicia	50 (75)	130 (195)
Benicia to Angel Island		
Channel of San Pablo Bay and San Pablo Strait	20 (30)	
Channel Vicinity of Southampton	20 (30)	40 (60)
Angel Island to the Golden Gate		
Point Knox Shoal	25 (max. depth 75 ft.) (37.5)	
Presidio Shoal	30 (45)	55 (82.5)
San Francisco Bar (Inner)	165 (max. depth 75 ft.) (247.5) (350 @ max. depth 100 ft.) (525)	165 (247.5)
Tomales Bay	35 (52.5)	35 (52.5)
	TOTAL	480 (720)

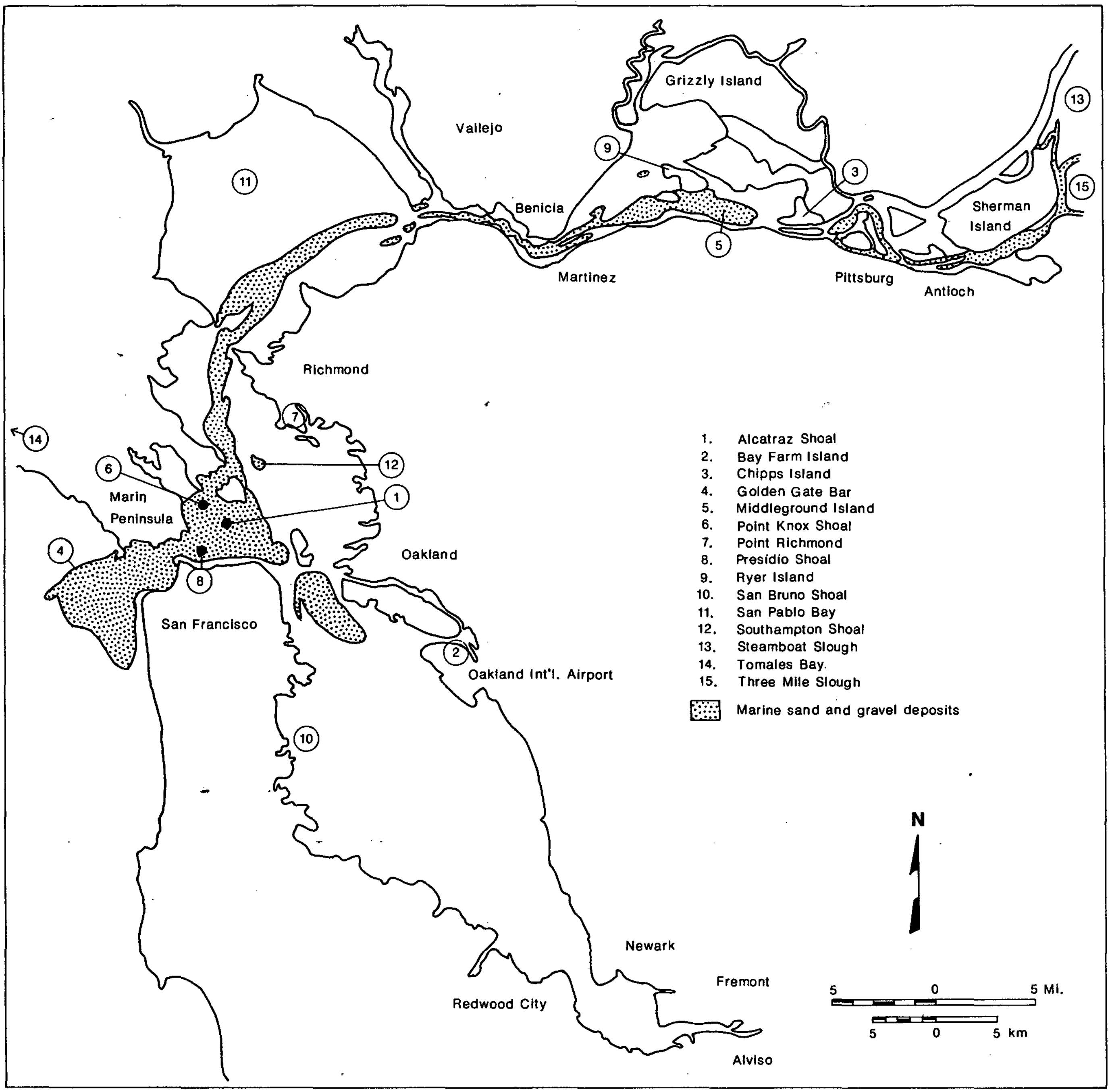


Figure 3.12 Marine sand and gravel deposits in San Francisco Bay and Sacramento River—Delta (after E. E. Welday, 1975). Known aggregate deposits are shown by dot pattern.

Table 3.13 Reserves and resources within sectors in the South San Francisco Bay P-C Region. The reserves (calculated through 1980) are material that commercial aggregate companies control, and for which the companies have valid mining permit. Resources include the reserves and any other material within the sector.

COUNTY	SECTOR	SAND AND GRAVEL AMOUNT (millions of tons)		CRUSHED STONE AMOUNT (millions of tons)	
		Reserves	Resources	Reserves	Resources
Alameda	A	242	383		
	B		88		
	C		99		
	D				1,041
	E	*	142		
	F	*	*		
	G	*	*		
	H				112
	I				299
	J		32		
	K		63		
	L		188		
	M			*	23
	N			*	*
	O			*	*
	P			*	*
Alameda Subtotal		259#	995+	20+#	1,495#
Parklands					
	JJ		7		
	KK		12		
	LL				316
	MM				82
Parklands Subtotal			19		398
ALAMEDA COUNTY TOTAL		259#	1,014+	20+	1,893#
Contra Costa	Q	*	5		
	R			*	*
	S			*	683
	T				121
	U				94
	V				29
	W			*	85+
	GG	*	*		
CONTRA COSTA CO. TOTAL		*	5+	54#	1,012+

* Proprietary data
\# Includes combined proprietary data

(continued)

Table 3.13 (continued)

COUNTY	SECTOR	SAND AND GRAVEL AMOUNT (millions of tons)		CRUSHED STONE AMOUNT (millions of tons)	
		Reserves	Resources	Reserves	Resources
San Francisco & San Mateo	X			*	*
	Y			*	35
	HH			*	*
San Francisco & San Mateo Subtotal				*	35+
Parklands					
	NN				1,600
Parklands Subtotal					1,600
SAN FRANCISCO AND SAN MATEO COUNTIES TOTAL		0	0	*	1,635+
Northern Santa Clara	I			27	125
	Z			*	37
	AA		37		
	BB			*	*
	CC			*	186
	DD	*	*		
	EE			*	97+
	FF			*	*
	II			*	*
Northern Santa Clara County Subtotal		*	37+	167#	445+
Parklands					
	OO				41
	PP		38		
Parklands Subtotal			38		41
NORTHERN SANTA CLARA COUNTY TOTAL		*	75+	167#	486+
P-C REGION TOTAL		259+#	1,122#	293#	5,199#

TOTAL RESERVES IN SOUTH SAN FRANCISCO BAY P-C REGION = 552 MILLION TONS
TOTAL RESOURCES IN SOUTH SAN FRANCISCO BAY P-C REGION = 6.3 BILLION TONS

* Proprietary data
\# Includes combined proprietary data

Table 3.14 Reserves and resources within sectors in the Monterey Bay P-C Region. The reserves (calculated through 1980) are material that commercial aggregate companies control, and for which the companies have valid mining permits. Resources include the reserves and any other material within the sector.

COUNTY	SECTOR	SAND AND GRAVEL AMOUNT (millions of tons) Reserves	SAND AND GRAVEL AMOUNT (millions of tons) Resources	CRUSHED STONE AMOUNT (millions of tons) Reserves	CRUSHED STONE AMOUNT (millions of tons) Resources
Monterey	G			*	*
	H	*	43+		
	I		208		
	J			*	31
	K		3		
	N	*	*		
	O	*	*		
	P	*	*		
Monterey County Subtotal		*	254+	*	31+
Parklands	S		20		
	T		4		
Parklands Subtotal			24		
MONTEREY COUNTY TOTAL		*	278+	*	31+
San Benito	E	*	226		
	F			*	395
SAN BENITO COUNTY TOTAL		*	226	*	395
Santa Cruz	A			*	1,004
	B	*	*		
	C	*	*		
	L			*	*
	M	*	*		
Santa Cruz Subtotal		*	*	*	1,004+
Parklands	Q				381
	R				555
Parklands Subtotal					936
SANTA CRUZ COUNTY TOTAL		*	*	*	1,940+
Southern Santa Clara	D	*	25		
	U	*	21		
SANTA CLARA COUNTY TOTAL		*	46		
P-C REGION TOTAL		195#	715#	591#	2,366+

TOTAL RESERVES IN MONTEREY BAY P-C REGION = 786 MILLION TONS
TOTAL RESOURCES IN MONTEREY BAY P-C REGION = 3.1 BILLION TONS
* Proprietary data
# Includes combined proprietary data

Estimated Consumption of Aggregate

Estimated 50-year aggregate consumption for nearby P-C regions is presented in Table 3.15. At the projected level of consumption (6.0 tons per person annually; 1.5 billion tons over 50 years), the South San Francisco Bay P-C Region's reserves will be depleted in 12 years (1999). Thus, if reliance is placed solely upon these deposits, a shortfall is predicted for the South San Francisco Bay P-C Region and the shortfall will occur long before a shortfall develops in the North San Francisco Bay P-C Region. In contrast, the Monterey Bay P-C Region is projected to have a surplus of aggregate available for its 50-year needs. Based on an average annual per capita consumption of 7.7 tons, approximately 374 million tons will be needed during the next 50 years, and 786 million tons were available at the end of 1980. Sand and crushed stone are currently imported into the South San Francisco Bay P-C Region from the Monterey Bay P-C Region. This arrangement will undoubtedly continue under present economic conditions.

Deep Sand and Gravel Deposits Within the Livermore Valley - Sunol Valley - Niles Cone Production District

One of the most geologically promising alternative sources of high quality (P.C.C.-grade) sand and gravel occurs in the Livermore Valley - Sunol Valley - Niles Cone Production District, below the current maximum permitted mining depth of existing gravel pits. The few deep water-well records available show locally continuous deposits of sand and gravel to depths of more than 700 feet in the Livermore Valley, more than 400 feet in Sunol Valley, and more than 500 feet in the Niles Cone. The present level of available data is adequate only to classify these lower aquifers as MRZ-3 without additional drilling and testing.

Before these deep deposits could be considered as resources, the thickness and continuity of interbedded aquicludes would require study, and the quality of the lower sand and gravel would need to be tested. However, since all materials in the several aquifers were derived from the same source rocks, and all of the deposits in the district are of approximately the same age, it is likely that rock quality would be high throughout the deposits.

Pit depths down to 100 feet below the local water table are feasible with today's mining technology. Utilization of these deep alternative resources would require care to preserve present ground-water quality, but would maximize recovery of valuable mineral resources in the P-C Region.

Potential Aggregate Resources Outside of OPR Boundaries

Several geologic units may become sources of aggregate in the future, but have not been classified as part of this overall study because they are located outside the OPR zones in the Monterey Bay or South San Francisco Bay P-C regions. These units contain stone or sand or gravel; they appear to be suitable for aggregate, based on written descriptions in geological reports and limited field examinations.

Sand and Gravel Resources

Several additional sources of sand and gravel occur within the South San Francisco Bay P-C Region. One such potential source in Alameda County is the geologic unit known as the Livermore Gravels. This formation has a stratigraphic thickness of 4,000 feet, covers an estimated 75 square miles of area, and underlies the hills on the east and west sides of Sunol Valley (Hall, 1958; Huey, 1948). The Livermore Gravels exposed in the vicinity of Vallecitos Valley contain sand, gravel, and partially cemented conglomerate. Near Mission San Jose, a lithologically similar formation, the Irvington Gravels, has been mined for Portland cement concrete aggregate, and is classified MRZ-2 and MRZ-3 in Part II of this report. Detailed mapping and sampling of the Livermore Gravels would be needed to delineate areas with suitable material in commercial quantities.

Another potential source in the South San Francisco Bay P-C Region (also just outside the OPR urbanizing boundaries) is the Santa Clara Formation. This formation has a stratigraphic thickness of more than 2,000 feet, and consists of conglomerate and interbedded sandstone, siltstone, and clay (Dibblee, 1966). The Santa Clara Formation extends along the lower foothills on both sides (east and west) of Santa Clara Valley. Little information is available about the quantity and quality of the sand and gravel in the Santa Clara Formation on the east side of the Santa Clara Valley, since it has not been quarried there. The Santa Clara Formation on the west side of Santa Clara Valley extends in a northwest direction from near Los Gatos to Palo Alto. Sand and gravel have been recovered from the conglomerate at several sites near Monte Vista and Stevens Creek Reservoir. The Santa Clara Formation in this area has been classified MRZ-2 and MRZ-3. However, the Santa Clara Formation extends for some distance beyond the OPR urbanizing boundary where it has not been classified. One active quarry (Stevens Creek Quarry) lies inside the OPR boundary. The conglomerate occurs in discontinuous lenses or beds throughout the formation and, therefore, detailed mapping and sampling will be required to find suitable material.

The San Benito Gravels are a group of Plio-Pleistocene continental deposits located south of Hollister (in San Benito County, Monterey Bay P-C Region). Although the gravels are not known to have been quarried, outcrops along Paicines Creek contain gravel that appears suitable. The following data are taken from Griffen (1967). The unit covers an area of approximately 150 square miles, and has a stratigraphic thickness of at least 2,000 feet. The main body forms a northwest-trending belt 2 to 5 miles wide. The portion of the San Benito Gravels that appears suitable for aggregate is the "white sands" section, which extends southeast from Tres Pinos to within a mile of Elkhorn Ranch, and is largely confined to the hills between Tres Pinos Creek and the San Benito River. The "white sands" section of the gravels covers over 20 square miles and has a maximum stratigraphic thickness of at least 800 feet. Gravel forms 20 to 25 percent of the "white sands" section, silt and clay form about 5 percent, and the remaining 70 to 75 percent is sand. A basal section at Tres Pinos contains approximately 30 feet of massive silt. Detailed mapping and sampling will be needed to locate suitable sites for quarry operations.

Crushed Stone Resources

The Mindego Hill Basalt, which underlies parts of Mindego Hill and Langley Hill in San Mateo County, is currently being quarried for aggregate. Expanded operations could supply material needed when other nearby quarries close. Cretaceous granodiorite forms the bulk of Montara Mountain, which overlooks Half Moon Bay. Although much of the exposed material is weathered, the western slope of the mountain may be suitable for quarrying, and operations there could provide substantial quantities of crushed stone. Large deposits of Franciscan Complex graywacke and greenstone occur in the mountains south of Los Gatos and east of San Jose, in Santa Clara County. Both areas are accessible by highways.

Portions of the Niles Canyon Formation (Cretaceous) in the vicinity of Niles and Sunol (Alameda County) contain very hard sandstones. Sandstone of the Briones Formation has been quarried at a number of sites between San Jose and Antioch. However, because of the variation in hardness and silt content between sites, detailed field mapping and testing will be necessary to delineate areas where suitable material exists.

The Calera Limestone, which is associated with rocks of the Franciscan Complex, occurs as a discontinuous zone of limestone bodies extending southeasterly from Calera Valley (Pacifica) in San Mateo County, through western Santa Clara County to New Almaden. Individual masses of limestone are as much as a mile in length and range from 40 feet to 2,500 feet in width. The largest known body of limestone occurs at Permanente in Santa Clara County, where the Kaiser Cement Company operates a large quarry to obtain limestone for the Permanente cement plant. Limestone unsuitable for the manufacture of cement is crushed and used for Portland cement concrete aggregate. A large tonnage of rock suitable for aggregate is still available at the Permanente Quarry. Several inactive quarries are located in the Calera Limestone between Pacifica and New Almaden, and limestone suitable for aggregate may be present. According to Kupferman (1980, p. 112) development of the individual deposits would probably be limited to aggregate quarries "... due to the limited extent of each mass and the dispersion of chert interbeds throughout the limestone."

An enormous body of granite forms the northern portion of the Gabilan Range along the Monterey-San Benito County boundary (Monterey Bay P-C Region). The granite covers an area of approximately 12 townships (approximately 400 square miles). The Southern Pacific Railroad traverses the Salinas Valley, which lies on the west side of the Gabilan Range. Large amounts of aggregate could be supplied by rail from this granite to nearby P-C regions. Similar material also is available in the Santa Lucia Range (Monterey County), but access is difficult. Cretaceous sandstone deposits along the east side of the Santa Clara Valley in the Monterey Bay P-C Region may contain suitable material, but have not been tested (Rogers and Williams, 1974, Plate 1).

Table 3.15 Projected aggregate consumption to the year 2030 for the South San Francisco Bay, North San Franciso Bay, and Monterey Bay P-C regions.

	SOUTH SAN FRANCISCO BAY P-C REGION		NORTH SAN FRANCISCO BAY P-C REGION		MONTEREY BAY P-C REGION	
	5-yr per capita consumption = 30.0 tons/person		5-yr per capita consumption = 44.0 tons/person		5-yr per capita consumption = 38.5 tons/person	
YEARS	Average Population (millions)	*Aggregate Consumption (million tons)	Average Population (millions)	*Aggregate Consumption (million tons)	Average Population (millions)	*Aggregate Consumption (million tons)
1981-1985	4.38	128.2	.792	33.2	.704	26.1
1986-1990	4.58	134.1	.860	36.4	.760	28.2
1991-1995	4.76	139.7	.940	39.4	.830	30.6
1996-2000	4.90	144.4	1.015	43.1	.848	33.3
2001-2005	5.02	148.3	1.087	46.3	.967	35.9
2006-2010	5.14	151.9	1.161	49.5	1.039	38.6
2011-2015	5.26	155.6	1.234	52.8	1.110	41.4
2016-2020	5.38	159.1	1.303	55.9	1.177	44.1
2021-2025	5.50	162.6	1.373	59.0	1.243	46.6
2026-2030	5.61	166.0	1.442	62.0	1.310	49.2
Total		1,489.8		478.0		374.0

*Aggregate consumption = Population (5-year average) X 5-year per capita consumption.

CONCLUSIONS

Within the North San Francisco Bay P-C Region, 25 sectors have been identified that contain a total of 2.4 billion tons of aggregate resources (0.9 billion tons of sand and gravel resources and 1.4 billion tons of crushed stone resources). This resource total includes material suitable for Portland cement concrete and material suitable only for asphaltic concrete, roadbase, or subbase.

Based upon available production data and population projections, the North San Francisco Bay P-C Region will need 478 million tons of aggregate during the next 50 years. Of this projected demand, 24 percent (approximately 115 million tons) must be suitable for Portland cement concrete. At the end of 1980, approximately 540 million tons of aggregate reserves existed within the P-C region, of which more than 112 million tons were suitable for use as P.C.C. aggregate. Total aggregate reserves amount to 113 percent of the projected demand, and P.C.C.-grade reserves amount to more than 97 percent of the projected P.C.C. aggregate demand. Unless new resources are permitted for mining, or alternative resources are utilized, existing reserves will be depleted in 49 years (2036) and P.C.C. grade material will have been utilized where lower quality aggregate would have been adequate. If a major earthquake were to occur within the P-C region and extensive reconstruction was necessary, the depletion date could arrive in less than the projected 49 years.

Alternatives

The North San Francisco Bay P-C Region has four alternatives to cope with the projected deficiency of P.C.C.-grade aggregate. Other alternatives are essentially combinations of the four discussed here.

1. Permit expansion of existing gravel pits and quarries if additional resources exist within sectors containing active operations.
2. Permit mining in the previously unmined sector.
3. Encourage exploration and where feasible, development of deposits within areas classified MRZ-3 or deposits outside of the OPR areas.
4. Rely upon imports of aggregate from outside of the P-C Region.

Permit Expansion of Existing Gravel Pits and Quarries

Four of the sectors in the P-C Region contain both permitted reserves and non-permitted resources of P.C.C.-grade aggregate. Permitted reserves are often much less than the total resources within a sector. The amount of sand and gravel resources within the Russian River Production District, for example, is much greater than the calculated amount of reserves. Mining of these deposits would supply all of the P.C.C.-grade aggregate and total aggregate needed in the North San Francisco Bay P-C Region. Because of the large volume of resources within the sectors, systematic long-range planning and development for the P-C Region would be possible.

Permit Mining in Previously Unmined Sectors

Permitting mining within the previously unmined sector would make available 29 million tons of P.C.C.-grade aggregate.

Encourage Exploration and Development of MRZ-3 Deposits

Several deposits classified as MRZ-3 within the North San Francisco Bay P-C Region are good potential sources of aggregate. Other deposits lie outside of the OPR zone and were not classified (marine sand and gravel deposits, and northwest-trending ridges underlain by rocks of the Franciscan Complex and Sonoma Volcanics) but may contain suitable material. In any of these deposits, a detailed exploration and testing program would be necessary to determine quality and extent of the aggregate deposit. The extraction of P.C.C.-grade aggregate from MRZ-3 areas could provide an alternative to mining in designated areas that are deemed by lead agencies to be more suitable for purposes other than mining.

Rely Upon Imports of Aggregate from Outside of the P-C Region

This approach, in the long run, would probably be the most expensive to the people living in the North San Francisco Bay P-C Region. When the reserves of P.C.C.-grade aggregate within this P-C Region are depleted, consumers would have to rely on outside imports. Supply-and-demand economics dictate that the price of scarce commodities will probably rise. Aggregate should be no exception. Transportation costs would increase as haulage distances increase, and these higher costs would be borne directly or indirectly by all consumers within the P-C Region.

Adverse environmental impacts would accompany this alternative. These include increase air emissions and fuel consumption by haul vehicles, and increased wear to local highways and rail lines.

While reliance on outside imports could alleviate any short-term deficit in the North San Francisco Bay P-C Region, adjacent P-C Regions cannot provide an unlimited supply of aggregate over the long term. Only the Monterey Bay P-C Region contains reserves in excess of its own 50-year needs, but this excess is insufficient to balance the shortfall in the South San Francisco Bay P-C Region. A long-term solution other than the import alternative is clearly needed.

ACKNOWLEDGMENTS

The Division of Mines and Geology gratefully acknowledges the full cooperation of local government agencies and the aggregate producers called upon for information during the course of this study. Special thanks are extended to the Association of Bay Area Governments, the planning departments of Marin, Napa, Solano, and Sonoma counties, the California Department of Water Resources, and the California Department of Parks and Recreation. The Pacific Gas and Electric Company supplied maps of its natural gas and electric power distribution networks.

Frederick C. Kruger, Mining and Economic Geologist, was retained as a consultant to review the methods and results of the study. Dr. Kruger's valuable commentary and suggestions were instrumental in completing this report.

Many DMG personnel assisted the authors in completing this report. Ralph C. Loyd, Associate Geologist, helped prepare 50-year population projections for the three P-C regions. Russell V. Miller and E. Leivas, associate geologists, assisted with classification work. Michael A. Silva, Geologic Aid, assisted with water-well analysis in Sonoma County. Typing and clerical support was supplied by Marianne Roja, Delores Abraham, Cheryl Zeh, Fe Lozaro, Marchella Porche, Marilynn Hicks, Renita Stone, Solita Religioso, Laura Gasner, and Darren White. Drafting was done by Richard Moar, Donald Anderson, Francis Rubish, Eleanor Taylor, Janet Smith, Jeffrey Tambert, Louise Huckaby, Edward Foster, and Anna Stratton. Word processing support was provided by the Department's Word Processing Center under the supervision of Patty Taylor.

Guidance throughout the course of the study was provided by James F. Davis, Rudolph G. Strand, Paul K. Morton, and David J. Beeby.

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APPENDIX A

Principles of the Mineral Resources Classification System of the U.S. Bureau of Mines and the U.S. Geological Survey
(From U.S. Geological Survey Circular 831)

Principles of a Resource/Reserve Classification For Minerals

By the U.S. Bureau of Mines and
the U.S. Geological Survey

GEOLOGICAL SURVEY CIRCULAR 831

A revision of the classification system published as U.S. Geological Survey Bulletin 1450-A

Principles of a Resource/Reserve Classification for Minerals

By the U.S. BUREAU OF MINES and the U.S. GEOLOGICAL SURVEY

INTRODUCTION

Through the years, geologists, mining engineers, and others operating in the minerals field have used various terms to describe and classify mineral resources, which as defined herein include energy materials. Some of these terms have gained wide use and acceptance, although they are not always used with precisely the same meaning.

Staff members of the U.S. Bureau of Mines and the U.S. Geological Survey collect information about the quantity and quality of all mineral resources, but from different perspectives and with different purposes. In 1976, a team of staff members from both agencies developed a common classification and nomenclature, which was published as U.S. Geological Survey Bulletin 1450-A–"Principles of the Mineral Resource Classification System of the U.S. Bureau of Mines and U.S. Geological Survey." Experience with this resource classification system showed that some changes were necessary in order to make it more workable in practice and more useful in long-term planning. Therefore, representatives of the U.S. Geological Survey and the U.S. Bureau of Mines collaborated to revise Bulletin 1450-A.

Long-term public and commercial planning must be based on the probability of discovering new deposits, on developing economic extraction processes for currently unworkable deposits, and on knowing which resources are immediately available. Thus, resources must be continuously reassessed in the light of new geologic knowledge, of progress in science and technology, and of shifts in economic and political conditions. To best serve these planning needs, known resources should be classified from two standpoints: (1) purely geologic or physical/chemical characteristics–such as grade, quality, tonnage, thickness, and depth–of the material in place: and (2) profitability analyses based on costs of extracting and marketing the material in a given economy at a given time. The former constitutes important objective scientific information of the resource and a relatively unchanging foundation upon which the latter more variable economic delineation can be based.

The revised classification system, designed generally for all mineral materials, is shown graphically in figures 1 and 2 (see page 5); its components and their usage are described in the text. The classification of mineral and energy resources is necessarily arbitrary, because definitional criteria do not always coincide with natural boundaries. The system can be used to report the status of mineral and energy-fuel resources for the Nation or for specific areas.

RESOURCE/RESERVE DEFINITIONS

A dictionary definition of resource, "something in reserve or ready if needed," has been adapted for mineral and energy resources to comprise all materials, including those only surmised to exist, that have present or anticipated future value.

Resource.–A concentration of naturally occurring solid, liquid, or gaseous material in or on the Earth's crust in such form and amount that economic extraction of a commodity from the concentration is currently or potentially feasible.

Original Resource.–The amount of a resource before production.

Identified Resources.–Resources whose location, grade, quality, and quantity are known or estimated from specific geologic evidence. *Identified resources* include economic, marginally economic, and subeconomic components. To reflect varying degrees of geologic

(Identified Resources – Continued)
certainty, these economic divisions can be subdivided into *measured, indicated,* and *inferred.*[1]

Demonstrated. – A term for the sum of *measured* plus *indicated.*

Measured. – Quantity is computed from dimensions revealed in outcrops, trenches, workings, or drill holes; grade and(or) quality are computed from the results of detailed sampling. The sites for inspection, sampling, and measurement are spaced so closely and the geologic character is so well defined that size, shape, depth, and mineral content of the resource are well established.

Indicated. – Quantity and grade and(or) quality are computed from information similar to that used for measured resources, but the sites for inspection, sampling, and measurement are farther apart or are otherwise less adequately spaced. The degree of assurance, although lower than that for measured resources, is high enough to assume continuity between points of observation.

Inferred. – Estimates are based on an assumed continuity beyond measured and(or) indicated resources, for which there is geologic evidence. *Inferred resources* may or may not be supported by samples or measurements.

Reserve Base. – That part of an identified resource that meets specified minimum physical and chemical criteria related to current mining and production practices, including those for grade, quality, thickness, and depth. The *reserve base* is the in-place demonstrated (measured plus indicated) resource from which reserves are estimated. It may encompass those parts of the resources that have a reasonable potential for becoming economically available within planning horizons beyond those that assume proven technology and current economics. The *reserve base* includes those resources that are currently economic (*reserves*), marginally economic (*marginal reserves*), and some of those that are currently subeconomic (*subeconomic resources*). The term "geologic reserve" has been applied by others generally to the *reserve-base* category, but it also may include the *inferred-reserve-base* category; it is not a part of this classification system.

[1]The terms "proved," "probable," and "possible", which are commonly used by industry in economic evaluations of ore or mineral fuels in specific deposits or districts, have been loosely interchanged with the terms *measured, indicated,* and *inferred.* The former terms are not a part of this classification system.

Inferred Reserve Base. – The in-place part of an identified resource from which inferred reserves are estimated. Quantitative estimates are based largely on knowledge of the geologic character of a deposit and for which there may be no samples or measurements. The estimates are based on an assumed continuity beyond the reserve base, for which there is geologic evidence.

Reserves. – That part of the reserve base which could be economically extracted or produced at the time of determination. The term *reserves* need not signify that extraction facilities are in place and operative. *Reserves* include only recoverable materials; thus, terms such as "extractable reserves" and "recoverable reserves" are redundant and are not a part of this classification system.

Marginal Reserves. – That part of the reserve base which, at the time of determination, borders on being economically producible. Its essential characteristic is economic uncertainty. Included are resources that would be producible, given postulated changes in economic or technologic factors.

Economic. – This term implies that profitable extraction or production under defined investment assumptions has been established, analytically demonstrated, or assumed with reasonable certainty.

Subeconomic Resources. – The part of identified resources that does not meet the economic criteria of reserves and marginal reserves.

Undiscovered Resources. – Resources, the existence of which are only postulated, comprising deposits that are separate from identified resources. *Undiscovered resources* may be postulated in deposits of such grade and physical location as to render them economic, marginally economic, or subeconomic. To reflect varying degrees of geologic certainty,

(**Undiscovered Resources** – Continued)
undiscovered resources may be divided into two parts:

Hypothetical Resources. – Undiscovered resources that are similar to known mineral bodies and that may be reasonably expected to exist in the same producing district or region under analogous geologic conditions. If exploration confirms their existence and reveals enough information about their quality, grade, and quantity, they will be reclassified as identified resources.

Speculative Resources. – Undiscovered resources that may occur either in known types of deposits in favorable geologic settings where mineral discoveries have not been made, or in types of deposits as yet unrecognized for their economic potential. If exploration confirms their existence and reveals enough information about their quantity, grade, and quality, they will be reclassified as identified resources.

Restricted Resources/Reserves. – That part of any resource/reserve category that is restricted from extraction by laws or regulations. For example, *restricted reserves* meet all the requirements of reserves except that they are restricted from extraction by laws or regulations.

GUIDELINES FOR CLASSIFICATION OF MINERAL RESOURCES

1. All naturally occurring metals, nonmetals, and fossil fuels in sufficient concentration can be classified in one or more of the categories.

2. Where the term *reserves* is used alone, without a modifying adjective such as indicated, marginal, or inferred, it is to be considered synonymous with the demonstrated-economic category, as shown in figure 1.

3. Definitions of resource categories can be modified for a particular commodity in order to conform with accepted usage involving special geological and engineering characteristics. Such modified definitions for particular commodities will be given in forthcoming government publications.

4. Quantities, qualities, and grades may be expressed in different terms and units to suit different purposes, but usage must be clearly stated and defined.

5. The geographic area to which any resource/reserve estimate refers must be defined.

6. All estimates must show a date and author.

7. The *reserve base* is an encompassing resource category delineated by physical and chemical criteria. A major purpose for its recognition and appraisal is to aid in long-range public and commercial planning. For most mineral commodities, different grades and tonnages, or other appropriate resource parameters, can be specified for any given deposit or area, or for the Nation, depending on the specific objectives of the estimators; therefore, the position of the lower boundary of the reserve base, which extends into the subeconomic category, is variable, depending on those objectives. The intention is to define a quantity of in-place material, any part of which may become economic, depending on the extraction plans and economic assumptions finally used. When those criteria are determined, the initial reserve-base estimate will be divided into three component parts: reserves, marginal reserves, and a remnant of subeconomic resources. For the purpose of Federal commodity assessment, criteria for the reserve base will be established for each commodity.

8. *Undiscovered resources* may be divided in accordance with the definitions of *hypothetical* and *speculative resources,* or they may be divided in terms of relative probability of occurrence.

9. *Inferred reserves* and the *inferred reserve base* are postulated extensions of reserves and of the reserve base. They are identified resources quantified with a relatively low degree of certainty. Postulated quantities of resources not based on reserve/reserve-base extensions, but rather on geologic inference alone, should be classified as undiscovered.

10. Locally, limited quantities of materials may be produced, even though economic analysis has indicated that the deposit would be too thin, too low grade, or too deep to be classified as a reserve. This situation might arise when the production facilities are already established or when favorable local circumstances make it possible to produce material that elsewhere could not be extracted profitably. Where such production is taking place, the quantity of in-place material shall be included in the reserve base, and the quantity that is potentially producible shall be included as a reserve. The profitable production of such materials locally, however, should not be used as a rationale in other

areas for classifying as reserves, those materials that are similar in thickness, quality, and depth.

11. Resources classified as reserves must be considered economically producible at the time of classification. Conversely, material not currently producible at a profit cannot be classified as reserves. There are situations, however, in which mining plans are being made, lands are being acquired, or mines and plants are being constructed to produce materials that do not meet economic criteria for reserve classification under current costs and prices, but would do so under reasonable future expectations. For some other materials, economic producibility is uncertain only for lack of detailed engineering assessment. The marginal-reserves category applies to both situations. When economic production appears certain for all or some of a marginal reserve, it will be reclassified as reserves.

12. Materials that are too low grade or for other reasons are not considered potentially economic, in the same sense as the defined resource, may be recognized and their magnitude estimated, but they are not classified as resources. A separate category, labeled *other occurrences,* is included in figures 1 and 2.

13. In figure 1, the boundary between *subeconomic* and *other occurrences* is limited by the concept of *current or potential feasibility of economic production,* which is required by the definition of a resource. The boundary is obviously uncertain, but limits may be specified in terms of grade, quality, thickness, depth, percent extractable, or other economic-feasibility variables.

14. Varieties of mineral or energy commodities, such as bituminous coal as distinct from lignite, may be separately quantified when they have different characteristics or uses.

15. The amount of past cumulative production is not, by definition, a part of the resource. Nevertheless, a knowledge of what has been produced is important to an understanding of current resources, in terms of both the amount of past production and the amount of residual or remaining in-place resource. A separate space for cumulative production is shown in figure 1. Residual material left in the ground during current or future extraction should be recorded in the resource category appropriate to its economic-recovery potential.

16. In classifying reserves and resources, it is necessary to recognize that some minerals derive their economic viability from their coproduct or byproduct relationships with other minerals. Such relationships must be clearly explained in footnotes or in an accompanying text.

17. Considerations other than economic and geologic, including legal, regulatory, environmental, and political, may restrict or prohibit the use of all or part of a deposit. Reserve and resource quantities known to be restricted should be recorded in the appropriate classification category; the quantity restricted and the reason for the restriction should be noted.

18. The classification system includes more divisions than will commonly be reported or for which data are available. Where appropriate, divisions may be aggregated or omitted.

19. The data upon which resource estimates are based and the methods by which they are derived are to be documented and preserved.

RESOURCES OF (commodity name)

[A part of reserves or any resource category may be restricted from extraction by laws or regulations (see text)]

AREA: (mine, district, field, State, etc.) UNITS: (tons, barrels, ounces, etc.)

Cumulative Production	IDENTIFIED RESOURCES			UNDISCOVERED RESOURCES	
	Demonstrated		Inferred	Probability Range (or)	
	Measured	Indicated		Hypothetical	Speculative
ECONOMIC	Reserves		Inferred Reserves		
MARGINALLY ECONOMIC	Marginal Reserves		Inferred Marginal Reserves		
SUB-ECONOMIC	Demonstrated Subeconomic Resources		Inferred Subeconomic Resources		

Other Occurrences	Includes nonconventional and low-grade materials

Author: Date:

FIGURE 1.—Major elements of mineral-resource classification, excluding *reserve base* and *inferred reserve base.*

RESOURCES OF (commodity name)

[A part of reserves or any resource category may be restricted from extraction by laws or regulations (see text)]

AREA: (mine, district, field, State, etc.) UNITS: (tons, barrels, ounces, etc.)

Cumulative Production	IDENTIFIED RESOURCES			UNDISCOVERED RESOURCES	
	Demonstrated		Inferred	Probability Range (or)	
	Measured	Indicated		Hypothetical	Speculative
ECONOMIC	Reserve		Inferred		
MARGINALLY ECONOMIC	Base		Reserve Base		
SUB-ECONOMIC					

Other Occurrences	Includes nonconventional and low-grade materials

Author: Date:

FIGURE 2.—*Reserve base* and *inferred reserve base* classification categories.

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APPENDIX B

Summary Of The Classification Of MRZ-3 Areas, Construction Materials Only

AREAS CLASSIFIED MRZ-3

A. *MARIN COUNTY:*

Plate 3.5 Bolinas Quadrangle
MRZ-3
(a) Franciscan Complex greenstone—Similar material is being quarried and crushed for aggregate in the Bay area. This deposit is classified MRZ-3 because of lack of underground data and information regarding suitability of rock for aggregate. Only known use for greenstone in the quadrangle is for fill.

Plate 3.8 Novato Quadrangle
MRZ-3
(a) Sonoma Volcanics andesite—Andesite and basalt from the Sonoma Volcanics has been quarried and crushed for use as aggregate a few miles to the north. The possible existence of tuff breccia in the deposit may make the andesite unsuitable for aggregate other than fill.

(b) Franciscan Complex greenstone—The material may be suitable for aggregate, but the bodies of greenstone may be too small to meet threshold values needed for a MRZ-2 classification.

(c) Franciscan Complex sandstone and shale—Some local deposits of sandstone suitable for aggregate probably occur within the one or more areas classified MRZ-3. The interbedded shale is unsuitable for aggregate. The area is classified MRZ-3 because available geologic mapping does not delineate between masses of sandstone and shale.

Plate 3.9 Petaluma Point Quadrangle
MRZ-3
(a) Novato Conglomerate—These two small areas have been classified MRZ-3 because there may be insufficient material present to meet threshold value.

(b) Franciscan Complex sandstone and shale—Sandstone suitable for aggregate is interbedded with shale, which is suitable only for fill. Available geologic mapping does not delineate between sandstone and shale. The area has been classified MRZ-3 because of the lack of information on the location of the masses of sandstone.

Plate 3.10 Petaluma River Quadrangle
MRZ-3
(a) Sonoma Volcanics andesite flows—Many small masses of andesite located within Quaternary landslide debris may be suitable for aggregate. Data regarding location, size, and extent of these bodies are not available.

Plate 3.11 Point Bonita Quadrangle
MRZ-3
(a) Franciscan Complex chert—This small area is underlain by chert, which has been used for aggregate in the Bay area. This is the northern tip of a large deposit which extends to the south.

Plate 3.12 San Francisco North Quadrangle
MRZ-3
(a) Franciscan Complex greenstone—Greenstone has been quarried for aggregate at several locations in Marin County. Data regarding degree of weathering and amount of tuff breccia within the greenstone is not available.

(b) Franciscan Complex chert—Chert suitable for fill and roadbase may be present in one or more of these areas, but rock quality data is not available.

(c) Franciscan Complex metamorphic rocks—These deposits contain material which consists primarily of metavolcanic rocks with some bodies of metachert. Exposures are small but prominent. Data on rock quality and quantity are not available.

Plate 3.13 San Geronimo Quadrangle
MRZ-3
(a) Franciscan Complex greenstone—Similar material is being quarried and used for aggregate in the Bay area. Data regarding suitability of the greenstone at these two localities are not available.

(b) Franciscan Complex sandstone and shale—Several areas are underlain by thickly bedded sandstone and interbedded shale. Similar material is being quarried for aggregate in Marin County. The areas are classified MRZ-3 because of the lack of available detailed geologic mapping delineating masses of sandstone from shale bodies.

Plate 3.14 San Quentin Quadrangle
MRZ-3

(a) Franciscan Complex metamorphic rocks—Some local bodies of rock (metamorphosed graywacke, greenstone, and metachert) suitable for aggregate undoubtedly exist within the areas, but because of the lack of information regarding exact location and size of the deposits, the areas are classified MRZ-3.

(b) Franciscan Complex sandstone and shale—Several areas underlain by sandstone and shale have been classified MRZ-3 because available geologic maps do not delineate between sandstone and shale. The shale is not suitable for aggregate (except for fill). Similar sandstone is being quarried for aggregate elsewhere in Marin County.

Plate 3.15 San Rafael Quadrangle
MRZ-3

(a) Franciscan Complex greenstone—Although similar material has been quarried for aggregate elsewhere in the Bay area, greenstone from the San Rafael Quadrangle has not been used. The areas are classified MRZ-3 because of the lack of subsurface data and rock quality data.

(b) Franciscan Complex chert—A quarry at the southwestern end of the area previously was worked for aggregate. The area has been classified MRZ-3 because of the possibility that there may not be enough material present to meet threshold value. Also, the deposit is structurally complex, with irregular distribution of other rock types with the chert.

(c) Franciscan Complex sandstone and shale—An inactive quarry is located within one of the areas classified MRZ-3. The inactive quarry produced dimension stone and aggregate. The areas are classified MRZ-3 because of the lack of data concerning quality and extent of material suitable for aggregate.

B. NAPA COUNTY:

Plate 3.16 Cordelia Quadrangle
MRZ-3

(a) Sonoma Volcanics andesite and basalt, and Quaternary landslide debris—This material is similar to that which is found within the adjacent MRZ-2(a) area, but quality data for subsurface material is not available.

(b) Domengine Formation sandstone, shale and clay—Aggregate and specialty sand has been recovered from the Domengine Formation elsewhere in the Bay area. Data on quality of material in this deposit is not available.

(c) Briones Formation sandstone with minor Sonoma Volcanics-Briones Formation sandstone has been quarried for aggregate elsewhere in the Bay area, but no quarry sites are known north of the Bay. Quality of the material and extent of the deposits are unknown.

(d) Franciscan Complex sheared shale and graywacke—This is the northern end of a narrow ridge which extends northward from the Benicia Quadrangle. Material suitable for aggregate is being quarried in the Benicia Quadrangle. However, rock exposed in several inactive quarries in Napa County appears to be suitable only for fill. Data regarding suitability of material from other localities within the MRZ-3 area is unavailable.

Plate 3.17 Cuttings Wharf Quadrangle
MRZ-3

(a) Sonoma Volcanics andesite and basalt flows with Quaternary landslide debris—This material is similar to that found within the adjacent MRZ-2(a) area, but data as to suitability of material for use as aggregate and extent of deposit is unavailable.

(b) Domengine Formation sandstone, shale and clay—Sand has been recovered from the Domengine Formation elsewhere in the Bay area. Because of the limited size of the areas and lack of quality data, only an MRZ-3 classification is justified.

(c) Unnamed Formation of Sims and others (1973)—This unit consists of mudstone, shale, siltstone, and conglomerate of the Great Valley Sequence, and includes the Oat Hill deposit. Only known use of this material is for fill, but it may be suitable for subbase.

(d) Briones Formation sandstone with minor Sonoma Volcanics—Sandstone of the Briones Formation has been quarried for aggregate at a number of sites in the Bay area, but no quarry sites are known north of the Bay. Quality of the material and extent of the deposits are unknown.

Plate 3.18 Mount George Quadrangle
MRZ-3

(a) Sonoma Volcanics rhyolite, andesite, basalt, and tuff—This deposit may contain material suitable for aggregate, but information concerning quality is not available.

Plate 3.19 Napa Quadrangle
MRZ-3
(a) Sonoma Volcanics andesitic to dacitic plugs or intrusive complex—These deposits include an inactive quarry site, but it is not known whether sufficient material remains to reach threshold value.

(b) Sonoma Volcanics andesite and basalt flows—This area includes two small deposits which probably do not contain enough material to meet threshold value. Suitability of the material for aggregate has not been demonstrated.

(c) Domengine Formation sandstone—This deposit has not been previously quarried, but sand suitable for fill or specialty sand may be present. Sand has been recovered from the Domengine Formation elsewhere in the Bay area.

C. SOLANO COUNTY:

Plate 3.20 Benicia Quadrangle
MRZ-3
(a) Franciscan Complex sheared shale and graywacke—This may be a continuation of the adjacent MRZ-2(a) area, but data on quality and subsurface extent are not available. Two inactive quarries located outside of the quadrangle contain material suitable only for fill.

Plate 3.16 Cordelia Quadrangle
MRZ-3
(d) Franciscan Complex sheared shale and graywacke—This area is underlain by sheared graywacke and silica-carbonate rock. Available data does not justify more than MRZ-3 classification for this area.

D. SONOMA COUNTY:

Plate 3.25 Cotati Quadrangle
MRZ-3
(a) Sonoma Volcanics basalt, scoria, and tuff—Although two inactive quarries are located in one of these areas, a field examination showed that most of the material appears to be suitable only for fill but the rock may be suitable for subbase aggregate. No data is available regarding suitability of the rock for aggregate at the other areas given an MRZ-3 classification.

Plate 3.27 Glen Ellen Quadrangle
MRZ-3
(a) Sonoma Volcanics andesite and basalt—Several small areas are underlain by volcanic rock. Similar material has been quarried elsewhere in the area for use as aggregate. Subsurface data and quality data are not available.

Plate 3.28 Kenwood Quadrangle
MRZ-3
(a) Sonoma Volcanics andesite and basalt—Two areas with several inactive quarry sites contain material similar to that which has been used for roadbase and asphaltic concrete aggregate. The deposits may be too small to meet threshold value.

(b) Sonoma Volcanics rhyolite—This deposit is similar to the MRZ-2(a) area, but has not been quarried. Rock quality and the extent of suitable aggregate are unknown.

(c) Sonoma Volcanics andesite and basalt—This material may be suitable for aggregate, but the deposit may be too small to meet threshold value.

Plate 3.29 Petaluma Quadrangle
MRZ-3
(a) Sonoma Volcanics andesite and basalt—This is a small deposit that may be suitable for aggregate, but has not been previously quarried and may be too small to meet suggested threshold value.

Plate 3.30 Santa Rosa Quadrangle
MRZ-3
(a) Sonoma Volcanics andesite and basalt—Some of these areas were quarried for paving blocks. Tuff and tuff-breccia may be present at depth. Lack of underground data precludes an MRZ-2 classification.

(b) Quaternary stream channel material—These deposits were mined in the past, but may not meet threshold value.

Plate 3.32 Sebastopol Quadrangle
MRZ-3

(a) Merced Formation sandstone, conglomerate and siltstone—There may be local accumulations of material suitable for some aggregate uses. Data regarding aggregate quality and quantity are not available. There were no known commercial operations in the past.

Plate 3.33 Sonoma Quadrangle
MRZ-3

(a) Quaternary alluvium—These areas lie adjacent to the Sonoma Creek channel deposits, but lack subsurface data needed for an MRZ-2 classification.

(b) Sonoma Volcanics andesite and basalt—The stone may be suitable for aggregate, but the deposit may be too small to reach threshold value.

(c) Sonoma Volcanics rhyolite with minor tuff—This material may be suitable for roadbase, but there may be insufficient material to meet threshold value, and data concerning the quality of the material is lacking.

Plate 3.36 Asti Quadrangle
MRZ-3

(a) Quaternary alluvium—Russian River terraces and flood plains, and alluvial fans. Examination of known sand and gravel deposits along the Russian River indicates that the commercial-grade sand and gravel extends outward from the river channel into the area overlain by soil of the Yolo series. Water-well logs when available, tend to support this observation. The area classified MRZ-3 is essentially that shown on the soil maps as Yolo series soil. Deposits of commercial-grade sand and gravel may occur in the area classified MRZ-3, but insufficient drill-hole data is available to justify an MRZ-2 classification of the area. Water-well logs or other underground data was not examined for this area.

(b) Franciscan Complex greenstone—Several areas are underlain by Franciscan Complex greenstone that may be suitable for aggregate. Greenstone is being quarried and crushed for aggregate elsewhere in the Bay area. Detailed surface examination and drill-hole data would be necessary to determine if the greenstone is suitable for aggregate.

Plate 3.37 Cloverdale Quadrangle
MRZ-3

(a) Quaternary alluvium—Russian River terraces and flood plains, and alluvial fans. Examination of known sand and gravel deposits along the Russian River indicates that the commercial-grade sand and gravel extends outward from the river channel into the area overlain by soil of the Yolo series. Water-well logs when available, tend to support this observation. The area classified MRZ-3 is essentially that shown on the soil maps as Yolo series soil. Deposits of commercial-grade sand and gravel may occur in the area classified as MRZ-3, but insufficient drill-hole data is available to justify an MRZ-2 classification of the area. Water-well logs or other underground data was not examined for this area.

Plate 3.38 Geyserville Quadrangle
MRZ-3

(a) Quaternary alluvium—Russian River terraces and flood plains, and alluvial fans. Examination of known sand and gravel deposits along the Russian River indicate that the commercial-grade sand and gravel extends outward from the river channel into the area overlain by soil of the Yolo series. Water-well logs, when available, tend to support this observation. The area classified MRZ-3 is essentially that shown on the soil maps as Yolo series soil. Deposits of commercial-grade sand and gravel may occur in the area classified MRZ-3, but insufficient drill-hole data is available to justify an MRZ-2 classification of the area. Water-well logs or other underground data was not examined for this area.

(b) Sonoma Volcanics—andesitic to basaltic lava flows. According to available geologic maps this area is underlain by andesitic to basaltic lava flows. This deposit has not been previously mined nor has it been tested for suitability for use as aggregate. However, similar material is being quarried and crushed for aggegate elsewhere in the North San Francisco Bay Region. Because of the uncertainty as to quality and quantity of material suitable for aggregate, only an MRZ-3 classification is justified.

(c) Quaternary alluvium—Dry Creek terraces and flood plains. This area extends outward from the creek channel and is overlain by the Yolo series soils. Water-well logs were not obtained for this quadrangle, but water-well logs for areas overlain by the Yolo series soils a short distance to the south indicate that commercial-grade sand and gravel may underlie some of the MRZ-3(c) areas.

Plate 3.39 Guerneville Quadrangle
MRZ-3

(a) Quarternary alluvium—Dry Creek terraces and flood plains. This area extends outward from the stream channel of Dry Creek into the area overlain by soil of the Yolo series. Examination of the site of former sand and gravel operations and available water-well logs tends to support this observation. The area classified MRZ-3(a) is essentially that shown on soil maps as Yolo series soil. Deposits of commercial-grade sand and gravel may occur within the area classified MRZ-3, but insufficient drill-hole data is available to justify an MRZ-2 classification of this area.

(b) Quaternary alluvium—Russian River terraces and flood plains, and alluvial fans. Examination of known sand and gravel deposits along the Russian River indicates that the commercial-grade sand and gravel extends outward from the river channel into the area overlain by soil of the Yolo series. Water-well logs when available, tend to support this observation. The area classified MRZ-3 is essentially that shown on the soil maps as Yolo series soil. Deposits of commercial-grade sand and gravel may occur in the area classified MRZ-3, but insufficient drill-hole data is available to justify an MRZ-2 classification of the area.

Plate 3.40 Healdsburg Quadrangle
MRZ-3

(a) Quaternary alluvium—Russian River terraces and flood plains, and alluvial fans. Examination of known sand and gravel deposits along the Russian River indicate that the commercial-grade sand and gravel extends outward from the river channel into the area overlain by soil of the Yolo series. Water-well logs when available, tend to support this observation. The area classified MRZ-3 is essentially that shown on the soil maps as Yolo series soil. Deposits of commercial-grade sand and gravel may occur in the area classified MRZ-3, but insufficient drill-hole data is available to justify an MRZ-2 classification of the area. However, water-well log data though meager, does tend to indicate a possibility of the presence of sand and gravel deposits in the MRZ-1 area west of the boundary between the MRZ-3 and MRZ-1 area along Forman Lane. The well logs indicate the possible presence of deposits of sand and gravel, but location data for the wells requires a field verification of each well location. This was not done during the present study.

(b) Quaternary alluvium—Dry Creek stream channel and terraces. This area extends outward from the creek channel and is overlain by soils of the Yolo series. Water-well data indicates the possible presence of deposits of sand and gravel, but insufficient data is available to justify an MRZ-2 classification.

Plate 3.41 Jimtown Quadrangle
MRZ-3

(a) Quaternary alluvium—Russian River terraces and flood plains, and alluvial fans. Examination of known sand and gravel deposits along the Russian River indicate that the commercial-grade sand and gravel extends outward from the river channel into the area overlain by soil of the Yolo series. Water-well logs when available, tend to support this observation. The area classified MRZ-3 is essentially that shown on the soil maps as Yolo series soil. Deposits of commercial-grade sand and gravel may occur in the MRZ-3, but insufficent drill-hole data is available to justify an MRZ-2 classification of the area. Available water-well logs tend to indicate that commercial-grade sand and gravel deposits may be located in the MRZ-3 area. However, distribution of water wells is so erratic that potential sand and gravel deposits could not be delineated.

(b) Franciscan Complex greenstone—Several areas on the east side of Alexander Valley are shown on the geologic map to be underlain by greenstone. Greenstone is being quarried elsewhere in the Bay area and crushed for use as aggregate. One or more of the areas classified MRZ-3 may contain greenstone suitable for aggregate. The MRZ-3 area a short distance south is the southwestern extremity of a very large deposit of greenstone.

(c) Sonoma Volcanics andesitic to basaltic lava flows—Deposits of volcanic rock of the Sonoma Volcanics are being quarried at several sites within the north Bay area. One or more of the areas classified MRZ-3 may contain material suitable for aggregate. However, a detailed site examination with sampling and laboratory testing of the rock would be necessary to determine if the material is suitable for aggregate.

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