Mineral Resource Assessment of Selected Areas in Clark and Nye Counties, Nevada, Edited by Steve Ludington
U.S. Geological Survey Scientific Investigations Report 2006-5197

Prepared in cooperation with the Nevada Bureau of Mines and Geology and the University of Nevada, Las Vegas

Chapter I. Mineral Resource Potential of the Rainbow Gardens Area of Critical Environmental Concern, Clark County, Nevada

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Summary and Conclusions

The Rainbow Gardens Area of Critical Environmental Concern (ACEC) contains known deposits of gypsum, as well as prospects for limestone, silica, lithium, copper, uranium, and sand and gravel aggregate. Only gypsum has been mined in significant quantities, and the PABCO (Apex) gypsum mine, immediately adjacent to the ACEC, is a major gypsum source, producing more than 1,000,000 short tons of gypsum annually.

The ACEC contains areas of high mineral resource potential for gypsum deposits in the Tertiary Muddy Creek Formation and areas of moderate mineral resource potential for gypsum in the Mesozoic Moenkopi Formation. Areas with high potential for limestone deposits are found in the northern part of the ACEC. There is an area with moderate potential for lithium (hectorite clay) deposits. The potential for undiscovered deposits of silica, uranium, and metals is low.

The ACEC has areas with high, moderate, and low potential for crushed-stone aggregate deposits. Unconsolidated material in the ACEC has high potential for sand and gravel aggregate deposits.

Introduction

This report was prepared for the U.S. Bureau of Land Management (BLM) to provide information for land planning and management, and, specifically, to determine mineral resource potential in accordance with regulations at 43 CFR 2310, which governs the withdrawal of public lands. The Clark County Conservation of Public Land and Natural Resources Act of 2002 temporarily withdraws the lands described herein from mineral entry, pending final approval of an application for permanent withdrawal by the BLM. This report provides information about mineral resource potential of these lands.

The Rainbow Gardens ACEC was studied in the field to confirm descriptions of the geology that were gleaned from the scientific literature. Samples were collected and analyzed, and representatives of companies with mining operations in and near the areas were contacted.

Definitions of mineral resource potential and certainty levels are given in appendix 1, and are similar to those outlined by Goudarzi (1984).

Lands Involved

The Rainbow Gardens ACEC is east of Las Vegas and southeast of Interstate 15 (fig. 1). The ACEC is bounded on the southeast and east by the Lake Mead National Recreation Area and on the north by Nellis Air Force Base. It is accessed most easily from Nevada State Highway 143 (Lake Mead Boulevard) and by several secondary and primitive roads that branch off of this highway. It may also be accessed from Hollywood Boulevard in southeast Las Vegas and by primitive roads in that area. A legal description of these lands is included in appendix 2.

Physiographic Description

The Rainbow Gardens ACEC is named for an area of colorful rock strata near its southeastern boundary. Near its western boundary, it includes Frenchman Mountain, a rugged ridge that forms the eastern backdrop for Las Vegas and reaches elevations of more than 1,200 m. The northwest part of the ACEC includes Sunrise Mountain, which is more than 1,000 m in height. The lowest part of the ACEC is at an elevation of about 440 m along its southern boundary in Las Vegas Wash, which drains into Lake Mead to the east. Streams and washes in the Rainbow Gardens ACEC drain westward into Las Vegas basin and eastward into Lake Mead.

Geologic Setting

The Rainbow Gardens ACEC is in the Basin and Range Physiographic Province, which is characterized by north-

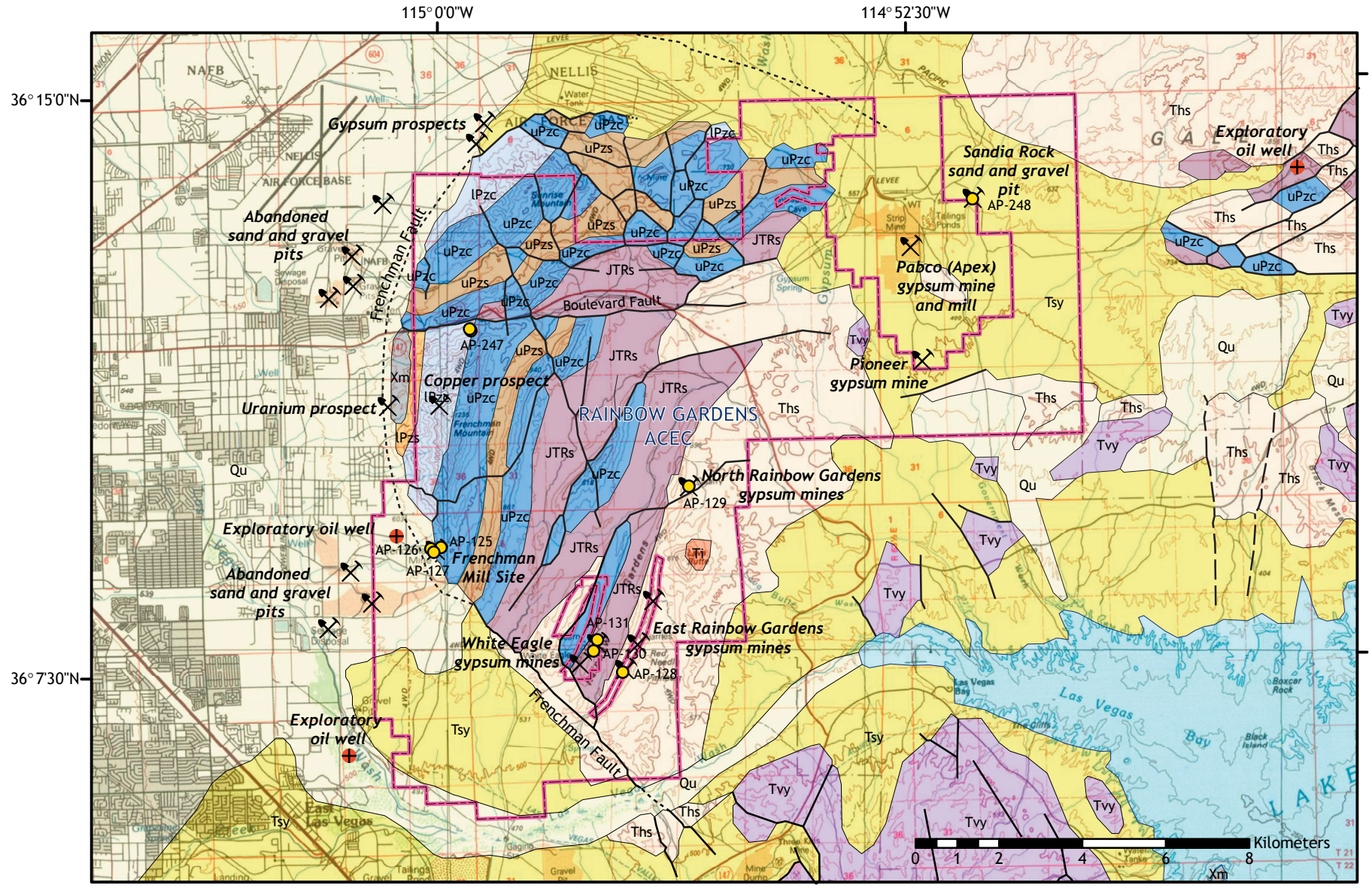

Figure 1. Generalized geology of the Rainbow Gardens Area of Critical Environmental Concern, showing mines, prospects, and locations of analyzed samples. Geology modified from Stewart and Carlson (1978).

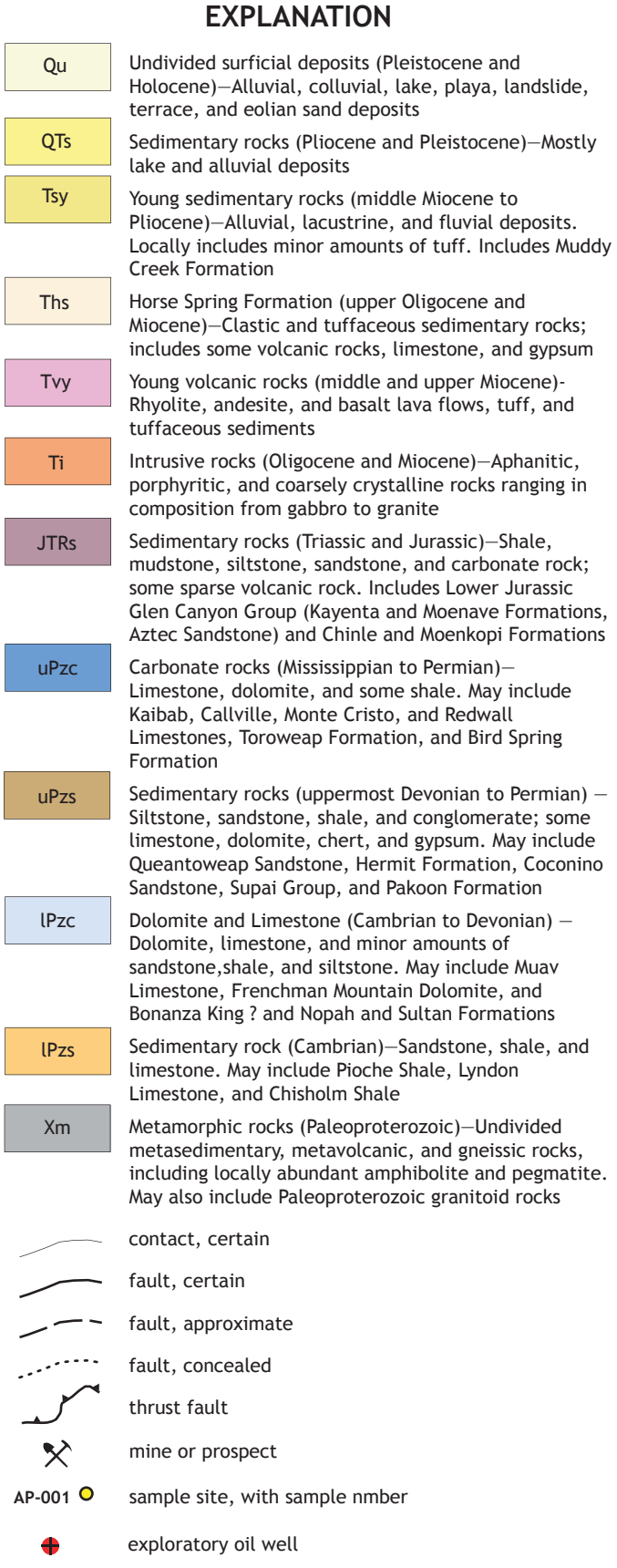

Figure 1.—Continued.

trending mountain ranges and intervening valleys. However, the ACEC lies near the border of this province with the Colorado Plateaus Province and exposes Paleozoic and Mesozoic strata that are similar to those of the Colorado Plateaus. The geology of the region is characterized by rocks ranging in age from Proterozoic through Miocene that are cut by a complex of late Cenozoic extensional faults. Important regional structural features include the Lake Mead Fault system, the Las Vegas Valley shear zone, and steep to moderately dipping normal faults. The Las Vegas Valley shear zone is a major west-northwest-striking right-lateral fault zone that extends across much of southern Nevada. It has accommodated as much as 65 km of dextral displacement to the northwest of the ACEC (Longwell, 1974; Wernicke and others, 1988; Deubendorfer and Black, 1992) and is associated with large-magnitude clockwise rotation of adjacent rocks. The Lake Mead Fault system is a major east-northeast-striking left-lateral fault zone (Anderson, 1973) that appears to merge with the right-lateral Las Vegas Valley shear zone.

Geology

The Rainbow Gardens ACEC has been completely mapped geologically at 1:24,000 scale (Bingler, 1977; Bell and Smith, 1980; Matti and others, 1993; Castor and others, 2000; Deubendorfer, 2003). Rock units range in age from Proterozoic through late Miocene. Proterozoic schist and gneiss, exposed along the western base of Frenchman Mountain (Matti and others, 1993), is overlain by relatively thin lower Cambrian sandstone and shale units and then by a thick sequence of carbonate-dominated Cambrian, Devonian, and Mississippian to Permian rocks. Mesozoic rocks, mainly composed of shallow marine to nonmarine Triassic and Jurassic redbeds, with some carbonate and gypsum beds, are capped by eolian sandstone. Rocks of the uppermost Oligocene to middle Miocene Horse Spring Formation and a red sandstone unit described by Bohannon (1984) are mainly composed of nonmarine red sandstone, with some carbonate rocks and tuff. The Muddy Creek Formation, which is mostly composed of poorly indurated sandstone and siltstone with local gypsum, limestone, and conglomerate units, filled late Miocene basins. The Paleozoic and Mesozoic strata are conformable, but the break between the youngest Mesozoic unit (Jurassic Aztec Sandstone) and the oldest Tertiary unit (basal part of the Horse Spring Formation) is marked by a low-angle unconformity.

The Rainbow Gardens ACEC contains six major structural elements: the Frenchman Mountain block, Sunrise Mountain block, Boulder Basin, Nellis Basin, Gale Hills block, and Las Vegas Valley. The Frenchman Mountain block is bounded by the Frenchman Fault and Las Vegas Valley on the west, the Sunrise Mountain block on the north, and the Boulder Basin on the east. The east-trending, left-lateral Boulevard Fault Zone separates the Frenchman Mountain block from the Sunrise Mountain block (Castor and others, 2000). The Frenchman Mountain block is dominated by east-tilted

Paleozoic, Mesozoic, and Miocene strata and widely spaced, generally northwest-dipping normal faults that have produced three major stratigraphic repetitions.

In contrast to the Frenchman Mountain block, the Sunrise Mountain block is composed of many small blocks. East-northeast-striking, moderately southeast-dipping Paleozoic and Mesozoic strata are cut by closely spaced normal, oblique, and strike-slip faults that fragment the Sunrise Mountain block. The structural complexity in the Sunrise Mountain block increases northward toward the Munitions Fault, a major east-striking fault zone that dips moderately northward and bounds the Sunrise Mountain block on the north.

The Frenchman Fault forms the west side of the Sunrise Mountain and Frenchman Mountain blocks, and has a northwest-striking southern strand partly within the southwest part of the Rainbow Gardens ACEC that accommodated normal dextral (Castor and others, 2000) and reverse dextral motion (R.E. Anderson, oral commun., 1998). This strand merges northward with the central north-striking part of the Frenchman Fault, which surfaces west of the ACEC (Matti and others, 1993) and extends into the northwest part of the ACEC.

The Boulder Basin is east of the Frenchman Mountain block and consists primarily of Miocene sedimentary strata that are tilted gently to moderately eastward. The northern part of the Boulder Basin is complicated by an east- to northeast-trending fold belt that extends beyond the east border of the ACEC (Deubendorfer, 2003), suggesting that the basin, once a half graben or series of half grabens, was significantly modified by north-south shortening. The late Miocene Muddy Creek Formation is locally deformed in this area.

The Nellis Basin, a small late Tertiary basin north of the Munitions Fault, extends southeast into the ACEC. A limestone member of the late Miocene Muddy Creek Formation is apparently confined to this basin. The basin may have developed in a right step or pull-apart along the Las Vegas Valley shear zone.

Within the Rainbow Gardens ACEC, bedrock exposed in the Gale Hills block, which bounds the Boulder Basin on the northeast, is almost all middle Miocene sedimentary rock. However, east of the ACEC, the Gale Hills block includes the southeast extension of the Las Vegas Valley shear zone, along which Paleozoic and Mesozoic strata are exposed (Deubendorfer, 2003).

Mining History

There are seven inactive open-pit gypsum mines in the Rainbow Gardens ACEC; most are in or near the Rainbow Gardens area (fig. 2). The best known is the White Eagle mine, where gypsum was mined from a series of narrow pits (fig. 3) between 1938 and 1956 by Pabco Products, Inc. (Papke, 1987) and later by Fibreboard Paper Products. According to Papke, the nearby East Rainbow Gardens pits (figs. 4, 5) were the source of gypsum for Pabco Products, Inc., in the late 1950s after mining ceased in the White Eagle area; however, U.S. Bureau of Mines records show the operator as Fibreboard Paper Products at this time.

Gypsum mining at the North Rainbow Gardens mine (fig. 6), about 5 km northeast of the White Eagle mine, began in the late 1950s (Papke, 1987). Fibreboard Paper Products was the operator at this mine (referred to by the U.S. Bureau of Mines as the "Henderson" operation). In 1959, the company switched its mining operations from the Rainbow Gardens area to the PABCO mine about 7 km to the northeast (see below). The North Rainbow Gardens mine was mostly idle until the late 1980s, when it was again operated by Nevada Gypsum and Mining and Nevada Gypsum, Inc. The last mining activity recorded at the property was in 1993 (Castor, 1994).

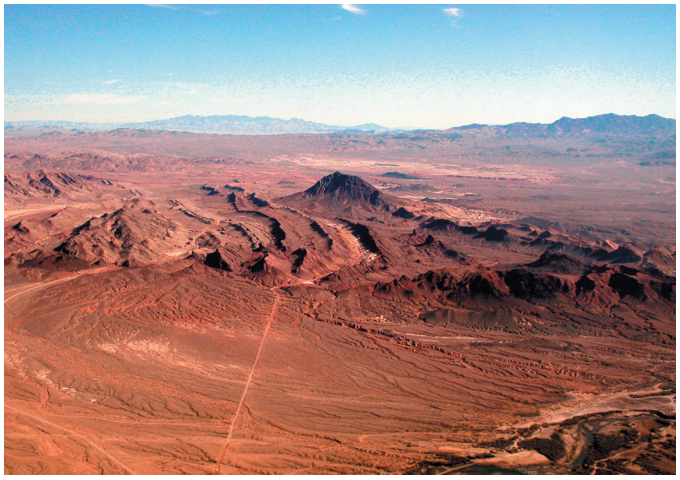

Figure 2. View looking northeast at part of the Rainbow Gardens Area of Critical Environmental Concern showing the abandoned East Rainbow Gardens pits in white gypsum beds in the Horse Spring Formation (center) and the access road in the foreground. Lava Butte is immediately behind. The abandoned Rainbow Gardens pits, including the White Eagle mine, are in the left center along Rainbow Gardens Road. The light-colored plateau beyond Lava Butte is capped by gypsite that is currently being mined by PABCO and Pioneer Gypsum.

Figure 3. White Eagle mine, Rainbow Gardens, looking north. Gypsum is in moderately east-dipping red sandstone in the lower part of the Moenkopi Formation. Sample AP-130 was taken north of the white vehicle in the distance.

Figure 4. East Rainbow Gardens gypsum mine, looking south. Dark, resistant conglomerate of Thumb Member of Horse Spring Formation caps the gypsum and forms skyline. Sample AP-128 is from outcrop behind vehicle.

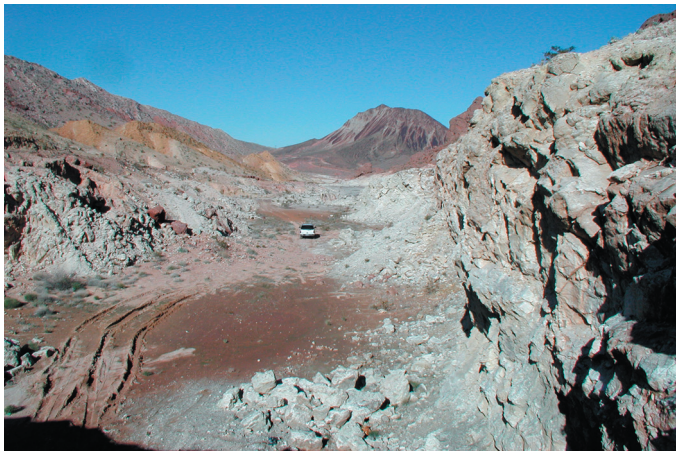

Figure 5. East Rainbow Gardens gypsum mine, looking north. Lava Butte is in background.

Figure 6. North Rainbow Gardens gypsum mine. The open pit was reclaimed in the middle 1990s after mining ceased in 1993.

The PABCO Gypsum Mine, also called the Apex Mine (fig. 7), is located in a large inlier of private land in the Rainbow Gardens ACEC (fig. 1). It is one of five active gypsum mines in Nevada and has been the site of continuous mining since 1959. U.S. Bureau of Mines records show that it was operated by Fibreboard Paper Products in 1959 and by Johns Manville Products Corp. between 1968 and 1976. In 1976 the operation was purchased by Pacific Coast Building Products, Inc., which currently owns the property as part of its PABCO Gypsum subsidiary. Production from the mine has been more than 1,000,000 short tons annually since 2001; however, the ore contains 70 to 80 percent gypsum, and production figures for beneficiated gypsum (92 percent or more gypsum by weight) must be adjusted downward to account for this factor.

The Pioneer Gypsum Mine, a subsidiary of D.L. Denman Construction of Las Vegas, began mining gypsum for cement manufacture and agricultural uses in 2001. The mine is located adjacent to the ACEC within the same inholding as the PABCO Gypsum mine. Production figures have not been published for this operation.

Although gypsum has been the main focus of mining in the Rainbow Gardens ACEC, the earliest mining operation was probably at the Frenchman mine, which produced minor amounts of copper in 1917 and 1918 (Longwell and others, 1965). Paul Watelet, a Belgian miner who managed Pacific Coast Gypsum and South Nevada Gold Mining, was purported to be the "Frenchman," and these companies reported discoveries of gypsum and gold east of Las Vegas between 1905 and 1912. Clippings in the Nevada Bureau of Mines and Geology Las Vegas district file from 1912 to 1914 indicate that the South Nevada Gold Mining Co. operated the Frenchman mine and report that the mill included a 300-ton-per-day cyanide plant and that a shipment of metal to an assay office was made. The ruins of a mill stand on the site shown on topographic maps as the Frenchman mine, but no ore was noted there or nearby.

Figure 7. PABCO (Apex) Mine. Gypsite ore is conveyed to be washed, calcined, and made into wallboard and plaster at the plant in the background.

Mineral Deposits

Gypsum

Open-pit operations at the PABCO Gypsum mine (Apex mine) are within 1 km of the Rainbow Gardens ACEC in a large inholding in the ACEC. The gypsum forms a thick, relatively resistant cap on a gently south-dipping plateau. It is underlain by sandy redbeds of the Muddy Creek Formation. Drilling indicates that the thickness of the gypsum exceeds 35 m in the vicinity of the mine (L. Ordway, PABCO mine manager, oral commun., 1997). The gypsum is generally covered by less than 2 m of sandy overburden and occurs in an area of 13 km^2 (Papke, 1987). Mineable reserves in this area are quite large, probably more than 400 million short tons. The gypsum ore mined by PABCO is transported from the open pit by conveyor belt and upgraded to gypsum suitable for plaster and wallboard production at a simple washing plant.

The ore mined by PABCO is generally friable and porous gypsite that consists of fine intergrown gypsum crystals with various amounts of admixed silt and sand. The gypsite is white to grayish orange or light greenish gray. Locally, it contains layers of fine-grained, sugary, compact gypsum. In places, relatively large selenite crystals or masses of crystals are present (Papke, 1987), and crystals as much as 20 cm long have been noted (Castor and others, 2000). Steeply dipping northwest-striking faults that probably have only minor amounts of offset are exposed in the pit.

The Pioneer Gypsum mine, also within 1 km of the ACEC boundary, exploits the same gypsum-bearing unit as the PABCO operation, and the gypsum appears to be of similar grade. The ore is shipped without processing for use in cement manufacture and agricultural applications.

Gypsum has been mined and prospected for at several sites within the Rainbow Gardens ACEC in the past, and gypsum prospect pits are common. The Permian-Pennsylvanian Pakoon Formation is the oldest unit that has been explored for gypsum. Other units that contain beds of relatively pure gypsum are the Toroweap, Kaibab, Moenkopi, and Horse Spring Formations. At the White Eagle mine, where the gypsum is in the lower redbed unit of the Moenkopi Formation, it is white to pale greenish yellow, as much as 35 m thick, and contains some silty interbeds. It was mined over a strike length of about 1,200 m from three pits, the largest of which is about 370 m long and 60 m wide. Papke (1987) reported 78 percent gypsum in a sample from the White Eagle mine; however, a select sample taken for this study from the White Eagle mine contains nearly 88 percent gypsum (sample AP-131, table 1).

Gypsum was also mined from the Thumb Member of the Miocene Horse Spring Formation about 1 km east and 5 km northeast of the White Eagle mine at the East Rainbow Gardens and North Rainbow Gardens areas (fig. 1). In the East Rainbow Gardens area, gypsum was mined from four pits over a strike length of about 1,500 m. The largest pit is about 550 m long and 30 m wide. A 25-m-long chip sample taken along the south end of the largest pit contains about 83 percent gypsum on the basis of chemical analysis (Sample AP–128, table 1; Ludington and others, 2005). In the North Rainbow Gardens area, site of the most recent gypsum mining within the ACEC, the gypsum-rich sequence is about 150 m wide and is apparently repeated by faulting and folding (Castor and others, 2000). Gypsum mined from the North Rainbow Gardens area in the 1980s and 1990s was shipped crude (generally 87 to 92 percent gypsum) for agricultural use or for use in cement. A select grab sample of gypsum taken from the North Rainbow Gardens mine for this study contains about 91 percent gypsum on the basis of chemical analysis (Sample AP–129, table 1; Ludington and others, 2005).

Mineral Resource Data System (MRDS) data (U.S. Geological Survey, undated) indicate that gypsum prospects occur in the Muddy Creek Formation to the north of the Rainbow Gardens ACEC and in the Kaibab Formation near Gypsum Cave. In addition, mining claim inholdings in the ACEC north of Gypsum Cave include gypsum prospects in the upper part of the Toroweap Formation. On the basis of our observations, the gypsum in the Toroweap occurs as relatively narrow, steeply south-dipping bodies, and only minor amounts of gypsum occur at Gypsum Cave.

Gypsum is abundant in the middle part of the Pakoon Formation, but this unit has only been the site of minor gypsum prospecting. Other gypsum-rich units in the area include the upper part of the Toroweap Formation, where resistant limestone is overlain by 10 to 30 m of gypsum, and the Harrisburg Member of the Kaibab Formation, which includes a gypsiferous sequence as much as 20 m thick (Castor and others, 2000). Harrisburg Member gypsum has been mined for many years at the Blue Diamond mine, about 30 km southwest of the Rainbow Gardens ACEC. In addition to gypsum in the lower redbed unit of the Moenkopi Formation, as at the White Eagle mine, abundant gypsum is also present in the Schnabkaib Member and upper redbed unit of the Moenkopi Formation.

Limestone

Relatively pure limestone suitable for use in Portland cement and possibly high-calcium lime occurs in the Rainbow Gardens ACEC but has not been mined. At Apex, about 9 km north of the ACEC, large amounts of high-calcium lime are produced annually from pure micritic limestone in the upper part of the Crystal Pass Member of the Sultan Formation. The fine-grained texture of this limestone is important, because more coarsely crystalline limestone decrepitates during calcination, making the production of lump lime impossible. Micritic carbonate is present in the unit in the Frenchman Mountain Quadrangle, but X-ray diffraction (XRD) analysis of a chip sample from this unit shows that it is dolomitic. No pure Paleozoic limestone is known to occur in the ACEC; the Paleozoic carbonate rocks there are either dolomitic, or contain interbeds of dolomite, sandy detritus, or minor to abundant chert (Castor and others, 2000).

Table 1. Composition of gypsum samples from the Rainbow Gardens ACEC compared with high-grade gypsum ore from the Blue Diamond mine and low-grade gypsum ore from the PABCO mine.

[All data in weight percent. Gypsum = 2.146 x SO_3. Data on White Eagle grab, Apex, and Blue Diamond samples are from Papke, 1987.]

Sample---------	AP-128	AP-129	AP-131	—	—	—
Location--------	Rainbow Gardens E	Rainbow Gardens N	White Eagle	White Eagle	Apex (PABCO)	Blue Diamond
Unit----------	Horse Spring	Horse Spring	Moenkopi	Moenkopi	Muddy Creek	Kaibab
Sample type---	chip	select grab	select grab	grab	grab	grab
SiO_2	5.89	0.86	0.24	1.53	9.43	0.33
Al_2O_3	0.89	0.11	0.05	0.15	3.94	0.03
Fe_2O_3	0.28	0.05	0.04	0.08	0.22	0.01
MgO	1.52	0.32	0.23	4.92	5.47	0.03
CaO	31.33	34.67	33.61	31.60	27.70	33.40
Na_2O	0.07	0.01	0.01	0.05	0.69	0.02
K_2O	0.39	0.04	0.04	0.15	0.68	0.02
LOI	21.2	21.2	20.4	14.8	13.2	18.3
CO_2	1.46	0.22	0.62	10.40	9.20	0.02
SO_3	38.48	42.23	40.98	36.50	29.40	48.10
Gypsum	82.57	90.61	87.93	78.33	63.09	103.22

Table 2. Comparison of some major element analyses of 35-m chip sample AP 320 and grab sample AP–324 (Rainbow Gardens ACEC) with Portland cement and high-Ca lime ore specifications.

[$CaCO_3$ % calculated using CaO x 1.78; MgCO3 % calculated using MgO x 2.09. Portland cement specifications from Ames and others (1994). High-Ca lime ore specification from Stanley T. Krukowski (oral commun., 2005).]

Element	AP-320	AP-324	Portland cement ore specification	High-Ca lime ore specification
SiO_2	4.04	1.86		<1
Al_2O_3	0.54	0.20		
Fe_2O_3	0.26	0.11		
MgO	0.92	0.54		<1
CaO	52.40	54.32	ca. 50	
Na_2O+K_2O	0.22	0.12	<0.4	
P_2O_5	0.14	0.08		
LOI	41.5	42.8		
$CaCO_3$	93.27	96.69		>95
$MgCO_3$	1.92	1.13		
total carbonate	95.19	97.82		

The Bitter Ridge Limestone Member of the Horse Creek Formation may locally have potential for use as cement or high-calcium limestone. Regionally this unit contains large thicknesses of nearly pure high-calcium limestone. However, in the Rainbow Gardens ACEC, it is commonly interbedded with tuff, volcanic breccia, and sandstone (Castor and others, 2000), and is not as economically desirable as in other locations.

Lacustrine algal limestone in the Nellis basin in the northern part of the ACEC may be more desirable because it is relatively pure and could be easily mined. This limestone unit, mapped as part of the Muddy Creek Formation (unit Tml, Castor and others, 2000) is as much as 50 m thick in places, is nearly flat-lying, and is exposed over about 1.5 km^2 in the ACEC. XRD analyses of this limestone indicate that it is nearly pure calcite, and the chemistry of a 35-m chip sample and a grab sample (samples AP-320 and AP-324, respectively, table 2) indicates that it is suitable for Portland cement. However, its chemistry and the fact that it is relatively coarse grained, indicate that it is not suitable for high-calcium lime production. The limestone is also exposed extensively to the north of the ACEC.

Lithium

A rise in lithium demand and consumption during the 1970s, driven by new uses coupled with concern about future availability for the production of deuterium, prompted significant lithium exploration by the U. S. Geological Survey. Exploration was mainly focused on modern playa deposits in Nevada and California, but deposits of older lithium-rich lacustrine sedimentary rocks were also studied. The upper part of the Lovell Wash Member of the Horse Spring Formation in the Frenchman Mountain quadrangle was found to contain a 40-m-thick section with average lithium content of 1,000 ppm (Brenner-Tourtelot and Glanzman, 1978; Brenner-Tourtelot, 1979). The presence of hectorite ($Na_{0.3}(Mg,Li)_3Si_4O_{10}(F,OH)_2$), a trioctahedral lithium-rich clay mineral, was suspected.

Samples collected from the Lovell Wash Member in both the Frenchman Mountain and Henderson quadrangles were found to have lithium contents as high as 900 ppm on the basis of atomic absorption analyses at the Nevada Bureau of Mines and Geology Analytical Laboratory (Castor and others, 2000). In addition, XRD analysis indicates that clay separates from one of these samples contains trioctahedral clay, and we concur that hectorite is probably present.

Sand and Gravel

The Sandia Aggregate sand and gravel pit (fig. 8) is in the northeastern part of the ACEC. It is about 2 km east of the PABCO Gypsum mine and is also operated by Pacific Coast Building Products, Inc. The pit is about 100 m by 800 m in area and 30 m deep. The material mined is Quaternary alluvium that is mostly composed of pebble- to boulder-sized clasts of Paleozoic carbonate rock.

Silica

According to Longwell and others (1965), the Sunrise Mountain silica deposit, which is probably in the Aztec Sandstone, lies in or near the Rainbow Gardens ACEC. No production has been recorded from this deposit and its location is poorly known. The Sunrise Mountain silica deposits may be on Nellis Air Force Base to the north of the ACEC. No evidence of mining in Aztec Sandstone exposures were found during detailed mapping in the area (Castor and others, 2000). Analyses given in Hewett and others (1936) for Aztec Sandstone from a silica prospect in the Muddy Mountains indicate that the silica content, about 94 percent, is too low to meet specifications for glass sand. White Aztec Sandstone from Whitney Pocket in the Gold Butte area contains only about 89 percent silica.

The silica-rich Coconino Sandstone occurs in places in the Rainbow Gardens ACEC; however, it is generally thin and occurs on steep slopes beneath thick Permian carbonate (Castor and others, 2000). One area in the ACEC contains Coconino Sandstone exposures as much as 70 m thick and 300 m wide over a distance of 2 km.

Metal Mines and Prospects

Frenchman Mine.—The Frenchman Mine, the site of an old mill (fig. 9) at the western base of Frenchman Mountain near the western border of the ACEC, was credited with small production of oxidized copper ore in 1917 and 1918 (Longwell and others, 1965). No copper minerals were found when the site was visited for this study, and samples taken from waste piles and a limonitic breccia outcrop to the south contain less than 20 ppm Cu, along with low Ag, Pb, and Zn contents (Samples AP-126 and AP-127, Ludington and others, 2005).

Figure 8. Sandia Aggregates sand and gravel pit in the Rainbow Gardens Area of Environmental Concern. Pit is about 110 m wide and 800 m long.

Figure 9. Remains of a mill at the reported site of the Frenchman Mine. No sign of mining was noted here; ore was probably transported from a mine site to the north.

About 3 km north of the Frenchman Mine is a group of adits that follow a north-striking, steeply east-dipping breccia zone as much as 12 m wide that is cemented by carbonate, hematite, and copper minerals. This is the only occurrence of copper minerals noted during detailed mapping of the Frenchman Mountain quadrangle (Castor and others, 2000). Access to the adits is by pack trail from the valley floor to the west, and the authors suspect that these adits were the source of ore processed at the Frenchman mill site described above. The breccia zone locally forms a contact between vuggy pale orange dolomite and brown dolomite of the Nopah Formation. Examination of samples of this breccia by reflected light microscopy and scanning electron microscope (SEM) with energy-dispersive X-ray analysis (EDX) shows that the copper minerals include primary chalcopyrite, along with secondary chalcocite, covellite, cuprite, and malachite (figs. 10 and 11). Tiny grains of a silver-bearing sulfide mineral are locally intergrown with the covellite and chalcocite. Samples from this site contain 0.7 percent to more than 1 percent copper and as much as 95 ppm silver, along with anomalously high Sb, As, Au, Hg, Mo, Ni, and Se (samples AP-345 and AP-345A, Ludington and others, 2005).

Uranium

A uranium prospect, the Little Hal, Steve Nos. 1 and 11 claims, is reported near the west edge of the Rainbow Gardens ACEC. Garside (1973) describes the prospect as occurrences of anomalous radioactivity (six times background) associated with pegmatite dikes in Precambrian metamorphic rocks. The location in Precambrian host rocks puts it west of the ACEC. During detailed mapping (Castor and others, 2000), radioactivity as high as three times background was noted in similar rocks in the same general area. Interestingly, uranium contents as high as 139 ppm occur in copper-rich rock (sample AP-345A, Ludington and others, 2005) from the adits described above, which are in the same general area. Uranium is associated with copper and base-metal deposits in carbonate rocks in the Goodsprings district about 50 km to the southwest; however, except for a shipment of five short tons of uranium ore from one mine, uranium occurrences there are very low grade (Garside, 1973).

Mineral Exploration and Development

The Rainbow Gardens ACEC contains 72 mining claims that are current as of 2005. Pacific Coast Building Products, Inc., holds 56 placer claims in sections 1, 12, and 13 of T20S, R63E, just to the west of the company's PABCO (Apex) mine. Bedded deposits of nonmetallic minerals, such as gypsum, are staked using placer claims. Several areas of claims that were presumably staked for gypsum are in the ACEC west of the PABCO mining area and claims. A group of four individuals holds three placer claims in section 14 of T20S, R63E, southeast of the PABCO claims near Gypsum Spring. Bingham's Pride holds four placer claims in sections 15 and 16 of T20S, R63E, west of Gypsum Spring. The Lima brothers hold seven placer claims in section 16 of T20S, R63E about 2 km west of Gypsum Spring. In addition, the Lima brothers hold eight claims in section 34 of T20S, R63E about 4 km to the south in the area of the north Rainbow Gardens gypsum pit.

Other small holdings within the ACEC include a single millsite claim held by Robert Dawson in section 2 of T20S, R63E, and a single claim held by J.L. Block in section 2 of T21S, R62E, in the east part of the ACEC near an abandoned sand and gravel pit.

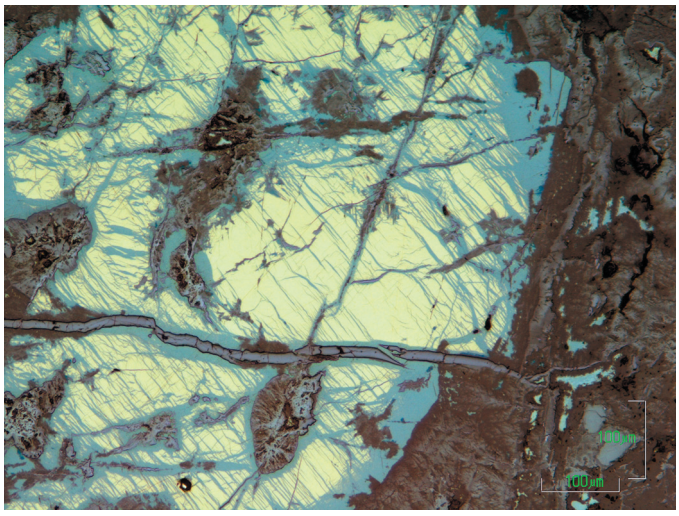

Figure 10. Photomicrograph of chalcopyrite (pale yellow) partly replaced by chalcocite (bluish gray) surrounded by iron oxide, cuprite, and malachite. Cross-polarized light. Sample AP-345A.

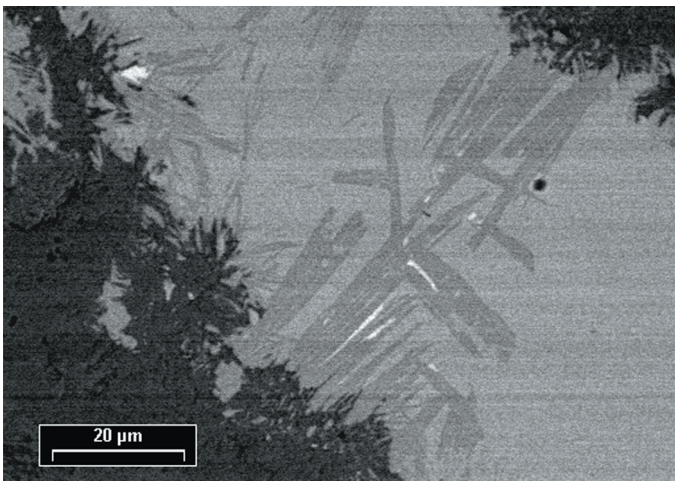

Figure 11. Back-scattered scanning electron microscope image of sample AP-345A, showing silver-bearing sulfide (bright) in chalcocite (gray) with blades of covellite (darker gray). Surrounding dark areas are cuprite and iron oxide.

Mineral Resource Potential

Locatable Minerals

Gypsum.—Parts of the Rainbow Gardens ACEC have high potential for gypsum deposits, with a high certainty level (tract RBG01, fig. 12). This tract contains extensions of the gypsum unit in the Muddy Creek Formation that is currently being mined at the PABCO and Pioneer Gypsum Mines. On the basis of present and past production and the existence of remaining gypsum resources, part of the Middle Miocene Thumb Member of the Horse Springs Formation has high potential, with moderate certainty (tract RBG02). Potential areas in this tract are a gypsum-rich unit mapped in the Thumb Member by Castor and others (2000). On the basis of past production and the presence of gypsum-rich beds (upper part of the Kaibab Formation and rocks in the lower part of the Moenkopi Formation), tract RBG03 has moderate potential with a moderate certainty level (fig. 12). The gypsum beds in tract RBG03 are generally lower in quality than those in tract RBG02, owing to the presence of silty interbeds. With the exception of the area including the North Rainbow Gardens mine (fig. 1), gypsum in tracts RBG02 and RBG03 occurs in relatively thin, moderately dipping deposits, and large volumes cannot be mined without extensive overburden removal. In parts of the Sunrise Mountain structural block north of the Boulevard Fault (fig. 1), the rock units are segmented by abundant faults into small blocks that render commercial gypsum mining unlikely.

Other units that have been explored, but not mined for gypsum in the ACEC, are the late Paleozoic Pakoon, Kaibab, and Toroweap Formations. In most of the ACEC, these Mesozoic and Paleozoic units are moderately dipping and the gypsum deposits, which are as much as 30 m thick, have been explored with narrow pits. More extensive mining would require removal of significant amounts of overburden, rendering the relatively low-value gypsum noncommercial. For instance, the upper part of the Toroweap Formation contains gypsum beds as much as 30 m thick. However, this gypsum is typically sandwiched between thick resistant carbonates of the Toroweap and the overlying Kaibab Formation, and thus only small amounts of gypsum could be mined by open pit methods without prohibitively expensive overburden removal. The three active gypsum mines in the Las Vegas area—PABCO (Apex), Blue Diamond, and Pioneer—exploit relatively flat-lying gypsum deposits that require removal of little or no overburden. Presumably, Fibreboard Paper Products moved its gypsum mining operations from the Rainbow Gardens area to the PABCO (Apex) location to reduce mining costs and to ensure long-term reserves.

Limestone.—An area underlain by limestone in the north part of the ACEC is considered to have high potential for the limestone deposits for cement production, with a moderate level of certainty (tract RBG04, fig. 12). Although the chemical composition of this limestone has not been directly determined, XRD analyses indicate that it is nearly pure calcium carbonate. Similar lacustrine limestone is mined by Nevada Cement Company for cement production in northern Nevada (Hardy and others, 2004). Other limestone units in the area are considered to have low potential because they are dolomitic or contain other impurities.

Lithium Clay.—An area underlain by lithium-rich sedimentary rocks in the Lovell Wash Formation is judged to have moderate potential as a source of lithium clay (hectorite), with a low certainty level (tract RBG05, fig. 12). The presence of such clay in the area has been established, but the size and purity of possible deposits are unknown. The potential for the production of lithium chemicals is considered to be low. Modern lithium production comes almost exclusively from brines pumped from beneath playas (Kunasz, 2005). Lithium extraction from such brine deposits is very inexpensive, and it is unlikely that other sources will be developed in the near future.

Silica.—An area in the north part of the Rainbow Mountains ACEC contains large exposures of Coconino Sandstone as much as 70 m thick; elsewhere in the area the unit is thinner (Castor and others, 2000). The sandstone is similar to that in the Arden ACEC; however, Coconino Sandstone deposits in the Rainbow Gardens ACEC constitute a much smaller resource and commercial potential is low. On the basis of analyses from other areas, potential for commercial silica deposits in the Aztec Sandstone in the Rainbow Gardens ACEC is also low.

Metals.—Although copper and silver minerals occur in a breccia zone on the west flank of Frenchman Mountain, the potential for hydrothermal base- or precious-metal deposits in the ACEC is low.

Detailed geologic mapping in the area did not reveal other occurrences of mineralized rock, and there is nothing distinctive about the geologic environment of the single occurrence that would suggest the presence of undiscovered deposits.

Although anomalous radioactivity was noted in Precambrian rocks west of the Rainbow Gardens ACEC, and anomalously high uranium occurs with copper minerals near the west edge of the ACEC, the area is considered to have low potential for uranium deposits.

Leasable Minerals

The area is not within the regions considered by the BLM to be prospectively valuable for oil and gas (Smith and Gere, 1983). A single oil exploration hole, McAuley Associates No. 2, was drilled in 1953 to 691 m inside the ACEC near its western border (fig. 1). No geologic data are available, and it was reported as a dry hole by Garside and others (1988). Another dry hole, was drilled to 915 m about 1 km west of the ACEC. Muddy Dome No. 1 was drilled by Rosen Oil Co. in 1965 to a depth of 1,662 m about 5 km east of the ACEC. This hole targeted the Gale anticline, a feature mapped in the Gale Hills block by Longwell and others (1965). The hole was col-

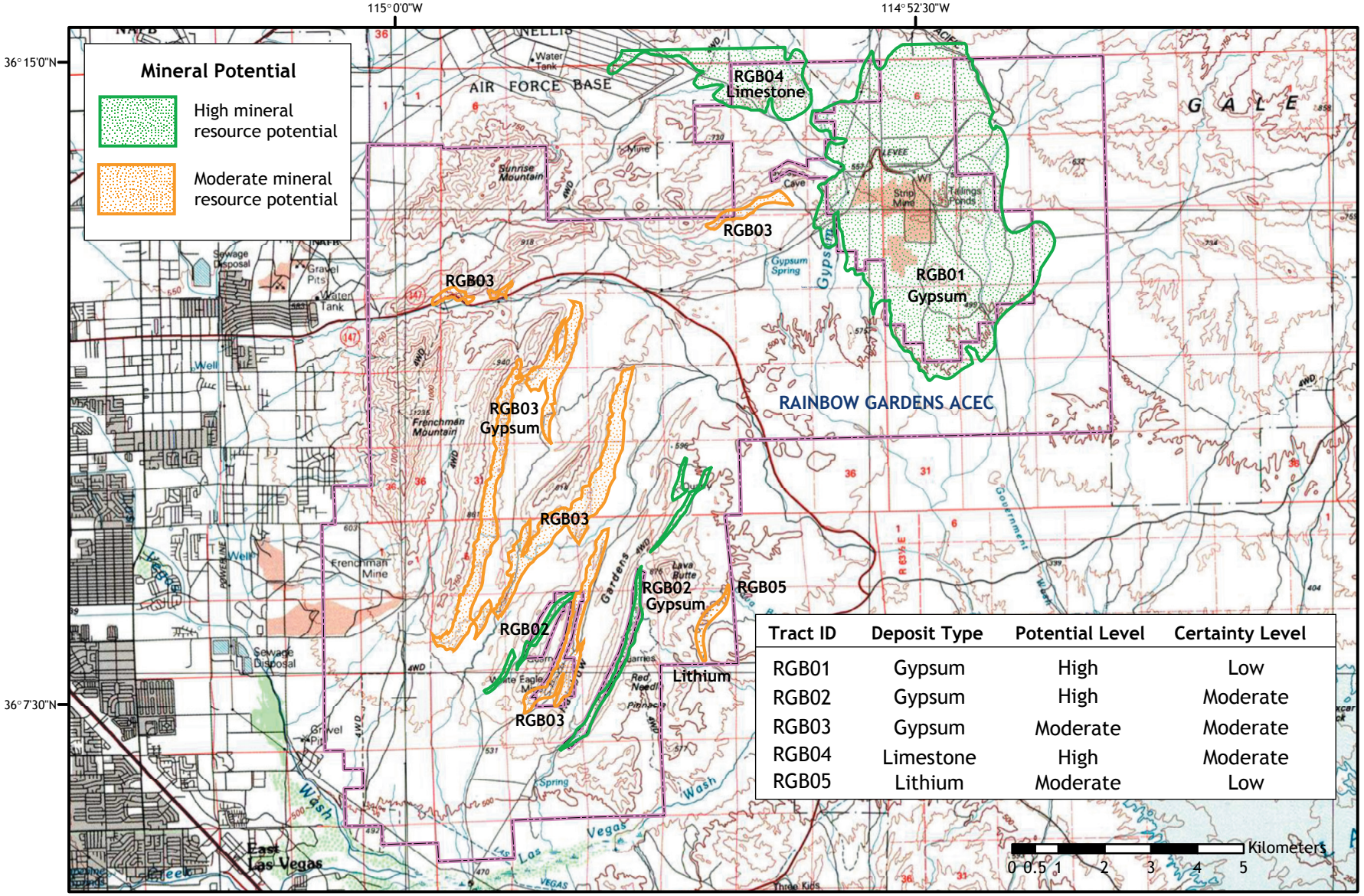

Figure 12. Mineral resource potential tracts for gypsum, limestone, and lithium resources in the Rainbow Gardens Area of Critical Environmental Concern (ACEC; outlined in pink).

lared in Jurassic sandstone and bottomed in the Permian Supai Formation. No oil and gas shows were reported, but fresh- and salt-water zones were noted at depth.

There is no indication of potential for brine or evaporite deposits of sodium or potassium. The Rainbow Gardens ACEC contains no known deposits of other leasable minerals, and the potential for their occurrence is low.

Salable Minerals

Crushed Stone.—High quality stone is confined to the Cambrian Nopah Formation, the Devonian Crystal Pass Member of the Sultan Formation, and the Permian Pakoon Limestone. These units contain less chert than other Paleozoic carbonate rocks. Together, they constitute tract ARBG01 (fig. 13), which has high potential for deposits of crushed-stone aggregate, with a moderate level of certainty.

Lower quality stone is characterized by chert-bearing carbonate rocks, and including the Cambrian Muav Limestone, Cambrian Frenchman Mountains Dolomite, Mississippian Redwall Limestone, and Permian Kaibab Formation. Portions of the Horse Spring Formation that are composed of conglomerate, sandstone, limestone, and volcanic rocks can also be considered in this category. These rocks constitute tract ARBG03 (fig. 13), which has moderate potential for deposits of crushed-stone aggregate, with a moderate level of certainty.

Triassic sedimentary rocks, Tertiary rocks of the Muddy Creek Formation, and gypsiferous and brecciated units of the Thumb Member of the Miocene Horse Spring Formation represent the lowest quality material, due to their friable nature, lack of thick sandstone and conglomerate units, and the presence of gypsum. These rocks constitute tract ARBG02 (fig. 13), which has low potential for deposits of crushed-stone aggregate, with a low level of certainty.

Sand and Gravel.—All the unconsolidated material in the Rainbow Gardens ACEC has high potential for sand and gravel aggregate deposits, with a high degree of certainty (tract ARBG04, fig. 13). Clasts in the most extensive and highest quality sand and gravel deposits are mainly carbonate rocks, and are in the southern and eastern part of the ACEC. The southern deposits are alluvial fans and are ideally situated to provide aggregate materials to the growing Las Vegas Valley. These materials are mostly carbonate rocks. The sand and gravel in the eastern part of the ACEC is mostly eroded from Miocene and Triassic deposits and may not perform as well in construction applications as aggregate supplied from the fans in the south.

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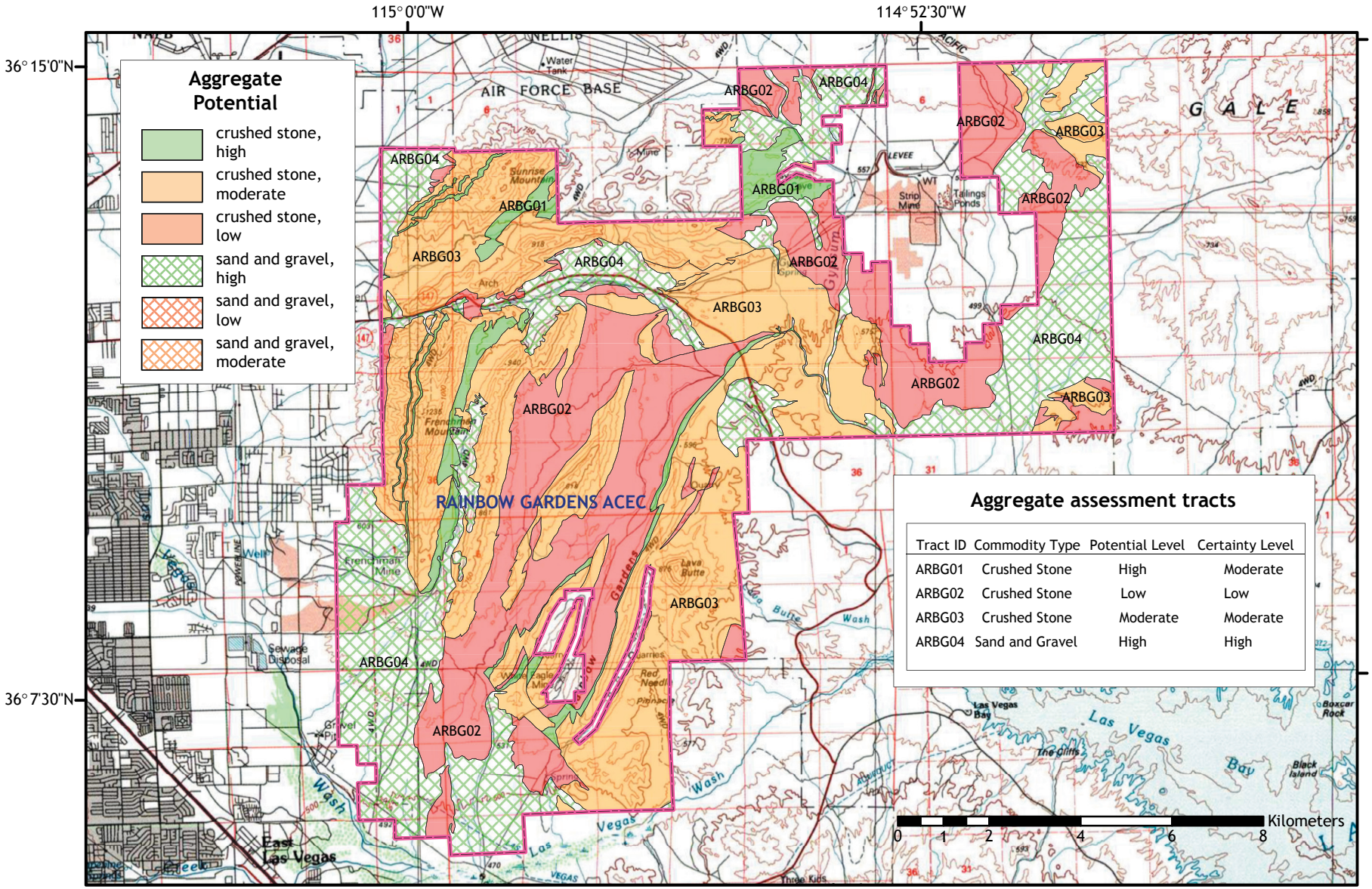

Figure 13. Mineral resource potential tracts for aggregate resources in the Rainbow Gardens Area of Critical Environmental Concern (ACEC; outlined in pink).

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