Whatcom County
Natural Resources Report

Mineral Resources

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We depend on minerals throughout our lives. In fact, each year an average of 40,000 pounds of new minerals are consumed for each American. At this level of consumption, the average child will need a lifetime supply of 800 pounds of lead...750 pounds of zinc...1,500 pounds of copper...3,593 pounds of aluminum...32,700 pounds of iron...26,550 pounds of clays...28,213 pounds of salt...and 1,238,101 pounds of stone, sand, gravel, and cement

American Mining Congress

INTRODUCTION

Document Purpose

The Whatcom County Mineral Resources Background Document is intended to serve as an information source for both the public and private sectors of the community. The background document complements the Mineral Resource Element of the County-wide Growth Management Comprehensive Plan. This document is supplied with the intent of providing information to decision makers and the general public involved in the planning process associates with the conservation and extraction of mineral resources in Whatcom County.

Historical Mining in Whatcom County

Mining activities in Whatcom County have taken place since the 1850's, though the nature, scope and extent of such activities has changed considerably through time. These changes have reflected the economics involved at each point in time at least as much as they reflect the geologic character of Whatcom County. Historically, the more important mineral commodities of Whatcom County have been coal, gold (placer and lode), sandstone, clay, peat, limestone, olivine, and sand and gravel aggregate, the latter three especially important at present. Many other commodities, however, have been prospected for or extracted.

METALLIC MINERAL RESOURCES

Overview

Historically, the exploitation of metallic minerals in Whatcom County has been limited, and since 1958 insignificant. In Mines and Mineral Deposits of Whatcom County, Washington, Wayne Moen states that silver, copper, lead, zinc and especially gold have been the only metallic minerals extracted with any economic significance.

Nearly all metallic mineral mining activities have been confined to the zones designated as the Mount Baker Mining district and the Slate Creek Mining district which are in the eastern portions of the county within the Mt. Baker National Forest. Rugged topography and extreme climatic conditions have limited accessibility and development of these mineral deposits. The Mount Baker Mining district is bounded on the north by the international boundary; on the east by Ross Lake; on the west by Sumas, Deming, and Lawrence; and on the south by a direct east-west line that intersects the peak of Mount Baker (Figure 1).

Placer and Lode Gold

Intermittent placer gold mining activity has taken place since the late 1850's, with more enduring and concentrated activities along the South Fork of the Nooksack River and in the Ruby Creek area of eastern Whatcom County. Numerous prospects have been made, but sites of notable production are limited. Of the lode, or vein, gold mining activities, the more notable and productive mines have been the Lone Jack, Great Excelsior, and Boundary Red Mountain mines.

Other Metals

While other metals, including silver, lead, zinc, and copper, have been prospected for and mined in Whatcom County, limited production has occurred. Deposits of these other metals were often found as accessory minerals during gold mining. Most extraction of these, therefore, was largely coincidental.

Mining Claims

In 1872, Congress enacted the General Mining Law, which established rules for lode and placer mining claims. The law dedicated itself to the principle that the mineral lands of the public domain were to be forever open to "exploration and occupation." The most important stipulations are summarized as follows:

1. Lode claims on a discovered vein of ore are to be no more than fifteen hundred feet long, no more than three hundred feet wide, and no less than twenty-five feet wide along that vein at the surface.

2. Placer claims are to be established, where possible, to conform with the U.S. system of rectangular land surveys; no individual can claim more than twenty acres and no association of individuals can claim more than 160 acres.

3. On both lode and placer claims, no less than $100 worth of work is to be performed every year in order to hold the claim until it is "patented" when land ownership passes to the claimant.

4. After staking a claim and satisfying various stipulations of the law, a claimant can file an application for a patent, post and publish a notice of his application, and after sixty days, barring unusual circumstances, the patent is approved (Watkins 1992).

There are thirty-seven patented mining claims in Whatcom County extending over 980 acres. The majority are located at the very eastern edge of the county in the Slate Creek district. Six are in the Mount Baker area. Gold, both lode and placer, is the main ore mineral of the Slate Creek district. There has also been some silver, lead-zinc, and iron noted (Moen 1969). In the Mount Baker district, ore minerals that have been found include: gold, silver, lead-zinc, copper and nickel.

Whatcom County has numerous current unpatented claims.

Figure 1. Moen's Map of mineral resources in Whatcom County

NON-METALLIC MINERAL RESOURCES

Overview

Whatcom County has deposits of coal, clay, limestone, sand and gravel, building stone, peat, olivine, quartz, and natural gas (Moen 1969). Most of these deposits are within a 30-mile radius of Bellingham and are shown in Figure 1. All these materials have at one time or another been produced in the county; however, at present (1993), only limestone, sand and gravel, building stone, and olivine are being mined.

Coal

Coal was the earliest mineral commodity to receive attention, with the first mining activity beginning in 1853 around Bellingham Bay by the Bellingham Bay Coal Co. Although coal mining ceased in 1955, significant reserves remain. These have been estimated at 327 million tons (Moen 1969). For the most part, these reserves of largely bituminous (moderate grade) coal are located in five larger coal fields. These are (1) the Bellingham field, located along Bellingham Bay in the Marietta and north Bellingham vicinity; (2) the Lake Whatcom coal zone, in the Silver Beach and Lake Padden vicinities; (3) the Blue Canyon coal zone, straddling Whatcom and Skagit counties, (4) an area four to seven miles south-southeast of Everson and west of the Nooksack River; and (5) the Glacier anthracite coal field, near Glacier on the Mount Baker Highway. Total production of coal in Whatcom County was just under 6 million tons, with 5 1/4 million coming from the Bellingham Coal Mines Company mine in the Bellingham field.

The most recent activity related to coal has been in the Glacier anthracite coal field. Exploration under a Whatcom County conditional use permit was carried out between the years of 1978 and 1984. This anthracite coal is characterized by hardness (in contrast to the soft, bituminous coal), low sulfur content and lack of solubility.

Oil and Gas

Exploratory activity for oil and natural gas deposits has been fairly intensive. While nearly 100 oil and gas wells have been drilled, only five (all yielding gas) have recorded a level of production approaching any significance (Moen 1969). All five were in the same general vicinity. Despite the lack of previous oil and gas discoveries of any consequence, occasional exploratory activity still takes place, most recently with gas exploration in the Ferndale area in 1992 (Marlen Hansen).

Peat

Peat is a soil characterized by high content of plant-derived, organic material and large amounts of moisture. This organic material may be in various stages of decomposition, depending on the moisture content and availability of air; with more moisture and less air inhibiting decomposition. Peat soils are generally located in undrained depressions where water is trapped, such as wetlands or along lakes. Numerous small peat deposits are located in Whatcom County. The larger deposits are in the areas surrounding, or in the vicinities of Fazon, Pangborn, Fountain, Green, Terrell, and Mosquito Lakes.

Of these larger peat deposits, only the deposit near Mosquito Lake has been exploited at a large scale, with 5000 tons of sphagnum peat sold to markets outside Whatcom County in the years 1935 to 1942 (Moen 1969). Other peat mining activities have been limited to local use. The uses of peat are for soil improvement, the making of certain fertilizers, barn litter, packing material, and fuel. Its most common usage in this region is as a soil conditioner.

Today, many areas in Whatcom County with peat deposits are rated as high quality wetlands and are considered to be more valuable if left in their natural state.

Asbestos

Limited quantities of high quality asbestos have been found in Whatcom County, but no deposit is extensive enough to be of commercial value. Moen (1969, p. 34) states that "the asbestos is associated with serpentinized phases of olivine and occurs as thin veinlets that are usually less than 1/4 inch in width". The more significant locations of asbestos are Bowman Mountain and Twin Sisters Mountain.

Quartz

Quartz, a silica mineral, occurs in many parts of the county, but most deposits are small. Common quartz occurs mainly in veins and irregular-shape lenses and pods in a wide variety of rocks. The veins occur most commonly in the mining districts of the county, quartz being a common mineral associated with ore deposits (Moen 1969).

Quartz was mined sporadically until the 1960's at a site located four miles southeast of Sumas. The silica from this site was used in the manufacture of a low-temperature cement. Much of this cement was used in the construction of Grand Coulee Dam.

Clay

Clay, categorized either common or fire, is mined for use in various types of brick and tile. It has been mined sporadically in Whatcom County, with activity gradually decreasing with time (Moen 1969). There are, however, dozens of notable common clay deposits throughout the county. Of the many historic extraction sites, several stand out as being more productive. These are the Brennan pit, located in southern Ferndale, and the Hampton pit, located near the intersection of Hampton and Trapline Roads, one and one half miles north of Everson.

Fire clay is used for production of heat resistant brick and tile. The larger deposits and all of the extractive activities concerning fire clay are located two and one half to four miles southeast of Sumas near the Reese Hill Road. Moen states that four mine areas were of significance, but does not specify production figures of these.

Current records indicate there is no clay extraction activity today other then the deposits removed on the surface in order to reach aggregate resources below. These clay soils or overburden may be used as liner for ponds or manure lagoons or used for berming a mining operation.

Olivine

Whatcom County is home to one of the largest know deposits of olivine in the U.S. The Twin Sisters Mountain is chiefly comprised of this mineral.

Olivine is an iron/magnesium silicate and is named for its olive green color. A rock of ninety percent or more olivine it is called dunite. Smith (1991) states that all commercial deposits are of igneous origin. Some occur as lens-like bodies, while others are massive by tectonic emplacement. A piece of the mantle is actually thrust through the crust to the surface to form huge deposits.

The Twin Sisters dunite was first investigated for economic potential in 1938 and mined in 1946. While olivine in general is fairly common, larger and purer deposits viable for commercial exploitation are rare (Moen 1969).

Olivine has many attributes which make it a commercially useful mineral. Smith lists many of the advantages olivine has over other industrial minerals, including chemical stability and mineral hardness, high melting point, and a durable grain that can be reclaimed.

The uses of olivine fall largely into three categories; (1) uses related to steel production, (2) to foundry activities, and (3) for refractory materials. It has been used as ballast on some North Sea oil rigs, as roofing tile, and as a source of magnesium for fertilizer. The Twin Sisters olivine, however, is usually crushed and mixed with a high alumina cement to form large bricks or plates. These bricks are then used as linings on high efficiency incinerators.

The extraction of high quality Twin Sisters dunite (olivine) by the Olivine Corporation, largely from the Swen Larsen Quarry, has ranged from 400 tons in the early years of operation to a present annual average of approximately 70,000 to 80,000 tons (Smith 1991). If demand for high efficiency incinerators increases, production will likely increase, also.

Construction Materials

Economic Significance

Revenues from crushed stone, sand, and gravel were over $180 million in 1989 and $135 million in 1991, putting Washington fifth among the states in production of sand and gravel (Joseph 1990). The Washington Aggregates and Concrete Association reports the following additional statistics:

1. A 2,000 sq. ft. Washington home consumes about 240 tons of sand and gravel.

2. Each land mile of typical county road requires approximately 4,600 tons of sand and gravel.

3. The I-90 project from Eastgate to Seattle will have utilized well over 1,000,000 cubic yards of concrete upon completion.

4. Each Washington citizen consumes 1.2 cubic yards of concrete and 11.3 tons (1 truckload) of sand and gravel each year.

The economics of the sand and gravel industry in Whatcom County is significant in terms of dollar value of the resource and number of people employed. According to information derived from a survey of industry operators, approximately 140 people were directly employed by mining activities in Whatcom County in 1990.

Figure 2. Uses of sand and gravel in the United States.

Figure 3. Uses of rock in the United States.

Building Stone

Building stone can be defined as any rock type that is suitable for construction purposes because it has acceptable durability and attractiveness and can be economically produced (Gulick 1992).

As recently as 1964, there were at least 50 producers of dimension stone or rough construction stone. By 1992, however, there were fewer than ten statewide (Gulick 1992). Today demand for rock is mainly for crushed and large landscaping stone, rockery, and exposed aggregates. Raw materials and production is unevenly divided over the state, with igneous rock varieties coming chiefly from western and central Washington and metamorphic rock (dolomite, marble and quartzite) production coming primarily from northeastern Washington.

In the late 1800's and early 1900's a sandstone quarry, called the Chuckanut Quarry, south of Bellingham operated on a commercial basis. This quarry closed when brick, concrete, and terra cotta were substituted for sandstone. A rock known as "Shuksan Stone" which is a green andesite, has also been used as building stone.

Gulick lists the Whatcom Skagit Quarry in his table of 'Producers of Decorative Stone in Washington' as the only quarry in Whatcom County. While this quarry is close to the Whatcom/Skagit county line, it is actually located in Skagit County. They supply a dark, dense rock used mainly for rockery material. The limestone quarries in the Kendall/Sumas area also produce rock for decorative and rockery purposes.

Limestone

Limestone has been mined since the early 1900's in Whatcom County (Moen 1969). Historically, the main use for limestone was for portland cement manufacturers and pulp and paper industries. Today, limestone is mined in the Red Mountain area, north of Kendall and is primarily used for rip-rap to mitigate effects of flooding, for crushed rock, and for pulp mills (Derkey and Gulick 1992) (Roubleau 1992).

Limestone mining has decreased significantly over the years. In 1966, about 500,000 tons of limestone was produced annually from deposits on Red Mountain, and from deposits north of Maple Falls (Moen 1969). In 1991, the Tilbury Cement Co. produced about 80,000 tons at the Kendall quarry; the Clauson Lime Co. produced 130,000 tons at the Silver Lake quarry (Derkey and Gulick 1992). By 1992, the Tilbury Cement Co. and the Clauson Lime Co. each mined about 10,000 tons (Derkey, Gulick and Lingley 1993).

Figure 4. Silver Lake Quarry, 1990. Mining limestone.

Sand and Gravel

The Fraser Glaciation occurred 20,000 to 10,000 years ago and was the last major advance and retreat of continental glaciers in Washington. This geologic event largely determined the surficial geology of what is now Whatcom County. The three phases of this glaciation, oldest to youngest, are the Vashon Stade, the Everson Interstade, and the Sumas Stade: a stade being a glacial episode marked by ice advance, and an interstade being a warmer climatic episode marked by temporary retreat of the ice (Easterbrook 1973).

The abundance of sand and gravel resources in Washington state is due largely to the process of glaciation, and to a lesser extent, recent and historic river deposits. Most important are the glacial outwash deposits of which there are several types; outwash kame deposits, outwash channel deposits, and outwash delta deposits. The latter is the most significant in volume, consistency, and ease of mining (Lepp and Flowers 1989). Historical river terrace deposits are an important resource in some locations. Gravel deposited by modern rivers is important, also, but many considerations must be taken into account before exploiting this type of source.

In Whatcom County, sand and gravel mining occurs mainly east of I-5 and north of Bellingham with some exceptions. The more important areas from east to west include: (1) the Siper and Hopewell Road area two miles north of Nugents Corner; (2) the Breckenridge Road area just east of Nooksack; (3) the Pangborn and Van Buren Road area two and one half miles southwest of Sumas; (4) the Pole and Everson Goshen Road area to the southwest of Everson; (5) the Axton Road area one mile east of Laurel; and (6) the Valley View Road area three miles to the east of Blaine. It is estimated that in 1993 approximately 1.5 million cubic yards of sand and gravel from upland pits were excavated in Whatcom County (Whatcom County Planning).

Extraction of river gravel occurs primarily on the banks of the Nooksack River between Deming and Lynden, as determined by aggregate size and composition. As of March, 1993, 34 gravel bars had approved status for extraction. Between 1990 and 1993 an average of 170,000 cubic yards per year of river gravel were removed from the Nooksack River (KCM Inc. 1994).

Figure 5. Axton Road site, 1990. Extraction of high quality gravel deposit.

GROWTH MANAGEMENT ACT

INTRODUCTION

The extraction of minerals, in particular sand and gravel, is especially important in areas characterized by growth, such as western Washington. In the late 1980s, sand and gravel extraction reached record levels in both tonnage and gross value, the material an essential element in the construction of roads, homes, schools, shopping centers and other structures. To a degree this reflected growth in economic activities, which in turn may reflect the health of the state's economy. Much of this growth is in the form of urbanization. While urbanization creates demand for sand and gravel resources, it may also encroach upon or build over those same resources, rendering them inaccessible. Strong community opposition to mining near residential, agricultural or sensitive environmental areas may limit extractive opportunities.

In 1990, the Washington State Legislature passed the Growth Management Act. Its purpose was to address the issue of economic and population growth and how best to manage or encourage such growth. One of the goals of the Act is to maintain and enhance resource-based industries, including the aggregate and mineral resource industries, with the purpose of assuring the long-term conservation of resource lands for future use. The Act mandates that each county shall classify mineral resource lands and designate and protect areas not already characterized by urban growth that have long-term commercial significance.

CLASSIFICATION OF MINERAL RESOURCES

The **Minimum Guidelines to Classify Mineral Resource Lands** (365-190-070 WAC) states that counties should classify lands with long-term commercial significance for extracting at least the following minerals: sand, gravel, and valuable metallic substances. Other minerals may be classified as appropriate. The Guidelines suggest using a detailed classification system provided by the Department of Natural Resources (Appendix A). Whatcom County chose to utilize this system (albeit abbreviated) with the adoption of the Interim Classification of Mineral Resources. This system classifies areas into Mineral Resource Areas (MRA) and Scientific Resource Sites (SRS), as defined below.

1. MRA-1--Areas where adequate information indicates that no significant mineral deposits are present, or where it is judged that there is little likelihood for their presence. This area shall be applied where well-developed lines of reasoning, based upon economic geologic principles and adequate data, demonstrate that the likelihood for occurrence of significant mineral deposits is nil or slight.

2. MRA-2--Areas where adequate information indicates that significant mineral deposits are present or where it is judged that there is a high likelihood for their presence. This area shall be applied to known mineral deposits or where well-developed lines of reasoning, based upon economic geologic principles and adequate data, demonstrate that the likelihood for occurrence of significant mineral deposits is high.

3. MRA-3--Areas containing mineral deposits the significance of which cannot be evaluated from available data.

4. MRA-4--Areas where available information is inadequate for assignment to any other MRA.

5. SRS containing unique or rare occurrences of rocks, minerals, or fossils that are of outstanding scientific significance.

During 1992, Whatcom County Planning, with consultant assistance[1], used existing resource information with the above classification methodology and delineated a classification map of sand and gravel deposits (Figure 6). The following sources of information were used for this project:

1. Soils listed under the USDA, Soil Conservation Service, Whatcom Soil Survey as probable sources of sand and gravel. A soil rated as a probable source has a layer of clean sand or gravel or a layer of sand or gravel that is up to 12 percent silty fines. This material must be as least 3 feet thick and less than 50 percent, by weight, large stones. All other soils are rated as an improbable source. Course fragments of soft bedrock, such as shale and siltstone, are excluded from this category.

2. Engineering characteristics of Geologic Materials, Western Whatcom County, (Easterbrook, 1976). Material types identified were those described as either "Sand" or "Mostly Gravel, Some Till."

3. Geologic map of Western Whatcom County, Washington (Easterbrook, 1976). Easterbrook's maps provided a general outline of the extent of sand and gravel-bearing geologic units.

4. Known locations of surface mining operations from a County-wide inventory completed by Whatcom County Planning during 1990. This provided information identifying areas where economically valuable deposits of sand and gravel exist or have existed.

5. Washington State Water Well Reports for Whatcom County.

The MRA-1 classification was applied to areas consisting of outcrops of pre-glacial geologic formations. Pre-glacial rocks generally consist of volcanic, metamorphic and lithified sedimentary rock not usually containing aggregate resources. Pre-glacial rocks have been identified mostly in the eastern and southern boundaries of the study area.

The MRA-2 classification was applied where the following conditions were met:

1. The location contains a mappable geologic unit described as containing well-defined zone(s) of appreciable sand and/or gravel; and

2. A portion of the mapped unit had evidence of currently or once having been used as an economic source of sand and/or gravel.

The MRA-3 classification was applied for areas which did not correspond to either of the other classifications due to lack of adequate information or where the following conditions existed:

1. The location contained a mappable geologic unit described as containing well-defined zone(s) of appreciable sand and/or gravel but data does not indicate that it has been used as an economic source of sand and/or gravel; or

2. The location is part of the study area that has evidence of once having been used as an economic source of sand and/or gravel but is not mapped as a geologic unit described as containing well defined zone(s) of appreciable sand and/or gravel.

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[1] [illegible] 1 [illegible], [illegible]. [illegible], [illegible]. [illegible] 2, 1992.

The MRA-4 classification was not applied as available information was sufficient to classify all areas into MRA-1, MRA-2, or MRA-3. The SRS classification was not a focus of this project.

During 1994, Whatcom County Planning and Development Services prepared a bedrock classification system. This system was based largely on Mines and Mineral Deposits of Whatcom County, Washington, by Wayne S. Moen, 1969, combined with field investigation of historic and currently active rock quarries with the potential for long term commercial use. This study concluded that most bedrock of Mesozoic or Paleozoic age in Whatcom County has the potential to be suitable for WSDOT or AASHTO specified construction material. These rocks occupy the northeast and southeast corners of the county as well as the southern half of Lummi Island. Darrington Phyllite, a soft graphitic rock of this age group, but usually unsuitable for the necessary specifications, was not included in this classification. Because the classified unit is composed of a variety of volcanic and sedimentary rocks with varying degrees of hardness, it is estimated that only 50% would be useable. Defining exactly where within the classified unit this material exists would be extremely costly. In many instances, the subject bedrock is overlain and hidden by varying thicknesses of aggregate or other Quaternary sediments (Goldthorpe, 1994). The following is a description of the rocks included in the classification system (from Moen, 1969).

Mesozoic:

Upper Jurassic - Lower Cretaceous sedimentary and volcanic rocks.

Greywacke, argillite, siltstone, slate, phyllite, greywacke breccia, ribbon chert, minor limestone, lenses of basalt flows.

Middle Jurassic volcanic rocks

Andesite, dacite, minor basalt, slate and greywacke interbeds.

Lower and Middle Jurassic marine rocks.

Dark gray, massive to thick-bedded, siliceous argillite, siltstone, and shale, including minor greywacke and limestone.

Upper Triassic and/or Lower Jurassic marine rocks.

Conglomerate, gritstone, greywacke, and carbonaceous argillite.

Paleozoic:

Permian rocks.

Limestone

Carboniferous and Permian volcanic rocks.

Predominantly altered andesite, basalt, and diabase with interbedded chert and argillite, including some tuff, greenstone, and spillte volcanic rocks.

Carboniferous - Permian sedimentary and volcanic rocks.

Sedimentary and volcanic rocks: undivided cherty and slatey argillite, siltstone, grewacke, chert, greenstone, tuff, andesite, and spillite volcanics, and predominantly sedimentary rocks of greywacke, argillite, and slate, including minor marble, siltstone, arkose, conglomerate, ribbon chert, and volcanic rocks.

Physical and Chemical Requirements: Aggregate

Natural aggregate varies widely in quality, depending on the source. Testing laboratories compare aggregate properties with predetermined standards to ensure that aggregate is suited for particular uses. Suitable aggregate consists of clean, uncoated particles of proper size and gradation, shape, physical soundness, hardness and strength, and chemical properties. The final use of the aggregate determines the specific properties sought.

Generally, specifications for aggregate used in cement concrete or bituminous mixes (asphalt) are more stringent than are those for other construction-related uses.

Mechanical sieving or screening is used to grade, or sort to size, aggregate. In general, aggregate for cement concrete should be well-graded throughout the sand and gravel range of particle sizes, although gap grading (aggregate with specific particle sizes missing) may be used and may be necessary for some products. No general statements can be made about specifications for bituminous mixes because they are dependent on pavement design.

Particle shape affects both the grading limits of aggregate used in cement concrete and the workability of the concrete. The presence of excessive amounts of angular particles can require addition of a greater percentage of sand to the mixture, which in turn requires more water and cement. In contrast, because intergranular contact provides strength in bituminous mixes, angular particles generally are desirable. Smooth particle surfaces offer little assistance in holding the aggregate in place in bituminous mixes. In both cement concrete and bituminous mixes, too many flat or long particle may be harmful.

Physical soundness is the ability of aggregate to resist weathering, particularly freeze-thaw and wet-dry cycles. Generally, aggregate that contains weak, easily broken, absorptive, or swelling particles is not suitable. Hardness and strength of aggregate affect the ability of the final product to resist mechanical breakdown. The breakdown of soft or weak particles during handling or mixing is deleterious in both cement concrete and bituminous mixes.

Ideally the aggregate is an inert filler, and it should not change chemically once in place. However, some aggregate contains minerals that chemically react with or otherwise adversely affect the concrete or bituminous mixes. In the manufacture of cement concrete, preference is toward stronger, high-density igneous rocks and those rock types which are less likely to react to certain chemicals used in the process.

When aggregate does not meet the required specifications, a number of corrective alternatives exist. These include (1) blending high-quality aggregate with the unsuitable aggregate to achieve an acceptable overall quality; (2) removing deleterious materials from the aggregate by processing techniques; (3) making adjustments during processing, such as recrushing to change particle shape; or (4) adding chemicals or making other adjustments to cement mixtures or bituminous mixes (Langer and Glanzman 1993).

Quantity

There are several components to consider when discussing resource quantity. These are: (1) volumes of minable material, (2) thickness of the deposit, and (3) the amount and characteristics of the overburden (Lepp and Flowers 1989). Thick deposits which have a minimal amount of overburden are most desirable. Generally deposits must have ten years of supply, should be at least 30 feet thick, and have less than 15 feet of overburden. These components may be considered against one another at any particular site.

7. GIS Classification and Designation Map

DESIGNATION OF MINERAL RESOURCES

Whatcom County completed interim designations approximately two years ago. These were based upon the following statutory direction: "On or before September 1, 1991, each county (required to plan under the Act) shall designate where appropriate... Mineral resource lands that are not already characterized by urban growth and that have long-term significance for the extraction of minerals... (RCW 36.70A.170)." "Minerals" include gravel, sand, and valuable metallic substances (RCW 36.70A.030(11). The Growth Management Act also directed counties to "adopt development regulations...to assure the conservation of...(designated) mineral resource lands...(RCW 36.70A.060(1)."

Whatcom County responded to the above mandates as follows: (1) By adopting Mineral Resource Land (MRL) designations covering 1,250 acres of lowland sand and gravel deposits. Of the 1,250 acres of uplands that were designated, approximately 250 acres are in the Agricultural zone and 1000 acres are in the Rural zone (either 5 or 10 acre densities). The designations also include river gravel bar supplies from the Nooksack River. All of these areas had existing reclamation permits from the State DNR covering at least twenty acres; and (2) By restricting density to one unit per twenty acres within MRL designations and, more recently, by requiring disclosure notices on property and development within three hundred feet of the MRL's.

The following is a discussion of new information obtained since the interim designations were made. This information on supply and demand should help to provide a basis for making decisions on final mineral designations as one component of the GMA Comprehensive Plan.

Permitted Reserves

A county-wide inventory of upland sand and gravel, river gravel and quarry rock was compiled and used to determine existing permitted reserves. Information was gathered from numerous sources; aerial photographs, files at Washington State Department of Natural Resources, staff interviews, Whatcom County permit records, site visits by Planning Staff, Whatcom County Assessor records, registration forms from mine owners for 1993 and 1994, the citizens advisory committee for GMA, staff at the Whatcom County Department of Transportation, and personal communication with mine operators and owners. The types of information gathered included: (1) type of material mined, (2) groundwater depth, (3) average depth of gravel pit, (4) number of acres disturbed and number reclaimed, (5) permit details, (6) legal status, and, (7) amount of reserves above and below the groundwater level for each mine. Overall results of the study are shown below. Specifically, the following methodology was used to determine sand and gravel reserves:

1. State and/or County permitted acreage and depth was determined.
2. Excavated and/or reclaimed areas was subtracted.
3. Remaining acreage was multiplied by depth and 1290 cubic yards. (1290 is equivalent to an 80% net to gross ratio). The ratio accounts for setbacks within the permitted area and overburden that may not be used).
4. Resulting figures were then compared against estimates received by the owners or operators of the site. When staff numbers were greater, the owner/operator estimate was used. When owner numbers were greater, staff numbers were used.
5. In a few cases, where the site has no permits but is grandfathered, an average annual rate of extraction was determined and then multiplied for 50 years. The resulting figure was used when it was less then the total above groundwater estimated reserves on the parcel. Otherwise, the total reserve figure was used.

Information on river gravel extraction activity came from Gravel Management Program Analysis, Lower Nooksack River, Comprehensive Flood Hazard Management Plan, 1994 by

KCM. Approximately 210,000 total cubic yards were removed from the Nooksack River at five different locations in 1993. An average figure of 170,000 cubic yards per year, calculated for the years 1990-1993 was used to project river gravel reserves over a fifty year planning horizon.

Study Results

In 1993, there were approximately 76 permitted surface mines in Whatcom County covering a total of 2,258 acres (Figure 12). A permitted surface mine is one that has either a valid DNR permit, a Whatcom County Surface Mine permit, a Whatcom County Condition Use permit or has non-conforming status. The total amount of permitted sand and gravel reserves held within these sites was approximately 57 million cubic yards (MCY). Total amount of permitted quarry rock reserves is presently estimated at 34.5 million cubic yards, comprised mostly of limestone from Red Mountain, two miles north of Kendall. The following table summarizes sand and gravel reserves by region and relationship above and below groundwater levels.

REGION (see fig 7)	**ABOVE GW (MCY)**	**BELOW GW (MCY)**
SIPER	5.8	2.5
ALM	7.0	1.65
AXTON	1.1	.2
GOSHEN	6.7	7.7
SUMAS	7.18	0
POLE	1.98	0
FOOTHILLS	3.8	0
BLAINE	4.56	.36
I-5 (mostly sand)	2.0	.23
T-38	4.27	0
TOTAL	**44.39**	**12.64**

Table 1. Permitted sand and gravel reserves by region, Whatcom County.

Figure 12. GIS Location Map

Figure 10. Total permitted reserves (excluding olivine) above and below water table.

Figure 11. Permitted reserves **in** MRL, above and below water table.

Reserve Considerations

The above reserve estimates are an approximation of reserve quantity. As discussed in the section on mineral classification (pg 12), construction aggregate varies widely in quality, depending on the source. Some mineral extraction sites in Whatcom County contain higher quality deposits than other areas. For example, the Blaine region contains relatively shallow deposits of sand and gravel intermixed with a high amount of silt material. The presence of these fines results in operational limitations during the wet seasons due to handling and other workability problems. The most valuable deposits contain low amounts of clays and relatively high amounts of material suitable for processing into a finished aggregate product.

During 1994, The Whatcom County Sand and Gravel Association obtained information through their own industry survey with regard to the availability and quality of mineral resources within Whatcom County. Surveys were sent to holders of the larger active permitted sites in the County. The survey found that of the 26 sites for which results were obtained, the total volume of available extractable material was just over 13 million cubic yards. Of this material, 43% was located below the water table. From these sites surveyed and from additional information, they concluded that approximately 44% of the material remaining in the surveyed sites is suitable for processed material and that 65-70% of the material sold from the combination of sites in the past has been processed material. This data may support the concern raised by some sand and gravel operators that, while overall reserves may be high, the percentage of gravel within these reserves may be lower than expected.

Demand

Per Capita consumption of sand and gravel and rock was determined by dividing 1993 extraction amounts by the County population during that year. Extraction amounts for 1993 came from the 1993 registration forms submitted by mine owners or operators and from the above mentioned KCM report. The amounts were broken down by upland sand and gravel, upland plus river sand and gravel, and quarry rock.

Material Type	1993 Extraction Amounts (cubic yards)	Per Capita Consumption (cubic yards/person)
Sand & Gravel	1,516,960	10.8
Upland and River Sand & Gravel	1,724,960	12.2
Rock (excluding olivine)	185,330	1.3[2]

Table 2. Per Capita Consumption, Whatcom County, 1993.

Population

Population estimates come from two sources and a best estimate for the years not covered. For the years 1993 to 2014 projections come from Whatcom County county-wide planning policies. For the years 2020 to 2040, the Mid-Forecast from <u>Population, Economic and Housing Projections, October 1991, Property Counselors in association with David Evans &</u>

[2] [illegible] 1993 [illegible]. [illegible] ([illegible] 1993).

Assoc., McCutcheon Demographics, Judith Stoloff & Assoc. was used. For the intervening years 2014 to 2019 an average was used to bridge the information gap.

Figure 8. Actual and projected population for Whatcom County.

The per capita consumption figures were then used to project sand & gravel and rock demand to 2042.

Year	Upland Sand & Gravel (cubic yards in millions)	Rock (excluding olivine) (cubic yards in millions)
	Cumulative Demand	Cumulative Demand
1993	1.5	0.2
2000	11.3	1.4
2010	30.2	3.6
2020	53.1	6.4
2030	80.8	9.7
2042	121.7	14.6

Table 3. Upland sand and gravel, and rock demand, Whatcom County, 1993.

Projecting the estimated 1993 per capita demand for construction aggregate over fifty years realizes a total demand of 145 MCY's (this includes 8.5 MCY's of river gravel). This assumes an equal consumption per person today and fifty years from today. Total per capita annual demand in Washington State in 1992 was 9 cubic yards of sand and gravel and 3 cubic yards of rock (Lingley and Manson, 1992). Supply considerations statewide, however, indicate that markets of the future will increasingly rely on crushed bedrock. Washington State DNR also anticipates that conservation and increasing production costs of rock products will reduce long-term gravel consumption (Lingley, 1994). They recommend, as a minimum for those counties opting to plan on a fifty-year horizon, that the fifty-year plan should include 4.8 cubic yards/person of sand and gravel and 4.8 cubic yards/person of quarried bedrock. This figure would

require approximately 115 MCY's for a fifty-year supply of construction aggregate in Whatcom County. If the final designations included all permitted reserves, they would still fall between 15 and 45 MCY's short (depending on which per capita figure is used) of reaching the supply goal. This shortfall could be greater due to a number of circumstance such as increased export markets, the possible substitution of masonry materials for wood products, or the construction of mass transportation systems. This also assumes an accurate reserve estimate.

Figure 11. Demand versus supply - Upland and river sand and gravel, Whatcom County.

<u>Operating Costs</u>

Concerning typical operating costs, Lingley and Norman (1991, p. 39) state that:

The concrete and asphalt aggregate mining businesses are intensely competitive. Typical returns on capital invested are 12 percent, and typical gross profits are $1.00/ton. Approximate per-ton mine operating costs are $0.50 for land owner royalties, $1.00 for loading (by front-end loaders or conveyor belts), $2.00 for processing (sorting and crushing), and $0.25/ton/mile for transportation. The costs of transportation controls the price of rock products; a moderate increase in the distance from mine to market markedly increases the cost of the rock.

The constraints of hauling costs limit the distance that viable sand and gravel resources can be located from the market. The typical prices given below[3] vary from site to site.

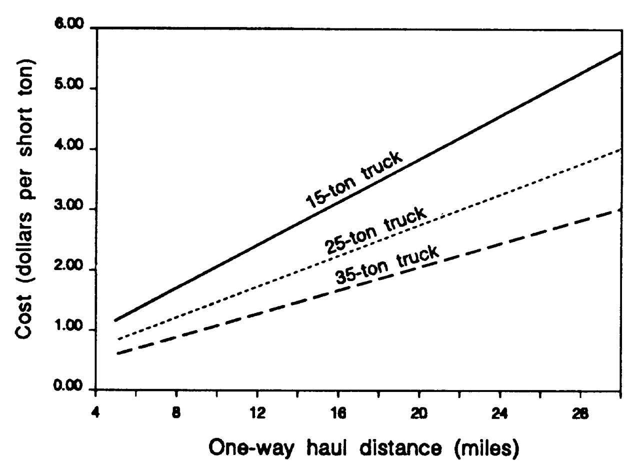
Typical 1991 Operating Costs (per ton in dollars):

$ .50 - Land owner royalties
1.00 - Loading (front-end or conveyor)
2.00 - Processing (sorting and crushing)
1.00 - Gross profit

4.50 - Total Cost (incl. gross profit) without considering transportation.

+ .20 - Transportation cost per ton/mile.

One-way Haul Distance (miles):



[3] [illegible], 1992, [illegible] 87.

The cost of gravel rises quickly with increased distance at 20 cents per mile. From the table above, it is apparent that the size of the truck is also important. For approximately the same price, $2.00 per ton, a 15-ton truck will go ten miles; a 25-ton truck, 15 miles; and a 35-ton truck, 20 miles.

Sand and Gravel Exports

Some export and import of sand and gravel occurs between Whatcom County and Canada. The issue of sand and gravel export is of local importance, given that Whatcom County is adjacent to the large, growing metropolitan center in the Lower Mainland Region of British Columbia. There is some concern that unnecessary landscape degradation and land-use conflicts are arising in portions of the County due to the export of this resource. Of the estimated 1.7 million cubic yards of sand and gravel, including river gravel, extracted annually in the county (1993), approximately ten percent or 170,000 cubic yards may be exported (exact figures are difficult to obtain).

With a large amount of current and predicted growth in the Lower Mainland region of British Columbia and various constraints on mineral extractive activities the issue of exports will continue to be of interest. Sand and gravel is also imported **from** Canada. The County Division of Maintenance and Operations imports 4,000 cubic yards to Point Roberts every seven years (Marlen Hansen, Public Works Department). Seattle imported more than three to four million cubic yards of sand and gravel via barge from Canada in 1991 (Eric Beresford, District Inspector, B.C. Ministry of Energy, Mines, and Petroleum Resources).

Three particular areas lend themselves to extraction for export due to their proximity to the international boundary, Canadian markets, and transportation routes. These are the Valley View Road area, Pangborn Road area, and, especially, the Halverstick Road area. In 1991, Columbia Aggregates applied for a permit to open a surface gravel mine near the Halverstick Road area and to export up to eight million cubic yards directly across the border by conveyor belt during a twelve to fifteen year period of operation.

Alternate Sources

Recyling

Recyling cement concrete and asphalt currently is a viable alternative for natural aggregate, and can be both economically and environmentally beneficial. In some states recycling is required. Recycling efforts have advantages in that (1) they may substitute for newly extracted materials, thus reducing the level of need to open new mines; (2) recycled materials may have certain properties which make their use preferable in certain cases (it is ideal as road base material); (3) they may reduce material demands on private mining operations by public agencies. At this time recycling of cement concrete and asphalt is uncommon in Whatcom County. Recycled materials often have considerable drawbacks with certain uses.

River Deposits

The Nooksack River is a source of sand and gravel production, with many agencies and private citizens viewing such a source favorably for two reasons, (1) the river is seen as a significant and renewable resource to be used as an alternative to expanding or opening new pit operations upland, and (2) the removal of gravel and the relationship to the issue of flood control.

Historically, the Nooksack River was a source of gravel until 1976, with gravel scalping operations removing up to 150,000 cubic yards annually. Such activity slowed in 1976 when a new royalty rate structure was imposed by the DNR in order to obtain more of a fair market value for the gravel for the citizens of the state. After a 1987 study by the Army Corps of Engineers, certain sites were identified as aggradational gravel bars and selected as scalping sites. Since that time the royalty rate structure has been further revised to ease permitting and encourage gravel extraction at those sites. As mentioned earlier, extraction of river gravel occurs primarily between Deming and Lynden, as determined by aggregate size and composition. As of March, 1993, 34 gravel bars had approved status for extraction. In 1993, 208,000 cubic yards of river gravel were removed from the Nooksack River (KCM, Inc. 1994). Recent annual extraction from this source is estimated at an average of 170,000 cubic yards per year.

Drawbacks to using the Nooksack River as a mineral resource as cited by gravel operators are as follows: (1) "the difficulty and costs in obtaining river access from property owners", (2) "regulatory and environmental restrictions on river operations" (more agencies are involved when streams are concerned), (3) "the better suitability of upland gravel for certain uses", (4) "actual physical problems with river gravel, i.e. sticks, excessive sand, and limited volumes from year to year', and (5) "the amount of royalty charged by the state". Other considerations include the fact that river access is often seasonal, and foreign materials in the aggregate are often subject to rot if they are not sorted out, which limits possible uses (DNR 1989).

The removal of gravel from rivers, however, is very complicated when viewed in terms of river dynamics. Gravel extraction has been documented to affect patterns of bank erosion, and to change the elevation and morphology of the river bed. These changes can in turn affect fish and wildlife habitat, flooding and engineering structures. Collins and Dunne (1990) state when evaluating a river for gravel extraction the following effects should be studied for past or probable future impacts:

Extracting more gravel than can be replenished from upstream causes bed degradation (gravel erosion) both upstream and downstream of the operation. This can result in the (1) undermining of pipelines or other buried structures, and bridge supports, (2) changing the shape of the channel which could affect aquatic habitat and salmon spawning sites, (3) erosion of substrate (material below the gravel) which could affect aquatic habitat, (4) lowering of groundwater levels, (5) bank collapse and erosion by increasing the heights of banks, and (6) downstream bars may erode if they receive less bed materials than is being carried downstream.

While the Nooksack River is the principal alluvial source under consideration for gravel use, other streams have possibilities for sand and gravel extraction. According to Bruce Mills from the Whatcom County Engineering Department these include: Boulder Creek, both Canyon Creeks, Gallup Creek, Glacier Creek, Porter Creek, and Swift Creek. A geologic investigation in 1975 estimated that the sediment load for Swift Creek alone was 123,000 cubic yards (Mills 1992). Although the Whatcom County Engineering Division estimates of these available resources range from 200,000 to 300,000 cubic yards per year, the actual numbers may be less due to prohibitive transportation costs, and the presence of large boulders that may hinder excavation and crushing activity.

Figure 16. Nooksack River gravel bar, 1990. Scalping operation.

SOCIAL AND ENVIRONMENTAL IMPACTS/LAND-USE CONSIDERATIONS

The following information addresses some of the social, environmental, or land-use issues that will be important to address within the context of future efforts to designate land for mineral extraction.

Air Quality

Air quality impacts from mining operations to adjacent land are in the form of dust and exhaust. Due to the climate in western Washington, characterized by three wet seasons and dry summers, dust impacts will often be seasonal in nature.

The emissions and their associated activities result from (1) processing activities; (2) stockpiling, and loading; and (3) emissions in the form of vehicle exhaust of machinery and trucks.

Emissions of dust, either through crushing and screening, or excavation and transfer, may be significant and are to some extent unavoidable. Mitigating measures, however, may be taken to reduce such impacts. Watering and paving of roads restricts the amount of dust generated due to traffic. Watering soil stockpiles and sorted gravel stockpiles, and vegetating berms may also reduce dust emissions. Rapid reclamation of sites is very important in reducing the amounts of particulate matter emitted.

Noise

Noise, according to the Environmental Protection Agency (EPA), is a "significant hazard to public health." Numerous studies show a link between distractive noise and human health. Unwanted noise can cause health problems such as stress, sleep disruption, and hinder mental and social well-being.

Sound is measured logarithmically in terms of decibels (DBA), which is a ratio between sound pressure level and sound frequency. Noise impacts must be considered in context of the frequencies sound. Certain noise frequencies have larger impacts on humans than others. Humans are more sensitive to those frequencies in the range of normal speech communications.

SELECTED DOMESTIC NOISE MAKES[4]	
ITEM	SOUND LEVEL dBA
Window air conditioner (10 ft.)	55
Inside quiet car (50 mph)	65
Vacuum cleaner (10 ft.)	75
Inside Sports car (50 ft.)	80
Garbage disposal (3 ft.)	80
Ringing alarm clock (2 ft.)	80
Flushing toilet	85
Lawn mower (operator's position)	105
Rock band (10 ft.)	115
Snowmobile (driver's position)	120

Table 4. Selected domestic noise makers and decibel levels

The Washington State Department of Ecology has enacted noise regulations, referred to as Environmental Designation for Noise Abatement or "EDNA's. Class A EDNAs are residential areas, Class B are commercial areas, and Class C are industrial areas. The maximum permissible noise levels are shown in the table below:

EDNA of Noise Source	EDNA of Receiving Property		
	Class A	Class B	Class C
Class A	55dBA	57dBA	60dBA
Class B	57dBA	60dBA	65dBA
Class C	60dBA	65dBA	70dBA

Table 5. EDNA Maximum decibels levels by class.

The code further states that between the hours of 10:00 PM and 7:00 AM the noise limitations of Table ? shall be reduced by 10 dBA for the receiving property within Class A EDNAs. In addition the code sets limits on the amount of dBAs that can be exceeded for short durations of time and lists exemptions to the noise level requirements as shown in table ?.

dBA	Minutes
15	1.5
10	5
5	15

Long-term noise impacts from surface mining generally result from the excavation and transport of various materials and the operation of crushers, screens, and washers. The noise levels at one hundred feet (100') from operating excavation and transport equipment are typically 70-80 decibels. Noise

4 [illegible], 1983, [illegible]. 346.

from crushers, screens and washers typically approach 90 decibels at similar distances.

Noise levels decrease with distance at approximately 6 decibels per doubling of distance from source of the noise. The rate at a typical mine site would then be as follows:

Distance (feet)	Level (dBA)
50	84
100	78
200	72
400	66
800	60
1500	55

Table 7. Decrease in decibel level with distance[5].

The control of noise can be achieved through reducing the sound produced, interrupting the path of the sound, and protecting the recipient (Vesilind and Parka, p. 343). The impacts of noise can be moderated by restricting hours of operation, construction of berms to act as sound buffers, locating pit activities in one area at a time, and by installation of muffling equipment on machinery. The construction of a twenty foot berm around a pit with 2:1 slopes on both sides of its peak may reduce sound from a typical 80 dBA to 50 dBA one hundred feet away from the noise source. In some cases either berms or material stockpiles can be strategically place so as to even further reduce noise impacts. Some additional noise impacts may be unavoidable.

Road and Traffic Impacts

Damage to roads can be severe, as many roads are not designed to accommodate heavy vehicles. Most county roads have insufficient gravel underlayment, limited widths, small shoulders, substandard geometrics and inadequate paving for sustained use by heavy trucks, as they were not designed or built for such purposes. However, many state highways are built to withstand heavy truck traffic, and in Whatcom County many of the significant mining areas are near these highways.

Dirt and other debris from truck tires is unsightly and may become road hazards to other vehicles. Mitigating measures include washing of wheels prior to site exiting, respecting load limits, especially during weather extremes, limited speeds, haul road agreements, and paved access.

Mining and Groundwater Quality

The natural characteristics and processes that made Washington's sand and gravel resources particularly valuable, also have made them productive aquifer systems. In Whatcom County, it is not uncommon to find aggregate mining concentrated over aquifer recharge areas, which are particularly sensitive portions of local aquifers.

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[5] [illegible] 1992.

Surface mining within an aquifer recharge area alters the infiltration dynamics and generally increases the vulnerability of the underlying ground water. Mining increases ground water vulnerability because it decreases the physical separation of ground water from the surface. In shallow unconfined aquifers, the gravel deposit may be the core of the aquifer itself. In such instances, a pond or lake is created and functions as a "window" of direct access to the ground water. In the case where the depth to ground water is greater than the excavation depth, the material remaining after the excavation can provide only limited protection from surface contaminants. The net result is still an increase in hydrologic susceptibility. In either case, mining activities releasing contaminants to the ground have an increased potential for transmission directly to ground water.

The primary "effluent" discharged at a gravel mine is turbid rinse water. Generally, operators are required to collect the wastewater on-site in retention and settling ponds where the fine sediment settles out. The collected water is then allowed to infiltrate back to the water table. Often the excavation pit is a component of the treatment system.

The high amount of suspended solids in the wash water may not pose a serious ground water problem once a sediment filter is established. However, the excavation pit and the continual collection and infiltration of wash water does raise the potential for contaminant migration. Chemical contaminants that are allowed to enter the pit via the wash water or spills in the area would have increased access to the aquifer. Once in the ground water, a chemical substance would be free to move with the water in the aquifer. Possible contaminants found at a mining site include lubricants and fuels. Other materials may enter the excavation pit from contaminated road runoff, agricultural practices, and other sources.

A more serious threat to ground water quality are concrete batch plants, particularly if process waters are discharged to ground water without treatment. Process waters from this type of activity have a high pH level and some additives. These waters may have a measurable and unacceptable affect on ground water if untreated. The risk to ground water from asphalt batch plants is lower than the risk from concrete batch plants and comes primarily from potential effects of stormwater, vehicle fueling and fuel storage and handling.

Mining into the aquifer adds more risks to the ground water quality. These risks include the potential to increase ground water turbidity and iron content and the potential to affect local ground water levels. Turbidity down-gradient from mining operations was found to increase significantly only when washing operations were involved. Another aspect of mining into ground water is the potential to destroy the hydrological barriers between different aquifers. The mixing of two aquifers could potentially affect the water quality and water levels of one or more of the aquifers.

Figure 17. Siper Road sand and gravel pit, 1990. Front end loader parked at ground water level.

Future land uses is another critical factor when evaluating ground water vulnerability. Land use can be viewed as an expression of contaminant potential. Certain types of surface activities have higher incidence of contamination than others. The subsequent use of a mined property should reflect not only the contaminant potential of the new activity but also the increased susceptibility of the ground water as a result of the mining (Stern, 1991).

Abandoned gravel pits have often been used for the disposal of various types of solid waste. The deleterious effects of this practice to ground water have been well documented and therefore, in general, this practice should be discontinued. The only materials that could be considered for disposal are those that are truly inert.

Thurston County, in their recent study on the effects of gravel mining on ground water, concluded that "gravel mining, in general, poses low to moderate risks to ground water quality and quantity. But consistent regulatory oversight of project design and approval, operation, monitoring and closure, and effective enforcement are necessary to minimize the risk of ground water quality degradation".

Process and Storm Water

During 1994 a general permit will be required from the Department of Ecology for process water and storm water associated with many sand and gravel operations, rock quarries and similar mining operations, including stockpiles of mined materials, concrete batch operations and asphalt batch operations. The goal of this permit is to implement management practices and to provide for enforcement of state and federal standards that apply to the quality of discharge water.

Sources of water discharge include processing activities and storm water runoff from the site. The following potential sources and resulting impacts to water quality, as listed by the Department of Ecology, include:

Impact/Material	Source:
Oil & grease Hydraulic fluid Fuels (hydrocarbons, degreaser, etc.)	Spills, leaks from equipment and storage tanks Maintenance shops Asphalt batch plant (scrubber water) Drive-thru truck washers Asphalt truck cleanup
Nitrate	Residue from blasting
Ligninsulfonate	Dust suppression
pH, dissolved solids	Concrete batch plant mix water Cement bagging operations Concrete truck wash water Concrete batch plant wash water

Turbidy	Concrete batch plant Concrete bagging operation Stormwater runoff/runon Asphalt batch plant Concrete truck wash water Concrete batch plant wash water Drive-thru truck washers Washing, screening or crushing rock Interception of perched aaquifer Discharge from settling ponds
Concrete admixtures (containing organics, chlorides, and dissolved solids)	Concrete batch plant mix water Concrete truck wash water Cement bagging operations

Table 8. Potential sources and resulting impacts to water quality.

Surface waters are impacted in many of the same ways as ground water. The source of water for many streams comes from ground water sources. Interruption of these groundwater flows may disrupt surface water quantity and stream flows.

Reclamation and Subsequent Land Uses

Visual blight and subsequent uses are the driving criterion for reclamation. Post mining uses may include wetlands and lakes, upland wildlife habitat, forest production, agricultural uses, and residential, industrial or commercial uses.

Sand and gravel pits in which the pit floor is seasonally or permanently below the water table provide excellent opportunities to create wetlands, lakes, and habitat for wildlife and fish. Recommendations for creating lakes and wetlands include: (a) use of retention pond sediment as a substrate for aquatic plants; (b) 25 percent of area shallow (less than two feet), 25 percent two to six feet deep, and the rest greater than ten feet deep; (c) irregular, gently sloping shoreline; (d) nesting islands greater than three feet and covered with at least eight inches of topsoil; (e) undisturbed, native vegetation along shoreline, and (f) steeper gradients to limit emergent plant growth where boating, swimming or fishing access is planned.

Figure 18. Valley View Road area near Blaine, 1990. Unreclaimed sand and gravel pit.

Biological diversity is the goal for an upland site reclaimed as wildlife habitat. Appropriate plants should be provided for food and cover for all seasons. These include: (a) conifers, hardwoods, grasses, and legumes that provide protective seasonal shelter, summer nesting cover, and some food (leaves, seeds, or nuts); and (b) plants that provide nectar or other food for insects. Structural components to enhance the attractiveness to wildlife are: (a) nest boxes and platforms, dead trees, fallen trees, and other perches or roosts for birds; (b) brush and rock piles for cover and denning for mammals and reptiles; (c) cut banks and irregular pit-floor topography; (d) water; and (e) some open space with only grasses and legumes.

Figure 19. North of Ferndale, off I-5, 1990. Sand pit reclaimed to quality wetland system.

Reclamation as forest land can result in revenue and lower taxes for the private landowner. However, sites that should not be considered for forestry have some or all of the following characteristics: area less than ten acres, slopes steeper than 3H:1V, soil depths less than 20 inches over bedrock, or a high permanent water table.

There is considerable overlap between high quality aggregate lands and high quality agriculture lands. Several deposits represent a primary source for sand and gravel and, as well, form the parent material for prime agricultural soils. Both large, deep, open pit mines and smaller projects removing ridges and high ground have been operating in these overlap areas in the agricultural district. The smaller projects usually occur on dairy farms where corn or grass is cultivated. Some raspberry farming has also occurred on reclaimed areas. Potential drawbacks from commercial mining in agricultural areas may include reclamation problems, the loss of scenic terrain, an increased risk of groundwater contamination from future agricultural practices, and soil rehabilitation difficulties.

Figure 20. British Columbia, 1990. Segment of a mine reclaimed to raspberry field.

When mining is completed in some areas, particularly those in close proximity to urbanization, the site may be subject to further development. Reclamation for this use requires pre-planning in order to conserve material for landscaping and space for re-vegetation, roads and other development. Of particular concern, however, is that decisions to further develop the site must take into account the increased susceptibility of the groundwater to new land-use activity.

BIBLIOGRAPHY (SOURCES CONSULTED):

Collins, Brian and Thomas Dunne. Fluvial Geomorphology and River-Gravel Mining: A Guide for Planners, Case Studies Included. California Department of Conservation, Division of Mines and Geology, Special Publication 98, 1990.

Columbia Aggregates. Gravel Surface Mine Draft Environmental Impact Statement. February, 1992.

Department of Ecology. Bob Raforth. Reference Sheet, General Permit for Process Water and Storm Water Associated with Sand and Gravel Operations, Rock Quarries, and Similiar Mining Operations. 1993.

Derkey, Robert E. and Charles W. Gulick. Washington's Mineral Industry-1991. Washington Geology. Vol.20, No.1, March 1992, p. 3-26.

Derkey, Robert E., Charles W. Gulick and William S. Lingley, Jr. Washington's Mineral Industry-1992. Washington Geology. Vol.21, No. 1, March 1993, p. 3.

Easterbrook, Don J. Environmental Geology of Western Whatcom County, Washington. Washington State University, Bellingham, Washington. 1973

Easterbrook, Don J. Geologic Map of Western Whatcom County, Washington. U.S. Geological Survey, Denver. 1976.

Environmental Protection Agency, Noise: A Health Problem. 1978.

Goldthope, Dougas. Geologist, Land Use Division, Whatcom County Planning and Development Services Department. Memo to Jeff Griffin. October 31, 1994

Gulick, Charles W. Building and Decorative Stone Production in Washington. Washington Geology. Vol. 20, No. 2, June 1992, p. 3.

Hart-Crowser. Draft-Phase I Whatcom County Mineral Resource Delineation and Classification Project. December, 1991.

Joseph, Nancy L. Industrial Minerals in Washington--Production and Potential. Washington Geologic Newsletter. Vol. 18, No. 4, December 1990, p. 8-20.

KCM, Inc. Whatcom Couny Flood Control Zone District, Lower Nooksack River Comprehensive Flood Management Plan, Gravel Management Program Analsis. Draft February 24, 1994, Seattle, WA.

Langer, William H. and V. M. Glanzman. Natural Aggregate - Building America's Future. U.S. Geological Survey Circular 1110. 1993.

Lepp, Louis R. and Gary A. Flowers. Natural Construction Materials. Engineering Geology in Washington. Vol. 1, Washington Division of Geology and Earth Resources Bulletin 78. 1989.

Lingley Jr., William S. and C. J. Manson. Directory of Washington Mining Operations. Washington Division of Geology and Earth Resources Information Circular 87. 1992, p. 76.

Lingley Jr., William S. and David K. Norman. Surface Mining and Surface Mining Law in Washington. Washington Geology. Vol. 19, No. 4, December 1991, p. 38-41.

Lingley Jr., William S. and Stephen P. Jazdzewski. Aspects of Growth Management Planning for Mineral Resource Lands. Washington Geology, Vol 22, No. 2, July 1994, p.36-45.

Mackintosh, E.E. and E.J. Mozuraitus. Agriculture and the Aggregate Industry:Rehabilitation of Extracted Sand and Gravel Lands to An Agricultural After-Use. Ontario Ministry of Natural Resources, Mineral Resources Branch. Industrial Mineral Background Paper 3. 1982.

Moen, Wayne S. Mines and Mineral Resources of Whatcom County, Washington. Dept. of Natural Res

Normand, David K. Surface Mining in Washington: Some Regulatory Responsibilities of Various Federal, State, and Local Government Agencies. Washington Division of Geology and Earth Resources, Open File Report 94-4. January 1994.

Norman, David K. and William S. Lingley, Jr. Reclamation of Sand and Gravel Mines. Washington Geology. Vol.20, No. 3, September 1992, p. 20-31.

Property Counselors, in association with David Evans & Associates, McCutcheon Demographics, Judith G. Stoloff & Associates. Population, Economic and Housing Projections, 1990-2000-2010. October 1991.

Smith, Jr. Corliss M. Industrial Minerals 1990. Mining Engineering. June 1991, p. 608.

Stern, Virginia, A. Gravel Mining and Ground Water Vulnerability: Minimizing The Risks to Ground Water Quality. Environmental Health Programs, Washington Department of Health. 1991.

Starkenburg - Kroontje, Lesa. Letter to Jeff Griffin regarding mineral survey information. October 27, 1994.

Thurston County Public Health and Social Services Department. Ground Water Management Program, The Direct and Cumulative Effects of Gravel Mining on Ground Water within Thurston County, Washington. Public Review Draft. 1993.

Vesilind, P. Aarne and Jeffrey J. Peirce. Environmental Pollution and Control. 2nd. ed., Stoneham, MA, Butterworth Publishers. 1983.

Washington Aggregates and Concrete Association. Foundation for Washington's Future. Prepared by the Center for Business Reserach at Gonzaga University. June 1992.

Washington State Department of Natural Resources, Division of Aquatic Lands, in cooperation with Washington State Department of Ecology. Gravel Removal from Rivers: For Reducing Flood Risks. December, 1989.

Washington State Department of Natural Resources, Washington Division of Geology and Earth Resources. Directory of Washington Mining Operations, 1992. September 1992, p. 8.

Washington State Office of Financial Management. Population Statistics. 1993.

Watkins, T.H. Intoduction: Law and Liquidation. Wilderness. Summer 1992, p. 11.

Whatcom County Sand & Gravel Association. Letter to Whatcom County Planning and Development Services and Surface Mining Advisory Committee. Survey results. September 12, 1994.

APPENDIX A

MINERAL RESOURCE LAND CLASSIFICATION SYSTEM

SECTION 1. CLASSIFICATION

1. Classification Criteria

a. Areas will be classified into Mineral Resource Areas (MRA) and Scientific Resource Sites (SRS), as defined in this section, and this classification shall be based on geologic and economic factors without regard to existing land-use and land ownership. The areas to be studied and their order of study shall be specified by local government.

b. To be considered significant for the purpose of the classification of mineral lands, a mineral deposit or a group of deposits that can be mined as a unit must meet the following criteria of marketability and threshold value. In these guidelines the term mineral deposits denotes natural occurrences of rock or mineral materials in or on the Earth's crust that are known to be economically minable and such rock or mineral materials that are not minable at present but which may come in such demand as to become economically minable in the foreseeable future. The term mineral resources is used herein as a collective term for all mineral deposits of a particular kind or for mineral deposits in general. For the purpose of evaluating marketability and threshold value, the size of mineral deposits shall include the amounts of naturally occurring rock or mineral material, of known or potential economic interest, that can be measured, indicated or inferred by using available geologic and geophysical evidence in commonly accepted fashion. The terms measured, indicated, and inferred are to be used as defined by the U.S. Bureau of Mines and the U.S. Geological Survey in U.S. Geological Survey Bulletins 1450-A and 1450-B.

(1) Marketability--In determining marketability, mineral deposits shall be divided into two categories: those containing non-strategic and those containing strategic mineral commodities. Unique or rare occurrences of rocks minerals or fossils that are of outstanding scientific significance are not required to meet marketability criteria.

(i) Non-strategic mineral commodities are those which are available domestically and of which the United States imports less than 50 percent of its needs as reported annually by the U.S. Bureau of Mines. Deposits of mineral commodities in this category must be minable, recoverable, and marketable under the technologic and economic conditions that exist at present or which can be estimated to exist in the foreseeable future. The amount of mineral resources needed for periods of the foreseeable future (50 years) shall be projected using past consumption figures, with appropriate adjustments based upon anticipated changes in market conditions and mining technology.

(ii) Strategic mineral commodities are those that are in short domestic supply and important for national defense or the well-being of the domestic economy. For the purposes of these guidelines, they are those mineral commodities of which the United States imports more than 50 percent of its needs, as reported annually by the U.S. Bureau of Mines, and that are judged to be minable, recoverable, and marketable in the foreseeable future if non-domestic sources of supply are cut off.

(iii) Foreseeable future, as used in this paragraph and elsewhere in the guidelines, is a time span of approximately 50 years. Because some of the conditions affecting extraction and marketability cannot be accurately projected 50 years into the future, conservative estimates shall be made in assessing whether a particular mineral resource can be mined, processed, and marketed within the next 50 years.

(2) Threshold value is the projected value (gross selling price) or the first marketable product from an individual mineral deposit, or from a group of deposits that can be operated as a unit, upon completion of extraction and any required mineral separation and processing. For those deposits which meet the marketability criteria, only those estimated to exceed the following threshold values in 1990 equivalent dollars shall be considered significant. These threshold values are intended to indicate in a general way the approximate minimum size of a mineral deposit that will be considered significant for classification and designation. The values are not intended, nor in practice could they be, for use as precise cut-off values. For some deposits in some areas, larger or smaller value than those specified would be required for a marketable deposit. If for technological or other reasons one or more parts of a mineral deposit cannot meet the marketability criteria, those parts shall not be considered in estimating whether the deposit exceeds the threshold value.

(i) Construction materials (minimum value $5,000,000)--Mineral materials capable of being used in construction, such as sand and gravel or crushed rocks, that normally receive minimal processing (commonly washing and grading) and for which the ratio of transportation costs to value of the processed material at the mine is high.

(ii) Industrial and chemical mineral materials (minimum value $1,000,000)--Non-metallic mineral materials that normally receive extensive processing, such as heat or chemical treatment or fine sizing, and for which the ratio of transportation costs to value of the material at the mine is moderate or low. Examples of this category include:

Limestone, dolomite, and marble, except where used as construction aggregate
Specialty sands
Clays
Diatomite
Phosphate
Coal, lignite, or peat mined primarily as a raw materials for chemicals such as montan wax
Salines and evaporites such as borates and gypsum
Feldspar
Talc
Building and dimension stone
Rock varieties producible into granules, rock flour, mineral wool, expanded shale, pozzolans, and other similar commodities

(iii) Metallic and rare minerals (minimum value $500,000)--Metallic elements and minerals, gemstones, and minerals that possess special properties valuable to science or industry. The ratio of transportation costs to the value of the material at the mine for this category is low. Examples include ores, deposits, or crystals of:

Precious metals (gold, silver, platinum)
Iron and other ferro-alloy metals (iron, tungsten, chromium, manganese)
Base metals (copper, lead, zinc)
Mercury
Uranium and thorium, except syngenetic deposits in shale
Rare earths

Minor metals, including rubidium and cesium
Gemstones and semi-precious materials
Niobium, tantalum
Optical-grade calcite

(iv) Non-fluid mineral fuels (minimum value $1,OOO,OOO)--Non-hydrothermal mineral fuels occurring in sedimentary rocks. Examples include:

Coal and coal bed methane
Lignite
Peat
Organic shale
Tar sand
Uranium and thorium (syngenetic deposits in shale)

(v) Unique or rare occurrences of rocks, minerals or fossils that are of outstanding scientific significance (no threshold value).

2. <u>Mineral Resource Areas (MRA) and Scientific Resources Sites (SRS)</u>

The following MRA and SRS categories shall be used in classifying lands. The geologic and economic data and the arguments upon which each unit MRA or SRS assignment is based shall be presented in the land classification information transmitted to a local government body such as a Zoning Board or the County Commissioners.

a. ....MRA-1--Areas where adequate information indicates that no significant mineral deposits are present, or where it is judged that there is little likelihood for their presence. This area shall be applied where well-developed lines of reasoning, based upon economic geologic principles and adequate data, demonstrate that the likelihood for occurrence of significant mineral deposits is nil or slight.

b. ....MRA-2--Areas where adequate information indicates that significant mineral deposits are present or where it is judged that there is a high likelihood for their presence. This area shall be applied to known mineral deposits or where well-developed lines of reasoning, based upon economic geologic principles and adequate data, demonstrate that the likelihood for occurrence of significant mineral deposits is high.

c. ....MRA-3--Areas containing mineral deposits the significance of which cannot be evaluated from available data.

d. ....MRA-4--Areas where available information is inadequate for assignment to any other MRA.

e. ....SRS containing unique or rare occurrences of rocks, minerals, or fossils that are of outstanding scientific significance.

3. <u>Documentation and Transmittal of Mineral Lands Classification Data</u>

a. ....Areas assigned to mineral resource lands shall be delineated on suitable maps of a scale adequate for use on lead agency general plan maps. These maps shall also show the boundaries of each permitting authority in the report area.

b. ....A map at a convenient scale and a summary report showing the mineral lands classification for an entire county or, at the direction of the Board or Commissioners, major subdivisions of a county, or a major mineral district that includes portions of two or more counties, shall be prepared after classification is complete. Each map and report shall be submitted to the Board or Commissioners which, after review and approval, shall transmit it to the appropriate lead agencies and shall make it available to other interested parties.

c. ....Mineral land classification reports of regions containing Construction Materials classified MRA-2 shall include the following additional information for each such mineral commodity:

(1) The location and an estimate of the total quantity of each such construction material that is geologically available for mining in the report region. The limits of the region shall be considered to be the consumption areas for each potentially producible construction mineral commodity under consideration.

(2) An estimate of the total quantity of each such construction material that will be needed to supply the requirements of both the county and the marketing region in which it occurs for the next 50 years. The marketing region is defined as the area within which such material is usually mined and marketed. The amount of each construction material mineral resource needed for the next 50 years shall be projected using past consumption rates adjusted for anticipated changes in market conditions and mining technology. These estimates shall be periodically reviewed.

4. Classification Priorities

Potential mineral lands that are most likely to be converted to uses that are incompatible with mining or which would preclude mining shall be classified first. Where the potential for conversion to incompatible land uses exists, those areas with mineral deposits of greatest statewide or regional significance containing strategic mineral commodities or non-fluid mineral fuels shall be classified first. The potential for loss may be through the process of urbanization or through other irreversible uses of the mineral lands, or of adjoining lands, with which mineral extraction would be incompatible.

5. Petitions for Mineral Lands Classification

a. ....Petitions may be brought before the Board or Commissioners by any individual or organization to classify mineral lands that are claimed to contain significant mineral deposits and which are claimed to be threatened by land uses incompatible with mining. Classification is a prerequisite to designation of regional or statewide significance.

SECTION II. DESIGNATION

1. Designation Criteria

Areas to be considered for designation by the Board or Commissioners will contain one or more mineral deposits of statewide or regional significance. Ordinarily, classification of an area as MRA-2 by a qualified geologist will constitute adequate evidence that an area contains significant mineral deposits, but other data, including the intent of beneficial mineral owners, shall be considered by the Board or Commissioners in determining the significance of specific mineral deposits and the desirability of designation.

2. Designation Procedures

a. ....Upon receipt from a qualified geologist of a mineral lands classification map and report delineating one or more areas classified as MRA-2 or SRS, the Board or Commissioners shall:

(1) Review the map and report to determine the sufficiency of the submitted data as a basis for designation and request such additional information as my be required.

(2) Determine the need for, and the priority of, designating the MRA-2 and SRS areas, taking into consideration the importance of the mineral deposits to the State or region thereof and the imminence of any threatened land-use changes that would be incompatible with mineral extraction.

(3) Notify the appropriate lead agencies of the decision to consider designation of one or more mineral resource areas within their jurisdiction.

(4) Set a date and place for a public hearing to consider the areas which the Board or Commissioners propose to designate as containing mineral deposits of statewide or regional significance. If practicable, the public hearing shall be held in or near the area proposed for designation.

(5) Notify all affected agencies and parties having an interest in the lands considered for designation.

b. At the public hearing to consider proposed designations, the Board or Commissioners shall seek the recommendations of concerned federal, state, and local agencies, educational institutions, civic and public interest organizations, and private organizations and individuals in the identification of mineral deposits of statewide or of regional significance. Such review and comment should address:

(1) The adequacy of the mineral land classification data transmitted by a qualified geologist and of any additional data transmitted by the Board or Commissioners, which together will constitute the principal basis for designation.

(2) Additional data bearing on the presence and marketability of mineral deposits proposed to be of statewide or of regional significance in the area under consideration, including the interest of beneficial mineral owners.

(3) The need, amount and location of mineral deposits of regional significance, namely Construction Materials as defined in Section 1, Subsection 1b of these guidelines, that should be designated to provide for the needs of the region.

(4) The need for the proposed designation of each mineral deposit of statewide significance, namely, Industrial and Chemical Mineral Materials, Metallic and Rare Minerals, Non-fluid Mineral Fuels and Rocks, Minerals, and Fossils of Outstanding Scientific Significance, as defined in Section 1, Subsection 1b of these guidelines. Ordinarily, such deposits are uncommon or rare, and economically significant occurrences warrant designation. However, some types, such as low-grade limestone, low-grade clays, and other rock varieties that may be processed into valuable mineral products are commonly present in such large quantities that designation would be warranted only where special circumstances exist. Such circumstances might include proximity of a mineral deposit to markets, transportation, or energy sources or to other raw materials with which they could be combined to produce more valuable products.

(5) The existing uses of the areas proposed for designation and the future uses of these areas as determined by local agencies.

(6) Values relating to recreation, watershed, wildlife, range, and other special consideration, such as critical areas.

c. ....Following the public hearing, the Board or Commissioners may designate to be of statewide or regional significance all or part of the areas classified as MRA-2 or SRS. The designation shall specify the following:

(1) The boundaries of the designated area.

(2) The mineral deposits of statewide or of regional significance contained in each designated area and an estimate of the amount of each mineral commodity that is available for mining under present or foreseeable technologic, economic, and land-use conditions for MRA-2 areas, or a description of the materials of scientific value in the SRS area.

(3) The reason that each designated area is of significance to the Sate or region, the advantages to the State or region that might be achieved from the extraction of the minerals of the area, and the adverse effects that might result from premature development to land uses that would preclude mining.

(4) The specific goals and policies to protect the areas containing mineral deposits designated to be of statewide or regional significance from premature development to uses that would preclude mining, or to uses with which mining would be incompatible.

(5) Lead agencies having jurisdiction over the area.

3. <u>Petitions for Designation</u>

a. ....Prior to permitting a use which would threaten the potential to extract minerals classified as MRA-2 or SRS but not yet designated, the lead agency may petition the Board or Commissioners for a designation hearing.

b. ....Petitions for a designation hearing may also be brought before the Board or Commissioners by any other party, provided that the Board or Commissioners have received and approved land classification information that indicates that the area in question is classified MRA-2 or SRS and that the Board or Commissioners have not yet considered designation. Petitions submitted to the Board or Commissioners shall include the following information.

(1) The petitioner's name, mailing address, and interest (beneficial, jurisdictional, or other) in the area to be considered for designation.

(2) A map (USGS 7 1/2' quadrangle or other appropriate map) showing the boundaries of the MRA-2 or SRS area the petitioner wishes to be designated.

(3) The reasons for requesting designation.

(4) The name and mailing address of each recorded land owner and each recorded lessee in an adjoining the area described. The Board or Commissioners shall then evaluate the data submitted in the petition as to their accuracy and sufficiency. If the Board or Commissioners find that the petition contains sufficient information and arguments to require a public hearing, then the Board or Commissioners shall schedule such a hearing and proceed as outlined in this section.

4. <u>Termination of Designation Status</u>

a. ....The status of mineral lands previously designated to be of statewide or regional significance may be terminated, either partially or wholly, by the Board or Commissioners on a finding that the protection afforded by designation is no longer necessary. In making this finding, the Board or Commissioners shall consult with affected lead agencies and beneficial owners of mineral resources as to the desirability of terminating designation. Such a finding may result from, but not be limited to, the following reasons:

(1) Depletion of the mineral deposit or deposits within the designated area.

(2) Demonstration that the mineral deposit or deposits within the designated area are in excess of quantities required for present or foreseeable future statewide or regional needs.

(3) Ending of the time limit, if any, for the designation to be in force.

b. ....Prior to making such a finding, the Board or Commissioners shall notify the beneficial owners of mineral resources and hold a public hearing. If practicable, it shall be held in or near the area in which the designated areas occur.

c. ....Petitions may be brought before the Board or Commissioners to terminate the designated status of mineral lands. Petitions submitted to the Board or Commissioners shall include the following information:

(1) The petitioner's name, mailing address, and interest (beneficial, jurisdictional or other) in the petitioned area.

(2) A map (USGS 7 1/2' quadrangle or other appropriate map) and legal description of the petitioned area.

(3) Reference to the specific action of the Board or Commissioners which designated the area.

(4) The reasons and supporting data as to why direct Board or Commissioners involvement is no longer necessary.

d. ....The Board or Commissioners shall then evaluate the data submitted in the petition as to their accuracy and sufficiency. If the Board or Commissioners find that the petition contains sufficient information and arguments to require a public hearing on termination, then the Board or Commissioners shall schedule such a hearing and proceed as outlined in this section.

SECTION III. COMPATIBILITY / INCOMPATIBILITY

The following land-use categories are to serve as examples to local government in assisting designation of MRA-2 lands. Compatible vs. incompatible categories will vary from one jurisdiction to another.

1. Incompatible - Land uses inherently incompatible with mining and/or which require a high public or private investment in structures, land improvements, and landscaping and which would prevent mining because of the higher economic value of the land and its improvements.

   Examples of such uses include:

   High-density residential
   Low-density residential with high unit value
   Public facilities

2. Compatible - Land uses inherently compatible with mining and/or which require a low public or private investment in structures, land improvements, and landscaping and which would allow mining because of the low economic value of the land and its improvements.

Examples of such uses include:

Very low density residential (for example: 1 unit per 10 acres)
Extensive industrial
Recreational (public/commercial)
Agricultural
Silvicultural
Grazing
Open space

APPENDIX B

UPLAND AND RIVER SAND AND GRAVEL

YEAR	POPULATION	RESERVES (cubic yards)	CUMULATIVE DEMAND
1993	140,900	57,871,414	1,724,960
1994	143,360	56,292,422	3,473,952
1995	145,863	54,682,896	5,253,478
1996	148,409	53,042,303	7,064,071
1997	151,000	51,370,101	8,906,273
1998	153,636	49,665,738	10,780,636
1999	156,319	47,928,652	12,687,722
2000	159,048	46,158,272	14,628,102
2001	161,824	44,354,017	16,602,357
2002	164,649	42,515,295	18,611,079
2003	167,524	40,641,505	20,654,869
2004	170,448	38,732,035	22,734,339
2005	173,424	36,786,261	24,850,113
2006	176,452	34,803,550	27,002,824
2007	179,532	32,783,257	29,193,117
2008	182,666	30,724,726	31,421,648
2009	185,855	28,627,289	33,689,085
2010	189,100	26,490,268	35,996,106
2011	192,401	24,312,970	38,343,404
2012	195,760	22,094,693	40,731,681
2013	199,178	19,834,722	43,161,652
2014	202,655	17,532,328	45,634,046
2015	207,192	15,174,580	48,161,794
2016	211,831	12,760,238	50,746,136
2017	216,574	10,288,035	53,388,339
2018	221,423	7,756,676	56,089,698
2019	226,380	5,164,836	58,851,538
2020	231,500	2,510,536	61,675,838
2021	236,130	(200,250)	64,556,624
2022	240,853	(2,968,651)	67,495,025
2023	245,670	(5,795,821)	70,492,195
2024	250,583	(8,682,934)	73,549,308
2025	255,595	(11,631,190)	76,667,564
2026	260,707	(14,641,810)	79,848,184
2027	265,921	(17,716,043)	83,092,417
2028	271,239	(20,855,161)	86,401,535
2029	276,664	(24,060,461)	89,776,835
2030	282,100	(27,332,081)	93,218,455
2031	287,742	(30,672,533)	96,728,907
2032	293,497	(34,083,194)	100,309,568
2033	299,367	(37,565,469)	103,961,843
2034	305,354	(41,120,789)	107,687,163
2035	311,461	(44,750,616)	111,486,990
2036	317,690	(48,456,439)	115,362,813
2037	324,044	(52,239,779)	119,316,153
2038	330,525	(56,102,185)	123,348,559
2039	337,136	(60,045,239)	127,461,613
2040	343,900	(64,070,819)	131,657,193

ROCK (EXCLUDING OLIVINE)

YEAR	POPULATION	RESERVES (cubic yards)	CUMULATIVE DEMAND
1993	140,900	41,170,000	185,330
1994	143,360	40,983,632	371,698
1995	145,863	40,794,010	561,320
1996	148,409	40,601,078	754,252
1997	151,000	40,404,778	950,552
1998	153,636	40,205,051	1,150,279
1999	156,319	40,001,837	1,353,493
2000	159,048	39,795,075	1,560,255
2001	161,824	39,584,704	1,770,626
2002	164,649	39,370,659	1,984,671
2003	167,524	39,152,879	2,202,451
2004	170,448	38,931,296	2,424,034
2005	173,424	38,705,844	2,649,486
2006	176,452	38,476,457	2,878,873
2007	179,532	38,243,065	3,112,265
2008	182,666	38,005,599	3,349,731
2009	185,855	37,763,987	3,591,343
2010	189,100	37,518,157	3,837,173
2011	192,401	37,268,035	4,087,295
2012	195,760	37,013,546	4,341,784
2013	199,178	36,754,615	4,600,715
2014	202,655	36,491,163	4,864,167
2015	207,192	36,221,813	5,133,517
2016	211,831	35,946,432	5,408,898
2017	216,574	35,664,886	5,690,444
2018	221,423	35,377,036	5,978,294
2019	226,380	35,082,742	6,272,588
2020	231,500	34,781,792	6,573,538
2021	236,130	34,474,823	6,880,507
2022	240,853	34,161,714	7,193,616
2023	245,670	33,842,344	7,512,986
2024	250,583	33,516,586	7,838,744
2025	255,595	33,184,313	8,171,017
2026	260,707	32,845,394	8,509,936
2027	265,921	32,499,697	8,855,633
2028	271,239	32,147,086	9,208,244
2029	276,664	31,787,423	9,567,907
2030	282,100	31,420,693	9,934,637
2031	287,742	31,046,629	10,308,701
2032	293,497	30,665,083	10,690,247
2033	299,367	30,275,906	11,079,424
2034	305,354	29,878,946	11,476,384
2035	311,461	29,474,046	11,881,284
2036	317,690	29,061,048	12,294,282
2037	324,044	28,639,791	12,715,539
2038	330,525	28,210,108	13,145,222
2039	337,136	27,771,832	13,583,498
2040	343,900	27,324,762	14,030,568