Preliminary Summary of Aggregate Mining in Oregon with emphasis in the Willamette River Basin

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I. Introduction

The purpose of this study is to summarize the technical information on aggregate mining in Oregon including updates of supply and demand since the last comprehensive forecasting of aggregate demand completed by Whelan (1995). Aggregate is a term that numerous definitions, but as used herein, aggregate is sand, gravel, and crushed rock used in the construction of roads and buildings. Aggregate resources within Oregon also include recycled materials. This study also attempts to assess the number of acres of Prime or High Value Soils that have been taken out of farm production by currently operating aggregate mines located along the floodplain of the Willamette River Basin in Oregon. The importance of investigating the relationship of Prime or High Value Soils and aggregate resources is that both resources often times are collocated. The study includes general information regarding many regions of Oregon, but the analysis focuses on the Willamette River Basin because (1) the bulk of Prime or High Value Soils are located in this area, and (2) the readily available digital data needed to complete spatial analyses of sand and gravel mines and soils distribution using Geographic Information Systems (GIS) are limited to this area.

The Institute of Natural Resources (INR) at Oregon State University served as the technical support for the Aggregate and Agriculture Consensus Group under contract with the Oregon Department of Transportation (ODOT). INR's scope of work included (1) convening a Technical Working Group composed of representatives with backgrounds in engineering, geology, and natural resources who represented a broad spectrum of stakeholders, (2) serving as the technical support team responsible for compiling readily available information to answer written questions posed by the various stakeholders, (3) regularly attend stakeholder meetings to present technical information and address additional questions on technical information needs by the stakeholder group, and (4) prepare a technical report summarizing the available information. The original process design envisioned convening and working with a formal Technical Working Group. Time and budget constraints led to a decision to have INR answer a specific list of questions. The questions posed by the stakeholder group can be found in Appendix No. 1. INR completed the work using readily available information and presented updates to the Consensus Group as requested. All of the technical work and lengthy presentations were made on October 18, 2004, November 2, 2004 and December 1, 2004. This report summarizes the technical results of the research offered in the presentations, as well as incorporates supplemental information in response to numerous reviewer's comments.

Careful examination of the stakeholder questions reveals that many of the stakeholder data needs overlapped from one process area to another, and that additional research was requested by the stakeholders during meetings and following the presentations. Likewise, many of the stakeholder questions could not be addressed because of the lack of readily available information, or because the requested information was considered proprietary by the aggregate mining industry. The technical support team's assessment of the availability of the information to respond to the individual questions can also be found in Appendix No. 1.

The organization of this report was directed by the Consensus Group into the following sections:

- A comparative impact of land use changes on farmland,
- A summary of the sources of aggregate,
- A summary of the demand for aggregate,
- Future considerations, and
- A summary of findings on the technical data, including what is clear and uncontested, what is contested, and what is unavailable with the current data.

The economic analyses requested by the stakeholder process group are not presented herein, but rather are the focus of a separate report prepared by Jaeger (2005). Many of the terms used in this report are at times misinterpreted, misunderstood, or have multiple meanings. For example, the Department of Land Conservation and Development (DLCD) define the Willamette Valley as Clackamas, Linn, Marion, Multnomah, Polk, Washington and Yamhill Counties and that portion of Benton and Lane Counties lying east of the summit of the Coast Range. The case study in this report includes the above referenced counties, as well as Columbia County, which is part of the Willamette River Basin as described by Hulse and others (2002). As a consequence, a glossary of terms can be found at the end of the report following the list of references. In addition to the stakeholder questions listed in Appendix No. 1, short summaries of the technical specifications for aggregate testing used by the Oregon Department of Transportation (ODOT) can be found in Appendix No. 2 for the interested reader. Appendix No. 3 is a listing of aggregate transportation costs for various states provided to INR from a member of the Consensus Group.

A. Comparative Impact on Farmland

According to Azuma and others (2002) over 80% of the shifts in land use from 1973 to 2000 on non-federal lands in western Oregon were from agriculture or wildland forests to low density residential or urban areas. While their research does not provide detailed information on the specific type of land use that shifts land use from agriculture or forest lands, Department of Land Conservation and Development (DLCD) maintains a statewide database of approved uses on lands zoned as Exclusive Farm Use (EFU). Until 2001, local government inventory information submitted to DLCD did not show “total acres disturbed” for various land uses. Instead, this information indicated the total acreage of a parcel subject to a mining or other land use proposal, even when the permitted mining or other land use disturbed only a portion of that parcel. DLCD began asking counties to provide information about total disturbed acres in 2001.

1. Land Use Changes. Assuming the DLCD database serves as the clearinghouse for land use in Oregon, data reported to DLCD by the various counties for a period spanning 1994 to 2003 were used as a proxy of the specific land uses that were potentially impacting lands zoned as EFU in Oregon. Data for Marion County were selected as a representative example because of concerns that high value soils were lost due to aggregate mining. As described in later sections of this report, sand and gravel accounts for 91% of the aggregate production from Department of Geology and Mineral Industries, Mineral Land Regulation and Reclamation (DOGAMI-MLRR)-permitted sites in Marion County with much of the aggregate mining occurring in areas with High Value Soils.

While the data distribution is less than ideal, examination of Figure 1 reveals that a broad spectrum of land uses were approved on lands zoned as EFU within Marion County from 1994 to 2003. While it is understood that many of these land uses are EFU-permitted activities, it is important to recognize that these activities can also take High Value Soils out of agricultural production much like building houses with lawns on High Value Soils in urban areas. For example, according to the DCLD database farm use includes building a farm Coop, filling in a floodplain, constructing a manure pond, miscellaneous ponds, construction of processing facilities, constructing warehouses to store fertilizer, and farm stands. Horse activities included constructing horse boarding facilities.

Likewise according to OARS 660-033-0010 regarding Agricultural Land an accessory use is a facility or improvement that is incidental to the operation of a facility and is either necessary for the operation and maintenance of the facility or that provides goods or services customarily provided at a facility. The DLCD database for Marion County defines accessory uses as including residential accessory structures, garages, barns, primary farm, floodplain development, reduction in special setbacks, accessory structures, storage buildings, replacement homes, tasting rooms, structures in floodplains, airport storage buildings, and equipment repair buildings. Nonconforming uses include truck depots, wrecking yards, and mobile home parks. Other uses include railroad spurs, bridges, road repair, and asphalt batch plants.

A rough comparison of the reported acreages impacted by the change in land use indicates that aggregate mining is only one of many uses taking land out of agricultural production. In Marion County, aggregate mining use also includes concrete batch sites, asphalt batch sites, storage areas, set backs and a host of other uses not associated with the actual mined area.

Hulse and others (2002, page 10) tabulate that 191,235 acres of Class I and Class II soils are within 1995 urban growth boundaries. The NRCS 1997 National Resources Inventory Results indicates that “Conversion of prime farmland soils to urban lands from 1982 to 1997 totaled an estimated 85,000 acres out of the 249,800 total acres converted from natural resource lands”. (see http://www.or.nrcs.usda.gov/technical/nri/res2urbprime.html)

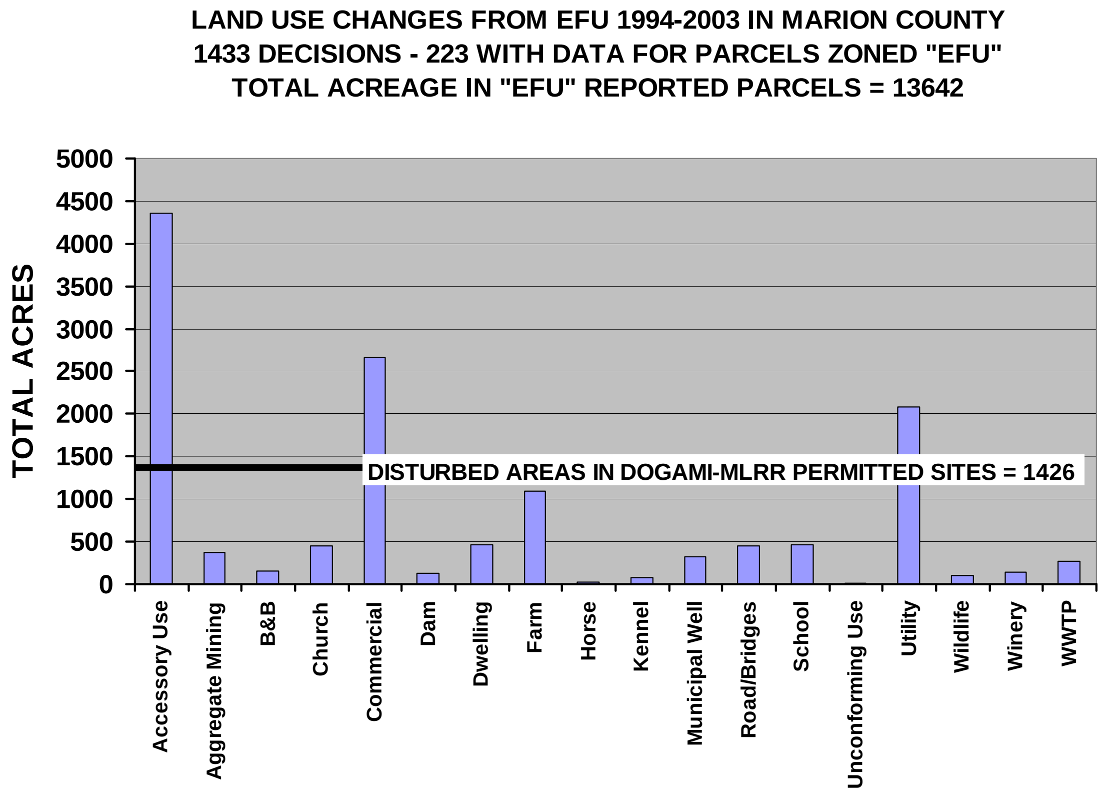

Figure 1. Chart depicting land use changes on lands zoned Exclusive Farm Use (EFU) in Marion County in the Willamette River Basin spanning the period from 1994-2003. The disturbed area associated with DOGAMI-MLRR-permitted aggregate sites in Marion County depicted for comparison. Note the many different types of land use that take farmlands out of production in Marion County which are comparable to other nearby counties in Oregon.

2. Impact of Aggregate Mining on Farmland. While the DOGAMI-MLRR maintain records of mined lands and production, the production records remain confidential by law. State-wide digital mapping of currently-permitted mine sites remains incomplete, but was completed along the floodplain in the Willamette River Basin as part of this study. Considered on the whole as outlined in Table 1, the significance of focusing on the Willamette River Basin is that area accounts for 60% to 65% of the commercially mined aggregate in Oregon.

According to DOGAMI-MLRR records, the total number of DOGAMI-MLRR permitted sites in the Willamette River Basin is 220, with 69 sites included in the floodplain, between 130 to 140 sites as upland quarries, and less than 12 sites located in the upstream reaches of rivers tributary to the Willamette River. Balzer (2004) developed a GIS layer or shape files for the 69 DOGAMI-MLRR-permitted mining related disturbances in the Willamette River Basin. As used herein, DOGAMI-MLRR permitted sites refers to currently active commercial mines and does not include historic sites. An example of what constitutes mining related disturbances at an active commercial mining site is shown on Figure 2.

The sand and gravel mine sites are predominantly located within the 100-year and/or 500-year floodplain; although some are located on fluvial terraces above and/or outside of both the 100-year and 500-year floodplains and within city limits or urban growth boundaries. As listed in Table 2, the GIS analysis of the 69 sand and gravel mine sites in the Willamette River Basin determined that 5953.8 acres are currently disturbed at currently active commercial mine sites permitted by DOGAMI-MLRR. The area of the DOGAMI-MLRR permitted mines derived from digitizing disturbed areas on aerial photographs of floodplain areas in the Willamette River Basin that fall within urban growth boundaries within the Willamette River basin is approximately 1,045 acres.

Region	Ton Aggregate	% of State	% Sand & Gravel	% Crushed Rock
WRB (10 counties)	**21,324,000**	**61**	**46***	**43***
Coast (5 counties)	**2,180,340**	**6**	**21**	**79**
Southern (3 counties)	**4,128,770**	**12**	**35**	**65**
Eastern (18 counties)	**7,098,955**	**20**	**40**	**60**
Total Oregon	**34,732,065**	**100%**	**43%**	**57%**

* WRB = Willamette River Basin, including Columbia County. *Columbia County records do not differentiate between sand and gravel vs. crushed rock. Consequently, the totals will not add up to 100%. Coast Counties include Clatsop, Tillamook, Lincoln, Coos and Curry Counties. Southern Counties include Douglas, Josephine and Jackson Counties. Eastern Counties include Hood River, Wasco, Sherman, Gilliam, Morrow, Umatilla, Wallowa, Union, Baker, Grant, Malheur, Harney, Lake, Klamath, Deschutes, Crook, Wheeler, and Jefferson.

Table 1. Summary of percentages of commercial sand and gravel versus crushed stone production for 2002-2003 in Oregon by region. Data from Marshall (2004) and Dugdale (2004)

County	Number of DOGAMI-MLRR Permitted Mine Sites	Disturbed Acres
Benton Co.	5	889.3
Clackamas Co.	12	661.0
Lane Co.	11	1420.1
Linn Co.	13	905.2
Marion Co.	15	1425.8
Multnomah Co.	2	149.2
Polk Co.	5	318.9
Washington Co.	1	6.1
Yamhill Co.	5	178.2
Total Willamette River Basin Exclusive of Columbia County	**69**	**5953.8**

Table 2. Summary of disturbed acres within active DOGAMI-MLRR-permitted sites located within the 100 and 500 year floodplain in the Willamette River Basin.

To quantitatively determine the number of acres of the different types of soils in the Willamette River Basin that have been taken out of agricultural production due to

DOGAMI-MLRR-permitted aggregate mining, the Willamette River Basin soils layer was downloaded from the Geographic Information Systems (GIS) datasets used to develop the Willamette River Basin Atlas (see Hulse and others, 2002). Using ArcMap, the soils layer was clipped with the aggregate mine shape files of Balzer (2004). The area by soil class was determined for each disturbed site polygon and summarized in Table 3. Because not all soils polygons maintained an irrigated or non-irrigated soil classification (e.g., unclassified: 40% irrigated, 18% non-irrigated), the data presented in Table 3 provide a reasonable estimate of the minimum soil-class-specific area that active DOGAMI-MLRR permitted aggregate mines occupy within the 100-year and 500-year floodplains in the Willamette River Basin.

For the reader who is unfamiliar with the Land Capability Classification system of the Natural Resources Conservation Service (NRCS), land capability class definitions area as follows: Class I contains soils having few limitations for cultivation; Class II contains soils having some limitations for cultivation; Class III contains soils having severe limitations for cultivation; Class IV contains soils having very severe limitations for cultivation; Class V contains soils unsuited to cultivation, although pastures can be improved and benefits from proper management can be expected; Class VI contains soils unsuited to cultivation, although some may be used provided unusually intensive management is applied; Class VII contains soils unsuited to cultivation and having one or more limitations which cannot be corrected; Class VIII contains soils and landforms restricted to use as recreation, wildlife, water supply or aesthetic purposes. Unclassified refers to areas where the soil classification is unknown or have not been classified by the US Department of Agriculture. The classifications change when irrigation was considered by the NRCS. The dataset used in this analysis was derived from the best available information compiled by Hulse and others (2002).

Following the same procedure outlined for determining the acreage of disturbed areas by soil classification, the Prime or High Value Soils layer compiled by the Oregon Department of Agriculture was clipped with the aggregate mine layer prepared by Balzer (2004). The area by soil classification was determined for each disturbed site polygons summarized in Figure 4. Careful examination of the summary statistics in Figure 4 reveals that a larger number of acres of Prime or High Value Soils are impacted by active DOGAMI-MLRR permitted mines as opposed to the analysis focusing just on Class I and Class II soils.

For the reader unfamiliar with Prime or High Value Soils, prime farmland soils are defined in the USDA-NRCS Title 430 National Soil Survey Handbook as "…land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops and that is available for these uses. It has the combination of soil properties, growing season, and moisture supply needed to produce sustained high yields of crops in an economic manner if it is treated and managed according to acceptable farming methods." The Farmland Protection Policy Act (Public

Law 97-98) (7 U.S.C. 4201, et seq.) and 7 CFR part 658 indicates that the classifications of these soils are determined by the Secretary of Agriculture.

Non-irrigated Soil Classification	**Acres**	**Irrigated Soil Classification**	**Acres**
1	82	1	82
2	2,262	2	1,779
3	612	3	602
4	740	4	701
5	1	5	0
6	42	6	0
7	97	7	0
8	972	8	0
unclassified	1,149	unclassified	2,794
TOTAL	**5,958**	**TOTAL**	**5,958**

Table 3. Summary of soil classes as defined by the NRCS Land Capability Classification that fall within disturbed areas within active DOGAMI-MLRR-permitted sites located within the 100 and 500 year floodplain in the Willamette River Basin and have been taken out of agricultural production.

On the basis of the GIS analyses integrating the disturbed areas associated with active DOGAMI-MLRR permitted mines located in the 100-year and 500-year floodplain with the soils maps classified under the Land Capability Classification system, the number of acres of Class I and Class II soils taken out of agricultural production ranges from 1,861 to 2,344 acres depending on whether the soils are reclassified by irrigable lands, or about 31% to 39% of the approximately 5,954 acres disturbed by mining along the floodplain in the Willamette River Basin. Likewise, the number of acres soils taken out of agricultural production classified using the Prime or High Value is 2,486 acres, or approximately 41% of the approximately 5,954 acres disturbed by mining along the floodplain in the Willamette River Basin. Consideration of the percentage of aggregate mined in the Willamette River Basin that is sand and gravel as listed in Table 1, coupled with the percentage of soils classified as Class I and Class II or High Value Soils that have been taken out of agricultural production by active DOGAMI-MLRR permitted mines located in the 100-year and 500-year floodplain, indicates that only about 14% to 19% of the sand and gravel aggregate mined in the Willamette River Basin was associated with Class I, Class II or High Value Soils. Neither analysis incorporates the approximately 1,045 acres of disturbed areas along the 100-year and 500-year floodplains located within urban growth boundaries.

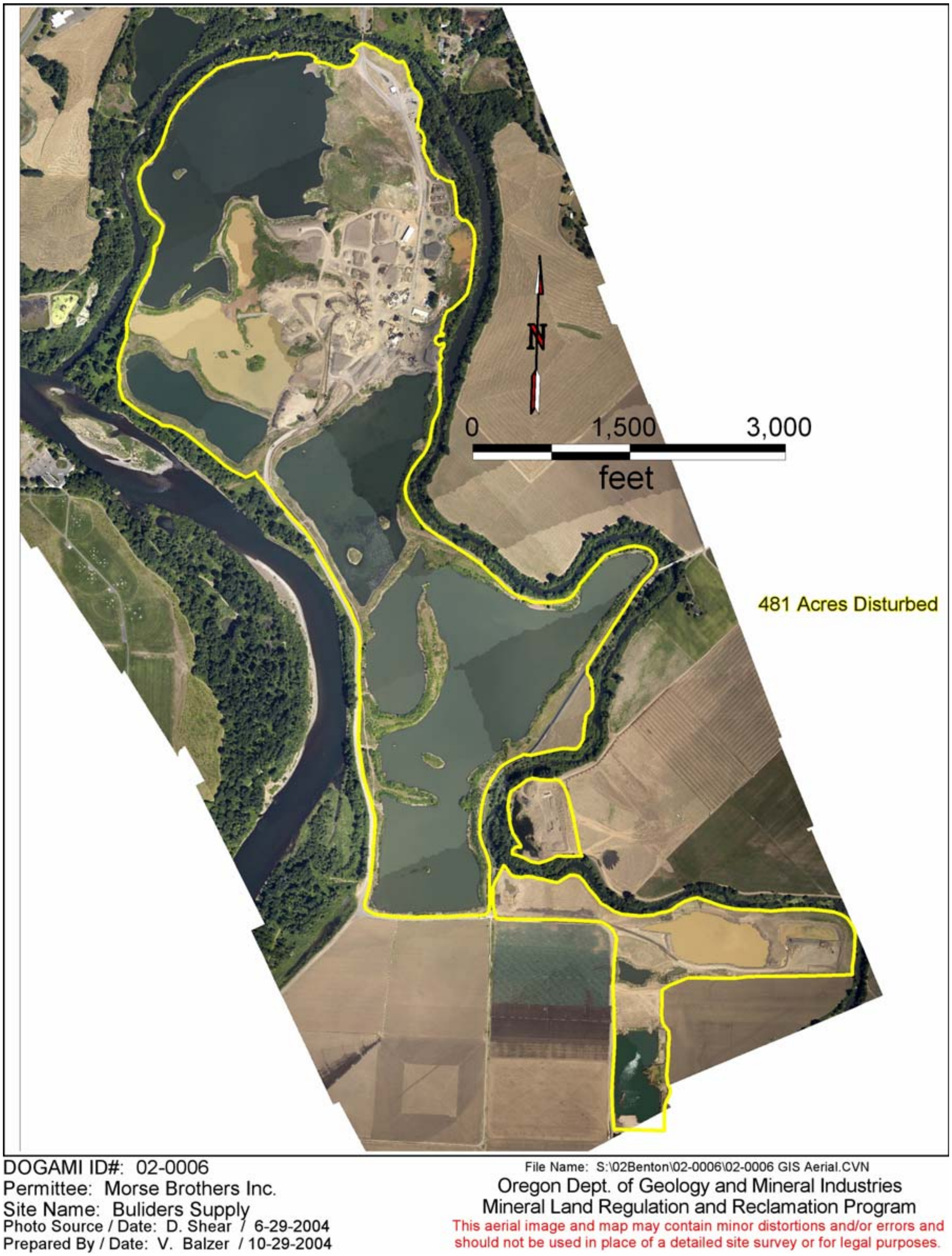

Figure 2. Aerial photograph showing outline of disturbed area associated with a typical active sand and gravel aggregate mine in the 100 year floodplain in the Willamette River Basin.

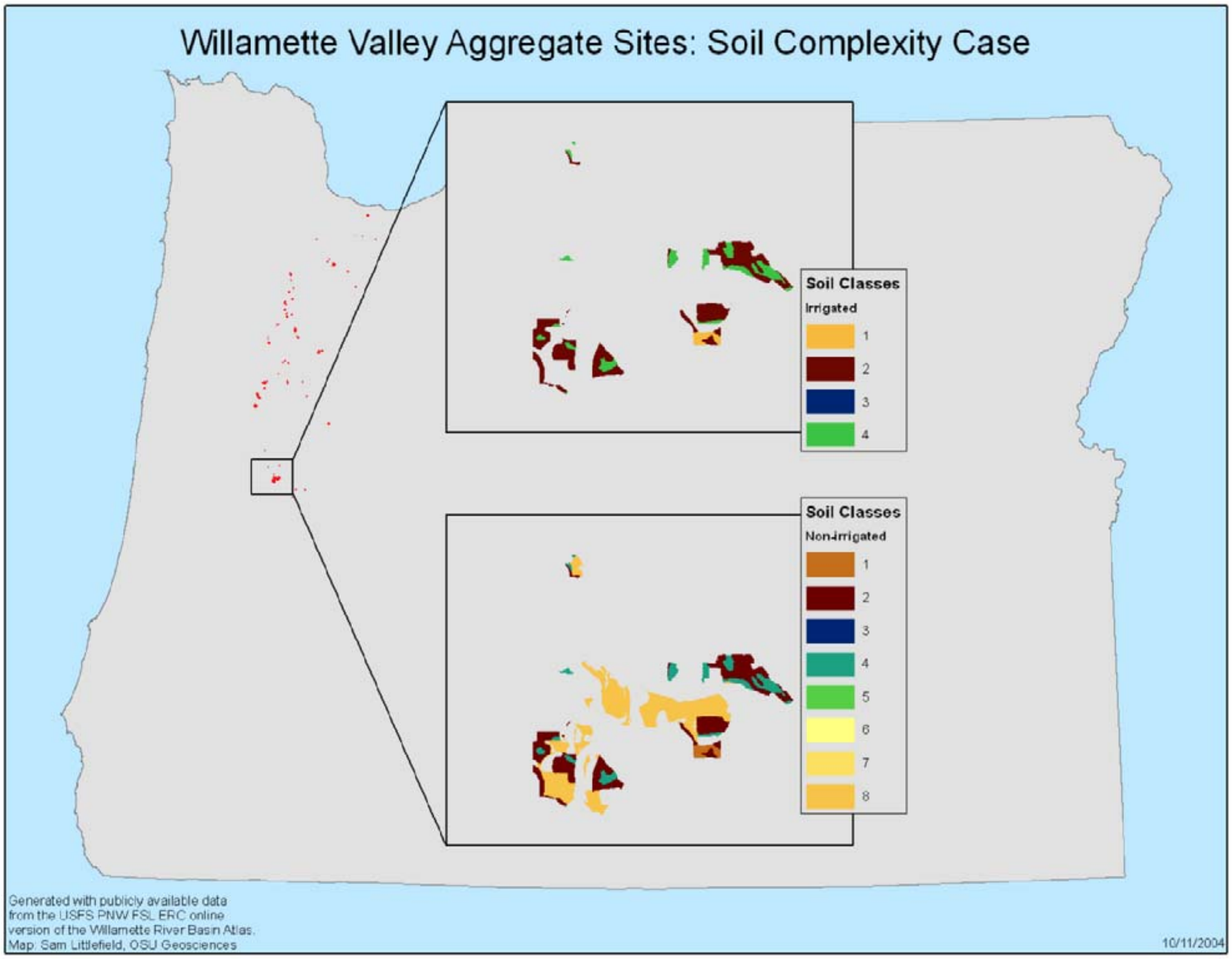

Figure 3. Summary of soil classes disturbed by aggregate mining in Willamette River Basin. Note the complexity of the different soils that can be found within an individual mine sites which underscores the value of GIS in this analysis. Note also that soil classes have been reclassified once irrigation is considered by the NRCS. The significance of this map is that it illustrates the challenge associated with attempts to site mines on the basis of soil classification.

3. Reclamation. Research focusing on the reclamation of lands disturbed by aggregate mining spans the past 20 years. Shaller and Sutton (1978), Kuennen (1983), Brown and others (1986), Toy and Hadley (1987), Ferris and others (1996) and the Office of Surface Mining, Department of Energy, and National Energy Technology Laboratory (2002) provide the most comprehensive reviews and guidelines to reclamation. Mackintosh and Mozuraitis (1982), Lowe (1983), Mackintosh and Hoffman (1985), Million and others (1987), and Robinson (1988) focus their research on the successes, failures, and costs associated with reclaiming aggregate sites for use in agriculture including fruit production. Norman and others (1996) provide specific guidelines to reclaiming mine sites in the Pacific Northwest. Nearly all workers report that reclamation designed to return the land to beneficial use should be planned before extraction, so that equipment is used for both mining and reclamation, with mined-out areas reclaimed concurrent with extraction in other parts of the operation (Langer and Glanzman, 1993).

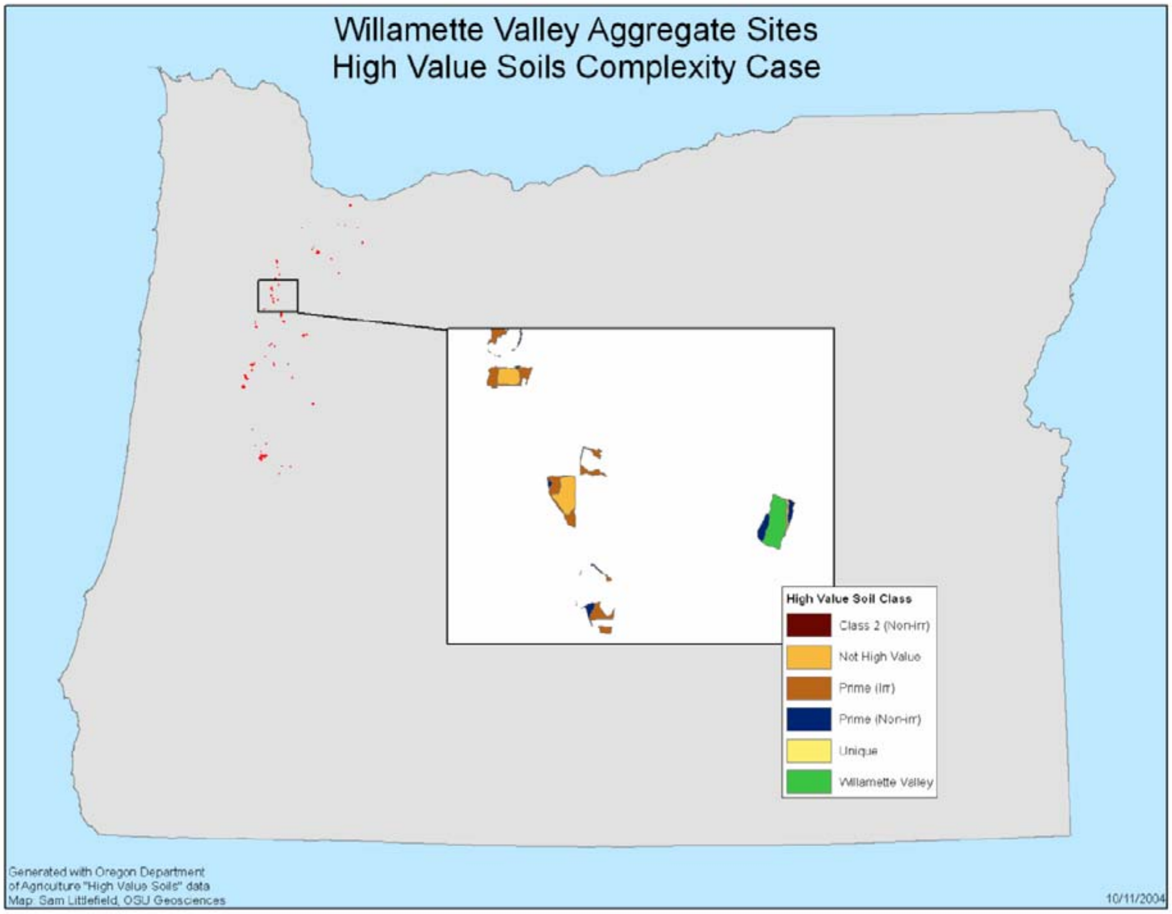

Figure 4. Areal summary statistics for aggregate mining sites by *High Value Soils* layer field category compiled by the Oregon Department of Agriculture. Comparison of the Table 3 with Table 2 reveals that a larger number of acres of Prime or High Value Soils are taken out of agricultural production by activeDOGAMI-MLRR permitted mines in the Willamette River Basin.

High Value Soil Classification	Disturbed Acres
Prime (irrigated)	**1,234**
Prime (non-irrigated)	**901**
Class 2 (non-irrigated)	**199**
Willamette Valley	**142**
Unique	**10**
TOTAL	**2,486**

Table 3. Summary of soil classes as defined by the Prime or High Value Soils that fall within disturbed areas within active DOGAMI-MLRR-permitted sites located within the 100 and 500 year floodplain in the Willamette River Basin and have been taken out of agricultural production.

Since the inception of the Mined Land Reclamation Act in 1971, approximately 4,600 acres of sand and gravel mines, as well as upland quarries, have been reclaimed statewide. As listed in Table 4, about 22% of the reclaimed lands were returned to agricultural use (Marshall, 2004). However, the definition of what constitutes agricultural use remains broad. For example, landowners apparently can elect to have a mined area that intercepts the water table and forms a lake which can then be considered agricultural use as either a source of irrigation water or stock watering (V. Balzer, personal communication). INR inspected such a site at the Green and White quarry

(DOGAMI-MLRR Permit No. 02-0008) located south of Corvallis where the pit was left as open water by and used as an aquaculture rearing pond by the landowner until market conditions prohibited continued use. DOGAMI-MLRR's records do not include the number of acres reclaimed as ponds or lakes which were later developed for agricultural use.

DOGAMI-MLRR's approach to reporting the mined lands reclamation data are consistent with aggregate mining reclamation standards. For example, the Management of Abandoned Aggregate Properties Program (MAAP) in Ontario, Canada focuses strictly on the rehabilitation and research of pits and quarries that were abandoned prior to January 1, 1990. MAAP is funded by the aggregate industry through a portion (1/2 cent) of the annual 6-cent per metric ton license levy, as prescribed in the regulations of the Aggregate Resources Act passed on Ontario, Canada. Over $2.5 million (US $2M) has been spent to date on rehabilitation since the program's inception in 1990 and over 200 hectares (500 acres) of land have been improved. MAAP's reported categories of reclamation and percentages are comparable to the records maintained by DOGAMI-MLRR. MAAP reports an average rehabilitation cost of $12,495 per hectare (US $4,100 per acre). However, they also report that land rehabilitation to crop use is typically more expensive. Oregon's Mined Land Reclamation Act of 1971 does not include funds for inventorying or reclaiming historic mine sites in Oregon.

Category of Reclamation	Acres	Percentage
Uncategorized	995	21.8
Agriculture	1,024	22.4
Anadromous Fish Habitat	33	0.7
Forestry	351	7.7
Housing	219	4.8
Open Space/Range	611	13.4
Other	740	16.2
Recreation	18	0.4
Returned to Exempt	92	2.0
Wildlife/Wetlands	488	10.7
2003 TOTAL STATEWIDE	**4,571**	

Table 4. Summary of disturbed acres within active DOGAMI-MLRR-permitted sites located within the 100 and 500 year floodplain in the Willamette River Basin.

B. Sources of Aggregate

According to Geitgey (1990) and Whelan (1995), aggregate materials in Oregon are produced by private companies, private landowners, and many federal, state agencies, counties, and municipalities. Crushed stone (basalt) is produced in all 36 counties; sand and gravel is produced in all but five counties. Aggregate is either sand and gravel retrieved from alluvium along Oregon waterways, from sand and gravel deposited in upland areas, from crushing of rock in upland areas, recycling, and importation. Production methods include open pits, quarries, and floating dredges.

1. Existing Mines. There are over 5,000 active and inactive aggregate sites in Oregon (see Figure 5). According to the Mineral Information Layer for Oregon (MILO) maintained by the Industrial Minerals Section of DOGAMI, approximately 1,474 sites have been selected for developing sand and gravel deposits. Over 3,600 sites have been selected for some sort of crushed stone resource. Not all aggregate sites are currently operating and some may have never existed beyond designation as a potential resource for later development. However, it is difficult to ascertain the number of aggregate sites with any degree of certainty because there is no single clearinghouse collecting this information.

The Department of Geology and Mineral Industries (DOGAMI-MLRR) administers the Mined Land Reclamation Act (the "act") passed in 1971 for commercial mines, or mines that sold aggregate (ORS 517.750-517.992). Since passage of the act, DOGAMI-MLRR has processed approximately 1058 permit applications for commercial mines; the new permit applications do not include amendments to existing permits (see Figure 6). The number of active commercial mines varies with time. DOGAMI-MLRR estimates that in 2004 approximately 800 commercial permitted mines were active and 564 mines were closed and reclaimed.

As listed on Table 5, the vast majority of aggregate produced in Oregon is by private entities. Mines producing less than 5,000 cubic yards or affecting less than one acre per year, or those used by on-site construction rather than commercial use are exempt from DOGAMI-MLRR regulations (Schnitzer, 1998). Columbia County is exempt from reporting to the DOGAMI-MLRR program because it adopted Ordinance No. 90-11 on June 20, 1990, as amended by Ordinance 2001-4 on March 14, 2001 to administer surface mining in that county.

Type of Producer	% of Total
Private Businesses with DOGAMI-MLRR permits	83.6
ODOT	4.1
Counties & Cities	4.0
BLM, USFS, & State Forests	1.9
Private Forestry	4.7
Smaller Producers	1.7
TOTAL	**100%**

Table 5. Summary of types of entities producing aggregate in Oregon. Adapted from Whelan (1995).

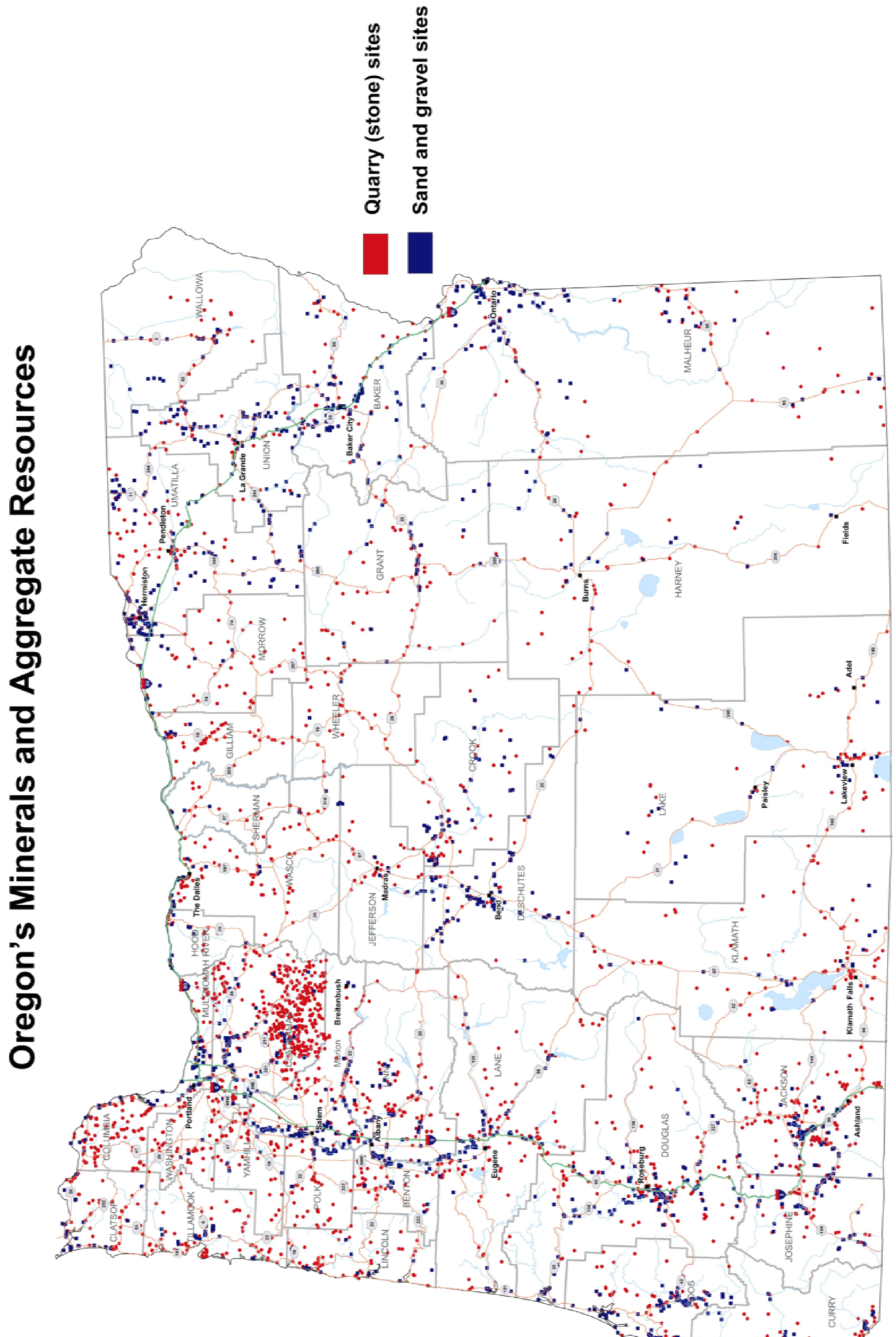

Figure 5. Map depicting approximate location of aggregate sites inventoried by the Industrial Minerals Section of DOGAMI. Figure provided courtesy of DOGAMI. Map does not include all sites on USFS and BLM lands.

An inventory of the US Forest Service (USFS) files indicates that approximately 2500 quarries have been used on USFS lands in Oregon. The Bureau of Land Management (BLM) files indicate that 1282 quarries are located on BLM lands in the western part of Oregon; the BLM has not inventoried the number of mines in the eastern part of Oregon. Approximately 50 quarries are located on the Oregon State Forest lands. The Oregon Department of Transportation (ODOT) owns or leases 750 aggregate sites (Wyttenberg and others, 2002). Quarries located on lands administered by the USFS, Oregon State Forests, or the BLM which mine material for exclusive use on these lands such as for road maintenance are exempt from a DOGAMI-MLRR permit.

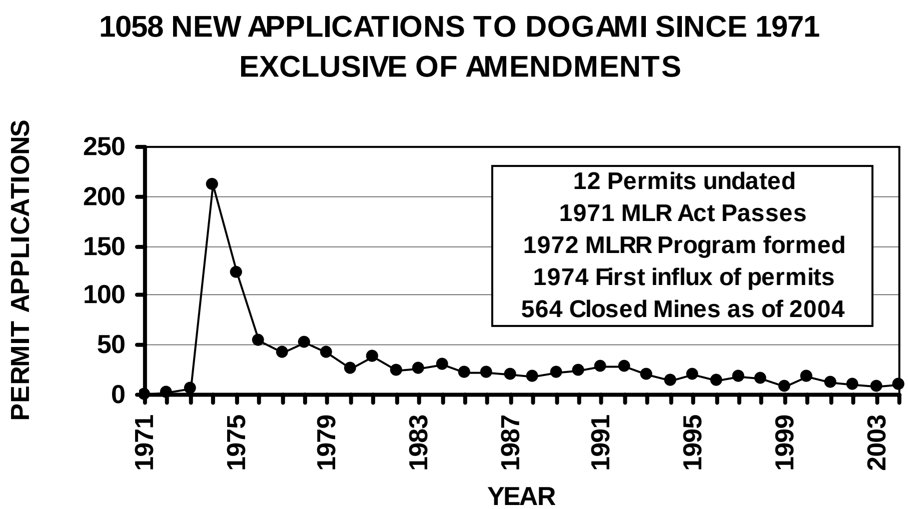

Figure 6. The Mineral Land Regulation and Reclamation (MLRR) program of DOGAMI-MLRR administers permit applications for commercial aggregate mines. Since 2001, permit applications processed by MLRR average 10 per year.

2. Sand and Gravel Deposits. As depicted on Figure 7, sand and gravel resources are located along the present day courses of Oregon's major rivers and river valleys, as well as in upland areas where ancient lakes, rivers, or glaciers once were located. As depicted on Figure 8, aggregate material is mined or dredged from in-stream sources in Oregon. The Oregon Department of State Lands (DSL) regulates aggregate mining or dredging activities within the bed and banks of "waters of the state". Oregon's Fill-Removal Law (ORS 196.800-990) requires individuals who remove or fill 50 cubic yards or more in "waters of the state" to obtain a permit from DSL.

The Oregon Water Resources Research Institute (OWRRI) reports that approximately 126 permits were issued for commercial gravel removal from 1967 to 1994 and Castro and Cluer (2003) indicate that approximately 40 commercial in stream gravel removal sites exist in Oregon. The Willamette River and Umpqua river basins host the bulk of the in stream gravel removal operations; however, Schnitzer and others (1999) report that the number of in stream operations continues to decline with time as operators decrease operations along Oregon water ways as new mines are subject to essential fish habitat (EFH) consultations by the National Marine Fisheries Service, Northwest Region

(NMFS) in response to the Magnuson-Stevens Fishery Conservation and Management Act. The biological opinions issued by NMFS suggest locating mines to upland locations to limit the impacts of gravel disturbance on salmon habitat and stream health (for example, see NMFS, 2004: Oregon Water Resources Research Institute, 1995). As a consequence, the stakeholder process group collectively decided not to complete additional research on this source of aggregate.

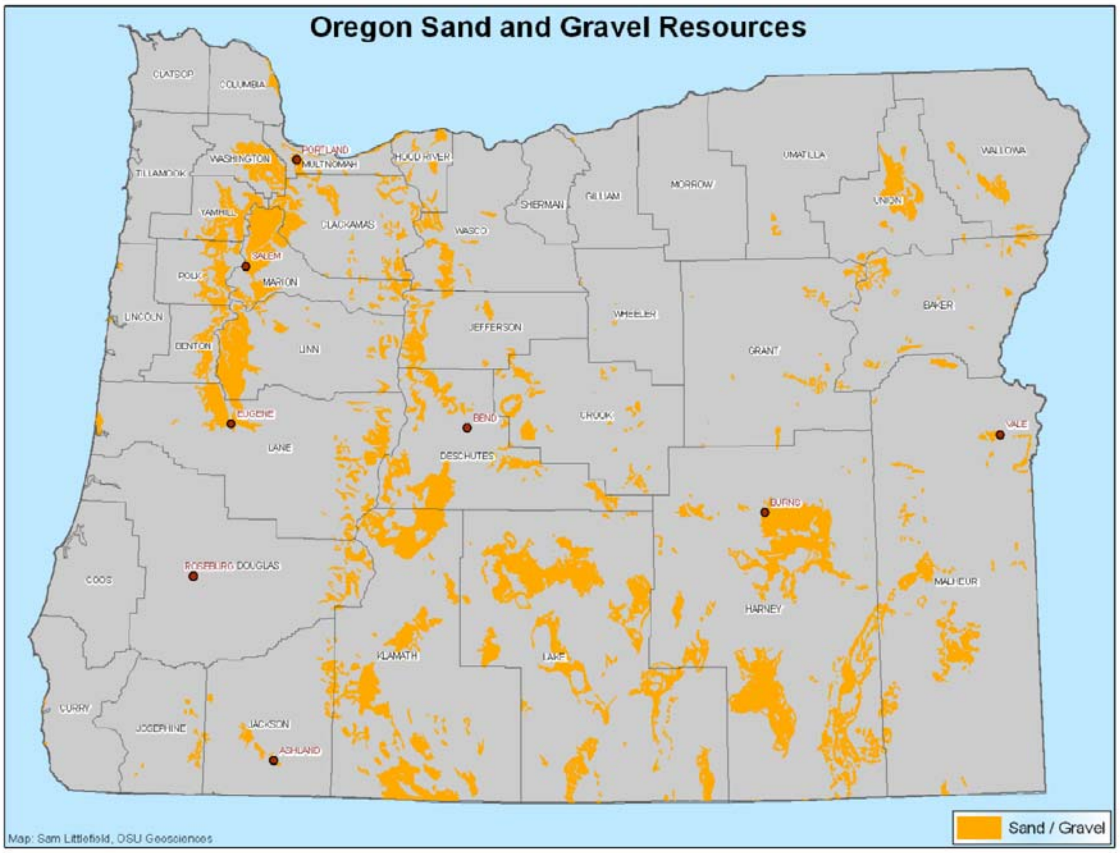

Figure 7. Bookstrom and others (1995) used the State Geologic Map of Oregon to develop first order approximations of potentially developable sand and gravel resources. On the basis of their analysis, the sand and gravel deposits depicted on this map include: alluvium, terrace gravels, glacio-fluvial deposits, glacial deposits, fanglomerate, older terrace gravels, and lacustrine and fluvial sedimentary rocks (unconsolidated to semi-consolidated clay, silt, sand, and gravel).

No quantitative estimates were published for sand and gravel resources in Oregon. Given that approximately 61% of the developed aggregate resources in Oregon were derived from mines located in the counties within the Willamette River Basin and approximately 46% of the Willamette River Basin production comes from mines located along the 100-year and 500-year floodplain, first order approximations of the potential aggregate resources were made for this area. These first order approximations used the mapping of floodplain deposits of the Willamette River by O’Conner and others (2001) and Bookstrom and others (1995), and assumed a variable thickness of the sand and gravel

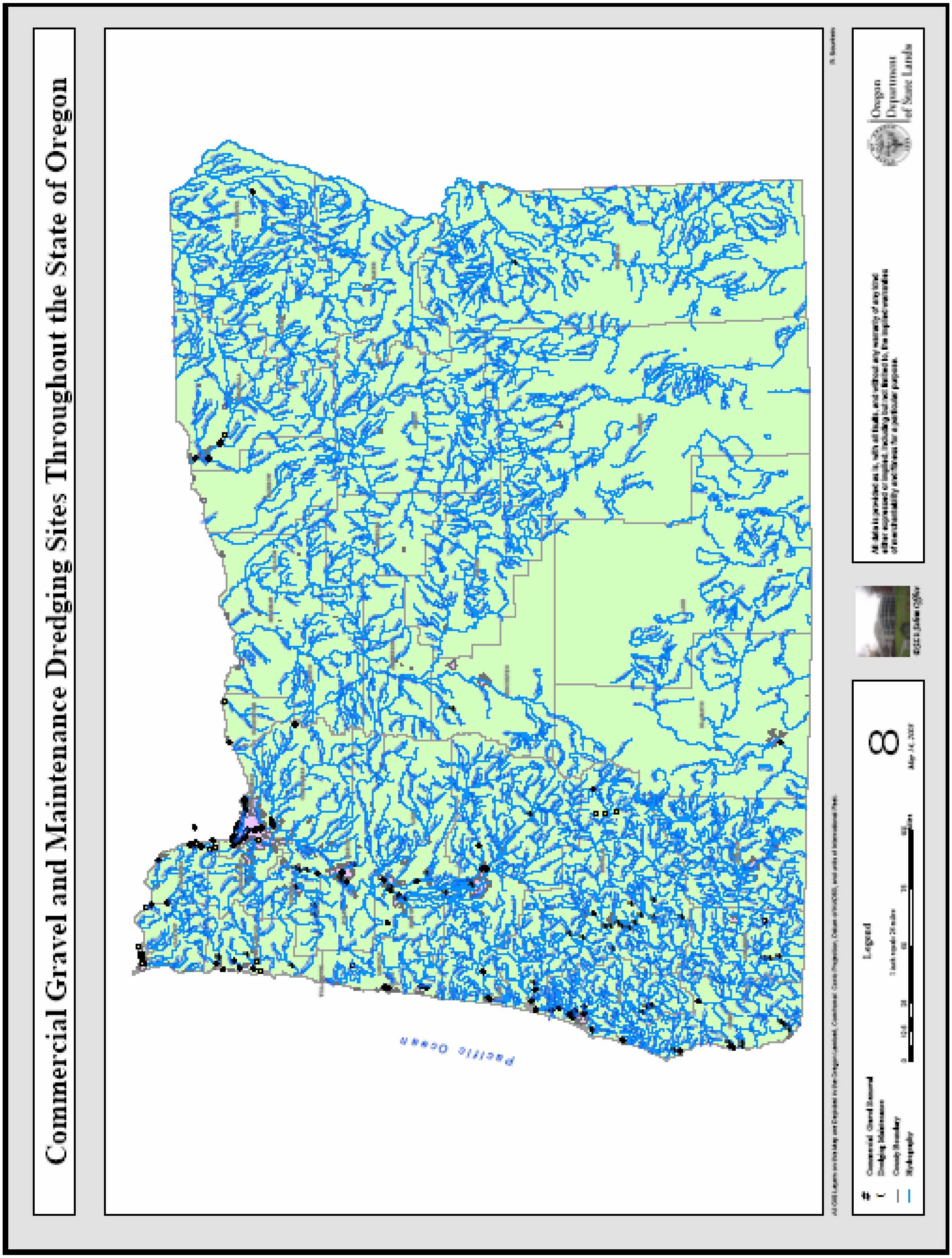

Figure 8. Map depicting locations of commercial in-stream sand and gravel mining in Oregon. Map courtesy of the Department of State Lands.

layers ranging from 10 to 30 feet which might be considered recoverable in the future within the Willamette River Basin. Through the use of GIS, the sand and gravel resources in the alluvium were calculated for the area which roughly corresponds to the two-year floodplain as defined by Schnitzer and others (1999) to range from 16.1 billion tons to 48.3 billion tons. For the floodplain and upland areas which roughly correspond to the 100-year floodplain and upland deposits as defined by Schnitzer and others (1999) the estimates of undeveloped resource ranges from 25.2 billion tons to 77.1 billion tons. For both estimates the calculations were corrected for areas that were “sterilized” by built areas or roads as defined in the GIS files developed for the Willamette River Basin Atlas (see Hulse and others, 2002) or areas where aggregate deposits were suspected of being overlain by overburden approaching 100 feet or more.

Sand and gravel aggregate resources are graded by the aggregate industry and ODOT as “concrete grade” and “base grade”. Portland cement concrete grade (PCC) aggregate has been naturally sorted, rounded, and polished in rivers and creeks. aggregate is used primarily in finished concrete work. According Planning Department of Shasta County, California (1998), concrete grade aggregate is valuable for finished concrete work because (1) the rounded material allows for a smooth finish, (2) the material requires less cement and water than crushed stone, (3) the material is easier to mix, pour, and place, and (4) the material is less costly than crushed stone and requires less processing. In Shasta County, California, the supply of PCC grade aggregate is more limited than non-PCC grade material.

Road base grade aggregate is material that may not meet the specifications or qualities for PCC grade material, but which is still useful for road base. However, road base must meet Federal and State adopted specifications for road construction applications. It includes material that may be more weathered, softer, and have more clay than PCC grade material. Like PCC grade aggregate, road base grade is also found along river and creek channels and terraces (Shasta County, 1998).

DLCD procedures and requirements for complying with Statewide Planning Goal 5 are silent with respect to the issue of concrete versus base grade aggregate. The only reference to base grade aggregate regarding “significance” is listed under OAR 660-023-0180(3)a, where “a representative set of samples of aggregate material in the deposit on the site meets applicable Oregon Department of Transportation (ODOT) specifications for base rock for air degradation, abrasion, and soundness, and the estimated amount of material is more than 2,000,000 tons in the Willamette Valley, or more than 500,000 tons outside the Willamette Valley.

3. Crushed Rock. On the basis of historic production data compiled by the US Geological Survey (1992-2002), crushed rock comprises approximately 50% to 60% of the total production in Oregon. As listed in Table 1, crushed rock comprises approximately 43% of the commercial aggregate production in the Willamette River Basin, 79% of the commercial aggregate production in the coastal counties, 65% of the commercial production in the southern counties, and 60% of the commercial production in the eastern counties. As depicted on Figure 9, the majority of the crushed rock resources are found in the Cascade Range and areas eastward.

While not depicted on Figure 9 due to irregular outcrop patterns and the scale of the map, volcanic rocks within the Willamette River Basin include the Columbia River Basalt (CRB) and mafic volcanic flows as summarized by Johnson and Raines (1995) with digital mapping included in the Willamette River Basin Planning Atlas of Hulse and others (2002). Both the CRB and mafic flows are quarried in the Willamette River Basin. For example, Morse Bros. apparently quarries the mafic volcanic flows near the Coffin Butte Landfill located north of Corvallis as depicted on Figure 10. However, some of these crushed rocks resources are also overlain by Prime or High Value Soils as depicted on Figure 10.

Quantitative estimates of crushed rock resources were not completed as part of this study. According to Bookstrom and others (1995):

"No quantitative estimates were made for undiscovered resources of rocks suitable for crushed-stone aggregate, because the required tonnage and grade models have not been compiled, and the potential supply is limited less by geology than by land-use patterns".

While Langer and Glanzman (1993) indicate that crushed stone can substitute for sand and gravel in most applications, Schnitzer and others (1999) state that "Upland quarries provide aggregate for asphalt and road base. Typically, however, they produce angular rock less suitable for concrete aggregate." Langer and Glanzman (1993) suggest that angular particles of crushed stone are desirable in asphaltic mixes because the contact between the angular particles provides strength. Langer and Tucker (2003) report that asphalt highways typically require crushed stone aggregates in order to achieve the required strength parameters (Langer and Tucker, 2003)

As discussed in later sections of this report, crushed rock is used in approximately 4% of the concrete manufactured in Oregon. The Kiewit Center for Infrastructure and Transportation indicates that it is possible to make concrete with 3,300 psi compressive strength or of any strength which is durable with either crushed or rounded aggregate. In fact, they report that high strength concrete (10,000+ psi) almost always uses crushed rock aggregate. For example, Neville (1997) reports "The influence of the type of coarse aggregate on the strength of concrete varies in magnitude and depends on the water/cement ratio of the mix. For water/cement ratios below 0.4, the use of crushed aggregates has resulted in strengths up to 38 percent higher than when gravel is used. With an increase in the water/cement ratio, the influence of aggregate falls off, presumably because the strength of the hydrated cement paste itself becomes paramount and, at water/cement ratios above 0.65, no difference in the strengths of concretes made with crushed rock and gravel has been observed."

Langer and Glanzman (1993) and Shasta County (1998) report that the rounded particles within sand and gravel are valuable in cement concrete because rounded particles apparently improve the workability of the wet concrete. The American Concrete Institute indicates that less water is needed to mix concrete using rounded rock aggregate with same "slump" properties as crushed rock aggregate (see Standard Practice for Selecting Proportions for Normal, Heavyweight and Mass Concrete, Method ACI 211.1, American Concrete Institute, 2005). Assuming a market value of $50 per ton for cement, Dr. Jim Lundy of the Kiewit Center for Infrastructure and Transportation suggests that less water use would yield a savings of approximately $2.10 per cubic yard of concrete.

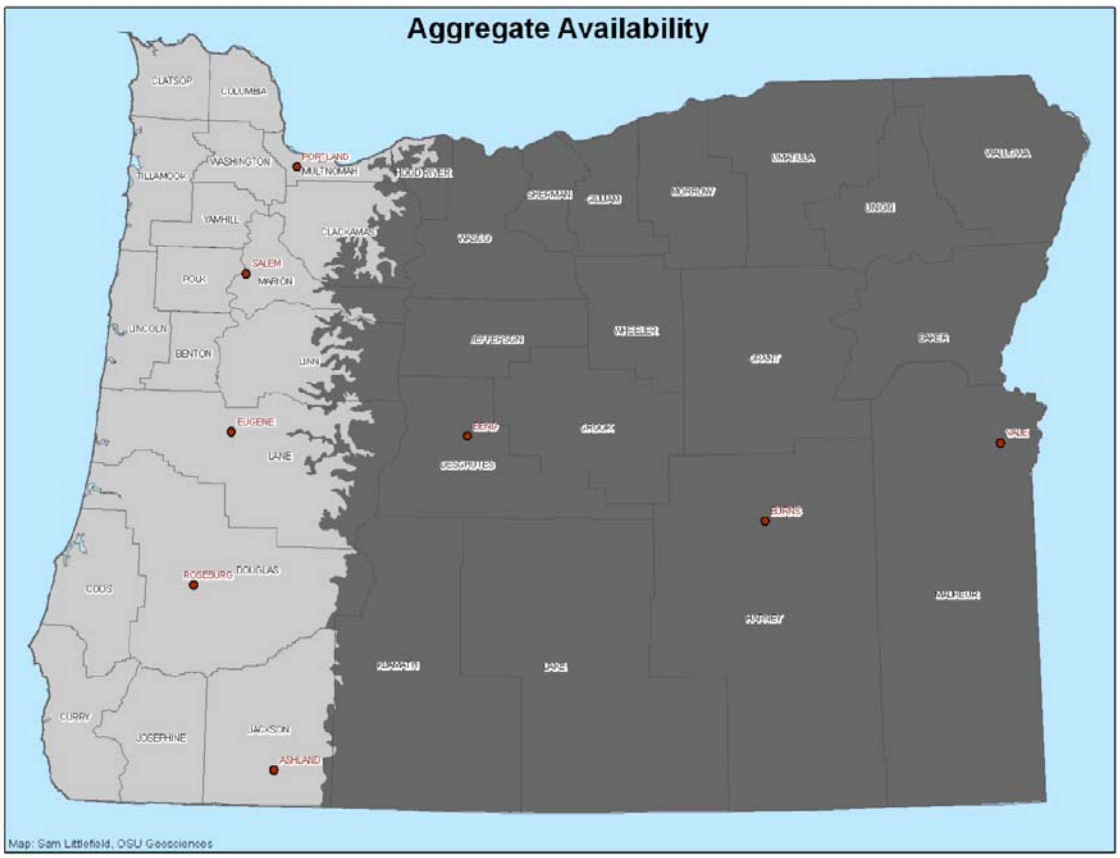

Figure 9. Bookstrom and others (1995) used the State Geologic Map of Oregon to develop first order approximations of potentially developable crushed rock resources. The dark gray areas were identified as potential areas of interest for developing crushed rock resources.

The cost difference is related to the need for additional water required to achieve the same workability when crushed aggregates are used as described by Method ACI 211.1 of the American Concrete Institute. Assuming that concrete strength is related to the water/cement ratio (and this is widely accepted in the transportation engineering industry), then more water implies more cement is required to achieve the same water/cement ratio (same strength). All this assumes admixtures, or additives, are not used.

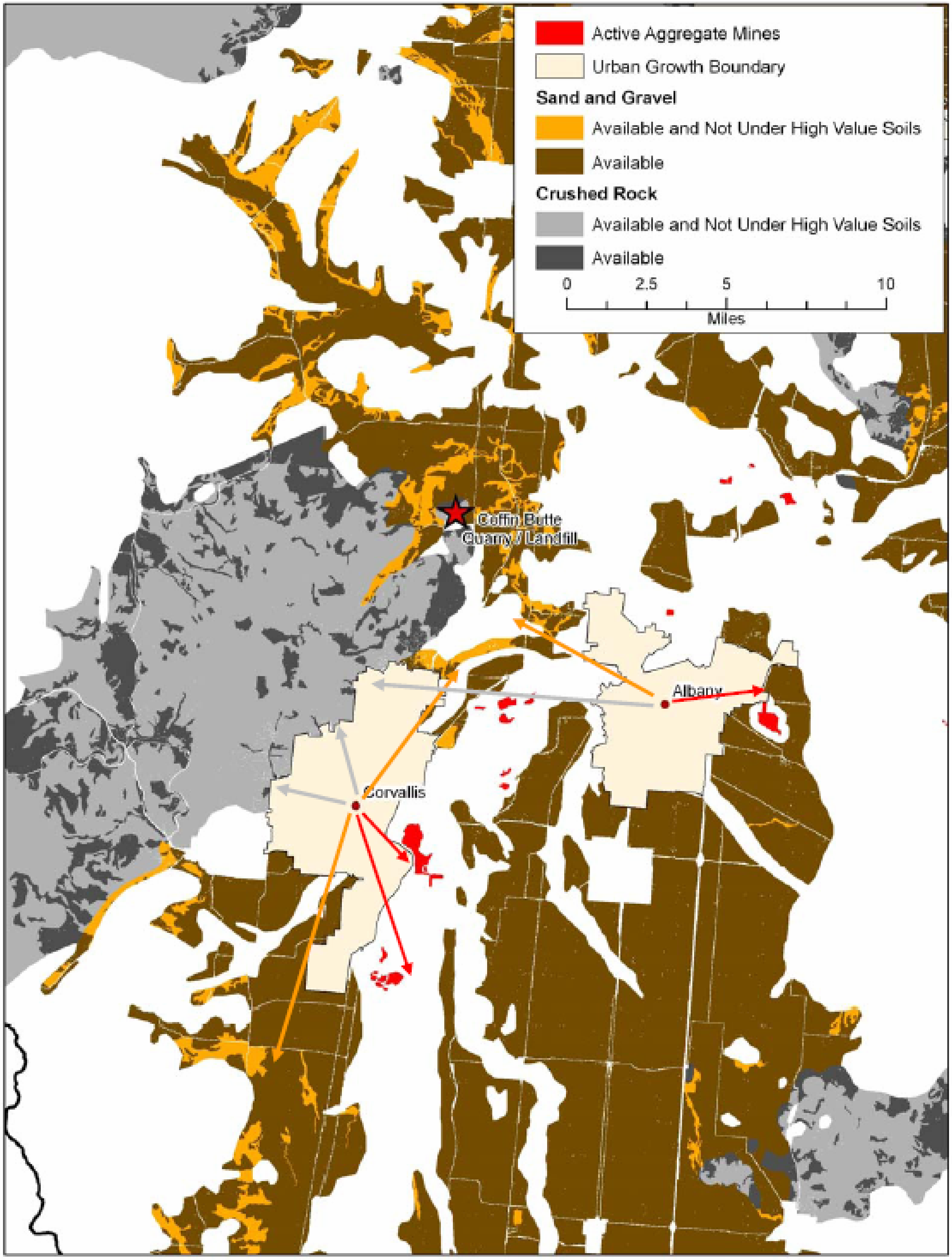

Figure 10. Crushed rock resources may also be overlain by Prime or High Value Soils. The dark gray areas reflect potential crushed rock resources overlain by High Value Soils near Corvallis. This mapped was field checked by visiting the crushed rock quarry near Coffin Butte Landfill north of Corvallis.

As reported for low water/cement ratios, Dr. Lundy reports that crushed aggregate mixes achieve higher strength than rounded aggregates; however, at high water/cement ratios, the difference is not noted. Consequently, it is possible that for low water/cement ratio mixes the use of crushed aggregates it may not be required to increase the amount cement to achieve the same strength. Conversely, at high water/cement ratios one likely would have to increase the amount of cement, thus increasing the cost.

Dr. Lundy concludes that the available information indicates that the analysis is limited. Dr. Lundy did not consider the impacts of admixtures (e.g., water reducers) to improve workability nor did his analysis consider the impacts of potential strength gains associated with the use of crushed aggregates at low water/cement ratios. Without a more thorough analysis (and perhaps laboratory work), it is virtually impossible to make definitive statements regarding the majority of crushed versus rounded aggregate.

However, all sand and gravel aggregates, as well as crushed rock aggregates, must be tested for resistance to abrasion, degradation, and soundness for use in asphalt concrete and Portland concrete cement, and for abrasion and degradation for use as base and shoulder materials on a case-by-case basis (Wyttenberg and others, 2002). A brief overview of each test as described by Wyttenberg and others (2002) is provided in Appendix No. 2.

While using lower quality sand and gravel or crushed rock aggregates potentially used in asphalt mixtures would likely lower the initial cost of a paving preservation project, the life of treatment would be reduced depending on the traffic volume and freeze-thaw conditions. ODOT is pursuing the concept of using lower quality aggregates for low volume road projects; the impact on aggregate demand will probably not be affected because low volume road preservation projects account for less than 10% of ODOT's total preservation program. Low quality aggregates used in medium to heavy traffic will obviously lead to premature pavement failures because low quality aggregate reduces to sand with repeated abrasion. ODOT reports rutting and tearing of pavements constructed with low quality aggregates in high traffic areas within six months of construction.

4. Recycled Materials. Other sources of aggregate include recycled materials. The US Geological Survey (1999) indicates that recycled aggregates produced from recycled concrete supply roughly 5 percent of the total aggregates market in the US. Whelan (1995) indicated that approximately 2 million tons of aggregate or approximately 4 percent of the total aggregate used in Oregon in 1995 were recycled each year in Oregon. The Oregon Department of Environmental Quality, Land Quality Division (2002) indicates 70,000 to 80,000 tons of aggregate products were landfilled in 2002. Twenty eight percent of the material was recycled into aggregate in 2002.

While the opportunity remains to use more recycled aggregates, one must consider that the US Geological Survey (1999) estimates the average capacity of a recycling facility is 163,500 tons per year. In other words, approximately 12 recycling facilities would be required to potentially double the quantity of available recycled materials in Oregon. A straw poll of aggregate processors in the Willamette River Basin indicates that many are not recycling concrete because they do not have crushing capabilities. Jake Polvi of the Kiewit Center for Infrastructure and Transportation estimates that the cost to purchase crushing equipment for recycling is in excess of $300,000 per unit.

Jake Polvi of the Kiewit Center for Infrastructure and Transportation estimates that if recycled materials were locally available, the cost to purchase one ton would approach $5.50 which was estimated to be cheaper than costs for using sand and gravel or crushed rock materials. Unfortunately, the reused concrete aggregate does not meet ODOT specifications for aggregates, including gradation, and would most likely be considered a pit run grade material. Jake Polvi of the Kiewit Center for Infrastructure and Transportation indicates that they are exploring the specifications and working with the ODOT material engineers to see how recycled materials may be used more effectively and hopefully create a useful market.

6. Imported Material. Imported aggregate continues to be a source of construction materials used in Oregon. Whelan (1995) estimated that approximately 2.4 million tons of aggregate were imported from Washington. Robert Whelan (personal communication) indicated that imported materials were more than likely increasing in use as some of the more mature quarries and pits such as those located on Ross Island begin the process of closing.

C. Demand for Aggregate

1. Total Demand. It is hard to imagine that a typical Oregonian's "share" of aggregate use in the state amounts to about 10 to 15 tons of sand, gravel, crushed rock, and recycled concrete and asphalt per year or about one dump truck load per person (Whelan, 1995; ODOT/DLCD, 2002). But when one considers that the Grand Coulee Dam required 17 million tons of aggregate, the Denver International Airport required nearly 5 million tons of aggregate, that approximately 85,000 tons of aggregate are used to construct the typical one mile stretch of a four lane highway, and that a typical six room home requires about 90 tons of aggregate, the typical Oregonian's use of crushed rock, sand, and gravel should come as no surprise to an individual citizen given the bigger picture (Bella Coola Rock Corporation, 2005). As Oregon's population grows so will the demand for aggregate.

The total amount of sand, gravel, and crushed rock produced in Oregon is difficult to quantify with any degree of certainty because no single state or federal agency collects the information. Only producers of commercial aggregate derived from outside of Oregon's waterways are required to report production to the DOGAMI-MLRR who maintains accurate records of commercial production or rock sold since the 1970s. Producers of commercial aggregate from Oregon's waterways report their production to the Oregon Department of State Lands (DSL). The US Geological Survey and the former Bureau of Mines have the most consistent records of aggregate production dating back to the 1930s. The Bureau of Mines and US Geological Survey surveyed a select group of producers and their information is not clear as to whether their inventories include commercial producers from Oregon's waterways, from outside of Oregon's waterways, counties, forest lands, etc.

Table 6 provides a comparison of the data reported by both agencies since 1997. Neither database accurately inventories total aggregate production in Oregon (Whelan, 1995). On the basis of data collected by Whelan (1995), the 1993 production of aggregate in Oregon is roughly 40% greater than the reported aggregate production by the US Geological Survey. However, the US Geological Survey data is the only source of consistent national aggregate data. On the basis of files maintained by the US Geological Survey from 1992 to 2002 the historic percentage split between tonnages of crushed rock comprises approximately 50% to 55% of the total aggregate produced in Oregon.

Year	USGS Records (Short tons)	DOGAMI-MLRR Commercial Aggregate Production (Short tons)
1997	44,423,145	38,829,870
1998	46,076,612	42,299,101
1999	44,312,914	37,888,196
2000	41,116,211	35,363,845
2001	41,998,061	31,647,122
2002	45,966,381	31,389,144
2003	41,667,367	

Table 6. How much aggregate is produced in Oregon is difficult to determine because there is no central clearinghouse of aggregate production records. The Bureau of Mines and US Geological Survey records are the most consistent database dating back to the 1930s. DOGAMI-MLRR maintains accurate records of commercial production or rock sold since the 1970s.

While DOGAMI-MLRR and DSL track commercial aggregate production by permittees, not all producers of aggregate are required to report to these agencies. For example, aggregate mining on lands administered by the U.S. Forest Service and the Bureau of Land Management for use on roads on these lands is exempt from permitting and reporting. Likewise, aggregate mining on lands administered by the Oregon Department of State Forests are also exempt from permitting and reporting to DOGAMI-MLRR and DSL unless the aggregate is used on lands beyond the jurisdiction of the state forests. Columbia County administers a permitting and reporting program outside of the DOGAMI-MLRR program. With the exception of DSL permitted commercial operations, these "permit-exempt" producers developed approximately 2.9 million tons of aggregate and rock materials in 2003-2004 beyond the production figures listed in the above table (USFS, various; Anthony Hyde, Columbia County, personal communication; Department of State Forests, personal communication). According to Castro and Cluer (2003), removal of in-stream aggregate approaches 5.5 million cubic yards per year or approximately 11 million tons beyond the DOGAMI-MLRR production figures listed in

Table 6. DSL records for 2003 reveal that over the past couple of years of records, the Columbia, Willamette, Umpqua and Chetco rivers host the bulk of the in-stream gravel operations.

2. Character of Demand. Aggregate is a high-bulk, low unit value commodity that derives value from being located near a market (Langer, 2002). As a consequence, the distribution of intensive aggregate mining in Oregon roughly corresponds to the general location of urban areas as depicted on Figure 11.

> "We can move rock cheaper by rail than we can on the highway. Our biggest reward is the reduction of risk by not having to have our trucks on the road". Dave Jensen -- Morse Bros.

However, the market area for a typical aggregate producer can often be larger than the immediate vicinity of the mines that are managed, zoned, and regulated for aggregate production (Robinson and Brown, 2002). For example, until 1999, Morse Bros. trucked 500,000 tons of aggregate annually from its Salem quarry to its Portland site -- about 13,000 trucks each year, nearly all returning to Salem with empty backhauls. Now, in partnership with the Portland & Western Railroad, Morse Bros. sends the aggregate to Portland by rail, on its own 17-car unit train (see http://www.trainweb.org/oregonshortline/roads.htm for more information).

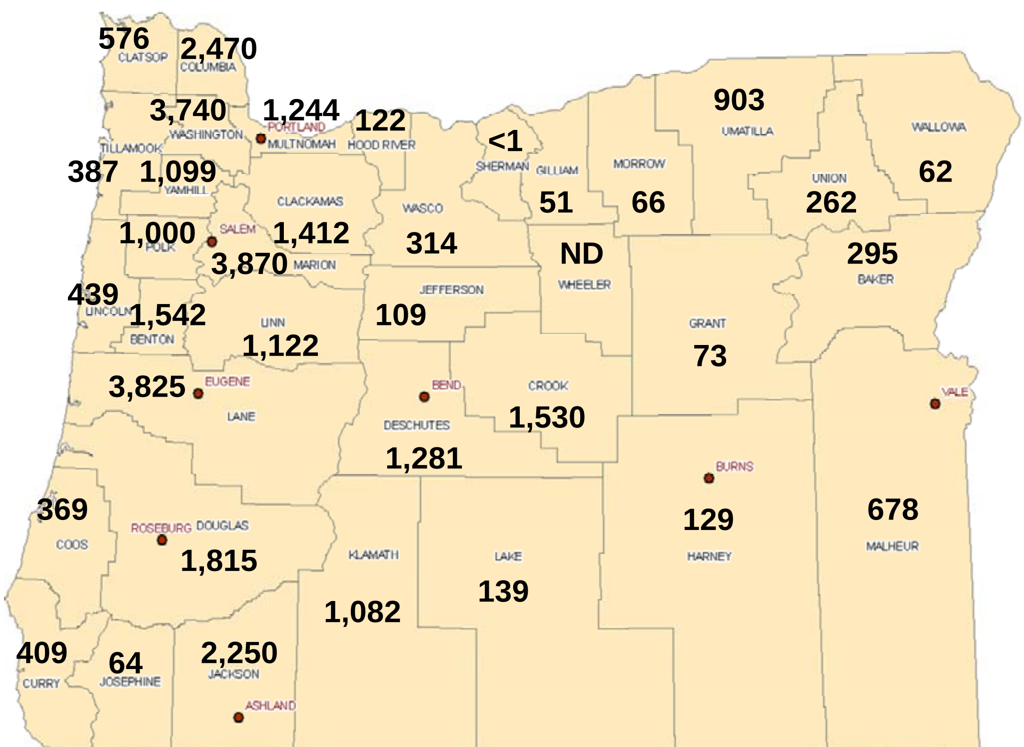

Figure 11. Commercial aggregate production in thousands of short tons by county. Note the strong correlation of aggregate production near urban areas. Data from Marshall (2004) and Dugdale (2004).

Whelan (1996; 1996) indicates that no one collects end-use data for aggregate. Whelan (1995) used predictive models to estimate the end-use consumption of aggregate for 28 end-uses. Table 7 provides a summary of select major and minor end use classifications. When viewed at the national level, aggregates derived from crushed rock are consumed in Portland cement concrete, road base, asphaltic concrete, and other applications, whereas almost half of the aggregates derived from sand and gravel are consumed in Portland cement concrete (Wilburn and Goonan, 1998).

Type of End-Use	% of Total
Roads	29.4
Non-Residential Construction	27.4
Residential Construction	16.2
Other Infrastructure	19.1
Railroad and Nonconstruction Uses	6.3
Farms, Ranches, and Agricultural	1.6

Table 7. Abbreviated summary of end-use consumption from Whelan (1995).

The use of sand and gravel versus crushed rock in different applications is probably a function of what is locally available and economic to transport. As listed in Table 1, crushed rock production exceeds sand and gravel production on a percentage basis in the coastal counties of Oregon, the eastern Oregon counties, and the southern Oregon counties, whereas sand and gravel production is more prevalent in Willamette River Basin. County-by-county summaries of commercial aggregate production as reported by DOGAMI-MLRR are depicted on Figure 12.

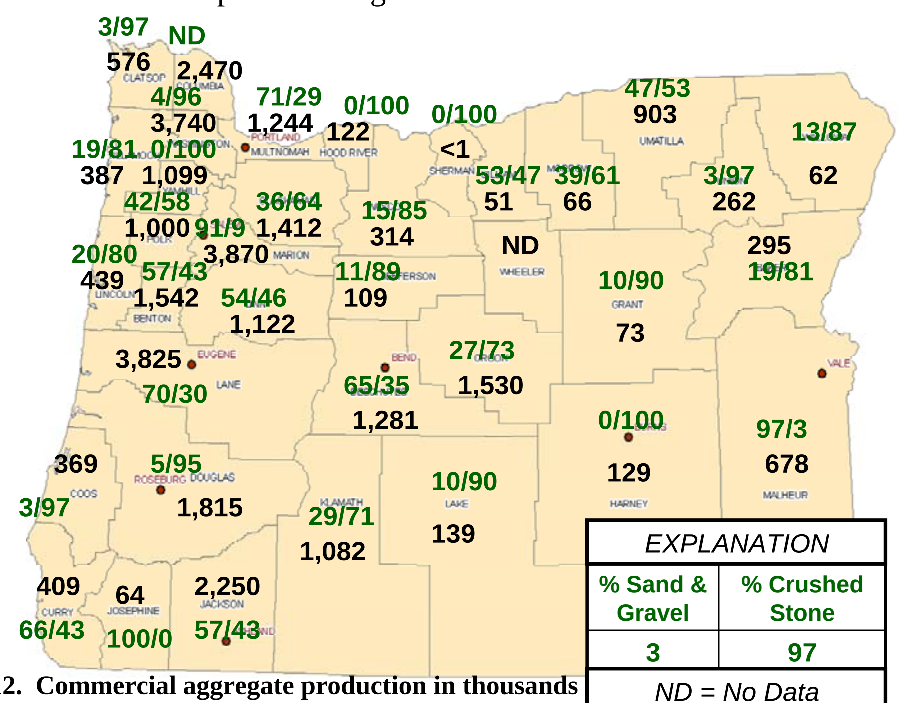

Figure 12. Commercial aggregate production in thousands of tons by county with percentage of sand and gravel and crushed stone. Data from Marshall (2004).

Product 2001 USGS Data	Sand & Gravel (short tons)	Crushed Rock (short tons)	Totals (short tons)
Concrete Agg. & Concrete Prod.	4,387,199	196,211	4,583,410
Asphalt Agg. & Bit. Mixture	1,984,160	239,202	2,223,362
Road Base	4,993,470	6,036,257	11,029,727
Fill	946,885	620,601	1,567,487
Miscellaneous	451,948	1,124,358	1,576,305
Unspecified	6,327,267	11,508,130	17,835,397
TOTAL	19,090,929	19,724,758	38,851,688

Table 8. Tonnage of product manufactured by each source of aggregate in Oregon. 2001 data from the US Geological Survey (2004).

When viewed at the state level as listed in Table 8, aggregates derived from crushed rock and sand and gravel are consumed in concrete and concrete products, asphalt and bituminous mixtures, road base, fill, and other applications. As listed in Table 9, approximately 12% of the total produced aggregate is used for concrete and concrete products, approximately 6% of the total produced aggregate is used for asphalt and related mixtures, and approximately 28% of the total produced aggregate is used for road base.

Product 2001 USGS Data	Sand & Gravel (short tons)	Crushed Rock (short tons)	Totals (short tons)
Concrete Agg. & Concrete Prod.	23%	1%	12%
Asphalt Agg. & Bit. Mixture	10%	1%	6%
Road Base	26%	31%	28%
Fill	5%	3%	4%
Miscellaneous	2%	6%	4%
Unspecified	33%	58%	46%
TOTALS	100%	100%	100%

Table 9. Percentage of source of aggregate in Oregon used for each product. 2001 data from the US Geological Survey (2004).

When viewed at the state level as listed in Table 10, approximately 96% of the extracted sand and gravel is used to manufacture concrete and concrete related products. Likewise, approximately 89% of mined sand and gravel is used for asphalt and related mixtures. Crushed rock comprises approximately 55% of the road base and over 70% of the miscellaneous uses. The US Geological Survey did not elaborate on what constituted unspecified uses in Tables 8,9, and 10, but some of the information is apparently grouped where it cannot be specified due to the information being proprietary.

Product 2001 USGS Data	Sand & Gravel (short tons)	Crushed Rock (short tons)	Totals (short tons)
Concrete Agg. & Concrete Prod.	**96%**	**4%**	**100%**
Asphalt Agg. & Bit. Mixture	**89%**	**11%**	**100%**
Road Base	**45%**	**55%**	**100%**
Fill	**60%**	**40%**	**100%**
Miscellaneous	**29%**	**71%**	**100%**
Unspecified	**35%**	**65%**	**100%**

Table 10. Percentage of product manufactured from each source of aggregate in Oregon. 2001 data from the US Geological Survey (2004).

3. Future Demand. The State of Oregon Office of Economic Analysis, Department of Administrative Services, and Portland State University Population Research Center Population Projections for Oregon estimate 5.5 Million people by 2040. When the population is integrated with aggregate use in Oregon, the annual per capita consumption approaches 10 to 15 tons, which is comparable to the national average in the United States and Canada (Robinson and Brown, 2002; Bella Coola Rock Corporation, 2005). As the population density increases, Whelan (1995) suggested that the annual per capita consumption decreases; consequently, the projected annual per capita consumption in Oregon is anticipated to decrease with time as depicted on Figure 13. The historic aggregate use per capita as determined from integrating aggregate production in Oregon as summarized by the US Geological Survey with the historic population records depicted on Figure 13 confirms Whelan's projections.

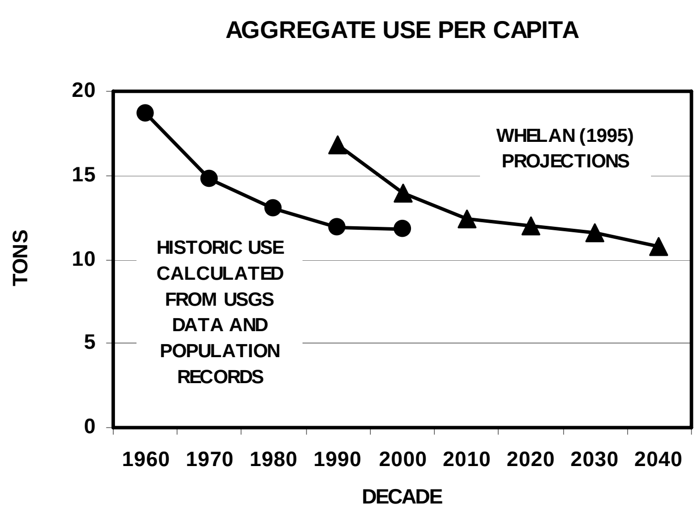

Figure 13. Per capita consumption of aggregate decreases as the population density increases. Data from Bureau of Mines, Portland State University Population Center (2004), and Whelan (1995).

Traditional methods of predicting aggregate consumption assume that demand correlates with population growth and that the annual number of tons used per capita remains unchanged as the population changes. On the basis of a county-by-county inventory of Oregon aggregate consumption, Whelan (1995) suggests that this assumption is not entirely true, and that rural counties typically have larger rates of annual consumption per capita as opposed to the more populated urban areas.

Acknowledging that the per capita consumption changes with time as depicted on Figure 13, and assuming (1) that the annual aggregate use per capita approaches 11 tons per capita as predicted by Whelan (1995) for 2040, and (2) that the past and current aggregate demand are poorly constrained, aggregate demands were calculated using the available population growth and aggregate production data from the US Geological Survey. While the data distribution is less than ideal, projected aggregate demand ranges from 60 million to 90 million tons by 2040 as depicted on Figure 14. Whelan (1995) forecasted an average annual demand of 52 million tons per year over this same period.

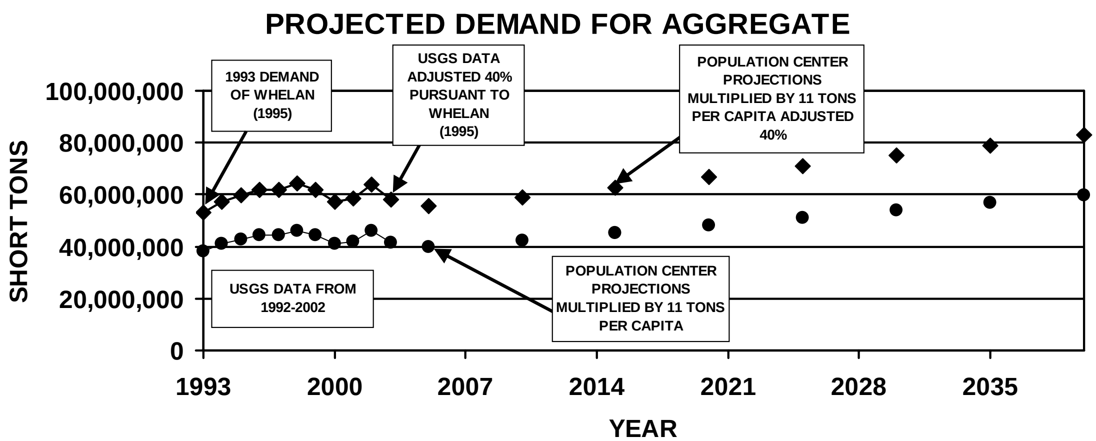

Figure 14. Predictions of aggregate demand are poorly constrained due to the limited information regarding actual demand. Integrating a per capita consumption of 11 tons per person with the anticipated population growth yields projected demands ranging from 60 to 90 million tons by the year 2040. For comparison, county-by-county projections by Whelan (1995) indicated an average annual demand of 52 million tons per year, with over 50% of this demand needed to meet the demands of the urbanizing Willamette River Basin for this same time period.

Jaeger (2005) used multivariate regression analysis of data on production of both sand and gravel and crushed rock from the US Geological Survey Minerals Information, (1992-2002), and the Bureau of Mines Minerals Yearbook (1932-1993) and combined these data with geographic, demographic and economic data across 45 states and for 33 years (1970-2002). The results of this statistical analysis yielded forecasts for aggregate use in Oregon ranging from about 90 to 150 million tons per year in 2050.

4. Road Use. The stakeholder process group requested information on specific uses of aggregate by ODOT, both currently and projected into the future. ODOT Deputy Director Doug Tindall reports negligible quantities of Portland concrete cement (PCC) pavement were used for the past few years, and the need for PCC pavement will probably remain negligible for the immediate future. The quantity of PCC pavement will likely never be very high, unless studded tires were banned and then the quantity may go up (Douglas Tindall, personal communication to INR via email August 4 and 13, 2004).

Because ODOT's concrete bids are based on lump sum prices in place, they do not bid materials by a unit price. However, the quantity of PCC for cement structures for highways needed in a year is about 66,500 tons, with approximately 50,000 tons of which is aggregate. However, that is poured in place concrete, and does not include pre-stress beams or slabs. ODOT does not have any way to estimate that quantity, except that it is likely more than the poured in place number.

ODOT estimates that hot mix asphalt is about 1.7 million tons per year, with approximately 1.6 million tons of which is aggregate. Other asphalt mixes (primarily emulsions) approach about 150,000 tons per year, with about 140,000 tons of which would be aggregate. Other asphalt materials are also about 150,000 tons per year. ODOT makes the same assumption on the portion of that which is aggregate (about 140,000 tons), but seals may use slightly less aggregate per ton of mix than do other mixes.

For base rock (which would include shoulder rock), ODOT uses about 1.6 million tons per year, this is all aggregate. The quantity of material needed for sub base is difficult to estimate as there is no way to tell how much aggregate is in embankments and how much is just dirt. ODOT uses about 400,000 tons per year for sanding, but the amount of pumice or cinders is difficult to differentiate from the crushed aggregate, so it is assumed that the total reported amount is aggregate.

Wyttenberg and others (2002) indicate that ODOT will need approximately 61 million tons of aggregate to meet the transportation needs of Oregon by 2017, or an average of approximately 4 million tons per year. ODOT's use in 2003 approached 3.79 million tons which represents approximately 9.1% of the total reported production for Oregon.

Because most ODOT projects bid projects on a lump sum basis with aggregate materials in place, aggregate costs as a percentage of total project costs are difficult to estimate with a high degree of certainty. ODOT estimated that the cost of aggregate is about 12% of the total cost of a pavement preservation project (see glossary) consisting of asphalt concrete paving. ODOT Deputy Director Doug Tindall indicates that the percentage is considerably less, somewhere between 3 to 4% for modernization projects (see glossary) including adding lanes.

ODOT estimates that doubling the price of aggregate through increased haul or extraction costs would not come close to doubling the costs of even the most paving intensive preservation projects. However, budget cuts preclude keeping up with preservation projects and the percentage of pavements below fair or better condition increases each year. As a consequence, incremental increases in cost of aggregate will limit the number of miles ODOT is able to preserve each year, thus increasing the rate of decline in pavement condition.

For new construction projects, Dr. Jim Lundy suggests that given the significant variation in the cost of aggregates across the state, coupled with the increased volatility of the petroleum and cement markets over the last 12 to 18 months, any estimates of the proportional cost of aggregates in new construction projects containing concrete or asphalt are highly questionable and will not be addressed as part of this study.

5. Transportation Costs. Transportation costs greatly affect the final cost of aggregate to the end user. The cost of aggregate transport is not widely published and varies widely across the US. For example, a telephone survey of state transportation departments completed by William Austin and provided to INR through Consensus Group member Bruce Chapin for this project reveal costs ranging from reported lows of $0.02 to 0.04 per ton mile in Wisconsin to $1.10 per ton mile in Wyoming. As listed in Appendix No. 3, confirmation of the costs listed in this survey through a telephone survey of Oregon trucking companies yielded different reported costs, thus revealing the dynamic nature of transportation costs over a short time span.

Robinson and Brown (2002) reported that transportation by truck costs an average $0.18 to $0.25 per ton per mile driven for transport distances of 30 to 50 miles. Transport distances of greater than 30 miles to 50 miles may thus increase the costs of natural aggregate to the user by a factor of 2 to 4 relative to the unit cost of aggregate at the extraction site (Whelan, 1995; Robinson and Brown, 2002).

In Jaeger's 2005 study, his research confirmed that truck hauling is the most used mode of transportation for aggregate delivery. He reports that the differences between many of the reported transportation rates is attributable to the distinction between the *average* cost per ton-mile (including load time and dump time), versus the *incremental* or *marginal* cost for an increase in the distance hauled. For example, he reports that the cost for a typical truck haul is calculated to be an average cost per ton-mile of $0.36 for a 15 mile haul. However, Jaeger (2005) reveals that an increase in the distance hauled by 2 miles leads to a decline in the average cost per ton mile declines $0.34. However, when considering the change in the total cost of the haul, the incremental cost for the added transportation is only $0.22 per ton-mile.

Robinson and Brown (2002) indicate that transport of aggregate by rail and water can offer significant cost advantages over truck transport. Rail and barge transport is increasingly being used to move aggregate to redistribution centers from which truck transport distances to construction sites can be reduced. Rail transport costs are approximately one-third truck transport costs, and, in 1999, barge transport of aggregate cost approximately $0.03 per ton per mile. As discussed in previous sections, the aggregate industry in Oregon is already using transport by rail from Salem to Portland as a means to save on truck wear and tear, as well as to limit the liability associated with heavy trucks on roads with vehicular traffic.

HDR Engineering (2004) suggest other opportunities exist for expanding the use of rail and water to move aggregate from the coastal areas of Oregon to inland markets may exist along the PNWR line in the McMinnville area, but also recognize that would require the construction of a loading facility on the Toledo Branch and another at the stockpile site in the Portland area. HDR Engineering (2004) also acknowledges that such an aggregate transportation plan would also require the purchase of a dedicated train set to move the aggregate, much like the one used by Morse Bros. at their Salem pit.

Jaeger (2005) reports that about one-half million tons of aggregate is currently shipped to Portland from British Columbia via barge. Her reports that the transportation costs for these barges from British Columbia into Portland are estimated to be as high as $8 to $10 per ton with off-loading costs making the total cost in Portland ranging from $14.50 to $16.50 per ton. Jaeger (2005) further points out that an important limitation for increased reliance on distant aggregate sources is that there are additional costs for delivery to a location that is not close to off-loading sites. Delivery therefore would then require additional truck hauling, sometimes adding 10 to 20 miles of truck haul costs which could add $4 to $6 to the off-loaded import price.

D. Future Considerations

1. Remaining High Value Soils in the Willamette River Basin. The stakeholder process group requested information on how many acres of Prime or High Value Soils underlie mapped sand and gravel deposits in the upland areas. The technical approach integrated the sand and gravel deposits mapped by Bookstrom and others (1995 – see Figure 7) with the High Value Soils layer provided by the Oregon Department of Agriculture (ODA), followed by reprojecting the Willamette River Basin Polygon and Built Area polygons of Hulse and others (2002) into a common projection and importing into a geodatabase.

ESRI's ArcToolbox was used to clip the ODA High Value Soils layer and the Sand and Gravel layer of Bookstrom and others (1995) using the Willamette River Basin polygon of Hulse and others (2002). The clipped Sand and Gravel layer was then used to clip the clipped High Value Soils layer. Processing within the geodatabase automatically included area recalculation. The newly created "Soils within Sand and Gravel polygons" dataset was clipped with the Built Areas polygons to account for "sterilized" areas unavailable to mining or agriculture with the final results listed in Table 11.

Soil Classification	Area of Soils in WRB (acres)	Area of soils in USGS-mapped sand & gravel areas in WRB (acres)	Area of soils in USGS-mapped sand & gravel areas in WRB minus "built" areas (acres)	% of Total Soil Classification corrected for "built" areas
Prime (irrigated)	121,034	24,353	21,356	17.6
Prime (non-irrigated)	1,225,555	552,687	457,052	37.3
Class I (non-irrigated)	9,572	8,393	735	7.7
Class II (non-irrigated)	141,274	37,701	27,255	19.29
Unique	5,345	1,415	1,288	24.1
Willamette Valley	745,252	244,867	218,857	29.4
TOTALS	**2,248,032**	**869,236**	**726,543**	**32.3**

Table 11. Summary of Prime or High Value Soils in the Willamette River Basin (WRB) that underlie mapped sand and gravel deposits in the upland areas as depicted on Figure 7. Note that the calculations correct for soils that have undergone resource sterilization by the built landscape. On the basis of this analysis, approximately 32.3 % of Prime or High Value Soils in the upland areas remain unbuilt.

2. Remaining High Value Soils in the Floodplain Areas of the Willamette River Basin

The stakeholder process group requested information on how many acres of high value soils underlie mapped sand and gravel deposits along floodplain areas of the Willamette River Basin. A new feature dataset, the Qal geology polygons from the dataset developed by Hulse and others (2002) was added to the geodatabase as the Floodplain deposit dataset. The Built Areas polygons were erased from the Floodplain deposit dataset to account for areas unavailable to mining or agriculture. The previously clipped High Value Soils feature dataset was clipped with the unbuilt portions of the Floodplain deposit dataset. The final results are summarized in the Table 12 and depicted on Figure 15. Integrating the total acreage of Prime or High Value Soils that remain "unsterilized" in the Willamette River Basin with the total disturbed area of Prime or High Value Soils associated with active DOGAMI-MLRR-permitted aggregate sites indicates that 0.7% has been taken out of agricultural production in the Willamette River Basin as summarized in the Table 13.

Soil Classification	Area of soils in unbuilt floodplain or alluvium (acres)
Prime (irrigated)	68,462
Prime (non-irrigated)	227,309
Class I (non-irrigated)	121
Class II (non-irrigated)	12,387
Unique	3,518
Willamette Valley	44,139
TOTALS	**355,936**

Table 12. Summary of Prime or High Value Soils in the Willamette River Basin (WRB) that underlie mapped sand and gravel deposits in the floodplain areas as depicted on Figure 15.

Soil Classification	Active DOGAMI-MLRR permitted mines located in floodplain disturbed areas (acres)	Area of soils in unbuilt floodplain or alluvium (acres)
Prime (irrigated)	1,234	68,462
Prime (non-irrigated)	901	227,309
Class I (non-irrigated)	0	121
Class II (non-irrigated)	199	12,387
Unique	10	3,518
Willamette Valley	142	44,139
TOTALS	**2,486**	**355,936**

Table 13. Comparison of disturbed areas associated with active DOGAMI-MLRR permitted mines located in the 100-year and 500-year floodplain to Prime or High Value Soils in the Willamette River Basin (WRB) that underlie mapped sand and gravel deposits in the floodplain areas as depicted on Figure 15.

3. Protecting the Sustainability of Aggregate Resources

It is obvious that readily available supplies of aggregate are necessary to maintain the investment in transportation infrastructure and to sustain economic growth in Oregon. Langer (2002) describes a number of approaches to protect aggregate resources from sterilization by urban growth. For example, Langer (2002) indicates that "…some local governments created special extraction districts where extraction was allowed by right, and all other uses were controlled through a conditional use. In other areas, aggregate properties were placed in overlay zones where resource extraction is allowed while simultaneously preserving the long-term land use for the area. Some local governments zoned aggregate properties as agriculture or industrial, and permitted extraction as a conditional or special use." Langer (2002) and MAAP (2002) provides case studies of sustainable management practices for aggregate resources in Utah, Colorado, California, Minnesota, and Washington, Canada and Italy.

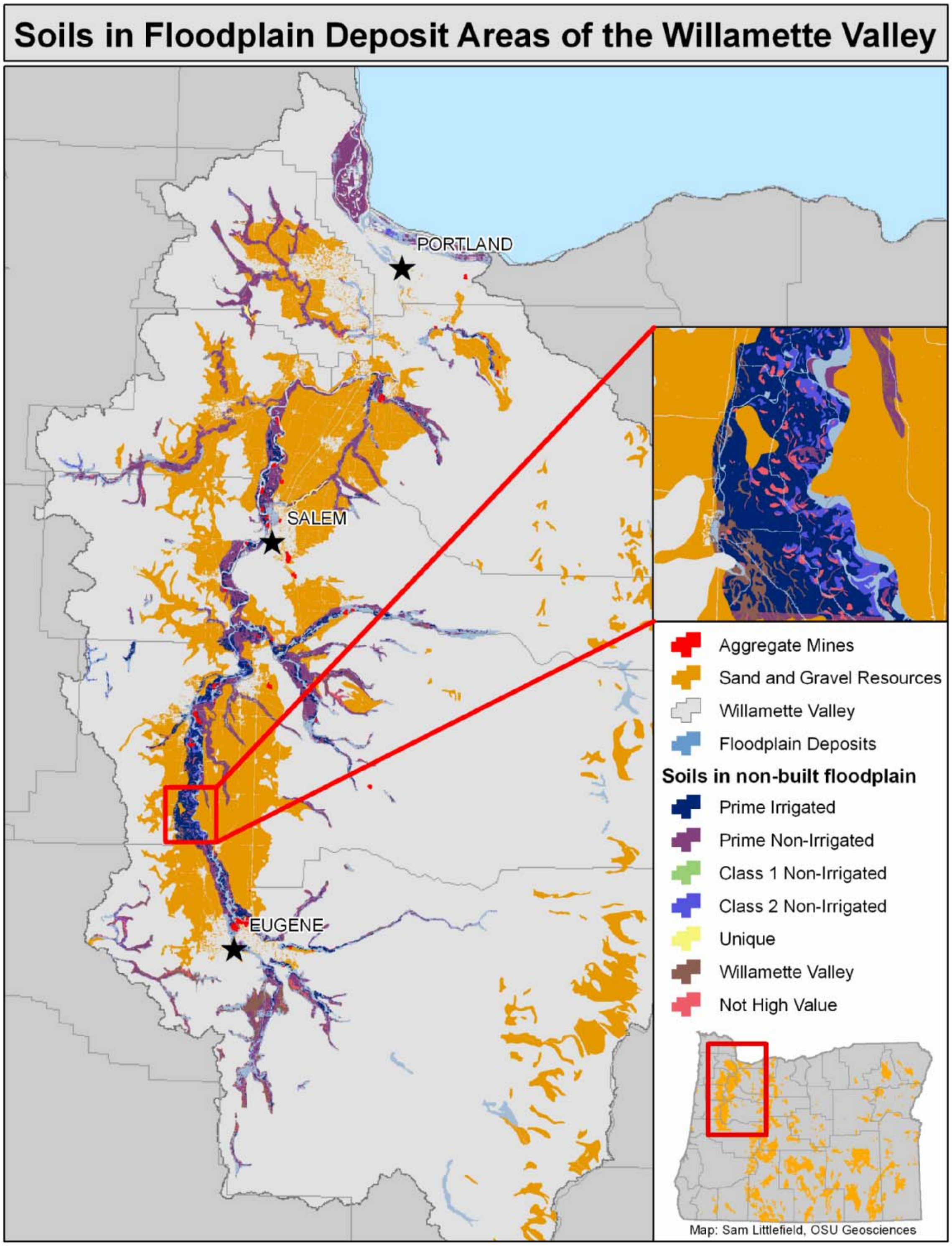

Figure 15. Map depicting the complexity of inventorying soils in the floodplain areas along the Willamette River. The inset reveals the variety of Prime or High Value Soils in a small area.

II. Summary of Findings on Technical Data

Given the aggressive data collection effort proposed by the stakeholder process group, the technical team has worked within their powers to provide the technical information in a concise form. The remaining challenge focuses on providing an assessment of the technical information that is (1) clear and uncontested, (2) contested, and (3) unavailable with the current data. It is recognized that the stakeholder process group may have disagreements on the technical information, so the technical team has attempted to summarize the information that is based on fact, based on professional judgment, and based on general agreement by the technical community.

A. What is clear and uncontested?

1. Aggregate mining is just one of many types of land uses that take land out of agricultural production. This is based on factual information that is collected by DLCD.

2. There is no state-wide assessment of how many acres of land are disturbed by aggregate mining in Oregon. Approximately 6,000 acres were disturbed by active DOGAMI-MLRR-permitted aggregate mines along the floodplain in the Willamette River Basin. The disturbed acreages do not include the impacts associated with historic sites because the Mined Land Reclamation Act of 1971 does not include funds for inventorying or reclaiming historic mine sites in Oregon. Over 1,000 acres of the approximately 6,000 acres fall within Urban Growth Boundaries. Approximately 1,800 to 2,500 acres of soils classified as Class I, Class II, or High Value Soils were disturbed by these mines. This is based on factual information that is collected by DOGAMI-MLRR and readily available maps of soils in Oregon.

3. Approximately 4,600 acres disturbed by commercial aggregate mining permitted by DOGAMI-MLRR were reclaimed state-wide. The reclaimed acreage does not include the approximately 6,000 acres of disturbed lands in the active DOGAMI-MLRR permitted mines along the floodplain in the Willamette River Basin because these mines are active. Over 1,000 acres were reclaimed to agricultural use. Reclaiming lands to agricultural use as defined by DOGAMI-MLRR covers a broad spectrum of land uses, varying from ponds used for agriculture to reclaimed lands used for crops. This is based on factual information collected by DOGAMI-MLRR.

4. DOGAMI-MLRR processed over 1,500 permit applications since passage of the Mined Land Reclamation Act in 1971. Over 560 mines have been closed since passage of the Mined Land Reclamation Act in 1971. Private businesses with permits from DOGAMI-MLRR account for approximately 84% of aggregate produced in Oregon. This is based on records maintained by DOGAMI-MLRR and published by DOGAMI.

5. Crushed rock is produced in all 36 counties; sand and gravel is produced in all but five counties. On the basis of historic production data compiled by the US Geological Survey (1992-2002), crushed rock comprises approximately 50% to 60% of the total production in Oregon. This is based on factual information on industrial minerals in Oregon published by DOGAMI and on the basis of production records maintained by the US Geological Survey. The US Geological Survey maintains the most consistent database of state-wide production of aggregate as opposed to DOGAMI-MLRR which monitors commercial mining of aggregate outside of in-stream areas.

6. Approximately 60% to 65% of the commercially mined aggregate in Oregon during the year 2003 is from the Willamette River Basin. Crushed rock comprises approximately 40% to 45% of the commercially mined aggregate in the Willamette River Basin. This is based on information maintained in the files of DOGAMI-MLRR (Marshall, 2004) and Columbia County records (Dugdale, 2004).

7. Approximately 40% of the commercially-mined aggregate in eastern Oregon is derived from sand and gravel resources. This information is based on DOGAMI-MLRR records summarized by Marshall (2004).

8. Approximately 12% of the aggregate produced in Oregon was used to make concrete in 2001. For the same time period, approximately 96% of the extracted sand and gravel was used to manufacture concrete and concrete related products. When making concrete, round particles in the aggregate are preferable because they improve the workability of the concrete as it is poured. If broken material is used and angular or flattish fragments exceed about 15% of the total volume, workability can be maintained only by increasing the amount of sand and water, thus reducing strength, or by adding more cement, thus increasing the cost of the concrete. This is based on information published by the US Geological Survey and the American Concrete Institute.

9. Crushed rock can be substituted for sand and gravel in most applications. Prime or High Value Soils overlie some crushed rock resources in the Willamette River Basin. This is based on work published by the US Geological Survey and digital data in the Willamette River Basin Planning Atlas by Hulse and others (2002)..

10. Asphalt highways typically require crushed rock aggregates in order to achieve the required strength parameters. This is based on work published by the US Geological Survey.

11. ODOT consumes approximately 3.8 million tons of aggregate per year and is projected to need an average of 4 million tons per year for the next 12 years. All aggregate used for ODOT applications must meet their materials specifications. This is based on published information by the US Geological Survey, ODOT specifications and applied research by the Kiewit Center for Infrastructure and Transportation at Oregon State University.

12. For pavement preservation projects, which consist primarily of asphalt concrete paving, the cost of aggregate is about 12% of the total cost of the project. For modernization projects (those where lanes are added), the percentage would be far less, perhaps as little as 3% or 4% or even lower in metropolitan areas. ODOT estimates that a doubling the price of aggregate would not come close to doubling the cost of even the most paving intensive preservation projects.

13. Trucking is the principal method of transporting aggregate from the point of extraction to the user. Rail and barge transport is increasingly being used to move aggregate to redistribution centers from which truck transport distances can be reduced. Rail transport costs are approximately one-third truck transport costs, and in 1999, barge transport of aggregate cost approximately $0.03 per ton per mile. This is based on factual information published by Whelan (1995), the US Geological Survey, and applied research by resource economist Dr. Bill Jaeger of Oregon State University.

14. The market area for a typical aggregate producer can often be larger than the immediate vicinity of the mines that are managed, zoned, and regulated for aggregate production. This is based on factual information published by the US Geological Survey and by Oregon aggregate producers.

15. Approximately 726,500 acres of high values soils remain potentially available for agricultural use in the upland areas of the Willamette River Basin. The number of acres potentially available for aggregate use remains unknown given the lack of information on the quantity and quality of aggregate available in the same areas. This is based on factual information available from published soils maps.

16. Approximately 356,000 acres of undisturbed high value soils remain in the floodplain areas of the Willamette River Basin. Disturbed areas associated with active DOAGAMI-MLRR permitted aggregate mining have impacted approximately 2,500 acres or 0.7% of the Prime or High Value Soils in the floodplain areas. This is based on factual information available from published soils maps and data from DOGAMI-MLRR.

B. What is contested?

1. An accurate accounting of the number of acres that various types of land uses inventoried by DLCD within EFU zones take Prime or High Value Soils out of agricultural production is difficult to ascertain with a high degree of certainty. This is based on factual information collected by DLCD.

2. Crushed rock resources are extensive in Oregon and the supply may be considered limitless.

3. Aggregate use per capita in Oregon approaches 10 to 15 tons per year. Annual demand was estimated to be approximately 52 million tons per year and may grow to 150 million tons per year by 2050. This is in part based on factual information published by DOGAMI, population projections published by Portland State University, forecasted projections made by INR, and forecasted projections made by resource economist Dr. Bill Jaeger of Oregon State University. Aggregate per capita use is based on DOGAMI-MLRR published information and consequently considered factual. The projected demand is based on per capita consumption trends and population projections provided by Portland State University. These projections are based on industry standards and multivariate statistical analyses of aggregate demand across the United States to project aggregate consumption.

4. On the basis of some reviewer's comments "…base grade gravels are quite abundant within the valley, but of little value. Gravel miners leave behind vast quantities of base grade once they strip off the top layer of concrete grade material…" The published literature and readily available research does not supports this statement.

5. There are no additional costs to mine crushed rock instead of sand and gravel. While members of the Consensus Group offered this conclusion, no data were provided to support this statement. According to Shasta County, California (1998), "…sand and gravel are… less costly than crushed stone and requires less processing…"

C. What is unavailable with the current data?

1. Accurate estimates of the amount of rock that will be mined per acre of land in the Willamette River Basin cannot determined due to the variations in rock thickness across the Willamette River Basin. The quantity and quality of aggregate remaining in the active DOGAMI-MLRR permitted sites cannot be accurately estimated.

2. No data exist regarding the quality (base-grade vs. concrete grade) of aggregate mined from active DOGAMI-MLRR permitted aggregate mines. Likewise, the production cost of each source and classification including siting costs, the geographical variations in cost, and the price trends in Oregon are apparently confidential information maintained by the aggregate mine operator.

3. The number of acres of Prime or High Value Soils taken out of agricultural production due to mining of crushed rock in upland areas of the Willamette River Basin is not available at this time. Beyond recently completing work on quarries located in Benton County, DOGAMI-MLRR has not compiled digital maps for quarries for the Willamette River Basin or elsewhere in the State of Oregon.

4. The actual depth of mining below the water table is apparently not monitored at active commercial mines by DOGAMI-MLRR or by county planners.

5. No data exist regarding the number of acres of Prime or High Value Soils taken out of agricultural production by historic mining. Likewise, no data exist on the number the historic mining sites and associate acreages that have become urbanized or reclaimed.

6. Although the available data suggests that over 5,000 aggregate sites are estimated to exist in Oregon, the number of these sites that have been verified by field inspection remains unknown.

7. The actual demand or tonnages of aggregate extracted in Oregon remains unknown as there is no central clearinghouse for reporting this information.

8. Transportation costs for aggregate by rail or barge can offer cost savings over truck transport only if (1) the infrastructure exists to transport aggregate by rail or barge in Oregon, and (2) aggregate distribution centers are available to load and unload aggregate on these modes of transportation. This is based on published information by the US Geological Survey, but there are no data for Oregon transporters.

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IV. Glossary

The following definitions were derived from many different sources. No citations have been provided given the multitude of sources. Specific citations are provided for interested readers desiring additional information on a specific topic.

Aggregate: A broad term that encompasses a variety of rock products used in construction of roads and buildings. It generally refers to loose rock in pieces up to 3 inches in diameter and suitable for use as a building material. The main forms of aggregate are sand, gravel, and crushed rock.

Aggregate resources: Naturally occurring concentrations of stone, rock, sand and gravel, decomposed granite, lime, pumice, cinders and other naturally occurring solid materials used in road building as defined by OAR 660-023-0180(1)(a). Not all crushed rock or sand and gravel is aggregate. Many deposits of rock are not suitable for construction or road building. The rock may be too soft or have chemical properties that render it unsuitable for commercial use. Some aggregate is obtained by recycling building materials, but most (about 96 percent) is produced by mining—extracting it from naturally occurring deposits of rock.

Agricultural land: Defined in Goal 3 as lands classified by the U.S. Natural Resources Conservation Service (NRCS) as predominantly Class I-IV soils in Western Oregon. Land in other soil classes that is suitable for farm use as defined in ORS 215.203(2)(a), taking into consideration soil fertility; suitability for grazing; climatic conditions; existing and future availability of water for farm irrigation purposes; existing land use patterns;

technological and energy inputs required; and accepted farming practices. Land that is necessary to permit farm practices to be undertaken on adjacent or nearby agricultural lands. Land in capability classes other than I-IV/I-VI that is adjacent to or intermingled with lands in capability classes I-IV/I-VI within a farm unit, shall be inventoried as agricultural lands even though this land may not be cropped or grazed. "Agricultural Land" does not include land within acknowledged urban growth boundaries or land within acknowledged exception areas for Goal 3 or 4.

ArcGIS: An information system for geographic data. Like all information systems ArcGIS has a well-defined model for working with data.

Asphalt: A paving material made by blending crushed rock with petroleum-based bonding agents. Technically, asphalt means the substance manufactured in oil refineries that's used to bind aggregate together to make pavement, but the word is widely used to mean the paving material as well.

Binder: Binder is the substance that is used to hold a pavement together.

Concrete: A mixture of aggregate, Portland cement, and water. Portland cement is a combination of clay, limestone, and sand that has been heated to high temperatures and then ground into a fine powder.

Cubic Yard: The standard measure of aggregate volume. A full-size pickup truck holds about two cubic yards. A typical dump truck holds ten to twelve cubic yards.

Disturbed areas: Land area where aggregate mining has removed soils to access underlying aggregate, as well as the processing facilities.

DOGAMI: Oregon Department of Geology and Mineral Industries.

DOGAMI-MLRR: Oregon Department of Geology and Mineral Industries – Mineral Land Regulation and Reclamation Program, the state agency that regulates most mining operations.

DLCD: Department of Land Conservation and Development,

DSL: Oregon Department of State Lands, the state agency that regulates in-stream aggregate removal.

ESRI: Environmental Systems Research Institute, Inc., the company who develops and distributes ArcGIS and related products.

Exclusive Farm Use (EFU): Exclusive farm use zone means a zoning district established by a county or a city under the authority granted by ORS chapter 215 or 227 that is consistent with the farm use zone provisions set forth in ORS 215.203 to 215.311, 215.438, 215.448, 215.452, 215.455 or 215.700 to 215.780. Zoning ordinances may be adopted to zone designated areas of land within the county as exclusive farm use zones. Land within such zones shall be used exclusively for farm use except as otherwise provided in ORS 215.213, 215.283 or 215.284. Farm use zones shall be established only when such zoning is consistent with the comprehensive plan.

Farmland: Land that is under farm or ranch operation in the state of Oregon. Agricultural Land" as defined in Goal 3 includes: (A) Lands classified by the U.S. Natural Resources Conservation Service (NRCS) as predominantly Class I-IV soils in Western Oregon and I-VI soils in Eastern Oregon; (B) Land in other soil classes that is suitable for farm use as defined in ORS 215.203(2)(a), taking into consideration soil fertility; suitability for grazing; climatic conditions; existing and future availability of water for farm irrigation purposes; existing land use patterns; technological and energy inputs required; and accepted farming practices; and (C) Land that is necessary to permit farm practices to be undertaken on adjacent or nearby agricultural lands.

Farm Use: As used in ORS 215.203, “farm use” means the current employment of land for the primary purpose of obtaining a profit in money by raising, harvesting and selling crops or the feeding, breeding, management and sale of, or the produce of, livestock, poultry, fur-bearing animals or honeybees or for dairying and the sale of dairy products or any other agricultural or horticultural use or animal husbandry or any combination thereof. “Farm use” includes the preparation, storage and disposal by marketing or otherwise of the products or by-products raised on such land for human or animal use. “Farm use” also includes the current employment of land for the primary purpose of obtaining a profit in money by stabling or training equines including but not limited to providing riding lessons, training clinics and schooling shows. “Farm use” also includes the propagation, cultivation, maintenance and harvesting of aquatic species and bird and animal species to the extent allowed by the rules adopted by the State Fish and Wildlife Commission. “Farm use” includes the on-site construction and maintenance of equipment and facilities used for the activities described in this subsection. “Farm use” does not include the use of land subject to the provisions of ORS chapter 321, except land used exclusively for growing cultured Christmas trees as defined in subsection (3) of this section or land described in ORS 321.267 (3) or 321.824 (3).

Floodplain: The 100-year and/or 500-year floodplain or off-channel mining area.

Geodatabase: A generic model or geographic database that defines all the types of data that can be used in ArcGIS—for example, features, rasters, addresses, and survey measurements—and how they are represented, accessed, stored, managed and processed. The geodatabase is a common framework shared by all ArcGIS products and applications.

Georeference: A description of the information provided to register the local planar system to the Earth (e.g. control points, satellite ephemeral data, inertial navigation data).

Gravel: An unconsolidated, natural accumulation of rounded rock fragments resulting from erosion, consisting predominantly of particles larger than sand (diameter greater than 2 mm), such as boulders, cobbles, pebbles, granules, or any combinations of these fragments. Gravel sites are usually found in or along the edge of a stream or river or in land where a river once flowed.

Gravel pit: Gravel pits produce sand and gravel.

GIS: Geographic Information Systems

In-stream: Within the two-year floodplain.

Land Capability Classification: According to the Natural Resources Conservation Service, land capability class definitions area as follows: Class I contains soils having few limitations for cultivation; Class II contains soils having some limitations for cultivation; Class III contains soils having severe limitations for cultivation; Class IV contains soils having very severe limitations for cultivation; Class V contains soils unsuited to cultivation, although pastures can be improved and benefits from proper management can be expected; Class VI contains soils unsuited to cultivation, although some may be used provided unusually intensive management is applied; Class VII contains soils unsuited to cultivation and having one or more limitations which cannot be corrected; Class VIII contains soils and landforms restricted to use as recreation, wildlife, water supply or aesthetic purposes.

Macadam: What the term "Macadamizing" refers to is using "graded" stones for the road base, in progressively finer layers. The result is a resilient, smooth top surface with the added benefit that surface water is able to drain through.

Mining: An excavation in the earth from which sand, gravel, and rock for crushing can be extracted. In-stream dredge mining in Oregon occurs within the stream and two-year floodplain. Off-channel or floodplain “pit” mining occurs between the two-year and 100-year floodplain. Upland mines are located outside of the 100-year floodplain and include extraction of sand and gravel from old river terraces, as well as quarries used to extract hard rock.

Modernization projects: A category of highway projects in the Statewide Transportation Improvement Program (STIP). STIP is Oregon’s four-year transportation capital improvement program. The Modernization Program funds capital construction projects which add capacity to the system, either through adding lanes, or building new facilities, such as bypasses.

ODOT: Oregon Department of Transportation, the state agency responsible for developing Oregon's system of highways and bridges, public transportation services, rail passenger and freight systems, and bicycle and pedestrian paths.

Orthorectified: The process of removing image displacement caused by tilt and terrain relief. Tilt, however, is not relevant in radar images.

Pavement Preservation: A category of highway projects in the Statewide Transportation Improvement Program (STIP). STIP is Oregon's four-year transportation capital improvement program. ODOT has adopted a pavement preservation program designed to keep highways in the best condition at the lowest lifecycle cost. The program focuses on taking preventative measures to add useful life to a road before the pavement reaches poor condition.

Polygon: The most common topological data structure is the *link/node* data model. This model contains two basic entities, the *link* and the *node*. The link is a series of points, joined by straight line segments that start and end at a node. The node is an intersection point where two or more arcs meet. Nodes also occur at the end of a *dangling* arc, e.g. an arc that does not connect to another arc such as a dead end street. Isolated nodes, not connected to arcs represent point features. A polygon feature is comprised of a closed chain of links.

Portland cement concrete grade: Aggregate that has been naturally sorted, rounded, and polished in rivers and creeks. PCC alluvial sand and gravel is used primarily in finished concrete work. It is valuable for finished concrete work because the rounded material allows for a smooth finish. It requires less cement and water than crushed stone, and is easier to mix, pour, and place. It is less costly than crushed stone and requires less processing. The supply of PCC sand and gravel is more limited than non-PCC grade material.

Prime soils: Prime farmland soils are defined in the USDA-NRCS Title 430 National Soil Survey Handbook, issued November 1996, as follows: Prime farmland is land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops and that is available for these uses. It has the combination of soil properties, growing season, and moisture supply needed to produce sustained high yields of crops in an economic manner if it is treated and managed according to acceptable farming methods.

The Farmland Protection Policy Act (Public Law 97-98) (7 U.S.C. 4201, et seq.) and 7 CFR part 658 defines prime soils as soils that have the best combination of physical and chemical characteristics for producing food, feed, fiber, forage, oilseed, and other agricultural crops with minimum inputs of fuel, fertilizer, pesticides, and labor, without intolerable soil erosion, as determined by the Secretary of Agriculture.

Additional information on the definition of prime, unique, or other productive soil can be found in section 1540(c)(1) of the Farmland Protection Policy Act.
(see also http://www.or.nrcs.usda.gov/technical/nri/res2urbprime.html)

Quarry: An open excavation from the earth's surface, usually for the extraction of hard rock aggregates.

Reclamation: Land restored to make it suitable for some beneficial use.

Recycled aggregates: Mainly composed of crushed concrete and crushed asphalt pavement.

Resource sterilization: According to the US Geological Survey, sterilization occurs when the development of a resource is precluded by another existing land use. For example, aggregate resources that exist under a housing development or shopping center commonly will not be extracted.

Road base grade aggregate: Road base grade alluvial sand and gravel is material that may not meet the specifications or qualities for Portland cement concrete grade material, but which is still useful for road base. However, road base must meet Federal and State adopted specifications for road construction applications. It includes material that may be more weathered, softer, and have more clay than PCC grade material. Like PCC alluvial sand and gravel, it is found along river and creek channels and terraces.

Short Ton: (2,000 pounds). The standard measure of aggregate weight. A cubic yard of aggregate typically weighs about 2,600 pounds.

Significant sites: Sites are considered significant if one of the following criteria is met: A representative set of samples of aggregate material in the deposit meets ODOT base rock specifications for air degradation, abrasion, and sodium sulfate soundness, and the estimated amount is more than 2,000,000 T in the Willamette Valley, or 100,000 T outside the Willamette Valley; The material meets local government standards establishing a lower threshold for significance than the subsection above; or the aggregate site is on an inventory of significant aggregate sites in an acknowledged plan.

Unique soils: The Farmland Protection Policy Act (Public Law 97-98) (7 U.S.C. 4201, et seq.) and 7 CFR part 658 defines unique soils as soils other than prime soils that are used for the production of specific high-value food and fiber crops, as determined by the Secretary of Agriculture. They have a special combination of soil quality, location, growing season, and moisture supply needed to economically produce sustained high quality or high yields of specific crops when treated and managed according to acceptable farming methods. Examples of such crops include citrus, tree nuts, olives, cranberries, fruits, and vegetables. Additional information on the definition of prime, unique, or other productive soil can be found in section 1540(c)(1) of the Farmland Protection Policy.

Upland: Areas outside of the 100-year floodplain.

Willamette Valley: According to DLCD, Clackamas, Linn, Marion, Multnomah, Polk, Washington and Yamhill Counties and that portion of Benton and Lane Counties lying east of the summit of the Coast Range.

Willamette River Basin: According to Hulse and others (2002), the Willamette River Basin contains all lands that drain into the Willamette River. For purposes of this report, it includes Clackamas, Columbia, Linn, Marion, Multnomah, Polk, Washington and Yamhill Counties and that portion of Benton and Lane Counties lying east of the summit of the Coast Range.

APPENDIX NO. 1
CONSENSUS GROUP QUESTIONS PRESENTED TO INR WITH ASSESSMENT OF DATA AVAILABILITY
Bolded Text in Data Availability Column indicates limitations in access to information by INR

Data Availability	Aggregate Mining/Farmland Consensus Process Questions Demand for Aggregate and Aggregate Sites
1. Present uses/consumption data from DOGAMI-MLRR and USGS 2. geographical distribution of commercial production and use from DOGAMI-MLRR 3. projected future uses to 2040 using Population Projections from Portland State University Pop. Center 4. ODOT use summarized by Wyttenberg and others (2002) **5. Aggregate quantities and grade considered proprietary information by OCAPA and NOT readily available.**	1. What do we know about the demands for aggregate in the state of Oregon: historically, current and projected for the future? Break down quantities by: a. Aggregate grade (base, concrete, asphalt, shoulder, sanding, other) b. Geographical region in which consumed: i. Each Willamette Valley urban area–Portland, Salem, Albany, Corvallis, Eugene/Springfield, others ii. Coastal urban areas iii. Southern Oregon–Roseburg, Medford iv. Central and Eastern Oregon, Bend v. Exported out of state c. Percentage of total that is consumed by ODOT
1. DOGAMI-MLRR permit records.	2. What has been the rate of permitting of new sand and gravel mines and quarry rock mines–historically (10 years), future projections?
1. ODOT specs apparently do not vary from region to region. Wyttenberg and others (2002) indicate ODOT uses both sand and gravel and quarry rock.	3. What are the uses for which ODOT requires round rock, and what are the uses for crushed basalt? How do the specs vary from region to region? What is the rationale for the choices? How would demand change if specs were changed?

1. Sources of aggregate data from USFS, BLM, DSL, State Forests, DOGAMI-MLRR and DOGAMI Industrial Mineral Database. 2. **Aggregate quantities and grade considered proprietary information by OCAPA and NOT readily available.**	**Aggregate Mining/Farmland Consensus Process Questions** **Supply for Aggregate** 4. What do we know about the sources of aggregate historically, currently and in the future from Oregon lands? Break down quantities by: a. Aggregate grade (base, concrete, asphalt, shoulder, sanding, other) b. Geographical region in which produced (as above). Associate aggregate in each area with soil types and with zoning. Estimate tons of rock, basalt, sand and gravel available. Categorize by sources: i. In stream Sources ii. Floodplain sources - high-water to 100 yr. flood iii. Upland sources (quarries) above the 100 yr.

Data Availability 1. DOGAMI Industrial Mineral Database provides map showing areas of mines. 2. **DOGAMI-MLRR apparently does NOT maintain files on quantity or quality in permitted sites.** 3. Wyttenberg and others (2002) inventory ODOT sites for quality and quantity.	floodplain - (may assume an infinite supply, just a matter of grade, and of economics of developing and transporting). iv. Along the Columbia River - Washington and Oregon sides c. What land acreage is now permitted for mining of sand and gravel? Provide maps showing geographic areas of mines. d. What supply is available (tons of rock) in DOGAMI-permitted sites? e. What is the quality of aggregate available in DOGAMI-permitted sites? (Quality with respect to ODOT specifications for base aggregate and Portland cement concrete: abrasion (AASHTO T96/ASTM C131); Oregon Degradation (ODOT TM 208); soundness (AASHTO T104/ASTM C88, ODOT TM 206); sand equivalent (AASHTO T176/ASTM D2419).
The Oregon Department of Environmental Quality inventoried quantities of concrete and asphalt being discarded.	5. What do we know about sources of aggregate from recycled sources? a. What supply could come from recycling waste concrete and asphalt? b. What quantities of concrete and asphalt are now being discarded?
1. DOGAMI-MLRR files and USGS database were used for this query.	6. What has been the rate of production of (a) sand and gravel and (b) quarry rock, over the past ten years?
1. The US Army Corps of Engineers does NOT maintain this information. 2. INR used comparisons to recent large construction projects.	7. What was the source of aggregate used to make the concrete in each major dam on the Columbia River? Were they quarry or alluvial sources?
1. DOGAMI, DEQ, DLCD and OWRD provided independent summaries to Consensus Group.	8. Please provide (or identify the process for providing) a chart cross referencing the various mining permit ID numbers used by DOGAMI, DEQ, ODOT, DLCD, and the counties.

1. Aggregate quantities and grade considered proprietary information by OCAPA and NOT readily available. Some information was provided to resource economist.	**Aggregate Mining/Farmland Consensus Process Questions** **Cost of Aggregate Supply** 9. What are the current, past and trends in prices of aggregate by grade (alluvial and basalt; base grade, concrete grade) in the following locations: a. Portland b. Salem c. Eugene d. Bend e. Roseburg
1. Aggregate production costs considered proprietary information by OCAPA and NOT readily available.	10. What are the comparative costs for mining quarry rock compared to mining alluvial rock (just mining costs, excluding transportation)? Break down by mining and processing operation.

OCAPA indicated during no apparent cost difference during Consensus Gp. mtg.	
Data Availability 1. Austin and Chapin telephone survey supplemented by published data in USGS and state geological survey reports.	11. What is the marginal cost of transportation by rail, truck, barge (dollars per additional mile, excluding loading, unloading, etc.)?
1. Kiewit Center for Transportation and ODOT provide reconnaissance level estimates. Better data not available due to fluctuations in fuel costs, cement costs, and statewide variation in aggregate costs.	12. Is the cost of aggregate a significant portion of highway costs? What portion? Would changing specs on the aggregate used (i.e. from alluvial rock to quarry rock) significantly impact the cost?

1. Willamette River Basin Planning Atlas Class I and II soils maps. 2. Oregon Dept. of Agriculture High Value Soils maps	**Aggregate Mining/Farmland Consensus Process Questions** **Supply of Farmland** 13. How many acres of high value farm soils are there in the state? (Include Class I, II, Prime and Unique soils.) How many acres historically existed? How many acres remain now for agricultural production?
1. Willamette River Basin Planning Atlas Class I and II soils maps. 2. Oregon Dept. of Agriculture High Value Soils maps. 3. DLCD EFU database. 4. DOGAMI-MLRR aerial photo mapping.	14. How many acres of high value farm soils have been lost to other uses? How much of the loss has gone to each non-farm use? Include: urban development (UGB expansion), aggregate mining, parks, roads, public utilities, urban wetland mitigation and other non-farm uses. Specifically, what acreage has been lost to aggregate mining and what portion of the total loss is it? a. Include maps of soil types, UGB's and aggregate mining areas (historic and present). b. Specify losses by soil class, number of acres and fraction of lost area relative to total area of each soil class.
1. DOGAMI-MLRR aerial photo mapping limited to 2004 and only to floodplain.	15. What has been the rate of loss of Class I and II soils to mining in acres per year?
1. DOGAMI-MLRR records.	16. How many acres and what percentage of aggregate mined areas have been reclaimed to cropland with the same production capability, and how much to grazing land?

1. DOGAMI-MLRR aerial photo mapping limited to 2004 and only to floodplain, except for Benton County in 2004-2005.	**Aggregate Mining/Farmland Consensus Process Questions** **Supply of Other Resource Lands** 17. What are the impacts to the lands where quarry aggregate is mined? (Similar set of questions as to farmland.)

Data Availability	**Aggregate Mining/Farmland Consensus Process Questions** **Relative Value to State of Farmland Resources and Aggregate Resources**
1. Analysis completed by Dr. Bill Jaeger.	18. What is the value to the Oregon economy of agricultural production from Class I and II soils? a. What portion is locally owned (% of dollar value)? b. What percent is exported out of state? c. What is the concentration of ownership? (Are there a few large producers?)
1. Aggregate ownership considered proprietary information by OCAPA and NOT readily available.	19. What is the value to the Oregon economy of aggregate production? a. What portion is locally owned? b. What portion is exported out of state? c. What is the concentration of ownership? (Are there a few large producers?)
1. Analysis completed by Dr. Bill Jaeger	20. What is the total cost to society of getting rock from Class 1 & 2 farm soils (including the lost value from not farming into perpetuity, the mining costs, and other societal costs) compared to the total cost to society of getting rock from alternate sites?

1. Siting Process Reform Task Force Group undertaking these questions.	**Aggregate Mining/Farmland Consensus Process Questions** **Existing Permitting Processes to Site Aggregate Mines** 21. DLCD Goal 5 process 22. DLCD Conditional Use Permit process (incl. local county processes) 23. DOGAMI permit process 24. DEQ permit process 25. DSL/COE 404 permit process 26. ODF&W 27. Water Resources Dept.

Supplemental Information Requests:

- Is Real Reclamation Possible?

Research by INR indicates that real reclamation to a broad spectrum of uses, including cropland, is possible. The degree of reclamation is a policy or contractual issue between the state agencies, landowners, and the mining companies.

- Permitting and Other State Models?

Siting Process Reform Task Force Group undertaking these questions. However, the USGS has provided summaries of other state models, and these papers are included in the INR report.

- EFU Land Conversion by Use?

DLCD database was used for this analysis. The historic data distribution is less than ideal, and DLCD started collecting additional land conversion data in 2001 to better address this issue.

APPENDIX No. 2

ODOT TM 208 – Oregon Air Aggregate Degradation

The degradation test is designed to measure the quantity and quality of the material produced by attrition similar to that produced in the roadway under repeated traffic loading and unloading. The degradation test is run for both a coarse and a fine sample.

The degradation test was originally developed to determine if aggregates used under thin (4-inch) asphalt concrete (AC) would degrade. It is probably not well suited for typical ODOT projects given their current design standards as ODOT does not build many 4-inch AC roads over thick aggregate bases. The ODOT degradation test apparently excludes the use of some crushed rock and promotes the use of sand and gravel in asphalt concrete mixtures. ODOT has had only a few “failures” in recent tests, primarily from crushed rock derived from the Coos Bay area.

ODOT TM 206/ AASHTO T-104 – Soundness of Aggregate by Use of Sodium Sulfate

The sodium sulfate soundness test is run for both coarse (> 4.75 mm) and fine (< 4.75 mm) aggregate samples. The test determines the resistance of aggregate to disintegration by saturated solutions of sodium or magnesium sulfate. This is accomplished by repeated immersions followed by oven drying to partially or completely dehydrate the salt precipitated in the permeable pore spaces of the aggregate. The sodium sulfate soundness test assesses the aggregate’s resistance to breakdown or disintegration. Immersing and drying the sample causes internal expansive forces from the re-hydration of the salt upon re-immersion. This simulates the expansion of water during freeze/thaw cycles, and furnishes information helpful in judging the soundness of aggregates subject to weathering. Crushed rock is more likely fail “soundness” tests.

ODOT TM 211/AASHTO T-96 - Resistance to Abrasion of Small Size Coarse Aggregate by Use of the Los Angeles Machine.

This test is a measure of degradation of mineral aggregates of standard gradings resulting from a combination of actions including abrasion or attrition, impact, and grinding in a rotating steel drum containing a specified number of steel spheres. Evaluation of resistance to abrasion is completed on a case-by-case basis.

APPENDIX NO. 3
Survey of States DOT by William Austin (2004) provided to INR by Consensus Group member Bruce Chapin.
Supplemented by INR by contacting trucking companies in Salem and Bend, Oregon and on-line resources.

STATE	% ALLUVIAL	% QUARRY	RECYCLE	USE	% IMPORTED	TRANS-TRUCK	TRANS-RAIL	TRANS-WATER
						CENTS TON/MI	CTS.T/MI	CENTS T/MI
Alabama								
Alaska								
Arizona			No		Little	NA	NA	NA
Arkansas	20	80	Yes	Hot Mix	10	NA	NA	NA
				Cement Paving				
California								
Colorado	60	40	Yes		5	NA	NA	NA
Conneticut								
Delaware	100	0	Yes		0	NA	NA	NA
Florida		100	Yes	Asphalt	30			
Georgia								
Hawaii								
Idaho								
Illinois	25	75	Yes		20	.11-.12Semi,.20 tandsm	.03+ load & un	.50+load & un
Indiana	20-30	70-80	Yes	Concrete fill	Little	.11-.12	.04-.06	.01-.03
				Asphalt Mix				
Iowa	Less than quarry	26,293,802 T	Yes		Some	2.50 10 mi,.12 add	NA	NA
Kansas								
Kentucky								
Louisiana	5	95	Yes	mainly base	100% quarry	0.07	0.05	.015-.017
Maine								
Maryland								
Massachusettes	10	90	Yes	All	None	NA	NA	NA
Michigan	No Info- see Mi Aggregates Asso.		Yes					
Minnesota	80	20	Yes	Base	Some	.45 1st-.09 after	0.03	0.015
Mississippi	75-80	25	some	drainage layers	30-	NA	NA	NA
Missouri	Little	Much	Some		2	0.25	0.06	9.50-10.25
							22.12T-400mi	incl. Material
								shipping & unloading
Montana	Nearly all	Very little	Yes		little	NA	NA	NA
Nebraska								
Nevada	95	5	Yes	base	None	NA	NA	NA
New Hampshire								
New Jersey								
New Mexico								
New York	65%?	35%?	Yes		some	NA	NA	NA
North Carolina								
North Dakota	0	100	Yes	Base				
Ohio					?	10	NA	Na
Oklahoma	2 coarse-98 fine	98	Yes	Base-concrete	10	0.10	0.035	NA
Oregon	not known	not known	yes	base & pavement	some	.14-.15 to .12.5 - .20	NA	NA
						See Note A.		
Pennsylvania								
Rhode Island	Nearly all	Very little	Yes	Base	very little	NA	NA	NA
South Carolina								
South Dakota								
Tennessee	10	90	Yes	concrete-asphalt10	10	0.15	0.05	NA
Texas								
Utah	95	5	Yes	25% hot mix				
				5% Base	very little	.02-.04	NA	NA
Vermont								
Virginia								
Washington	70	30	yes 100%		little	NA(trade secrets)	NA	NA
West Virginia								
Wisconsin	25	70+5% recyc	some		very little	.02-.04	NA	NA
Wyoming	60-70	30-40	Yes	pavement	10	1.1	NA	NA
						See Note B.		
A. First range of numbers from Austin and Chapin (2004)					**Total**	**2.9**		
Second range of numbers dervied from					**Avg. cents/ton-mile**	**$0.26**		
Stark Trucking (503-393-6662); Cascade Trucking (541-382-4285) in August 2004								
B. http://www.wsgs.uwyo.edu/minerals/aggregate.aspx								