# THE DIRECT AND CUMULATIVE EFFECTS OF GRAVEL MINING ON GROUND WATER WITHIN THURSTON COUNTY, WASHINGTON

1995

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## EXECUTIVE SUMMARY

During the last several years, there has been a significant increase in the number of presubmission conferences related to proposals for new gravel mines or expansions of existing mines. There have also been several applications for local special use permits submitted for new mines or expansions. Some of these applications or proposals have been for sites located in areas underlain by aquifers that are highly susceptible to contamination and that already have known ground water quality problems.

Because of these proposals and applications, there has been a high degree of public interest in gravel mining within Thurston County. One of the primary concerns was about the environmental effects of gravel mining, especially on ground water quality. Although gravel mining is a relatively common industrial activity, its environmental effects are not well documented. In addition, regulatory agencies responsible for overseeing gravel mining usually have not required ground water quality monitoring as part of mining permit conditions.

As a result, the Thurston County Health Department could not provide conclusive assurances that gravel mining was not having a harmful effect on ground water quality. In order to assure that ground water was not being adversely affected, the Thurston County Board of County Commissioners enacted a moratorium directing the Thurston County Planning Department not to accept any new Special Use Permit applications for gravel mining operations. The purpose of this moratorium was to allow staff time to study the environmental effects of gravel mining and the present system for overseeing and regulating mining.

As of 1993, gravel mining had taken place on approximately 1,108 acres in Thurston County, which is 0.23 per cent of the county's surface area. There are now approximately 107 acres of gravel pit lakes within the county, which equals 1.5 per cent of the total area of surface water in the county. By the year 2023, it is estimated that there could be 287 acres of gravel pit lakes, equaling approximately 4.1 per cent of the total area of surface water in the county.

The process of mining consists of a number of separate activities, such as excavating, screening, washing, asphalt or concrete making, vehicle maintenance and fueling. The environmental effects of gravel mining on ground water vary widely, depending on which specific activities take place on a given site. In order to evaluate these environmental effects, it is necessary to view each gravel mining operation as the sum of the environmental effects of these component activities. Each associated activity adds additional risks, which vary in size with the type and scale of that associated activity.

The simplest form of gravel mining, excavating above the water table with no associated activities such as vehicle maintenance or asphalt batch plants, causes a relatively low risk to ground water quantity and quality. Because even the limited protection provided by the soil layer has been removed, these excavations are extremely sensitive to the introduction of any type of contamination. But because this type of mining is essentially a relatively simple process of loading unconsolidated materials, it does not pose a serious risk of introducing contaminants.

Mining into an aquifer brings some additional risks for ground water quality. This includes potential increases in ground water turbidity and iron content, and local water level changes. The only cases found in this study in which turbidities were increased by gravel mining involved gravel washing operations. Significantly increasing the iron content of ground water by physically disturbing the aquifer materials requires a combination of heavily iron-coated aquifer materials, organic material, and bacteria that is very uncommon in Thurston County. There are a number of studies on record in which improved aeration of by creating a gravel pit lake causes shifts in the local water table that depend on the ground water gradient, the permeability of the aquifer, and the size of the lake. For the geological conditions found in Thurston County, the additional risk presented by simple excavation within an aquifer is small. Well structured regulatory oversight and proper enforcement of a carefully-designed set of best management practices is necessary to minimize this risk.

Concrete batch plants are a more serious risk to ground water quality, particularly if process waters are discharged to ground water without adequate treatment. These process waters can have high pH levels and there are a variety of cement additives that can significantly effect a wide variety of water quality parameters. The nature of most cement plant process water discharges is such that inadequate treatment of those waters will have a measurable and unacceptable effect on ground water. Concrete batch plants, especially if there is any form of discharge, would require a high degree of regulatory oversight to avoid ground water quality degradation.

Asphalt batch plants present less risk to ground water than concrete plants. The potential risk from asphalt plants is mainly from the effects of stormwater, vehicle fueling, and fuel storage and handling. However, asphalt plants are still a very significant source of risk to ground water quality and require adequate regulatory oversight.

Petroleum leaks and spills resulting from vehicle and equipment fueling, maintenance, and washing are the most common threat to ground water associated with gravel mining. This risk varies depending on the scale of these activities and the degree of oversight provided by the mining operation management. That petroleum leaks and spills are a problem is clear from Department of Ecology incident reports. Because of the lack of ground water monitoring and follow-up investigations on these incidents, the actual degree of ground water impact is unknown.

Creating gravel pit lakes lowers the water table in wells up-gradient from the lake and raises them on the down-gradient side. This is a relatively local effect, but can measurably affect water levels in wells very near to the gravel pit lake.

Mining into an aquifer could potentially breach the hydrological barriers between different aquifers. If this were to happen, water in the two aquifers could mix, potentially affecting water quality or water levels in one or more aquifers. Many gravel pits in Thurston County are located close to the Vashon Till, a major aquitard, suggesting that the potential for intermixing of aquifer waters is significant.

Abandoned gravel pits have often been used for the disposal of various types of non-inert solid wastes. The adverse effects of this practice are well documented and compelling enough that this practice should, in general, be completely discontinued. Only truly inert materials should be placed within gravel pits.

In summary, gravel mining may have a complex array of environmental effects on ground water. This is because different mining operations will each consist of a different set of mining and processing activities. The environmental effects can only be understood by examining each separate activity in the mining operation. Each of these component activities has a different environmental effect and requires a different management approach to risk reduction. Gravel mining, in general, poses low to moderate risks to ground water quality and quantity. But consistent regulatory oversight of project design, operation, monitoring and closure, and effective enforcement if necessary, can minimize the risk of ground water quality degradation.

## I. Introduction

Although gravel mining is a widespread and common activity within Washington and the rest of the United States, its environmental effects are not well documented. Before any regulatory system for gravel mining can be properly designed and implemented, the environmental effects must be known and quantified.

Modern civilization consumes a wide variety of resources in the course of its day-to-day activities. Some of these resources that society considers essential are obtained only by mining mineral deposits. Mining has taken place nearly everywhere in the world, including Thurston County. There are two main types of mining, underground mining and surface mining, depending on the location of the resource that is being mined.

The types of mineral resources found within Thurston County are clay, quarry rock, iron oxides, coal, peat, metals, and sand and gravel. All of these are located near the earth's surface and so are classified as surface-minable resources.

Deposits of geologically recent clays within the city of Centralia, just south of the Thurston County border, have been mined for many years. Potentially minable clay deposits are found in Thurston County in the late Eocene Northcraft Formation and the early Pleistocene Logan Hill Formation (Noble and Wallace, 1966). Because clay deposits are highly impermeable and do not easily permit infiltration of potentially contaminant-bearing waters, they are a low threat to ground water.

Quarry rock was mined in the Tenino area for a number of years from sandstone layers within the upper part of the McIntosh Formation (Noble and Wallace, 1966). Very limited mining of this formation for decorative and dimension stone has taken place in recent years and there is some potential for future expansion. The basalt of the Crescent Formation in the Black Hills and other locations in northwestern Thurston County have been mined for road ballast, rip-rap, and similar uses. The Northcraft Formation in the Bald Hills also has mined for similar uses. In most areas where minable stone is found there are very limited ground water resources and the potential for aquifer contamination is low.

Iron oxides potentially suitable for pigment (umber) manufacture, are found in several locations (Valentine, 1960). These deposits are small and were formed where iron-rich waters enter bogs or wetlands. The changes in environmental conditions caused iron to be precipitated as "bog iron". Occurrences are found near the Black River in Township 17 North, Range 3 West, section 25 and near Lake St. Clair in Township 17 North, Range 1 East, sections 4 and 6. Because these deposits are in environmentally sensitive areas closely associated with wetlands, they are probably not minable.

Significant coal deposits are found within the Skookumchuck Formation in southern Thurston County and northern Lewis County (Snavely and others, 1958). There is one large coal mine in southern Thurston County, which will probably continue to operate for many years into the future. This mine may seek to expand, or other parties may seek to open new mines in this area. Coal mining is regulated primarily by the Federal government and is not regulated by local land use permits. Coal mining can have very significant environmental effects, which are well documented in many studies.

Valentine (1960) lists 23 areas totalling 2,988 acres within Thurston County that contain peat resources. Almost half of these peat resources are in the Black River valley between Black Lake and Littlerock. Wetland restrictions would probably make this low-unit-value resource difficult to mine, although at least one peat mine in Thurston County has a valid Department of Natural Resources mining permit. Peat mining could have several possible effects on ground water. These include increasing the levels of tannins and lignins, changing pH and color, increasing nitrate levels, and introducing pathogens. Because of the limited potential for peat mining in Thurston County, its potential environmental effects will not be discussed further in this report.

There are few significant occurrences of metal ores within Thurston County. Gibson (1940) describes low levels of gold and silver within veins in basalt in the Black Hills. Unpatented mining claims were once filed for placer gold along Waddell Creek, and there are other scattered locations in the Black Hills where short exploratory tunnels were developed by prospectors. There are also scattered locations where copper-stained basalt can be found. None of these occurrences produced significant amounts of metals and the possibility of significant amounts being located in the future is very low.

Sand and gravel are by far the most important mineral resource in Thurston County and the only resource, except coal, that has been the target of significant mining activities. These resources are also generally located in areas of high ground water susceptibility. For those reasons, the environmental effects of sand and gravel mining are of far greater concern than other types of mining. This report will discuss only the effects that gravel mining may have on ground water. As used here, the term "gravel" will also refer to sand-sized material.

## II. Methods of Study

This study was conducted in three parts. The first part was a comprehensive review of published technical and scientific literature on the environmental effects of gravel mining on ground water. Computer bibliographic database searches were used extensively to locate sources, and an effort was made to locate useful unpublished data. The result was a very complete collection of information, world-wide in scope, related to gravel mining and ground water.

The records of regulatory agencies that oversee gravel mining were also examined in order to assess the types and frequencies of complaints, records of inspection reports, and incidents that could have resulted in ground water contamination. This included records on associated activities that commonly accompany gravel mining and covers events such as fuel spills and leaks, stormwater discharges, and other discharges. These listings include information on incidents up to 1993. It should be noted that these incident reports are only the regulatory agency's side of the incident and may not represent the full story.

The information on the direct effects of gravel mining gathered in the first two parts of the study was used to study the cumulative effects of gravel mining in Thurston County. The cumulative effects study considered the individual effects of single gravel mines, the total area of mined sand and gravel deposits in Thurston County, and estimates of probable future demand for sand and gravel in Thurston County. This information was interpreted to evaluate the probable future effects of gravel mining in Thurston County based on different patterns of future mining activity.

The area of gravel excavations in Thurston County was estimated using the ARC/CAD geographic information system (GIS), along with the total area of ground water exposed by gravel excavations. The outlines of existing gravel pits were taken from digital Washington Department of Natural Resources (DNR) maps of Thurston County soils and DNR gravel mining records. Additional gravel excavations were digitized into the GIS from U. S. Geological Survey 7.5 minute series topographic maps and 1:2,000 airphotos. The areas of exposed water within gravel excavations were obtained from topographic maps and airphotos.

## III. Summary of mining practices

There are three basic types of gravel mining operations, defined by their relationship to the water table; dry pit, wet pit, and dredging (Newport and others, 1974). In a dry pit, gravel is extracted above the water table. In a wet pit, gravel is being extracted from below the water table. In dredging operations, gravel is being extracted from existing water bodies, including lakes, rivers, and estuaries. Dredging operations are rare in Thurston County and will not be discussed.

A dry pit is the simplest type of gravel mining and the equipment involved can range from small bucket loaders and dump trucks to large power shovels, bucketwheel excavators, and belt conveyors (Tepordei, 1992). Wet pits normally excavate gravel using either a drag-line excavator (Figure 1) or a drag scraper (Figure 2) (Landberg, 1982). Both of these types of excavators have the main part of the excavating machinery above water, with a relatively simple bucket entering the water and doing the excavating.

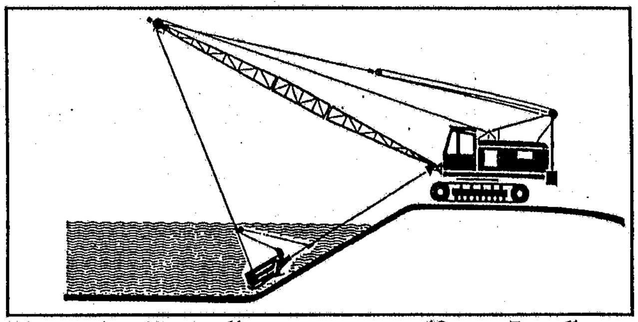

**Figure 1** Drag line excavator (from Landberg, 1982).

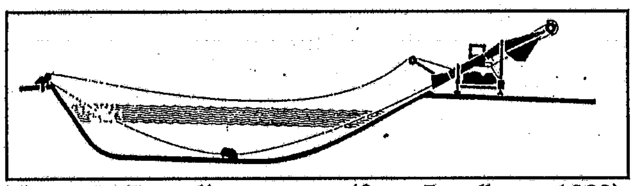

**Figure 2** Drag-line scraper (from Landberg, 1982)

Gravel producers supply products for a wide variety of end uses. Most of these uses, especially construction or specialty applications have exacting requirements. These requirements include size grading, strength, wear resistance, reactivity, and clay or organic material content (White and others, 1990). In order to meet these requirements, producers generally must process the gravel after it is mined. Processing methods include crushing the larger material, washing with water, and sizing with vibrating screens. The processed materials are transferred by combinations of conveyor belts, bucket elevators, and screw conveyors (Tepordei, 1992).

Many Puget Sound area gravel producers have ready-mix concrete and/or asphalt batch plants on the property or within a short haul distance (White and others, 1990). Some companies also lease pit-floor space and sell gravel to other companies that manufacture products such as pre-cast concrete products. Many gravel producers also have vehicle fueling and maintenance facilities located near the gravel excavation site.

## IV. Direct mining effects

The essence of gravel mining is the act of physically extracting the gravel. Everything else that happens between the extraction of the gravel and its end use should be classified as "associated activities". The primary environmental effects of gravel excavation are related to physically disturbing the aquifer materials and exposing the aquifer to the air by forming a lake. For mines excavating above the water table, the environmental problems are very similar to those posed by stormwater disposal in any other extremely environmentally sensitive area.

## Physical Effects

### Turbidity

Turbidity is caused by the presence in water of suspended material such as clay, silt, fine organic material, plankton, or other fine inorganic or organic matter. Ground water normally has turbidity levels below 1.0 NTU (nephelometric turbidity units) and levels above 5.0 NTU are easily seen in a glass of water (U.S. E.P.A., 1992). Turbidity can have other undesirable effects, but it is regulated in public water supplies primarily because it interferes with the action of chlorine as a disinfectant and provides organic precursors that may help form trihalomethanes (Driscoll, 1986). For this reason, the Washington State Department of Health established a primary maximum contaminant level of 1.0 NTU for turbidity. In addition to reducing the effectiveness of disinfection, turbidity may also affect the taste of drinking water and cause sedimentation or staining of household fixtures. Other possible effects are clogging of well screens and wear on pumps or other machinery. In locations where ground water discharges to surface water, increasing the turbidity of ground water may have a harmful effect on the surface water ecosystem.

Gravel mine operators try to avoid gravel deposits that contain large amounts of silt and clay, which reduce the value of the deposit. Many gravel products must have a very low content of fine materials, and the need for extensive washing raises the cost of production. Examples are concrete aggregate, in which clay and silt reduces the strength of the concrete, and gravel for septic system drainfields, in which silt and clay can produce clogging of the drainfield. A high content of fines in the gravel deposit not only produces a large volume of turbid wash water, it also creates a problem of how to dispose of large amounts of silt and clay waste products. In general, even the best gravel deposit will contain some silty layers or some silt or clay coating on the gravel.

Ground water turbidity may be increased by physically disturbing the aquifer materials by mining, gravel washing, or by incidental generation of turbid runoff from erosion of disturbed areas. This mining-related turbidity can enter the aquifer either by direct discharge into ground water exposed by mining or by infiltration into coarse materials exposed by mining operations.

Gravitational settling and interstitial straining are the two main mechanical mechanisms by which turbidity is reduced in porous media, (Behnke 1969). Gravitational settling occurs when the greater density of suspended particles causes them to sink out of the water. Interstitial straining occurs when transported particles are filtered out as the turbid solution flows between the grains of fine sediments.

Friedman and Sanders (1978) summarized the results of other studies and concluded that very-coarse-silt-size spheres in still water would settle at 0.27 cm per second or less. Gibbs and others (1971) measured the gravitational settling rates in still water for silt-size glass spheres in water. They found that coarse-silt-size spheres (0.05 mm) settled at 0.2 cm per second and they predicted that fine-silt-sized spheres (0.01 mm) would settle at less than 0.01 cm per second, or 28 feet per day.

Most actual silt to clay-size particles are flattened or tabular rather than spherical and so would settle at a rate less than similar-size spheres because of their lower mass to diameter ratio. Based on a settling rate of less than 28 feet per day as given above, silt-size turbidity particles should settle out of suspension in a gravel pit lake relatively rapidly, probably within several days.

As shown in Table 1, very fine clay particles can be as much as 40 times smaller than fine-silt-size particles. The empirical formula developed by Gibbs and others (1971) predicts that fine-clay-size spheres with a diameter of 0.00025 mm would settle at a rate of 0.000005964 cm per second in still water at 20°

C. This is approximately 0.017 feet (0.2 inches) per day. This suggests that the very finest clay fractions of turbidity could settle out on a time scale measured in weeks or months. This settling rate is substantially slower than horizontal ground water flow rates in Thurston County gravels. Sinclair and Hirschey (1992) estimated the mean ground water flow velocity in the Grand Mound/Scatter Creek area to be 16 feet per day, with values ranging from 1.3 to 60 feet per day. Given a settling time of weeks or months and the rapid flow rates of some Thurston County aquifers, clay particles could travel relatively long distances. Using the settling rate of 0.017 feet per day, it would take approximately 1175 days (3.2 years) for fine clay to settle 20 feet. In that time, traveling at 16 feet per day, the clay could travel approximately 3.5 miles.

Table 1
Grain Size Scale Used By American Geologists
(Dietrich and others, 1982)

| Size | Grade Name | mm | mm |
|---|---|---|---|
| Silt | coarse | 1/16 - 1/32 | 0.062 - 0.031 |
| | medium | 1/32 - 1/64 | 0.031 - 0.016 |
| | fine | 1/64 - 1/128 | 0.016 - 0.008 |
| | very fine | 1/128 - 1/256 | 0.008 - 0.004 |
| Clay | coarse | 1/256 - 1/512 | 0.004 - 0.002 |
| | medium | 1/512 - 1/1024 | 0.002 - 0.001 |
| | fine | 1/1024 - 1/2048 | 0.001 - 0.0005 |
| | very fine | 1/2048 - 1/4096 | 0.0005 - 0.00025 |

There are several effects that could modify the settling rates given above. Chemical action could cause clay particle to clump together, or flocculate, increasing the settling rate. Water currents could help keep particles in suspension longer than would be possible in still water, decreasing the settling rate.

Clay minerals consist of interlocking sheets composed of silicon and oxygen atoms. These sheets are bound together by positively charged cations such as sodium, calcium, and potassium. The chemical sites that are occupied by these cations cause the clay particles to have a negative surface charge when those cation sites are empty. For this reason, suspended clay particles have a tendency to clump together in the presence of dissolved cations. This is why clay particles settle so quickly when they reach salt water. Thurston County ground water is generally low in dissolved cations, so the effect of chemical flocculation on clay settling rates would be expected to be very small.

Sediment particles that are heavier than water can be kept suspended by the action of moving water. The faster the water is moving, the larger the particles that can be kept suspended. Newport and others (1974) report studies indicating that currents of 0.18 miles per hour would suspend brick clay and currents of 0.72 mph would move fine mud and loam. The fastest ground water recorded in Thurston County, as discussed above, is 60 feet per day which equals 0.0005 mph. This is well below the amount of current needed to keep even the finest sediments in suspension.

Sediment clogging by turbid waters is a key factor in determining how far gravel mining related turbidity will travel. Behnke (1969) examined gravitational settling and interstitial straining together in a study of surface infiltration for artificial ground water recharge. He applied solutions containing 43-203 ppm of turbidity derived from suspensions of two different natural soils. The turbid solutions were applied to two sieved sands and two natural soils inside 85 cm long columns. The soils were packed to reproducible densities and the vertical head of the turbid solutions were kept constant.

Behnke found that surface deposits that reduced flow developed within eight hours in all cases studied. With the solution containing 203 ppm turbidity, there was more than a six-fold reduction in flow in one hour. With a solution containing 43 ppm turbidity, it took slightly less than 4.5 hours for a similar reduction in flow to develop (Figure 3). He concluded that clogging is essentially a surface process, with detectable reductions in flow as little as 0.50 cm below the surface. He found that gravitational settling was the initial clogging mechanism, with interstitial straining becoming dominant later. Other studies generally agree that filtration of suspended material happens mainly at the recharge surface, but feel that some colloidal particles (1.0 to 0.1 microns) can penetrate to "appreciable distances" (Nightingale and Bianchi, 1977).

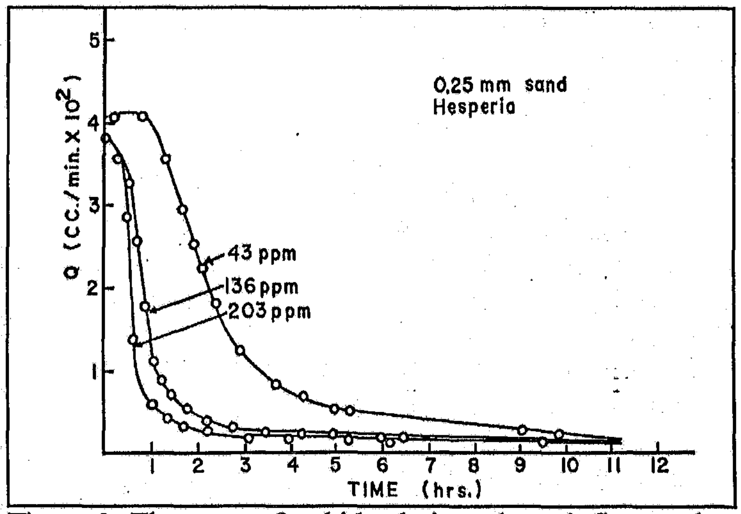


**Figure 3** Flow rate of turbid solutions through fine sand as a function of time (from Behnke, 1969).

Behnke also found that clogging was less rapid with combinations of the finer soils and coarser turbidities, where the suspended particles and soil particles were most similar in size. For coarser textured soils (.25 mm sand), the high silt turbidity produced the most rapid clogging. For the finer textured soils (.10 mm sand), the high clay turbidity produced the most rapid clogging.

Behnke's study showed that the clogging layer becomes established within a matter of hours and that it takes place at or very near the surface. These results are most relevant to washing gravel or otherwise creating turbidity above the water table, where gravitational settling and water flow are parallel. In gravel pit lakes, these two processes occur in different locations in the lake because the force of gravity that governs gravitational settling is oriented vertically downward and ground water flow, which governs interstitial straining, flows horizontally.

Durbec and others (1987) found that the amount of clogging in gravel pit lake walls in France varied significantly depending on pit morphology, vegetation on the walls, bank materials, and water turbidity. They also found that a superficial zone on the upper walls of gravel pit lakes is not greatly affected by clogging and another zone along the bottom and lower part of the walls of the gravel pit lake (Figure 4) is where most clogging occurs. Their study also found that clogging in the bottom of the gravel pit lake did not vary significantly throughout the pit and that the majority of the clogging was found in the upper 10 cm of the bottom sediments.

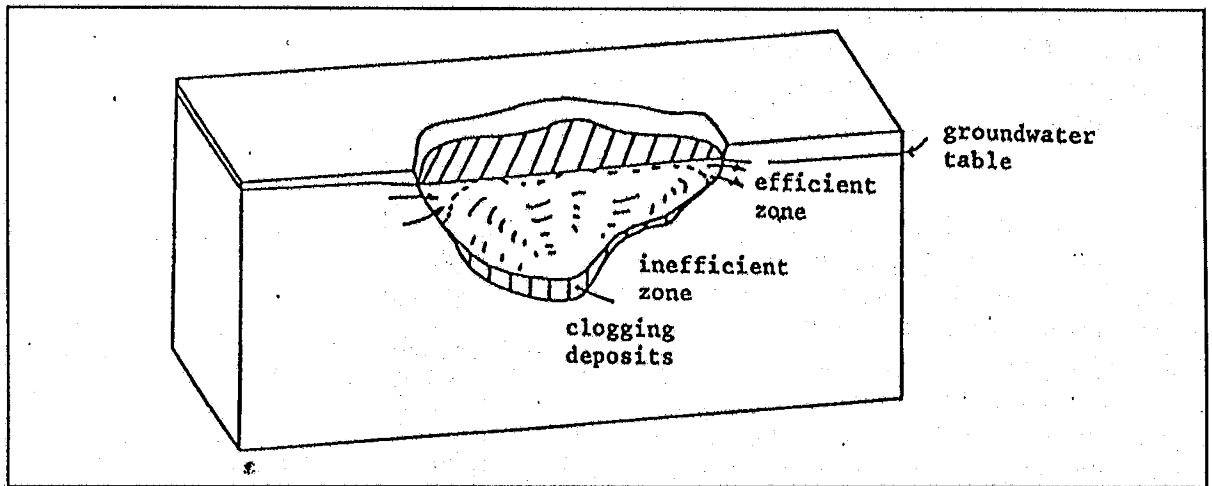


**Figure 4** Sediment clogging patterns in gravel pit lakes (from Durbec, 1987).

Landberg (1982) cites German research showing that, due to ground water flow, clogging of the banks should start on the downgradient end of the gravel pit lake. If clogging was extensive, it could raise the water level in the lake, which could also raise the water level in the aquifer up-gradient from the lake. Landberg reported that Swedish studies had not found any lake with significant clogging. He suggested that this could be explained by the relatively recent age of the pits (less than 25 years).

The studies described above produce a clear picture of the behavior of turbidity in gravel pit lakes. The silt fraction of turbidity should settle or be filtered relatively rapidly, probably over a matter of hours or days. The finer clay fraction could remain suspended for a much longer period of time. Sediment clogging happens primarily on the surface of the bottom and lower sides of the lake. The upper part of the banks of the gravel pit lake is largely unclogged and permits efficient hydrological exchange between the lake and the aquifer.

This information can be compared to data from several sites in the Pacific Northwest. The most complete data available on the movement of low levels of turbidity through aquifer materials is from collector wells, called Ranney Collectors. These systems draw in water through horizontal screened pipes placed beneath rivers or lakes (Figure 5). Surface water infiltrates into the screened pipes, flows into a central connector, and is pumped into the water system (Mikels, 1992). The horizontal screened pipes are jacked into place so that they will not disturb the sediments below the surface water body. The studies cited involved collection pipes located from 8 - 21 feet below the river bottom.

Comparing the river and collector turbidity data shows that relatively low levels of turbidity are greatly reduced by passage through a short distance of aquifer materials. The remaining turbidity in the collector samples is probably the finer clay fraction.

In response to local complaints, the Oregon Department of Environmental Quality studied well turbidity in the vicinity of a gravel extraction and washing operation near Milton-Freewater, Oregon (Mathiot, 1978). The aquifer below this site consists of unconsolidated alluvial fan gravels of very high permeability.

This DEQ study found a turbidity plume that extended more than a mile to the north (downgradient) of the gravel operation. The average turbidity of the water being discharged from the washing operation into the pond at the site was 2,737 nephelometric turbidity units (NTU). Nearly all wells sampled within the first 6,000 feet of the turbidity plume were measured at 5 NTU or more. Many wells within the first 3,000 feet of the plume had turbidity levels of 10 NTU or more. Nearly all wells outside the plume had turbidities of 2 NTU or less.

This data shows again that only a small percentage of the initial turbidity is transmitted through aquifer materials. However, if the initial turbidity levels are high enough, significant amounts of turbidity can be carried over a mile through very highly permeable aquifer materials. This should not automatically be taken to mean that a 6,000 foot buffer zone around gravel mining operations is necessarily warranted. The actual distance that turbidity would travel would depend on local factors, which should be evaluated in a geohydrologic report before the start of mining operations.

Simple gravel excavation probably will not produce turbidity levels that would be detectable off the mine site. Because of the higher turbidity loads they generate, gravel washing operations are more likely to produce turbidities that can migrate significant distances. The distance turbidity will be transported in ground water will vary between different sites depending on the type and size of

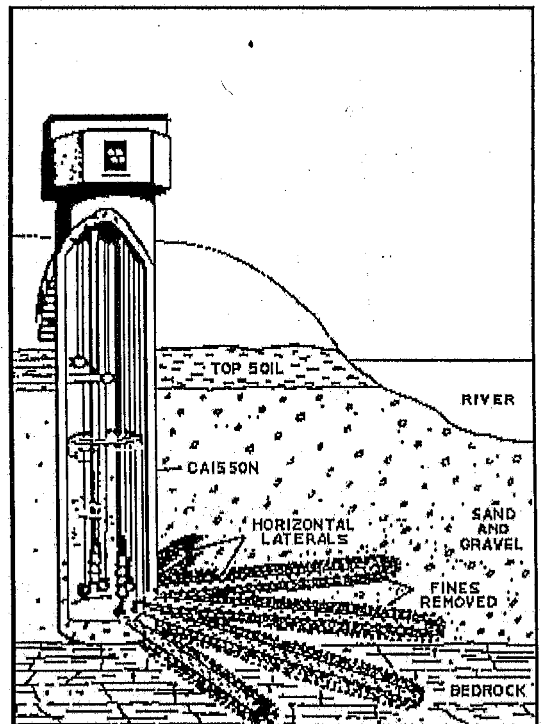

**Figure 5** Cross-section through a Ranney Collector system (from Mikels and Bennet, 1978).

Table 2
Turbidity Data From Ranney Collector Systems

| System | Mean Turbidity (NTU) | Standard Deviation (NTU) | River Source | River Turbidity (NTU) |
|---|---|---|---|---|
| Boardman, OR[1] | 0.04 | 0.02 | Columbia | 0.9 - 13 |
| Fort Benton, MT[1] | 0.05 | <0.01 | Missouri | 1.5 - 34 |
| Kalama, WA[1] | 0.30 | 0.03 | Kalama | 1.0 - 4.0 |
| Port Angeles, WA[1] | 0.11 | 0.04 | Elwha | 0.6 - 35 |
| Sonoma County, CA[1] | | | | |
| Collectors 1 & 2 | 0.12 | 0.04 | Russian | 1.1 - 20 |
| Collectors 3, 4, & 5 | 0.05 | 0.02 | Russian | 1.1 - 20 |
| Kennewick, WA[2] | 0.13 | 0.04 | Columbia | 2.1 - 8.6 |
| Kalama, WA[2] | 0.31 | 0.03 | Kalama | 0.9 - 4.6 |

1) Mikels and Bennett, 1978. Data are 1988 means.
2) Mikels, 1992. Data represent 10 samples from 12/87 to 3/90.

the particles causing the turbidity, the pore sizes of the aquifer media, the ground water flow velocity, and the ionic strength of the ground water.

There are many causes, other than gravel mining, that can increase turbidity in ground water (Table 3). Sandhu and others (1977) studied samples from 98 water sources in South Carolina and found that iron and colloidal material were chiefly responsible for turbidity in 19 percent of the water sources. The U.S. Geological Survey, in its aquifer characterization study of northern Thurston County (Dion and others, 1994) found iron levels exceeded the state maximum levels (MCL) in 16 percent of the wells sampled and that manganese exceeded the MCLs in 30 percent of the wells sampled.

Table 3
Non-mining Sources of Ground Water Turbidity

| Source | Cause | Reference |
|---|---|---|
| poor well development | fine sediments are washed from the aquifer by well pumping | Driscoll, 1986 |
| changes in well pumping rates | turbulent flow disturbs sediments | Trela, 1986 |
| corrosion of distribution pipes | colloidal and particulate iron | Sandhu and others, 1978 |
| artificial ground water recharge (stormwater) | turbid surface waters are discharged into ground water | Behnke, 1969<br>Nightingale and Bianchi, 1977 |
| sulfur turbidity | chlorination of waters containing hydrogen sulfide | Lyn and Taylor, 1992 |
| turbid surface waters | turbid surface waters entering ground water during floods periods | U.S. E.P.A., 1992 |
| changes in chemical conditions (Eh-pH) | dissolved Fe, Mn, and other substances form colloidal suspensions | Trela, 1986 |
| high organic matter content | water source located near a marsh or swamp | Driscoll, 1986 |

Because of the many potential causes of turbidity in ground water, it may be difficult to determine the cause in a specific case. If sufficient pre-mine monitoring data is available, it may be possible to show whether the turbidity was a pre-existing condition unrelated to mining. If there are monitoring wells at the mine site that were sampled at the appropriate time, they might show the amount of turbidity generated by mining. Tracers, such as fluorescein dye, can be used in some cases to determine flow rates and directions. Each of these methods has some limitations. Often pre-mining sampling data is not available. Often monitoring wells are not present or were not sampled when the alleged turbidity was being generated. It is difficult to use tracers over long distances and introducing chemical tracers into a drinking water supply may be a controversial technique.

Another way to determine whether a particular gravel mine may be the cause of a turbidity problem is to look at the distance from the mine to the well of concern and the timing of the turbidity problem. If these factors and the approximate ground water velocity are known, it may be possible to determine whether turbidity related to the mine is a potential cause of the problem. Similarly, turbidity problems in wells located up-gradient from the mining operation in most cases can not be a result of the mining activity.

Noble (1987) applied this method to show that a gravel pit in northern Lewis County was not the source of turbidity in a near-by well. The well was located 600 feet away from the edge of the gravel pit, hydrologically connected by sands and gravels of high permeability. The owners of the well complained of high turbidity 24 hours after flood waters from the Skookumchuck River had entered the gravel pit. The neighbors asserted that the pit was the source of the turbidity in their well, and requested that the pit operators install a berm to remedy the situation. Noble calculated that the ground water flow speed in that area was in the range of 1.3 - 13 feet per day, which is a typical range for ground waters in this area. It would be necessary to have a flow rate of 600 feet per day for the gravel pit to have been the source of the observed turbidity. Noble proposed as an alternate explanation that the rapidly rising water table caused by the flooding mobilized clay and silt in the aquifer in the immediate vicinity of the well.

The sequence of mining operations can have a major effect on sediment clogging and turbidity transport. If gravel excavation starts at the up-gradient end of the gravel deposit and proceeds downgradient, the incipient aquifer clogging layer will be excavated along with the gravel, eliminating a significant form of aquifer protection. If mining starts at the downgradient side of the deposit, the clogging layer will be preserved as mining proceeds up-gradient. Development of the clogging layer can also be enhanced by early reclamation of the downgradient face of the excavation to increase vegetation growth.

Planning the gravel mining operation to preserve the clogging layer is a possible best management practice. It can be useful in aquifer protection while still being low in cost to the mine operator. One disadvantage of using this technique to maximize filtration is that it could produce enough clogging to cause a "dam" across the aquifer, potentially affecting local ground water flow patterns. The effect of this local change in aquifer permeability is not likely to be perceptible for more than a short distance from the site. Another disadvantage is that this technique may be in conflict with the most efficient sequence of mining operations for the site.

## Water temperature effects

During the summer months, when the air temperature is greater than the ground temperature and input of heat from the sun is high, opening a gravel pit lake would tend to increase the temperature of the water passing through it. During the winter, the air is generally cooler than the ground, input of solar heat is greatly reduced, and water passing through a gravel pit lake would tend to be cooled.

In northern Thurston County, ground water temperatures ranged from 8.5° to 14.5° C (47° to 58° F). 94 per cent of the samples were between 9° and 12° C (48° to 54° F). This means that, based on average Olympia monthly temperatures, the effect of gravel pit lakes would be to cool ground water from October to April. The same effect would cause heating from May to September.

This analysis does not fully account for the effect of solar heating, which is the largest source of heat input to lakes (Wetzel, 1983). Air temperature is partly a result of solar heating, but the direct input of sunlight is not considered here. This solar heating would tend to increase the summer heating action.

This is not expected to be large, due in part to the relatively rapid rate at which ground water moves, compared to other types of lakes.

Sinclair and Hirschey (1992) estimated the mean ground water flow velocity in the Grand Mound/Scatter Creek area to be 16 feet per day, with values ranging from 1.3 to 60 feet per day. This would means that average ground water in that area would require at least 62 days to pass through a 1,000 foot long gravel pit lake. The average Olympia temperature for July is 63.1° F and the average for August is 62.7° F. This is approximately 9 to 15 degrees F higher than typical ground water temperatures. This suggests that, depending of the size of the gravel pit lake, local ground water temperatures could show seasonally variable temperature effects of up to several degrees from gravel pit lake formation. Because of the high thermal inertia of aquifer materials and the effects of dilution, the effect would be expected to be limited to an area several hundred feet downgradient of the gravel pit lake.

Water level effects

When a lake is formed by excavating gravel out of an aquifer, it inevitably causes a shift in the local ground water surface (Landberg, 1982). Before the lake was developed, the local water table was a gently sloping surface, with ground water flowing down the ground water gradient toward the areas where the water table is the lowest. The water table was sloping because the aquifer materials had a certain resistance to the passage of ground water.

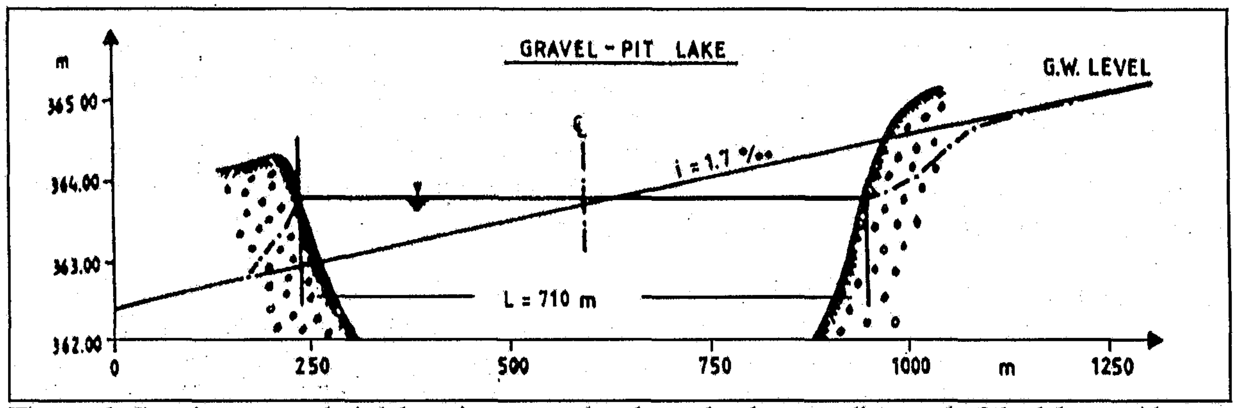


**Figure 6** Creating a gravel pit lake raises water levels on the downgradient end of the lake, and lowers them on the upgradient end (from Landberg, 1982).

As soon as a lake is excavated, this resistance to the flow of ground water is removed. What was formerly the ground water table at the site of the lake becomes the lake surface. Like all open bodies of water, it is horizontal and the water level in the lake at its center is equal to the old ground water table at that same point (Figure 6). This means that ground water levels immediately adjacent to the pit will be lowered at the up-gradient end of the lake and raised at the downgradient end. The amount of raising or lowering at the lake boundary is approximately one-half the length of the lake times the local ground water gradient. This effect is accentuated if a series of gravel pit lakes are formed parallel to the ground water gradient (Morgan-Jones and others, 1984)

In Thurston County, ground water gradients range from 0 to approximately 50 feet per mile (Noble and Wallace, 1966). Most ground water gradients are less than 20 feet per mile. This means that a ground water lake half a mile long in the direction of ground water flow, with a gradient of 20 feet per mile would raise the water table approximately 5 feet at the downgradient boundary and lower the water table approximately 5 feet at the up-gradient end.

Geoengineers (1992) studied a proposed gravel pit in southern Thurston County that would create a gravel pit lake approximately 4,400 feet long. The ground water gradient in that area is approximately 10 feet per mile. Geoengineers computer modeling estimated that the resulting lake level would be 4.6 feet below the ground water surface at the up-gradient end of the lake and 4.6 feet above the ground water level at the downgradient. They estimated, based on aquifer testing and computer modeling, that the effect of creating the lake would result in lowering the water table 0.5 feet at a well 300 feet up-gradient.

Removing mined material from the aquifer

Removing gravel from below the water table is equivalent, in short-term effects, to removing the same volume of water from the aquifer. After mining has finished, the effect is to increase the storage capacity (coefficient of storage) in the area of the lake (Landberg, 1982). This happens because the porosity is increased from approximately 25-40% for sand and gravel to 100% for open water. This means that more water can be extracted from wells near the lake with less drawdown in the water table because of the large amount of water available in the lake.

Increased evaporation

Geoengineers (1992) found that creating a gravel pit lake in southern Thurston County would increase evapotranspiration, causing a decrease in ground water recharge of 4.6 inches per year for each acre converted to open water. This is consistent with the range of decreases in recharge of 0.8 to 4.5 inches per year per acre reported in Shope (1990) for similar situations in New Hampshire. The decrease in recharge of 4.6 inches per year per acre is equivalent to an evaporation rate of 0.24 gallons per minute per acre or 126,100 gallons per year per acre.

ARC/CAD GIS analysis shows that there are now approximately 107 acres of gravel pit lakes in Thurston County. The evaporation loss from these lakes is equivalent to ground water withdrawals of 5,044,000 gallons per year. A single new gravel mine proposed for the Violet Prairie area, if approved, would create 4 acres per year of gravel pit lake. Other extraction operations will create new lakes at a roughly estimated rate of 2 acres per year. This will produce a significant increase in the evaporative losses to ground water (Table 6). By the year 2023, this increase will amount to a 2.7-fold increase over the 1993 rates. If distributed evenly over the whole of Thurston County, these losses are probably not critical. But if concentrated in particular areas, they may be sufficient to have a measurable impact.

Table 6
Predicted Evaporation Losses from Gravel Pit Lakes

| Year | Total Acreage | Evaporative Losses (gal./year) |
|---|---|---|
| 1993 | 107 | 13,493,000 |
| 2003 | 167 | 21,059,000 |
| 2013 | 227 | 28,625,000 |
| 2023 | 287 | 36,191,000 |

Comparing the area of gravel pit lakes to other surface water bodies in Thurston County provides another perspective. ARC/CAD GIS analysis shows that there are 6,950 acres of surface water in Thurston

County. The 107 acres of existing gravel pit lakes amounts to 1.5 per cent of this area. The 287 acres of gravel pit lakes estimated to be developed by the year 2023 would be 4.1 per cent of the total area of the natural surface water bodies.

Water chemistry effects

Rasmussen (1985) compared the water quality in a gravel pit lake with water quality in the Big Sioux aquifer in eastern South Dakota. He found that the lake water had higher pH, lower alkalinity, lower calcium hardness, lower magnesium hardness, lower total hardness, lower iron and manganese, and lower total dissolved solids than water from up-gradient and downgradient wells. A significant difference in these parameters between the up-gradient and downgradient wells was not apparent in all cases. He attributed the difference in these parameters between the wells and the lake to aeration of the lake waters and biological activity. Similar water quality patterns and conclusions are found in other masters theses that studied the same gravel pit lake and aquifer system (Kothari, 1985; Perry, 1986) and in a study from Hungary (Perjes, 1982). All these authors concluded that the mere presence of a lake caused by previous gravel mining did not degrade ground water quality. In general, they found the effects of increased aeration that lake formation provided had a beneficial effect on water quality.

Labroue and others (1988) found measurable removable of nitrate from ground water in association with gravel-pit lakes. They found the highest denitrification in old unclogged lakes and no activity in recently-opened lakes or older, clogged lakes. In a separate paper, they suggest that reclaiming gravel pits with nitrate-fixing vegetation such as alder trees may improve water quality (Labroue and others (1986).

Interchanges between aquifers

Mining into ground water can potentially breach the hydrologic barriers that separate different aquifers. If this happens, water in the two aquifers can mix, potentially affecting the water quality or water levels in one or more of the aquifers. If the affected aquifers have different water quality, this can be an immediate problem. Even if the affected aquifers have the same water quality, loss of that barrier between aquifers may become important in the future if the water quality in one aquifer deteriorates. In addition to potential water quality effects, interchanges between aquifers can cause water level changes.

Some differences in water quality among Thurston County aquifers are shown in Table 4. The aquifers are listed in order from shallowest to deepest, with the Vashon Recessional Outwash (Qvr) on the left and Tertiary Bedrock (Tb) on the right. Dion and others (1994) found that deeper aquifers are more likely to have higher concentrations of naturally occurring constituents, such as iron, manganese, and calcium. They found that shallower aquifers were more likely to have human-caused constituents, such as nitrates and other septage-related compounds. The data given in Table 4 are averages for all of northern Thurston County. Local variations in water quality among aquifers may be greater.

Table 4
Average Water Quality In Thurston County Aquifers

| Constituent | Qvr | Qvt | Qva | Qf | Qc | TQu | Tb |
|---|---|---|---|---|---|---|---|
| Dissolved oxygen | 6.5 | 5.7 | 5.7 | 4.0 | 2.2 | 0.2 | 0.5 |
| Specific conductance | 118 | 140 | 128 | 142 | 150 | 144 | 190 |
| Sodium | 5.2 | 6.0 | 5.8 | 6.0 | 6.7 | 7.6 | 20 |
| Nitrate | 1.0 | 0.95 | 0.84 | 0.33 | 0.25 | <.10 | <.10 |
| Iron (ppb) | 16 | 19 | 14 | 20 | 21 | 81 | 11 |
| Manganese (ppb) | 3 | 2 | 3 | 8 | 6 | 52 | 3 |
| Hardness (as $CaCO_3$) | 41 | 52 | 51 | 54 | 57 | 54 | 71 |

Concentrations are in ppm unless noted.
Specific conductance expressed as microsiemens per centimeter at 25° C.

Washington State law related to the construction of water wells (Ch. 173-160-075) is very explicit that interconnections between aquifers are not allowed:

> "In constructing, developing, redeveloping, or conditioning a well, care shall be taken to preserve the natural barriers to ground water movement between aquifers and to seal aquifers or strata penetrated during drilling operations which might impair water quality or result in cascading water."

In Thurston County, approximately 14 percent of existing gravel pits are located in areas where the surface soils are developed from the Vashon Till. This glacial hardpan unit is a primary aquitard that separates the overlying Vashon Recessional Outwash gravels from the underlying Vashon Advance Outwash sands and gravels. The fact that so many gravel pits are located close to a major aquitard suggests that the potential for causing intermixing of aquifers is significant.

A recent example of the effect gravel mining can have on aquifer barriers between aquifers is provided by the 1993 High Rock Aquifer break incident near Monroe in northwestern Washington. Workers cleaning up a material slough at the base of a gravel slope breached fine silty sand deposits that were acting as a confining layer for the High Rock aquifer (Garland and Liszak, 1994). The initial discharge from the breach was estimated at 2,000 gallons per minute (gpm). Over the course of several days, the flow decreased to 400-500 gpm. An estimated 25,000 cubic yards of material was eroded by the water, causing sedimentation in a stream, wetlands, adjacent property, and lake. Water levels in wells and discharges from springs were lowered as far as 1,500 feet from the break. It is estimated that water levels have dropped an average of four feet over an affected area of approximately 100 acres (Garland and Liszak, 1994). This incident clearly demonstrates the need for gravel operators to clearly understand to location of aquifer boundaries below their operations.

Physical disturbance of aquifer materials

When gravel is mined below the water table it disturbs the aquifer materials, which can have a number of physical and chemical effects. The main physical effect, as discussed above, is the generation of turbidity from suspended silt and clay particles. In most cases, gravel is relatively chemically stable in contact with water because any unstable components were removed by the erosional and depositional forces that formed the gravel deposit. The primary exceptions to this rule that are relevant to Thurston County involve calcium, and iron and manganese.

The volcanic rocks that form the Black Hills and Bald Hills contain largely basalt and andesite (Noble and Wallace, 1966). These rocks contain approximately 5-7 per cent calcium (Dietrich and others, 1982) within calcium feldspar and other calcium minerals. As these minerals weather, calcium can be liberated in significant amounts. This process can be accelerated if gravel deposits containing significant amounts of basalt or andesite are mechanically disturbed by mining or crushing and washing.

This potential addition of calcium is unlikely to have a harmful effect for two reasons. 1) Most Thurston County gravel deposits do not contain significant amounts of these volcanic rocks, which are highly undesirable in most types of gravel-based products because they are chemically reactive, lacking in physical strength, and produce clays upon decomposition. 2) Ground water in Thurston County is classified as moderately to highly aggressive. Aggressive waters have high dissolved oxygen or carbon dioxide contents, low alkalinity and hardness, and low pH (DeBarry and others, 1982). This means they tend to dissolve soluble materials from pipes and other plumbing materials that they contact. This can increase the amount of iron, lead, and copper delivered at the tap in drinking water supplies.

Thurston County ground water, based on data from the northern part of the county, is neutral to slightly acidic, with a mean pH ranging from 6.6 in the shallowest aquifer (Vashon Recessional Outwash) to 7.8 in the deepest (Tertiary Bedrock) (Dion and others, 1994). Sixty-four per cent of the samples in that study were soft and 30 per cent were described as moderately hard. Mean dissolved oxygen levels were moderately high, ranging from 6.5 in the shallowest aquifer to 0.5 in the deepest (Dion and others, 1994). The calculated Aggressive Index of average shallow northern Thurston County ground water is 9.4, which classifies it as highly aggressive (DeBarry and others, 1982). This means that an increase in dissolved calcium would be beneficial by reducing the aggressiveness of the ground water.

Viswanathan (1990) describes an Australian study in which dredge mining for rutile sands (titanium ore) increased the iron content of ground water from 1 ppm to nearly 20 ppm. The dredged sand was washed and the tailings, rich in iron and organic material, were redeposited in the excavated lagoons. Bacteria, feeding on the organic material, changed the iron from its insoluble oxidized state to the soluble reduced state.

Some aquifers in Thurston County, such as the Deposits of the Penultimate Glaciation (formerly Salmon Springs) are stained with iron oxides (Dion and others, 1994) and there are accumulations of bog iron in other locations (Valentine, 1960). Iron-stained gravel has a lower iron content than alluvial rutile deposits, which generally contain magnetite or other iron-rich minerals. In most cases, simply disturbing iron stained gravels would not liberate significant amounts of soluble iron. If abundant organic matter were present, such as manure from agricultural operations, it is possible that chemical changes caused by bacterial activity could increase the iron content in ground water. This potential liberation of iron may be counteracted in part by the effect of increased aeration in gravel pit lakes reducing iron levels, as discussed above under water chemistry effects. The presence of iron staining or accumulations is another factor that should be discussed in the geohydrologic report prepared for permit applications for major gravel mining operations.

Batch plant discharges

Concrete batch plants are sometimes associated with gravel mining operations. Process water from these plants commonly has a very high pH (11 to 12) (Ecology, 1993). Some cement additives can also cause high biochemical oxygen or high nitrate concentrations in ground water. Some water quality data from concrete batch plants is given in Table 5. Storm water discharges from concrete plants can also introduce these same contaminants into ground water.

Table 5
Measured Concentrations of Some Pollutants in Concrete Washwater

| Parameter | Number of Analyses | Low | High | Mean |
|---|---|---|---|---|
| pH | 8+ | 7.2 | 12.5 | 11.4 |
| Nitrate | 6 | 0.3 | 24 | 6.8 |
| Chloride | 3 | 15 | 96 | 55 |
| Sulfate | 1 | 333 | 333 | N/A |
| Total Dissolved Solids | 4+ | 103 | 3600 | 2258 |
| $BOD^5$ | 7+ | 1 | 30 | 11.1 |
| Chemical Oxygen Demand | 4+ | <6.8 | 188 | 86 |
| Total Organic Carbon | 4 | 16 | 54 | 32 |
| Total Phosphorus | 2 | 0.01 | 0.29 | N/A |
| Oil and Grease | 6+ | <1 | 33 | 19 |
| Iron (total) | 2 | 0.23 | 0.92 | 0.58 |
| Total Suspended Solids | 2+ | 1 | 45 | N/A |
| Alkalinity | 3 | 57 | 2180 | 1056 |

All measurements are given as parts per million (ppm).
Data source is Department of Ecology (1993)

Asphalt batch plants use different raw materials and produce a product that is very different from concrete. The ingredients used in making concrete are generally highly reactive, while asphalt is more inert. Asphalt is also highly viscous and if spilled cannot penetrate into the ground. Asphalt plants do use a lot of complex machinery, which requires cleaning, lubrication, and maintenance. In addition, fuels are required to heat the asphalt and keep it in a semi-liquid form. Leaks, spills, accidents, and run-off from equipment and fueling areas can produce stormwater discharges that contain significant amounts of a variety of chemicals, fuels, and other potential contaminants. This stormwater is the primary source of ground water risk related to asphalt plants. If the storm water is kept free of contamination and properly treated, the threat to ground water is relatively low. If storm water becomes contaminated or is disposed improperly, the possibility of measurable ground water contamination is significant.

Hydrocarbon spills during mining

Washington Department of Ecology files were searched for information related to sand-and-gravel mining operations. The search included 94 files from a 12-county area overseen by WDOE's Southwest Regional Office in Olympia. Representative material from several more counties (King, Snohomish, and Skagit) was obtained at WDOE's Bellevue Office through the efforts of the Thurston County Citizens' Planning Association.

These files reveal more than 20 inspections or complaint investigations that cite problems with hydrocarbon spills and/or oil and fuel containment, storage and handling procedures. None of these reports confirms damage to groundwater or quantifies the area affected. It should be noted that these incident reports are only the regulatory agency's side of the incident and may not represent the full story. In a few cases removal of contaminated soil was required and in at least one instance a Spill Prevention Countermeasure Control Plan was initiated. (required by U.S. DOT regulations if more than 660 gal of aboveground oil storage on site).

Definite statements regarding ground water are not usually given and all the recorded incidents involve potential but unverified effects. There are occasional comments such as: "no contamination from the surface has reached the groundwater" or "migration of petroleum contamination through the soil did not occur". None of these reports confirms damage to ground water or quantifies the area affected by the problem. Follow-up sampling is rarely mentioned, and when noted, it is generally to verify the removal of petroleum contaminated soils. These samples are invariably for total petroleum hydrocarbons in soils, not groundwater. Follow-up ground water sampling results were not on file for any of the incidents.

Wells down-gradient from two gravel mines in Thurston County and one in Lewis County were sampled for total petroleum hydrocarbons as part of this study. No detectable hydrocarbons were found, at a detection limit of 0.5 ppm.

These incident reports and limited sampling are not a quantitative assessment of discharges from gravel mining operations, but they do provide some information about the relative frequency and type of hydrocarbon release incidents. While not common, incidents of this type represent a significant source of risk to ground water. The general lack of ground water quality monitoring for appropriate parameters makes it impossible to define the exact degree of risk.

Discharges to surface water

In some cases, ground water does receive a substantial amount of recharge from surface waters. This is particularly common during winter months when surface water levels are high due to abundant rainfall. If ground water is being recharged by surface water, then any contaminants discharged to surface water by a mining operation could be indirectly introduced into ground water.

Department of Ecology records contain numerous gravel-mining-related incidents involving surface water (Appendix C). WQ sampling and analysis results not usually part of these records and if present are generally for pH and turbidity. Typical problems concern high-pH process water overflow from concrete batch plant ponds, fuel spills directly to surface waters from broken pipelines or damaged tanks, and turbid stormwater runoff. Few extraction operations (two in the files examined) have NPDES permits, although they are frequently recommended in reports.

Discharges of these types to surface water can clearly have negative effects on plant and animal life and their habitat. In Thurston County, it has been well documented in studies on the Deschutes River and Scatter Creek that large amounts of water are interchanged between surface and ground water (Dion and others, 1994; Sinclair and Hirschey, 1992). Discharge of gravel-mining-related contaminants to surface water in an area of ground water recharge would have an effect similar to discharging those contaminants into a gravel pit lake. The primary difference would be that moving surface water would tend to dilute and transport the discharge waters.

<u>Post-mining effects</u>

Solid waste disposal

Abandoned gravel mines have traditionally been attractive sites for solid waste disposal. This has often taken place without permits or regard for the consequences to ground water. Because of their extremely high aquifer susceptibility, ground water contamination has often take place.

Sweet and Fetrow (1975) studied an abandoned gravel pit in northwestern Oregon in which 3,000 tons of wood wastes had been deposited. Leachate from the wood wastes lowered the pH, increased iron and manganese levels far above background, and caused high levels of lignin-tannin. These effects rendered a number of down-gradient public and private wells unusable. Goldthorp and Hopkin (1972) documented the migration of high levels of liquid industrial wastes that had been deposited in an abandoned gravel pit. Contamination of ground water from paint wastes deposited in an abandoned gravel pit is documented by the U. S. Agency for Toxic Substances and Disease Registry (1989). Morgan-Jones and others (1984) documented serious degradation of ground water quality down-gradient from abandoned gravel pits west of London that had been filled with a variety of waste materials. Numerous other well-documented cases are on record.

Most sites identified as solid waste problems in Ecology records did not have Solid Waste Disposal Permits. Typical problems involved demolition material (concrete, asphalt), dumping/storage of woodwaste and petroleum contaminated soils at unpermitted pit sites. No follow-up monitoring of groundwater was conducted except at the Lakeside (Pacific Sand and Gravel) pit at Carpenter Road, which had to meet landfill closure requirements after the fact. The sampling results indicated that "no tested state Primary Maximum Contaminant Levels were exceeded in any of the surface or groundwater samples collected . . . state Secondary Maximum Contaminant Levels for manganese and iron were exceeded in samples from some domestic wells and all site monitoring wells". No other data to substantiate or quantify groundwater effects was found in any of the files surveyed.

There can be no doubt that poorly controlled disposal of solid wastes into gravel pits can lead to serious ground water contamination. The evidence for this is so compelling that the worst practices of the past regarding waste disposal into gravel pits must be absolutely forbidden.

Biological effects

Gravel pit lakes have the potential to attract migratory waterfowl. These birds could potentially increase nitrate levels in ground water if present in large enough numbers. No data is available on these effects and any conclusions would be speculative.

If gravel pit lakes were accessible to livestock, nitrate and bacteriological levels could potentially be significantly increased. It has been well documented in studies of the Henderson, Eld, and Totten Inlet watersheds that higher fecal coliform and nitrate levels are found in areas of streams where livestock have access to surface water or where manure storage drains to surface water (Taylor, 1984, 1986).

## V. Cumulative Effects

The total area of past and present gravel excavations is 1,064 acres as shown in Figure 7. This does not include the 44 known borrow pits, which are gravel excavations less than three acres in size. Assuming an average size of one acre for each borrow pit raises the total estimated mined area to 1,108 acres. The estimated area of ground water exposed by gravel mining is 40 acres. The total area of Thurston County is 487,040 acres, so gravel mining has taken place on 0.23% of the county's lands.

The gravel mines with local and DNR permits are shown in Figure 7 and listed in Appendix A. There 52 mines with DNR permits comprising 2,215.4 acres. There are also numerous other mines not listed that are classified by DNR as inactive or terminated.

### Gravel resources of Thurston County

An attempt was made to map the potential gravel resources of Thurston County. A map was developed from digital Washington Department of Natural Resources maps of Thurston County soils that included the following soils series:

- Baldhill very stony sandy loam
- Everett very gravelly sandy loam
- Grove very gravelly sandy loam
- Riverwash
- Spana gravelly loam
- Spanaway gravelly sandy loam
- Spanaway stony sandy loam
- Spanaway-Nisqually complex
- Tenino gravelly loam

Based on their textures, these were determined to be the soil types suitable for use as gravel. When this digital map was completed, the digital coverage of known gravel extraction sites was overlain to check whether it was consistent with the known patterns of gravel mining.
When the two maps were overlain, the map of known gravel extraction sites did not agree well with the predicted gravel resources. A significant number of gravel pits lay outside the area shown to be suitable for gravel extraction, based on soil textures. To help resolve this problem the map of gravel pits was digitally overlain on a map of the geology, prepared by the U.S. Geological Survey.

Digital coverage for geology is currently only available for the northern part of Thurston County, as studied by Dion and others, (1994). This coverage included 76 per cent of the mined gravel acreage in the county, so it is a good basis for analysis. This showed that in the northern part of the county, 86 per cent of the area mined for gravel lies within the Vashon Recessional Outwash. 14 per cent of the area mined lies beneath areas mapped as Vashon Till. Vashon Till, also known as glacial hardpan, is a compressed mixture of clay, silt, sand, and gravel not usually thought of as being suitable for gravel extraction. However, Vashon Till is commonly closely associated with coarse sands and gravels, which are the probable target of the mining activities.

Soil maps are based on the materials in the first five feet below the surface. Because mining operations can excavate sand and gravel substantially below that depth, they could potentially mine in some locations not shown as suitable on the soils map. Additional GIS analysis will be conducted to refine the prediction of gravel resources until it agrees with the data on gravel mine locations. This map and information will be presented in the final draft of this report.

## VI. Summary and Conclusions

As of 1993, gravel mining had taken place on approximately 1,108 acres in Thurston County, which is 0.23 per cent of the county's surface area. There are now approximately 40 acres of gravel pit lakes within the county, which is equivalent to 0.6 of the total area of surface water in the county. By the year 2023, it is estimated that there will be 220 acres of gravel pit lakes, equaling approximately 3.2 per cent of the total area of surface water in the county.

The environmental effects of gravel mining on ground water vary widely, depending on the specific activities that are taking place. In order to evaluate these environmental effects, it is necessary to view each gravel mining operation as the sum of the environmental effects of these component activities. Each associated activity adds an additional increment of risk, which varies in magnitude with the type and scale of the associated activity.

The simplest form of gravel mining, excavating well above the water table with no associated activities such as vehicle maintenance or asphalt batch plants, causes a relatively low risk to ground water quantity and quality. Because the protective soil layer has been removed, these types of excavations are extremely sensitive to the introduction of any type of contamination. But this type of mining, because it is essentially a relatively simple process of loading unconsolidated materials, does not pose a serious risk of introducing those contaminants.

Mining below the water table and into an active aquifer brings some additional minor risks to ground water quality. This includes the potential to increase ground water turbidity and iron content, and to affect local water levels. The only cases on record in which turbidities downgradient from gravel excavations have been increased significantly are when gravel washing operations are involved. Significantly increasing the iron content of ground water by physically disturbing the aquifer materials requires a combination of heavily iron-coated aquifer materials, organic material, and bacteria that is rather unusual. For the geological conditions found in Thurston County, the additional risk presented by simple excavation within an aquifer is small. Adequate management and proper enforcement of a well-designed set of best management practices is necessary to keep this risk at an acceptable level.

Concrete batch plants represent a more serious threat to ground water quality, particularly if the process waters are discharged to ground water without adequate treatment. These process waters can have high treatment of those waters will have a measurable and unacceptable effect on ground water. Concrete batch plants, especially if there is any form of discharge, would require a high degree of regulatory oversight if risk is to be held to an appropriate level.

Asphalt batch plants are present a lower risk to ground water than concrete plant, primarily from stormwater, vehicle fueling, and fuel storage and handling. Like concrete plants however, asphalt plants are a very significant source of risk to ground water and require adequate regulatory oversight and enforcement.

Petroleum leaks and spills resulting from vehicle fueling, maintenance, and washing are probably the most common major threat to ground water associated with gravel mining. This risk can be difficult to assess, because it is highly variable depending on the scale of these activities and the degree of oversight provided by the mining operation management. That a problem exists with petroleum leaks and spills is clear from Department of Ecology incident reports. Because of the lack of ground water monitoring and follow-up investigations on these incidents, the actual degree of ground water impact is unknown.

Creation of gravel pit lakes lowers the water table in wells up-gradient from the lake and raises them on the down-gradient side. This is a relatively local effect, but can measurably affect water levels in wells very near to the gravel pit lake.

Abandoned gravel pits have often been used for the disposal of various types of solid wastes. The adverse effects of this practice are very well documented and compelling enough that this practice should, in general, be completely discontinued. Only truly inert materials should be placed within gravel pits.

In summary, gravel mining has a complex array of environmental effects on ground water. This is largely because different mining operations will each have a different set of mining and processing activities that make up that operation. The environmental effects can only be understood by looking at each separate activity in the mining operation. Each of these component activities has a different environmental effect and requires a different management approach to risk reduction. Gravel mining, in general, poses low to moderate risks to ground water quality and quantity. But adequate regulatory oversight of project design and approval, operation, monitoring and closure, and adequate enforcement are necessary if risks are to be kept to an acceptable level.

REFERENCES

Behnke, J. J., 1969, Clogging in surface spreading operations for artificial ground-water recharge: Water Resources Research, v. 5, no. 4, p. 870-876.

DeBarry, D. W., Kidwell, J. R., and Malish, D. A., 1982, Corrosion in potable water supplies: U. S. Environmental Protection Agency Office of Drinking Water Publication no. EPA 570/9-83-013, 220 p.

Dietrich, R. V., Dutro, J. T., and Foose, R. M., 1982, AGI data sheets: Washington, American Geological Institute.

Dion, N. P. Turney, G. L., and Jones, M. A., 1994, Occurrence and quality of ground water in northern Thurston County, Washington. U. S. Geological Survey Water Resources Investigation Report 92-4109, 188 p.

Driscoll, Fletcher G., 1986, Groundwater and wells: St. Paul, Johnson Division, 1089 p.

Durbec, A.; Ackerer, P.; Zilliox, L., 1987, Hydrodynamical exchanges between gravel pits and the aquifer: a risk for groundwater quality. In Vulnerability of Soil and Groundwater to Pollutants: Proceedings of International Conference [Noordwijk aan Zee, Netherlands], Mar. 30-Apr. 3, 1987, p. 1001-1009.

Washington Department of Ecology, 1993, Draft general permit fact sheet for process water and storm water associated with sand and gravel operations, rock quarries, and similar mining facilities, including stockpiles of mined materials, concrete batch operations and asphalt batch operations. Unpublished fact sheet, Washington Department of Ecology, Central Regional Office, 18 p.

Friedman, G. M.; Sanders, J. E., 1978, Principles of sedimentology: John Wiley & Sons, New York, 792 p.

Garland, D., and Liszak, J., 1994, The High Rock Aquifer Break of October 1993: Washington Department of Ecology Northwest Regional Office Technical Memorandum, October, 1994, 32 p.

Geoengineers, 1992, Geotechnical and hydrologic services, Lakeside Industries' proposed Tilley Road Project, Thurston County, Washington, December, 16, 1992: Unpublished report for the Thurston County Planning Department.

Gibbs, R. J.; Matthews, M. D.; Link, D. A., 1971, The relationship between sphere size and settling velocity: Journal of Sedimentary Petrology, v. 41, no. 1, p. 7-18.

Gibson, John Frank, 1940, A study of three Washington ores: University of Washington Master of Science thesis, 53 p., 1 plate.

Goldthorp, G. D.; Hopkin, D. V., 1972, Migration of liquid industrial waste from a gravel pit: Groundwater Pollution in Europe, Proceedings of a Conference [Reading, England], 1972, 3 p.

Kothari, Nilaksh, 1985, Evaluation of gravel extraction on groundwater movement and quality: South Dakota State University M. S. thesis, 70 p.

Labroue, J., and Pinay, G. 1988, Natural nitrate removal from groundwaters. Possibility of application to the reclamation of gravel pit lakes: Annales de Limnologie ANLIB3 v.22, no.1, p. 83-88.

Labroue, J., Tourenq, J.N., Mieussens, C., Robert, J., and Donville, B., 1988, Role of gravel pit lakes in the removal of nitrate from phreatic aquifers of the Garonne Valley: an attempt at an evaluation: Annales de Limnologie ANLIB3 v.24, no.1, p. 31-38.

Landberg, Johan, 1982, Hydrogeological consequences of excavating gravel pits below the water-table in glaciofluvial deposits: Chalmers University of Technology [Goteborg, Sweden] and University of Gothenburg Doctor of Philosophy thesis, 300 p.

Lyn, T. L.; Taylor, J. S., 1992, Assessing sulfur turbidity formation following chlorination of hydrogen sulfide in groundwater: Journal AWWA, September 1992, p. 103-112.

Mathiot, K., 1978, Milton-Freewater ground water turbidity problem: Unpublished report, Water Resources Department, Oregon Department of Environmental Quality, 10 p.

Mikels, M. S., 1992, Characterizing the influence of surface water on water produced by collector wells: Journal AWWA, September 1992, p. 77-84.

Mikels, F. C. and Bennett, T. W., 1978, Cooling water intakes utilizing Ranney collectors or Ranney intakes: Larval Exclusion Systems for Power Plant Cooling Water Intakes, Proceedings of the San Diego, California Workshop, February 7-8, 1978, Argonne National Laboratory, 15 p.

Morgan-Jones, Martin; Bennett, Stephen; Kinsella, J. V., Hydrological effects of gravel winning in an area west of London, United Kingdom: Ground Water, v. 22, no. 2, p. 154-161.

Newport, B. D.; Moyer J. E., 1974, State-of-the-art: sand and gravel industry: Environmental Protection Agency Technology Series Report EPA-660/2-74-066, June 1974, 40 p.

Nightingale, H. I.; Bianchi, W. C., 1977, Ground-water turbidity resulting from artificial recharge: Ground Water, v. 15, no. 2, p. 146-152.

Noble, John, 1987, Findings and opinions at Hilpert gravel pit regarding ground water quality: Unpublished private report dated October 7, 1987, 16 p.

Noble, J. B.; Wallace, E. F., 1966, Geology and ground-water resources of Thurston County, Washington; Volume 2: Washington Division of Water Resources Water-Supply Bulletin 10, v. 2, 141 p., 5 plates.

Perjes, T., 1982, Hydrogeological and environmental analysis of the relationship between surface mining and riverine water wells: International Mine Water Association 1st Conference [Budapest, Hungary], April 19-24, p. 96-101.

Perry, M. L., 1986, Impacts of large-scale gravel excavations, precipitation and runoff on groundwater movement and quality: South Dakota State University M. S. thesis, 73 p.

Rasmussen, J. R., 1985, Seasonal effect of large-scale gravel excavation on groundwater quality: South Dakota State University M. S. thesis, 102 p.

Sandhu, S. S.; Warren, W. J.; Nelson, Peter, 1978, Trace inorganics in rural potable water and their correlation to possible sources: Water Research, v. 12, no. 4, p. 257-261.

Shope, B., 1990, Potential impacts of below water table sand and gravel mining operations on ground water quality: Proceedings of the FOCUS Conference on Eastern Regional Ground Water Issues [Springfield, Massachusetts], Oct. 17-19, 1990, p. 361-371.

Sinclair, K. A. and Hirschey, S. J., 1992, A hydrologic investigation of the Scatter Creek/Black River area, southern Thurston County, Washington State: Evergreen State College, unpublished MS thesis, 192 p.

Snavely, P. D., Jr.; Brown, R. D., Jr.; Roberts, A. E.; Rau, W. W., 1958, Geology and coal resources of the Centralia-Chehalis district, Washington: U.S. Geological Survey Bulletin 1053, 159 p., 6 plates.

Sweet, H. R., and Fetrow, R. H., 1975, Ground water pollution by wood waste disposal: Ground Water, vol. 13, no. 2, pp. 227-231.

Taylor, M. M., 1984, The Henderson/Eld Inlet Water Quality Study: Thurston County Environmental Health Division Report for the Washington Department of Ecology, 159 p.

Taylor, M. M., 1986, Totten Inlet and Watershed - A Bacteriological Water Quality Investigation: Thurston County Environmental Health Division Report, 159 p.

Tepordei, V. V., 1992, Construction sand and gravel, annual report 1990: U. S. Bureau of Mines, 34 p.

Trela, J. J., 1986, Should ground water samples from monitoring wells be filtered before laboratory analysis? Yes and no: Proceedings of the Sixth National Symposium and Exposition on Aquifer Restoration and Ground Water Monitoring, Columbus, Ohio, May 19-22, 1986, p. 295-300.

U. S. Agency for Toxic Substances and Disease Registry, 1989, Health assessment for Big River Sand and Gravel Company, National Priorities List (NPL) site: Wichita, Kansas, Region 7. CERCLIS No. KSD980686174, 11 p.

U.S. E.P.A. Office of Drinking Water, 1992, Manual of Small Public Water Systems; Boca Raton, CRC Press, Inc., 211 p.

Valentine, G. M., 1949, Inventory of Washington Minerals: Washington Division of Mines and Geology Bulletin 37; Part I, Nonmetallic Minerals (second edition - revised by M. T. Huntting, 1960), 175 p.

Viswanathan, M. N., 1990, Mineral sand mining and its effect on groundwater quality: Water Science Technology, v. 22, no. 6, p. 95-100.

Wetzel, R. G., 1983, Limnology: Orlando, Saunders College Publishing, 767 p.

White, W. W., III; Stebbins, Scott; Hillman, Thomas, 1990, Puget Sound region sand and gravel market study: U. S. Bureau of Mines Report BIA 64-III, 149 p.

**APPENDIX A**
**EXISTING SURFACE MINING PERMIT SITES - AS OF 1993**

| SAND AND GRAVEL | | | | | |
|---|---|---|---|---|---|
| **DNR Permit** | **Operator Name** | **Sec.** | **Township** | **Range** | **Permitted Acres** |
| *10442 | J.D. Dutton, Inc. | 36 | 19 | 2W | 5 |
| 10835 | Ted Sundberg | 9 | 18 | 2W | 11 |
| *11214 | Department of Transportation | 18 | 18 | 2W | 4.7 |
| 10473 | Tom Martin Construction | 28 | 18 | 2W | 10 |
| 10895 | Carl Willrich | 28 | 18 | 2W | 20 |
| 11472 | William Jones Co. | 29 | 18 | 2W | 20 |
| 11821 | William Jones Co. | 29 | 18 | 2W | 20 |
| 11832 | William Jones Co. | 29 | 18 | 2W | 5 |
| 11419 | Tom Martin Construction | 2 | 18 | 1W | 53 |
| 10938 | Pacific Sand and Gravel | 9/10 | 18 | 1W | 12 |
| 10385 | Olympia Sand and Gravel | 10 | 18 | 1W | 65 |
| 12168 | Olympia Sand and Gravel | 10 | 18 | 1W | 33 |
| 10348 | Pacific Sand and Gravel | 10 | 18 | 1W | 23 |
| 10706 | Pacific Sand and Gravel | 12 | 18 | 1W | 70 |
| 10002 | Holroyd Land Co. (Neilson/Pacific) | 17 | 18 | 1E | 330 |
| 10958 | Thurston County | 18 | 18 | 1E | 13 |
| 12500 | Nisqually Sand and Gravel/Lakeside | 28/29 | 18 | 1E | 80 |
| 12633 | Hard Rock Crushing | 13/24 | 17 | 3W | 80 |
| 10601 | Arthur J. Mell | 13 | 17 | 2W | 30 |
| 11988 | Milton Emerick (Fairview S&G) | 18 | 17 | 2W | 80 |
| *12116 | Howard R. Larson | 22 | 17 | 2W | 10 |
| 12115 | Howard R. Larson | 28 | 17 | 2W | 12.5 |
| 12577 | Tom Martin Construction | 28 | 17 | 2W | 40 |
| 11016 | Boe Sand and Gravel | 6 | 17 | 1W | 10 |
| 12615 | Norman Hutson | 6 | 17 | 1W | 5 |
| 11766 | Lacey Oaks Stables (Land Use Co.) | 11 | 17 | 1W | 9 |
| 12659 | Great Western Supply/O'Neill | 20/21 | 17 | 1W | 10 |
| 12614 | Milton Emerick | 30 | 17 | 1W | 20 |
| 10781 | Thurston County | 31 | 17 | 1W | 10 |
| *12217 | Quigg Brothers - McDonald | 29 | 17 | 2E | 20 |
| 12592 | Tom and Claudia Westbrook | 9 | 16 | 3W | 5 |
| 12094 | Department of Natural Resources | 10 | 16 | 3W | 15 |
| 11337 | James Hendricks | 31 | 16 | 3W | 5 |
| *10457 | Martin Sand and Gravel | 34 | 16 | 3W | 25 |

| SAND AND GRAVEL | | | | | |
|---|---|---|---|---|---|
| DNR Permit | Operator Name | Sec. | Township | Range | Permitted Acres |
| 10349 | Cascade Materials, Inc. | 3 | 16 | 2W | 50 |
| 12285 | Pacco, Inc. | 5 | 16 | 2W | 10 |
| 11902 | Kellis A. Hamilton | 25/36 | 16 | 2W | 172 |
| 12014 | Washington Asphalt Co. | 28/29 | 16 | 2W | 250 |
| *11360 | Department of Transportation | 29 | 16 | 2W | 32 |
| 12640 | Granger/Breen | 33 | 16 | 2W | 50 |
| 11294 | M.A. Segale, Inc. | 5 | 16 | 1W | 50 |
| 10453 | Thurston County | 5 | 16 | 1E | 22 |
| 11703 | Thurston County | 24 | 16 | 2E | 30 |
| 10443 | Pacific Sand and Gravel | 1 | 15 | 3W | 18 |
| 10734 | Dulin Construction, Inc. | 2 | 15 | 3W | 45 |
| *11914 | Martin Sand and Gravel | 2 | 15 | 3W | 9.2 |
| 10282 | Cascade Hauling Co. | 11 | 15 | 3W | 28 |
| 11110 | Lewis County | 11 | 15 | 3W | 13 |
| 10452 | Martin Sand and Gravel | 11 | 15 | 3W | 30 |
| *10189 | Cascade Hauling Co. | 14 | 15 | 2W | 4 |
| 11089 | Pacificorp Electric Operations | 10/15 | 15 | 1W | 150 |
| 12602 | North Fork Timber Company | 11 | 15 | 1W | 10 |
| | | | | | 2,215.4 |

* Listed by DNR records as inactive or terminated

| COAL | | | | | |
|---|---|---|---|---|---|
| DNR PERMIT | OPERATOR NAME | Sec. | Township | Range | PERMITTED ACRES |
| 10145 | Washington Irrigation and Development Co. | 13/24 | 15 | 2W | 4,000 |
| | | | | | 4,000 |

| ROCK QUARRIES | | | | | |
|---|---|---|---|---|---|
| DNR PERMIT | OPERATOR NAME | Sec. | Township | Range | PERMITTED ACRES |
| 10496 | Kaufman Brothers Construction | 19/30 | 18 | 2W | 40 |
| 11831 | Hodges Homes, Inc. | 27 | 18 | 2W | 2 |
| 12140 | Jones Quarry | 29 | 18 | 2W | 65 |
| 12602 | North Fork Timber | 11 | 15 | 1W | 10 |
| | | | | | 117 |

## APPENDIX B

| Potential Groundwater Problems Associated With Gravel Mining - Hydrocarbon Spills and Runoff Recorded in WDOE Files | |
|---|---|
| Anderman Sand and Gravel (Belfair, Mason) | (1990) WDOE inspection in response to complaint. "Sheen caused by ... waste oil spillage from past practices ... will send letter." |
| Arlington Sand and Gravel (Arlington, Snohomish) | (1987) Complaint initiated inspection which revealed "significant quantity of various types of petroleum product in ponded and standing water on site" -- soil surface around shop "saturated with oils". Sources of contamination were: leaking equipment, poor house-keeping practices, fuelling operations and inadequate cover or containment for stored waste oils. Found past evidence of oil having been washed into Stillaguamish River. Upgradient location of fuel tanks/pumps allows spills to flow toward river. Investigator recorded soil saturated with fuel to 2½ or 3 feet in vicinity of fuel islands. Notice of Violation (RCW 90.48) and penalty of $500.00 recommended. |
| Associated Sand and Gravel (Everett, King) | (1991) Follow-up investigation (soil borings and wells) on site from which underground storage tank (UST) had been removed disclosed total petroleum hydrocarbons exceeding Model Toxic Control Act clean-up standards. Contamination is below a paved area and may extend beneath an on-site structure. Engineering firm recommends leaving in place until facility closes. |
| B & L Construction and Trucking (Tacoma, Pierce) | (1991) Inspection of 15 acres storage and maintenance area near gravel mining operation revealed poor waste oil storage practices and uncontained leakage from equipment. Operator advised to hire waste consultant/recycling firm. Sampling and follow-up inspection advised but not found in file. |
| Cadman Sand and Gravel (Black Diamond, King) | (1991) Drop-in inspection: "major environmental contamination risk at this facility is associated with handling and storage of petrochemicals." including uncovered uncontained storage tanks. Waste water from truck washing operation has measured pH of 11 and flows uncontained down a haul road "where it is completely percolated into the ground." No State Waste Discharge Permit at time of inspection. |
| Corliss Redi-Mix (Enumclaw, King) | (1989) "Some problem with chemical/oil storage and handling." Spillage on ground and cement additives stored outside containment area. "Asked for better practices and cleanup". |
| Foran Landfill/Gravel (Tacoma, Pierce) | (1992) Urban Bay Action Team (UBAT) inspection. No containment of 6,000 gallon diesel fuel tanks. Gravel around smaller tank heavily stained with oil. Open container of used oil. Inspector suggests covering and berming. |

| Potential Groundwater Problems Associated With Gravel Mining - Hydrocarbon Spills and Runoff Recorded in WDOE Files | |
|---|---|
| Gilbert Western Corp (Camas, Clark) | (1989) Waste oil tank overflow (oil flow valve directed oil outside containment facility?). Not reported. Cleanup of oil contaminated soil and immediate repair of secondary-containment flow valve required. |
| Lakeside Industries (Aberdeen, Gray's Harbor) | (1989) Malfunctioning gauge caused rupture of 12,000 gallon above-ground storage tank during fuel delivery. Approximately 100 gallons diesel oil "saturated a small wetland area" connected to Chehalis River. Prompt response by Lakeside clean-up crew and proper agencies notified. Small section of wetland affected by removal of contaminated soil. No Spill Prevention Containment and Countermeasure Plan on site. |
| Lakeside Industries (Lacey, Thurston) | Inspection revealed following violations at Hogum Bay Rd. asphalt plant:<br>1. inadequate containment around all above-ground storage tanks (AGST)<br>2. cleaning of equipment with high pressure washer and use of petroleum/detergents released as "effluent discharge to ground and/or waters of the state." No NPDES or State Waste Discharge permit.<br>3. equipment maintenance pit "grossly contaminated" with petroleum and "suspected organic compounds". Soil removal required.<br>Lakeside submitted a Spill Prevention Control and Countermeasure Plan in accordance with 40CFR Sect. 112.7 approx. 1 mo. later -- addressed all issues. No further correspondence found.<br>(1987) Crane collapsed and crushed a diesel tank (approx. 200 gallons discharged to ground). No follow-up correspondence or sample data in file.<br>(1981) Former site for plant on Carpenter Rd. reportedly had record of fuel spills to ground. Fuel storage area formerly had drain to gravel pit. |
| Lakeside Industries (Anacortes, Skagit) | (1991) Complaint and follow-up investigation at asphalt plant. Approx. 1,000 cu yards of petroleum contaminated soil (PCS) was excavated and recycled through plant. "Confirmational analyses indicated that cleanup standards were met." On-site drums removed. No further correspondence? |
| Martin Construction (Lacey, Thurston) | (1990) RCRA compliance inspection of truck storage and maintainence facility. Spillage of oil and other hazardous materials; improper storage of waste oil. Wastewater from steam cleaning system discharged directly to ground. "Evidence of extreme oil contamination" -- removal and treatment of soils required by WDOE. Connection with gravel mining operation not clear. |

| Potential Groundwater Problems Associated With Gravel Mining - Hydrocarbon Spills and Runoff Recorded in WDOE Files | |
|---|---|
| Meridian Aggregate (Granite Falls, Snohomish) | (1991) Removal of underground storage tank exposed an area highly contaminated with waste motor oil, apparently from many years of accumulation. Site had been used for equipment maintenance. "Visual observation disclosed veins of old motor oil" flowing. Site was excavated to remove all visable contaminated soil (sent to asphalt plant) and later sampling confirmed total petroleum hydrocarbons (TPH) within allowable limits. |
| Quigg Brothers-McDonald (Aberdeen, Gray's Harbor) | (1992) Fuel transfer valve system apparently tampered with causing diesel fuel release to containment area and to several storm drain catch basins. No notification of authorizing agency as per Ch. 90.56.280 RCW. Spill response plan and removal of petroleum-contaminated soils ordered by WDOE. |
| R & R Joint Venture (Vancouver, Clark) | (1991) Inspection terms operation "unsatisfactory". No containment for lube racks and fuel tanks. Poor solid waste disposal practices (waste oil, paint, cleaning compound, old batteries, etc.) on site. |
| Robison Construction (Tacoma, Pierce) | (1987) Improper on-site storage caused spillage of 1,000 gallons of diesel to ground and ultimately into Clear Creek. Tacoma-Pierce Co. Health requires clean-up involving excavation, testing of sediment residual BTX and landfarming of contaminated sediments. Spills prevention and management plan also required in lieu of permit revocation. |
| S & W Sand and Gravel (Puyallup, Pierce) | (1989) Oil contaminated soil confirmed by laboratory tests (Geotechnical Testing is of the opinion that "no contamination from the surface has reached the groundwater"). Soil to be removed to depth of 2 feet. S & W must stop allowing discharge of wastewater from steam cleaner to ground (oil/water separator will be required). |
| Tucci and Sons (Puyallup, Pierce) | (1991) Complaint investigation at gravel pit and asphalt plant. Diesel line from fuel tank to batch plant was underground and could not be determined to be leaking. Asphalt (source of complaint) leaked from above ground tanks but "hardens readily and does not appear to be a problem." Contaminated soil from another site stored in gravel yard - no cover or containment. Soil staining around diesel refueling area. Follow-up inspection to confirm covering of contaminated soils and spill prevention at diesel refueling area recommended - not in file. |

| Potential Groundwater Problems Associated With Gravel Mining - Hydrocarbon Spills and Runoff Recorded in WDOE Files | |
|---|---|
| Washington Dept. of Transportation (Elwa Pit, Clallam) | (1990) Complaint investigation. Gravel pit is primarily used for storing sand and gravel, culverts and other construction material and for burning "roadside debris". Observations: improper disposal of oil from application truck and maintenance shop oil/water separator and catch basin; improper disposal of pesticide rinseate from applicator truck; improper storage of chemicals. Sample results indicated petroleum contaminated soils were present in pit but did not comfirm pesticide contamination. DOT to undertake remedial action. "Since migration of petroleum contamination through the soil did not occur, site will not be listed on Site Management Information System." |
| Woodworth and Co. (Tacoma, Pierce) | (1991) Urban Bay Action Team inspection summary: improper storage of unlabeled wastes; "inevitable leakage" around hot mix asphalt plant. |

Misc. unconfirmed reports connected with hydrocarbons:

(1990) Oil dumping and burying of used filters and antifreeze by trucking firm in Redmond (connection with gravel mining?)

(1990) Oil leakage from gear boxes and discharge of diesel oil from truck washing at asphalt plant in Silverdale.

(1991) Early notice letter to gravel mining company in Kent advising inclusion in WDOE database of known or suspected contaminators under Model Toxics Control Act. Informal report attached indicates "most significant contamination" was from leaking diesel fuel pumps.

(1991) "Groundwater contamination is likely" from UST excavations with standing water at abandoned aggregate supply site in Lynnwood.

(1991) Evidence of leakage of petroleum hydrocarbons from above ground storage tanks at trucking company in Anacortes. ASTs not bermed.

## APPENDIX C

| Surface Water Problems Associated with Gravel Mining as Indicated by Material in WDOE Files | |
|---|---|
| Concrete Batch Facilities: | |
| Aggregate Supply (Bellevue, permitted to Lakeside Gravel) | (1973) "Settling ponds appear to be seeping contaminated water into a drainage ditch" which feeds into a wetland adjoining Kelsey Creek. No follow-up? |
| Associated Sand and Gravel (Everett, King) | Numerous (15) incidents of high pH wastewater and silt discharge to Pigeon Creek in '89-'90 (some samples collected). Spill of 80 gallons of antifreeze from truck maintenance shop to creek in 1989. Penalties assessed for violations of NPDES permit. |
| BO-MAC Sand and Gravel (Port Orchard, Kitsap) | (1989) cement waste dumped into creek (truck washout pond located adjacent). "General disregard of environmental regulations". |
| Cadman Concrete (Monroe, Snohomish) | (1991) Concrete batch plant - no State Waste Discharge Permit. High pH discharge (confirmed by lab analysis) from settling ponds to surface waters. |
| Cadman Gravel Co. (Redmond, King) | (1982) Concrete waste washed from cement truck into creek. |
| Lakeside Gravel (Bellevue, King) | (1987) Temporary batching operations were generating "significant volume of wastewater" to sump (and then to?). "Likely that the disposal of wastewater is to waters of the state". Lakeside agrees to plug sump and pump and haul all wastewater to Issaquah site and to refrain from truck washing at this plant. |
| Lonestar Northwest (Tacoma, Pierce) | (1990) Notice of Violation for exceeding pH discharge limit issued by City of Tacoma Sewer Utility Division. "Illegal uncontrolled discharges" to Hylebos Waterway. No State Waste Discharge Permit. |
| Shope Concrete Products Co. (Puyallup, Pierce) | (1990) High pH waste water and sediment-laden storm water being discharged into storm water drainage system discharging to Puyallup River. Water samples taken; no State Waste Discharge Permit. |
| Stoneway Concrete (Renton, King) | "Some 16 enforcement actions dating back to 1970" (1986) Backhoe operator struck underground pipeline causing release of 70,000 gallons diesel oil (1,000 gallons directly to Green River) -- $10,000 penalty assessed. Numerous penalties assessed for discharge of untreated wastewaters. |
| Stoneway Concrete (Renton, King) | (1978) Dragging of truck-wash sediment from settling basin "inadvertently opened a discharge pipe" allowing high-pH turbid wastewater to enter Cedar River. Trout and salmon mortality in excess of 4,000 estimated. Other species not accounted for. Total damage to Cedar River resource estimated at 11,040.41. Not clear how much of this was actually collected: WDOE mitigated their $1,500 penalty for discharge to state waters to $250.00.<br><br>(1969) Citizen complaint to Seattle Times results in inspection of facilities by Water Pollution Control Board. Violations of water pollution control laws and company's waste discharge permit were noted and deadline for compliance was set (this was apparently ignored). No evidence in file of any penalty for non-compliance.<br><br>Note: total of 25 recorded "incidents" involving concrete plants found in the Southwest Office files plus the 16 "enforcement actions" referred to in Stoneway's file which remain unexplained. |

| Surface Water Problems Associated with Gravel Mining as Indicated by Material in WDOE Files | |
|---|---|
| Gravel Pit/ Sediment Pond Discharges: | |
| Active Construction (Gig Harbor, Pierce Co.) | (1990) Sediment-laden rainwater runoff from inactive pit discharges to county ditch and then into McCormack Creek. Inspector: "I have not been back or recontacted them because I am waiting for guidance regarding gravel pit issues from my supervisors." Mine operator apparently made attempts to solve the problem by redesigning and regrading of settling ponds. |
| Anderman Sand and Gravel (Mason Co.) | (1989) WDOE inspection in response to citizen complaints leads to notification of DNR (permitting agency) regarding water quality problems caused by erosion of steep slopes and colloidal nature of resultant turbidity. "The lower settling ponds appear to have reduced holding capacity" -- ponds overflow during large storms. Lab analysis report incomplete; no indication of location of high turbidity sample. Where are sample locations recorded?<br><br>DNR issues Stop Work Order in January, followed by Provisional Surface Mining Permit for resumption of mining on a limited basis due to completion of remedial drainage control measures. "Violations of the state clean water statutes . . . are probably occurring as a result of unusually impermeable strata underlying the mine."<br><br>Second Stop Work Order issued by DNR in December. Dept. official observed "significant volume" of sediment-laden water overflowing from pond and ultimately into Union River.<br><br>(1990) WDOE testimony indicates that Anderman does not have and has not applied for a discharge permit and such permit could only be issued if the discharge were brought into compliance with state water quality standards. "To date, the WDOE has not taken formal compliance actions against Anderman" -- has instead coordinated enforcement with DNR. Citizen complaint filed in November '90 suggests that overflow problem has not been solved. |
| Black River Sand and Gravel (Bellevue, King) | (1989) Turbid water discharge to Jenkins Creek (Class AA). Lab analysis of samples shows 11.4 and 12.9 NTU in creek water. Penalty reduced to $500.00 due to mitigating circumstances (vandals disconnected power supply to pumps causing water to overflow settling pond dike). |
| Canyon Sand and Gravel (Tacoma, Pierce) | (1986-89) Complaints refer to silting-up of Canyon Creek due to runoff from undredged sedimentation ponds. "Has been a problem in the past." Inspections but no file record of sampling. |
| Carl Carlson Gravel (Clark Co.) | (1979) "Silt form the surface mine, caused by poor operating procedures and lack of erosion control, has created mud deltas in Mud Lake." Co. Planning Council questions DNR acceptance of reclamation plan that "does not meet the minimum requirements" of Chapter 78.44.030 RCW. WDOE order in file requires erosion control plan within 30 days, but subsequent correspondence indicates "no effort whatsoever has been taken to comply with the plans the applicant proposed." Clark Regional Planning Council urges WDOE to take enforcement action - no record of any action in file. Correspondence suggests that County will issue stop-work notice which will be in effect until Carlson obtains a grading permit. |
| Concrete Nor'West (Mt. Vernon, Skagit) | (1974 and 1980) Turbid water from gravel washing operation flowing into Samish River. Penalty of $500.00 assessed in '81 for violation of State Waste Discharge Permit and Chapter 90.48.080 RCW. |

| Surface Water Problems Associated with Gravel Mining as Indicated by Material in WDOE Files | |
|---|---|
| Friend and RIckalo (Aberdeen, Gray's Harbor - rock quarry) | (1989) Complaint alleges that retention-pond overflow produces "white foamy material in creek". Inspection unable to confirm, but status of expired NPDES permit and associated discharge monitoring reports uncertain. Poor truck-washing practices noted.<br><br>(1992) Unannounced inspection. Administrative extension issued on NPDES in 1986: all site runoff must comply with state water quality standards. Vehicle maintenance area "well maintained". |
| Hamlet Hilpert Gravel (Lewis Co.) | (1986) Adjoining property owners alleged that floodwaters from Skookumchuck River have entered the gravel pit and contaminated the groundwater (causing local wells to become turbid). Mine is located on the floodplain. WDOE inspection reported inundation of "messy" fuel storage area at pit site - tanks had no locking system. Recommendations: geologist review of turbidity issue and construction of bermed/sealed fuel storage area with appropriate sump above 100 yr. flood.<br><br>(1987 - 88) WDOE ordered pit perimeter be diked to specification to prevent infiltration of floodwaters.<br><br>(1991) Enforcement order issued in response to WDOE Shorelands Program inspection which disclosed that dike was not constructed as specified - "cannot adequately serve its intended purposes".<br><br>(1992) Hilpert files Notice of Appeal allegING that operation was in "substantial compliance" with Flood Control Zone Permit as amended and requests WDOE "be put to strict proof as to the allegation that the past or continued operation of the pit constitutes a threat of aggravated flooding". Outcome of appeal? |
| Lakeridge Gravel - Lakeridge Paving Co.(Pierce Co.) | (1989) County issued cease-work order in response to 2 consecutive days of WQ violations. Wash water retention ponds overflowing. Dredging of ponds and ditches and installation of dry-screening process in progress. No NPDES permit. |
| Lakeside Gravel (Bellevue, King) | (1973) $100.00 penalty for discharge of dichloromethane into unnamed creek. Order of Termination of Permit (no date) for surface discharge of waste water in a condition of > 50 NTU. |
| Lakeside Industries (Issaquah, King) | (1987) $2000 penalty for discharge of oil to state waters (piping of underground diesel storage tanks ruptured). Failed to notify WDOE as required by 90.48.360 RCW. Lakeside contends: "due to the negligence of Lakeside Gravel Co. in controlling heavy surface water runoff, the road above our tanks washed out allowing water and sand and gravel to wash in and fill the dike. This caused the tanks to float, breaking off the service piping". They blame gravel co. since concrete containment around fuel tanks was adequate to control any on-site spill but could not handle the off-site stormwater runoff coming from the adjacent property. |

| Surface Water Problems Associated with Gravel Mining as Indicated by Material in WDOE Files | |
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| Lakeside Sand and Gravel (Issaquah, King) | (1988) EPA proposed Section 309(g) Administrative Penalty Action in response to allegations that Lakeside "discharged pollutants on 9 separate occasions to North Fork Creek". Pollutants included "soil particles", cement and cement waste and reached the creek via drainage ditch. $25,000 administrative penalty proposed - no Final Order in file, no water analysis records.<br><br>(1987) $1000 penalty for lack of stormwater controls causing "oil and muddy waters to enter Jordan Creek". $2000 penalty for separate incident involving discharge of cement waste water and turbid runoff to N. Fork Issaquah Creek.<br><br>(1982) $4000 penalty for discharge of contaminated wastewater to Jordan Creek (in violation of SWDP and RCW 90.48.080).<br><br>(1978) $ 500 penalty for discharge of turbid industrial wastewater to Jordan Creek on 1/18/78. $2000 penalty for discharge of contaminated stormwater causing turbidity in Jordan Creek on 10/20/78. Inspection report says "samples taken" - results not in file. $2000 penalty for discharge of industrial process wastewater into Jordan Creek on 10/28/78.<br><br>(1972) WDOE memorandum outlines apparent violations and possible corrective actions. Inspection of 9/19/72 in response to three complaints of turbid water discharge. "Both sludge lagoons were full of sludge" - treatment methods seem ineffective.<br><br>(1971) DOE memorandum: Lakeside's temporary waste discharge permit renewal application not acceptable until adequate facilities are installed. |
| Meridian Aggregate Co. (Mt. Vernon, Skagit) | (1988) $1000 penalty for wastewater discharge causing siltation of Carpenter Creek. |
| Olympia Sand and Gravel (Olympia, Thurston) | (1983) Complaint alleges Olympia is polluting Woodland Creek. Field check: operator advised that discharge from lower settling pond is too turbid - "rehab" work on ponds is requested.<br><br>(1981) Settling ponds are overflowing into Woodland Creek. "When heavy rains occur, groundwater infiltrates ponds causing discharge of silty water because wiers are by-passed. Nothing he (operator) can do about it." |
| Rainier Rock (Sumner, Pierce) | (1988) Heavy siltation of adjacent creek. "Current slopes in the pit cause almost all surface water to run toward the creek". Transfer of surface mine permit and redesign of siltation ponds proposed to avoid DNR Stop Work Order then in process. |

| Surface Water Problems Associated with Gravel Mining as Indicated by Material in WDOE Files | |
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| Reserve Silica Corp. (Ravensdale, King permitted to L-Bar Products) | (1991) Follow-up inspection. "Off-site flow of contaminated storm water has been a source of water quality violations the last two years". Reserve had submitted application for renewal of State Waste Discharge Permit. "Next permit issued should require monthly inspection of berms which direct stormwater flow". Oil, fuel and chemical container handling are very poor.<br><br>Cement kiln-dust depository areas are capped, and vegetated and groundwater monitoring reports for the underlying aquifer are being submitted to SHW. "Michele Underwood said that no violations of ground water quality have been reported for the site".<br><br>(1990) Inspection comments: surface area of settling ponds has decreased since last visit; yard and sump area are flooded and runoff is reaching surface waters; oil storage and handling has not been improved (no cover or containment); drainage ditch on property boundary has filled with sediment and needs to be cleaned out (again); no site plan has been submitted per last year's request. WDOE will require NPDES permit? |
| Salmon Bay Sand & Gravel (Seattle, King) | (1991) Letter from Seattle Engineering Dept. advised that Salmon Bay truck drivers were dumping concrete slush and gravel into storm sewers. Requests company review disposal practices with personnel. |
| Stoneway Concrete (Renton, King) | (1986) Penalty notice ($500.00) for release of turbid waters from settling ponds to Cedar River. |
| Sunset Quarry (Issaquah, King) | (1991) DOE Notice of Violation: Sunset continued to discharge contaminated process wastewater and stormwater runoff into Tibbetts Creek; has been out of compliance with SWDP conditions since 1986. 1986 order to apply for NPDES permit ignored. Condition of 1988 order to cease all discharges has not been met.<br><br>Notice of King Co. Code Violation: failure to comply with request to correct code violations detailed in (1990) order. Specified work on sediment ponds to be completed within 10 days, long-term erosion, sedimentation, and drainage control plans to be prepared by civil engineer and submitted for review. Plans for restoring disturbed portions of affected creeks to be prepared by stream/wetland ecologist and coordinated with construction/drainage plans. Further correspondence indicates provisions of notice were later partially satisfied with "conceptual drainage plan" prepared without the professional assistance specified. No record of enforcement. |
| Woodworth and Co. (Pierce Co. - asphalt plant) | (1991) Sediment analysis of catch basin (unlined overflow pond which flows to city storm drain) downhill from plant yields arsenic, copper, lead and zinc ppm measurements below Sediment Quality Objectives established by EPA.<br><br>UBAT inspection reveals intermittent overflows of washwater from settling ponds, improper storage of potentially hazardous materials (referred to in associated summary of problems related to hydrocarbon spills)<br><br>(1989) City of Tacoma Planning Dept. requests agency review of Woodworth's methods of handling waste and storm water. "Turbidity problems are occurring in the waterway at the point where the storm water outfall line serving the gravel pit and surrounding area enters the waterway". Health Dept. responds that their staff had monitored the discharge to the storm drain from the Woodworth facility and found that turbidity parameters of WA State WQ standards had been exceeded. NPDES permit should be required for this discharge but has not been obtained. |

## APPENDIX D

| Potential Groundwater Problems Associated With Gravel Mining<br>Solid Waste Disposal Incidents From WOE Files | |
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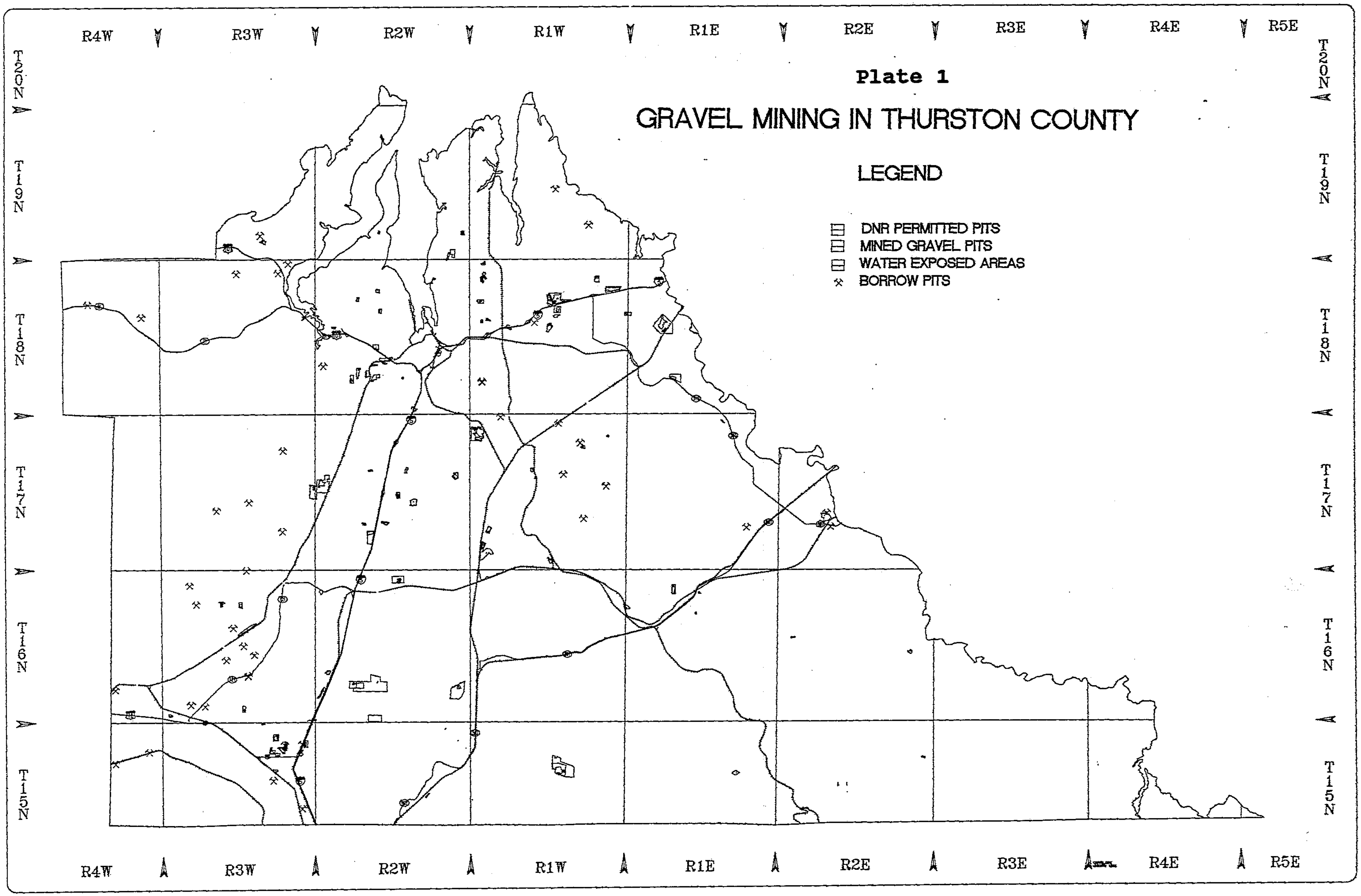
| Nonpermitted: | |
| Anderman Sand and Gravel (Mason Co.) | (1989) accepted approx. 200 cu yards of contaminated soil from Belfair Texaco station fuel tank replacement project. Removal ordered by WOE, DNR.<br><br>(1992) Mason Co. Environmental Health issues Notice of Violation: operating wood waste landfill without a permit. Also in violation of Chapter 70.95 RCW for receiving of waste tires without permit. |
| Fairview Sand and Gravel (Olympia, Thurston Co.) | (1990) dumping concrete, asphalt and rebar. Possibility that County would amend permit to include use of site for this purpose.<br><br>(1991) complaints about piles of bark stored near creek |
| Fife Sand and Gravel (Pierce Co.) | (1991) operated unpermitted Petroleum Contaminated Soil (PCS) treatment facility. Pierce Co. alleged that Fife had then expanded operations beyond restrictions in amended Unclassified Use Permit. NPDES permit to be required. |
| Lakeside Industries dba Pacific Sand and Gravel (Lacey, Thurston Co.) | Lakeside apparently operated demolition landfill 1971-1988, and for last couple of years was in violation of Solid Waste Regulations adopted in late 1985. Facility ceased operation in 1988 without regard for closure requirements of the new regulations. |
| Permitted as landfills: | |
| Dietrich Landfill (Clark Co.) | (1992) materials outside the definition of demolition (foundry ash, sheetrock, yard debris) were dumped at this former gravel mine which was classified as a demolition landfill under Solid Waste Permit. |



R4W
R3W
R2W
R1W
R1E
R2E
R3E
R4E
R5E
T20N
T19N
T18N
T17N
T16N
T15N
Plate 1
GRAVEL MINING IN THURSTON COUNTY
LEGEND
DNR PERMITTED PITS
MINED GRAVEL PITS
WATER EXPOSED AREAS
BORROW PITS