APPLIED RESEARCH
ON
SOURCE WATER PROTECTION ISSUES
IN THE
AGGREGATE INDUSTRY
PHASE I FINDINGS

Prepared for:

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This document is an internal discussion paper and as such, does not represent Ministry of Natural Resources policy.

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1.0 Executive Summary

1.1 *Overview of Study*

The Ministry of Natural Resources (MNR) issued a request for price quotation on January 18, 2006 for a study entitled "Applied Research on Source Water Protection Issues in the Aggregate Industry". The primary purpose of the proposed study was: "**to provide participants in source water protection planning with a comprehensive overview of critical applied research regarding the impacts of aggregate extraction on groundwater and surface water"**. A report released by the Province of Ontario in November 2004 entitled "*Watershed Based Source Protection: Implementation Committee Report to the Minister of the Environment*" made a series of recommendations related to specific potential issues and/or threats to drinking water sources. The Implementation Committee identified 24 specific issues that could represent a risk to a source of drinking water. The Committee made no assumptions about the prevalence of threats associated with these issues but focused on ensuring appropriate management strategies exist in the event that threats were identified in a watershed and determined to represent a risk to a source of drinking water.

Specific issues ranged from abandoned water wells or land drainage to waste disposal facilities or hazardous and liquid industrial waste. Aggregate extraction was listed as one of the specific issues. The Committee studied these issues and made recommendations on appropriate risk management tools for each issue. The Committee highlighted the following potential source water concerns related to the aggregate industry:

- Removal of material, which reduces the amount of filtering material above a groundwater source;
- Exposing the water table, allowing for easier introduction/migration of surface pollutants;
- Potential loss of water quantity as a result of existing aggregate operations (i.e. Permit to Take Water);
- Risk of importation of contaminated or deleterious fill to rehabilitate closed sites;
- Activities within an existing extraction site which may introduce potential risks to source water (i.e. asphalt recycling, on-site storage of fuel).

The research study proposed by MNR was developed to address the concerns noted by the Implementation Committee, including whether aggregate extraction and processing are compatible with the objective of source water protection. Decision makers require a sound scientific basis for making decisions with respect to aggregate operations to ensure the protection of drinking water sources and, through provincial policies, allow activities to continue that are not a concern. Given the importance of both water resources and aggregate resources, it is critical that decisions are made using all of the appropriate and available information.

The objective of the current research proposal is to assess the potential impacts on source water, from activities of the aggregate industry, through a review of documented studies of the industry as related to water quality and quantity. The current research proposal also examines how the aggregate industry and land use activities associated with the aggregate industry are controlled or regulated in the context of source water protection planning throughout the world. The overall research project is divided into three phases:

- **Phase I** – a comprehensive literature search and review and identification of future needs.
- **Phase II** – a Case History Study focussing on Ontario sites and possibly other sites in a similar environment and identification of any future research needs.
- **Phase III** – the development of Best Management Practices and Guidelines with particular emphasis in vulnerable areas as well as recommendations on water conservation practices and low water response protocols.

This report addresses the Phase I component of the research proposal as presented in the Terms of Reference. The primary tasks in this study were to document and summarize the findings of each reference as related to source water protection planning and the aggregate industry in Ontario and to identify data gaps and future research needs.

An advisory committee was established to oversee the project and to provide initial guidance in the preparation of the report. The committee includes members from the following organizations:

- Ministry of Natural Resources;
- Ministry of the Environment;
- Ministry of Northern Development and Mines;
- Association of Municipalities of Ontario;
- Ontario Stone, Sand and Gravel Association;
- Canadian Environmental Law Association; and
- Grand River Conservation Authority.

1.2 *Summary of Findings*

<u>Source Water Protection and the Aggregate Industry</u>

A literature review was conducted to assess how the aggregate industry and associated land use activities are addressed or regulated in the context of source water protection programs throughout the world. The review focused on programs in Canada, United States and Europe. The review of source water protection showed that there is a broad interpretation of what is defined as the "aggregate industry". The aggregate industry, in the context of source water protection, includes the physical extraction process and operational activities, any on-site uses such as asphalt plants, and any land use rehabilitation once the extraction is completed. Unregulated land uses were often included as part of the aggregate industry.

The following finding are highlighted with respect to source water protection controls or regulations and the aggregate industry:

- Discussion regarding the aggregate industry are typically generic and broad scale, often focusing on potential contaminants of concern rather than operational activities, particularly in the United States.

- Most of the source water protection plans that deal specifically with the aggregate industry are developed at a local planning scale such as county, municipality or even wellhead protection area and are dealt with through land use planning. From a planning perspective there is often no distinction between the aggregate extraction process, ancillary uses at an aggregate site and land use after extraction is complete.

- Many jurisdictions combine mining activities into one category, including metallic mining (e.g. gold, copper, nickel), non-metallic mining (e.g. coal, borax), and often further sub-divided into surface mining or sub-surface mining. The primary concerns are typically related to acid mine drainage, mineral processing and mine waste disposal such as mine tailings. There was limited discussion or reporting regarding concerns with the aggregate extraction process.

- The aggregate extraction industry, and mining industry in general, is typically dealt with through specific industry-related controls or environmental regulations in most jurisdictions.

- Source water protection issues, as well as aggregate regulations in other jurisdictions, must be viewed in the context of the specific setting and/or local issues. For example most aggregate extraction in the American mountain states is through in-stream mining, with very specific issues for gravel mining in rivers. In specific geographic areas of Sweden restrictions have been placed on aggregate extraction in order to maintain and utilize the water supply within the sand and gravel formations in these areas.

Many jurisdictions, from country to county, have concerns with respect to the extraction industry but in most cases the findings of studies presented do not indicate an negative impact from the aggregate extraction operation itself. The concern is more often the control of land use and land use activities during and after extraction.

Controls or best management practices (BMP's) found in the literature, that would relate to source water protection, are typically found in aggregate licensing or land use zoning controls rather than directly related to source water protection legislation. Most information pertaining to source water protection and the aggregate industry is very general at the provincial or state level. In areas where source water or wellhead protection classifies aggregate extraction the following controls or best management practices are typically recommended:

- Prohibit extraction in the immediate wellhead area (variable distance or time-of-travel from the well) due to concerns about external sources of bacterial contamination from surface runoff combined with the "loss of filtration" from the extracted material. Extraction is typically allowed elsewhere in a shallow aquifer system.

- Control or elimination of runoff from offsite into the extraction area.

- Extraction below the water table may or may not be allowed, and would typically required a detailed assessment if allowed.

- Requirement for strict security and access controls to limit access related to illegal dumping.

- Tight control, storage and use of fuels and other petroleum products.

- Treat ancillary uses separately. Ancillary uses are often not allowed within groundwater protection areas.

- Highly regulated and controlled storage, stockpiling or landfilling of inert material.

- Site planning for aggregate extraction licensing will include post-extraction land use and control of the land use.

In reviewing source water protection and wellhead protection programs throughout the world several approaches were taken with respect to controls for aggregate extraction within groundwater protection areas. Some programs, did not allow aggregate extraction within the most sensitive areas, closest to the wellhead. This is typically the area where there is a short time-of-travel, usually less than a year, from a surface source of contamination to the wellhead. The concern is the migration of microbial contamination and any land use, such as aggregate extraction, that would increase the local vulnerability within the aquifer or decrease the time of travel to the wellhead would be prohibited within these areas. In areas where there are highly vulnerable aquifers, such as Dayton, Ohio, aggregate extraction is still allowed in the groundwater protection district but are well regulated and controlled, primarily related to runoff controls and site security. Post-extraction land uses are tightly regulated.

Potential Effects/Changes to the Physical System from Aggregate Extraction

The extent of the potential impacts on the hydrogeological and hydrological system will vary for each aggregate activity and the sensitivity of the hydrogeologic and hydrologic system. The discussion of the findings is divided into five categories:

1) groundwater quantity;
2) groundwater quality;
3) surface water quantity;
4) surface water quality; and,
5) cumulative impact.

Groundwater Quantity

The physical presence of an excavation can have a variety of potential effects on the groundwater system. Some effects or changes will be minor, such as the impact of above water table extraction on groundwater flow direction and water balance. Other operations such as dewatering of a quarry, could significantly alter the local groundwater flow system if no mitigation measures were in place.

The following is highlighted with respect to the findings within the literature reviewed, as related to potential groundwater quantity impacts and aggregate extraction:

- Aggregate extraction causes limited change to the overall water balance of an aquifer system, unless large scale unmitigated dewatering occurs, and will have limited potential impact on source water protection from a groundwater quantity perspective.

- Changes in the groundwater flow system, as a result of aggregate extraction below the water table, may locally modify capture areas of a municipal well or well field in the same aquifer, depending on proximity of the aggregate operation to the municipal well or well field.

- Water table changes resulting from quarrying operations were more extensive than those for gravel pits. The impacts are more likely to occur during operational activities (i.e. quarry dewatering). In the long-term, local water level declines generally occur upgradient of a below water table extraction operation and slightly increase downgradient of the post-extraction lake.

- The existence of post-extraction lakes increases the overall groundwater storage within the aquifer where extraction has occurred.

- Various studies demonstrated that appropriate mitigation, including infiltration trenches and barrier walls, could reduce the impact of aggregate extraction on local groundwater levels.

Groundwater Quality

Groundwater quality issues associated with the aggregate industry can be divided into three areas as related to source water protection concerns:

1) operational activities such as on-site storage of fuel;

2) ancillary uses on-site, such as asphalt plants; and,

3) future land uses, site rehabilitation or uncontrolled/illegal dumping.

The following findings are highlighted:

1) Operational Activities

Available literature indicates that there are limited documented instances of water quality impacts on groundwater as a result of normal operational activities from aggregate extraction. No documented cases of contamination of a municipal water supply well were found as a result of normal aggregate operational activities.

Potential water quality issues, associated with changes to the physical system as a result of aggregate extraction include:

- A decrease in the contaminant attenuative ability when the soil layer and unsaturated zone is removed. This results in an increased potential for contaminants to enter and travel through the groundwater system from any surface source of contamination (e.g. surface runoff, future land uses). Where the aggregate extends to ground surface the loss is minimal unless there is a water supply immediately adjacent to the extraction area.

- Water quality changes downgradient of a post-extraction lake as a result of exposure of the water table to the atmosphere. These changes include changes in pH and dissolved oxygen that could impact nutrient and metal concentrations, locally down gradient of the post-extraction lake. The degree of impact is a function of the existing water quality and existing impact from surface sources of contamination

- Thermal plumes from the below water extraction and post-extraction ponds were typically very localized. Depending on the hydrogeologic setting, the impact was typically less than 200 m.

- Potential for an influx of poor quality water from deeper geologic units, in quarrying operations where lower geologic units with poor water quality are breached during extraction operations. This was not an issue in gravel pits.

2) Ancillary Uses On-site

- Existing literature does not show any documented instances of water quality impacts on drinking water supply wells from ancillary uses, such as asphalt plants.

3) Future Land Use, Site Rehabilitation or Uncontrolled Dumping

- Post-extractive use of an aggregate site, in particular infilling with non-inert material, presents a significant potential source for groundwater contamination.

- Abandoned or uncontrolled access aggregate sites have the greatest potential for generating contaminants that could be introduced to the groundwater system through historical practices of illegal dumping. Not withstanding this concern, there is limited information in the literature indicating contamination of municipal water supply systems from poor landfilling practices or illegal dumping in closed or abandoned pits and quarries.

- The risk or impacts from the loss of attenuation is directly connected to the management of the potential operational contaminants (i.e. petroleum products) and the management of adjacent stormwater runoff or post extractive application of agricultural products.

Surface Water Quantity

Surface water quantity in streams, wetlands or adjacent lakes can be altered by a change in the groundwater flow as a result of extraction and dewatering and the subsequent change in groundwater discharge; or from direct discharge of dewatering or process water. Potential changes or disruptions in groundwater flow have a much greater potential to impact ecological features, compared to impacting a drinking water supply, due to the sensitivity of aquatic features.

Findings of the literature search, related to potential surface water quantity impacts can be summarized as follows:

- The ecological functions of streams, lake and wetlands are more sensitive to the potential groundwater flow system modifications from aggregate activities compared to impacts on municipal drinking water systems. The scale of the impact is a function of many factors including, proximity to the surface water features, scale of the operation, location of the aggregate operation within the groundwater flow system (i.e. recharge are or discharge area), thickness of the aquifer and depth of the extraction operation.

- Aggregate operations typically have a limited local impact on surface water systems except potentially where unmitigated quarry dewatering occurs.

- Karstic environments may be the most sensitive hydrogeologic environment, with respect to potential impacts from quarrying where dewatering occurs, as a result of interception of conduit flow.

Surface Water Quality

In Ontario, the potential impact of aggregate extraction on surface water quality is primarily a result of direct discharge of poorer quality water to the local water courses or wetlands. The poorer quality of the discharge water could be from naturally poor groundwater quality or from water degraded through onsite processes, in particular suspended sediment or total dissolved solids.

Findings of the literature search indicated the following:

- The potential for surface water quality impacts exist, related to discharge to surface water from aggregate operations, however the noted impacts have been limited. Suspended sediment appears to be the most common impact when water from aggregate operations is discharged to a surface water course but can be easily mitigated.

- Instream mining operations have the greatest potential to impact surface water quality due to sediment loading and alteration of the stream bed. This is not permitted in many jurisdictions in Ontario.

Cumulative Impacts

One of the issues often raised with respect to aggregate extraction is the cumulative impact of aggregate extraction on a local scale. Since aggregate can only by mined where it exists, it often means that there will be more than one pit or quarry within a subwatershed or catchment area, often in areas of glacial meltwater channels or outwash deposits.

An assessment of cumulative effects would take into account the impacts on groundwater quantity and quality and surface water quantity and quality as presented discussed above and then superimpose these changes on a larger scale. The scale considered would depend on the type and sensitivity of the physiography (e.g. the geomorphic landscape and climate) in a particular area (e.g. catchment, subwatershed, watershed). The difficulty with cumulative impact assessments for something as specific as aggregate extraction is that other land use changes or natural physical changes will also be superimposed on any changes from aggregate extraction making quantification of changes attributed to aggregate extraction difficult.

Potential physical impacts include: modifications to the hydrologic cycle (e.g. changes in evapotranspiration or run off), changes in water levels and modification to the groundwater flow system and the overall water balance. There were limited studies related to cumulative impacts.

There are few studies in the literature that address cumulative impact of aggregate extraction. Case history studies that do assess cumulative impacts do not appear to show impacts to the groundwater system at a subwatershed scale although local impacts were observed on a site specific basis.

1.3 *Potential Source Water Impacts and the Aggregate Industry*

The concern with respect to aggregate extraction is usually one of a potential increased risk of impacts to water quality that could affect drinking water if the aggregate resource is also a water supply aquifer. Areas where high quality aggregate resources exist will typically be areas of higher vulnerability to contamination from any land use, whether extraction occurs or not. As a result there will typically be concerns with respect to source water protection for any land use. The issues for source water protection, as related to the aggregate industry, encompass three basic components:

- the physical impacts of the actual extraction and processing of aggregate;
- the potential impacts of aggregate extraction on the changes to aquifer vulnerability and the ability to protect source water; and,
- the potential future land use in areas where there have been potential changes to the aquifer vulnerability.

These basic components are reflected in the five concerns presented by the Source Water Protection Implementation Committee

Concern 1) Removal of material, which reduces the amount of filtering material above a groundwater source; and

Concern 2) Exposing the water table, allowing for easier introduction/migration of surface pollutants

The most unique aspect of the aggregate industry, compared to other industries is the extraction process itself where there is a removal of geologic material from the physical system. With the loss of soils and some or all of the unsaturated zone, as a result of aggregate extraction, there is increased exposure of the shallow groundwater system to contaminants from ground surface, in particular increased microbial (bacteria, viruses or pathogens) contamination. There will also be a decreased time of travel for any potential surface source of microbial contamination, from the area where aggregate extraction has occurred, to a drinking water supply if runoff from any surface source of contamination entered the extraction area..

The Technical Experts Committee (TEC) which prepared the document *Watershed-Based Source Protection Planning,* November 2004, had a pathogen subcommittee to develop a strategy to protect drinking water sources from disease-causing microbial contaminants from a public health perspective. Recommendations for source protection for municipal wells included:

- A two-year Time of Travel (TOT) pathogen zone will be delineated for all municipal drinking water wells, with land use practices monitored to prevent any additional activity that could increase the risk of pathogen contamination.

- Within the 2-year TOT, there will be a 100 metre radius prohibition zone where the most stringent restrictions on activities and practices related to pathogens sources will be applied.

The main issue, with respect to the aggregate industry, is the impact of removal of the soil zone and additional aggregate material from above the water table. Although the aggregate industry does not “generate” pathogens, some of factors that affect survival and retention time of pathogens have been altered with the removal of the soil zone and some of the unsaturated zone. The impact of this alteration will be variable. Each setting will be different, but consideration should be given to:

- the travel times from an aggregate operation to a source of drinking water;

- surface water runoff from outside areas of active aggregate extraction into an active aggregate operation or un-rehabilitated area; and,

- post-extraction land use with the potential to increase pathogen risks in areas of higher aquifer vulnerability if there are drinking water sources within a two-year Time of Travel of the extraction operation.

The issue is similar for the potential migration of hydrocarbons (e.g. gasoline, diesel fuel) if the soils zone is removed, at least temporarily, reducing the opportunity for natural biodegradation of hydrocarbons. Controls are in place to properly handle and store fuels on-site and the literature search did not indicate there were water quality issues as a result of fuel spills. Consideration should be given however, to the aquifer vulnerability of an aggregate extraction site and potential travel times to any adjacent drinking water source when siting fuel storage and re-fuelling areas.

Concern 3) Potential loss of water quantity as a result of existing aggregate operations (i.e. Permit to Take Water)

Extracting the aggregate resource does not mean that recharge function of the resource will be lost. There may be a minor modification to the flow system or water balance, but that does not necessarily mean there will be a negative impact. The actual extraction of the resource has minimal impact on the overall aquifer water balance. Certain operational approaches could impact the water balance, if not mitigated. Findings of the literature review indicated the following:

- Water quantity impacts to drinking water supplies are highly unlikely from passive (i.e. non-pumping) aggregate extraction. Impacts from quarry dewatering pose the greatest potential risk to quantity impacts for groundwater supplies, however water taking is usually well-regulated through a permitting and monitoring process and a sudden catastrophic impact, although possible, is unlikely.

- Water quantity impacts to aquatic and terrestrial features, which are much more sensitive to minor changes in flow or discharge compared to drinking water supplies, are much more likely to be impacted, depending on site-specific conditions. Detailed investigation protocols are required to develop appropriate controls, monitoring programs and mitigation alternatives. Potential impacts are more likely to occur when extraction takes place within or near groundwater discharge areas, adjacent to surface water features. Considerable legislation exists and there are many controls in place that address these concerns

Concern 4) Risk of importation of contaminated or deleterious fill to rehabilitate closed sites.

The literature search revealed that this was a major issue throughout the world. The greatest concern is water quality impacts from after use either through regulated or unregulated waste disposal or fill. Historically, old gravel pits were often used for waste disposal. Although not necessarily an aggregate activity, it is a major concern for source water protection as these areas are often classified as waste disposal sites rather than gravel pits. From a source water protection issue, the concern would be controlling illegal dumping in un-regulated sites and regulated sites with out adequate security controls. Current controls and legislation will minimize any risk of importation of contaminated or deleterious fill at sites to be closed in the future. From a source water protection issue, the concern would be controlling illegal dumping in both un-regulated sites and regulated sites without adequate security controls. This is potentially an issue anywhere but gravel pits appear to “attract” illegal dumping.

Concern 5) Activities within an existing extraction site which may introduce potential risks to source water (i.e. asphalt recycling, on-site storage of fuel).

A review of source water protection elsewhere and general discussion in the literature indicate that there are two areas of concern, with respect to potential risks at an existing aggregate operation, being regular operational activities and ancillary usage of the site. There were no documented cases or discussions of documented cases of significant water quality impacts in the literature from any form of operational activity, as related to municipal drinking water supplies. Any documents reviewed, where surveys were conducted or discussed did not indicate any major instances of contamination from normal aggregate operations.

Concerns from ancillary uses such as asphalt plants are often raised with respect to aggregate operations. Although these industrial uses are a potential risk to water quality there was little documented evidence of actual water quality impacts as a result of these activities.

1.4 *Future Research Needs/Data Gaps*

The common concern/issue regarding source water protection and the aggregate industry typically cited throughout the world is the loss of “filtering” material and/or direct exposure of the water table (from below table extraction) to potential contamination from a surface source. Since areas of aggregate extraction are typically also areas of higher aquifer vulnerability, due to the physical nature of the geologic deposit, source water protection is a concern for any land use in these areas. The removal of the active soil zone and at least a portion of the underlying unsaturated zone is relatively unique to the aggregate industry and can potentially impact the rate of movement, mobility, and degradation certain contaminants. Although this can occur to varying degrees with any land development, aggregate extraction usually takes place over a longer time, so there is an increased vulnerability for a longer time. The exposure of the water table to the surface can also affect groundwater chemistry.

The following areas of further scientific research assessments in the literature are recommended. If there is limited information available site-specific research projects may be necessary:

1) Assessment of the impact of loss of some or all of the attenuative zone within a gravel extraction site on the fate, persistence and mobility of pathogens. In particular, does this loss affect the fate, mobility and persistence of pathogens such that there is an increase the length of time of survival of certain pathogens.

2) Assess the potential impact of loss of the attenuative soil zone and unsaturated zone with respect to the migration of petroleum products. The primary water quality issue cited for operational activities related to aggregate extraction is the potential for spills of petroleum products and the greater risk of ground water contamination due to the attenuative loss of surficial soils and geologic material. A literature review of research related to the natural attenuation of hydrocarbons should be conducted, similar to the pathogen assessment.

3) Assess the potential modification of water quality of groundwater in contact with gravel pit lakes or ponds. The interaction of lake/pond water with groundwater should be assessed within wetlands/aquatic literature in the context of below water aggregate extraction to determine if there are any water quality issues of concern related to source water protection.

There is little evidence of known impacts of the operational aspects of aggregate extraction on municipal drinking water supplies or municipal aquifers. Where there are findings of an impact, there are typically other contributing factors, often sources of contamination from other land use activities. Much of the information necessary to assess the impact of aggregate extraction on groundwater and surface water will be found in case histories or regulatory files (e.g. MOE water quality interference files and MNR site license monitoring programs).

The following information should be collected in Phase II of the research study, as part of the Case History Research. Much of this information can be used to either supplement the findings of phase or provide documentation to address some of the data gaps or perceived data gaps from the Phase I investigation. The following is recommended:

1) Review MOE well interference files from regional offices to determine the extent of well interference complaints from aggregate extraction, whether interference has occurred on a municipal drinking water supply, and if so what were the factors that caused the interference. This should be divided into sand and gravel extraction and quarrying, sue to the different operational issues.

2) Review MOE water quality interference files from regional offices to determine the extent and type of quality interference complaints that have occurred related to aggregate extraction activities.

3) Obtain MNR documentation on existing pits and quarries with respect to location and type of operation and cross-reference with locations of capture zones or well head protection areas, if possible, from existing groundwater management studies in the province (e.g. How many active gravel pits and quarries are in fact within capture zones of municipal wells?). From this data, identify and review any case histories of gravel pits or quarries in Ontario that are within close proximity (e.g. 5-year capture zone) to municipal water supplies. This information will provide a “reality check” on the potential extent and magnitude of water issues and aggregate extraction.

4) Review documentation on abandoned pits and quarries, in particular locations and current land use. This could be done through the Management of Abandoned Aggregate Properties (MAAP) Program. Due to the potential scale of this investigation it is proposed that several areas should be selected for pilot projects to determine the level off effort required to conduct this study. Based on the findings, a larger scale assessment may be necessary. Pilot areas could be selected from different parts of the province to determine whether there are any existing issues with respect to abandoned pits and quarries, are they within capture zones of municipal wells, do increase the risk to water quality in water aquifers, are further investigations

or controls required? Depending on the findings, a larger scale study may be conducted.

5) Review results of monitoring programs required for site licences. Not every property will have a monitoring program however there are many sites where substantial groundwater and surface water monitoring is conducted. Annual reports are filed with MNR. However there is no apparent data base that would summarize whether there are impacts occurring, if so how they occurred, how they were mitigated etc. Alternatively there are many sites where data has been collected and show no apparent change in water level, water quality stream flow etc. It would be important capture this information as part of the case history research. This would aid in determining sites or settings that are most sensitive to specific operational conditions or not sensitive. Specific areas should be proposed for pilot studies in consultation with the committee. Areas of different geologic settings and types of aggregate operations should be selected.

6) Review and document the long-term results of aggregate applications that were contentious and the approval of the application was determined at the Ontario Municipal Board (OMB)

2.0 INTRODUCTION

2.1 *Background*

The Ministry of Natural Resources (MNR) issued a request for price quotation on January 18, 2006 for a study entitled "Applied Research on Source Water Protection Issues in the Aggregate Industry". The primary purpose of the proposed study was "**to provide participants in source water protection planning with a comprehensive overview of critical applied research regarding the impacts of aggregate extraction on groundwater and surface water"**.

The development of source water protection legislation in Ontario evolved from recommendations made by Commissioner O'Connor in the *"Report of the Walkerton Inquiry"*, Part One", released January 2002 and Part 2, released May 2002. One of the overriding themes was to develop a watershed-based approach to source water protection in Ontario. In February 2004 the provincial government released a document entitled "*White Paper on Watershed-based Source Protection Planning*". The White Paper was produced for discussion and comment to refine Ontario's policy and legislative framework for source protection planning. The Province also established a Technical Experts Committee and an Implementation Committee to provide advice on, among other things, a process for assessing threats to sources of drinking water in Ontario and best management practices to protect watersheds.

In December 2005, the Clean Water Act, 2005 was introduced in the Ontario Legislature. The Act has not received Royal Assent yet parliament. A key focus of the legislation is the production of locally-developed, science-based Assessment Reports characterizing individual watersheds and assessing potential drinking water threats. Eventually Source Protection Plans will be developed for watersheds in Ontario, under the jurisdiction of Conservation Authorities.

A report released by the Province in November 2004 entitled "*Watershed Based Source Protection: Implementation Committee Report to the Minister of the Environment*" made a series of recommendations related to specific potential issues and/or threats to drinking water sources. The list of issues examined by the Committee was based largely on the experience and expertise of staff from various municipalities, conservation authorities and the Ministry of the Environment providing input to the Committee. The Committee made no assumption about the prevalence of these threats but focused on ensuring that appropriate management strategies exist in the event that such threats were identified in a watershed and determined to represent a risk to a source of drinking water. The issues examined by the Committee could represent a risk to a source of drinking water in a number of ways such as an activity could produce pollutants that could contaminate drinking water, create a pathway for contamination to reach a source of drinking water or have an adverse effect on water quantity.

The Committee identified “aggregate extraction” as one of the 25 specific issues studied. The Committee indicated the following in Section 5.5 of their report, as related to aggregate extraction:

The potential source water concerns that would be assessed in the source protection planning process include:

- *Removal of material, which reduces the amount of filtering material above a groundwater source;*
- *Exposing the water table, allowing for easier introduction/migration of surface pollutants;*
- *Potential loss of water quantity as a result of existing aggregate operations (i.e. Permit to Take Water);*
- *Risk of importation of contaminated or deleterious fill to rehabilitate closed sites;*
- *Activities within an existing extraction site which may introduce potential risks to source water (i.e. asphalt recycling, on-site storage of fuel).*

The potential concerns listed by the Committee, include more than “aggregate extraction” concerns as they more broadly reflect all aspects of the aggregate industry and land use issues associated aggregate sites. A major concern is the number of abandoned aggregate sites on private land. The research proposal developed by the MNR is designed to address these concerns.

2.2 *Terms of Reference*

There are widely varying opinions and perceptions about the impacts of the aggregate industry on water, from both a water quality and quantity perspective. The type and magnitude of impact varies depending on the type of extraction (i.e. sand and gravel or rock quarrying, above or below water table extraction and dry or wet extraction), the geologic setting, future regulated or unregulated land use.

The proposed research needs to address the concerns noted by the Implementation Committee (see Section 2.1), including whether aggregate extraction and processing are compatible with the objective of source water protection. Decision makers require a sound scientific basis for making decisions with respect to aggregate operations to ensure the protection of drinking water source and allow activities to continue that are not a threat. Given the importance of both the water resource and aggregate resource, it is critical that decisions are made using all of the appropriate and available information.

The objective of the current research proposal is to assess the potential impacts on source water, from activities of the aggregate industry, through a review of documented investigations of the industry as related to water quality and quantity. The current research proposal also examines how the aggregate industry is controlled or regulated within source water protection planning throughout the world. The overall research project is divided into three phases:

- **Phase I** – a comprehensive literature search and review and identification of future needs.
- **Phase II** – a Case History Study focusing on Ontario sites and possibly other sites in a similar environment and identification of any future research needs.
- **Phase III** – the development of Best Management Practices and Guidelines with particular emphasis in vulnerable areas as well as recommendations on water conservation practices and low water response protocols.

This report addresses the Phase I component of the research proposal as presented in the Terms of Reference, as described below.

<u>Phase I Component – Literature Research</u>

As indicated above, Phase I is divided into the literature research component and identifying future needs component.

The following is a list of literature research sub-components presented in the request for proposal.

1) *Source water, well head and water intake protection programs in other jurisdictions within Canada, the United States, and globally and how aggregate extraction/ processing is classified/addressed*.

2) *Documented instances of water contamination or interference from Ontario and pertinent global aggregate operations. This review would include impacts on surface water bodies (wetlands, lakes, rivers etc) regardless if they are potable supplies or not.*

3) *Document and evaluate activities within the extraction site that may introduce potential risk to source water (e.g. asphalt recycling, on-site fuel storage*).

4) *Previous studies of water quality and quantity in Ontario pit and quarry operations (e.g. MISA, Water Resources Studies prepared by the Ministry of the Environment).*

5) *Previously documented relevant geological scenarios (e.g. karst) and how these geological environments have influenced aggregate operations and their impacts*.

Although described as part of Phase I work a number of these sub-components overlap with Phase II, as related to case histories. In particular Points 2) and 4) deal primarily with case histories and are not the focus of this phase of work, although a number of case histories were found within "open" literature.

Phase I Component – Identify Future Needs

An important component of the Phase I work is to identify future research needs. This is to be determined based on the findings of the literature review assessment, as related to source water protection issues. Future research needs and data gaps are to be identified, and incorporated into Phase II work.

3.0 Approach to the study

3.1 *Literature Review*

A literature search was conducted using two approaches. The first approach was to conduct a formal technical literature search through University library services, including but not limited to the following:

- Web of Science
- Applied Science Abstracts
- ASCE Research Library
- GPO Access (U.S. Government Publications)
- Analytical Web Base
- Science Citation Index
- Mining Environment Database
- Environment Management of Pollution Sciences

The second approach to the literature search was through general internet web searches from internet search engines. This typically provided extensive regulatory (i.e. federal, provincial and state agencies) industry publications and less frequently conference proceedings. The search also often provided information from contentious issues such as mine or quarry proposals where there was considerable opposition.

The type of information found in the literature search could be divided into five categories:

1) Refereed scientific publications or research papers specifically related to aggregate extraction.

2) Research or investigative publications including government agencies such as the US Geological Survey, State of Minnesota Department of Natural Resources, Environment Canada.

3) Scientific publications not directly related to aggregate extraction and source water protection but contain technical information relevant to the types of impacts that could occur through aggregate extraction. These documents were not the focus of the search, but were reviewed when found.

4) Information of interest found in references that aid in understanding issues related to aggregate extraction and source water protection, which could include case histories, unpublished reports and legal or environmental assessments.

5) Source water protection, water management, or land use controls as related to source water protection planning or aggregate extraction controls.

A publications reference list is presented in Appendix A.

3.2 *Presentation of Findings*

The primary task in this study was to document and summarize the findings of each reference and the relevance to source water protection planning and the aggregate industry in Ontario.

A major component of the literature review was obtaining and reviewing documentation regarding controls for the aggregate industry, within the context of source water protection and planning, in other jurisdictions throughout Canada, United States and other parts of the world. In order to develop and implement possible controls or requirements for aggregate extraction, as related to source water protection planning, an understanding of existing legislation in Ontario is also necessary. As well, the applicability of the controls for the aggregate industry in the context of source water protection planning needs to be understood. Information is presented from other jurisdictions related to controls on aggregate extraction. Section 5 presents an overview of the aggregate industry and source water protection.

The extent of the potential impacts on the hydrogeological and hydrological system will vary for each related aggregate activity and the sensitivity of the hydrogeologic and hydrologic system. After reviewing the technical literature and the typical concerns or issues presented for source water protection planning, as related to the aggregate industry, the discussion of the findings was simplified into five categories, as presented in Section 3.3. The major categories were:

1) groundwater quantity;

2) groundwater quality;

3) surface water quantity;

4) surface water quality; and,

5) cumulative impact.

All changes or modifications to the physical system for each of the first four categories are typically captured on a site-specific basis (e.g.. if a spill were to occur at an aggregate operation it would be assessed on a site-specific basis). The cumulative impact category was added to address the broader issue of the potential impact of combining a number of aggregate operations together in one area. As indicated above, the impact these changes or modifications have on source water will depend on many factors. These factors are discussed for each category in Section 6 with respect to the potential extent of impact and risk as related to source water protection planning.

A summary each technical document, publication or report reviewed is presented in Appendix C. A summary sheet was developed to attempt to maintain some consistency in the review and capture the necessary information. Information such as the document title and author is included along with the agency or organization, how the document was located and a general ranking of the document. The technical summary includes type of study, activity definition, hydrogeologic/hydrologic setting, summary of findings, factors to consider and relevance to Ontario.

4.0 Overview of the Literature Search Findings

The literature search within scientifically based/refereed journals did not find publications directly relating aggregate extraction and source water protection. Various publications were found which documented, to a limited extent, the impacts of gravel extraction or gravel pits on wells within the immediate area of the extraction sites. The majority of the publications considered to have some relevance to the issue of aggregate extraction and source water protection presented impacts of aggregate extraction, primarily gravel pits, on local groundwater water quality and local groundwater flow. Most of these publications did not deal directly with the physical impact of aggregate extraction but dealt with post aggregate extraction land use, both regulated and unregulated.

Publications dealing with quarries primarily examined potential impacts and modification to the groundwater flow system as a result of dewatering within quarry settings. A number of publications investigated the changes to local the groundwater flow system as a result of below water table extraction.

It is noted that authors of a number of publications reviewed for this study also carried out literature reviews related to their research. They indicated that very little formal work regarding aggregate extraction and potential hydrological impacts has in fact been reported in scientific journals. For example, Gandy et al, 2004 (**Reference #11**) in a paper entitled "*The Hydrogeological Behaviour of Flooded Sand and Gravel Pits and its Implications for the Functioning of the Enclosing Aquifers*" stated the following:

> "*The axes of many of England's major valleys host a large number of abandoned former sand-and-gravel operations, which invariably flooded up to the local water table level, suggesting the existence of hydraulic connectivity with the enclosing aquifers. Although they are widely appreciated as recreation amenities, for e.g. fishing and water sports, very little work has been carried out on the water resources implications of the presence of large pit lakes. A literature review has revealed that the only paper in the open literature which deals specifically with the hydrological effects of sand and gravel extraction is that of Morgan-Jones at el (1984) (**Reference #19**), which is now 20 years old*."

A recent Master of Science thesis by Guenther (2003) (**Reference #39**) entitled "*Development of Aquatic Communities in Aggregate Ponds in Southern Ontario*" examined the ecology and water quality of differing sizes of ponds in gravel pits and quarries. Guenther's review of literature stated the following:

"*Much of the literature available regarding aggregate ponds is published as gray literature such as guides, reports and non peer-reviewed documents. Primary literature for this field of study is limited*."

The majority of publications in the literature were related to operational activities that are not typically common in Ontario. A substantial number of publications exist relating to gravel extraction, or gravel mining as it is commonly referred, directly from streams and rivers. In particular, this was noted within the U.S. mountain states, and coastal marine extraction in areas such as Washington State (**Reference #29**) and coastal northern European countries. These areas are typically the only areas where sand and gravel is present within the specific jurisdiction. Not all of the available publications in this area were collected and reviewed, a sufficient number of appropriate publications were collected, that provide a good overview, for issues of relevance to Ontario. Areas in Ontario where extraction is allowed within rivers or lakes are extremely limited.

Conducting a literature search for source water protection, as related to aggregate extraction, proved to be more complex than the scientific literature review. Much of the information related to source water protection is generic in nature. For example the United States Environmental Protection Agency (USEPA) has a major website devoted to source water protection (see Appendix A). It provides an overview of source water protection in the United States. The site also provides links to all of the source water protection programs and wellhead protection programs for individual states. Much of the information again was generic, often with reference back to the USEPA. European literature was similar, in that there are major directives from the European Union (EU) guiding member countries with respect to water management and protection. As discussed in Section 5, many of the controls associated with source water protection and the aggregate industry are either applied within the industry or are implemented at a local zoning scale. As a result, the literature search for good relevant information was more of an exercise in "tracking down" specific programs referenced throughout the literature. As more of these documents were compiled, it became evident that there were many similarities with respect to issues and how the issues are addressed.

An issue that arose while conducting the literature search was how to "capture" information, findings, observations etc. from the literature that was not necessarily "scientifically defensible" (i.e. peer reviewed or published in a refereed journal) but would still aid in understanding the potential impacts of aggregate extraction. As will be discussed later, it is likely that the most meaningful information will be information obtained from case history studies and their applicability to various geologic settings, or types of extractive operations in Ontario.

5.0 Source Water Protection and the Aggregate Industry

5.1 *Overview*

A literature review was conducted to assess how the aggregate industry is addressed or regulated in source water protection programs throughout the world. As part of this study a request was made to the MOE with respect to the background information that was collected for the provincial Source Water Protection program. A comprehensive review was not conducted for source water protection programs throughout North America. Many of the programs were similar in nature on a broad generic scale. Specific issues, such as the aggregate industry were not examined. The current study did find that much of the information available for higher level jurisdictions, such as provinces or states, is generally generic in nature.

The present review is comprehensive, however it must be recognized that this is an active evolving regulatory area and it is difficult to obtain a "snapshot" of current practices for all jurisdictions. Source water protection is regulated at levels ranging from country to municipality. It became evident during the literature search that it would be difficult to obtain all the source water protection plans as most are in fact developed at a local planning scale. A knowledge of the aggregate industry regulations and/or environmental legislation will often be necessary to understand the rationale for a specific approach to source water protection for each jurisdiction as the industry may be regulated through other controls or legislation.

The following is noted with respect to source water protection controls or regulations and the aggregate industry, as determined during the literature search:

- Discussions regarding the aggregate industry are typically generic and broad scale, often focusing on potential contaminants of concern rather than operational activities, particularly in the United States.

- Most of the source water protection plans that deal specifically with the aggregate industry are developed at a local planning scale such as county, municipality or even wellhead protection area and are dealt with through land use planning. From a planning perspective there is often no distinction between the aggregate extraction process, ancillary uses at an aggregate site and land use after extraction is complete.

- Many jurisdictions combine mining activities into one category, including metallic mining (e.g. gold, copper, nickel), non-metallic mining (e.g. coal, borax), and often further sub-divided into surface mining or sub-surface mining. The primary concerns were typically related to acid mine drainage, mineral processing and mine waste disposal such as mine tailings. There was limited discussion regarding concerns with the aggregate extraction process.

- The aggregate extraction industry, and mining industry in general, is typically dealt with through specific industry-related controls or environmental regulations in most jurisdictions.

- Source water protection issues, as well as aggregate regulations in other jurisdictions must be viewed in the context of the setting or local issues. For example most aggregate extraction in the American mountain states is through in-stream mining, with very specific issues for gravel mining in rivers. Another example is Sweden where restrictions have been placed on aggregate extraction in specific geographic areas to maintain and protect the water supply, limited to sand and gravel formations in these areas.

It became evident in the literature search that there were similar issues with respect to how the aggregate industry is viewed and how it is regulated or controlled as related to drinking water protection and environmental impacts. Many jurisdictions, from country to county, have concerns with respect to the extraction industry but in most cases the findings of studies presented do not indicate an actual negative impact from the aggregate extraction operation itself. The concern was more often the control of land use during and after extraction.

The following excerpt, although only related to sand and gravel extraction, summarizes the essence of concerns typically found in the literature. These concerns are similar to the Implementation Committee's issues presented in Section 2.1. The following is an introduction from a proposed groundwater management program for Kitsap County, Washington State (1997) (**Reference SW7**) entitled "*Issue Paper: Sand and Gravel Mining*":

> *"This issue paper examines contamination of ground water through sand and gravel mining operations. The goal is to ensure that regulatory programs are adequate to prevent adverse effects from sand and gravel mining operations upon ground water quality.*
>
> *Sand and gravel operations do have the potential to adversely impact ground water quality, both as a result of the extraction process and in site reclamation. However, sand and gravel mining is also an important economic resource as well as a necessary resource for transportation and development purposes. Unfortunately, some of the characteristics that make sand and gravel resources valuable, also make them very good aquifer and/or recharge materials.*
>
> *Sand and gravel mining within an aquifer recharge area will, at a minimum, increase the vulnerability of an aquifer to be contaminated because it decreases the distance between the*

ground water table and land surface. In some cases, the excavation actually penetrates the shallow aquifers, creating a pond or lake and a direct access to ground water.

The primary effluent discharged at a sand and gravel mine operation is turbid rinse water. Generally, operators are required to collect waste water on-site in retention and settling ponds where the fine sediment settles out. The collected water is then allowed to infiltrate back to the water table. Often the excavation pit is a component of the treatment system. High concentrations of suspended solids in the wash water does not pose a serious groundwater problem since sediment is unable to migrate beyond the immediate infiltration site. Even though the turbid wash water at a gravel mine is not a significant ground water pollutant, the excavation pit and the continual collection and infiltration of wash water does raise the potential for other sources of contaminant to migrate to the aquifer. Hydrologic susceptibility is increased at the pit site when saturated or near saturated conditions exist under the pit. Any chemical contaminants that are allowed to enter the pit via wash water or spills in the area would have quicker access to the aquifer. Once in the ground water, a chemical substance would be free to move with the water in the aquifer. Possible contaminants found at a mining site include lubricants and fuels. These materials may be stored on-site or may enter the excavation pit from contaminated road and work area runoff.

Beyond the risks associated with active mining, one of the largest threats to ground water appears to be the excavation pit itself. Reclamation of a site may include refilling a pit as well as slope and drainage stabilization. Within the recharge areas of a vulnerable aquifer, the decision to fill or not fill an excavation is one of the most critical with regards to water quality. Excavation pits have been used both legally and illegally as dump sites for a variety of wastes. In the past, little care has been given to the classification of the material used as fill. Many community landfills have been developed in "reclaimed" gravel pits. Industries have used excavation pits as disposal sites for mixed wastes. Over the years it has not been uncommon to find pits used as "dumps" for a variety of potentially hazardous fill materials. In many cases, materials historically used to fill pits would today be classified as a dangerous waste, not inert material (Ch. 173-303 WAC).

Future land use is an important factor to consider in reclamation of a site. The increased vulnerability of underlying aquifers to contamination should be factored into any land use permitting decisions. Additional controls to be established under the Growth Management Act should address sand and gravel mining and reclamation operations which overlie aquifer recharge areas.

The exact number of sand and gravel operations (existing and old) in Kitsap County is not known with certainty. However, the State Department of Natural Resources (DNR), which has permitting authority over all sand and gravel mining operations of greater than three *acres, has identified 43 existing, closed, or potential sites (29 active; 10 terminated; 2 pending applications; and 2 cancelled).*

Notwithstanding the potential for ground water contamination from sand and gravel mining, there have been few, if any, documented incidents in Kitsap County. This may indicate that existing controls (and operations) are adequate to generally protect groundwater, or it may only mean that monitoring is lacking, so problems go undetected."

The above excerpt illustrates many of the perceptions related to what constitutes the "aggregate industry", and is generally echoed in the Implementation Committee Report. The aggregate industry, in the context of source water protection is interpreted to encompass:

- the physical extraction process;
- the potential for contamination from the on-site extraction activities;
- the potential for contaminated runoff within the excavation to infiltrate to the underlying aquifer;
- the loss of "filtration" by the material excavated or the direct exposure to the water table;
- illegal or uncontrolled after-use activities;
- historical land use activities in former pits;
- Future land use activities

Many of these activities are addressed through controls or regulations unrelated to the current source water protection initiative, but are important in protecting source water. The following section highlights some of the applicable legislation in Ontario to put the issue of source water protection and aggregate extraction in the context of existing controls or regulations.

5.2 *Legislation Applicable to the Aggregate Industry in Ontario*

Decision makers need the appropriate information for making decisions with respect to aggregate operations and water related issues which ensures the protection of Ontario's drinking water sources. Knowledge of the existing legislation or regulations, as related to the aggregate industry, is a necessary part of the information needed to make decisions. Although it is beyond the scope of this study to provide full documentation of appropriate relevant and applicable legislation and controls it is important to understand what type of controls and regulations exist that currently provide source water protection through the management and protection of groundwater and surface water. With this understanding and an understanding of potential impacts or increased risks that are related to aggregate industry appropriate source water protection planning decisions can be made.

The following is a brief summary of legislation that governs aggregate extraction and the impacts of aggregate extraction in Ontario. It is not meant to be all-inclusive but is meant as an overview to aid in understanding of where source water protection legislation may fit in the overall regulatory framework.

The aggregate industry in Ontario is regulated by the Ministry of Natural Resources (MNR) through the Aggregate Resources Act (ARA). The main purposes of the ARA are:

1) to provide for the management of the aggregate resources of Ontario;

2) to control and regulate aggregate operations on Crown and private lands;

3) to require the rehabilitation of land from which aggregate has been excavated; and,

4) to minimize the adverse impact on the environment in respect of aggregate operations.

The ARA requires that an aggregate operator must obtain a licence or permit to operate a pit or quarry. Licence or wayside permit is required to operate a pit or quarry on private land designated under the ARA. At present, private lands in most of southern Ontario are designated under the ARA; the only private lands currently designated in northern Ontario are in the Sudbury, Wawa and Sault St. Marie areas. Private land within non-designated areas of the province are not regulated by the ARA. An aggregate permit is required to operate a pit or quarry on Crown land.

There are two types of licences: a Class A licence is required to remove more than 20,000 tonnes per year from a pit or quarry; and a Class B licence is required to remove less than 20,000 tonnes per year.

The *Aggregate Resources of Ontario Provincial Standards, Version1 (AROPS)* establishes a set of standard criteria that aggregate applications and operations on Crown land and private land designated by regulation must conform. Fifteen categories of application are outlined within the AROPS and reflect various types of undertakings (pit/quarry, above water table/below water table extraction, underwater extraction, Class A/B, Crown land/private land). Categories 1-8 for are for licences, 9-13 are for aggregate permits, 14 is a forest industry exemption and 15 is a wayside permit. Each category of application includes site plan standards, report standards, prescribed conditions, and notification and consultation standards, In addition, there are operational and compliance assessment standards common to the type of instrument (licence, wayside permit or aggregate permit).

Licence and permit applications proposing to extract aggregate material from within or near the water table (i.e. pit within 1.5 metres or quarry within 2 metres), require a hydrogeological report prepared by a qualified individual in support of the application.

The "*qualified*" individual must be a registered "*Professional Geoscientist"* as defined under the *Professional Geoscientists Act* who is qualified to prepare hydrogeological reports or an individual who is licensed as a "*Professional Engineer*" under the *Professional Engineers Act* and who is competent by virtue of training and experience, to engage in practices that would also constitute the practice of professional geosciences (i.e. hydrogeology).

There are two levels of investigations. A Level 1 hydrogeological report is a preliminary hydrogeological evaluation to assess the water table elevation and determine the potential for adverse impacts to groundwater and surface water resources. A Level 2 report is conducted where results have identified the potential for adverse impacts on groundwater and surface water resources. An impact assessment is required and proposed mitigation options are assessed.

For applications proposing to extract above the water table, a hydrogeological report is not required. However, a determination of the water table by a qualified individual must be included in the summary statement supporting the application.

Any operations that require pumping must obtain a Permit to Take Water. Discharge Permits are typically required for dewatering, usually through a Certificate of Approval from the Ministry of the Environment.

The Planning Act also governs aggregate extraction through regulating development and land use planning and the policies of the *Provincial Policy Statement (PPS*). The PPS, revised in 2005, was issued under Section 3 of the Planning Act and is intended to provide policy direction on matters of provincial interest related to development and land use planning. The mineral aggregate component of the PPS includes the following:

- aggregates will be protected for long term use;
- aggregates should be made available as close to the markets as is realistically possible;
- existing operations shall be protected from incompatible activities and land uses;

- in areas adjacent or within known aggregate deposits, development which would preclude or hinder the operation will only be permitted if the resource is not feasible or the proposed development serves a greater long-term public interest and issues of public health, safety and environmental impact are addressed;

- progressive rehabilitation of aggregate operations is required;

- aggregate operations on prime agricultural land are permitted as an interim use provided site rehabilitation restores the site to the same average soil quality for agriculture; and,

- exceptions to rehabilitation on prime agricultural land are possible if there is a substantial quantity of aggregate below the water table, other alternatives have been considered and are suitable and agricultural rehabilitation in remaining areas are maximized.

Approvals/requirements may also apply under other legislation, as related to source water protection, depending on potential issues or concerns. These include but are not limited to the following:

- Ontario Water Resources Act (OWRA)

- Environmental Protection Act

- Environmental Assessment Act

- Federal Fisheries Act

- Planning Act

- Municipal Act

- Lakes and River Improvement Act

- Liquid Fuels Handling Code under the TSSA

- Conservation Authorities Act

- Greenbelt Act

- Oak Ridges Moraine Act

- Clean Water Act, 2005

Issues that are addressed in these acts include, but are not limited to the following:

- permits to take water, if pumping occurs,
- storm water management plans,
- sediment control plans,
- well interference,
- water quality interference,
- impacts on aquatic systems,
- discharge to surface water, and,
- source protection plans.

Any aggregate operations that require significant pumping may require, under the OWRA, a Permit to Take Water (>50, 000 Litres per day) and for discharge, a Sewage Discharge Permit, usually through a Certificate of Approval from the Ministry of the Environment.

5.3 *Source Water Protection – Canadian Examples*

Source water protection and the approach to source water protection has been evolving globally over the last fifteen years. Ontario has been developing a framework for source water protection over the last three years, as discussed in Section 2.1. Other jurisdictions in Canada have developed or are developing source water protection programs. The following section summarizes a number of the Canadian examples, at the provincial level and at the County, Township or municipal level. Not all municipal source water protection programs are included in this review. The literature search typically found the programs that are on websites and are a higher "profile". It was the finding of this study that most of the "higher profile" programs are typically more comprehensive than the "hard to find" programs, by the nature of the issues and level of effort required to develop programs.

Most provinces have water protection or water management plans in place. There is typically limited information in the provincial plans related to source water protection and aggregate extraction or overall mining/mineral extraction. The following section summarizes the findings and level of detail at the provincial level as well as provides several examples of source water protection, as related to the aggregate industry, at the local level. A more detailed presentation of the individual programs are presented in Appendix B.

5.3.1 Summary of Provincial Examples

Nova Scotia - A document prepared by the Nova Scotia Department of Environment and Labour entitled "*Developing a Municipal Source Water Protection Plan: A Guide for Water Utilities and Municipalities*" (**Reference SW20**) presented five risk categories for land uses related to potential contaminants. On a scale from the lowest risk (1) to the highest risk (5), "quarries" were included in Category 4. To put this into perspective, Category 4 also included, "agricultural production: dairy, livestock, nurseries, orchards; golf courses; and high density housing: lots smaller than 0.5 acre".

Saskatchewan – A Saskatchewan Environment document entitled "*Wellhead Protection*" (**Reference SW28**), dated September 2004. Lists potential sources of contamination in the document. No specific references were made to aggregate operations other than a potential source of contaminants was "unattended wet and dry excavation sites". Asphalt plants were listed, indicating petroleum derivatives as the contaminant.

Newfoundland – The Newfoundland Department of Environment and Conservation (DEC) released a document in March 2004 (**Reference SW31**) entitled "*Management of Protected Water Supply Areas*". Many of Newfoundland's public water supplies are surface water supplies. Protected water supply areas are developed under the Water Resources Act, through applications to the DEC. Existing resource development activities, such as aggregate extraction, may be permitted to continue in areas designated as Water Supply Protection Areas if these activities do not impair water quality.

New Brunswick - NewBrunswick has divided its protection programs into watershed and wellhead protection areas as there is considerable surface water supply usage within several major watersheds. An overview of wellhead protection areas is presented in a document (**Reference SW34**) entitled "*Protecting Sources of Municipal Drinking Water: An overview of New Brunswick Well Field Protection Programs*" dated March 2005. An overview to protection of watersheds is presented in a document (**Reference SW33**) entitled "*A Guide to New Brunswick's Watershed Protected Area Designation Order*".

Watershed protected areas have three distinct zones, the water course itself (Area A), a 75-m setback zone (Area B) and the remainder of the watershed's drainage area (Area C). No activities are permitted as related to aggregate extraction in areas A and B. Aggregate extraction is permitted outside the 75-m area, but the only process allowed within the designated watershed protection area is crushing.

Wellhead protection areas are also divided into three zones, primarily based on time of travel of the groundwater. Zone A is the closest zone to the well and all forms of contamination are a concern, but pathogens are a significant concern due to the short travel time to the wellhead. Zone B is still a concern for solvents, pesticides etc, while zone C is the remainder of a well capture area. There appears to be no restrictions specifically related to aggregate extraction in any zone within a wellhead protection area, other than typical restrictions related to impairment of water quality or water use as part of other environmental legislation. There are specific requirements for environmental impact assessments for mining or mineral extraction, similar to the type of requirements in Ontario.

British Columbia – British Columbia appears to have focused on drinking water protection rather than source water protection. The *Drinking Water Protection* act was passed in April 2001. In 2003 the *Drinking Water Protection Regulation* was passed and in 2005 the *Groundwater Protection Regulation* was passed. Much of the focus of these acts was related to proper drilling and installation of wells, licensing of drillers, water operators etc. and development of wellhead protection zones. There was little discussion with respect to threats assessment or contaminant sources inventories. Aggregate extraction, in the context of source water protection is controlled through the Ministry of Water Land and Air Protection. A document (**Reference SW39**) entitled "*Environmental Objectives and Best Management Practices for Aggregate Extraction*" addresses aggregate extraction as related to source water protection through controls related to:

- water supply assessment, related to drinking water and fish habitat;
- nitrate and blasting residue from explosives;
- hydrogeologic impact study for any water diversion or pumping;
- fuel handling and spill containment; and,
- site rehabilitation or site reclamation plans.

5.3.2 Local Case History Examples - Canada

Most of the relevant examples, providing details with respect to specific land use controls or issues are at the local planning scale. The following Canadian examples are presented to provide a perspective on the issue of source water protection and aggregate extraction.

Newfoundland Case History - Town of Steady Brook, Steady Brook Watershed Management Plan (**Reference SW30**)

The Town of Steady Brook developed a Watershed Management Plan, that was to act a template for other watershed management plans in Newfoundland, completed in September 2005. Drinking water is obtained from a surface water source. A management plan was developed through identification of risks and potential threats to the water supply and the watershed area contributing to the water supply.

Mining, including quarrying, was identified as a potential risk to water supply, due to risk of fuel spills and the contribution of sediment and nutrients to the water supply. The priority ranking for potential threats to water quality listed quarrying/mining as a medium risk for petroleum products, a high risk for sediments and a low risk for nutrients.

Region of Waterloo , Ontario

The Region of Waterloo initiated a Water Resource Protection Strategy in 1994 to minimize the impact of land use on municipal water supplies. The Region of Waterloo probably has conducted the most extensive source water protection documentation, related to aggregate extraction, of any documentation reviewed. A study was completed in 2004 as part of a Provincial Water Protection Fund Project, entitled "*Assessment of Aggregate Resources and Groundwater Protection – Background Report No. 2 – Final*" (**Reference SW8**). Companion documents include a draft report entitled "*Development Principles for Aggregate Policies for Water Supply Protection*" (**Reference SW8a**), "*Aggregate Policies and Study Guidelines for Water Supply Protection*" (**Reference SW8b**) and appendices including a "*Draft Guidelines for Hydrogeological studies for Proposed Mineral Aggregate Resource Extraction Project*s" (**Reference SW8c**). These documents were reviewed and contained substantial background information similar to the source water protection review conducted for this study.

Companion work conducted by the Region included a pilot modelling project (**Reference #27**) assessing individual impacts and cumulative impacts of aggregate extraction in a watershed within the Region of Waterloo, undergoing aggregate extraction pressures. This study is discussed in more detail in Section 6.

The draft guideline for hydrogeological studies follows a similar format to studies required under the ARA described in the previous section. The following highlights some of the policy developed for the Region of Waterloo (**Reference SW8b**):

> "The development of policies and guidelines to assess the impact of aggregate extraction activities on drinking water source areas recognizes that the majority of issues associated with

aggregate extraction (a list of potential impacts is provided in Table 1) will be unique to the individual extraction pit. For example, potential impacts to private wells will depend on several factors including the distance from the pit to the well and the geologic setting. Because of this localized impact, the approach to developing groundwater protection protocols for aggregate extraction (outside of very sensitive groundwater protection areas) will focus on ensuring that sufficient studies are undertaken to support the change in land use being requested. This approach will build on the hydrogeologic study guidelines accompanying the Aggregate Resources Act. In addition, the following guiding principles were used to develop these policies and guidelines.

- The closer an aggregate operation is to a municipal water supply, the greater the chances of impact to that supply.

- The potential for cumulative impacts to water resources increases as the number of aggregate operations within a geographic area increases.

It is proposed that new aggregate operations should not be allowed in Well Head Protection Sensitivity Areas (WPSA) 1 and 2; and any existing operations within Sensitivity Areas 1 and 2 will be encouraged to adopt beneficial management practices (BMPs).

These areas represent the most sensitive land area contributing water to the supply. Sensitivity 1 areas reflect the shortest travel time to the wells (two year time of travel), are delineated around supply wells that are more vulnerable to contamination and are critical to Region's water supply infrastructure. For some wells, Sensitivity 1 areas also represents the areas where the MOE is requiring the Region develop microbial protection plans to ensure that microbial contamination of the wells does not occur and that land activities do not disturb the natural filtration capacity of the soil around the wells. These wells, which draw groundwater under the direct influence of surface water, are considered by the MOE to be the most vulnerable type of municipal supply well. Sensitivity 2 areas surround Sensitivity 1 areas and represent slightly less vulnerable areas due to the greater time of travel to the well (ten years) or delineate the area immediately surrounding the well (two year time of travel) for deeper, less vulnerable supply wells. New aggregate operations that are to be located outside of Sensitivity Areas 1 and 2 should complete a hydrogeological study to determine if the operations can proceed or if there are any site-specific limitations, management or monitoring required as part of the development approval. The studies should be undertaken using a staged approach similar to hydrogeological investigations proposed in the AROPS."

5.4 *Source Water Protection – United States Examples*

The United States Environmental Protection Agency (USEPA) is the lead agency on source water protection in the United States. They developed a source water protection guidance program requiring each state to follow the guidance program and develop state wide source protection programs and wellhead protection programs (**Reference SW35A**). State source water assessments were required including among other things a threats assessment, related to drinking water sources. The USEPA provides a "Potential sources of Drinking Water Contamination Index" (**Reference SW35**). The list is intended as resource guide for creating an inventory list for potential source of contaminants and the type of contaminant potentially generated from each source. Potential contaminants listed by the USEPA are very extensive. The following sources are listed, which are relevant to the aggregate industry:

POTENTIAL SOURCE	CONTAMINANT
Commercial / Industrial	
Cement/Concrete Plants	Barium, Benzene, Dichloromethane or Methylene Chloride, Ethylbenzene, Lead, Styrene, Tetrachloroethylene or Perchlorethylene (Perc), Toluene, Xylene (Mixed Isomers)
Mines/Gravel Pits	Lead, Selenium, Sulfate, Tetrachloroethylene or Perchlorethylene (Perc), 1,1,1-Trichloroethane or Methyl Chloroform, Turbidity

As with many programs mines, including metal and industrial minerals are combined with gravel pits. No distinction is made for any form of mineral extraction. The listing of contaminants of concern must be put into perspective with other potential sources. For example, public buildings and retail operations have more potential contaminants listed. Almost every potential source of contaminant from retail operations to machine shops and home manufacturing and virtually any commercial or industrial source lists tetrachloroethylene 1,1,1-trichloroethane and methyl chloroform as a potential contaminant. There was no information at the national level, specifically related to source water protection and aggregate extraction.

As indicated above, source water protection programs were developed for each state and included a threats assessment. The USEPA website lists links to each state source water protection program and wellhead protection program (**see Appendix A**). There was very limited information with respect to source water protection and aggregate extraction for most states. Much of the information was general or generic, following the general USEPA guide. Many states merely developed their own general guidelines for source water protection and subsequently required local municipalities to develop their own specific source water protection program.

Several examples are presented below that provide the typical level of detail and approach to the dealing with the aggregate industry, or in a number of cases the mining industry in general. More detailed information is provided in Appendix B.

5.4.1 Summary of State Examples

Michigan – Michigan has developed a "*Source Water Assessment Program*" (**Reference SW12**), through the Department of Environmental Quality, for both groundwater (wells) and surface water (surface water intakes). The state refers to the EPA list of potential sources of contamination. No specific information was presented beyond a standard data base search of known contaminant sources. The state recommends managing land use and wellhead protection at the local planning level.

West Virginia has developed a "*Source Water Assessment and Wellhead Protection Program*" (**Reference SW26**), through the Department of Health and Human Resources. They provide a list of potential contaminant sources and whether there is a high medium or low threat to groundwater and surface water. Gravel pits were listed as a low risk for both surface water and groundwater. Asphalt plants were listed as a medium threat to groundwater and a high threat to surface water. There was no indication of how the list was developed.

Louisiana has developed a "*Source Water Assessment Program*" and a "*Potential Susceptibility Assessment of Mississippi River Source of Public Drinking Wate*r" (**Reference SW29**). There are numerous drinking water intakes along the Mississippi River and the river is a focus of source water protection. The state has listed potential sources of contamination to surface water and include sand and gravel pits and asphalt plants in the lower risk category. With respect to groundwater, sand and gravel pits are listed as a potential source of contamination with the contaminants of concern listed as being "creates a conduit from surface, surface runoff", implying that there is an increased risk by removing sand and gravel as there is no additional contaminant of concern introduced by the physical extraction process.

New York State developed a "*Source Water Assessment Program Plan*" (**Reference SW13**), in 1999. The New York State program generally follows the EPA approach related to contaminants of concern, using the specific contaminants listed by the EPA. The only reference to quarries or gravel pits was related to an assessment of potential risk from different land cover types, for general contaminant categories. Quarries and pits are listed as having a low or negligible risk for all contaminant categories, including bacteria and petroleum products. There was no indication how the ranking of potential risks were developed.

5.4.2 Local Case History Examples – United States

Dayton Ohio - Dayton, Ohio was one of the first cities in North America to develop groundwater protection measures in the mid 1980's, given concerns regarding the high vulnerability to surface sources of contamination of the shallow unconfined groundwater supply aquifer. The water supply is comprised of approximately 100 urban wells, primarily in shallow sand and gravel aquifers with limited natural protection. Well field protection was introduced in 1988 and has continued to evolve over time. The City created two "zoning districts" (**Reference SW37)**. A Wellhead Operating District (WO) is present immediately adjacent to wells owned by the City. A Well Field Protection Overlay District (WP) has been created to encompass lands within a well field protection area, being the area in which contaminants are reasonably likely to migrate to a municipal well, generally within a one-year time-of-travel in the aquifer.

Dayton's current zoning requirements allows aggregate extraction within a well field protection overlay district subject to a number of conditions:

- provide an approved excavation and facilities plan that includes groundwater conditions, extent and depth of excavation, use and disposition of topsoil and a vegetation plan to stabilize any disturbed material;

- a surface drainage plan, as drainage from roadways and offsite watercourses are prohibited and the final grading shall minimize all surface drainage into the excavation;

- a post-excavation and operational land use plan; and,

- a security plan, unauthorized access shall be strictly prohibited as long as any excavations remain on site.

Dayton's Contaminant Hazard Potential Ranking, as classified by source, has a ranking from 1-9 with one being the lowest hazard and nine being the greatest hazard. Sand and gravel and quarrying operations are considered a low risk, rating a two, similar to general farming.

Kitsap county, Washington - Issues related to sand and gravel mining in Kitsap County, Washington State were presented in an excerpt in Section 5.1. The following is a summary of Kitsap County's approach to best management practices for sand and gravel mining, to prevent adverse effects on groundwater quality (**Reference SW7**). It is noted that the recommendations were not formalized by state agencies possibly because the State does not consider sand and gravel mines to be a significant threat to groundwater. The County wanted to adopt the practices into the county's planning process as concerns were raised by the County regarding the lack of effectiveness of the state regulatory programs due to staffing and funding constraints. The following is highlighted:

- A detailed hydrologic report is required for excavation below the water table as part of an Environmental Impact Study (EIS)
- Mining activities within designated wellhead protection areas, sensitive aquifer areas or principle recharge zones an EIS should be considered.
- Associated activities such as concrete, asphalt and other industries located at a mining site will be assess related to State Waste Discharge Permits and shall not be located adjacent to exposed groundwater.
- All sites should maintain a fuels/hazardous waste management plan and all fuel storage shall be above ground and properly contained and monitored.
- After closure of the site, all contaminated material must be removed from the site and there should be no filling of the site, unless it is establish that any fill is inert fill.
- Future land use decisions should reflect the increased groundwater vulnerability at the site.

5.5 *Source Water Protection – World Examples*

The European Union (EU) has been developing a water protection framework over the last six years. The approach to source water protection is general due to the wide range of situations and issues for its member countries. The most prevalent source water protection issue in Europe is nitrate contamination from agriculture. A Groundwater Directive (80/68/EEC) was issued in 1980 by the European Commission aimed at controlling the discharge of substances to groundwater. A Water Policy Directive (2000/60/EC) was developed in 2000, to replace the 1980 Groundwater Directive, proposing an integrated approach to protection an management focusing on the quantity and quality of groundwater within a river basin context, similar to Ontario's watershed based approach. This is to be integrated within a wider framework of environmental policies dealing with a full range of human activities. Member countries are required to develop groundwater protection and management plans, similar to the approach of each US state from USEPA directives.

There is also various legislation related to mining and the environment (**References SW2 and SW23**). Again, these are very broad based framework that member countries follow to develop specific legislation related to mining activities, protection of the environment, and controls on mining waste. The only discussion found in any documents, related to mining extraction at the EU level, was in a document entitled "*Promoting Sustainable Development in the EU non-Energy Extractive Industry*" (**Reference SW19**). The focus of the discussion was the legacy of abandoned mine sites and unrestored quarries, primarily related to acid mine drainage. There was no reference to the aggregate industry.

A literature search was conducted for source water protection and the aggregate industry throughout Europe, at the country level. The level of regulation and controls were highly variable. The following examples are presented as related to aggregate extraction and source water protection planning. These examples are considered typical of countries that are progressive in dealing with source water protection issues. A more detailed discussion is presented in Appendix B.

5.5.1 Summary of European Country Examples

Northern Ireland – Northern Ireland has developed a "*Policy and Practice for the Protection of Groundwater in Northern Ireland*" (**Reference SW6**) through the Department of the Environment (Environment and Heritage Service Branch). Policies were developed to deal with groundwater taking (abstraction), waste disposal, interference, contaminated lands and other activities that could affect water quality. Policies developed for Northern Ireland list quarrying, mining and gravel extraction, both above and below the water table, as activities that might impact groundwater. The main concerns are any proposed "mineral workings" within Source Protection Zones and the removal of all or part of the unsaturated zone above an aquifer. Detailed studies are required and appropriate mitigation measures must be developed to protect groundwater quantity and quality. A document entitled *"Reducing the Effects of Surface Mineral Workings on the Water Environment - A Good Practice Guide"* 1998 is the guidance document to be followed.

Scotland - Scotland updated their "*Groundwater Protection Policy for Scotland*" in 2003 (**Reference SW5B**). A document was also found, entitled "*The Groundwater regulations 1998: Code of Practice on Mineral Extraction*" (**Reference SW5**). A section within the Groundwater Protection Policy entitled "*Engineering Including Mining and Quarrying*" deals with a variety of issues such as landfill engineering and remediation of contaminated lands, as well as mining and quarrying.

Many of the issues associated with mining and quarrying in Scotland are related to coal mining rather than aggregate extraction. Issues are primarily related to water quality impacts from mine spoils or dewatering of surface mines. The Code of Practice on Mineral Extraction (**Reference SW5**) list the greatest risk from mineral extraction as groundwater pollution from fuel and oils and from leaching of waste rock. Controls for fuel storage and use are in place at all mineral extraction sites. The only discussion related to the risks associated with sand and gravel mining indicated that if there were no additives to the wash water used in the operation then "no pollutants should be introduced to the groundwater regime from the process".

Sweden – Sweden passed a Bill in 1997/98 that proposed 15 environmental quality objectives (EQO) to be achieved within 20-25 years (**References SW41 and SW42**). Objective No. 2 is high-quality groundwater. There are areas of Sweden that are threatened by overexploitation and a deterioration in water quality, especially due to agriculture. Acidification of waters with high nitrogen concentrations is a concern. The main aquifers are glaciofluvial sand and gravel deposits. They cover only a few parts of Sweden but more than 75% of the population is supplied by drinking water from these resources. Areas of increased development in Sweden are stressing the sustainability of water supply in these sand and gravel deposits by overexploitation of the water supply and extraction of sand and gravel, for use as construction material. One of the other EQO's is a "Good Built Environment", part of which includes gravel extraction. With the primary water supply found in a limited area of shallow sand and gravel deposits the following was included as part of the EQO:

- Deposits of gravel that are valuable for the drinking water supply and the natural and cultural landscape are preserved.

- Natural gravel may be used only if a substitute material is not feasible, given the area of application in question.

- By 2010 the extraction of gravel will not exceed 12 million tones per year and the proportion of reused materials will represent at least 15% of the ballast used.

Crushed rock from quarrying is currently the main substitute for sand and gravel, supplying over half of the 70 million tones of aggregate used in 2003.

5.6 *Source Water Protection Summary*

The majority of the discussion in the literature, related to aggregate extraction and source water protection, raised similar concerns as that of the Implementation Committee. The concern with respect to aggregate extraction is usually one of a potential increased risk of water quality impacts on the local aquifer, if the resource is also used for water supply. Areas where high quality aggregate resources exist will typically also be an area of higher vulnerability to contamination from any land use, whether extraction occurs or not. The concern is potential increased vulnerability with aggregate extraction. There is also a concern that with respect to water quality issues from the aggregate extraction land use or after use of the site.

The issues for source water protection, as related to the aggregate industry, encompass three basic components:

- the physical impacts of the actual extraction and processing of aggregate;
- the potential impacts of aggregate extraction on the changes to aquifer vulnerability and the ability to protect source water; and,
- the potential future land use in areas where there have been potential changes to the aquifer vulnerability.

Introduction of new regulations or controls for the aggregate industry would net necessarily address issues such as past practices or uncontrolled use of a site. Typical controls or best management practices (BMP's) found in the literature that would relate to source water protection are usually found in aggregate licensing or land use zoning controls rather than directly related to source water protection legislation. Most information pertaining to source water protection and the aggregate industry is very general at the provincial or state level. In areas where source water or wellhead protection addresses aggregate extraction and the aggregate industry the following types of controls are often in found:

- Prohibit extraction in the immediate wellhead area (variable distance or time-of-travel from the well) due to concerns about external sources of bacterial contamination from surface runoff combined with the "loss of filtration" from the extracted material. Extraction is typically allowed elsewhere in a shallow aquifer system.
- Control or elimination of runoff from offsite into the extraction area.
- Extraction below the water table may or may not be allowed, and would typically required a detailed assessment if allowed.
- Strict security and access controls to limit access related to illegal dumping. Highly regulated and controlled storage, stockpiling or landfilling of inert material.
- Tight control, storage and use of fuels and other petroleum products.
- Treat ancillary uses separately. Ancillary uses are often not allowed within groundwater protection areas.
- Site planning for aggregate extraction licensing will include post-extraction land use and control of the land use.

6.0 Summary of Potential Effects/Changes in Physical Systems related to the aggregate industry

This section, summarizes the findings of the technical literature search as related to potential effects or changes to physical systems, for both quantity and quality. The section is divided into five main components as discussed in Section 3.2. This was done for simplicity of discussion, related to the four main components physical system that could be impacted and a fifth component related to the issue of cumulative impact, beyond potential site-specific impacts. A general discussion is presented for each section related to issues or potential impacts followed by a summary of findings from the literature search. Factors to consider are also discussed, where appropriate, to understand the implications of some of the findings relative to a particular geologic setting, climate issue or planning issue.

6.1 *Groundwater Quantity*

The physical presence of an excavation can have a wide variety of potential effects on the groundwater system. Some effects or changes will be minor, such as the impact of above water table extraction on the groundwater flow direction. Other operations such as dewatering of a quarry, below the water table, with no mitigation measures could significantly alter the local groundwater flow system.

Potential changes to the direction and flux of groundwater flow as a result of aggregate extraction are caused by two general mechanisms:

(1) a change in the water balance, more specifically the groundwater balance and

(2) a change to the characteristics of the porous media.

Changes in the water balance

Above the water table extraction factors include:

- Changes in runoff and evapotranspiration
- Changes in unsaturated fractured rock and conduit flow

Below the water table extraction factors include:

- Changes in runoff and evapotranspiration

- Dewatering of an excavation (most common in quarries) reduces the water level in the excavation thus inducing a hydraulic gradient to direct groundwater flow to the excavation in three dimensions. This induces a drawdown cone in the vicinity of the excavation and is analogous to a large diameter pumping well. The extent of drawdown will depend on the size of the excavation and the pumping rate, the hydrostratigraphy (particularly whether the flow is occurring in unconfined, semi-confined or confined geologic units), local recharge conditions and the potential for interception of a surface water body by the drawdown cone.

- The physical extraction of aggregate material below the water table (i.e. dragline operation in sand and gravel pits) will also induce flow towards the excavation, at least on a temporary basis. The removal of solid material is replaced by inflowing water. The rate of extraction dictates an equivalent flow of water needed to replace the additional void space.

Changes in the characteristics of the geologic material

Above the water table extraction factors include:

- Loss of geologic material and soils above the water table and modification of run off patterns.

- Induced fracturing from blasting in quarries or stress release from the quarry excavation and removal of load bearing material.

Below the water table extraction factors include:

- Removal of porous media and subsequent infilling with water creates a zone of very high permeability. This zone would act as a local hydraulic lens pulling water in from upgradient and releasing it downgradient through the pond (i.e. the path of least resistance). There may be an increase or decrease in local groundwater recharge depending on climatic conditions for evaporation versus evapotranspiration. The total groundwater flow through the extraction area and the groundwater flow paths are altered on a local scale and the impacts on a more intermediate/regional scale will depend on the size and location (i.e. is it in a recharge area or discharge area) of the extractive activity relative to the overall groundwater flow system.

- Removal of porous media and subsequent infilling with material of lower permeability. There will be a decrease in recharge on a local scale. The total groundwater flow through and the groundwater flow paths are altered on a local scale. a This is typically not done in Ontario but is done in many areas of Europe where land available for development is limited.

6.1.1 General Findings in the Literature

Publications found in the literature for sand and gravel extraction, that discussed water quantity impacts or changes to the groundwater flow system (**References #18, #26, #5, #11, and #21**), indicated that there was either no impact on the water table or only a very localized impact as a result of aggregate operations or the presence of post extraction lakes. In one study however, in West Germany (**Reference #18**), municipal wells were adjacent to and within a local area containing 20+ gravel pits. The existence of the gravel pits, combined with pumping of the shallow wells within the same aquifer, modified the shallow groundwater flow such that agricultural areas with high concentrations of nitrate in the groundwater were now within the capture zone of some of the wells. The municipal wells were less than 200 m from gravel pit lakes in some cases.

Predictive computer modelling or water budget analyses related to gravel extraction and post extraction scenarios were presented in a number of publications (**References #13, #23, #24, #25, #27, #15, #9, and #38**). The biggest factor in determining the extent of impact within an unconfined overburden aquifer setting is whether the gravel pit is being dewatered. Where no dewatering occurred there was limited alteration of the groundwater flow system beyond a vary local scale. In the modelling scenarios where dewatering was simulated (**References #27 and #9**), extensive impacts on the local groundwater flow system in the unconfined aquifer are shown. It is noted that although the scenario of dewatering of a gravel pit was modelled, there was only one instance in the literature reviewed (**Reference SW8**) where dewatering of a gravel pit, located in the Region of Waterloo, was part of the operational scenario.

Other publications which had some component of water budget assessment as part of the overall study indicated that a change in recharge within a local setting could result in a decrease in recharge or an increase in recharge. In one study in New Hampshire (**Reference #15**), a water budget analysis showed that there could be a decrease of on-site recharge over the 50 acre extraction site by 4%, for above the water table extraction and a decrease of annual on-site recharge by as much as 22% for below the water table extraction. It is noted that snow melt was not taken into account in the assessment. The discussion of the results stated that the evaporative losses can be offset by modifications to surface run off due to the creation of the gravel pit. The discussion also indicated that the creation of the pond substantially increased the storage capacity of the aquifer, many times greater than the annual recharge rate.

Groundwater flow modelling of cumulative impacts on various hypothetical rehabilitation scenarios for a series of gravel pits within a watershed in the Region of Waterloo (**Reference**

#27) predicted that recharge to the local aquifer system would increase by 10.8% if the gravel pits were extracted without by dragline (i.e. no dewatering) and post-extraction ponds were created. The modelling predicted there would be a decrease in overall watershed recharge by 3.8% if the gravel pits were completely infilled with low permeability material to ground surface such that there would be zero recharge to the aquifer system from within all of the gravel pits. There is no known scenario of this type in Ontario, however it does present a worst case scenario on a watershed scale.

In one publication from Finland (**Reference #10**) an increase in recharge was noted in above the water table extraction where there was a decrease in evapotranspiration. Changes in the water table and aquifer water balance due to evaporative losses from gravel pits in the mid-west USA (**Reference #9**), a semi-arid setting where precipitation is low and evaporative losses are high, were considered small and had little hydrological effect on the groundwater system.

Modelling of various post-extraction scenarios in the Mill Creek watershed in Puslinch Township (**Reference #24**), in Caledon, Ontario (**Reference #23**) and a study in Italy (**Reference #13**) indicated very minor localized impacts and modifications to the groundwater flow system as a result of extraction. The studies also demonstrated various mitigative designs to further minimize local impacts. For example, the purpose of the modelling carried out in the Italian study (**Reference #13**) was to provide mitigative design for aggregate operations to prevent flooding of farmlands downgradient of the extraction site. In this case, the model predicted that the unmitigated extraction and pond formation for a single large quarry would create substantial increases in water levels downgradient of the quarry. Simulations incorporating a number of smaller excavations, with portions of the excavations lined in specific locations, predicted there would be no significant change to the groundwater flow regime.

An analytical solution for gravel extraction below the water table (**Reference #25**) suggests that the impact on the water table remains close to the pit, even more so as the pit gets larger, due to the buffering capacity of the pit pond.

The impacts to surrounding water levels and groundwater flow systems from quarry operations and dewatering of quarries are more significant compared to non-dewatered gravel pits. A study by the Minnesota Department of Natural Resources (**Reference #5**) investigating dewatering of quarries in Minnesota indicated that dewatering produced significant drawdown at the sites studied. One of the sites showed that the location of the quarry, located adjacent to a surface water course, resulted in the quarry intercepting groundwater that would have discharged to the surface water system. In another quarry study (**Reference #17**) an exploratory borehole at a quarry in Wisconsin intercepted a local fracture in a confined aquifer system causing a 12 m decline in the water level in local private water, within hours of the borehole being drilled. The impact was subsequently mitigated by plugging the borehole.

Quarrying either above or below the water table in extensive karstic areas can cause significant changes to both surface and subsurface flow as major flow conduits are intercepted and cut-off (**References #6, #21 and #22**). Although presented for completeness, these publications deal with major karstic terrain, found in very few settings in Ontario.

6.1.2 Summary of Findings Related to Potential Groundwater Quantity Impacts by the Aggregate Industry

The following is highlighted with respect to the findings within the literature reviewed, as related to potential groundwater quantity impacts and aggregate extraction:

- Aggregate extraction causes limited change to the overall water balance of an aquifer system, unless large scale unmitigated dewatering occurs, and will have limited potential impact on source water protection from a groundwater quantity perspective.

- Changes in the groundwater flow system, as a result of aggregate extraction below the water table, may modify capture areas of a municipal well or well field in the same aquifer, depending on proximity of the aggregate operation to municipal well or well field.

- Water table changes relating to quarries were more extensive than those for gravel pits. The impacts are more likely to occur during operational activities. Long-term, local water level declines generally occur upgradient of a below water table extraction operation and increase slightly downgradient of the post-extraction lake.

- The existence of post-extraction lakes increases the overall groundwater storage within the aquifer where extraction has occurred..

- Various studies demonstrated that appropriate mitigation, including infiltration trenches and barrier walls, could reduce the impact of aggregate extraction on the local groundwater levels.

6.2 *Groundwater Quality*

Groundwater quality concerns related to the aggregate industry, as described by the Implementation Committee, can be divided into three components based on activities that could generate a potential contaminant of concern:

- operational activities such as on-site storage of fuel;

- ancillary uses on-site, such as asphalt plants; and,

- future land uses, site rehabilitation or uncontrolled/illegal dumping.

The onsite sources of contaminants include but are not limited to petroleum products and dust suppressants from normal operational activities and possible release of contaminants related to ancillary uses (e.g. asphalt plant).

Backfilling of non-inert material both above and below the water table can leach contaminants and enter the groundwater flow system directly where no fine grained layer exists within the excavation.

An unmitigated loss of the surficial soil layer and loss of any amount of the unsaturated zone reduces the attenuative capabilities of the porous media to biodegrade, and chemically or physically interact with any potential contaminants that would be introduced through overland flow or acidic precipitation.

The exposure of a gravel pit pond to the atmosphere, precipitation and surface water run off can lead to a modification of aqueous chemistry through changes in nutrient inputs, oxygen demand, biological processes, water temperature etc. The resulting groundwater- surface water interchange can modify the groundwater quality downgradient of the gravel pit pond.

The extractive operation, particularly quarrying, often extends through several hydrostratigraphic units with varying chemical make ups. Additionally as one moves deeper in the groundwater flow system there is a tendency for higher dissolved minerals due in part to longer residence times. Poorer quality water from a lower unit may be re-infiltrated through dewatering and recharge into a shallower unconfined system.

The shallower groundwater systems in Ontario typically have average groundwater temperatures within 2-3 degrees Celsius of the long term average air temperature (10^{o}C) Temperatures at the water table can vary by more than 10^{o}C depending on the thickness of the unsaturated zone. Ponds will warm and cool groundwater seasonally, depending on their size and depth and rate of interchange with the shallow groundwater system. Removal of the unsaturated zone may alter the shallow groundwater temperature immediately underlying the excavation thus creating the potential for a thermal plume to migrate from the extraction site.

6.2.1 General Findings in the Literature

General discussions on the removal of the upper soil layer are presented in publications from Europe (**References #7, #8, #10**). Studies in Finland (**Reference #10**) showed minor increases in concentrations of some dissolved minerals directly below an above the water table gravel pit. Work in Sweden (**Reference #7**) focusing on pit rehabilitation showed similar findings when the soil layer is removed. The Finnish study (**Reference #10**) found the pond water was elevated in organic matter and sulphates, relative to the groundwater. It is noted that water quality issues associated with northern Europe are related to acid rain in contact with the exposed groundwater and high levels of nutrient loading from agricultural activities. Other studies found that the water quality of post extraction ponds could vary and can be nutrient rich or poor, with corresponding oxygen levels (**Reference #8**) or that there was no difference between the pond water and the adjacent groundwater (**Reference #11**).

Research conducted at the University of Guelph (**Reference #39**) examined the development of aquatic communities in Southern Ontario in post extraction aggregate ponds of different ages and sizes. Morphometric, chemical, physical and biological features were surveyed to determine the effect of pond age and pond volume on the succession of aquatic communities in gravel pit and quarry ponds. Results showed low concentrations of nitrate, and low levels of metals in all but one of the 15 sites surveyed.

No publications were found in refereed journals that presented or discussed groundwater quality impacts to drinking water systems as a result of onsite contamination or unregulated dumping at aggregate extraction sites. There were number of publications or references within publications that discuss the issues related to historical landfilling within old gravel pits or unregulated dumping in gravel pits due to lack of on site controls.

A recent study in Slovenia (**Reference #35**) indicated unregulated waste dumping in former gravel pits is a likely threat to the local aquifer. Historical mining of sand and gravel in “gravel plains” near the City of Ljubljana, Slovenia has resulted in the infilling of gravel pits with waste. The area has naturally reforested over time and is now an important area for water supply. As a result of the landfilling there are now numerous undetermined waste sources throughout the area. Current water quality assessment of the drinking water supply does not show an impact from the dumping of waste, even though some waste areas are as close as 260 m from pumping wells. Further investigations are ongoing to determine the impact of waste infilling within the overall aquifer system.

A study reviewing a “borrow” pit program in Maine (**Reference #32**) noted that the second most common deficiency after natural buffer deficiencies, in gravel pits greater than 5 acres in size, was secondary containment of petroleum products. Sites smaller than 5 acres are not regulated and as a result they often became illegal dumping grounds for waste materials. No discussion of water quality specific water quality issues was presented.

Biosolid and soil nutrient applications increased nitrate concentrations at a gravel pit reclamation and topsoil manufacturing site in New Hampshire (**Reference #33**). A study was conducted to determine if the management practice of repeated application of biosolids in a former gravel pit posed a risk to groundwater quality. Results showed higher concentrations of nitrate in areas where stockpiling of the biosolids occurred. Results also showed high nitrate concentrations upgradient of the site making an overall assessment of the impact of the current site usage more difficult. Trace metal concentrations were within acceptable drinking water limits.

Post-extractive application of soil nutrients at a former gravel pit in British Columbia had no effect on groundwater quality (**Reference #28)**. Monitoring showed an increase in soil nutrients but no effect on groundwater or surface water quality. Elevated nitrate concentrations at a municipal well water supply in West Germany was interpreted as being related to gravel extraction (**Reference #18**). This study was discussed in the previous section. The existence of adjacent pit ponds modified the local groundwater flow system such that groundwater with elevated nitrate concentrations, impacted by adjacent agricultural practices, was re-directed to the capture zones of adjacent wells. It is noted that there more than 20 gravel pits and a series of municipal wells, operating within the area of the gravel pits, in a shallow aquifer. Water quality of the shallow aquifer far exceeded the drinking water quality objectives for nitrate at many locations within the aquifer due to long-term historical agricultural practices.

The discharge water quality from a limestone quarry in England had a pH of 12.5 and a conductivity of 6000 uS (**Reference #4**). This was likely a combination of deeper groundwater and processing activity. Gravel pits and quarries that contact sulphide ore deposits can exhibit very acidic water quality with subsequent high levels of various metals (**Reference #2 and #14**).

Thermal plume modelling within a groundwater flow system (**Reference #23**) was incorporated into a subwatershed study in the Caledon area of the Credit River watershed where extensive aggregate extraction occurs. The Caledon study concluded that the thermal impacts were minimal and local with less than 0.5^{o}C change in temperature 100 m from the area of extraction. A review of the field data from a number of gravel pits in the Mill Creek watershed in the Township of Puslinch (**Reference #26**) had similar conclusions. The study also reviewed additional thermal modeling assessments from unpublished reports and concluded that the thermal plumes from gravel pits generally dissipated in less than a one year travel time downgradient of the gravel pit pond.

An issue often questioned related to quarrying, is the impact of blasting on water quality in local wells. The previously discussed study by the Minnesota Department of Natural Resources concluded that the physical effects of blasting did not alter the local well water quality (**Reference #5**).

Although there was limited information on specific scientific studies, there were a number of reports or findings that indicate there are few documented water quality issues associated with aggregate extraction operations. This information will hopefully be captured in Phase II work, as much of the information is related to case histories. There are a number of instances however, where case histories may not be fully documented as the information has been obtained and comments provided by regulatory agencies but the raw data was not presented. The following example shows the type of information "captured" during current literature search. The excerpt below is from a ruling by the State of New York Department of Environmental Conservation (DEC) April, 2005, related to an application for a sand and gravel operation to extend below the water table and create a 10 ha lake (**Reference #40**). The excerpt, from the Administrative Law Judge, is a summary of the New York DEC evidence as related to the concern about potential water quality impacts from aggregate extraction below the water table.

Position of Department of Environmental Conservation Staff

*"Department Staff maintained that sand and gravel mining below the water is a common practice. Indeed, at present, more than 300 sand and gravel mines operating in the State mine aggregate below the water table. In its experience, no such mining activity has ever resulted in the contamination of a drinking water supply. (T, 4/4/03, p. 152) Moreover, Department Staff observed that mining below the water table often occurs within primary and principal aquifers where public water supplies are also located. (Id., p. 158) Noting the lack of scientific data to support a conclusion to the contrary, Department Staff concurred with the conclusion reached by BCI Geonetics, Inc., of Laconia, New Hampshire, in its 1988 study entitled "**The Impact of Sand and Gravel Mining on Groundwater Resources**." (Exhibit 19) This study which entailed a comprehensive review of the scientific literature, field interviews with water supply managers, and an examination of case studies from New Hampshire, Ohio and New York, concluded that they had "found no scientific documentation containing evidence that excavating gravel above or below the water table was detrimental to an underlying aquifer." (Exhibit 19, p. 13)*

In further support of its position, Department Staff also cited the Department's own study entitled, "Upstate New York Groundwater Management Program Summary" (Exhibit 18) In a section dealing with mineral extraction, this report, at page 30, states:

> *Sand and gravel are good aquifer materials and the mining of them often occurs in productive aquifer areas. This mining often raises concerns in the public's mind about possible environmental impacts such as alteration of local groundwater flow patterns, use and possible spillage of petroleum products at the site, direct exposure of groundwater in mines near major transportation routes where spills are likely to occur, and possible illicit dumping of solid or hazardous wastes at the site.*
>
> *DEC knows of no instance when significant groundwater quality or quantity problems have occurred at mines in New York State. In issuing Mined Land Reclamation Permits, DEC evaluates possible impacts on groundwater in the vicinity of mining sites.*"

An attempt was made to obtain these documents but they are apparently not available in electronic form and may have to be obtained through the regulatory agency. This should be pursued for Phase II, as part of the case histories assessment.

6.2.2 Summary of Findings Related to Groundwater Quality Impacts by the Aggregate Industry

A review of source water protection, presented in Section 5, showed that there is a broad interpretation of the "aggregate industry" with respect to potential water quality issues related to the industry. Groundwater quality issues associated with the aggregate industry can be divided into three areas of the aggregate industry as highlighted at the beginning of Section 6.2:

- operational activities such as on-site storage of fuel;
- ancillary uses on-site, such as asphalt plants; and,
- future land uses, site rehabilitation or uncontrolled/illegal dumping.

The findings in the literature are summarized as follows:

<u>Operational Activities</u>

- Available literature indicates that there are limited documented instances of water quality impacts on groundwater quality as a result of normal operational activities. There were no documented cases of contamination of a municipal well from regular operation activities during aggregate extraction. During Phase II, this will be assessed in more detail as part of the case history assessment.

Potential water quality impacts associated with changes to the physical system, as a result of aggregate extraction include:

- A decrease in the contaminant attenuative ability when the soil layer and unsaturated zone is removed. This results in an increased potential for contaminants to enter and travel through the groundwater system from any surface source of contamination (e.g. surface runoff, future land uses)
- Water quality changes downgradient of a post-extraction lake as a result of exposure of the water table to the atmosphere. These changes include changes in pH and dissolved oxygen that could impact nutrient and metal concentrations, locally down gradient of the post-extraction lake.

- Thermal plumes from below water extraction and post-extraction ponds were typically very local. Depending on the hydrogeologic setting, the impact was typically less than 200 m.

- Potential for an influx of poor quality water from deeper geologic units, in quarrying operations where lower geologic units, of poor water quality, are breached during extraction operations.

<u>Ancillary Uses On-site</u>

- Existing literature does not show any documented instances of groundwater quality impacts from ancillary uses, such as asphalt plants, at aggregate extraction sites. This will be assessed in more detail as part of the case history investigations in Phase II.

<u>Future Land Use, Site Rehabilitation or Uncontrolled Dumping</u>

- Post-extractive use of an aggregate site, in particular infilling with non-inert material presents a significant potential source for groundwater contamination.

- Abandoned or uncontrolled access aggregate sites have the greatest potential for generating contaminants that could be introduced to the groundwater system through historical practices of illegal dumping. Not withstanding this concern there is limited information in the literature indicating contamination of municipal water supply systems from these types of activities. Future work in Phase II will assess this in more detail.

- The risk or impacts from the loss of attenuation is directly connected to the management of the potential operational contaminants (i.e. petroleum products) and the management of adjacent stormwater runoff or post extractive application of agricultural products.

6.3 *Surface Water Quantity*

Streams, rivers and some wetlands receive a portion of their water from groundwater, known as base flow. Base flow is important ecologically to:

- sustain low flows in surface water systems;

- moderate stream temperatures and provide cool thermal regimes in the summer and warm thermal regimes in the winter for fish habitat;

- generate opportunities for reproduction through direct discharge to streams (i.e. upwellings) or maintaining wetlands.

Surface water quantity in streams, wetlands or adjacent lakes can be altered by a change in the groundwater flow as a result of extraction and dewatering and the subsequent change in groundwater discharge; or from direct discharge of dewatering or process water. Potential changes or disruptions in groundwater flow have a much greater potential to impact ecological features, compared to impacting a drinking water supply, due to the sensitivity of aquatic features. A small change in the vertical gradient, due to a change in groundwater flow patterns may be sufficient to impact spawning areas in a adjacent stream, yet the overall surface water flow may not have measurably changed.

6.3.1 General Findings

The literature search results, where modifications to groundwater flow systems can cause changes to groundwater discharge were previously discussed in Section 6.1. Changes in groundwater discharge were presented in the context of reductions to base flow which can impact site specific discharge to spawning areas; and overall volumetric discharge particularly in smaller headwaters type streams. In particular, two separate studies reviewed the impacts of a concentrated group of gravel pits within a single subwatershed in Puslinch Township (Wellington County) on an adjacent coldwater stream (**References #26, and #42**). The findings concluded that there were no measurable impacts on overall volumetric flow in the adjacent creek and only a limited impact on local groundwater discharge conditions. The modifications to the groundwater flow system were very localized.

Studies involving intensive groundwater extraction (i.e. 4000 l/s) adjacent to coldwater streams indicated that although levels of stream water depletion occurred the drawdown of the water table was minimized due to reinfiltration of water (**Reference #43**) and that the stream water levels recovered relatively quickly upon the cessation of pumping (**Reference #44**).

Where major flow conduits in karstic environments are intercepted and cut off by quarrying, both above and below the water table, surface flows may be impacted (**References #6, #21 and #22**). This situation potentially occurs in major karstic environments, which are very limited in Ontario.

6.3.2 Summary of Findings Related to Potential Surface Water Quantity Impacts by the Aggregate Industry

Findings of the literature search, related to potential surface water quantity impacts can be summarized as follows:

- The ecological functions of streams, lake and wetlands are more sensitive to the potential groundwater flow system modifications from aggregate activities compared to impacts on municipal drinking water systems. The scale of the impact is a function of many factors including, proximity to the surface water features, scale of the operation, location of the aggregate operation within the groundwater flow system (i.e. recharge are or discharge area), thickness of the aquifer and depth of the extraction operation.

- Aggregate operations typically have a limited local impact on surface water systems except potentially where unmitigated quarry dewatering occurs.

- Karstic environments may be the most sensitive hydrogeologic environment, with respect to potential impacts from quarrying where dewatering occurs, as a result of interception of conduit flow.

6.4 *Surface Water Quality*

The greatest issue with respect to surface water quality, as found during the literature search, is instream mining of sand and gravel and "marine" or coastal mining. This involves extraction of aggregate directly from a surface water body, primarily a river or stream or along a coastal area where there are deltaic deposits of sand and gravel. These types of operations are very limited in Ontario (e.g. St. Mary's River).

In Ontario the potential impact of aggregate extraction on surface water quality is primarily a result of direct discharge of poorer quality water to the local water courses or wetlands. The poorer quality of the discharge water could be from naturally poor groundwater quality or from water degraded through onsite processes, in particular suspended sediment or total dissolved solids. Other potential impacts would include the discharge of a subsurface contaminant plume originating from a pit or quarry backfilled with waste or the redirection of naturally poorer groundwater as a result of the modification of the groundwater flow system and subsequent discharge. A Certificate of Approval from MOE is required for any surface discharge from an aggregate site in Ontario.

6.4.1 General Findings

In 1986, the Ministry of the Environment announced the Municipal Industrial Strategy for Abatement (MISA) as an approach to controlling Point Source discharge to clean up Ontario's waterways. Eight industrial sectors were identified as major dischargers with Industrial Minerals listed as one of the major dischargers. Sand and gravel pits and quarries were a subsection of this sector, known as Structural Materials. As part of the MISA strategy monitoring programs were developed to assess the water quality of discharge water at selected industry locations (**Reference #41**). Results would form the basis of developing discharge criteria and limits for appropriate water quality parameters within the industry. Six selected sand and gravel and quarry operations were sampled, either at wash water overflow location, from settling ponds or discharge water from dewatering operations. Results indicated the following:

- selected samples exceeded the aesthetic objective levels for chloride and/or aluminum and/or iron, commonly exceeded in groundwater supplies;
- oil and grease were detected at two sand and gravel locations on 1 of 2 sampling dates;
- phenol was measured near the detection limit at on sand and gravel operation on one occasion;
- ethylbenzene and xylene were measured at levels near the detection limit on one occasion at one site; and,
- ammonia was not detected, and nitrate concentrations were well below drinking water objectives.

The organics measured at low concentrations were attributed to lubrication agents and fuel usage for heavy equipment. Elevated water quality parameters such as nitrate and chloride found at the sites may be attributed to the water quality of the groundwater being pumped or it may be from runoff into the extraction area.

As indicated above, the majority of literature related to potential impacts of aggregate extraction on surface water quality dealt with in stream mining of sand and gravel. This type of operation is prevalent in mountain areas and where major rivers and creeks are "fed" from mountain snow packs. Only a few documents were reviewed for this report as many of them cite similar issues or concerns. A publication by the US National Marine Fisheries Service (**Reference #29**), regarding a national gravel policy, summarizes the environmental effects of gravel extraction as a result of extraction of alluvial material from within or adjacent to a stream or river bed. Impacts include: a disruption of sediment supply and movement of sediment; increase of sediment transport and siltation; potential for petroleum spills by instream use of heavy equipment; and, destruction of riparian zones and spawning areas. There are only a few instances of this type of operation occurring in Ontario, but any issues should be determined during the Phase II study.

The only discussion found in the literature, related to surface water quality problems from aggregate extraction, was in a study conducted by the New York State Department of Environmental Conservation (DEC) in 1995 (**Reference #30**). The study entitled "*Resource Extraction Management Practices Catalogue for Nonpoint Source Pollution Prevention and Water Quality Prevention in New York State*" indicated the following. In 1993 the DEC:

"identified nearly 1,500 water body segments in New York State, comprising 725,000 acres of surface (freshwater), marine (Bay and ocean) water and almost 500 miles of Great Lakes shoreline that have been negatively impacted by nonpoint source (NPS) pollution. Of these, resource extraction (this includes all extraction activities such as aggregate mining and oil and gas exploration) is the primary source of water quality problems on a relatively small number of water bodies. Eleven (11) segments of water bodies were identified where resource extraction was the primary source of a water quality problem. Thirty-nine (39) segments of water bodies were identified where extraction was the secondary source of impairment. Of the eleven segments, seven (7) were impacted by sediment from surface mining operations. Sand and gravel removal was the dominant form of surface mining identified."

Suspended sediment problems were also noted in studies for gravel pits in Maine (**Reference #32**) and quarrying in karstic limestone (**Reference #21**). Suspended sediment issues appear to be independent of the type of extraction and appears to be more related to onsite processes such as aggregate washing and discharge of water off-site. The severity of the impacts was not quantified in any of the studies.

As was discussed in Section 6.2 groundwater entering a quarry from a different geologic formation than the formation being excavated or pumped may exhibit different water qualities depending on the composition of individual rock units and the age of the water (**References #2, #4 and #14**). Subsequent discharge of poorer quality water could potentially cause impacts on receiving streams or wetlands.

6.4.2 Summary of Findings Related Potential Surface Water Quality Impacts by the Aggregate Industry

Findings of the literature search, related to potential surface water quantity impacts can be summarized as follows:

- The potential for surface water quality impacts exist, related to discharge to surface water from aggregate operations, however the noted impacts have been limited. Suspended sediment appears to be the most common impact when water from aggregate operations is discharge to a surface water course. Case history assessments in Phase II may provide a more complete assessment.

- Instream mining operations have the greatest potential to impact surface water quality due to sediment loading and alteration of the stream bed.

6.5 *Cumulative Effects*

One of the issues often raised (e.g. **Reference SW8**) with respect to the impact of aggregate extraction is the cumulative impact of aggregate extraction on a local scale. Since aggregate can only by mined where it exists, it often means that there will be more than one pit or quarry within a subwatershed or catchment area. This is especially true for sand and gravel extraction, since major gravel resources are found in areas such as glacial meltwater channels (e.g. Caledon area and Puslinch Township).

The issue of addressing cumulative effects of any land use change is determining what it is that in fact needs to be assessed. An assessment of cumulative effects would take into account the impacts on groundwater quantity and quality; and surface water quantity and quality as presented in the previous sections and then superimpose them on a larger scale. The scale considered would depend on the type and sensitivity of the physiography (e.g. the geomorphic landscape and climate) in a particular area (e.g. catchment, subwatershed, watershed).

Potential physical impacts or changes described previously are typically assessed on a site-specific basis. The following impacts or changes are considered the most significant when trying to assess the cumulative impact from aggregate extraction:

(1) Cumulative impact as a result of local modifications to the hydrologic cycle. This impact is reflected as a change in the water balance and more specifically a change in the groundwater recharge as a result of changes in evapotranspiration and runoff. Evapotranspiration is modified by changes in vegetative cover and the creation of post-extraction lakes. Runoff is changed as a result of modification of the local landscape. A change in recharge could affect local groundwater levels, available groundwater in storage and potential discharge to streams and wetlands.

(2) Change in the aquifer water levels and a re-distribution of water (i.e. from groundwater to surface water) resulting from dewatering during operation.

(3) A modification to the 3-dimensional hydraulic gradient where groundwater flow paths are re-distributed thus affecting groundwater flow divides, and discharge to specific reaches of streams or wetlands.

(4) Plumes of poorer quality groundwater that could migrate downgradient from numerous pits or quarries and impact the aquifer or surface water discharge points. These zones of poor quality water could be from operational aspects or from areas where unregulated infilling activities have occurred. Pumping of water supply wells downgradient could cause co-mingling of the plumes of water.

6.5.1 General Findings

Few studies are available that specifically address cumulative impacts of aggregate extraction. One recent study (**Reference #27**) was a groundwater modelling study conducted by the Region of Waterloo, for the Cedar Creek subwatershed, in response to the potential increase in below water extraction at a number of licensed gravel pits. Three sets of simulations were conducted, two of which were considered hypothetical extreme-case conditions. One aggregate extraction scenario demonstrated a decrease in overall recharge (3.8%) within the subwatershed when simulations were conducted assuming post-extraction gravel pits to be completely infilled with lower permeability material, and assumed zero recharge from all gravel pits in the subwatershed. Simulations for this scenario indicated a base flow reduction of 8.1% within the subwatershed. It is noted that there are very few instances, if any, of this practice occurring in Ontario at individual sites. It is considered unrealistic, but would be a worst case scenario, yet the cumulative impact from a water balance perspective is only a 3.8% loss of recharge within the watershed.

In the second scenario, more closely representative of typical extraction conditions, gravel pits were simulated as below water extraction pits, without any dewatering. Recharge was assumed to be the total precipitation within the pit areas as additional runoff was assumed to offset evaporative losses. The simulation showed an increase in overall recharge of 10.8% and an increase in local base flow of over 22%.

The potential effects on the overall recharge to the groundwater system were not specifically quantified in the other publications discussed in Section 6.1. Changes in groundwater discharge to various surface water reaches were presented in the Caledon study (**Reference #23**) which showed increases in base flow in some reaches, primarily downgradient of the post-extraction lakes. Other areas, upgradient of the post-extraction lakes and in areas where the groundwater divide shifted showed decreases in base flow in some reaches upgradient and adjacent to the post-extraction lake. Simulations conducted using a series of smaller post-extraction lakes, following the water table slope, greatly decreased changes to base flow throughout the local stream reaches. There was no overall change in water balance on the subwatershed scale.

Reviews of case history data (**#26, #42**) from a cluster of gravel pits located in a glacial outwash channel in the Mill Creek subwatershed Puslinch Township did not show any apparent impacts, on a subwatershed scale, on the groundwater flow system but did demonstrate local modifications to the groundwater flow system. The local modifications to the flow system and water balance do not appear to result in measurable impacts on a larger scale. Studies are continuing within the subwatershed. The major change that has taken place is an increase in aquifer storage due to the creation of lakes as a result of below water table extraction.

Other studies provide qualitative conclusions that the impacts are not significant on an aquifer wide scale **(References #5, #9, #13 and #17**).

6.5.2 Factors to Consider

The following discussion presents a number of issues to consider based on findings in the literature and our experience in attempting to deal with cumulative impact assessments.

The critical questions in considering cumulative impacts are whether local impacts are additive, what form does the additive impact take, can the individual and additive impacts be measured properly, and can a cause and effect relationship be established?

As an example, consider the impact from transforming a pre-extraction landscape to one with a large number of post-extractive lakes. The change in the water balance will cause the individual pit or quarry to be either a groundwater source (increased recharge) or sink (decreased recharge) or there could be no change. If one were to consider this source or sink occurring in a closed groundwater system with all recharge water discharging at the bottom end of the basin and all other recharge in the basin remaining constant then one would theoretically expect to see a change in all the water levels in the basin reflecting the hydraulic gradient needed to discharge the new total value of recharge. Within this controlled scenario the measurement of the change in water levels can only be measured with any accuracy (i.e. centimetre scale) close to the source of the change. In a practical sense the same holds for measuring the streamflow, as the change in recharge compared to the overall recharge may be so small that statistical analysis may not separate the change from the range of error in measurement. Taking this ideal situation additional components can be added, including the following:

- Groundwater basins are not usually closed basins and do not necessarily follow surface water divides so that changes in a groundwater flow system may be transmitted beyond the surface watershed and may not be reflected directly in the groundwater discharge in the surface watershed where they are located.

- Changes in groundwater levels due to a local source or sink can change the recharge characteristics within its cone of influence thus changing the infiltration, interflow runoff components further afield which subsequently may buffer the changes in the downstream groundwater discharge component.

- Natural variations in recharge both spatial and temporal (long-term and short-term) complicate separating out these absolute changes due one or more lakes.

- The changes have a transient nature to them and may take a considerable time (i.e. ten's to hundreds of years in most subwatersheds) to be transmitted through the hydrologic system.

This same discussion applies to dewatering during the extractive phase noting that: (1) pumping may be a greater sink term than a post-extractive lake, (2) a majority of the annual pumping may represent onsite stormwater management and (3) the discharge water is re-cycled within the overall hydrologic system but may potentially impact one component at the expense of another.

If the change in recharge due a large collection of ponds or dewatering is a significant percentage of the overall watershed or subwatershed water balance then impacts should be observed. However, aggregate extraction does not usually occur in an area with no other land use changes occurring, making it difficult to quantify cause and effect impacts on a larger scale. An overall assessment of cumulative impacts on the water balance can be carried out independently by superimposing the aggregate operations within a watershed similar to superimposing the impacts of multiple pumping wells. In order to confirm the predicted impacts or site-specific measured impacts within the larger setting one must consider the following:

> *The quantification of changes in the water balance, the potential impacts on the functional linkages within the watershed and the ability to take field measurements for input into these assessments must take into account the interdependence of the impacts of all land uses and land use changes if one is carry out a cumulative effects assessment. The relative changes in the water balance from various land use components must be considered when addressing impact including the ones which do not usually fall under any review process specific to a detailed water balance (e.g agricultural practices such as crop rotation or reforestation of portions of a watershed).*

The effects relating to unmitigated local modifications to the flow system and impacts on spawning areas or wetlands may be more easily carried out where the impacted areas are in the "measurable" local area of influence. In this case the cumulative aspect may relate more to the number of wetlands or spawning areas affected.

A similar consideration may be applied to the cumulative potential for groundwater contamination. The unmitigated plumes of degraded water which may originate from aggregate pits are not additive with the context of concentration within the aquifer but may be represented by the total amount of aquifer degraded. Where the plumes discharge to surface water, mass loadings may be considered the cumulative impact.

7.0 Discussion - the aggregate industry and Potential Source Water impacts

The Phase I study focussed on conducting a literature review with respect to the potential impacts of the aggregate industry on groundwater and surface water. The literature review also examined how source water, wellhead and water intake protection programs typically addressed or classified aggregate extraction/processing. The purpose of the present research project is to aid decision makers in source water protection planning with respect to the compatibility of the aggregate industry and source water protection.

Section 2.1 presented the Source Water Protection Implementation Committee's concerns with respect to aggregate extraction and are reiterated below:

> "*The potential source water concerns that would be assessed in the source protection planning process include:*
>
> 1) *Removal of material, which reduces the amount of filtering material above a groundwater source;*
>
> 2) *Exposing the water table, allowing for easier introduction/migration of surface pollutants;*
>
> 3) *Potential loss of water quantity as a result of existing aggregate operations (i.e. Permit to Take Water);*
>
> 4) *Risk of importation of contaminated or deleterious fill to rehabilitate closed sites; and,*
>
> 5) *Activities within an existing extraction site which may introduce potential risks to source water (i.e. asphalt recycling, on-site storage of fuel).*"

The majority of the discussion in the literature, related to aggregate extraction and source water protection, raised similar concerns as that of the Implementation Committee. The level of concern varied depending on the local factors. In the UK there were issues associated infilling of extraction areas as the land is valuable for development purposes. In Europe, groundwater quality is a major issue, rather than the extraction itself. In some areas there is substantial competition for both the aggregate and water resource. For example, in Sweden the main aquifers are in sand and gravel deposits. Since both resources are scarce, deposits of gravel that are valuable drinking water sources are protected and there is an emphasis on quarrying stone and reusing material for construction purposes.

The location of an aggregate resource cannot be changed as that is where the resource was deposited as a result of physical processes. The reality of the aggregate industry is that it is most economical to obtain the resource as close to development as possible, given that is where the major use will occur. It is also economical to utilize the resource found at or as close to ground surface as possible. A physical aspect of aggregate deposits is that they typically contain substantial quantities of water. Water within the aggregate resource may provide water to water supply wells and provide water to maintain healthy aquatic ecosystems.

The concern with respect to aggregate extraction is usually one of a potential increased risk of impact to water quality that could affect drinking water if the aggregate resource is also a water supply aquifer. Areas where high quality aggregate resources exist will typically be an area of higher vulnerability to contamination from any land use, whether extraction occurs or not. As a result there will typically be concerns with respect to source water protection for any land use in a an area of high vulnerability. The issues for source water protection, as related to the aggregate industry, encompass three basic components:

- the physical impacts of the actual extraction and processing of aggregate;
- the potential impacts of aggregate extraction on the changes to aquifer vulnerability and the ability to protect source water; and,
- the potential future land use in areas where there have been potential changes to the aquifer vulnerability.

These basic components are reflected in the five concerns presented by the Source Water Protection Implementation Committee. A discussion of each of the five concerns is presented below.

Concern 1) Removal of material, which reduces the amount of filtering material above a groundwater source; and

Concern 2) Exposing the water table, allowing for easier introduction/migration of surface pollutants

These concerns are similar and are combined together for discussion purposes. The most unique aspect of the aggregate industry, compared to other industries is the extraction process itself where there is a removal of geologic material from the physical system. With the loss of soils and some or all of the unsaturated zone, as a result of aggregate extraction, there is increased exposure of the shallow groundwater system to contaminants from ground surface in particular increased microbial (bacteria, viruses or pathogens) contamination. There will also be a decreased time of travel for any potential surface source of microbial contamination, from the area where aggregate extraction has occurred, to a drinking water supply. There is no evidence to suggest that microbial contamination is an issue within the aggregate industry, as there were no documented cases of microbial contamination from an aggregate extraction operation. It is the potential for contamination from surface run off and increased atmospheric exposure of the water table that is the issue. The major concern, with respect to source water protection, is the length of time that bacteria or pathogens can survive in the groundwater system and potential time of travel to a drinking water source from the source of contamination.

The Technical Experts Committee (TEC) which prepared the document *Watershed-Based Source Protection Planning,* November 2004, had a pathogen subcommittee to develop a strategy to protect drinking water sources from disease-causing microbial contaminants from a public health perspective. The Committee conducted an extensive scientific literature review and assessment of experience and approaches in other jurisdictions. A discussion paper was presented within the TEC report. The report indicated that there are many factors that affect the retention time and survival of bacteria and viruses in soil, including but not limited to: moisture content, moisture holding capacity, temperature, organic matter, soil properties, soil depth, filtration capability and microbe physiology.

Recommendations for source protection for municipal wells included:

- A two-year Time of Travel (TOT) pathogen zone will be delineated for all municipal drinking water wells. For wells that are determined to be of low/moderate vulnerability land use practices within the 2-year TOT will be managed and monitored to prevent any additional activity that could increase the risk of pathogen contamination. For wells that are determined to be highly vulnerable, land use practices within the 2 year TOT would be managed to eliminate, where practical, or restrict any activity which is contributing to the risk of pathogen contamination.

- Within the 2-year TOT, there will be a 100 metre radius prohibition zone where the most stringent restrictions on activities and practices related to pathogens sources will be applied.

The main issue, with respect to the aggregate industry, is the impact of removal of the soil zone and additional aggregate material from above the water table. Although the aggregate industry does not “generate” pathogens, some of factors that could affect survival and retention time of pathogens have will be altered with aggregate extraction. The impact of this alteration will be variable. Each setting will be different, but consideration should be given to:

- the travel times from an aggregate operation to a source of drinking water;

- surface water runoff from outside areas of active aggregate extraction into an active aggregate operation or un-rehabilitated area; and,

- post-extraction land use with the potential to increase pathogen risks in areas of higher aquifer vulnerability if there are drinking water sources within a two-year Time of Travel of the extraction operation.

The issue is similar for the potential migration of hydrocarbons (e.g. gasoline, diesel fuel) if the soils zone is removed, at least temporarily, reducing the opportunity for natural biodegradation of hydrocarbons. Controls are in place to properly handle and store fuels on-site and the literature search did not indicate there were water quality issues as a result of fuel spills. Consideration should be given however, to the aquifer vulnerability of an aggregate extraction site and potential travel times to any adjacent drinking water source when locating fuel storage and re-fuelling areas.

Concern 3) Potential loss of water quantity as a result of existing aggregate operations (i.e. Permit to Take Water)

Extracting the aggregate resource does not mean that recharge function of the resource will be lost. There may be a minor modification to the flow system or water balance, but that does not necessarily mean there will be a negative impact. The actual extraction of the resource has minimal impact on the overall aquifer water balance. Certain operational approaches could impact the water balance, if not mitigated. Findings of the literature review indicated the following:

- Water quantity impacts to drinking water supplies are highly unlikely from passive (i.e. non-pumping) aggregate extraction. Impacts from quarry dewatering pose the greatest potential risk to quantity impacts for groundwater supplies, however water taking is usually well-regulated through a permitting and monitoring process and a sudden catastrophic impact, although possible, is unlikely. A case history review proposed for the Phase II work will provide a more detailed assessment of areas most sensitive to site-specific impacts and possible methods to mitigate these impacts

- Water quantity impacts to aquatic and terrestrial features, which are much more sensitive to minor changes in flow or discharge compared to drinking water supplies, are much more likely to be impacted, depending on site-specific conditions. Detailed investigation protocols are required to develop appropriate controls, monitoring programs and mitigation alternatives. Potential impacts are more likely to occur when extraction takes place within or near groundwater discharge areas, adjacent to surface water features. The scale of a potential impact will depend on factors such as the thickness of the aquifer, depth of excavation relative to the aquifer thickness, and scale of the operation. Considerable legislation exists and there are many controls in place that address these concerns as discussed in Section 5.2

Concern 4) Risk of importation of contaminated or deleterious fill to rehabilitate closed sites.

The literature search revealed that this is a major concern throughout the world. The major concern is water quality impacts from after use either through regulated or unregulated waste disposal or fill. Historically, old gravel pits were often used for waste disposal. Although not necessarily an aggregate activity, it is a major concern for source water protection as these areas are classified as waste disposal sites rather than gravel pits. There are several documented cases of groundwater quality issues as a result of illegal dumping. Most of these are the result of water wells within close proximity to the former gravel pit, and were often impacted private residential wells. From a source water protection issue, the concern would be controlling illegal dumping in both un-regulated sites and regulated sites without adequate security controls. This is potentially an issue anywhere but is more of an issue in gravel pits.

Current controls and legislation will minimize any risk of importation of contaminated or deleterious fill at sites to be closed in the future. The greatest risk is unregulated or illegal dumping in closed or abandoned sites with limited control on access. Assessment of the potential for these sites to impact water quality of drinking water aquifers would aid in determining the level of risk these sites pose. This is a separate issue from the closure of active sites.

Concern 5) Activities within an existing extraction site which may introduce potential risks to source water (i.e. asphalt recycling, on-site storage of fuel).

A review of source water protection elsewhere and general discussion in the literature indicate that there are two areas of concern, with respect to potential risks at an existing aggregate operation, being regular operational activities and ancillary usage of the site.

Operational Activities

There were no easily found documented cases or discussions of documented cases of significant water quality impacts in the literature from any form of operational activity, as related to municipal drinking water supplies. Any documents reviewed, where surveys were conducted or discussed did not indicate any major instances of contamination from normal aggregate operations. Comments were made in several publications that having no documented instances of water quality impacts from aggregate operations could also be due to lack of monitoring. Although there are no apparent documented cases of water quality impacts as a result of normal aggregate operations, this will be further addressed through a more detailed case histories assessment (Phase II), as discussed in Section 8.

Ancillary Uses

Concerns from ancillary uses such as asphalt plants are often raised. Although these industrial uses are a potential risk to water quality there was little documented evidence of actual water quality impacts as a result of these activities. Whether there are increased risks to water quality as a result of these uses is a data gap that can be addressed in Phase II work, in reviewing case histories as discussed in Section 8

8.0 future research needs/data Gaps

Future studies related to source water protection and the aggregate industry can be divided into two components, the scientific research needs and data gaps.

8.1 *Future Scientific Research Needs*

The common concern/issue regarding source water protection and the aggregate industry typically cited throughout the world is the loss of “filtering” material and/or direct exposure of the water table (from below table extraction) to potential contamination from a surface source. Technically, it should be described as loss of “attenuative” capability rather than filtering as the soil and active bacteria in the soil will do more than filter out contaminants. Since areas of aggregate extraction are typically also areas of higher aquifer vulnerability, due to the physical nature of the geologic deposit, source water protection is a concern for any land use. As indicated in Section 7, the removal of the active soil zone and at least a portion of the underlying unsaturated zone is relatively unique to the aggregate industry. Although this can occur to varying degrees with any land development, aggregate extraction usually takes place over a longer time, so there is an increased vulnerability for a longer time. The impact of this removal on the attenuative capability of the site, with respect to the rate and mobility of pathogens and degradation of hydrocarbons was beyond the scope of this phase of study. The impact of this removal of material should be addressed to determine whether it has any implications for source water protection, as related to time of travel within the aquifer.

The exposure of the groundwater zone to the atmosphere and surface water will result in a mixing of water that will alter the water quality of the downgradient groundwater the extent and type of impact was not fully assessed during this study. It is expected that there are other areas in the scientific literature that will have documented studies of this type that were not evident in the “aggregate” literature.

The following areas of further scientific research assessments in the literature are recommended. If there is limited information available site-specific research projects may be necessary:

1) Assessment of the impact of loss of some or all of the attenuative zone within a gravel extraction site on the fate, persistence and mobility of pathogens. In particular, does this loss affect the fate, mobility and persistence of pathogens such that there is an increase the length of time of survival of certain pathogens. The findings could result in more conservative setbacks (i.e. two-year Time of Travel) for aggregate extraction near drinking water supplies in the same aquifer. The findings could also result in additional regulation of future land use controls within the area of aggregate extraction.

2) Assess the potential impact of loss of the attenuative soil zone and unsaturated zone with respect to the migration of petroleum products. The primary water quality issue cited for aggregate extraction is the potential for spills of petroleum products and the greater risk of ground water contamination due to the attenuative loss of surficial soils and geologic material. There was no direct evidence in the literature of this being an actual contaminant issue at aggregate extraction sites. However it is not likely to be cited in scientific literature as being directly related to aggregate extraction. There will however, be well documented research related to the behaviour of hydrocarbons in the soil zone, the unsaturated zone and within the groundwater flow system. A literature review of research related to the natural attenuation of hydrocarbons should be conducted, as related to the specific issue of concern in the aggregate industry. This will also be addressed in Case History reviews in Phase II.

3) Assess the potential modification of water quality of groundwater in contact with gravel pit lakes or ponds. The mixing of pond water with groundwater has been the focus of studies related to species diversification within gravel pit ponds and quarries. There has been some documentation in the literature with respect to gravel pit ponds altering groundwater quality, primarily related to nutrient issues. The interaction of lake/pond water with groundwater should be assessed within wetlands/aquatic literature in the context of below water aggregate extraction to determine if there are any water quality issues of concern related to source water protection.

8.2 *Data Gaps/Case History Research*

As discussed throughout the report, there is little evidence of known water quality impacts related to operational aspects of aggregate extraction on municipal drinking water supplies or municipal aquifers. Where there are findings of an impact, there are typically other contributing factors, often sources of contamination from other land use activities which existed regardless of aggregate extraction activities.

Much of the information necessary to assess the impact of aggregate extraction on groundwater and surface water will be found in case histories or regulatory files (e.g. MOE water quality interference files and MNR site license monitoring programs). There is a considerable volume of data within the files of regulatory agencies that would provide a greater understanding of the magnitude of problems or issues related to aggregate extraction and source water protection. As part of this study a request was made to review some of these files, however access could not be arranged with the timeframe of this study and there are potential concerns with privacy issues.

The literature search also showed many situations where illegal dumping occurred in abandoned or unregulated gravel pits or quarries. There were also a number of documents that showed no evidence of impact on water quality from aggregate extraction. This was qualified in some cases by saying that perhaps impacts were not found because of lack of monitoring. Case histories where monitoring has been conducted will aid in determining what issues are important in developing an appropriate source water protection program. It could also be important to follow up on contentious applications that were presented at the Ontario Municipal Board (OMB). Applications that were approved and have been in operation for a number of years may provide insight into whether concerns or issues did in fact arise, and if so did mitigation work, are they relevant to source water protection etc?

The following information should be collected in Phase II of the research study, as part of the Case History Research. Much of this information can be used to either supplement the findings of phase or provide documentation to address some of the data gaps or perceived data gaps from the Phase I investigation. The following is recommended:

1) Review MOE well interference files from regional offices to determine the extent of well interference complaints from aggregate extraction, whether interference has occurred on a municipal drinking water supply, and if so what were the factors that caused the interference. This should be divided into sand and gravel extraction and quarrying, due to the different operational factors.

2) Review MOE water quality interference files from regional MOE offices to determine the extent and type of quality interference complaints that have occurred related to aggregate extraction activities.

3) Obtain MNR documentation on existing pits and quarries with respect to location and type of operation and cross-reference with locations of capture zones or well head protection areas, if possible, from existing groundwater management studies in the province (e.g. How many active gravel pits and quarries are in fact within capture zones of municipal wells?). From this data, identify and review any case histories of gravel pits or quarries in Ontario that are within close proximity (e.g. 5-year capture zone) to municipal water supplies. This information will provide a “reality check” on the potential extent and magnitude of water issues and aggregate extraction.

4) Review documentation on abandoned pits and quarries, in particular locations and current land use. This could be done through the Management of Abandoned Aggregate Properties (MAAP) Program. Due to the potential scale of this investigation it is proposed that several areas should be selected for pilot projects to determine the level of effort required to conduct this study. Based on the findings, a larger scale assessment may be necessary. Pilot areas could be selected from different parts of the province to determine whether there are any existing issues with respect to abandoned pits and

quarries, are they with capture zones of municipal wells, do they create an increased risk to the water quality of drinking water aquifers, are further investigations or controls required? Depending on the findings, a larger scale study may be conducted.

5) Review results of monitoring programs required for site licences. Not every property will have a monitoring program however there are many sites where substantial groundwater and surface water monitoring is conducted. Annual reports are filed with MNR. However there is no apparent data base that would summarize whether there are impacts occurring, if so how they occurred, how they were mitigated etc. Alternatively there are many sites where data has been collected and show no apparent change in water level, water quality, stream flow etc. It would be important capture this information as part of the case history research. This would aid in determining sites or settings that are most sensitive to specific operational conditions or not sensitive. Specific areas should be proposed for pilot studies in consultation with the committee. Areas of different geologic settings and types of aggregate operations should be selected.

6) Review and document the long-term results of aggregate applications that were contentious and the approval of the application was determined at the Ontario Municipal Board (OMB).

Appendix A

Documented References

Bibliography

Reference #1

Drew, L.J., W.H. Langer and J.S. Sachs, 2002. Environmentalism and Natural Aggregate mining. *Natural Resources Research*, Vol. 11, No. 1.

Reference #2

Piispanen, R. and T. Nykyri, 1997. Acidification of Groundwater in Water-filled Gravel Pits – a New Environmental and Geomedical Threat. *Environmental Geochemistry and Health*, Volume 19, 111-126.

Reference #3

Pulido-Bosch, et al., 2000. Intensive Agriculture, Wetlands, Quarries and Water Management. A case study (Campo de Dalias, SE Spain). *Environmental Geology*, Volume 40 (1-2), 163 -168.

Reference #4

Mayes, W.M., A.R.G. Large and P.L. Younger, 2005. The Impact of Pumped Water from a De-watered Magnesium Limestone Quarry on an Adjacent Wetland: Thrislington, County Durham, UK. *Environmental Pollution*, Volume 138, 443-454.

Reference #5

Green, J.A., J.A. Pavlish, R.G. Merritt and J.L. Leete, 2005. Hydraulic Impacts of Quarries and Gravel pits, Minnesota Department of Natural Resources, Division of Waters.
http://www.dnr.state.mn.us/publications/waters/quarries_impacts.html

Reference #6

Pulido-Bosch, A., J.M. Calaforra, P. Pulido-Leboeuf and S. Torres-Garcia, 2004. Impact of quarrying gypsum in a semi desert karstic area (Sorbas, SE Spain). *Environmental Geology*, Volume 46, 583-590.

Reference #7

Larsson, K.P., 2003. Soil Management Strategies to Establish Vegetation and Groundwater Recharge when Restoring Gravel Pits. *KTH Land and Water Resource Engineering.* 18pp.

Reference #8

Sander, A, 1996. The Impact of Gravel Extraction on Groundwater. *ISBN 91-620-4570-9*. 120pp.

Reference #9

Arnold, L.R., W.H. Langer and S.S. Paschke, 2003. Analytical and Numerical Simulation of the Steady-state Hydrologic Effects of Mining Aggregate in Hypothetical Sand-and-Gravel and

Fractured Crystalline-rock Aquifers. *USGS Water Resources Investigations Report 02-4267*, 56pp.

Reference #10

Hatva, T., 1994. Effect of Gravel Extraction on Groundwater. *IAHS Publication no. 222, Proceedings of the Helsinki Conference.*

Reference #11

Gandy, C.J., P.L. Younger, J. Henstock, T. Gill, and D. Wardrop, 2004. The Hydrogeological Behaviour of Flooded Sand and Gravel pits and its Implications for the Functioning of the Enclosing Aquifers. *Hydrogeochemical Engineering Research and Outreach (HERO), University of Newcastle Upon Tyne.* 46pp.

Reference #12

Eberts, S.M. and E.S. Bair, 1990. Simulated Effects of Quarry Dewatering Near a Municipal Well Field. *Ground Water 28(1)*, 37-47.

Reference #13

Gambolati, G., and G. Galeati, 1990. Analysis of Hydrologic Impact of Quarrying Systems by a 3-D Finite Element Model. *Journal of Hydraulic Engineering, 116(11)*, 1368-1402.

Reference #14

Castro, J.M. and J.N. Moore, 2000. Pit Lakes: Their Characteristics and Potential for Remediation. *Environmental Geology, 39(11)*, 1254-1260.

Reference #15

Shope, S.B., Potential Impacts of Below Water Table Sand and Gravel Mining Operations on Groundwater Quantity (publication source unknown).

Reference #16

Townley, L.R., and M.G. Trefry, 2000. Surface Water-ground Water Interaction Near Shallow Circular Lakes: Flow Geometry in Three Dimensions. *Water Resources Research 36(4)*, 935-948.

Reference #17

Jansen, J., W.P. Fassbender, P. Jurcek, L.L. Barreto and L.F. Boyer, 1999. A Rapid Drawdown Event Related to Quarry Operations in a Dolomite Aquifer. *Groundwater Management and Research*, 110-114.

Reference #18

Treskatis, C., 1999. Hydraulic and Hydrochemical Influence of Gravel Pit Lakes on Groundwater Protection Zones. *International Association of Hydrogeologists, XXIX Conference, Hydrogeology and Land Use Management.*

Reference #19

Morgan-Jones, M., S. Bennett, and J.V. Kinsella, 1984. The Hydrological Effects of Gravel Winning in an Area West of London, United Kingdom. *Ground Water, 22(2),* 154-161.

Reference #20

Streetly, M., 1998. Dewatering and Environmental Monitoring for the Extractive Industry. *Quarterly Journal of Engineering Geology*, *Volume 31*, 125-127.

Reference #21

Hobbs, S.L., and J. Gunn., 1998. The hydrogeological Effect of Quarrying in Karstified Limestone: Options for Prediction and mitigation. *Quarterly Journal of Engineering Geology*, *Volume 31*, 147-157.

Reference #22

Lolcama, J.L., A. Cohen and J. Tonkin. Deep Karst Conduits, Flooding, and Sinkholes: Lessons for the Aggregate Industry.

Reference #23

Ostrander, M.D., R. Blackport, P.J. Martin, and M. Picotti, 1998. Impact of Aggregate Extraction Activities on Cold Water Discharge and Water Table Drawdown. Symposium on Groundwater in a Watershed Context, Burlington, Ontario, Canada, December 1998.

Reference #24

Beatty Franz and Associates Limited, January, 1997. Groundwater Modelling for Reid's Heritage Homes, Township of Puslinch.

Reference #25

Nielson, K.A., 2000. Folgevirkninger af Rastofgraning under Grundvandsspejlet. *Chalmers Tekniska Hogskola*, Miljoprojekt Nr. 526.

Reference #26

Blackport, B., and C. Portt, 2002. A Functional Analysis of the Impact of Aggregate Extraction on Groundwater and Fish Populations in Mill and MacCrimmon Creeks, *Fisheries and Oceans Canada.*

Reference #27

S.S. Papadopulos & Associates, 2004. Analyses of the Potential Effects of Aggregate Extraction Operations on Water Resources in the Cedar Creek Subwatershed.

Reference #28
Van Ham, M., K. Lee and B. Maclean, Pit to Park: Gravel Mine Reclamation Using biosolids, unknown publication source
http://www.gvrd.bc.ca/nutrifor/pdfs/PittoPark.pdf

Reference #29
National Gravel Extraction Policy, 2005. National Marine Fisheries Service a Division of the US Government National Ocean and Atmospheric Administration
http://www.nmfs.noaa.gov/habitat/habitatprotection/pdf/anadfish/(05-06-10)%20FINAL%20GRAVEL%20GUIDANCE.pdf

Reference #30
Resource Extraction Management Practices for Non-point Source Water Pollution Prevention in New York State, April 1995. Prepared by NYS Department of Environmental Conservation.
http://nysl.nysed.gov/Archimages/3575.PDF

Reference #31
William H. Langer, 2002. A General Overview of the Technology of In-Stream Mining of Sand and Gravel Resources, Associated Potential Environmental Impacts, and Methods to Control Potential Impacts. USGS Open File Report OF-02-153
http://pubs.usgs.gov/of/2002/ofr-02-153

Reference #32
Five Year Status Report on the Borrow Pit Program, 1998. Maine Department of Environmental Protection
http://www.maine.gov/dep/blwq/docstand/ims98rep.doc

Reference #33
McDowell W. H., T J. Chestnut, 2002. Final Report to DES and NH State Legislature, June 1998 – November 2001, Monitoring Demonstration at a Top-Soil Manufacturing Site in New Hampshire.
http://www.wrrc.unh.edu/pubs/reports/rr64.pdf

Reference #34
John A. Welhan, 2001. Ground-Water Interactions near the Highway Pond Gravel Pit, Pocatell, Idaho, Idaho Geological Survey, Staff Report 01-3

http://www.idahogeology.org/Services/Hydrogeology/PortneufGroundWaterGuardian/my_drinking_water/hwypond/report/IGSstaff_report01_03.pdf

Reference #35
Urbanc, M., M Breg., 2005. Gravel Plains In Urban Areas: Gravel Pits As An Element of Degraded Landscapes, Acta geographica Slovenica, 45-2, 2005, 35-61
http://www.zrc-sazu.si/giam/03_AGS_45-2_UrbancBreg.pdf

Reference #36
Steve Blodgett, 2004. Environmental Impacts of Aggregate and Stone Mining: New Mexico Case Study, Center for Science in Public Participation, New Mexico
http://www.csp2.org/REPORTS/Environmental%20Impacts%20of%20Sand%20and%20Gravel%20Operations%20in%20New%20Mexico.doc.pdf

Reference #37
Reeve, M. J., F. W. Heaven, N.A. Duncan, 2000. Evaluation of Mineral Sites Restored to Agriculture, Land Research Associates
http://www.defra.gov.uk/environ/landuse/restore/

Reference #38
Pacific Groundwater Group, 1999. Document Summaries and Areas of Further Investigation Maury Island Gravel Mining Impact Studies, Department of Ecology, Washington State
http://www.ecy.wa.gov/pubs/9929.pdf
http://www.ecy.wa.gov/pubs/992039.pdf

Reference #39
Lisa Guenther, 2003. Development of Aquatic Communities in Aggregate Ponds in Southern Ontario, M.Sc. Thesis, University of Guelph.

Reference #40
ALJ Ruling for Southern Dutchess Sand and Gravel Inc., April 2005. New York State Department of Environmental Conservation
http://www.dec.state.ny.us/website/ohms/decis/southerndutchessr.html

Reference #41
Senes Consultants Limited, 1989. Aggregate Industry MISA Preregulation Monitoring Program Results, prepared for the Aggregate Producers Association of Ontario.

Reference #42

Golder and Associates, 2005. Mill Creek Annual Cumulative Impact Assessment – 2004 Township of Puslinch Ontario

Reference #43
Nyholm, T., S. Christensen and K.R. Rasmussen. 2002. Flow depletion in a small stream caused by groundwater abstraction from wells. *Ground Water 40(4)*, 425-437.

Reference #44
Chen, X., and L. Shu. 2002. Stream-aquifer interactions: Evaluation of depletion volume and residual effects from groundwater pumping. *Ground Water 40(3)*, 284-290.

Reference #45
Acreman, M.C., at al. 2000. Does Groundwater Abstraction Cause Degradation of Rivers and Wetlands? *J.CIWE, 14,* 200-206.

“Source Water” Protection and Related References

General Web site USEPA:
http://www.epa.gov/safewater/source/contacts.html
Lists state source water protection sites

Reference SW1
City of Astoria – Oregon – Source Water Assessment Summary Brochure PWS00055_Astoria - PD
http://www.deq.state.or.us/wq/dwp/SWAReports/PWS00055_Astoria.pdf

Reference SW2
EU Countries Legislation on Mining Waste (Annex No. 7)
http://europa.eu.int/comm/environment/waste/studies/mining/mining_annexes.pdf

Reference SW3
William H. Langer, 2002, Managing and Protecting Aggregate Resources, USGS, Open File Report 02-415
http://pubs.usgs.gov/of/2002/ofr-02-415/ofr-02-415_508.pdf

Reference SW4
van der Moolen, Bert, and Ian Wilson, 2003. Towards a New European Coastal Mineral Aggregates Planning Regime, European Journal of Spatial Development.
http://www.nordregio.se/EJSD/article1.pdf

Reference SW5
The Groundwater Regulations 1998: Code of Practice on Mineral Extraction, Scotland
http://www.scotland.gov.uk/library5/environment/tgwr.pdf

Reference SW5A
Scottish Water and Environment Services Act – 2003, Scotland
http://www.opsi.gov.uk/legislation/scotland/acts2003/20030003.htm

Reference SW5B
Groundwater Protection Policy for Scotland
http://www.sepa.org.uk/pdf/policies/19.pdf

Reference SW6
Policy and Practice for the Protection of Groundwater in Northern Ireland, Environment and Heritage Service, Department of the Environment, Northern Ireland
http://www.ehsni.gov.uk/pubs/publications/Policy_and_Practice_for_the_Protection_of_Groundwater_in_Northern_Ireland.pdf

Reference SW7
Issue Paper: Sand and Gravel Mining, May 20, 1997. Kitsap County, Washington State
http://www.kpud.org/reference/docs/kc_groundwater/sandgrav.pdf

Reference SW8
Macdonald, Ian, Eric Hodgins, February 2004. Assessment of Aggregate Resources and Groundwater Protection Background report No. 2 Final, Regional Municipality of Waterloo
http://www.region.waterloo.on.ca/web/region.nsf/0/30BE9624B64CC0F68525706D0055EE14/$file/BG2.pdf?openelement

References SW8a-e
Region of Waterloo General Water Protection web site
http://www.region.waterloo.on.ca/web/region.nsf/0/30BE9624B64CC0F68525706D0055EE14

Reference SW9
Groundwater Quality Protection Strategies, Fraser River Action Plan. Environment Canada, prepared by Golder Associates
http://www.rem.sfu.ca/FRAP/gqpp.pdf

Reference SW10

Securing a Safe Supply, The Development of a Water Protection Policy for the County of Oxford, County of Oxford, Ontario, June 2003.
http://new.county.oxford.on.ca/Portals/_county/WaterPolicy/Securing_A_Safe_Supply%5B1%5D.pdf

Reference SW11

Dakota County 2020 Environment and Natural Resource Management Policy Plan, Dakota County, Minnesota, October 1999.
http://www.co.dakota.mn.us/planning/pdf/compplan/6EnvNatural.pdf

Reference SW12

Michigan Source Water Assessment Program, 1999
http://www.deq.state.mi.us/documents/deq-wb-swpu-swipp-guidance.pdf

Reference SW12a

http://www.michigan.gov/documents/DEQ-swap99_4707_7.pdf

Reference SW12b

http://www.deq.state.mi.us/documents/deq-wb-dwehs-wpu-swapfinalreport.pdf

Reference SW13

New York State Source Water Assessment Program Plan, New York State Department of Health, November, 1999
http://www.health.state.ny.us/nysdoh/water/swapp.pdf

Reference SW14

Zoning Ordinance of the City of Dover, New Hampshire, Chapter 170, Dover, New Hampshire, contains Sections 170-28.3 Groundwater Protection and 170-29 Extraction Industries
http://www.ci.dover.nh.us/Archives/Code/ch170.pdf

Reference SW15

A Template for Preparing Wellhead Protection Plans for Municipal Well, Wisconsin Department of Natural Resources, July 2000.
http://www.dnr.state.wi.us/org/water/dwg/gw/pubs/planning.pdf

Reference SW16

Replacement Nottinghamshire Mineral Local Plan, Nottinghamshire County Council, Nottinghamshire, England, Revised Deposit, May 2003 http://www.nottinghamshire.gov.uk/home/environment/planningmatters/mineralsandwasteplanning/mineralslocalplan/revisedminlp.htm

Reference SW17

Council Directive 80/68/EEC - Protection of Groundwater Against Pollution Caused by Certain Dangerous Substances, December 1979 – Council of European Communities
http://europa.eu.int/eur-lex/lex/LexUriServ/LexUriServ.do?uri=CELEX:31980L0068:EN:HTML

Reference SW17a

Update to Reference SW17, 1995
http://europa.eu.int/eur-lex/lex/LexUriServ/LexUriServ.do?uri=CELEX:31995Y0228(01):EN:HTML

Reference SW19

Promoting Sustainable Development in the EU Non-energy extractive industry, Communication from the European Union, 2000
http://europa.eu.int/eur-lex/lex/LexUriServ/site/en/com/2000/com2000_0265en01.pdf

Reference SW20

Developing a Municipal Source Water Protection Plan: A Guide for Water Utilities and Municipalities – Step 3 Identify Potential Contaminants and Assess Risk – Department of Environment and Labour, Nova Scotia,
http://www.gov.ns.ca/enla/water/docs/WaterProtectionPlanStep3.pdf

Reference SW21

Additional Information Requirements for Mining and Mineral extraction Projects, Mineral Branch, Department of Natural Resources, New Brunswick, 2004
http://www.gnb.ca/0009/0377/0002/0001/0012-e.pdf

Reference SW22

Idaho Ground Water Quality Rule, IDAPA 58, Title 01, Chapter 11, Board of Environmental Quality, State of Idaho, 2005
http://adm.idaho.gov/adminrules/rules/idapa58/0111.pdf

Reference SW23

MINEO – User Need Document, Part 4 - Overview of the European Union environmental legislation in mining
http://www.brgm.fr/mineo/UserNeed/MINEO_mining%20legislation.pdf

Reference SW24

Controlling and Mitigating the Environmental Effects of Mineral Extraction in England, Mines Policy Statement #2 (MPS2), Office of the Deputy Prime Minister, London, England, March 2005
http://www.planninghelp.org.uk/NR/rdonlyres/F30D2011-A67F-4877-BA30-E17585943A1C/0/MPS2.pdf

Reference SW25
Minerals Planning Policy Wales, December, 2000
http://www.wales.gov.uk/subiplanning/content/minerals/minerals-e.pdf

Reference SW26
West Virginia Source Water Assessment and Wellhead Protection Program, West Virginia Department of Health and Human Resources
http://www.wvdhhr.org/bph/SWAP

Reference SW27
Drinking Water Protection Program, Department of Environmental Quality, Louisiana
http://www.deq.louisiana.gov/portal/Default.aspx?tabid=1743

Reference SW28
Wellhead Protection, EPB 299, Environmental Protection Branch, Saskatchewan Environment, September 2004
http://www.se.gov.sk.ca/environment/protection/water/EPB%20299%20-%20Wellhead%20Protection.pdf

Reference SW29
Source water Assessment Program, Potential Susceptibility Assessment of a Mississippi River Source of Public Drinking Water, Louisiana Department of Environmental Quality, 2000
http://www.deq.louisiana.gov/portal/Portals/0/evaluation/aeps/swap/Miss_River_SWAP_Initial_Susceptibility_Report.pdf

Reference SW29A
http://www.deq.louisiana.gov/portal/Portals/0/evaluation/aeps/swap/appv-gw.pdf

Reference SW30
Steady Brook Watershed Management Plan – prepared by Debbie Hearn, Western Newfoundland Model Forest, in collaboration with the Newfoundland Department of Environment and Conservation and Department of Natural Resources, for Steady Brook Newfoundland, September 2005

http://www.wnmf.com/main/whatsnew/sb%20watershed/steady%20brook%20watershed%20plan.pdf

Reference SW31
Management of Protected Water Supply Areas – Department of Environment and Conservation, Government of Newfoundland Labrador, March 2004
http://www.env.gov.nl.ca/env/Env/waterres/Surfacewater/Watershed_Protection/Designation_Process_Booklet_Mar26_2004.pdf

Reference SW31A
Newfoundland Water Resources Act
http://www.hoa.gov.nl.ca/hoa/statutes/w04-01.htm
http://www.env.gov.nl.ca/Env/env/waterres/Policies/PDWR95-01.asp

Reference SW32
Minerals Task Force, related to minerals lands designations and locations of asphalt plants, Thurston County, Washington State, June 8, 2004
http://www.co.thurston.wa.us/permitting/Mineral_Lands_Task_Force/MLTF_Notes/Task_Force_Meeting_Notes_2004_06_08.pdf

Reference SW33
A Guide to New Brunswick's Watershed Protected Area Designation Order, Department of the Environment, New Brunswick
http://www.gnb.ca/0009/0371/0004/watershed-e.pdf

Reference SW34
Protecting Sources of Municipal Drinking Water – An Overview of New Brunswick's Wellfield Protection Program, Department of the Environment, New Brunswick
http://www.gnb.ca/0009/0371/0001/Wellfield-E.pdf

Reference SW35
Potential Sources of Drinking Water Contamination Index – U.S. Environmental Protection Agency
http://www.epa.gov/safewater/swp/sources1.html

Reference SW35A
State-Federal Source Water Assessment and Protection Program Measures – Final Reporting Guidance, March 2005, U.S. EPA
http://www.epa.gov/safewater/protect/pdfs/guidance_swp-measures.pdf

Reference SW36
Source Water Assessment Plan Implementation of The Safe Drinking Water Act 1996 Amendments, Oregon State, 1996
http://www.deq.state.or.us/wq/dwp/SWAPCover.htm

Reference SW36A
Contaminant Source Inventory, Oregon Department of Environmental Quality and Oregon Health Division, February 2000, State of Oregon
http://www.deq.state.or.us/wq/dwp/SWAP/SWAPSec5.pdf

Reference SW37
City of Dayton, Ohio Zoning Code, Chapter 150, Zoning Code, 2004, Dayton Ohio
http://www.ci.dayton.oh.us/planning/Documents/CurrentZoningCode.pdf

Reference SW37A
Model Well Field Protection Zoning, Miami Valley Regional Planning Commission, Dayton, Ohio, April 2003 http://www.mvrpc.org/pdf/env/modelWellFieldProtectionOrd2003.pdf

Reference SW38
Environment Protection (Water Quality) Policy, South Australia, 2003
http://www.epa.sa.gov.au/pdfs/epwq_policy.pdf

Reference SW39
Environmental Objectives and Best Management practices for aggregate Extraction, 2002, Ministry of Water, Land and Air Protection, Vancouver Island Region, British Columbia
http://wlapwww.gov.bc.ca/vir/pa/aggregate.pdf

Reference SW40
Final Report, Panel Review of British Columbia's Drinking Water Protection Act, February 13, 2002, Drinking Water Review Panel
http://www.hlth.gov.bc.ca/protect/pdf/dwrp_final.pdf

Reference SW41
Swedish Environmental Objectives – Interim Targets and Action Strategies
http://www.regeringen.se/content/1/c4/11/97/2aa978ad.pdf

Reference SW42
Environmental Quality Objectives, Sweden – A Good Built Environment, Gravel Extraction
http://www.sgu.se/sgu/en/miljo/miljomal/bebyggd_niv2_e.html
http://www.sgu.se/sgu/en/naturresurs/grukro_e.html

APPENDIX B

Source Water Protection Summaries

Canadian Examples

Source water protection and the approach to source water protection has been evolving over the last fifteen years. Ontario has been developing a framework for source water protection over the last three years, as discussed in Section 1.1. Other jurisdictions in Canada have developed source water protection programs. The following section summarizes a number of the Canadian examples, at the provincial level and at the County, Township or municipal level. Not all municipal source water protection programs are included in this review. The literature search typically found the programs that are on websites and are a higher "profile". It was our finding that most of these higher profile programs are typically more comprehensive than the "hard to find" programs, by the nature of the issues, level of effort and assessment completed for these programs. The following Canadian examples are presented for discussion purposes.

Most provinces have water protection or water management plans. There is typically limited information in the provincial plans related to source water protection and aggregate extraction or overall mining/mineral extraction. The following examples highlight the findings and level of detail at the provincial level.

Provincial Examples

Nova Scotia - A document prepared by the Nova Scotia Department of Environment and Labour entitled "*Developing a Municipal Source Water Protection Plan: A Guide for Water Utilities and Municipalities*" (**Reference SW20**) highlights the following:

In Step 3 - *Identify Potential Contaminants and Assess Risk* for land uses and their relative risk to source water five risk categories were presented from lowest risk (1) to greatest risk (5). "Quarries" were included in Category 4. To put this into perspective, Category 4 also included, agricultural production: dairy, livestock, nurseries, orchards; golf courses; and high density housing: lots smaller than 0.5 acre. The table below shows the land use and the relative risk to source water.

Assessing Risk To Source Water

Land Uses and their Relative Risk to Source Water

Least risk

1. Land surrounding reservoir/well, owned by water utility/municipality
2. Permanent open space dedicated to passive recreation
3. Woodlands and managed forests

1. Field crops: pasture, hay, grains, vegetables
2. Low-density residential: lots greater than 2 acres
3. Churches, municipal buildings

1. Institutional uses
2. Medium-density residential: 0.5 to 1.0 acre lot sizes
3. Commercial uses with limited hazardous material storage or underground chemical or fuel storage

1. Agricultural production: dairy, livestock, nurseries, orchards,
2. Golf courses, quarries
3. High-density housing: lots smaller than 0.5 acre

1. Retail commercial: gasoline, farm equipment, automotive, dry cleaners, photo labs, machine shops, furniture strippers
2. Industrial: all forms of manufacturing and processing
3. Underground chemical and fuel storage
4. Waste disposal: pits, dumps, ponds, lagoons, landfills

Greatest risk

Saskatchewan Environment presents a document entitled "*Wellhead Protection*" (**Reference SW28**), dated September 2004. Potential sources of contamination were listed in the document and relevant potential sources are listed in the table below. No specific references were made to aggregate operations other than a potential source of contaminants was "unattended wet and dry excavation sites". Naturally occurring sources from rock and water were listed as well as mining and mining wastes related to coal, metallic ores phosphate and gypsum. Asphalt plants were listed indicating petroleum derivatives as the contaminant.

Appendix A
Potential Sources of Groundwater Contamination

Source	*Health, Environmental or Aesthetic Contaminant*
Industrial Sources (B)	
Material stockpiles (coal, metallic ores, phosphates, gypsum)	Acid drainage; other hazardous and nonhazardous wastes
Waste tailing ponds (commonly for the disposal of mining wastes)	Acids; metals; dissolved solids; radioactive ores; other hazardous and nonhazardous wastes
Unattended wet and dry excavation sites (unregulated dumps)	A wide range of substances; solid and liquid wastes; oil-field brines; spent acids from steel mill operations; snow removal piles containing large amounts of salt
Mining operations (surface and underground)	Mine spoils or tailings that often contain metals; acids; highly corrosive mineralized waters; metal sulfides
Unsealed abandoned mines used as waste pits	Metals; acids; minerals; sulfides; other hazardous and nonhazardous chemicals
Asphalt plants	Petroleum derivatives

Newfoundland, Department of Environment and Conservation (DEC) released a document in March 2004 (**Reference SW31**) entitled "*Management of Protected Water Supply Areas*". Many of Newfoundland's public water supplies are surface water supplies. Protected water supply areas are developed under the Water Resources Act, through applications to the DEC. Existing resource development activities such as aggregate extraction may be permitted to continue in designated areas if these activities do not impair water quality. Section 39 of the Water Resources act details activities prohibited from protected public water supply areas. Sections relevant to aggregate extraction include:

> **ACTIVITIES NOT PERMITTED IN A DESIGNATED AREA**
>
> 6.9 Activities, operations or facilities associated with aggregate extraction and mineral exploration such as work camps, vehicle parking and maintenance facilities, washing of aggregates, asphalt plants, discharge or deposit of waste material into a body of water, and significant disturbance to land for mineral exploration purposes.

ACTIVITIES REGULATED IN A DESIGNATED AREA

7.6 Mineral exploration related activities and aggregate extraction, or any other construction activity incidental to mining and quarrying including access roads, stream crossings, land drainage with adequate treatment, land clearing and excavation.

New Brunswick has divided its protection programs into watershed and wellhead protection areas as there is considerable surface water supply usage from several major watersheds. An overview of wellhead protection areas is presented in a document (**Reference SW34**) entitled "*Protecting Sources of Municipal Drinking Water: An overview of New Brunswick Well Field Protection Programs*" dated March 2005. An overview to protection of watersheds is presented in a document (**Reference SW33**) entitled "*A Guide to New Brunswick's Watershed Protected Area Designation Order*"

Watershed protected areas have three distinct zones, the water course itself (Area A), a 75-m setback zone (Area B) and the remainder of the watershed's drainage area (Area C).

No activities are permitted as related to aggregate extraction in areas A and B. Aggregate extraction is permitted outside the 75-m area, but the only process allowed within the designated watershed protection area is crushing. Any washing or grading must be performed beyond the designated watershed area.

Wellhead protection areas are also divided into three zones, primarily based on travel times. Zone A is the closest zone and all forms of contamination are a concern, but pathogens are a significant concern due to the short travel time to the wellhead. Zone B is still a concern for solvents, pesticides etc, while zone C is the remainder of the capture area. There appears to be no restrictions specifically related to aggregate extraction in any zone within a wellhead protection area, other than typical restrictions related to impairment of water quality or water use as part of other environmental legislation. Concerns are more related to the type of contaminant present.

Beyond the designations in the water protection programs, there are "*Additional Information Requirements for Mining and Mineral Extraction Projects*" (**Reference SW21**) as part of New Brunswick's *Environmental Impact Assessment Regulation*. Requirements include: full documentation of all plans (e.g. waste generated, location an storage of chemicals and fuels, containment of site runoff, erosion controls, dewatering techniques); environmental assessment (e.g. hydrological and hydrogeological conditions, fisheries resources); summary of potential environmental impacts; and a summary of proposed mitigation (e.g. monitoring programs, groundwater and surface water protection methods and spill proof chemical storage areas).

British Columbia appears to have focused on drinking water protection rather than source water protection. The *Drinking Water Protection* act was passed in April 2001. In 2003 the *Drinking Water Protection Regulation* was passed and in 2005 the *Groundwater Protection Regulation* was passed. Much of the focus of these acts was related to proper drilling and installation of wells, licensing of drillers, water operators etc. and development of wellhead protection zones. There was little discussion with respect to threats assessment or contaminant sources inventories. Aggregate extraction, in the context of source water protection is controlled through the Ministry of Water Land and Air Protection. A document (**Reference SW39**) entitled "*Environmental Objectives and Best Management Practices for Aggregate Extraction*" addresses aggregate extraction as related to source water protection through the following:

> ***Water Resources***
>
> ***2.3.2 Surface Water***
> *If the water supply for the proposed mine is to be from a surface water source such as a river, creek, lake or spring, then the long-term reliability of that supply should be certified by a qualified professional engineer or hydrologist. The engineer or hydrologist should be a member of the Association of Professional Engineers and Geoscientists of British Columbia, and have experience in surface water hydrology and water supply engineering.*
>
> *It is important that the hydrology report confirm that there is an adequate water supply available for the proposed mining operation without adversely affecting downstream fish habitat or other water users. This may be critical in August and September when flow rates are low. Pump hoses must be screened to prevent impacts to small fish and other aquatic organisms. If possible, water used in the mining operation should be recycled.*
>
> ***A licence pursuant to the Water Act is required for the storage, diversion and use of surface water.***
>
> *Explosives handling and utilization should be conducted in a manner, which minimizes the opportunity for nitrate and blasting residue contamination of site runoff, adjacent watercourses and groundwater.*
>
> ***2.3.3 Groundwater***

Although a licence is not required for the use of groundwater, it is important that the long-term quality and quantity of groundwater be protected to maintain fish habitat and potable water supplies of adjacent property owners. MWLAP recommends that a hydrogeologic impact study be conducted by a qualified engineer or geoscientist to assess potential impacts of pit or quarry developments on the wells of adjacent properties or any nearby surface water bodies. To prevent impacts to wells and streams, it is important that pits are designed and operated in a manner that does not cause or require lowering of the water table. At most sand and gravel sites, the Ministry of Energy and Mines will only permit mining to within one metre of the annual high water table to prevent unacceptable impacts to groundwater quality and available

Fuel Handling and Spill Containment

To reduce the adverse environmental impacts associated with fuel spills, MWLAP recommends that:

- *no permanent fuel storage facility be constructed on the mine site;*
- *tanks of limited capacity (under 600 litres) be used to refuel equipment in the pit, but should not be used for permanent storage;*
- *refueling of equipment not be done within or adjacent to any of the established environmental buffers or within 50 metres of any pit drainage structures;*
- *a spill contingency plan to deal with any spills of fuel, oil, lubricants or hydraulic fluids be developed in accordance with the BC guidelines for industrial emergency response contingency plans (BC Ministry of Environment, Lands and Parks, 1992);*
- *an emergency spill containment kit should be maintained on site whenever the pit is in operation;*
- *the operator must immediately contain, report and remediate any spill of hydrocarbon or other deleterious substances. Contaminated materials shall be disposed of in a manner acceptable to the Regional Pollution Prevention Manager;*
- *stationary engines and related drive mechanisms be provided with drip pans;*
- *stormwater from parking and service areas should be passed through an oil/water separator prior to disposal at an approved discharge.*

SITE REHABILITATION

Before the start of aggregate extraction the proponent must submit a site reclamation plan and receive approval from the Ministry of Energy and Mines. Consideration should be given to the most appropriate use of the site following mining. Careful and thorough site assessment and planning before extraction are critical to successful rehabilitation. Several key factors must be assessed in advance. These include deposit *and overburden characteristics, water availability, adjacent land uses and local planning policies. Often the rehabilitation of the former mine site for wildlife habitat is the most appropriate use. Progressive rehabilitation may be beneficial in such cases.*

Case History Examples-Canada - Local zoning related to aggregate extraction

Most of the relevant examples, providing details with respect to specific land use controls or issues is at the local planning scale. The following relevant Canadian examples are presented to provide a perspective on the issue of source water protection and aggregate extraction.

Newfoundland Case History - Town of Steady Brook, Steady Brook Watershed Management Plan (Reference SW30)

The Town of Steady Brook developed a Watershed Management Plan, that was to act a template for other watershed management plans in Newfoundland, completed in September 2005. Drinking water is obtained from a surface water source. A management plan was developed through identification of risks and potential threats to the water supply and the watershed area contributing to the water supply.

Mining, including quarrying, was identified as a potential risk to water supply, due to risk of fuel spills and the contribution of sediment and nutrients to the water supply. The priority ranking for potential threats to water quality listed quarrying/mining as a medium risk for petroleum products, a high risk for sediments and a low risk for nutrients, as shown on the tables below

Table 7. Potential contaminants from existing and possible watershed uses.

Watershed Use/Activity	Potential Contaminant	Cause
Drinking Water	Chlorination by-products	Chlorination
Natural Occurrences	Chlorination by-products	Natural organic loading
	Sediment	Increased Streamflow
	E. coli, coliforms, Giardia	Wildlife
Snowmaking	Sediment	Increased volume of water required stirs up sediment
Forestry	Sediment	Forest cover removal (Domestic and Commercial)
		Construction and use of logging roads
	Nutrients	Forest cover removal (Domestic and Commercial)
	Petroleum products	Fuel spills or leaks
	Chlorination by-products from organic loading	Forest cover removal (Domestic and Commercial)
		Construction and use of logging roads
Transmission Lines	Petroleum products	Line Maintenance
		Vegetation Maintenance
	Sediment	Line Maintenance
		Vegetation Maintenance
	Toxins	Chromate copper arsenate treated utility poles
Recreation/Tourism	Sediment	Motorized vehicle use
	Petroleum products	Motorized vehicle use
		Fuel storage at cabins
	E. coli, coliforms, Giardia	Cabin pit privies
		Human-related activities
Mining and Quarrying	Sediment	Mineral exploration, mining and quarrying activities
	Nutrients	Vegetation Removal
	Petroleum products	Mineral exploration, mining and quarrying activities

Table 8. Priority ranking for potential threats to water quality.

Potential Contaminant	Severity of Risk	Potential Cause	Probability of Occurrence	Priority Rank
Pathogenic Microbes (E. Coli, Coliforms, Giardia)	Catastrophic	Pit Privies	Medium[3]	High
		Cabins (Swimming)	Low	Medium
		Wildlife	High	High
		Camping	Low	Medium
Chlorination By-Products (THMs, HAAs)	Critical	Domestic Cutting	Low	Medium
		Commercial Harvesting	Medium	Medium
		Forest Road Construction/Use	Low	Medium
		Natural Organic Loading	Medium	Medium
		Treatment (Chlorine)	N/A[3]	N/A[3]
Toxins (Arsenic) (Pesticides)	Critical	Utility Line CCA Poles	Low	Medium
		Forest Protection	N/A[4]	N/A[4]
		Silviculture	N/A[4]	N/A[4]
Petroleum Products	Moderate	Motorized Vehicle Use [1]	High	Medium
		Camping & Recreation [2]	Low	Low
		Domestic Cutting	Medium	Medium
		Cabins (Fuel Storage)	Low	Low
		Commercial Harvesting	Medium	Medium
		Forest Road Construction/Use	Medium	Medium
		Utility Line Structure Maint.	Low	Low
		Utility Line Vegetation Maint.	Medium	Medium
		Silviculture	Low	Very Low
		Mineral Exploration	Low	Very Low
		Quarrying / Mining	Medium	Medium
		Aircraft	Very Low	Very Low
Sediments	Moderate	Motorized Vehicle Use [1]	High	Medium
		Domestic Cutting	Low	Low
		Commercial Harvesting	High	Medium
		Forest Road Construction/Use	High	Medium
		Utility Line Structure Maint.	Low	Low
		Utility Line Vegetation Maint.	Low	Low
		Mineral Exploration	Low	Low
		Quarrying / Mining	High	Medium
		Snowmaking	High	Medium
		Increased Streamflow	High	Medium
		Forest Fire	Medium	Medium
Nutrients	Minor	Commercial Harvesting	Medium	Low
		Domestic Cutting	Very Low	Very Low
		Mineral Exploration	Very Low	Very Low
		Quarrying and Mining	Low	Very Low
		Forest Fire	Medium	Low
Salt	Minor	*No Cause at Present*	N/A	N/A

[1] Includes ATV, snowmobile and motorized boats
[2] Includes animal watch, berry picking, bird hunting, bird watching, canoeing, skiing, fishing, hiking, hunting, mountain biking, rare plants, sight seeing, snaring, snowshoeing, trapping, and wood gathering.
[3] Based on existing distances from pit privies to water; if 30 metres is achieved, probability can be reduced to low.
[3] The amount of chlorine added to the drinking water cannot be controlled by watershed protection practices.
[4] The application of pesticides and toxic fire retardants are not permitted in a public water supply area.

Region of Waterloo

The Region of Waterloo initiated a Water Resource Protection Strategy in 1994 to minimize the impact of land use on municipal water supplies. The Region of waterloo probably has conducted the most extensive source water protection documentation, related to aggregate extraction, of any documentation reviewed. A study was completed in 2004 as part of a Provincial Water Protection Fund Project, entitled "*Assessment of Aggregate Resources and Groundwater Protection – Background Report No. 2 – Final*" (**Reference SW8**). Companion documents include a draft report entitled "*Development Principles for Aggregate Policies for Water Supply Protection*" (**Reference SW8c**), "*Aggregate Policies and Study Guidelines for Water Supply Protection*" (**Reference SW8b**) and appendices including a "*Draft Guidelines for Hydrogeological studies for Proposed Mineral Aggregate Resource Extraction Project*s" (**Reference SW8a**). These documents were reviewed and contained substantial background information similar to the source water protection review conducted for this study. Companion work conducted by the Region included a pilot modelling project (**Reference SW27**) assessing individual impacts and cumulative impacts of aggregate extraction in a watershed within the Region of Waterloo, undergoing aggregate extraction pressures. Of note however is that many of the scenarios modelled in the study were hypothetical extreme case scenarios, which would not be typical in an Ontario setting. Some of the guidelines draft guidelines developed used this information and it may be prudent to assess the Region's work more closely. The Region has one unusual gravel extraction operation, which is located near the Grand River and dewaters the excavation at very high pumping rates. Shallow river wells are located near the dewatering operation and this appears to have raised concerns about aggregate extraction and the impact on groundwater supply. No scientific assessments or reviews were conducted as part of the Region's assessment.

The draft guideline for hydrogeological studies follows a similar format to studies required under the ARA described in the previous section. The following excerpt highlights the policy development for the Region of Waterloo (**Reference SW8b**):

> ***POLICIES***
> ***Guiding Principles for Policy Development***
> *The development of policies and guidelines to assess the impact of aggregate extraction activities on drinking water source areas recognizes that the majority of issues associated with aggregate extraction (a list of potential impacts is provided in Table 1) will be unique to the individual extraction pit. For example, potential impacts to private wells will depend on several factors including the distance from the pit to the well and the geologic setting. Because of this localized impact, the*

approach to developing groundwater protection protocols for aggregate extraction (outside of very sensitive groundwater protection areas) will focus on ensuring that sufficient studies are undertaken to support the change in land use being requested. This approach will build on the hydrogeologic study guidelines accompanying the Aggregate Resources Act. In addition, the following guiding principles were used to develop these policies and guidelines.

1. The closer an aggregate operation is to a municipal water supply, the greater the chances of impact to that supply.
2. The potential for cumulative impacts to water resources increases as the number of aggregate operations within a geographic area increases.

While not specifically addressed in this policy framework, the approach to assessing impacts to municipal drinking water intakes from surface water should also be done through investigation. In general, the assessment would have to consider the size and/or volume of surface water potentially affected by extraction activities since the impacts are primarily related to a change in water budget. At this time it is not feasible to develop a framework to assess the impact to surface water intakes as the assessment/protection criteria for these intakes has not been established as part of the source water protection planning process being developed by the MOE.

Close to Water Supply Wells
Policy:
New aggregate operations should not be allowed in Well Head Protection Sensitivity Areas (WPSA) 1 and 2; and
Any existing operations within Sensitivity Areas 1 and 2 will be encouraged to adopt beneficial management practices (BMPs).

Rationale:
Potential impacts from aggregate operations to municipal water supplies include interference by dewatering, increased vulnerability to spills during operation, increased vulnerability to microbial contamination through disturbance of the natural filtration capacity of the soil/sediments, and potential incompatibility of the post-extraction land uses and water supply activities. Preventing these land uses from locating adjacent to municipal supply wells provides a high level of protection to the supply wells, is based on the precautionary principle and uses the Region's current authority through the planning approval process.

These areas represent the most sensitive land area contributing water to the supply. Sensitivity 1 areas reflect the shortest travel time to the wells (two year time of travel), are delineated around supply wells that are more vulnerable to contamination and are critical to Region's water supply infrastructure. For some wells, Sensitivity 1 areas also represents the areas where the MOE is requiring the Region develop microbial protection plans to ensure that microbial contamination of the wells does not occur and that land activities do no t disturb the natural filtration capacity of the soil around the wells. These wells, which draw groundwater under the direct *influence of surface water, are considered by the MOE to be the most vulnerable type of municipal supply well. Sensitivity 2 areas surround Sensitivity 1 areas and represent slightly less vulnerable areas due to the greater time of travel to the well (ten years) or delineate the area immediately surrounding the well (two year time of travel) for deeper, less vulnerable supply wells. The potential overlap of aggregate operations with these wellhead areas is a total of approximately 17 km2 (1700 hectares) which represents approximately 10 percent of identified aggregate resources in Waterloo Region. Areas of overlap are shown in Figures 1 and 2.*

Adoption of beneficial management practices (BMPs) by existing operations will assist in reducing the potential that these activities will impact water supply. Examples of common aggregate industry BMPs were gathered by the Region as part of a previous project and are shown in Appendix A.

Outside Sensitive Wellhead Protection Sensitivity Areas

Policy:

New aggregate operations that are to be located outside of Sensitivity Areas 1 and 2 should complete a hydrogeological study to determine if the operations can proceed or if there are any site-specific limitations, management or monitoring required as part of the development approval; and

The studies should be undertaken using a staged approach whereby the first stage will reduce the amount of data to be collected, the subsequent evaluation, and limit the proponent's expenses where feasible and reasonable.

Rationale:

In areas that are further away from water supply intake areas, rigorous hydrogeologic assessments will be adequate to assess the impact of aggregate extraction activities. In some cases specific conditions for monitoring and/or management practices could be included as a condition of development. These studies would go beyond that currently required by the Aggregate Resources Act in terms of scope, the degree of detail required and applying them to above water table extraction approvals. The detailed requirements of the hydrogeological assessments are included in Appendix B. Overviews of the intent of each stage of study and the assessment to be required are summarized below.

Stage One Hydrogeological Study

The purpose of the Stage One study is to provide a preliminary evaluation of the potential impacts on groundwater and surface water resources. It will include collection of site location information, a comprehensive review of existing data, a door-to-door survey of existing groundwater users in the area and a limited field investigation. The guidelines will establish a minimum monitoring period and a protective buffer for establishing the water table that is used to assess the depth of extraction for above the water table extraction activities. This latter requirement is necessary to ensure that the depth of extraction incorporates seasonal water level highs and that water levels are representative of the water table during average precipitation levels.

The results of the Stage One study will be documented in an environmental assessment report. The report will also present a proposed monitoring program to monitor during the extraction period and during rehabilitation. The monitoring would consist of water level measurement, water quality sampling and submittal of annual to biannual reports. The monitoring should also include establishment of trigger levels to measure detrimental impacts and development of contingency plans to mitigate any impacts.

If the Stage One study concludes the site is suitable for aggregate extraction, and regulatory authorities agree, then a detailed Stage Two Hydrogeologic Study will not be required. If the report indicates the potential for impacts or the regulatory authorities disagree with the reports conclusions, then a Stage Two Hydrogeologic Study will be required. A Stage One study will only be used for applications above the water table and is not to be used for below water table extraction activities as the potential impact from these activities on water resources is greater.

Stage Two Hydrogeological Study

The Stage Two study will be undertaken under the following conditions:

- *The Stage One report indicates potential impact to the groundwater and/or surface water regimes*
- *The regulatory authority is not agreement with the conclusions of the report*
- *Proposed aggregate extraction is below the water table*
- *Existing above water table aggregate operation that extend operations below the water table*
- *Aggregate operations involving washing operations*
- *A Permit to Take Water is requested for the operations*

The Stage 2 report would have to show that the proposed operations would not cause any significant change in aquifer vulnerability or water balance. Aquifer vulnerability is a measure of the susceptibility or vulnerability of the aquifer to contamination from surface land uses and activities, and is primarily a function of the soil type and depth of geologic material above the water table.

All new operations should also be encouraged to implement BMPs as discussed for existing pits in Sensitivity Areas 1 and 2.

United States Examples

The United States Environmental Protection Agency (USEPA) is the lead agency on source water protection in the United States. They developed a source water protection guidance program requiring each state to follow the guidance program and develop state wide source protection programs and wellhead protection programs (Reference 35A). State source water assessments were required including among other things a threats assessment related to drinking water sources. The USEPA provides a "Potential sources of Drinking Water Contamination Index" (Reference 35). The list is intended as resource guide for creating an inventory list for potential source of contaminants and the type of contaminant potentially generated from each source. Potential contaminants listed by the USEPA are very extensive. The following sources are listed, which are relevant to the aggregate industry:

POTENTIAL SOURCE	CONTAMINANT
Commercial / Industrial	
Cement/Concrete Plants	Barium, Benzene, Dichloromethane or Methylene Chloride, Ethylbenzene, Lead, Styrene, Tetrachloroethylene or Perchlorethylene (Perc), Toluene, Xylene (Mixed Isomers)
Mines/Gravel Pits	Lead, Selenium, Sulfate, Tetrachloroethylene or Perchlorethylene (Perc), 1,1,1-Trichloroethane or Methyl Chloroform, Turbidity

To put the listing into perspective, public buildings and retail operations have more potential contaminants listed. Almost every potential source of contaminant from retail operations to machine shops and home manufacturing and virtually any commercial or industrial source lists tetrachloroethylene 1,1,1-trichloroethane and methyl chloroform as a potential contaminant. There was no additional information, at the national level, related to source water protection and aggregate extraction.

As indicated above, source water protection programs were developed for each state and included a threats assessment. The USEPA website lists links to each state source water protection program and wellhead protection program (**See Appendix A**). There was limited information with respect to source water protection and aggregate extraction for most states. Much of the information was general or generic, following the general USEPA guide. Many states developed their own guidelines for source water protection and required municipalities to develop their own source water protection program.

Several examples are presented below that do provide the typical level of detail and approach to the aggregate industry, or in a number of cases mining in general.

Michigan has developed a **"***Source Water Assessment Program*" (**Reference SW12**), through the Department of Environmental Quality, for both groundwater (wells) and surface water (surface water intakes). Michigan has a voluntary wellhead protection program (WHPP). Assessment of geologic sensitivity as well as threats and risk assessments are required. The state referred to the EPA list of potential sources of contamination. No specific information was presented beyond a standard data base search of known contaminant sources. The state recommends managing land use and wellhead protection at the local planning level.

West Virginia has developed a "*Source Water Assessment and Wellhead Protection Program*" (**Reference SW26**), through the Department of Health and Human Resources. They provide a list of potential contaminant sources and whether there is a high medium or low threat to groundwater and surface water. Gravel pits were listed as a low risk for both surface water and groundwater. Asphalt plants were listed as a medium threat to groundwater and a high threat to surface water.

Source Category	Source Name	Threat to Ground Water	Threat to Surface Water
Industrial	Asphalt plants	M	H
	Cement/concrete plants	M	M
	Gravel pits	L	L

Louisiana has developed a "*Source Water Assessment Program*" and a "*Potential Susceptibility Assessment of Mississippi River Source of Public Drinking Water*" (**Reference SW29**). There are numerous drinking water intakes along the Mississippi River and the river is a focus of source water protection. The state has listed potential sources of contamination to surface water and include sand and gravel pits and asphalt plants in the lower risk category. With respect to groundwater, sand and gravel pits are listed as a potential source of contamination with the contaminants of concern listed as being "creates a conduit from surface, surface runoff" (**Reference SW29a**).

New York State developed a "*Source Water Assessment Program Plan*" (**Reference SW13**), in 1999. The New York State program generally follows the EPA approach related to contaminants of concern, using the specific contaminants listed by the EPA. The only reference to quarries or gravel pits was related to an assessment of potential risk from different land cover types, for general contaminant categories. Quarries and pits are listed as having a low or negligible risk for all contaminant categories, as shown below.

Contaminant Category	Land Cover Types						
	Mixed Forest	Deciduous Forest	Woody Wetlands	Emergent Wetlands	Barren (Quarries, mines, pits)	Barren (Bare rock and sand)	Barren (Transitional, clearcut)
Halogenated Solvents	N	N	N	N	N	N	N
Petroleum Products	N	N	N	N	L	N (L)	N (L)
Pesticides/Herbicides	N	N	N	N	N	N	N
Other Industrial Organics	N	N	N	N	N	N	N
Metals	N	N	N	N	N	N	N
Nitrates	N	N	N	N	L	L	L
Phosphorus	N	N	N	N	N	N	N
Sediments/Turbidity	N	N	N	N	N	N	N
Protozoa	L	L	L	L	L	L	M
Enteric Bacteria	L	L	L	L	L	L	M
Enteric Viruses	L	L	L	L	L	L	M
Cations/Anions (Salts, Sulfate)	N	N	N	N	L	L	L
Industrial Radionuclides	N	N	N	N	N	N	N
Disinfection Byproduct Precursors	N	N	N	N	N	N	N (L)

Definitions:

Negligible (N): Land use type results in minimal, if any, presence of the contaminant category

Low (L): Land use type results in detections that are expected to be rare and, if detected, contaminant concentrations are expected to be below levels of concern for drinking water.

Medium (M): Land use type results in detections that are expected to be uncommon but, if detected, contaminant concentrations could be expected to be at or above levels of concern for drinking water.

High (H): Land use type results in detections that may occur frequently at levels of concern for drinking water.

Notes:
When two ratings are given, the rating in the parentheses "( )" is considered to reflect the worse case scenario, and the rating not in the parentheses is considered to be the more common situation.

Case History examples-United States – Local zoning related to aggregate extraction

Dayton, Ohio (**Reference SW37**)

Dayton, Ohio was one of the first cities in North America to develop groundwater protection measures in the mid 1980's, given concerns regarding the high vulnerability of the shallow groundwater supply. The water supply is comprised of approximately 100 urban well fields, primarily in shallow sand and gravel aquifers with limited natural protection. Well field protection was introduced in 1988 and has continued to evolve over time. The City created two "zoning districts". A Wellhead Operating District (WO) is present around wells owned by the City. A Wellhead Protection Overlay District (WP) is created to encompass lands within a well field protection area in which contaminants are reasonably likely to migrate to a municipal well, generally within a one-year time-of-travel. The following is taken from Dayton's current zoning requirements (**Reference SW37)** as related to aggregate extraction, within a well field protection overlay district:

WP WELL FIELD PROTECTION OVERLAY DISTRICT

§ 150.3232 CONDITIONAL USES.

(C) The excavation, extraction, mining, or processing of sand, gravel, and limestone from the earth for resale shall remain as conditional uses in the WP Well Field Protection Overlay District subject to Board of Zoning Appeals approval of an excavation and facilities plan that includes, but is not limited to:

(1) An existing site plan with topographic detail at two feet contour intervals, all planimetric information, depth to ground water and flood plain characteristics where applicable;

(2) The proposed extent and depth of excavation;

(3) Slope angle of excavation walls (any final slopes shall be at the angle of repose for the remaining material);

(4) Use and disposition of the spoil and/or overburden materials from the excavations including a landscaping and vegetation plan to stabilize any disturbed material;

(5) Surface drainage plan.

(a) Drainage into on-site excavations from proximate off-site transportation facilities such as roadways and roadbeds and off-site watercourses is prohibited unless the applicant provides a plan which otherwise protects the excavations from off-site waterborne regulated substances.

(b) The final on-site grading shall minimize all surface drainage into the excavations.

(6) A post-excavation and operation land use plan.

(7) A security plan (unauthorized access shall be strictly prohibited as long as any excavations remain on-site).

(D) The requirements of this section shall be in addition to any applicable regulations in this chapter.(Ord. 27788, passed 8-3-88; Ord. 29213-96, 5-15-96).

Dayton's Contaminant Hazard Potential Ranking, as classified by source, has a ranking from 1-9 with one being the lowest hazard and 9 being the greatest hazard. As shown below, sand and gravel and quarrying operations are considered a low risk, in the range of general farming.

SIC #	DESCRIPTION OF WASTE SOURCE	RATING*
1	AGRICULTURAL PRODUCTION - CROPS	1-2
2	AGRICULTURAL PRODUCTION - LIVESTOCK	
21	Livestock, except Dairy, Poultry and Animal Specialities	(5 for Feed
24	Dairy Farms	4
25	Poultry and Eggs	4
27	Animal Specialities	2-4
29	General Farms, Primarily Livestock	2
14	MINING AND QUARRYING ON NON-METALLIC MINERALS, EXCEPT FUELS	
141	Dimension Stone	2
142	Crushed and Broken Stone, including Rip Rap	2
144	Sand and Gravel	2
145	Clay, Ceramic, and Refactory Minerals	2-5
147	Chemicals and Fertilizer Mineral Mining	4-7
148	Nonmetalic Minerals Services	1-7
149	Miscellaneous Nonmetallic Minerals, Except Fuels	2-5

Kitsap county, Washington (**Reference SW7**)

Issues related to sand and gravel mining in Kitsap County, Washington State were presented in an excerpt in Section 3.2.1. The following is the Kitsap County's approach to controlling sand and gravel mining, to prevent adverse effects on groundwater quality, as presented in its final draft document in 1997 (**Reference SW7**). It is noted that the recommendations were not formalized by state agencies, but the County wanted to adopt them into the counties planning process. It is also noted that concerns were raised by the County regarding the lack of effectiveness of the regulatory programs due to staffing and funding constraints.

> *Ground water resource protection is the responsibility of the Department of Ecology (Ecology). Ecology's role in sand and gravel operations is at least twofold. First: Ecology has an opportunity for environmental review of a proposed project. Second:*

In the past several years, Ecology as a water quality authority has identified some best management practices (BMP's) for sand and gravel operations. Originally, Ecology planned to adopt BMP's as either guidelines or formal rules for industry to follow in order to comply with the requirements of chapter 173-200 WAC Water Quality Standards for Ground Waters of the State of Washington. Some of the BMP's first identified are:

- *For sites with a planned excavation depth lower than the ground water table, a detailed hydrologic report should be filed. The report may be a part of a complete EIS or an appendix to a SEPA check list.*
- *When mining activities are to be located in designated wellhead protection areas, special protection areas, sensitive aquifer areas, or principal recharge zones, an EIS should be considered.*
- *Mining activities located in designated wellhead areas or special protection areas identified under Ch. 173-200 WAC should be considered for a State Waste Discharge Permit by the regional office of the Department of Ecology. If Ecology determines specific protection measures should be required to protect water quality, they may be incorporated into the terms of the DNR operation permit or established as a separate permit administered by the regional office of Ecology.*
- *Where possible, mining sites should utilize internal drainage, in order to support continued ground water recharge and minimize off-site discharges.*
- *When ground water is exposed during the mining operation and the resulting impoundment is larger than three acres, ground water should be monitored for both water level (monthly) and water quality (quarterly to semi-annually) over the life of the operation. Water level and water quality monitoring should also be considered when depth to seasonal high water is reduced to five feet or less.*
- *Associated activities such as concrete, asphalt, and other industries located at sites described in 2 above, will be reviewed for State Waste Discharge Permits by Ecology.*
- *Associated activities such as concrete, asphalt, or other batch processing plants shall not be located immediately adjacent to exposed ground water.*
- *Truck and equipment wash runoff should be routed to an approved retention and treatment facility, equipped with an oil-water separator prior to its release to retention ponds.*
- *Fuel (oils) storage and handling facilities should be located some distance from the main sediment and wash water retention facility. All such facilities should be equipped with approved containment, monitoring, and collection systems. Fuel storage should be above ground. These sites should be lined and bermed with sufficient capacity to accommodate spills and leaks. Runoff from adjacent surfaces should be routed to a retention pond that can be monitored and cleaned in the event of a spill.*
- *All sites should maintain a fuels/hazardous waste management plan. The plan will be maintained by the operator and be available on the site at all times.*
- *At the closure of the site, after accidental spills, or at the request of DNR/Ecology, all contaminated material will be removed and disposed of with*

approved methods and at approved disposal sites. Contaminated material will not be used as fill at the site.

- *In general, impoundments of greater than three acres should not be filled. These sites should be stabilized as lakes and ponds and the surrounding area revegetated to ensure stability of the site. Future land use decisions should reflect increased ground water vulnerability at the site. Individual sites may be filled if it can be demonstrated that sufficient inert material can be obtained to serve as fill. Impoundments of less than three acres should not be filled if there is doubt as to the quality or supply of inert fill.*
- *Excavation pits should not be used as landfill disposal sites for unclassified or non-inert wastes. In general, municipal landfills are not an appropriate use for sand and gravel sites located over semi-confined and unconfined ground water.*
- *Pits with standing water that are slated to be filled may use only approved inert earth materials (native fill/overburden) to fill the area up to the high water table. The remaining fill should meet the conditions described in 12 and 13.*
- *Future land use should reflect the increased vulnerability of ground water at the site.*

After further evaluation, Ecology determined the above BMP'S, or modifications thereof, will not be formalized. Rather the water quality (both surface and ground waters) will be protected through the Emergency Waste Discharge General Permit Program (see chapter 173-226 WAC); or the standard individual National Pollutant Discharge Elimination System (NPDES) or state waste discharge permit systems. Some of the above BMP's (and possibly a few others) probably will be incorporated as conditions of the permits issued under the general permit program for surface mining which includes sand and gravel operations. This change of direction does not preclude DNR from using BMP's to encourage development of new mining and reclamation technologies designed to protect ground water. In Kitsap County, a new sand and gravel operation requires an Unclassified Use Permit (even for a site less than three acres). The application for permit triggers the SEPA process and also a public hearing process (Renee' Beam - personal communication, June, 1992). DNR normally give much weight to the local evaluation in its permit-decision process.

Gaps and Problems

Although not discussed above, there are several other laws and federal and State agencies that are peripherally involved in sand and gravel mining to some degree. For example, the State Department of Fisheries regulates mining in river channels as part of its Hydraulic Permit process under Chapter 75.20 RCW. DNR has proposed amendments to Chapter 78.44 RCW to clarify and tighten up the regulatory guidance in existing statutes, but they have not been passed by the Legislature. The proposed amendments are intended to clarify local vs. state authorities. For example, county government would have the authority to regulate mining operations such as truck traffic, public safety and noise; and could become the sole regulation of mine reclamation. The amendments would codify reclamation requirements and ensure the right of local government to regulate land use. However, according to DNR staff

(Personal communication. Norman, November 1992), the department does not intend to offer the amendments as an Agency-request bill during the 1993 Legislative session. The apparent low DNR priority (possibly not shared by dedicated staff) has precluded a push for stronger controls, and may indicate the department does not consider sand and gravel mines to be a significant threat to ground water.

Recommendations and Strategies

SG 1. Kitsap County, through its Department of Community Development, should utilize the draft BMPs in SEPA review of new sand and gravel mining proposals to assure adequate consideration has been given to ground water protection in the project design.

SG 2. Kitsap County and cities include a policy in their Comprehensive Plans which provides that land use of reclaimed sand and gravel mines be carefully evaluated because of the increased susceptibility of aquifers to contamination due to the mining activities.

SG 3. Encourage DNR to fully consider Ecology's draft BMPs to assure permits are conditioned, as they relate to operation and site-reclamation, to ensure ground water protection.

World Examples

The European Union (EU) has been developing a water protection framework over the last six years. The approach to source water protection is general due to the wide range of situations and issues for its member countries. The most prevalent issue in Europe is nitrate contamination from agriculture. A Groundwater Directive (80/68/EEC) was issued in 1980 by the European Commission aimed at controlling the discharge of substances to groundwater. An action programme was proposed for integrated groundwater protection and management (96/C355/01) in 1996 recognizing that groundwater resources are limited and need to be managed and protected. This was again followed up with a Water Policy Directive (2000/60/EC), to replace the Groundwater Directive, proposing an integrated approach to protection and management focusing on the quantity and quality of groundwater within a river basin context. This is to be integrated within a wider framework of environmental policies dealing with a full range of human activities. Member countries are required to develop groundwater protection and management plans, similar to the approach of USEPA and each state.

The Directive's requirements for each country include with respect to groundwater:

- The creation of management units for groundwater known as groundwater bodies and the classification of these bodies into either good or poor status dependent on quantity and chemical quality;
- To ensure that no deterioration in status occurs;
- To restore bodies of groundwater at poor status to good status where this is technically feasible and does not entail disproportionate cost;
- To prevent or limit the entry of pollutants to groundwater;
- To identify and reverse any significant and sustained upward trends of pollutants in groundwater;
- To introduce control regimes for abstraction and for diffuse sources liable tocause pollution;
- The drafting of a new groundwater directive concerned with pollution prevention.

There is also various legislation related to mining and the environment (**References SW2 and SW23**). Again, these are very broad based framework that member countries follow to develop specific legislation related to mining activities, protection of the environment, controls on mining waste etc. The only discussion found during the review, related to mining extraction at the EU level, was a "Communication from the Commission" entitled "*Promoting Sustainable Development in the EU non-Energy Extractive Industry*" (**Reference SW19**). The legacy of abandoned mine sites and unrestored quarries was discussed. The major concern was primarily acid mine drainage. The commission recommended conducting an inventory of abandoned sites and environmental problems and identification of corrective measures. No specific discussion of aggregate extraction was presented.

A search was conducted for aggregate extraction and source water protection in Europe at the Country level. The level of regulation and controls were highly variable. The following examples are presented as related to aggregate extraction and source water protection planning.

Northern Ireland has developed a "*Policy and Practice for the Protection of Groundwater in Northern Ireland*" (**Reference SW6**) through the Department of the Environment (Environment and Heritage Service Branch). Policies were developed to deal with groundwater taking (abstraction), waste disposal, interference, contaminated lands and other activities that could affect water quality. The following policies developed for Northern Ireland are of relevance to aggregate extraction and source water protection:

Interference with Aquifers and Groundwater

There are a variety of activities in which Environment and Heritage Service has a direct interest because such activities might impact on groundwater. These activities include:

- *quarrying, mining and gravel extraction both above and below the water table;*
- *construction of roads, railways, tunnels, etc.;*
- *landfill using low permeability liners and seals which might impede groundwater cross-flow; and*
- *borehole construction and borehole abandonment.*

4) Equivalent protection for water resources and the water environment will be sought from the physical disturbance of groundwater levels or impedance of groundwater flow as from that caused by groundwater abstraction.

In order to achieve a sustainable resource, Environment and Heritage Service will seek to protect existing abstractions and the quantity and quality of the groundwater using the planning process and other available powers unless mitigation measures have been satisfactorily applied.

5)Environment and Heritage Service will object to proposed mineral workings or engineered underground barriers which are likely to cause harm to the groundwater environment unless mitigation measures can be agreed through the planning process.

Proposed development in Source Protection Zones are of most concern, but so too is the removal of all or part of the unsaturated zone of an aquifer. The unsaturated zone may act to protect the groundwater by filtration of solids and the breakdown of pollutants by oxygenation and biological degradation. Proposed barriers to groundwater flow may cause the water table to rise or to divert groundwater flow, lead to surface flooding, or in the case of a groundwater cut-off, to the derogation of existing abstraction points.

6) Best practice is essential for the construction and backfilling of boreholes, tunnels, shafts and wells.

Improperly constructed or abandoned boreholes and shafts can act as preferential pathways for movement of contaminants from the surface to the water table or from one aquifer unit to another. Short-circuiting of the natural soil and drift/strata layers means that only minimal natural breakdown of the contaminant may occur leading to potentially greater impact on groundwater quality. With regard to mineral workings *and their potential impact on the water environment, particular attention will be given to issues and guidance detailed in the DETR document "Reducing the Effects of Surface Mineral Workings on the Water Environment - A Good Practice Guide" 1998.*

Scotland updated their "*Groundwater Protection Policy for Scotland*" in 2003 (**Reference SW5B**). A document was also found, entitled "*The Groundwater regulations 1998: Code of Practice on Mineral Extraction*" (**Reference SW5**). A section within the Groundwater Protection Policy entitled "*Engineering Including Mining and Quarrying*" deals with a variety of issues such as landfill engineering and remediation of contaminated lands, as well as mining and quarrying. The following is highlighted with respect to mining and quarrying:

H1.2 Threats to groundwater

H1.2.1 There are a variety of threats that engineering activities can pose to groundwater including:

The backfilling and storage of spoil materials from mines and quarries

H1.2.2 Exposure to the air changes the chemistry of some materials which may result in increased leaching of contaminants. For example, spoil removed from coal mines often produces ferruginous water after being exposed to the atmosphere. To prevent leachate from these materials from polluting surface waters and groundwaters the spoil materials need to be appropriately stored and backfilled.

Dewatering activities and the subsequent rebound of groundwater

H1.2.3 Engineering activities, especially mining and quarrying, often involve working below the natural groundwater table. Groundwater may therefore be abstracted in order to artificially lower the water table. This can result in a reduction in flow to dependent surface waters and terrestrial ecosystems as well as impacting other groundwater users.

H1.2.4 Once dewatering ceases, groundwater levels will generally recover to the original groundwater level. In the case of coal and some other metaliferous mining activities, contaminants such as iron and sulphate, can be 'flushed' into groundwater as the water table recovers. This can result in contamination of aquifers and the outbreak of contaminated minewaters at ground level causing pollution of surface waters.

Drilling and development of boreholes

H1.2.5 Inappropriate drilling and design of a borehole can create a preferential flow path for groundwater to flow between two previously separate groundwater units. In some cases, such as in contaminated land investigation and remediation, this can result in deterioration in the quality of previously uncontaminated groundwater.

Construction of below ground structures
H1.2.6 The creation of voids or the backfilling of materials into a void can result in a change to the permeability and porosity of the aquifer. The creation of below ground structures, for example the construction of a low permeability wall can cause an alteration to the groundwater flow direction and result in changes to the groundwater levels. This may impact on dependent surface water features and terrestrial ecosystems.

Drainage systems
H1.2.7 Large-scale drainage systems can result in alteration to the groundwater level or flow direction by the creation of preferential flow paths along which groundwater can easily flow. In some cases where this results in a reduction in groundwater levels this could impact on surface waters or other groundwater dependent features such as wetlands.

Use and storage of fuels and other substances
H1.2.9 The storage, use and transfer of chemicals, including hydrocarbons, from equipment used in engineering activities can have the potential to result in entry of List I substances to groundwater or pollution of groundwater by List II substances. Storage and transfer of chemicals is detailed in Section F of this policy.

Blasting and physical disturbance of the aquifer
H1.2.10 Engineering activities, including blasting, can cause geological instabilities. This can especially be an issue where old mine workings are present close to or under the site since these have the potential to collapse. If collapse occurs this can result in an alteration in groundwater flow, due to blockage of underground drainage channels, and in some cases causes problems such as the surface discharge of historically contaminated minewaters. Increased permeability may result from physical disturbance, including blasting.

Many of the issues associated with mining and quarrying in Scotland are related to coal mining rather than aggregate extraction. Issues are primarily related to water quality impacts from mine spoils or dewatering of surface mines. In the Code of Practice on Mineral Extraction (**Reference SW5**) list the greatest risk from mineral extraction as groundwater pollution from fuel and oils and from leaching of waste rock. A discussion of rock storage and backfilling focused on leaching from mine spoils and waste rock. Controls for fuel storage and use are in place at all mineral extraction sites. There is also the potential for impact from pumping of groundwater, altering flow paths. The only discussion related for the risks associated with sand and gravel mining stated:

"*The voids created by sand and gravel extraction are often below the water table and frequently fill with water due to the permeable nature of the rock strata. Sand and* *gravel extraction utilizes a series of such ponds to settle the fines out of the extracted sands and gravels. This is generally a closed loop system with the water used for washing percolating back into the rock. Assuming no additives are used, no pollutants should be introduced to the groundwater regime from this process.*"

APPENDIX C

Summary of References

1) Document Code	2) Document Rating	3) Publication Date
Reference #1	Low/Medium	2002

4) Document Title	5) Document Type
Environmentalism and Natural Aggregate Mining. *Natural Resources Research*, Vol. 11, No. 1.	Journal

6) Author(s)	7) Agency / Organization
Drew, L.J., W.H. Langer and J.S. Sachs.	USGS

8) Geographic Location
USA

9) How Was This Document Located
Library

10) Type of Study
Discussion Paper on aggregate mining

11) Activity Definition
Aggregate Mining Industry

12) Factors to Consider
N/A

13) Summary of Findings / Conclusions
Focuses on the balance between need and impact. Need is significant but people don't want impacts in their area. Singled out dust, noise and traffic. No mention of water based impacts. Proper rehabilitation of pits can provide ecological benefits however waste disposal in pits can cause significant impacts.

14) Relevance To Ontario

General discussion on the issues associated with aggregate extraction and the environment

1) Document Code	2) Document Rating	3) Publication Date
Reference #2	High	1997

4) Document Title	5) Document Type
Acidification of groundwater in water-filled gravel pits – a new environmental and geomedical threat. *Environmental Geochemistry and Health*, Volume 19, 111-126.	Journal

6) Author(s)	7) Agency / Organization
Piispanen, R. and T. Nykyri.	

8) Geographic Location
Finland

9) How Was This Document Located
Library

10) Type of Study
Site specific assessment of water quality impacts from gravel pit ponds

11) Activity Definition
Below water table gravel extraction

12) Factors to Consider
Located in a very acid rain environment, very young groundwater, in contact with rocks containing sulphides

13) Summary of Findings / Conclusions Gravel pit water in contact with underlying sulphide and jarasite bearing schists become quite acidic (pH 3.4). Gives rise to high concentrations of various metals within the gravel pit pond. Paper also notes an area outside of Ottawa where same situation exists.		
14) Relevance To Ontario Potentially relevant to some gravel pit locations overlying "shield" bedrock in eastern and northern Ontario.		
1) Document Code Reference #3	**2) Document Rating** Medium	**3) Publication Date** 2000
4) Document Title Intensive agriculture, wetlands, quarries and water management. A case study (Campo de Dalias, SE Spain). *Environmental Geology*, Volume 40 (1-2), 163 -168.		**5) Document Type** Journal
6) Author(s) Pulido-Bosch, et al.	**7) Agency / Organization**	
8) Geographic Location Spain		
9) How Was This Document Located Library		
10) Type of Study Site specific assessment		
11) Activity Definition Above and below water table gravel extraction		

12) Factors to Consider Location of the gravel pit ponds in the flow system, type of surrounding land use		
13) Summary of Findings / Conclusions Gravel pits are providing a means for increased artificial recharge to an underlying aquifer. In addition numerous gravel pits have become natural wetlands which subsequently became a protected feature. Other gravel pits are used to regulate flooding.		
14) Relevance To Ontario General issues related to water balance or flow alteration		
1) Document Code Reference #4	**2) Document Rating** Medium	**3) Publication Date** 2005
4) Document Title The impact of pumped water from a de-watered Magnesium limestone quarry on an adjacent wetland: Thrislington, County Durham, UK. *Environmental Pollution*, Volume 138, 443-454.		**5) Document Type** Journal
6) Author(s) Mayes, W.M., A.R.G. Large and P.L. Younger	**7) Agency / Organization**	
8) Geographic Location England		
9) How Was This Document Located Library		
10) Type of Study Case history		
11) Activity Definition Below water table quarrying in limestone.		

12)Factors to Consider Direct discharge of water to a wetland.
13)Summary of Findings / Conclusions Impacts of general discharge and process water from a limestone quarry on a wetland. Water exhibited a high pH (12.5), conductivity of 6000 and substantial sediment loading. Impacts could be mitigated through pre treatment.
14)Relevance To Ontario General dewatering of quarries, water quality issues would be unusual in Ontario

1) Document Code	2) Document Rating	3) Publication Date
Reference #5	Medium/High	2005

4) Document Title	5) Document Type
Hydraulic impacts of quarries and gravel pits, Minnesota Department of Natural Resources, Division of Waters.	State Publication

6) Author(s)	7) Agency / Organization
Green, J.A., J.A. Pavlish, R.G. Merritt and J.L. Leete	Minnesota State

8) Geographic Location
Minnesota

9) How Was This Document Located
Internet

10) Type of Study
Case histories, field monitoring of gravel pits and quarries

11) Activity Definition
Below water table pits and quarries.

12) Factors to Consider
Pumping versus non-pumping impacts, location within the flow system, proximity to discharge areas

13) Summary of Findings / Conclusions
Dewatering of quarries produces significant drawdown and flow modification in the local groundwater system. Monitoring did not exhibit any water level impacts from gravel pits. The pits were not dewatering. There were no impacts on local well water quality from quarry blasting. There was insufficient monitoring data to comment on thermal plumes.

14) Relevance To Ontario
Similar geologic settings

1) Document Code	2) Document Rating	3) Publication Date
Reference #6	Medium	2004

4) Document Title
Impact of quarrying gypsum in a semidesert karstic area (Sorbas, SE Spain). *Environmental Geology*, Volume 46, 583-590.

5) Document Type
Journal

6) Author(s)
Pulido-Bosch, A., J.M. Calaforra, P. Pulido-Leboeuf and S. Torres-Garcia

7) Agency / Organization

8) Geographic Location
Spain

9) How Was This Document Located
Library

10) Type of Study
Site specific assessment of a quarry

11) Activity Definition
Above and below water table quarrying/mining

12) Factors to Consider
Intensely karstified area with unique morphology and ecology, dry climatic

13) Summary of Findings / Conclusions
Significant changes to overall conduit drainage can occur resulting in impacts on spring discharge and surface flows. More of a focus on impacts on sensitive karst morphology and ecology.

14) Relevance To Ontario
Not the same type of karst in Ontario

1) Document Code	**2) Document Rating**	**3) Publication Date**
Reference #7	Medium/High	2003

4) Document Title	**5) Document Type**
Soil management strategies to establish vegetation and groundwater recharge when restoring gravel pits. *KTH Land and Water Resource Engineering.* 18pp.	PhD thesis

6) Author(s)	**7) Agency / Organization**
Larsson, K.P.	University

8) Geographic Location
Sweden

9) How Was This Document Located
Internet

10) Type of Study
Field investigation and laboratory studies of the physical properties of soil for gravel pit rehabilitation

11) Activity Definition
Loss of attenuative capabilities of soil zone and how to rehabilitate the soil to maintain the “purification” process in the soil.

12) Factors to Consider
Acid rain needs to be buffered by the soil in the Sweden setting. The natural water quality changes appear to be minor in the studies conducted. The stripping of and or modifying of soil in other land use changes would create similar types of impacts but the impacts could be greater in aggregate sites given the coarse nature of the material.

13) Summary of Findings / Conclusions General comments on the reduction in attenuation (biological and geochemical filter) of potential contaminants due to removal of soil layer and unsaturated zone. Provides for mitigation for above water table extraction.
14) Relevance To Ontario The changes in water quality may applicable in parts of northern Ontario, general discussions regarding water quality issues are of interest

1) Document Code Reference #8	**2) Document Rating** Medium	**3) Publication Date** 1996
4) Document Title The impact of gravel extraction on groundwater. *ISBN 91-620-4570-9*. 120pp.		**5) Document Type**
6) Author(s) Sander, A.	**7) Agency / Organization**	
8) Geographic Location EU		
9) How Was This Document Located Internet		
10) Type of Study Overview/discussion paper. A field and literature (1965-1996) survey. (The summary and Figure captions are the only text in English)		
11) Activity Definition Below water table gravel extraction		

12) Factors to Consider - existing nutrient levels and oxygen levels in the gravel pit pond - travel time or distance to a drinking water source
13) Summary of Findings / Conclusions General comments on the reduction in attenuation of potential contaminants due to removal of soil layer. Existence of pond can affect local groundwater quality depending on the depth of the pond and whether it is nutrient rich or nutrient poor and the corresponding oxygen levels. The potential impacts (which appear minor) will depend on the travel distance/time to a water intake.
14) Relevance To Ontario General discussions on the interaction of surface water ponds with the groundwater flow system

1) Document Code Reference #9	**2) Document Rating** Medium/High	**3) Publication Date** 2003
4) Document Title Analytical and numerical simulation of the steady-state hydrologic effects of mining aggregate in hypothetical sand-and-gravel and fractured crystalline-rock aquifers. *USGS Water Resources Investigations Report 02-4267*, 56pp.		**5) Document Type** Government publication
6) Author(s) Arnold, L.R., W.H. Langer and S.S. Paschke	**7) Agency / Organization** United States Geological Survey	
8) Geographic Location USA mid-west (Colorado)		
9) How Was This Document Located Internet		

10) Type of Study Predictive computer modeling
11) Activity Definition Below water table gravel extraction
12) Factors to Consider Precipitation is much less in areas being modeled. Models considered dewatering of extraction areas in all simulations. The initial conditions and boundary conditions were tailored to the typical operations in the Front Ranges of Colorado. Modeling can be complex depending on the hydrogeological setting.
13) Summary of Findings / Conclusions The radius of influence extended from 400 m to 4500 m for dewatering in fractured crystalline rock and sand and gravel respectively. Significantly, the effects of the existence of the water filled pits and the potential evaporative losses in this area were modeled and concluded to have little hydrological effect on the aquifer compared to the overall groundwater budget.
14) Relevance To Ontario Model conditions are site-specific but the minimal impact of evaporative losses in a semi arid climate is useful in assessing evaporative losses in a humid climate.

1) Document Code Reference #10	**2) Document Rating** Medium/High	**3) Publication Date** 1994
4) Document Title Effect of gravel extraction on groundwater. *IAHS Publication no. 222, Proceedings of the Helsinki Conference.*		**5) Document Type** Journal
6) Author(s) Hatva, T.	**7) Agency / Organization**	
8) Geographic Location Finland		

9) How Was This Document Located Library
10) Type of Study General discussion on potential impacts and site specific water sampling at extraction sites.
11) Activity Definition Post and operational gravel extraction above and below the water table.
12) Factors to Consider The existing groundwater quality within the aquifer.
13) Summary of Findings / Conclusions Changes in water chemistry are noted immediately below/adjacent to site for above the water table extraction as result of soil removal. Mitigation available post extraction. Water chemistry in pit lakes and adjacent aquifer is similar in most cases. Large ponds relative to the size of the aquifer (width and depth) can alter groundwater quality based on other site specific conditions including the existing quality of the inflow water. No detailed degraded water quality analysis is provided and no background controls. Reference is made to agricultural activities and dust control salts. Increased organic matter in the ponds and sulphates are more readily attributed to the actual pit ponds. Presents an increase in recharge.
14) Relevance To Ontario Similar physical factors to Ontario.

1) Document Code	**2) Document Rating**	**3) Publication Date**
Reference #11	Medium/High	2004
4) Document Title The hydrogeological behaviour of flooded sand and gravel pits and its implications for the functioning of the enclosing aquifers. *Hydrogeochemical Engineering Research and Outreach (HERO), University of Newcastle Upon Tyne*. 46pp.		**5) Document Type** University Publication

6) Author(s)	7) Agency / Organization
Gandy, C.J., P.L. Younger, J. Henstock, T. Gill, and D. Wardrop	University of Newcastle

8) Geographic Location
England

9) How Was This Document Located
Library

10) Type of Study
Literature review. Numerical modeling.

11) Activity Definition
Post extraction gravel pit lakes.

12) Factors to Consider
Literature review turned up very few papers, same as current study. Discussion related to the groundwater flow system modification focused more on pit blinding (introduction of low permeability fine grained layer to the pit bottom, through erosion and deposition). Discussion on modifications is basic. Modelling will be site specific to climate and setting.

13) Summary of Findings / Conclusions
No specific findings relating to modification of the various groundwater flow systems aside from field data showing pit lakes not acting as a flow through lake (higher water levels in lake compared to adjacent water table in aquifer) indicating potential impact from blinding. Minor reduction in recharge to aquifer. Chemistry inside and outside of lakes are very similar.

14) Relevance To Ontario
Similar physical factors to Ontario gravel pits relating to deposition of fine grained material.

1) Document Code	2) Document Rating	3) Publication Date
Reference #12	High	1990

4) Document Title	**5) Document Type**
Simulated Effects of Quarry Dewatering Near a Municipal Well Field. *Ground Water 28(1),* 37-47.	Journal

6) Author(s)	**7) Agency / Organization**
Eberts, S.M. and E.S. Bair	

8) Geographic Location
Ohio

9) How Was This Document Located
Library

10) Type of Study
Numerical modeling.

11) Activity Definition
Below water table extraction sand, gravel and limestone.

12) Factors to Consider
Substantial sources of contamination already exist in the area of the pits and quarries and municipal wells. Contaminant sources not related to aggregate activities.

13) Summary of Findings / Conclusions
Both dewatering and the cessation of dewatering can modify the flow system and water levels such that more leachate is produced from the existing contaminant sources and the wells capture zones potential capture contaminated water if the water levels rise into the contaminant sources after the cessation of pumping.

14) Relevance To Ontario
Limited – but does show the potential types of impacts with the cessation of pumping, if pumping or dewatering has be taking place for a long time

1) Document Code	2) Document Rating	3) Publication Date
Reference #13	High	1990

4) Document Title
Analysis of hydrologic impact of quarrying system by a 3-d finite element model. *Journal of Hydraulic Engineering, 116(11),* 1368-1402.

5) Document Type
Journal

6) Author(s)
Gambolati, G., and G. Galeati

7) Agency / Organization

8) Geographic Location
Italy

9) How Was This Document Located
Library

10) Type of Study
Numerical modelling.

11) Activity Definition
Below water table extraction.

12) Factors to Consider
Site specific hydrogeologic and climatic setting will be a factor in design and water table modification. Modelling for post extraction lakes.

13) Summary of Findings / Conclusions
Carrying out extraction in smaller pits as opposed to one large pit, locating the pits properly and preferential sealing of selective pit faces can prevent any significant modifications to the groundwater flow system.

14) Relevance To Ontario
Similar to Ostrander modelling (B15)

1) Document Code	**2) Document Rating**	**3) Publication Date**
Reference #14	High	2000

4) Document Title	**5) Document Type**
Pit lakes: their characteristics and potential for remediation. *Environmental Geology*, *39(11)*, 1254-1260.	Journal

6) Author(s)	**7) Agency / Organization**
Castro, J.M. and J.N. Moore	

8) Geographic Location
New Hampshire

9) How Was This Document Located
Library

10) Type of Study
Discussion paper.

11) Activity Definition
Below water table extraction, primarily related to open pit mines.

12) Factors to Consider
Not specifically aggregate extraction but should be consider where aggregate deposits are located in areas where metal bearing strata are located.

13) Summary of Findings / Conclusions
Pit lakes formed metal extraction sites particularly sulphide ores can lead to serious water quality problems (acidic, high levels of various metals). Various approaches to minimizing impacts are discussed including filling the mine quickly with water, mitigating waste piles
14) Relevance To Ontario
Extraction in Northern and Eastern Ontario.

1) Document Code	2) Document Rating	3) Publication Date
Reference #15	Medium/High	

4) Document Title	5) Document Type
Potential Impacts of Below water Table Sand and Gravel Mining Operations on Groundwater Quantity.	

6) Author(s)	7) Agency / Organization
Shope, S.B.	

8) Geographic Location
New Hampshire
9) How Was This Document Located
Internet
10) Type of Study
Site specific water budget analysis
11) Activity Definition
Above and below the water table extraction.

12) Factors to Consider Site specific to local topography and climate. Relatively small subcatchment. Does not take into account 3D flow system modifications resulting from ponds acting as a groundwater sink.
13) Summary of Findings / Conclusions 4% decrease (above the WT extraction) and 22% decrease (below wt extraction) in recharge for the extraction area, but did not take into account snowmelt. Much smaller % for the entire watershed (subcatchment) which is only 250 acres. If surface runoff is incorporated recharge will be maintained or increased depending on where the recharge is directed.
14) Relevance To Ontario Similar approach to water balance assessment as it is a similar climate setting.

<table>
<tr><td>1) Document Code
Reference #16</td><td>2) Document Rating
High</td><td colspan="2">3) Publication Date
2000</td></tr>
<tr><td colspan="3">4) Document Title
Surface water-ground water interaction near shallow circular lakes: Flow geometry in three dimensions. Water Resources Research 36(4), 935-948.</td><td>5) Document Type
Journal</td></tr>
<tr><td colspan="2">6) Author(s)
Townley, L.R., and M.G. Trefry</td><td colspan="2">7) Agency / Organization</td></tr>
<tr><td colspan="4">8) Geographic Location
General</td></tr>
<tr><td colspan="4">9) How Was This Document Located
Library</td></tr>
</table>

10) Type of Study Analytical and numerical modeling of hydraulic response of aquifer to various lake geometries.
11) Activity Definition Post extraction gravel pits below the water table.
12) Factors to Consider Can be applied to post-extraction lakes in common generic settings, looks at location within the groundwater flow system and the aquifer configuration.
13) Summary of Findings / Conclusions Capture zones of lakes (modification to the water table and 3-D flow field) are presented for various geometries and recharge scenarios. Most sensitive to aquifer thickness and recharge values and less sensitive to aquifer width.
14) Relevance To Ontario General findings related to location of a post-extraction lake within a groundwater flow system and aquifer system

1) Document Code Reference #17	**2) Document Rating** High	**3) Publication Date** 1999
4) Document Title A rapid drawdown event related to quarry operations in a dolomite aquifer. *Groundwater Management and Research*, 110-114.		**5) Document Type**
6) Author(s) Jansen, J., W.P. Fassbender, P. Jurcek, L.L. Barreto and L.F. Boyer	**7) Agency / Organization**	
8) Geographic Location Wisconsin		

9) How Was This Document Located Library
10) Type of Study Site specific data and discussion for the pumping of a quarry
11) Activity Definition Quarrying in a confined dolomite aquifer.
12) Factors to Consider Depressurization of a confined aquifer; critical failure mitigated; importance of characterization and monitoring
13) Summary of Findings / Conclusions Local water wells dropped 40 feet within hours when a boring 75 feet below the quarry floor hit a local fracture. Impacts noticed 4800 feet from quarry. Wells recovered within 9 days when the borehole was grouted up.
14) Relevance To Ontario Specific to potential impacts of aggregate extraction in areas of confined bedrock aquifers

1) Document Code Reference #18	**2) Document Rating** High	**3) Publication Date** 1999
4) Document Title Hydraulic and hydrochemical influence of gravel pit lakes on groundwater protection zones. *International Association of Hydrogeologists, XXIX Conference, Hydrogeology and Land Use Management.*		**5) Document Type**

6) Author(s)	7) Agency / Organization
Treskatis, C.	

8) Geographic Location
West Germany

9) How Was This Document Located
Library

10) Type of Study
Site specific data and discussion related to a number of gravel pits and municipal wells in close proximity, within the same shallow aquifer

11) Activity Definition
Below water table aggregate extraction in a number of gravel pits

12) Factors to Consider
Municipal wells adjacent to pits; pits within cone of capture; heavy agriculture leading to poor water quality independent of the pits.

13) Summary of Findings / Conclusions
Shallow unconfined municipal water supplies immediately adjacent to 20+ gravel pits have been impacted by nitrates, change in groundwater flow. Agriculture was heavy prior to and during aggregate extraction.

14) Relevance To Ontario
Shows the potential impact of numerous gravel pits and municipal wells within the same aquifer, in close proximity to each other, but not a typical Ontario situation

1) Document Code	2) Document Rating	3) Publication Date
Reference #19	High	1984

4) Document Title	5) Document Type
The hydrological effects of gravel winning in an area west of London, United Kingdom. *Ground Water, 22(2)*, 154-161.	Journal

6) Author(s)	7) Agency / Organization
Morgan-Jones, M., S. Bennett, and J.V. Kinsella	

8) Geographic Location
London, England

9) How Was This Document Located
Library

10) Type of Study
Site specific water quality and general discussion on quality and hydraulics.

11) Activity Definition
Post extraction gravel pits above and below the water table.

12) Factors to Consider
Agricultural activity and infilling with waste create the water quality issues. Water table modifications are localized.

13) Summary of Findings / Conclusions
Lake modifies water table as generally expected. Field values indicate lowering upgradient and raising downgradient. Infilled pits and sealed reservoirs give rise to the opposite.

14) Relevance To Ontario
General modifications to the local water table, from typical aggregate extraction activities

1) Document Code Reference #20	2) Document Rating High	3) Publication Date 1998

4) Document Title Dewatering and environmental monitoring for the extractive industry. *Quarterly Journal of Engineering Geology, Volume 31,* 125-127.	5) Document Type Journal

6) Author(s) Streetly, M.	7) Agency / Organization

8) Geographic Location General
9) How Was This Document Located Library
10) Type of Study General discussion Paper
11) Activity Definition Dewatering in the extractive industry.
12) Factors to Consider The level of data collection and monitoring is related to the potential for impacts.
13) Summary of Findings / Conclusions It is cost effective to collect baseline data for characterization and impact assessment to prevent unacceptable impacts and provide for appropriate design and mitigation.

14) Relevance To Ontario
General guidelines

1) Document Code	2) Document Rating	3) Publication Date
Reference #21	Medium/High	1998

4) Document Title	5) Document Type
The hydrogeological effect of quarrying in karstified limestone: options for prediction and mitigation. *Quarterly Journal of Engineering Geology*, *Volume 31*, 147-157.	Journal

6) Author(s)	7) Agency / Organization
Hobbs, S.L., and J. Gunn.	

8) Geographic Location
General

9) How Was This Document Located
Library

10) Type of Study
Discussion Paper

11) Activity Definition
Quarrying karst above and below water table.

12) Factors to Consider
Hydraulic impacts more limited to local groundwater flow system

13) Summary of Findings / Conclusions Presents detailed discussion on potential impacts and mitigative measures. Ecological impacts most sensitive. Water quality impacts generally associated with suspended sediment and accidental spills that can be mitigated through BMP’s.
14) Relevance To Ontario Large scale karst features, not typical in Ontario, but general information is relevant

1) Document Code Reference #22	**2) Document Rating** Low/Medium	**3) Publication Date**
4) Document Title Deep Karst Conduits, Flooding, and Sinkholes: Lessons for the Aggregate Industry.		**5) Document Type**
6) Author(s) Lolcama, J.L., A. Cohen and J. Tonkin.	**7) Agency / Organization**	
8) Geographic Location General (USA)		
9) How Was This Document Located Internet		
10) Type of Study Discussion Paper		
11) Activity Definition Quarrying karst above and below water table.		

12)Factors to Consider
Focus is mainly on the impact on quarrying operations. Limited consideration of aquifer quantity disruption.
13)Summary of Findings / Conclusions
Significant hydraulic shifts in groundwater flow system particularly with conduit flow and related connection to surface flows. Significant consideration to geotechnical issues (ie sinkholes)
14)Relevance To Ontario
Relevant in more karstic areas which are limited in Ontario.

1) Document Code	2) Document Rating	3) Publication Date
Reference #23	High	

4) Document Title	5) Document Type
Impact of aggregate extraction activities on cold water discharge and water table drawdown.	

6) Author(s)	7) Agency / Organization
Ostrander, M., R. Blackport, P.Martin and M. Picotti.	Study conducted for Credit Valley Conservation

8) Geographic Location
Caledon, Ontario
9) How Was This Document Located
File
10)Type of Study
Numerical Modelling
11)Activity Definition

Gravel extraction below water table.
12)Factors to Consider Limited impact on the aquifer beyond local flow system.
13)Summary of Findings / Conclusions Simulated drawdown resulting from various extraction geometries and post extraction lake scenarios demonstrated potential impacts on local cold water stream. Impacts can be minimized with various geometries and step lake designs. Thermal impacts are minimal and localized.
14)Relevance To Ontario Study within a glacial meltwater channel in Ontario

1) Document Code Reference #24	**2) Document Rating** High	**3) Publication Date** 1997
4) Document Title Groundwater modelling for Reid's Heritage Homes, Township of Puslinch.		**5) Document Type** Consulting study
6) Author(s) Beatty Franz and Associates Limited	**7) Agency / Organization** Consultants	
8) Geographic Location Puslinch Township, Ontario		
9) How Was This Document Located Files		

10) Type of Study Numerical Modeling
11) Activity Definition Gravel extraction below water table.
12) Factors to Consider Model not calibrated with site specific data related to groundwater discharge (ie streambed piezometer data). Limited impact on the aquifer beyond local flow system.
13) Summary of Findings / Conclusions Simulated drawdown resulting from various extraction and post extraction lake scenarios demonstrated potential impacts on local cold water stream and the viability of mitigative cutoff wall and pumping designs. No impacts to the stream during post extraction and low extraction rates. Impacts can be mitigated to various extents under higher extraction rates.
14) Relevance To Ontario Study is within a meltwater channel in Ontario

<table>
<tr><td>1) Document Code
Reference #25</td><td colspan="2">2) Document Rating
High</td><td>3) Publication Date
2000</td></tr>
<tr><td colspan="3">4) Document Title
Folgevirkninger af rastofgraning under grundvandsspejlet. Chalmers Tekniska Hogskola, Miljoprojekt Nr. 526.</td><td>5) Document Type</td></tr>
<tr><td colspan="2">6) Author(s)
Nielson, K.A.</td><td colspan="2">7) Agency / Organization</td></tr>
</table>

8) Geographic Location General
9) How Was This Document Located Internet
10) Type of Study Analytical Modeling (Only summary in English)
11) Activity Definition Gravel extraction below water table.
12) Factors to Consider Location of extraction operation relative to the aquifer setting
13) Summary of Findings / Conclusions Solution and sensitivity analysis of extraction indicates that impact on water table remains close to extraction. Impacts can be minimized by extraction with a large footprint first and then going deeper.
14) Relevance To Ontario General understanding of impacts of the scale of extraction operation relative to the aquifer system

1) Document Code	**2) Document Rating**	**3) Publication Date**
Reference #26	High	2002
4) Document Title A functional analysis of the impact of aggregate extraction on groundwater and fish populations in Mill and MacCrimmon Creeks, *Fisheries and Oceans Canada.*		**5) Document Type** Peer Review

6) Author(s)	7) Agency / Organization
Blackport, B., and C. Portt	Consulting report for DFO

8) Geographic Location
Puslinch Township, Ontario
9) How Was This Document Located
File
10) Type of Study
Peer Review of site specific studies aggregate and fisheries studies and associated monitoring data
11) Activity Definition
Gravel extraction below water table at numerous locations
12) Factors to Consider
Cumulative impact of numerous extraction operations, climatic data
13) Summary of Findings / Conclusions
Review of hydrogeologic, hydrologic and fisheries data in the vicinity of 5 adjacent gravel pits indicated local modification to the groundwater flow system but no significant impacts relating to reductions in baseflow, thermal plumes, changes to groundwater chemistry or intermediate/regional reductions in water level or flow system.
14) Relevance To Ontario
Within a glacial meltwater channel in Ontario

1) Document Code	2) Document Rating	3) Publication Date
Reference #27	High	2004

4) Document Title	5) Document Type
Analyses of the potential effects of aggregate extraction operations on water resources in the Cedar Creek subwatershed.	Consulting report

6) Author(s)	7) Agency / Organization
S.S. Papadopulos & Associates	Study conducted for the Region of Waterloo

8) Geographic Location
Region of Waterloo

9) How Was This Document Located
File

10) Type of Study
Numerical modeling

11) Activity Definition
Gravel extraction below water table.

12) Factors to Consider
Cumulative impact assessment used a number of extreme scenarios including, dewatering of all gravel pits and having no recharge into any of the gravel pits.

13) Summary of Findings / Conclusions
Cumulative impacts on the rehabilitation of a number of pits demonstrated that recharge would either increase (no infilling of pits %10.8) or decrease (infilling with low permeability material 3.8%). Active dewatering of the pits during operation would have a significant impact on the shallow unconfined groundwater flow system.

14) Relevance To Ontario
Assessment of areas where there are multiple gravel pits present.

<table>
<tr><td>1) Document Code
Reference #28</td><td colspan="2">2) Document Rating
Moderate</td><td>3) Publication Date
Unknown, after January 2000</td></tr>
<tr><td colspan="3">4) Document Title
Pit to Park: Gravel Mine Reclamation Using Biosolids</td><td>5) Document Type
Summary Paper</td></tr>
<tr><td colspan="2">6) Author(s)
Mike Van Ham (SYLVIS Environmental Inc.), Ken Lee (Greater Vancouver Regional District), Barry McLean (Valley Gravel Sales Ltd.)</td><td colspan="2">7) Agency / Organization
Unknown, likely combined authors</td></tr>
<tr><td colspan="4">8) Geographic Location
Aldergrove / Abbotsford (Greater Vancouver District), British Columbia, Canada</td></tr>
<tr><td colspan="4">9) How Was This Document Located
Internet search:</td></tr>
<tr><td colspan="4">10) Type of Study
Environmental study report of water quality at site using biosolids application as part of rehabilitation of below water table extraction site.</td></tr>
<tr><td colspan="4">11) Activity Definition
Rehabilitation of below water table extraction site.</td></tr>
<tr><td colspan="4">12) Factors to Consider
Extraction complete, objective to create recreational area (part) as part of rehabilitation plan. Biosolids use on-site, focus on water quality impacts. Inclusion of private wells in monitoring program.</td></tr>
<tr><td colspan="4">13) Summary of Findings / Conclusions
Post application increase in soil nutrients, no effect on groundwater or surface water was observed.</td></tr>
</table>

14) Relevance To Ontario Moderate, related to impact of biosolids application as part of rehabilitation.

1) Document Code Reference #29	**2) Document Rating** Medium to low	**3) Publication Date** Unknown, current
4) Document Title NMFS National Gravel Extraction Policy		**5) Document Type** Policy description
6) Author(s) Unknown, NMFS	**7) Agency / Organization** United States, NOAA National Marine Fisheries Service (NMFS)	
8) Geographic Location Various, United States		
9) How Was This Document Located Internet search: http://swr.nmfs.noaa.gov/hcd/gravelsw.htm		
10) Type of Study Policy description and rationale, includes general description of activities and potential impacts.		
11) Activity Definition Gravel extraction in or near streams.		
12) Factors to Consider Focus on in-stream or near stream (floodplain) gravel extraction effects to aquatic life and habitat.		

13) Summary of Findings / Conclusions Conclusions that in-stream or near-stream gravel extraction can impact aquatic life and habitat, specific list of impacts provided. Guidelines recommended to avoid or minimize impact. Recommendation to seek gravel resources away from streams (upland / terrace deposits) to avoid aquatic impacts.
14) Relevance To Ontario Limited to in-stream or near-stream aggregate extraction operations or proposals.

1) Document Code Reference #30	**2) Document Rating** Moderate	**3) Publication Date** April 1995
4) Document Title Resource Extraction Management Practices Catalog For Nonpoint Source Pollution Prevention and Water Quality Protection in New York State		**5) Document Type** Management Plan
6) Author(s) Unknown, various	**7) Agency / Organization** NYS Department of Environmental Conservation, Division of Water, Bureau of Water Quality Management	
8) Geographic Location New York State, United States		
9) How Was This Document Located Internet search:		
10) Type of Study Management Plan to be implemented as part of the (New York State?) Water Quality Act of 1987.		
11) Activity Definition Resource extraction, including surface extraction, oil and gas and solution mining.		

12) Factors to Consider Variety of resource extraction types, discussion of nonpoint source pollution implications of sand and gravel extraction according to New York State experience.
13) Summary of Findings / Conclusions Sedimentation from sand and gravel operations appears to be the most widespread form of water quality problem associated with resource extraction in New York State. It accounts for only 7 of the 1500 segments of water with water quality issues
14) Relevance To Ontario Moderate, general discussion of nonpoint source issues related to sand and gravel extraction.

1) Document Code Reference #32	**2) Document Rating** Low	**3) Publication Date** Unknown, after 1998
4) Document Title Five-Year Status Report on Borrow Pit Program		**5) Document Type** Summary of Program
6) Author(s) unknown	**7) Agency / Organization** Maine Department of Environmental Protection	
8) Geographic Location Maine, United States		
9) How Was This Document Located Internet search: www.maine.gov/dep/blwq/docstand/ims98rep.doc		
10) Type of Study Regulation of pits program status summary.		

11) Activity Definition Above water table sand and gravel extraction.
12) Factors to Consider Extraction regulation, reporting of background, fees and expenditures, permitting and review process, enforcement and deficiencies noted.
13) Summary of Findings / Conclusions Common deficiencies noted include no secondary containment for petroleum products, erosion / sedimentation problems and insufficient separation to the seasonal high water table.
14) Relevance To Ontario Low, summary of regulation / permitting / deficiencies and enforcement process in Maine.

1) Document Code Reference #33	**2) Document Rating** Moderate to Low	**3) Publication Date** March 15, 2002
4) Document Title Final Report to DES and NH State Legislature, June 1998-November 2001 Monitoring Demonstration at a Top-Soil Manufacturing Site in New Hampshire		**5) Document Type** Study Summary, report to Legislature
6) Author(s) William H. McDowell & Tamara J. Chestnut University of New Hampshire	**7) Agency / Organization** unknown	
8) Geographic Location Hooksett New Hampshire, Idaho, United States		
9) How Was This Document Located Internet search		

10) Type of Study Groundwater quality impact evaluation of repeated biosolids application and topsoil “manufacturing” at reclaimed above water table gravel pits.
11) Activity Definition Above water table gravel pit rehabilitation and after-use.
12) Factors to Consider Unknown geologic setting, possible unconfined sand and gravel aquifer, after use of site as biosolids application site, biosolids stockpiling prior to application, topsoil regeneration and topsoil removal every 5 years (approx.). Limited analysis of groundwater table fluctuation, slope or flow. Extensive water quality sampling.
13) Summary of Findings / Conclusions Biosolids application results in concentration increase of nitrate and DOC in groundwater, greatest increase near stockpiling locations. Nitrate increased to above 10 mg/L. Some increase in metals concentration also observed, but not above water quality limits. Off-site nitrates were also elevated, unrelated to the biosolid application
14) Relevance To Ontario Moderate to low, concepts and issues can be applied to after-use of above water table gravel pits.

<table>
<tr><td>1) Document Code
Reference #34</td><td colspan="2">2) Document Rating
Medium to high</td><td>3) Publication Date
January 2001</td></tr>
<tr><td colspan="3">4) Document Title
Ground-Water Interactions Near the Highway Pond Gravel Pit, Pocatello, Idaho</td><td>5) Document Type
IGS Staff Report</td></tr>
<tr><td colspan="2">6) Author(s)
John A. Welhan, Idaho Geologic Survey</td><td colspan="2">7) Agency / Organization
Idaho Geologic Survey (IGS), United States</td></tr>
<tr><td colspan="4">8) Geographic Location
Near City of Pocatello, Idaho, United States</td></tr>
</table>

9) How Was This Document Located Internet search
10) Type of Study Groundwater quality Impact evaluation of gravel pit pond, focus on source of bacteria in private well near pond.
11) Activity Definition Below water table sand and gravel extraction.
12) Factors to Consider Unconfined water supply aquifer, large variation in water table (25 ft), distant recharge area and variable annual recharge, uncontrolled domestic refuse disposal, public access and recreational (fishing/canoe/kayak/off-road/all-terrain vehicle) use, domestic and municipal wells in same aquifer and close proximity to pond.
13) Summary of Findings / Conclusions Pond level reflects water table level and slope. Overall aquifer flow direction unaffected, flow into pond on upgradient edge, away from pond on downgradient edge. Water table variation of up to 25 ft leads to large pond level variations and pond size fluctuation. Pond suspected as source of bacterial contamination in private well 200 to 500 ft distant. Future reclamation plans will need to take into account water table rise.
14) Relevance To Ontario Moderate, settings, concepts and issues similar, extent of natural water table variation unlikely to occur in Ontario, given the steep-sided narrow bedrock valley that the aquifer in which the aquifer is located

<table>
<tr><td>1) Document Code
Reference #35</td><td>2) Document Rating
Moderate to Low</td><td>3) Publication Date
November 9, 2005</td></tr>
<tr><td colspan="2">4) Document Title
Gravel Plains in Urban Areas: Gravel Pits as an Element of Degraded Landscapes</td><td>5) Document Type
Journal Paper</td></tr>
</table>

6) Author(s) Mimi Uranc, Mateja Breg	7) Agency / Organization Acta Geographica Slovenica, 45-2, 2005, 35-61

8) Geographic Location
City of Ljubljana, Slovenia

9) How Was This Document Located
Internet search:

10) Type of Study
Mapping and survey of gravel pits in area of city to examine after-use and potential risks to groundwater of illegal or unrestricted and unregulated waste dumping.

11) Activity Definition
Above water table gravel pit after-use, primarily un-regulated

12) Factors to Consider
Thick sand and gravel deposit, likely unconfined sand and gravel aquifer. Nearby municipal water well, likely in aquifer. Unregulated dumping in abandoned pits of various sizes.

13) Summary of Findings / Conclusions
Unregulated waste dumping in former gravel pits is a likely threat to water quality in aquifer and at municipal well, although no municipal wells have been impacted to date. Increased aquifer monitoring is needed away from the local sources on contamination as the extent of impact is unknown.

14) Relevance To Ontario
Moderate to low, concepts and issues can be applied to after-use of above water table gravel pits.

1) Document Code	2) Document Rating	3) Publication Date
Reference #36	Low	January 2004

4) Document Title	5) Document Type
Environmental Impacts of Aggregate and Stone Mining, New Mexico Case Study	Discussion / Issue Paper

6) Author(s)	7) Agency / Organization
Steve Blodgett	Center for Science in Public Participation

8) Geographic Location
New Mexico, United States

9) How Was This Document Located
Internet search:

10) Type of Study
Discussion of generalized impacts or potential impacts, quantitative analyses.

11) Activity Definition
Aggregate Extraction.

12) Factors to Consider
Arid climate (annual precipitation 4 to 12 inches, few perennial streams exists), inclusion of industrial mineral mines, lack of specific data.

13) Summary of Findings / Conclusions
Airborne particulate emissions (dust) as most recognized health hazard. Sediment loads not a problem due to low precipitation and runoff. Groundwater use cited as “major environmental impact” but no specifics given. Cumulative impact discussion focuses on air pollution and traffic.

14) Relevance To Ontario
Low, no specific data or analysis, arid climate.

<table>
<tr><td>1) Document Code
Reference #37</td><td>2) Document Rating
Moderate</td><td>3) Publication Date
June 2, 2000</td></tr>
<tr><td colspan="2">4) Document Title
Evaluation of Mineral Sites Restored to Agriculture</td><td>5) Document Type
Environmental Assessment Report</td></tr>
<tr><td colspan="2">6) Author(s)
Land Research Associates</td><td>7) Agency / Organization
Ministry of Agriculture and Food,
Great Britain</td></tr>
<tr><td colspan="3">8) Geographic Location
Great Britain</td></tr>
<tr><td colspan="3">9) How Was This Document Located
Internet search:</td></tr>
<tr><td colspan="3">10) Type of Study
Quantitative study of quality of land restored to agriculture in Great Britain after aggregate extraction and rehabilitation.</td></tr>
<tr><td colspan="3">11) Activity Definition
Rehabilitation of above water table aggregate extraction.</td></tr>
<tr><td colspan="3">12) Factors to Consider
Climate, regulatory framework, site operation technique differences.</td></tr>
<tr><td colspan="3">13) Summary of Findings / Conclusions
Rehabilitation to agricultural land of equal value does occur if certain best management practices are followed, lists bmp's for rehabilitation to agricultural land.</td></tr>
</table>

14) Relevance To Ontario
Moderate, factors to consider during operations and rehabilitation.

1) Document Code	**2) Document Rating**	**3) Publication Date**
Reference #38	Moderate	June 2000

4) Document Title	**5) Document Type**
Maury Island Gravel Mining Impact Studies, Publication No 00-09-005	Fact Sheet and supporting documentation

6) Author(s)	**7) Agency / Organization**
Unknown.	Washington State Department of Ecology, United States

8) Geographic Location
Maury Island, Washington State, United States
9) How Was This Document Located
Internet search:
10) Type of Study
Summary of environmental impact assessment of proposed large-scale aggregate extraction, includes groundwater impacts related to extraction and aquatic impacts related to pier construction and transport of aggregate by ship. Includes groundwater modeling.
11) Activity Definition
Above water table extraction.
12) Factors to Consider
Large scale extraction proposal (7.5 million tons per year, 350 feet of gravel removed above the water table). Multi-layered aquifer/aquitard system, thick unsaturated zone, existing presence of contaminated soils on-site. Climate / recharge process.

13) Summary of Findings / Conclusions

Predicted groundwater impact is a decrease in recharge due to modification of vegetative cover, change in annual recharge distribution, and related decrease in groundwater levels and linked base flow discharge at springs. Water level declines of 1 ft on-site and 0.5 ft immediately adjacent to the site, overall impact is predicted to be insignificant.

14) Relevance To Ontario

Moderate, general discussion of issues and possible impact.

1) Document Code	**2) Document Rating**	**3) Publication Date**
Reference #39	Moderate	2003

4) Document Title

Development of Aquatic Communities In Aggregate Ponds in Southern Ontario

5) Document Type

Master's Thesis

6) Author(s)

Lisa Guenther

7) Agency / Organization

University of Guelph

8) Geographic Location

Southern Ontario

9) How Was This Document Located

Library search

10) Type of Study

Assessment of the water quality and aquatic species diversity in aggregate ponds throughout Southern Ontario

11) Activity Definition

Post-extraction lakes and ponds in gravel pits and quarries

12) Factors to Consider

Geologic setting, size of extraction and age of post-extraction lake

13) Summary of Findings / Conclusions Water quality of post-extraction lakes show some variability, however the water quality is generally good and would support aquatic communities		
14) Relevance To Ontario High, general discussion of water quality of post-extraction lakes in Ontario setting.		
1) Document Code Reference #40	**2) Document Rating** High	**3) Publication Date** 2005
4) Document Title ALJ Ruling for Southern Dutchess Sand and Gravel Inc.		**5) Document Type** Case History-legal ruling
6) Author(s) Richard Wissler, Administrative Law Judge	**7) Agency / Organization** New York State Department of Environmental Conservation	
8) Geographic Location New York State		
9) How Was This Document Located Internet search:		
10) Type of Study Summary of ruling for an Application for below water table extraction at a gravel pit		
11) Activity Definition Below water table extraction in an aquifer with a municipal water supply		
12) Factors to Consider Below water extraction area, size of extraction, runoff characteristics, distance to surface water and distance to a municipal water supply in the same geologic unit.		

13) Summary of Findings / Conclusions
Evidence presented at the hearing, by the Department of Environmental Conservation, showed studies in New York state and elsewhere had not found any instances of water quality impacts on a municipal drinking water supply from aggregate extraction operations.
14) Relevance To Ontario
Similar geologic setting as many areas of Ontario

1) Document Code	2) Document Rating	3) Publication Date
Reference #41	High	May, 1989
4) Document Title Aggregate Industry MISA Preregulation Monitoring Program Results		**5) Document Type** Consulting Report
6) Author(s) Senes Consultants Limited	**7) Agency / Organization** Consultant – prepared for The Aggregate Producers Association of Ontario	
8) Geographic Location Ontario		
9) How Was This Document Located MNR Files		
10) Type of Study Assessment of water quality from discharge water selected gravel pits and quarries in Ontario.		
11) Activity Definition Below water table extraction in gravel pits and quarries		

12)Factors to Consider Geologic setting, adjacent land use, scale of operation
13)Summary of Findings / Conclusions Results indicated very limited water quality impacts from extraction operations on water being discharged from gravel pits and quarries.
14)Relevance To Ontario Focus on Ontario

1) **Document Code** Reference #42	2) **Document Rating** High	3) **Publication Date** 2005
4) **Document Title** Mill Creek Annual Cumulative Impact Assessment – 2004 Township of Puslinch Ontario		5) **Document Type** Consulting Report
6) **Author(s)** Golder Associates	7) **Agency / Organization** MNR	
8) **Geographic Location** Township of Puslinch, Ontario		
9) **How Was This Document Located** File		
10) **Type of Study** Monitoring Data Review and Impact Assessment		
11) **Activity Definition** Gravel extraction below water table.		
12) **Factors to Consider** Numerous pits are located immediately adjacent to a cold water stream.		
13) **Summary of Findings / Conclusions** Cumulative impacts from a number of pits do not show any significant declining trends in water levels. On a local scale the groundwater flow system is modified and flow directions have been locally focused towards the ponds. There is no measurable impact on the volumetric flow within the adjacent coldwater creek. Thermal plumes from the ponds do not appear to migrate further than 60m.		

14) Relevance To Ontario Glacial deposits in southern Ontario		
1) Document Code Reference #43	**2) Document Rating** Medium	**3) Publication Date** 2002
4) **Document Title** Flow depletion in a small stream caused by groundwater abstraction from wells. *Ground Water 40(4)*, 425-437.		**5) Document Type** Journal
6) Author(s) Nyholm, T., S. Christensen and K.R. Rasmussen	7) **Agency / Organization**	
8) Geographic Location Denmark		
9) How Was This Document Located Library		
10) Type of Study Field and numerical analysis of impact of pumping well on adjacent stream.		
11) Activity Definition Potential simulation of below water table extraction or quarry dewatering.		
12) Factors to Consider Extraction is 60 metres from stream.		

13) Summary of Findings / Conclusions Field results showed a loss in stream flow from a reduction in local groundwater gradients and subsequent reduction in groundwater discharge. The test indicated that the stream did not act as a hydraulic boundary and that flow still occurred towards the stream and remained a gaining stream. Re-infiltration of water influenced the development of the drawdown cone.		
14) Relevance To Ontario Similar general hydrogeologic setting to coldwater streams in southern Ontario.		
1) Document Code Reference #44	**2) Document Rating** Medium	**3) Publication Date** 2002
4) **Document Title** Stream-aquifer interactions: Evaluation of depletion volume and residual effects from groundwater pumping. *Ground Water 40(3)*, 284-290.		**5) Document Type** Journal
6) Author(s) Chen, X., and L. Shu.	7) **Agency / Organization**	
8) Geographic Location General		
9) How Was This Document Located Library		
10) Type of Study Numerical analysis of impact of pumping well on adjacent stream.		
11) Activity Definition Potential simulation of below water table extraction or quarry dewatering.		

12) Factors to Consider

13) Summary of Findings / Conclusions

Modeling results indicated that the reduction in stream flow is a combination of the reduction in groundwater discharge and induced infiltration. In low conductance streams reduction of groundwater discharge takes place shortly after pumping and accounts for the major streamflow loss as compared to induced infiltration which takes place later. Upon cessation of pumping (4500 m^3 /day) the recovery is dependent on the original rate of groundwater discharge and the areal recharge. With nominal recharge of 117mm/year recovery after 90 days of pumping only took 30 days.

14) Relevance To Ontario

Similar general hydrogeologic setting to coldwater streams in southern Ontario.

1) **Document Code**	2) **Document Rating**	3) **Publication Date**
Reference #45	moderate	June 2000

4) **Document Title**	5) **Document Type**
Does Groundwater Abstraction Cause Degradation of Rivers and Wetlands. *J.CIWE, 14*, 200-206.	Journal

6) **Author(s)**	7) **Agency / Organization**
Acreman, M.C., at al.	

8) Geographic Location

England

9) How Was This Document Located

Library

10) Type of Study

Overview assessment of regional degradation of rivers and wetlands.

11) Activity Definition

Abstraction of groundwater on a regional scale

12)Factors to Consider This study was not specific to the type of groundwater extraction and considered impacts on a regional scale.
13)Summary of Findings / Conclusions In general intensive groundwater extraction was found to cause degradation to streams and wetlands but other abiotic factors such as channelisation, sedimentation, reduced rainfall and land use change can be contributing factors.
14)Relevance To Ontario Consideration for various factors must be incorporated into cumulative effects when considering cause and effect.