University of Alberta

Evaluation of the Potential for Reuse of Industrial Wastewaters Currently Disposed of by Deep Well Injection in Alberta

by

Yan Chen ©

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ABSTRACT

A study was undertaken involving the review of deep well injection practices of non-oilfield waste streams in Alberta. The overall objective of the study was to evaluate and report on chemical characteristics and disposal volumes of non-oilfield waste streams disposed of by deep well injection. Detailed records on disposal activities in Alberta were obtained from Alberta Energy and Utilities Board. These records included information taken from microfiche of original applications and approvals, and injection volume data for the wells.

A total of 37 Class Ia wells are currently being used for deep well disposal of a variety of non-oilfield waste streams in Alberta. The following preliminary recommendations were put forward for each of the wells:

- Additional information needs to be collected on source characteristics and/or disposal rates to better assess their potential for treatment and reuse.
- The potential of waste streams for treatment and reuse needs to be further investigated.

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1.0 INTRODUCTION

1.1 Water Use for Injection Purposes in Alberta

Canada is a water-rich country with an abundance of freshwater ecosystems, including lakes, ponds, rivers, streams, prairie potholes, and wetlands. However, the Province of Alberta holds only 2.2% of Canada's total freshwater supply (AENV, 2002). During 2001, Alberta allocated more than 9.4 billion m^3 of water for a variety of uses (AENV, 2004). Water allocations for specified uses are illustrated in Figure 1.1.

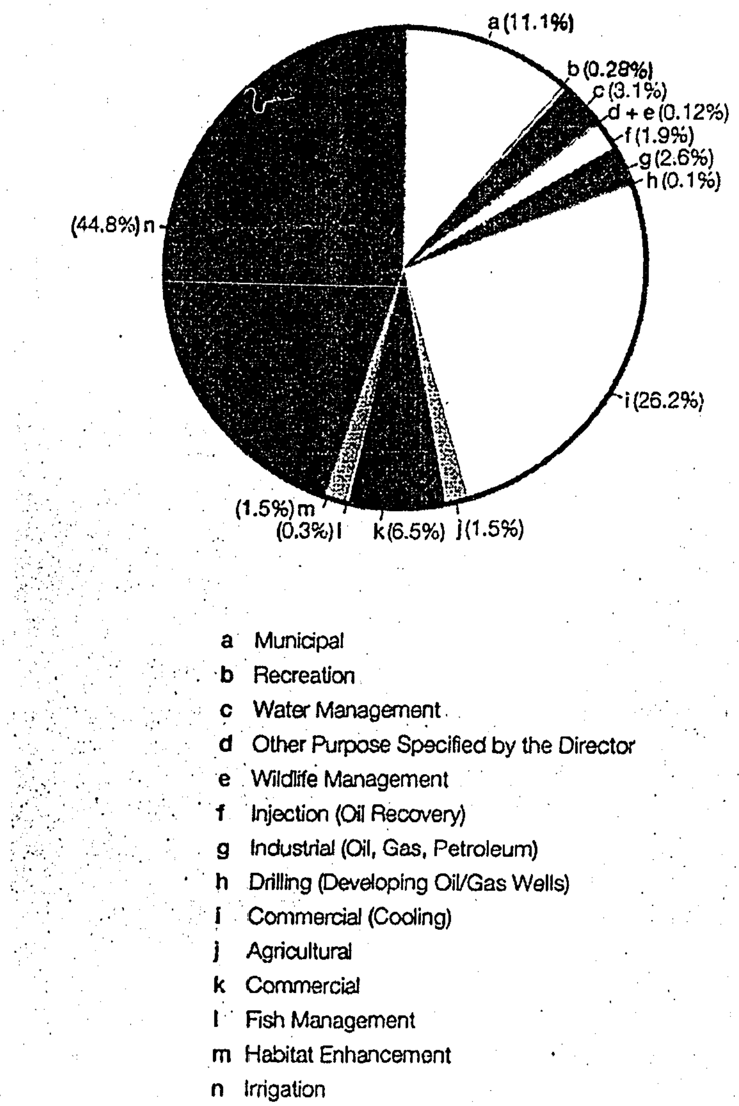

Figure 1.1. Water allocations for specified uses in Alberta (from Committee, 2004).

Major wastewater source categories reported in Alberta are given in Table 1.1. The deep well disposal volume was 281,000,000 m^3 in 2001. Provincial deep well disposal volumes showed a gradual increase from 1972 due to development and growth of industry and the preference for this method of disposal (Figure 1.2).

Table 1.1. Major wastewater sources in Alberta (from AENV, 2004).

Sources	Amount
Deep Well Disposal (Industrial and oilfield, including produced water)	281,000,000 m^3/yr (2001)
Industrial Wastewater (EPEA approved major facilities)	146,000,000 m^3/yr (2001)
Municipal Effluent (Industrial and domestic sewage wastewater)	391,000,000 m^3/yr (1999)

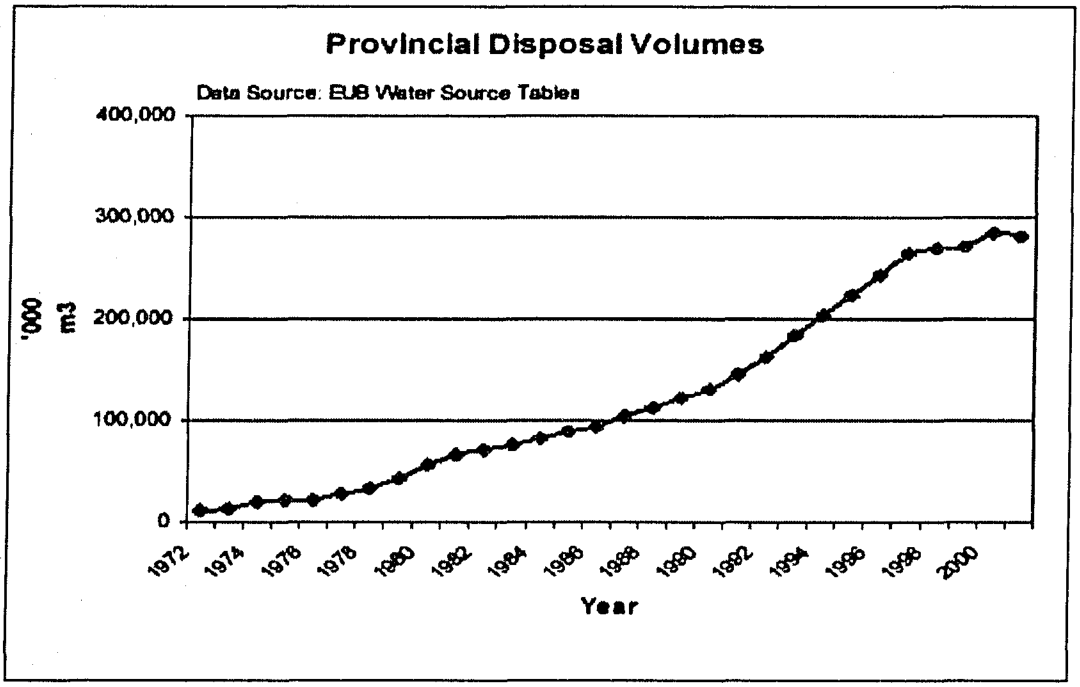

Figure 1.2. Provincial deep well disposal volumes (from AENV, 2004).

1.2 Need for Water Conservation in Alberta

Alberta's surface and groundwater supplies are invaluable resources. Although Alberta has a relatively large supply of fresh water, with rapid population growth and increasing use of water by people, the available water supply and its quality are under increased strain. The quality of life, and indeed life itself, depends on access to a healthy and sustainable water supply for the environment, community and economic well-being (AENV, 2003). In the face of increasing economic and population growth, and scientific uncertainty about future supplies of water, there is clearly a greater need for water conservation in Alberta. Moreover, recent periods of drought in Alberta have added to this pressure and increased awareness of the need to rigorously examine opportunities for conservation and reclamation practices (AENV, 2003).

The Alberta government recently committed to a water strategy for the purpose of addressing pressures on the province's water resources. The strategy of *Water for Life* (AENV, 2003) seeks to develop and/or maintain:

- Healthy, sustainable ecosystems (e.g., watershed, rivers, streams, lakes, wetlands and groundwater);
- A safe, secure drinking water supply;
- Reliable, quality water supplies for a sustainable economy; and
- Knowledge necessary to make effective water management decisions.

Many Albertans have pointed out the need for an increased emphasis on water conservation (AENV, 2003). Some people have expressed concerns specifically about the use of water for underground injection activities. Use of fresh water by industry and subsequent deep well injection of wastewater results in potentially-reusable water being permanently lost from available water resources. Deep well injection represents an older waste management practice, one that is still considered effective. However, in view of a greater need to consider promotion of water conservation and reuse of reclaimed water, a need exists for better information on deep well disposal practices with respect to quantity and quality of liquid wastes. Better information is also needed to form a basis for deciding whether some of these wastes are suitable for treatment and reuse.

1.3 Overview of Project

Because deep well injection is the cheapest method of permitted waste disposal after wells begin operating, facilities that rely on this technique have little economic incentive to consider conservation and reclamation practices for liquid wastes. However, the Government of Alberta has recognized the need for water conservation and established *Water for Life: Alberta's Strategy for Sustainability* in 2002 (AENV, 2003). The Advisory Committee on Water Use, Practice and Policy has reviewed the use of water for underground injection purposes and recommended research into technologies to conserve the water rather than disposing of it in the ground.

However, a comprehensive database of deep well injection activities in Alberta does not exist. Such information is required to make decisions about whether water resource management options that are more sustainable might be made available for use by industrial users practicing this approach. Such a project would involve searching out and documenting deep well injection practices currently implemented in Alberta. The overall objective of this project to: (1) identify and document available data and information on deep well disposal practices of wastewater in Alberta, (2) evaluate quantity and quality of the wastes injected, and (3) identify preliminary opportunities for reclamation and reuse of selected wastes.

This project is linked to Alberta's *Water for Life Strategy*, and will benefit the strategy in two ways:

- It will increase knowledge and understanding about characteristics of freshwater use and ultimate deep well injection practices of industry; and
- It will assist in the identification and improvement of monitoring activities of freshwater use ultimately destined for permanent disposal by deep well injection.

2.0 LITERATURE REVIEW

Increased efforts to reduce contamination of surface and ground water resources and accelerated production of diverse types of relatively untreatable wastewaters have stimulated interest in waste disposal. Deep well injection, a process for permanently storing waste in underground strata, is one option. Deep wells have been used successfully for decades in oil-producing provinces to return large volumes of saline water, removed during oil production, to the subsurface. Deep well injection of wastewater and liquid hazardous wastes is an important disposal practice worldwide. Most industrialized nations employ deep-well injection for the disposal of wastes (Saripalli et al., 2000). In Alberta, industrial waste has been disposed through deep wells since the early 1950s (Apps and Tsang, 1996).

To obtain background information on deep well injection as a possible solution to an industrial waste problem, factors that must be considered include legal issues, site suitability and waste characteristics – to mention but a few. These factors, plus the design, drilling, evaluation, completion and operation of injection wells, will be discussed in this review.

2.1 Waste Characteristics

Because injection of liquid wastes into subsurface rock strata constitutes the use of a natural resource (storage space), only concentrated, highly-polluted, relatively untreatable wastes should be considered (Ross, 1968). The volume of waste is economically important, because the injection rate of a well is limited and because its operating life may depend on the total amount of fluid injected (Ross, 1968). The intake rate of injection wells can vary widely, and is dependent on the permeability, thickness and compressibility of the injection horizon and the injection pressure (Ross, 1968).

Physical and Chemical Characteristics. The suitability of a waste for subsurface injection depends on its physical and chemical properties and those of the aquifer fluids and minerals (Ross, 1968). A decrease in the permeability of the injection horizon and subsequent increase in injection pressure (or decrease in injection rate) can occur as a result of the plugging of pores. Plugging can be caused by (Ross, 1968): (1) suspended solids or entrained gas in the injected fluid, (2) reactions between injected and interstitial fluids, (3) autoreactivity of the waste at aquifer temperature and pressure, and (4) reactions between injected fluids and aquifer minerals (Ross, 1968). Plugging at or near the well bore can also be caused by bacteria and mold.

Most waste streams disposed through deep wells to date have been liquid. Of these liquid wastes, the vast majority are brine solutions. The remainder is water-based and contains a variety of organic compounds and metallic salts. Water to be injected into deep wells is usually treated before injection to remove suspended solids, dissolved iron and manganese, and entrained air to prevent plugging and avoid corrosion problems (Koziorowski and Kucharski, 1972). Bacteria can be detected by appropriate testing procedures and, if present in harmful numbers, can be controlled with various chemicals (Ross, 1968).

Autoreactivity of Injected Waste. Wastewaters that are stable on the surface can become unstable at aquifer temperature and pressure. Such instability can lead to polymerization of resin-like materials to form solids. Other reactions, such as precipitation of calcium carbonate, can occur because of the decreased solubility of dissolved gas at high temperatures (Headlee, 1950 as cited by Ross, 1968).

Reactions between Wastes and Aquifer Minerals. A small number of minerals comprise nearly the entire mass of sandstone aquifers. The average sandstone, as determined by Clarke (1924) and cited by Ross (1968), consists of 66.8% SiO_2 (mostly quartz), 11.5% feldspars, 11.1% carbonate minerals, 6.6% micas and clays, 1.8% iron oxides and 2.2% other minerals. Limestone and dolomite aquifers are primarily $CaCO_3$ and $CaMg(CO_3)_2$, but impure aquifers can contain as much as 50% noncarbonate constituents such as SiO_2 and clay minerals (Ross, 1968). Quartz, feldspars and micas can for practical purposes be considered nonreactive, except in highly alkaline or acidic solutions (Ross, 1968).

Carbonate minerals, which comprise limestone and dolomite aquifers and act as cementing agents in sandstones, are soluble in acids. The reaction of carbonate minerals with acid wastes can be beneficial, if no undesirable precipitates result and if the generation of CO_2 gas does not cause excessive pressure buildup or plugging of the injection horizon (Koziorowski and Kucharski, 1972).
Clay minerals are common constituents of sedimentary rocks, and are known to reduce the permeability of sandstone to water compared to their permeability to air (Warner and Lehr, 1981). The water permeability of a clay-bearing sandstone decreases with (Warner and Lehr, 1981): (1) decreasing water salinity, (2) decreasing valence of the cations in solution, and (3) increasing pH of water.

Based on the foregoing discussion of waste characteristics, it can be concluded that a given wastewater may be suitable for deep well injection if:

1. It is toxic and cannot readily be treated or disposed of in other ways;
2. The volume is practical to the underground storage space; and
3. The chemical and physical characteristics allow injection with or without prior conditioning with reasonable assurance that the injection well will not be rapidly and permanently plugged during operation.

2.2 Selection of Disposal Sites

Geological and hydrological conditions are primary considerations when determining whether or not an area is suitable for subsurface disposal of liquid wastes. An industry considering subsurface disposal must determine (1) whether an underground formation will accept fluids, (2) at what rates and pressures it will do so, and (3) how the injected fluids will move within the formation (Apps and Tsang, 1996). If an area is tectonically stable, and geophysical or geological data exist to define the fault system, such an area may have potential for accepting limited volumes of waste. However, a detailed study of the geology and the hydrodynamic effects resulting from injection of fluids would be mandatory before such a system is used for disposal purposes.

2.2.1 Geological Considerations

The specific location of a proposed waste injection well site must be determined from a detailed analysis of local geology. However, in certain cases generalizations can be made, based on regional geologic considerations, concerning the suitability of the area for waste injection wells. Sedimentary rocks are, in most cases, selected for subsurface disposal, although fluids have been injected into metamorphic complexes with varying degrees of success (Everdingen, 1974).

Rocks comprising the earth's crust are classified as igneous, metamorphic, and sedimentary. Although all these rocks can under certain circumstances have sufficient porosity and permeability to act as reservoirs for injected fluids, consolidated sedimentary rocks are most likely to have geologic characteristics suitable for waste injection wells. These characteristics include (Warner and Lehr, 1981):

1. The injection horizon should have sufficient porosity, permeability, and extent to act as a liquid storage reservoir at safe injection pressures;
2. The formation should be uniform sandstone, limestone or dolomite or, under favourable conditions, a fractured shale;
3. The formation should be of a large areal extent and sufficient thickness, and possess adequate overlying and underlying impermeable strata or aquicludes;
4. The formation should be salt-water filled and artesian in nature, and possess fluids and rocks that are compatible with the injected fluids; and
5. The injection horizon should be below the level of fresh water, and should be separated vertically from fresh water and other natural resources by rocks that are, for practical purposes, impermeable to waste.

Most sedimentary rocks with these characteristics were deposited in a marine environment and, below the present level of fresh water circulation, contain saline water in the pores (Warner, 1965). This interstitial saline water is not suitable for most uses and only occasionally contains enough dissolved minerals to be commercially valuable. These sedimentary rocks do, however, contain naturally occurring oil, gas, coal, and sulfur (Warner, 1965). Important considerations in selecting a waste injection well site are, therefore, protection of developed and undeveloped deposits of minerals and hydrocarbons, and the preservation of possible gas storage reservoirs.

Sandstones, limestones, and dolomites are sedimentary rocks that are porous and permeable enough in the unfractured state to accept relatively large volumes of waste. Naturally fractured limestones and shales may provide satisfactory injection horizons, since oil and gas are produced from these rocks in many areas. Artificially fractured shales have been suggested as reservoirs for liquid radioactive waste (Frgic et al., 2002).

Porous and permeable sandstone bodies entirely surrounded by impermeable shales have been suggested as possible reservoirs for liquid waste. Sandstones that would provide suitable injection horizons are present in the thick sequence of sedimentary rocks, but several factors intrude on their use for waste injection (Everdingen, 1974). These factors are:

1. Rapid lateral changes in rock properties, which make the evaluation of possible injection horizons difficult;
2. The danger of seismic activity, which could rupture casings in the injection wells or in nearby abandoned wells or perhaps damage the confining strata;
3. The presence of extensive oil and gas accumulations; and
4. The general extension of potable groundwater to depths of 2,000-3,000 feet.

Other types of structural and stratigraphic traps contain oil and gas, and would also hold injected waste under the proper conditions. In aquifers where a hydrodynamic gradient exists, the mechanics of fluid entrapment are modified (Warner and Lehr, 1981). These factors should be considered when selecting a waste injection well site where lateral confinement of the waste is desired.

Synclinal basins are of particular interest to the consideration of potential injection well sites because (1) they contain relatively thick sequences of salt-water-bearing sedimentary rocks and (2) the subsurface geology of these basins is often well known as a result of wells' having been drilled for oil and gas (Everdingen, 1974). In addition, if these are closed basins, fluids are believed to be unable to circulate out of them. Because of their comparatively favourable geologic characteristics, synclinal basins have received consideration as sites for the injection of liquid radioactive waste (Everdingen, 1974).

Just as major synclinal basins tend to be geologically favourable sites for deep well injection, other areas may be unfavourable because they have a relatively thin sedimentary rock cover or none at all. Areas with relatively impermeable igneous and metamorphic rocks at the surface can generally be eliminated from consideration as possible waste injection well sites (Everdingen, 1974).

2.2.2 Hydrological Considerations

One of the most important considerations with respect to subsurface disposal is the question of what happens to the waste after it is injected into the receiving formation or aquifer. The hydrological data, in addition to its value in predicting long range injection performance, is crucial to the design and selection of surface treating equipment, injection pumps and casing. Hydrological data are also required to determine the net effect of the pressure increase on the surrounding formation (McLean, 1968).

Research in petroleum engineering and groundwater hydrology has produced a number of useful equations for evaluating the hydrology of the receiving formation (Rhee et al., 1993). Using these equations, injection rates and pressure can be estimated from data obtained from nearby wells. The pressure effect developed in the formation with time and distance or various injected volumes can also be calculated. However, because of the many local factors that can affect the performance of a well, actual testing must be undertaken at the well to measure its injection capacity.

2.3 Drilling and Completion of Injection Wells

2.3.1 Drilling Injection Wells

When the drilling of a disposal well is being considered, it is most important to ensure that (1) potable water horizons are completely protected, (2) all oil, gas and mineral water horizons are adequately separated, and (3) the disposal horizon is isolated (Warner, 1965). A typical schematic of disposal well construction is shown in Figure 2.1. Drilling the well down to the disposal formation is conducted in accordance with accepted practices within the area (Warner and Lehr, 1981).

The equipment used for drilling an injection well influences the economics and operating performance of the well. Cable tools are frequently used for drilling the disposal formation, particularly when casing is set above the formation (Warner and Lehr, 1981). There are many areas, however, where the use of cable tools is not feasible because of high pressure, extreme depth, soft formations, etc. (Warner and Lehr, 1981). The chances of formation damage are less when wells are drilled with cable tools rather than rotary tools. Mud and lost-circulation material will not be lost to the formation, which could cause a plugging action (Warner and Lehr, 1981). Drilling is at a slower rate with cable tools, but in most areas their cheaper price offsets the difference in drilling costs.

When rotary tools are used to drill the disposal formation, several different procedures can be followed. The well or formation conditions and accepted or approved practices within an area help determine which procedure will be used. These procedures include (Warner and Lehr, 1981):

1. Drill a full-sized hole to total depth and install casing through porous disposal zone or zones. This method is recommended for unconsolidated formations subject to sloughing or caving;
2. Drill a full-sized hole through all porous zones or to the point where circulation is lost, and place casing immediately above the porous disposal zones;
3. Drill a full-sized hole to immediately above, or to the top of, the disposal formation and install casing at this point. Then, drill a reduced-diameter hole through all the porous zones or until circulation is lost. If possible, clear water should be used as drilling fluid when drilling the reduced hole. This will prevent plugging from mud and lost-circulation material; and

4. Drill a full-sized hole to immediately above, or to the top of, the disposal zone, and then drill a reduced-diameter hole (rat hole) to total depth and set casing at the point where the hole size was reduced. After the casing has been set, ream the reduced hole to remove mud or other materials, using water as the drilling fluid.

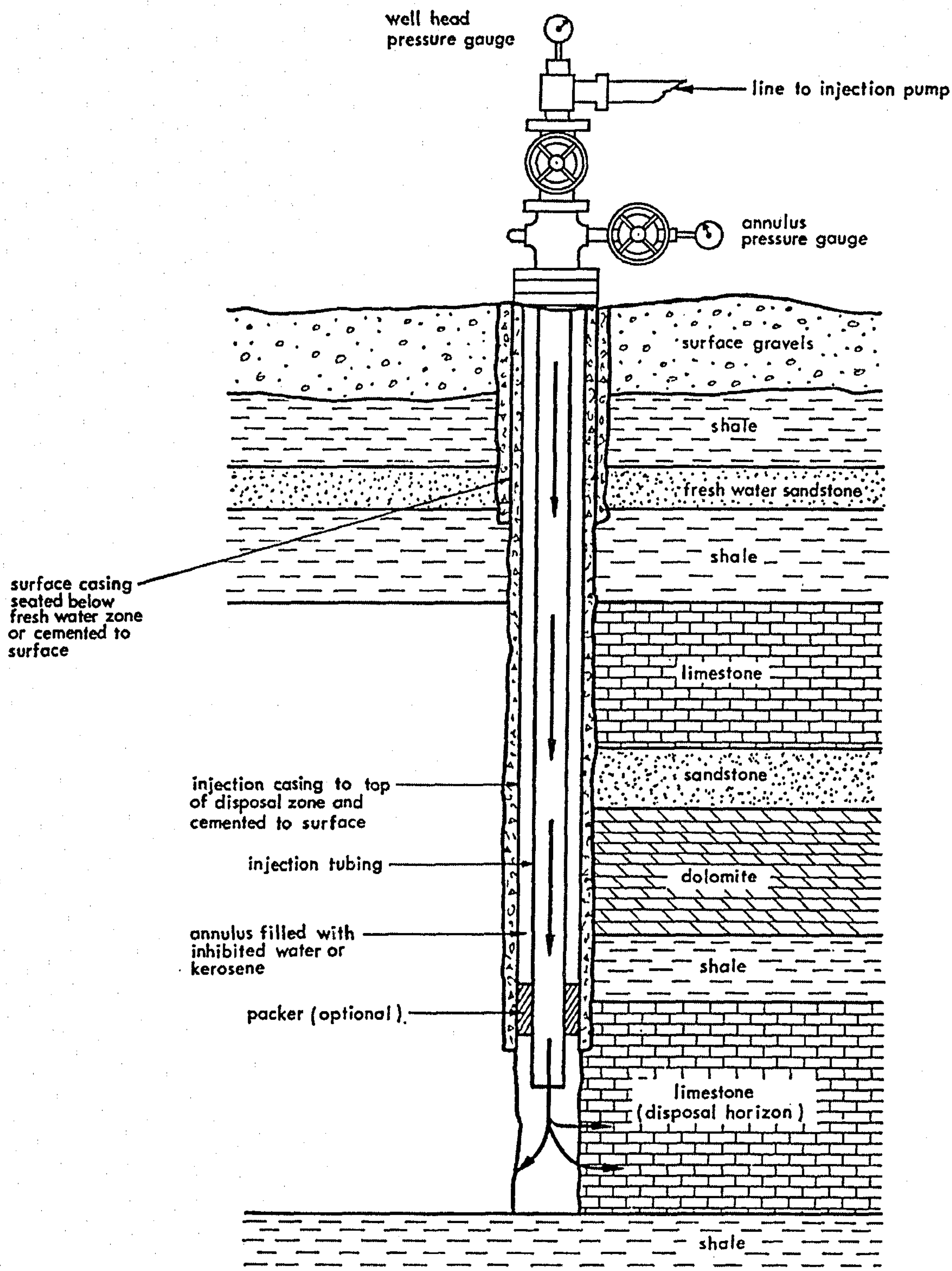

Figure 2.1.Typical disposal well construction (from McLean, 1968).

2.3.2 Evaluation of the Injection Horizon

Physical characteristics of the subsurface horizon into which waste liquids are to be injected can be determined by means of various geologic and engineering techniques and tools. Some rock properties can be estimated from samples taken from surface outcrops, when such outcrops exist. More reliable information can be obtained from the records of nearby deep wells, from samples taken from the injection well, and from tests run in the well during and after drilling (Warner and Lehr, 1977).

The following information should be obtained for any injection well: Depth to which fresh water extends; sequence of geologic formations; thickness, porosity, permeability, and temperature of the injection horizon; and quality of water and fluid pressure in the injection horizon (Warner and Lehr, 1977). Table 2.1 summarizes information desired in subsurface evaluation of the disposal horizon, and methods available for evaluation. Some of the logging tools listed in Table 2.1 can be rented or purchased and used by the well owner, but the usual practice is to have the work performed by an oilfield service company specializing in this type of work (Warner, 1965).

Rock properties that can be determined by core analysis include porosity, permeability, and mineralogy. The fluids in the core can also be removed and analyzed. Core analyses can be performed by companies specializing in this work. In using porosity and permeability data from core analyses, it is crucial to remember that a single core sample may not be representative of the injection horizon as a whole.

Drill cuttings and cores are obtained during drilling. Electric logs, sonic logs, radioactive logs, and drill stem tests can be run after the entire hole or a portion of it has been drilled (Warner, 1965). Pumping and injectivity tests can be performed through the drill stem before the hole has been completed, or through the casing or tubing after the hole has been completed.

Table 2.1. Summary of information desired in subsurface evaluation of disposal horizon, and methods available for evaluation (from Warner, 1965).

2.3.2.1 Information Desired	Methods Available for Evaluation
Porosity	Cores, electric logs, radioactive log, sonic logs
Permeability	Cores, pumping or injection tests, electric logs
Fluid pressure in formations	Drill stem tests
Water samples	Cores, drill stem tests
Geologic formation	Drill time logs, drilling samples, cores,
Intersected by hole	Electric logs, sonic logs, radioactive logs, caliper logs
Thickness and character of disposal horizon	Same as above
Mineral content of formation	Drilling samples, cores
Temperature of formation	Temperature log
Amount of flow into various horizons	Injectivity profile

2.3.3 Completion of Injection Wells

The final phase of injection well construction is termed "completion," and consists of inserting the well casing, cementing the casing in place, perforating or slotting the casing if the hole is completely cased, and stimulating the injection horizon (Ross, 1968). Correct completion of an injection well insures that the injection horizon is segregated from other strata and improves the operating characteristics of the well. Figure 2.2 is an example of well completion showing the depth of surface casing, production casing and injection interval.

Selection of the completion method can be based on oilfield experience if the injection well is in an oil-producing area. If it is not, selection must be made on the basis of areal geological data and from data obtained when the well was being drilled (McLean, 1968). Figure 2.3 illustrates two of several completion methods that can be used with a disposal well. Open-hole well completion methods can be used in competent (strong and cohesive) strata and are advantageous because they are cheaper. They facilitate treatment of the injection horizon in the event of plugging, and no casing is exposed to corrosive waste fluids at the injection horizon.

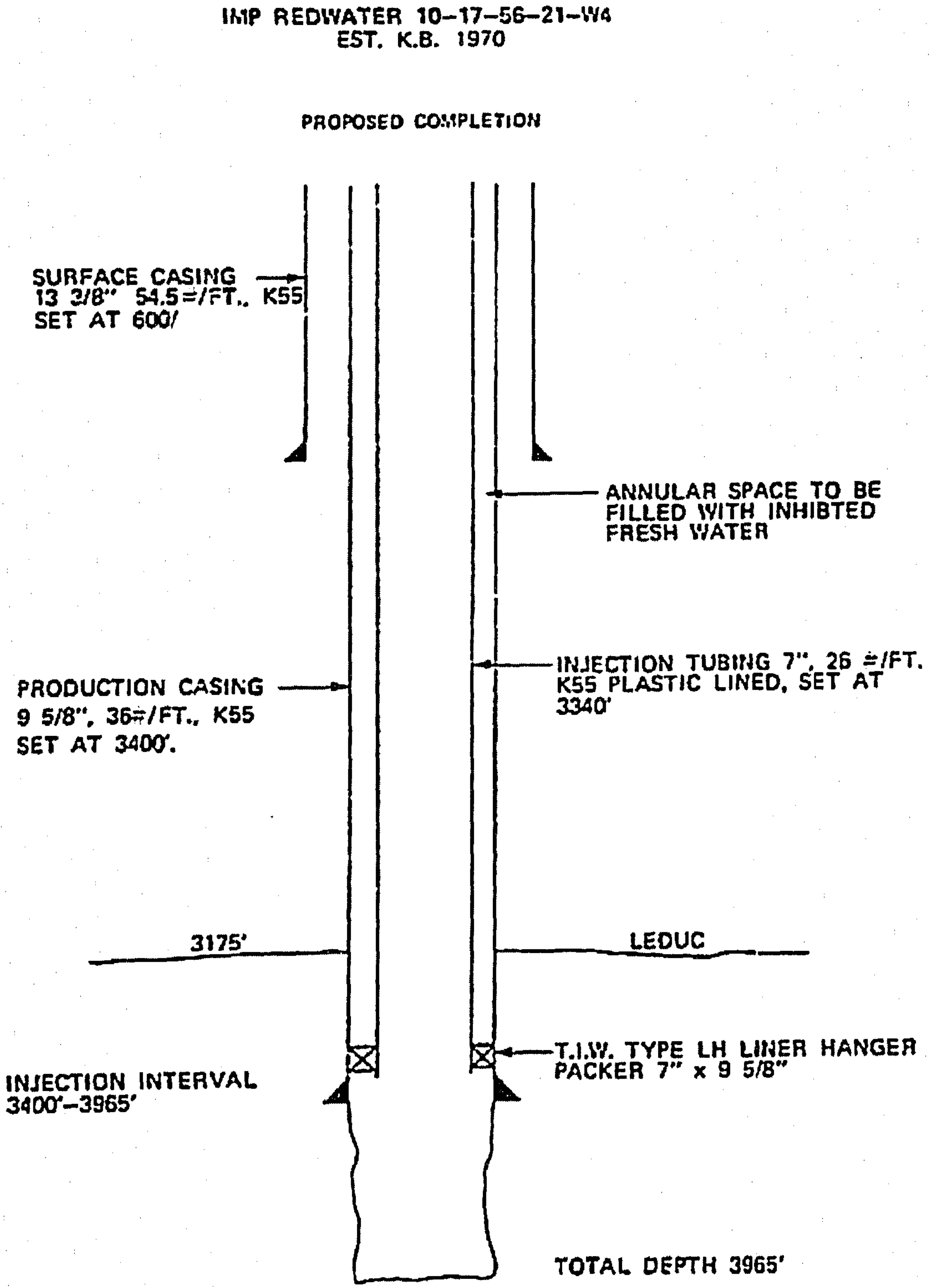

Figure 2.2. Well completion of IMP REDWATER 10-17-56-21-W4 (from EUB Application No. 800984).

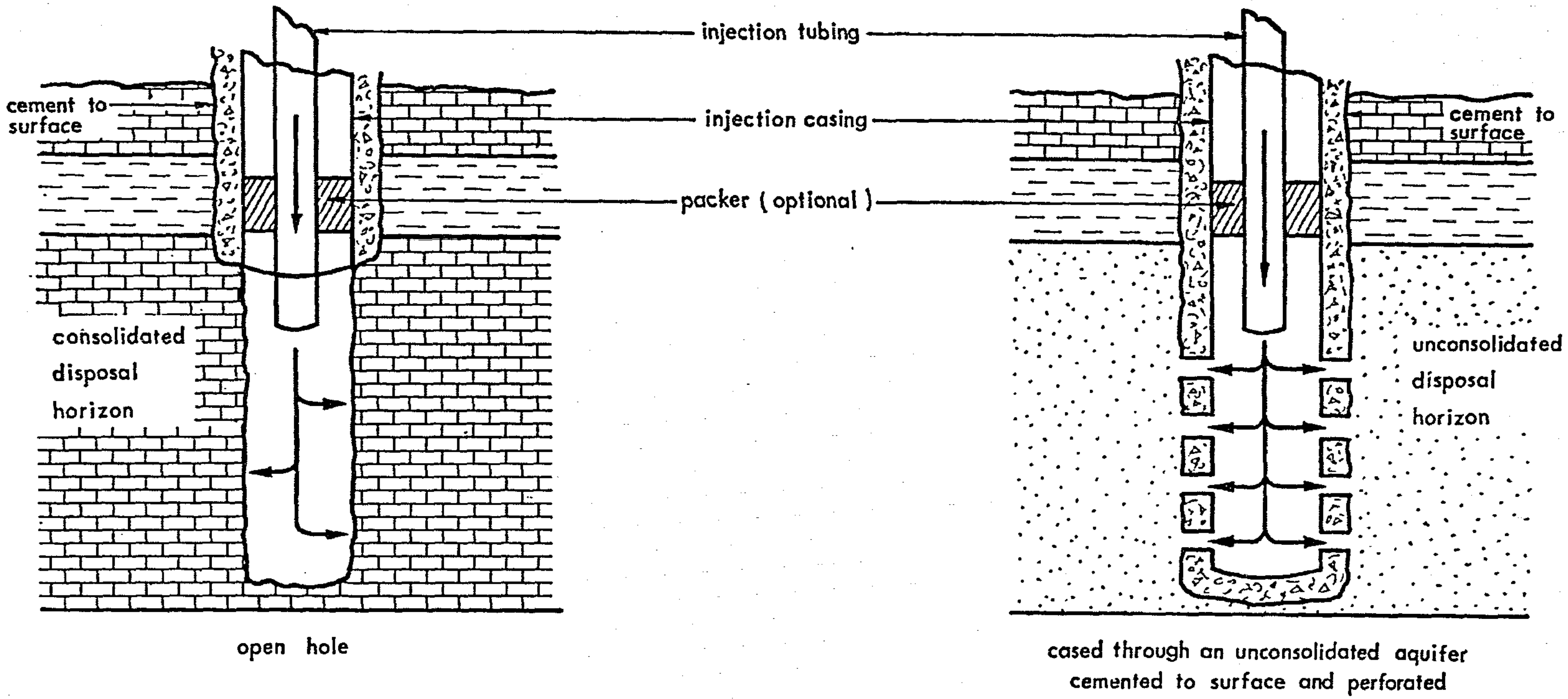

Figure 2.3. Typical completion methods for disposal wells (from McLean, 1968).

Casing and Tubing. Casing is used to protect freshwater aquifers from contamination by salt water from deeper strata. The design features of a casing program depend on well depth, fluid pressure, type of well completion, expected future remedial work on the well, and, in some cases, the expected future drilling time in the casing (Warner, 1965).

More than one diameter of casing is necessary with deep wells (Figure 2.4). Larger-diameter surface casing may extend from a few hundred to several thousand feet below the surface. Smaller diameter casing is run through the surface casing to the top of the disposal horizon (Figure 2.4) or to the bottom of the hole, depending on the method of completion used (Warner and Lehr, 1977).

If waste is pumped through the casing without tubing, corrosion can be a problem. Casing can develop leaks as a result of corrosion or excessive pressure (Zhan, 1998). Casing can, however, be internally coated with cement or plastic to prevent corrosion. Casing failure can be detected by radioactive tracer injection and subsequent gamma ray logging, by flow meter logging, or by caliper surveys (Warner and Lehr, 1977). Tubing can be composed of corrosion-resistant alloy or plastic, or it can cement-lined. Epoxy-resin plastic tubing, completely resistant to corrosion, has been successfully used in salt-water disposal wells (API, 1960).

Packers can be set at the bottom of a casing string (Figure 2.4) to segregate it completely from the corrosive fluids inside the tubing and from the high pressures that may be used in tubing (Warner and Lehr, 1977). Packers are recommended only when conditions require their use, since they may become corroded and difficult to remove as a consequence.

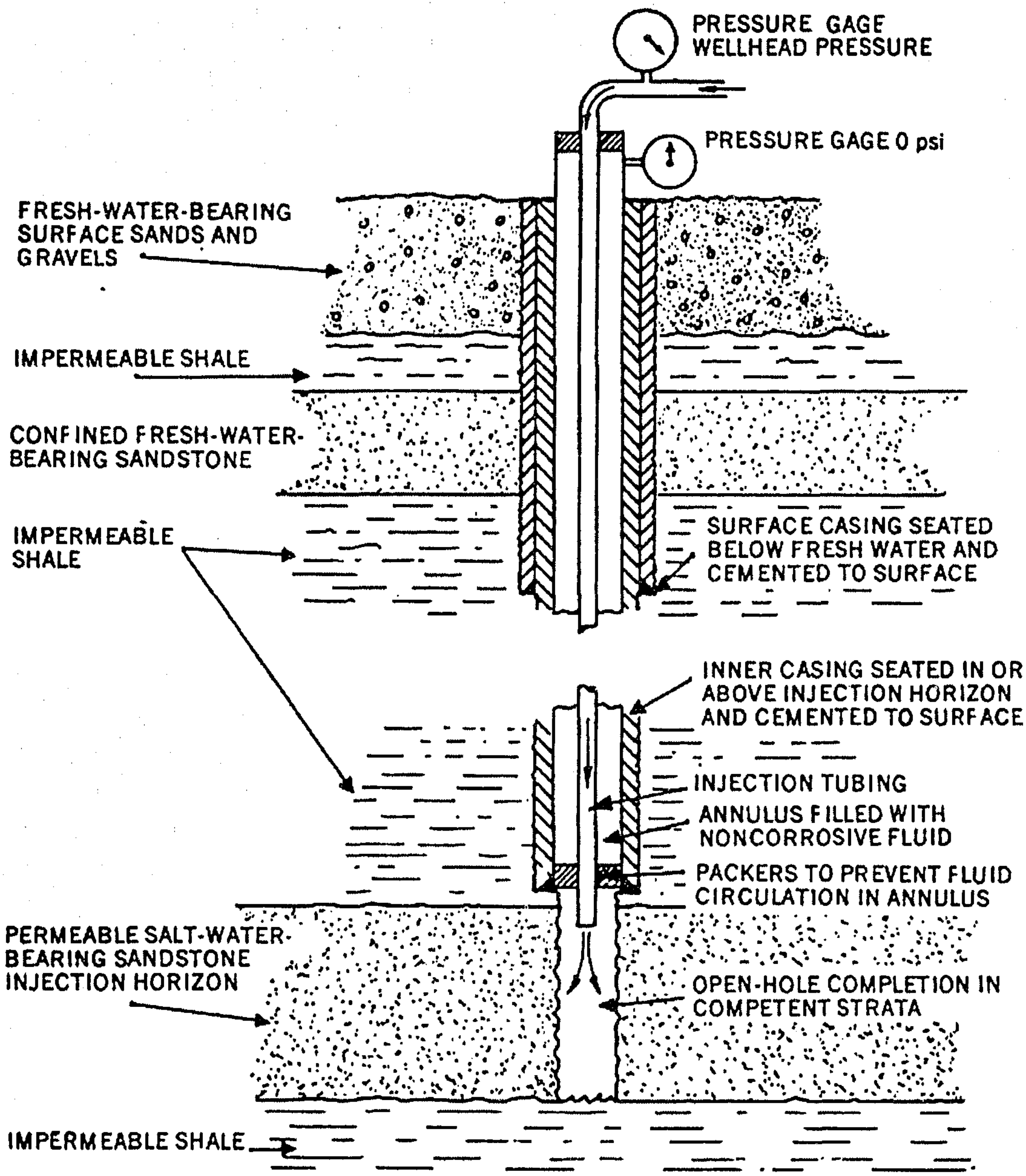

Figure 2.4. Schematic diagram of a waste injection well completed in completed sandstone (from Warner and Lehr, 1977).

Casing Cementing. The annulus between the rock strata and casing is cemented to (1) prevent mixing of waters contained in aquifers penetrated by the well, (2) prevent waste from being injected into aquifers other than those in the injection horizon, (3) protect the pipe from external corrosion by subsurface waters, and (4) increase casing strength (Ross, 1968). Oil and gas well cementing regulations usually require complete filling of the annular space between the surface casing and the wall of the hole with cement. Those regulations also require that a minimum number of feet at the base of the interior (production) casing be cemented (Warner and Lehr, 1977).

Oil and gas well cementing regulations often require an appropriate well log to insure that cementing has been accomplished. They also require pressure testing of a cemented well to insure that leakage does not occur behind improperly cemented casing. Tests for improperly cemented casing can also be conducted by injecting radioactive tracers into gas or liquid in conjunction with subsequent gamma ray surveys.

Figure 2.5 illustrates problems that can be encountered with improperly constructed wells, or wells originally drilled for hydrocarbons and used for disposal purposes. The casing is seldom cemented to the surface, permitting corrosion of the casing and subsequent contamination of other porous formations. The cement seats in such wells may be channeled, which would allow wastes to migrate upward between the casing and the well bore (McLean, 1968). A well drilled and utilized for hydrocarbon extraction may be considered for disposal purposes if the casing is relatively new and of the required grade, and if a cement bond or microseimogram log is run to check the effectiveness of cementing behind the casing (McLean, 1968).

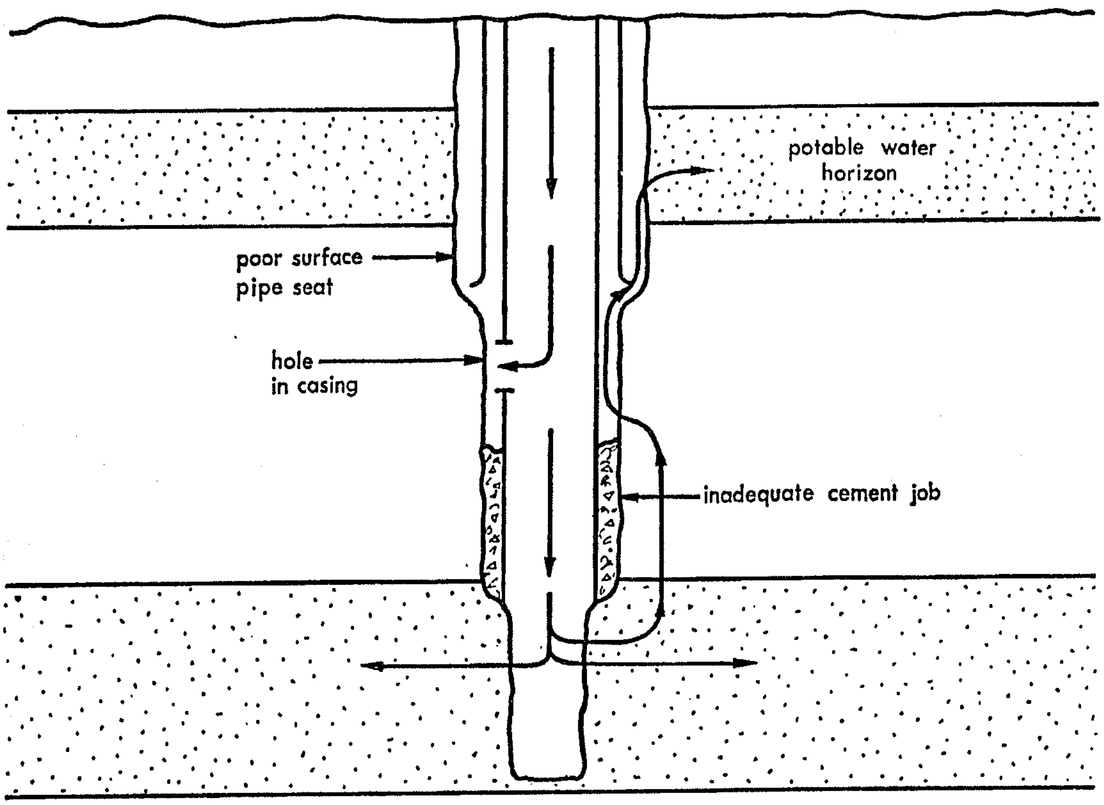

Figure 2.5. Problems of inadequate construction and design of a disposal well (McLean, 1968).

Well Testing. Prior to approval of a disposal well for service, several logs and tests must be conducted. Injectivity testing must be conducted to assess the fracture pressure of the host zone. Hydraulic isolation of the host zone must be demonstrated in all injection and disposal wells prior to being put into service. A suite of temperature logs is the principal evaluation method, and must be supplemented by one of the following: a radioactive trace log, a cement bond log, or an oxygen activation log (Apps and Tsang, 1996). These logs must be run at, or following injection at, the maximum requested injection pressure.

2.4 Operation of Injection Wells

2.4.1 Permeability Reduction During Operation

The danger of reduction in permeability of the disposal horizon during operation is an important problem in the injection of waste into deep aquifers. Reduction in permeability to injected water could occur through: (1) precipitation reactions between wastewater and interstitial water or wastewater and aquifer minerals, (2) gas-producing reactions, (3) development of reaction coatings on aquifer minerals, and (4) dispersion of clay minerals as a result of ion exchange or salinity reduction in interstitial waters (Warner, 1965).

The chemical character of wastewater would be expected to be somewhat different at each injection site; therefore, so too would the potential for changes in the permeability in the injection horizon. Plugging at or near the well bore can also be caused by (1) bacteria, algae, and mold on sand particles; (2) the sheaths of capsulated bacteria and iron bacteria; and (3) sulfate-reducing bacteria that produce H_2S, which reacts with iron to form insoluble FeS_2 (Ross, 1968). Bacteria can be controlled with various chemicals, but caution must be exercised because many otherwise useful bactericides produce insoluble products when added to oilfield brine.

Plugging of the injection horizon in the immediate vicinity of the injection well bore by suspended solids is a common problem. These solids may be present initially, or may occur when waters that are in chemical equilibrium are subjected to changes in temperature, pressure, or gas content. In such an event, dissolved constituents – particularly manganese or iron – may precipitate. These precipitates can plug the injection well face or pores near the face. Other solids can precipitate through reaction of corrosive waters with pumping equipment and well casing or tubing.

Entrained and dissolved air increases the corrosiveness of water. Because the permeability of sandstone to water containing only a small amount of entrained gas is much less than its permeability to water alone, entrained air can also act directly to plug the pores of the injection horizon (Warner, 1965). Therefore, water to be injected into wells must routinely be treated to remove suspended solids and dissolved iron and manganese. It must also be de-aerated before injection to prevent corrosion and plugging problems. Figure 2.6 is a generalized schematic of a surface treatment plant.

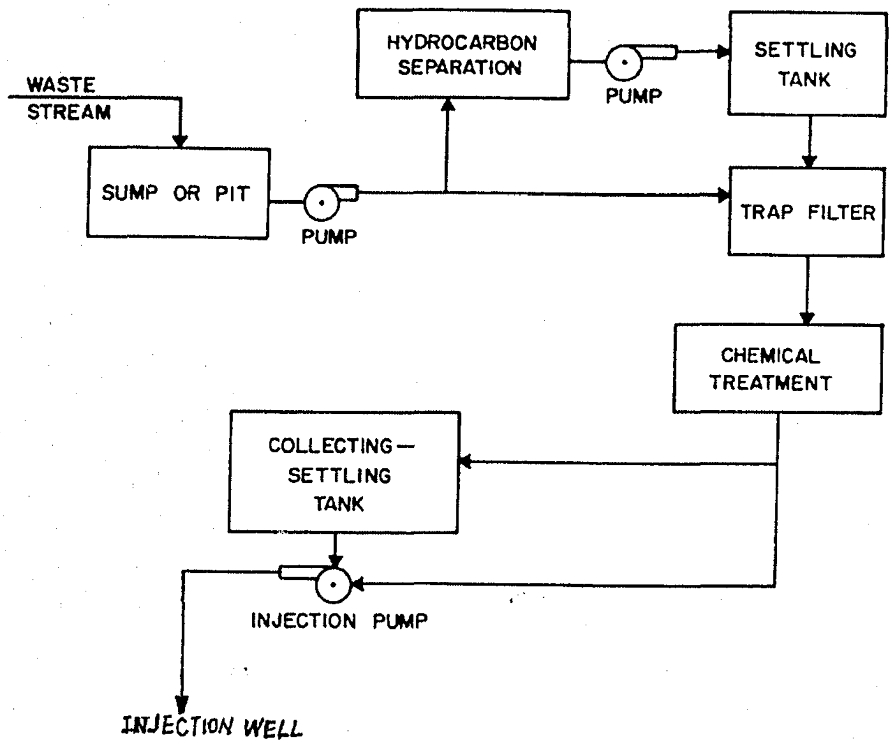

Figure 2.6. General scheme of surface treatment facilities (from Everdingen, 1974).

2.4.2 Injection Well Monitoring

A monitoring program must include a daily record of injection pressures and rates, and annulus pressure (EUB, 1995). The successful and continued performance of any disposal operation is contingent upon a properly designed monitoring program that will detect early failure of well components or formation plugging that may develop. Frequent analyses of the effluent from the treating plant must be undertaken as a control of plant efficiency and to assure that plugging materials are not entering the well bore.

Injection pressure is monitored to provide a record of reservoir performance. A record of daily injection rates and pressures will detect failures of equipment in the well such as a casing leak or failure of a pack. Injection pressure can be expected to increase with the time due to the natural effects of reservoir pressure buildup and plugging of the pore spaces from material in the waste (Warner, 1975).

The American Petroleum Institute (API, 1960) recommends pressure monitoring of the fluid column between the injection tubing and the well casing as a means of injection well monitoring. If a packer is used to segregate the fluid in this annular space from the fluid being injected (Figure 3), monitoring of the pressure can permit detection of tubing or packer leaks.

The volume of injected wastewater is monitored to (1) allow for estimates of the distance of wastewater travel, (2) allow for interpretation of pressure data, and (3) provide a permanent record of volume of emplaced wastewater. Complete chemical analyses are made periodically on composite or grab samples. Because bacteria may have a deleterious effect on reservoir permeability, periodic biological analysis of some wastewaters may be desirable to ensure that organisms are not being introduced (Warner, 1975).

2.4.3 Injection Well Failure

Injection wells can fail in a variety of ways. The most critical type of failure is one that could contaminate freshwater or other valuable natural resources. Well failure is attributed primarily to excessive injection pressure in combination with inadequate casing and improper well cementation (Sauveplane, 1996). Other types of failure, such as plugging of the injection horizon, can also occur. Contamination of groundwater or other natural resources could occur through lateral movement of injected fluids within the injection horizon.

Engineering knowledge that will virtually assure the reliability of well facilities has been developed (Mogharabi, 1995). Consequently, failure of injection wells resulting from improper construction is avoidable. The escape of injected waste through abandoned wells that penetrate the injection horizon could, in most cases, be prevented by thorough study of the records. Leakage of injected waste through the strata that confine the injection horizon is not likely to occur if competent geologic evaluation of the injection horizon has been performed.

Groundwater contamination from oilfield brines has been reported as possibly having occurred through improperly-plugged abandoned wells or through wells that inject brine into near-surface horizons at high pressure (Crouch, 1964). Experience in the petroleum industry has shown that most fracturing will occur in the horizontal plane without damage to the confining strata (McLean, 1968). However, there are a number of documented cases of vertical fracturing, and this possibility must always be considered. The regional principal stress should be determined before proceeding, as fracturing usually occurs perpendicular to this stress. Furthermore, the presence of unsealed fault fractures, as shown in Figure 2.7, could allow the formation fluids or the waste itself to migrate under pressure along these faults or fractures and thereby contaminate or detrimentally affect horizons (McLean, 1968).

The hazards of conducting subsurface disposal in areas of unplugged wells are illustrated in Figure 2.8. The disposed fluids or the formation fluids under pressure can be forced up the unplugged or inadequately plugged well bores and into other horizons or freshwater sources (McLean, 1968). Cases have been documented in other areas where the fluids have migrated along highly permeable streaks in overlying horizons (as shown in Figure 2.8), and up shallower well bores (McLean, 1968).

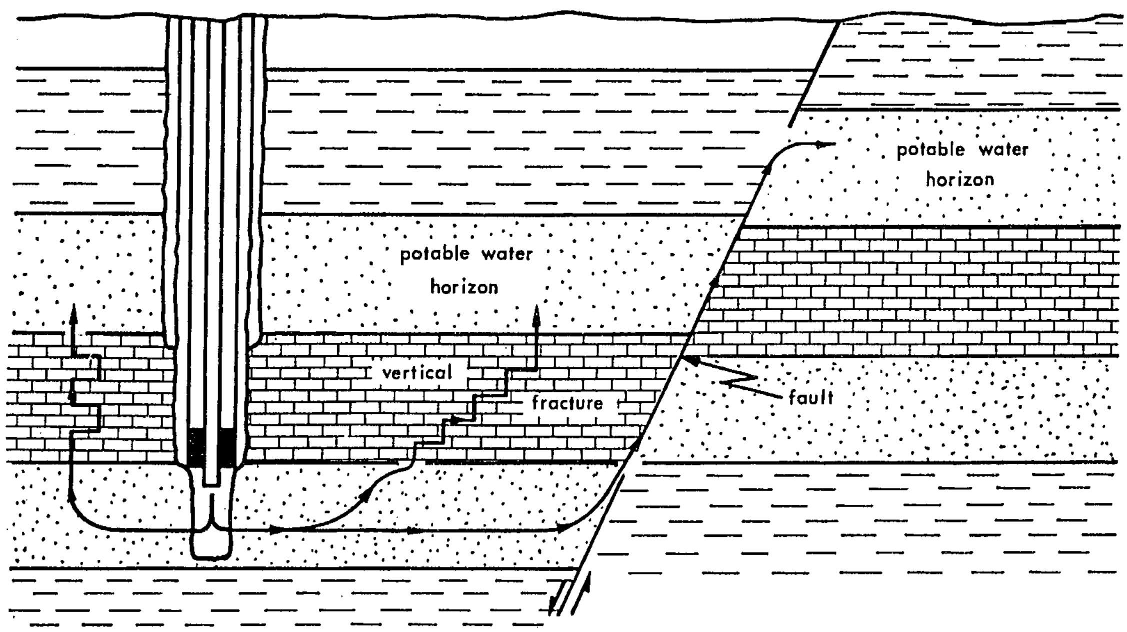

Figure 2.7. Hazards of subsurface disposal in fracture and faulted areas (from McLean, 1968).

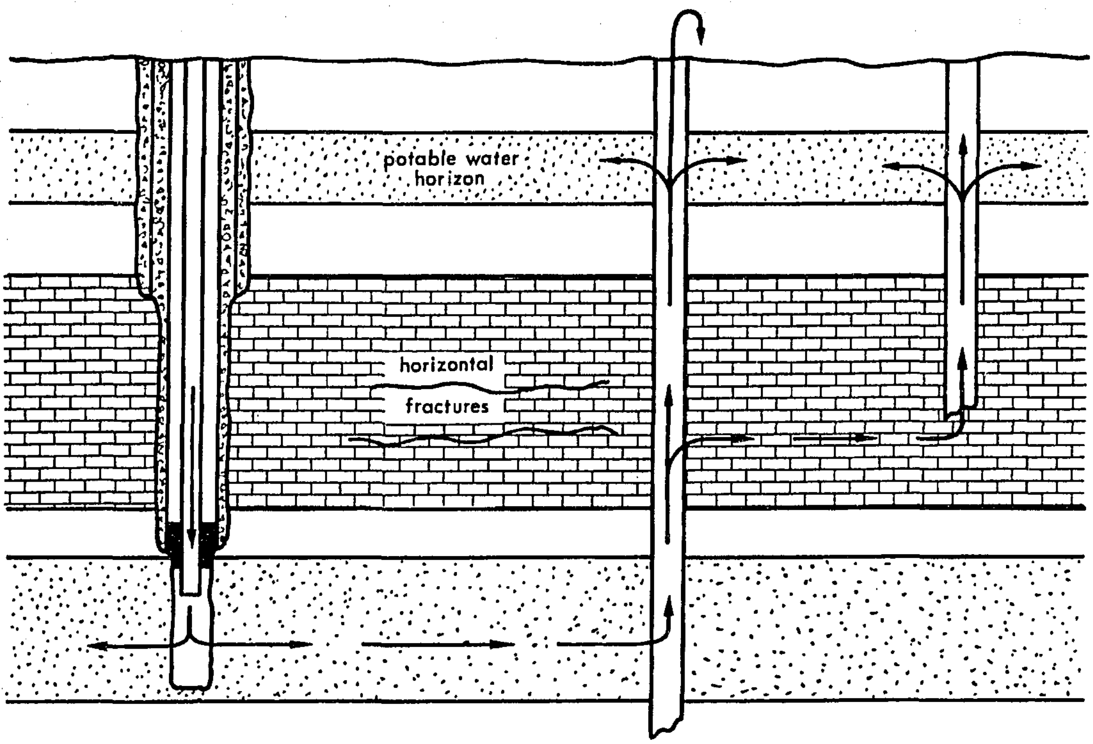

Figure 2.8. Hazards of subsurface disposal in areas of unplugged wells (from McLean, 1968).

2.5 Regulations of Injection Wells

2.5.1 Alberta Regulations

Requirements and regulations for disposal wells in Alberta are contained in EUB IL 94-2, Guide G-51, Injection and Disposal Well, Well Classifications, Completion, Logging, and Testing Requirements (EUB, 1995). According to the EUB, deep well disposal of oilfield and industrial wastewaters in Alberta can be a safe and viable disposal option when wells are properly constructed, operated, and monitored. Deep well disposal should be guided by the following principles:

- Waste minimization shall be implemented prior to using the deep well disposal option.
- Resource conservation, including surface water and the waste streams themselves, shall be pursued whenever possible.
- Disposal wells are classified and designed on the basis of the fluid being injected. These waste classifications are described below.
- Waste fluids shall not be diluted solely for the purpose of avoiding waste fluid classification.
- Operators of surface facilities that generate or process waste material that is disposed through Class Ia or Class Ib wells are expected to design and operate those facilities using sound waste management practices and principles of waste minimization.

Regulatory activities of the EUB focus on issues related to:

- Wellbore integrity to ensure initial and ongoing containment of the disposal fluid in the interests of both hydrocarbon conservation and groundwater protection;
- Formation suitability to ensure initial and ongoing confinement of the disposal fluid in the interests of both hydrocarbon conservation and groundwater protection;
- Suitability of the waste stream for deep well disposal having regard for the nature of the fluid, the integrity of the well, and alternative waste management options; and

- Reporting and manifesting of disposed wastes.

According to EUB Guide 51 (EUB, 1995), the general characterization criteria that must be met to qualify waste streams for deep well disposal are listed below. A qualified waste stream:

- pH between 4.5 and 12.5;
- Does not meet surface water discharge criteria;
- Has a nonhalogenated organic fraction of less than 10% by mass, unless either of the following is true:
  - It is an untreatable sand or crude oil/water emulsion;
  - It is an antifreeze or dehydration fluid that contains greater than 60% water by mass;
- Has one or more halogenated organic compounds in a total combined concentration less than 1000 mg/kg; and
- Has a polychlorinated biphenyl (PCB) concentration of less than 50 mg/kg.

Wells for deep well disposal of wastewater in Alberta are licensed by the Alberta Energy and Utilities Board (EUB) according to the class system defined in EUB Guide 51 (EUB, 1995). Guide 51 identifies five different classes of injection and disposal wells.

Wells used for injection or disposal service are classified according to the fluid injected or disposed as follows:

- Class Ia: Oilfield or industrial waste streams;
- Class Ib: Produced water, specific common oilfield streams, and waste streams meeting specific criteria.;
- Class II: Produced water or brine equivalent;
- Class III: Hydrocarbons, inert or other gases into a reservoir matrix for storage, enhanced recovery, or disposal purposes; and
- Class IV: Fresh water or steam.

Figure 2.9 shows the detailed relationship between well classes and waste characteristics.

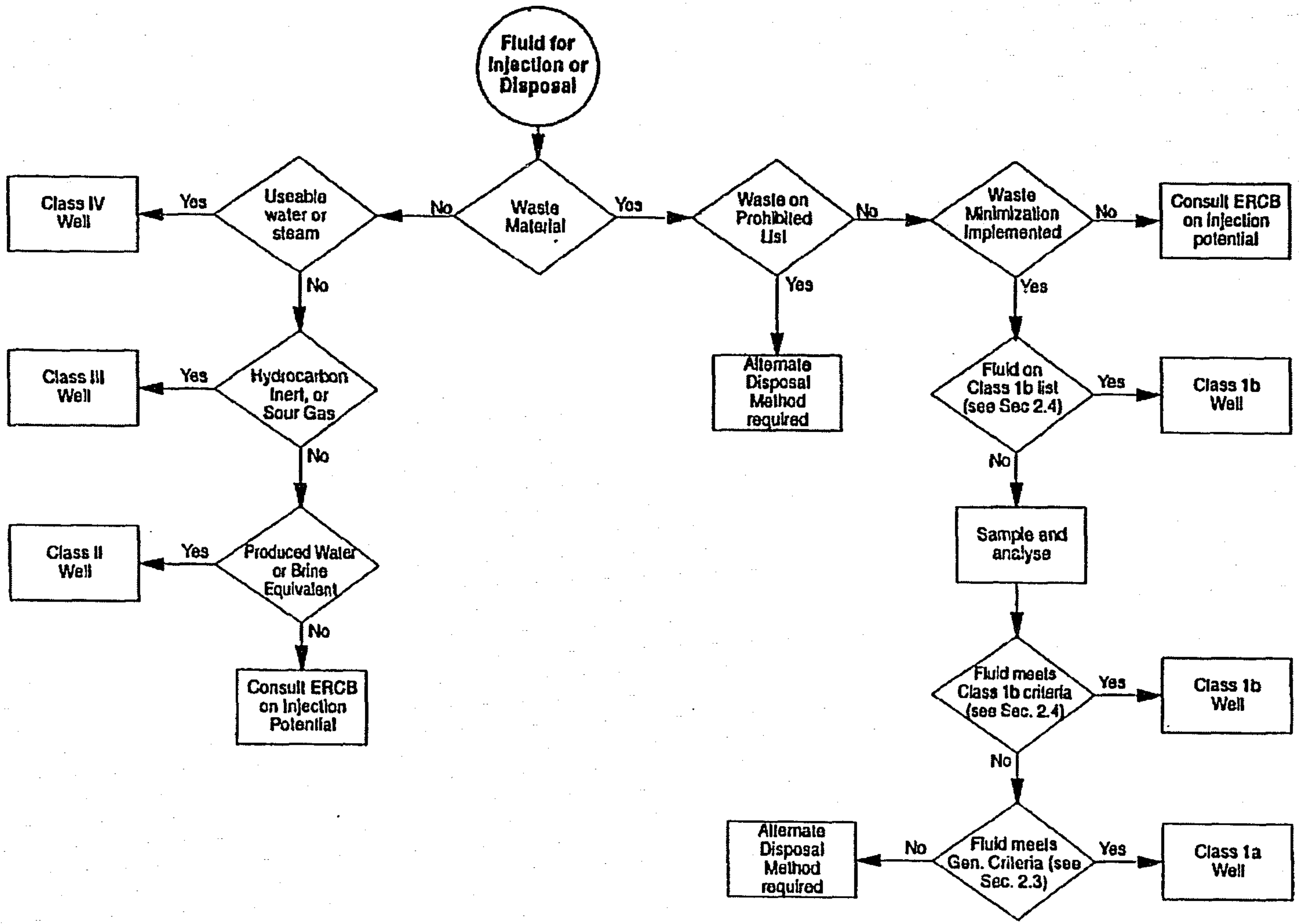

Figure 2.9. Relationship between well classes and waste characteristics (from EUB, 1995).

2.5.2 USEPA Regulations

The Underground Injection Control (UIC) Program provides standards, technical assistance and grants to state governments in the United States to regulate injection wells in order to prevent them from contaminating drinking water resources. USEPA (2002) defines the five classes of wells according to the type of fluid they inject and where the fluid is injected. These classes are as follows:

- Class I: Hazardous and non-hazardous wastes below the lowermost Underground Source of Drinking Water (USDW);
- Class II: Oil and gas production brine and related wastes;
- Class III: Super-heated steam, water, or other fluids;
- Class IV: Hazardous or radioactive wastes. These wells are banned under the UIC program because they directly threaten public health; and
- Class V: Waste that does not fall within the other categories of wastes.

The vast majority of US states have agreed to administer all USEPA regulations regarding the issuance of permits and monitoring underground injection well activities (Golder, 2002). They have accepted primacy in regulation of deep well disposal, but still follow closely the regulations set by the federal EPA. Table 2.2 lists the states reviewed, and indicates regulations or well occurrences of interest.

Table 2.2 Summary of UIC regulation review for various U.S. states (from Golder, 2002).

State	Primacy (Yes or No)	Notable Regulations or Well Occurrences
Alabama	Yes (Class II)	Class II UIC Program administration by the Oil and Gas Board.
Arkansas	Yes	Permit applications for Class I underground injection wells reviewed by staff of Arkansas Department of Environmental Quality, Arkansas Oil and Gas Commission and sometimes EPA.
California	Yes (Class II)	Class I wells not allowed in California. All fluid disposed must be generated in conjunction with oil and gas production. The Department of Toxic Substances Control determines whether a waste is hazardous.
Florida	Yes (Class I,III IV, and V)	Florida Department of Environmental Protection (DEP) regulates underground injection according to the federal Safe Drinking Water Act. Class II wells are regulated separately by the Florida Geological Survey. Only state with Class I wells for municipal wastewater disposal.

Table 2.2. Summary of UIC regulation review for various U.S. states (From Golder, 2002) (Continued).

State	Primacy (Yes or No)	Notable Regulations or Well Occurrences
Georgia	Yes	Permit applications have section requiring chemical, physical, and radioactive characteristics of injected fluid. No UIC permit will be issued for injection of fluids that exceed maximum contaminant levels for any constituent regulated under Georgia's drinking water standards.
Hawaii	No	Administered by Hawaii Dept of Health and EPA. Type and quantity of injected fluid required, but not specific.
Illinois	Yes	Only 4 Class I wells operating, no Class III, over 2000 Class V shallow wells.
Kansas	Yes	Class I and V permits shall be effective for a fixed term not to exceed 10 years. Class I hazardous waste injection well permits to be reviewed at least annually. Pretreatment requirement in regulations for compatibility with well tubing and casing and with disposal formation.
Louisiana	Yes	Regulated by Injection and Mining Division.
Maine	Yes	UIC administered by state Department of Environmental Protection (DEP). No Class I, II or III wells in Maine, but are allowed by regulations.
Montana	Yes (Class II)	Class II wells regulated by the Montana Board of Oil & Gas Conservation.
Nebraska	Yes (Class I,II IV, and V)	State regulations specify applicants must provide proposed operating data including average and maximum daily rate and volume of fluid injected, average and maximum injection pressure, source and analysis of chemical, physical, radiological and biological characteristics of injection fluids
New Mexico	Yes	Underground injection in connection with oil and gas production regulated by Oil Conservation Division. Other classes regulated be NM Environmental Department.
North Carolina	Yes	State Rule 15A NCAC 2C.0209 gives a complete list of permitable well types. Examples of allowable wells include air conditioning water return wells, in situ groundwater remediation wells, and experimental technology wells.
Ohio	Yes	12 permitted Class I wells in operation. State regulation specify applicants must provide proposed operating data including average and maximum daily rate and volume of fluid injected, average and maximum injection pressure, source and analysis of chemical, physical, radiological and biological characteristics of injection fluids.
Oklahoma	Yes	Fees specified in regulations for surface facilities of any Class I hazardous waste injection well.
South Dakota	Yes (Class II)	Class I wells banned.
Tennessee	Yes (Class I and V)	Administered by Tennessee Division of Water Supply, Ground Water Management Section. Class II wells regulated by EPA, and there are no Class III wells in state.
Texas	Yes	Class I wells regulated by Texas Natural Resource Conservation Commission. Operating requirements specify restriction on maximum injection pressure, rates and volumes of injected fluids. Monitoring also includes injection fluid analyses.

Table 2.2. Summary of UIC regulation review for various U.S. states (From Golder, 2002) (Continued).

State	Primacy (Yes or No)	Notable Regulations or Well Occurrences
Washington	Yes	Class I, III and IV wells are banned.
Wyoming	Yes	Class I include all wells that dispose of waste on a commercial basis, even if the waste would otherwise be eligible for disposal into a Class II well.

2.6 Summary

A review of the available information concerning use of deep wells for subsurface injection of liquid wastes was conducted to obtain background information on method as a possible solution to an industrial waste problem. Liquid waste disposal through properly constructed and operated injection wells is relatively safe and unlikely to contaminate surface water or potable ground water. According to this review, deep well injection of waste is technically feasible in many areas. If properly planned and implemented, it is unlikely to harm natural resources. While deep well injection is an older waste management technique, at this point in time it is still considered effective and safe.

Of the methods of waste disposal permitted, deep well injection is the least expensive. However, in recent years the Government of Alberta has recognized the need for water conservation. In view of a greater need to consider promotion of water conservation and reuse of reclaimed water, better information is needed on deep well disposal practices with respect to quantity and quality of industrial waste. Better information is also needed in order to be able to decide whether some of these wastes are suitable for treatment and reuse.

Information was not observed in the literature about jurisdictional guidelines or regulations pertaining to treatment or reuse of industrial waste as an alternative to deep well disposal. Waste characteristics observed in the literature pertained to oilfield deep well disposal. Thus, there is lack of published information on industrial waste characteristics in relation to disposal options. Most of the literature addresses technical knowledge and management experience concerning deep well injection of wastes.

Based on the summary of the background literature review, the overall objectives of this project were to:

- Examine the quantity and quality of industrial wastes injected into deep wells in Alberta;
- Identify, categorize and document various types of industrial wastes currently disposed of by deep well injection in Alberta; and
- Identify preliminary opportunities for reclamation and reuse of selected wastes.

Achievement of the objectives is expected to lead to better management and conservation practices of water by industry in Alberta.

3.0 METHODS

The project involved a search for and documentation of practices of deep well injection of industrial wastes throughout the Province of Alberta. The methods employed included collection of data for industrial facilities currently disposing of wastewaters by deep well injection, and categorizing these wastewaters based on sources, volumes, and physical/chemical properties wherever possible.

Primary activities of the project involved:

(1) Interaction with Alberta Environment (AENV) and Alberta Energy and Utilities Board (EUB) in order to identify and gather records on deep well injection activities in Alberta;

(2) Evaluation and organization of data and information received by the Energy and Utilities Board on deep well injection activities;

(3) Identification and documentation of waste streams currently disposed of by deep well injection based on data and information received;

(4) Categorization of the current state of deep well injection practices in the Province of Alberta, including industrial activities and waste types subject to deep well injection, deep well injection quantity, and, where available, quality; and

(5) Identification of different recommendations for each category to better assess the source liquids for treatment and reuse as an alternative to injection.

3.1 Records of Information Request

In order to obtain well data, a meeting was arranged in August 2004 with P. Valupadas and R. George of AENV (Edmonton). Suggestions received from this meeting were summarized as follows:

- Check with AENV for Environmental Management System Database (EMS) information to identify any new industries using deep well injection;

- Contact C. Adolf of EUB (Calgary) to set up a meeting regarding a request for non-oilfield deep well injection records, as the EUB has registry files and reports of industries practicing deep well injection;
- Contact D. Pryce (Canadian Association of Petroleum Producers – CAPP) to explain what was being undertaken and to ask for suggestions concerning procurement of information;
- Contact A. Schulz (Canadian Petroleum Products Institute – CPPI) to explain what was being undertaken and to ask for suggestions concerning procurement of information; and
- Contact Dave Onuczko, Executive Director, Northeast Capital Industrial Association (NCIA) to explain what is being undertaken and to ask for suggestions concerning procurement of information.

J. Yan of AENV (Edmonton) was contacted by email and telephone during August 2004 concerning the EMS Database to identify new industries using deep well injection. Data on Active Groundwater Oilfield Injection Licenses were extracted from the EMS Database and emailed in September 2004. However, these licenses were not related to deep well injection of industrial wastes. J. Yan suggested contacting the EUB, because that group has the original applications and registry files of deep well activities in Alberta.

Contact with D. Pryce (CAPP) and A. Schulz (CPPI) was conducted during September 2004. It was indicated that CAPP and CPPI industry members were aware of the interest in current deep well disposal activities. Both people indicated that individual industries should be contacted directly to request information regarding their disposal activities. Contact was made with D. Onuczko (NCIA) also during September 2004. D. Onuczko indicated that a number of industries within NCIA generate small volumes of liquid wastes which are trucked to injection sites. He also suggested that individual industries should be contacted directly to request information regarding their disposal activities.

Contact was then made with C. Adolf (EUB, Calgary) in September 2004. After a series of discussions, thirteen packages of numerous applications (in microfiche) and EUB records of injection volumes (in hard copy) were forwarded to the University of Alberta by courier and Canada Post during October and November of 2004.

3.2 Well Data Evaluation

Well data evaluation included categorizing, ordering, and summarizing data received from the EUB. The purpose of the evaluation was to reduce these data to intelligible and interpretable form. The data were broken down into constituent parts to facilitate analysis. These parts included general well properties, and quantity and quality characteristics of liquids disposed of in the wells.

3.2.1 Raw Information Organization

Materials provided by EUB included the following information:

- Injection volume records of Class Ia wells currently licensed in Alberta; and
- Application and approval microfiche of Class Ia wells and several wells of other classes.

To find the appropriate information on microfiche, data on all of the microfiche were scanned and saved on CD with ScreenScan Software in Rutherford Library of University of Alberta. The microfiche was scanned as "image files" rather than text files. Image files with the same application number were copied to one Microsoft Word file, and the Word file was named with this application number.

The applications were examined to extract information on Class Ia deep well disposal of industrial wastewaters. The type of industrial activity was available from the applications and older approvals. Older approvals described deep well injection activities in detail, while newer formats of approval were more general in nature. Some of the older approvals were superseded by newer ones.

Review of applications revealed that twenty-one approvals were issued by the EUB to industrial facilities for 37 Class Ia deep wells. The twenty-one approvals issued by EUB to industrial facilities for Class Ia deep well disposal and their respective applications are listed in Table 3.1. Numbers in bold and underlined are approval numbers. Numbers below approval numbers are application numbers according to the respective approvals. They are listed in annalistic sequence.

3.2.2 Summary of Well Properties

Applications for each approval were reviewed and well properties were summarized using the template shown in Table 3.2. This template was organized based on all the available information on well properties:

The parameters "top of injection interval measured depth," "minimum packer setting depth," and "maximum wellhead injection pressure" indicated the level of groundwater protection for a given well. These parameters provide the basis of groundwater protection at specific locations.

Surface casing constitutes the primary line of protection against ground water contamination. A second line of protection is the production casing in the well – which is isolated from the injected fluids by a packer and corrosion inhibited fluid in the annulus. A production packer is set below the minimum packer setting depth and the annular space above the packer is filled with a non-corrosive liquid. A third line of protection against ground water contamination is the disposal zone's reservoir pressure, which is not to exceed the maximum wellhead injection pressure. Finally, no water is allowed to be injected into the formation above the top of injection interval measured depth.

Table 3.1. Deep well applications for approvals.

3924	4779	5737	6114	6660	7070	7290	7547	7742
6803	7030	*820188	840924	830865	841049	*840246	921157	861064
9773	790087	881087	890835	880053	891013	*840676	941190	891508
830140	800281		900255	880679	921246	840839		941039
	800984		900489	881976	950029	*851178		941328
	840526		900733	890659		*861413		990087
	851462		900893	911059		*880078		1083119
	920026		901186	921164		931118		
	940643		901379	930310				
			910249					
			910734					
			911484					
			910250					
			911639					
			920878					
			920899					

7842	8133	8185	8251	8317	8713	8784	8926	8951
3349	790267	960991	*959	8513	910585	*9402	800818	1092592
920805	840326		7164	770952	920251	851081	861103	
941351	921492		790087	780322	921166	881087	890567	
	951632		*800075	800905	1071957	941713	950664	
			951711	861235	1338131		1069205	
			881087	881087			1094730	
				872060				
				910408				
				950195				

9013	9699	9700
1250509	1312265	800613
1259677		8981087
		1310506

* The application number mentioned in approval; however, no information was received on the application by EUB.

Note: Approval number is the most recent number indicated on file from records supplied by EUB.

Table 3.2. Template for summarizing well properties.

Approval #	EUB Appl #	Field	Formation	Approval Holder	Scheme type	G 51 type	Well Name	Unique Identifier
XXXX	XXXXXX	XXX	XXX	XXXX	XXX	XX	XXXXX	XXXXX

Top of Injection Interval Measured Depth (metres KB)	Minimum Packer Setting Depth (metres KB)	Maximum Wellhead Injection Pressure, kPa (gauge)
XXX	XXX	XXX

Approval #: Approval # that EUB issued to the industrial facility for deep well disposal.
EUB Appl #: Application # that industrial facility applied for the approval by EUB for deep well disposal.
Field: Area of deep well in Province of Alberta.
Formation: Name of zone in area for disposal of waste streams.
Approval Holder: Industrial facility that holds approval issued by EUB for deep well disposal.
Scheme type: Discharge method of wastewater from industrial facility.
G 51 type: Well classification type according to EUB Guide 51.
Well Name: Name of well.
Unique Identifier: Location of well, e.g. well with unique identifier B0/14-01-50-01W4/0 located in Section 1, Township 50, Range 1, West of 4th Meridian.

3.2.3 Summary of Injection Volumes

Information on injection volumes provided by EUB included monthly injection volumes and total hours of injection per month. Injection volumes data of each well were reviewed and summarized using the template shown in Table 3.3. This template was organized based on all the available data on injection volume records. Injection volume and rate were plotted by Microsoft Excel according to actual injection records provided by EUB.

Table 3.3. Template for summarizing well injection volumes.

Injection Started	Time Series Plot of Monthly Injection Volume	Time Series Plot of Hourly Injection Rate	Average Annual Injection Rate (m^3/yr)	Average Monthly Injection Rate ($m^3/month$)	Cumulative Injection Amount to Sep, 2004 (m^3)
XXXX	See Figure XXXX	See Figure XXX	XXX	XXX	XXX

Injection started:	Date on which the deep well began operating.
Time series plot of monthly injection volume:	A plot of injection volume on a monthly basis.
Time series plot of hourly injection rate:	A plot of injection rate according to monthly injection hours.
Average annual injection rate:	Calculated from the average of annual injection volumes.
Average monthly injection rate:	Calculated from the average of monthly injection volumes.
Cumulative injection amount:	Calculated from the sum of monthly injection volumes for the month that injection volume records began to be provided until September 2004.

3.2.4 Summary of Source Characterization Data

Information on source characterization of waste streams was provided in application and approval microfiche. According to Table 3.1, approvals and their respective applications were examined to extract waste analysis records of each Class Ia well. These records were included and discussed in the results section.

3.3 Categorization of Deep Wells

A simple scheme was developed to categorize the wells reviewed in this project based on the actual quality and quantity of source liquids. This scheme used eight different categories as shown in Table 3.4. These categories are described further below. Criteria used to decide whether the injection volume was small or large do not exist. Based on comparison of all the available injection volume records, a monthly injection volume of 10,000 m^3/month was used as an arbitrary criterion to categorize the amount of injection volume.

Table 3.4. Well application categories and respective defining criteria.

Category	Defining Criteria
A	low to intermediate disposal rate (<10,000 m^3/month), multiple or numerous sources
B	low to intermediate disposal rate (<10,000 m^3/month), discrete or few sources
C	intermediate to high disposal rate (>10,000 m^3/month), discrete or few sources, unreadable or outdated source characterization data
D	intermediate to high disposal rate (>10,000 m^3/month), discrete or few sources, readable source characterization data with appearance of extensively contaminated source liquids
E	intermediate to high disposal rate (>10,000 m^3/month), discrete or few sources, indication that individual contaminants present in source liquids would require some form of specific treatment prior to general reuse
F	information lacking on disposal rate, indication that individual contaminants present in source liquids would require some form of specific treatment prior to general reuse
G	waste liquids being disposed includes contaminated groundwater
H	negligible amounts of waste fluids injected during recent years, infrequent injection periods

Category A Wells. Category A wells were classified as having low to intermediate disposal rates (<10,000 m^3/month) of waste streams from multiple (or numerous) individual sources.

Category B Wells. Category B wells were classified as having low to intermediate disposal rates (<10,000 m^3/month) of waste streams from discrete (or few) individual sources.

Category C Wells. Category C wells were classified as having intermediate to high disposal rates (>10,000 m^3/month) of waste streams from discrete or few sources, however with source characterization data unreadable or outdated (before 1970).

Category D Wells. Category D wells were classified as having intermediate to high disposal rates (>10,000 m^3/month) of waste streams from discrete or few sources. In addition, source characterization data indicated the appearance of extensively contaminated liquids.

Category E Wells. Category E wells were classified as having intermediate to high disposal rates (>10,000 m^3/month) of waste streams from discrete or few sources. In addition, source characterization data indicated that individual contaminants present in source liquids would require some form of specific treatment prior to general reuse.

Category F Wells. Category F wells were classified as having no information on disposal rates. In addition, source characterization data indicated that individual contaminants present in source liquids would require some form of specific treatment prior to general reuse.

Category G Well. This category of wells was used to identify a special case were contaminated groundwater is extracted from the subsurface and injected into a disposal well.

Category H Wells. Category H wells were classified as having negligible amounts of waste fluids injected during recent years and/or infrequent injection periods over the time in which data were available for review. For example, injection volumes for some of these wells were <1,000 m^3/month during the past ten years.

3.4 Identification of Recommendations

The last step of the study was to make recommendations for selected categories to better assess source liquids for treatment and reuse as an alternative to injection. The recommendations were based the quantity and quality of the source liquids. Basically, if the injection rate was high and source characterization data indicated the appearance of lowly contaminated liquids, it would be recommended to pursue investigating treatment and reuse as an alternative to injection. Otherwise, as a first cut, it would be considered uneconomical to purse treatment and reuse. The following two types of preliminary recommendations were considered for each category:

- If there was not sufficient information to assess the potential of source wastes for treatment and reuse as an alternative to injection, it was recommended to request additional information on source characteristics and/or disposal rates.
- Based on the available information on the quantity and quality of source liquids, the potential of waste streams for treatment and reuse was recommended for further investigation.

4.0 RESULTS

4.1 Approval No. 3924

Approval No. 3924 was issued to Husky Oil Operations Ltd. on August 15, 1983. It included three wells: HUSKY REFINERY NO. 3, HUSKY REFINERY NO. 5 and HUSKY NO. 6 LLOYD SWD 10C-1-50-1. General properties of these wells are provided in Table 4.1. Time series plots of monthly injection volumes and hourly injection rates are depicted in Figures 4.1 to 4.3 and Figures 4.4 to 4.6, respectively.

4.1.1 HUSKY REFINERY NO. 3 and HUSKY REFINERY NO. 5

Application No. 6803 indicates that these two wells were completed in the Beaverhill Lake Formation and were utilized to dispose of refinery wastewater from the Refinery Salt Pond of Husky Lloydminster Refinery, Lloydminster, Alberta. The application also indicates that these two wells would dispose of approximately 900 barrels per day of refinery waste fluid. According to actual injection records, the amount of waste fluid disposed in each of the two wells was approximately 100 m^3 per day. That number was estimated from average monthly injection rates.

According to actual injection records of HUSKY REFINERY NO.3, the average monthly injection rate was 2,930 m^3/month (this number was calculated from data covering the period 1971 to 2004 inclusive). This well began operating on March 14, 1952. However, volumes were not reported until 1971. According to actual injection records of HUSKY REFINERY NO. 5, the average monthly injection rate was 2,710 m^3/month (calculated from data covering the period 1977 to 2004 inclusive). This well began operating on September 1, 1977.

As depicted in Figures 4.1, 4.2, 4.4, and 4.5, the monthly injection volumes and hourly injection rates of the two wells were identical from 1977 to 2004. However, the monthly injection volumes were not constant (Figures 4.1 and 4.2). The highest monthly injection volume for both wells was 9,900 m^3, in September 2003. The hourly injection rate for both was about 280 m^3/hr in November 2000, which was substantially higher than at other times (Figures 4.4 and 4.5). Given this large difference, the original records should be checked for typographical errors.

Waste analysis of the Husky Refinery Salt Pond liquid as provided by Application No. 6803 on the microfiche was difficult to read. The microfiche indicated that a number of parameters, including Ca^{2+}, Mg^{2+}, Fe, SO_4^{2-}, Cl^-, NO_3^-, CO_3^{2-}, were analyzed but actual quantities and concentration units are unreadable. An up-to-date detailed chemical analysis of the refinery waste would be useful in this case.

4.1.2 HUSKY No. 6 LLOYD SWD 10C-1-50-1

Application No. 830140 indicates that this well was added to supplement the above two wells. It began operating on December 14, 1984, and is being used to dispose of "produced water" from the Husky Lloydminster Refinery. According to actual injection records, the average monthly injection rate has been 2,860 m^3/month (calculated from data covering the periods 1984 to 1985 and 1995 to 2004 inclusive). Injection volumes were not reported between 1986 and 1994.

Monthly injection volumes for this well were not constant (Figure 4.3). The highest monthly volume was 10,400 m^3, in August 1996. As shown in Figure 4.6, the peak hourly injection rate was ~1,000 m^3/hr during April and May 2000. No information on chemical analysis of the produced water was provided.

4.1.3 Recommendations

The average monthly volume of liquid wastes from the Husky Lloydminster operation injected into the three wells was approximately 10,000 m^3, which is considered a large amount. Unfortunately, there is insufficient information on the chemical characteristics of the individual sources to determine potential for treatment and reuse of those wastewaters. Given these conditions, the following recommendations are made in order to better assess the potential of the waste liquids for treatment and reuse as an alternative to disposal through injection:

- Because the reported numbers are very large, injection volume records of HUSKY REFINERY NO. 3 and NO. 5 for November 2000 should be checked for typographical errors.
- Because virtually no historical data exist on the type and amount of chemicals present, an up-to-date chemical analysis of source liquids injected into these wells should be made available.

Table 4.1. General properties of the wells included in Approval No. 3924.

Approval #	EUB Appl #	Field	Formation	Approval Holder	Scheme type	G 51 type	Well Name	Unique Identifier
3924	830140	Lloydminster	Beaverhill Lake	Husky Oil Operation Ltd.	Disposal	Class Ia	HUSKY REFINERY NO. 3	B0/14-01-050-01W4/0
							HUSKY REFINERY NO. 5	B0/14-01-050-01W4/2
							HUSKY No. 6 LLOYD 10C-1-50-1	00/10-01-050-01W4/0

Well Name	Top of Injection Interval Measured Depth (metres KB)	Minimum Packer Setting Depth (metres KB)	Maximum Wellhead Injection Pressure, kPa (gauge)
HUSKY REFINERY NO. 3	36	21	7,500
HUSKY REFINERY NO. 5	37	22	7,500
HUSKY No. 6 LLOYD 10C-1-50-1	189	169	8,000

Well Name	Injection Started	Time Series Plot of Monthly Injection Volume	Time Series Plot of Hourly Injection Rate	Average Annual Injection Rate (m^3/yr)	Average Monthly Injection Rate (m^3/month)	Cumulative Injection Amount to Sep, 2004 (m^3)
HUSKY REFINERY NO. 3	March 14, 1952	See Figure 4.1	See Figure 4.4	28,300	2,930	983,000
HUSKY REFINERY NO. 5	September 1, 1977	See Figure 4.2	See Figure 4.5	33,600	2,710	872,000
HUSKY No. 6 LLOYD 10C-1-50-1	December 14, 1984	See Figure 4.3	See Figure 4.6	30,800	2,860	303,000

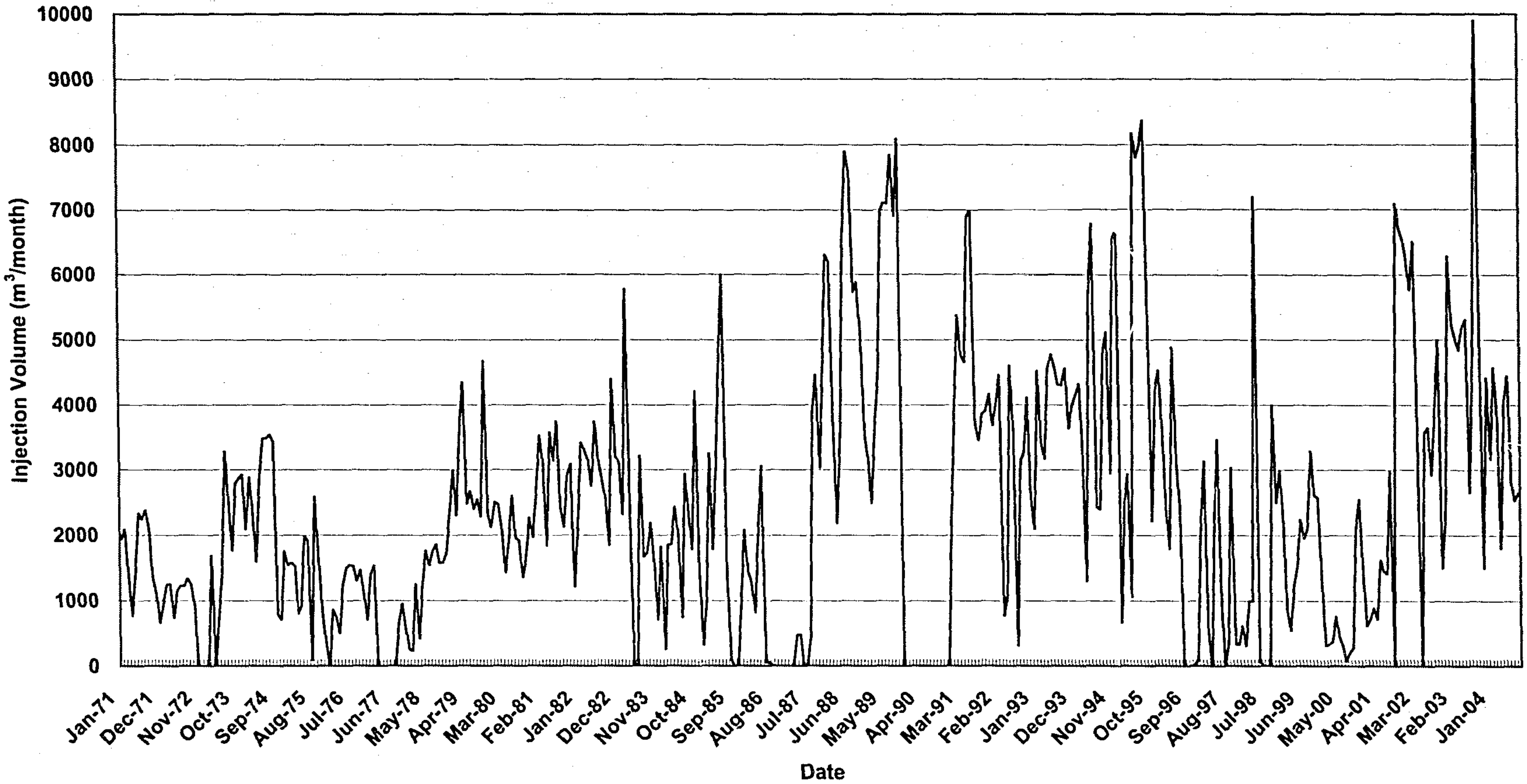

Figure 4.1. Time series plot of monthly injection volume of Husky Refinery No. 3.

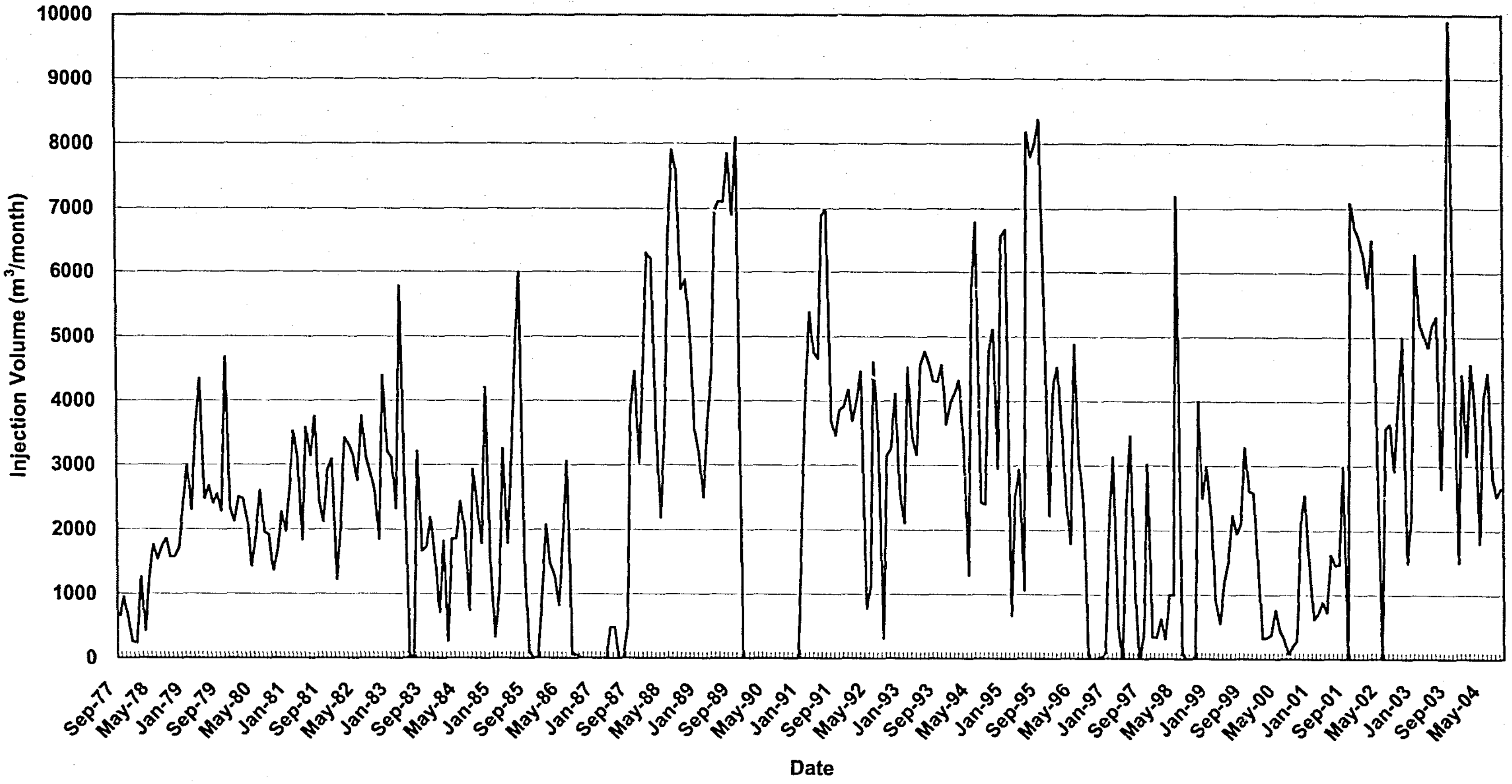

Figure 4.2. Time series plot of monthly injection volume of Husky Refinery No. 5.

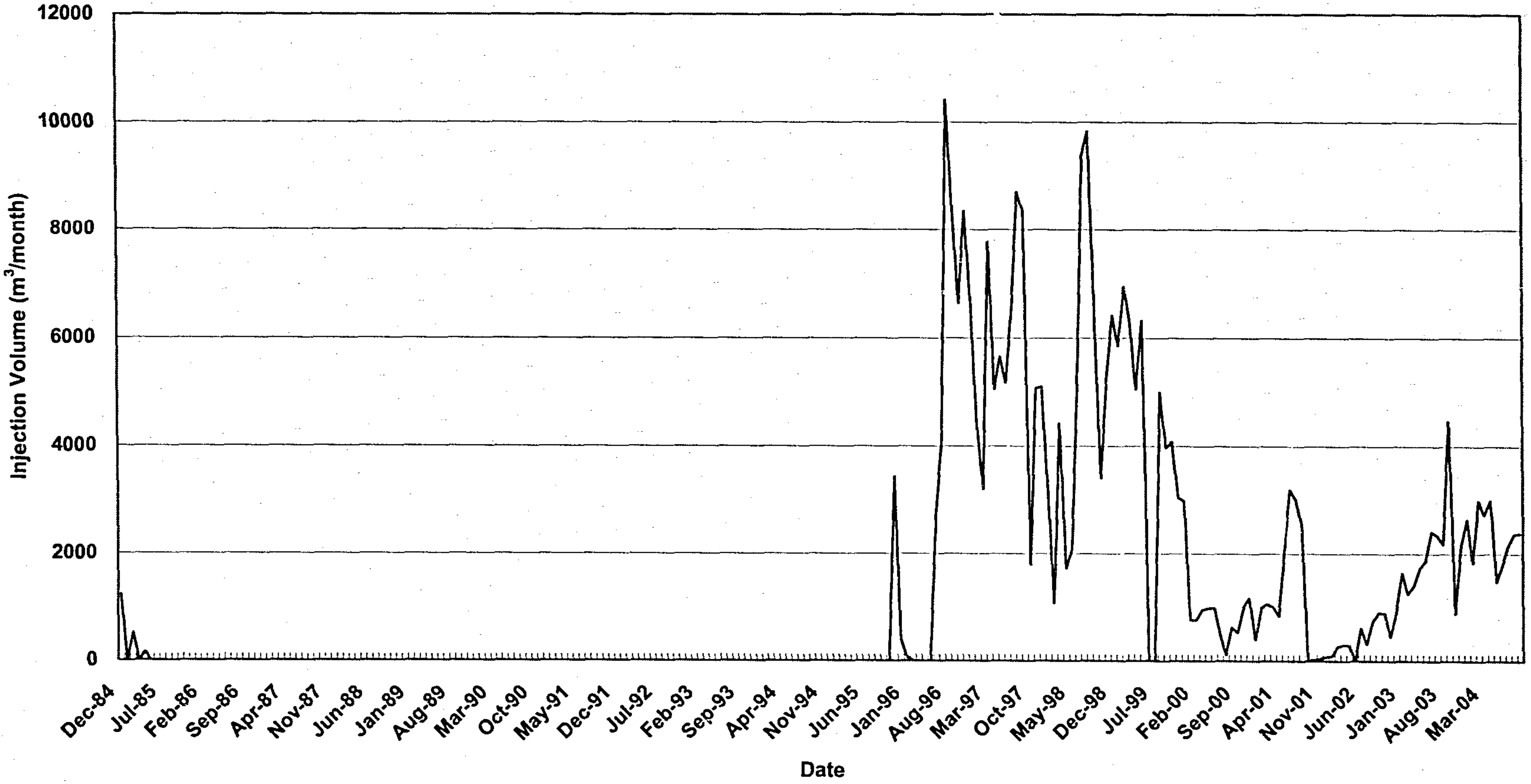

Figure 4.3. Time series plot of monthly injection volume of Husky No. 6 LLOYD 10C-1-50-1.

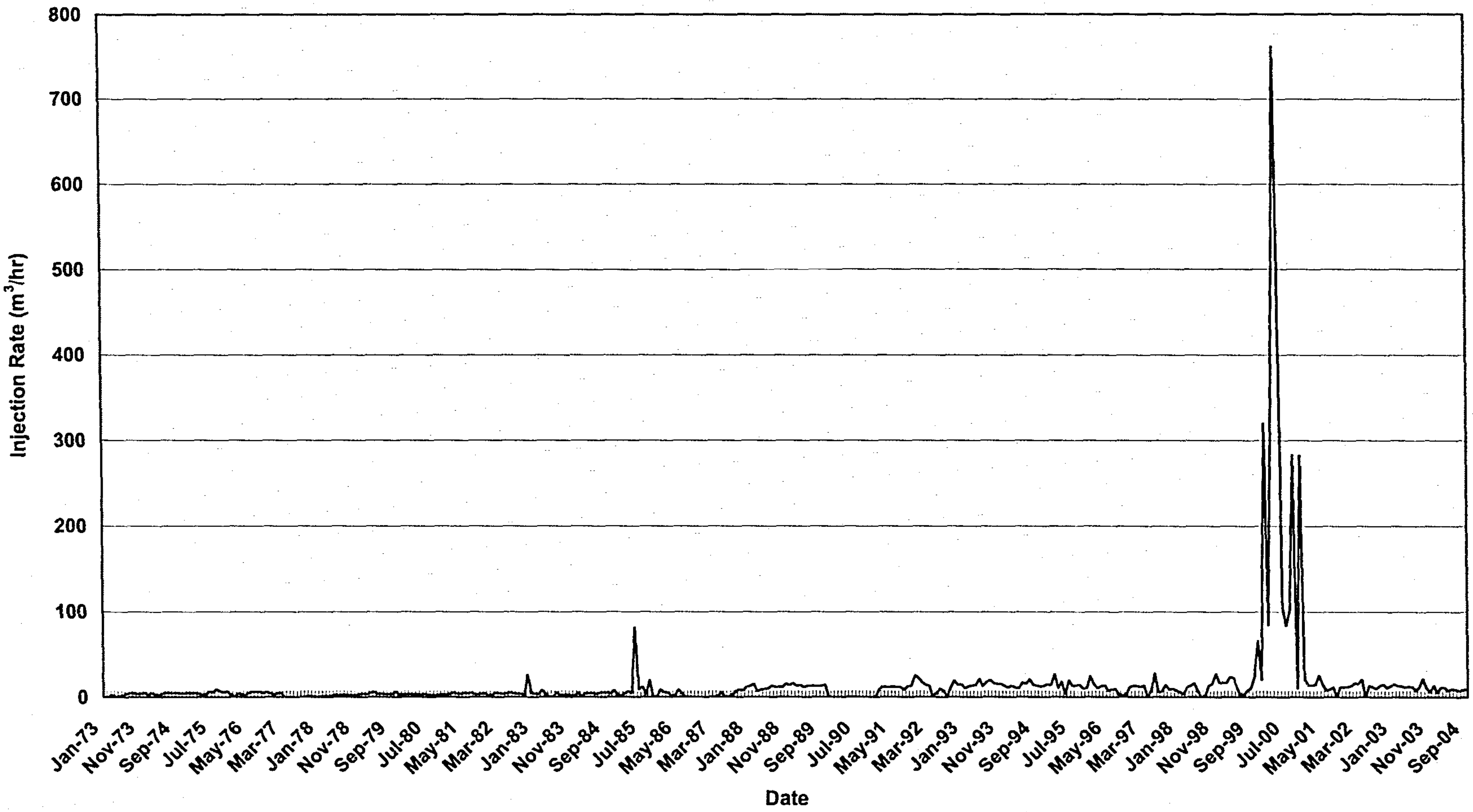

Figure 4.4. Time series plot of hourly injection rate of Husky Refinery NO. 3.

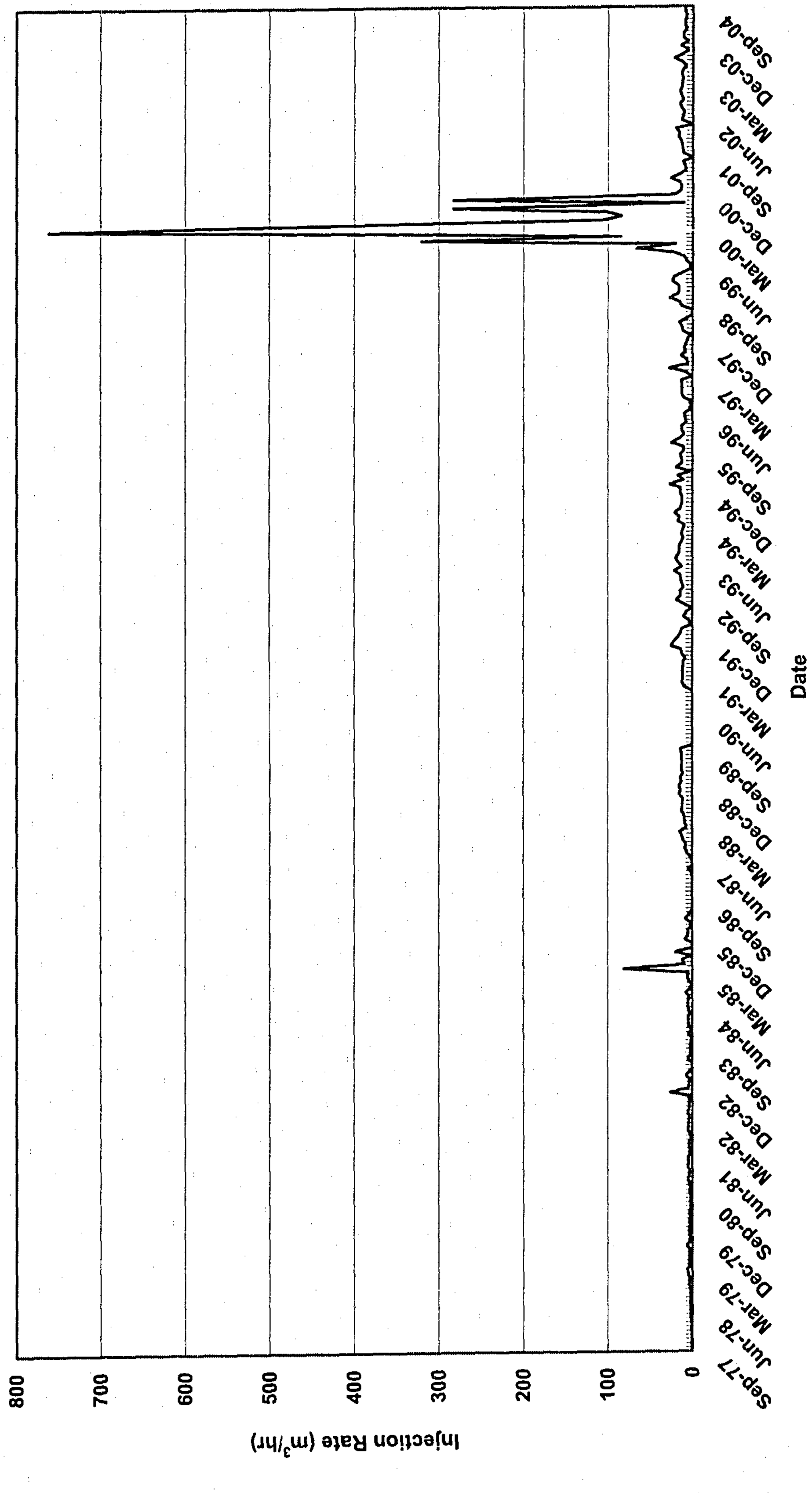

Figure 4.5. Time series plot of hourly injection rate of Husky Refinery NO. 5.

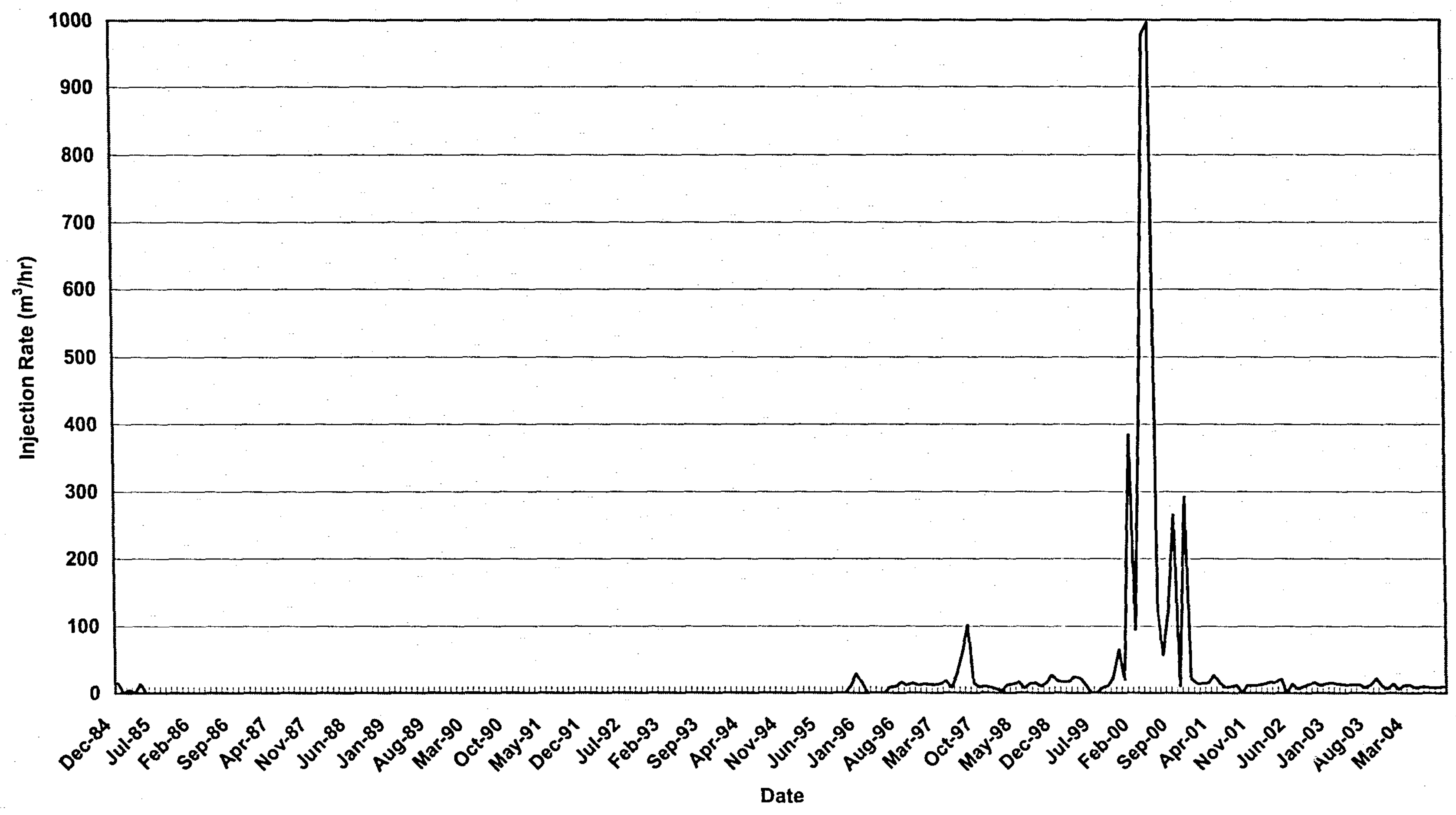

Figure 4.6. Time series plot of hourly injection rate of Husky NO.6 LLOYD 10C-1-50-1.

4.2 Approval No. 4779

Approval No. 4779 was issued to Sherritt Inc. on October 27, 1994. It included two wells: IMP REDWATER 10-17-56-21 and IMP REDWATER 6-17-56-21. The general properties of these wells are presented in Table 4.2. Time series plots of monthly injection volumes and hourly injection rates are depicted in Figures 4.7 to 4.10. Sources and characteristics of the wastes injected into these wells are listed in Tables 4.3 to 4.5.

4.2.1 IMP REDWATER 10-17-56-21

Application No. 7030 indicates that Imperial Oil Enterprises Ltd. proposed to dispose of wastewater from its Redwater Fertilizer Plant by injection into well IMP REDWATER 10-17-56-21 without any limitation on volume. Based on Application No. 840526, the plant's production units with their respective production capacities are listed in Table 4.3. As shown in Table 4.3, the plant produced about 10,650 tonnes/day of waste fluids from its nine production units. According to actual injection records, the amount of waste fluids disposed to IMP REDWATER 10-17-56-21 was approximately 1,200 m^3/day. This number was estimated from the average monthly injection rate of the well.

According to the actual injection records, the average monthly injection rate was 34,500 m^3/month (calculated for the periods 1990 to 1994 and 2001 to 2004 inclusive). Injection volumes were not reported between 1995 and 2000. The subject well began operating on July 26, 1973. However, no volumes were reported until 1990. As shown in Figure 4.7, the monthly injection volumes were not constant. The highest monthly injection volume was 64,300 m^3, in August 1992.

As provided by Application No. 7030, the plant effluent had a chemical composition as outlined in Table 4.5. It included following parameters: NO_3^-, NH_3, PO_4^{3-}, Cr^{6+}, CO_3^{2-}, SO_4^{2-}, suspended solids and pH. The data were derived from the analysis of a 24-hour composite sample of wastewater being injected on a monthly basis (Application No. 7030). There was also a summary of an environmental monitoring survey of Redwater Fertilizer Plants effluent of January 1980 (shown in Table 4.4, as provided by Application No. 800281). The chemical composition of the waste included substances such as Cr^{6+}, NO_3^-, NH_3 and SO_4^{2-}. The concentrations of chemicals were above general surface water discharge criteria and thus these wastewaters would require specific treatment.

4.2.2 IMP REDWATER 6-17-56-21

Application No. 800984 indicated that, due to the declining disposal capacity of IMP REDWATER 10-17-56-21, an additional disposal well (IMP REDWATER 6-17-56-21) was required to maintain the disposal capacity of wastewater from the Redwater Fertilizer Plant. This application indicated that Esso Chemical Canada proposed to dispose of approximately 113,550 m^3 of wastewater monthly in conjunction with operations of the Redwater Fertilizer Plant through IMP REDWATER 6-17-56-21. This water had the same source and characteristics as that injected into well IMP REDWATER 10-17-56-21.

According to actual injection records, the average monthly injection rate of IMP REDWATER 6-17-56-21 was 30,400 m^3. This number was calculated from data for the periods 1990 to 1994 and 2001 to 2004 inclusive. Injection volumes were not reported between 1995 and 2000. The subject well began operating on July 29, 1981, but volumes were not reported until 1990. As shown in Figure 4.8, the monthly injection volumes were not constant. The highest monthly injection volume was 65,100 m^3 (in March 1993).

4.2.3 Recommendations

The average monthly volume of wastewater from the Redwater Fertilizer Plant for disposal to the two subject wells was about 30,000 m^3 for each well, which is considered a large amount of wastewater. Waste characteristics show that some contaminants, such as Cr^{6+}, NO_3^-, NH_3 and SO_4^{2-}, require specific treatment.

These wastewater sources clearly fall into a category that requires further investigation of treatment capabilities. Given the nature and level of some of the contaminants, economics associated with treatment and reuse of the source liquids must also be carefully considered.

Table 4.2. General properties of the wells included in Approval No. 4779.

Approval #	EUB Appl #	Field	Formation	Approval Holder	Scheme type	G 51 type	Well Name	Unique Identifier
4779	940643	Redwater	Leduc	Sherritt Inc.	Disposal	Class Ia	AGU REDWATER 10-17-56-21	00/10-17-056-21W4/0
							AGU REDWATER 6-17-56-21	00/06-17-056-21W4/0

Well Name	Top of Injection Interval Measured Depth (metres KB)	Minimum Packer Setting Depth (metres KB)	Maximum Wellhead Injection Pressure, kPa (gauge)
AGU REDWATER 10-17-56-21	1,004	984	9,450
AGU REDWATER 6-17-56-21	992	972	8,400

Well Name	Injection Started	Time Series Plot of Monthly Injection Volume	Time Series Plot of Hourly Injection Rate	Average Annual Injection Rate (m^3/yr)	Average Monthly Injection Rate (m^3/month)	Cumulative Injection Amount to Aug, 2004 (m^3)
AGU REDWATER 10-17-56-21	July 26, 1973	See Figure 4.7	See Figure 4.9	411,000	34,500	3,590,000
AGU REDWATER 6-17-56-21	July 29, 1981	See Figure 4.8	See Figure 5.10	373,000	30,400	3,160,000

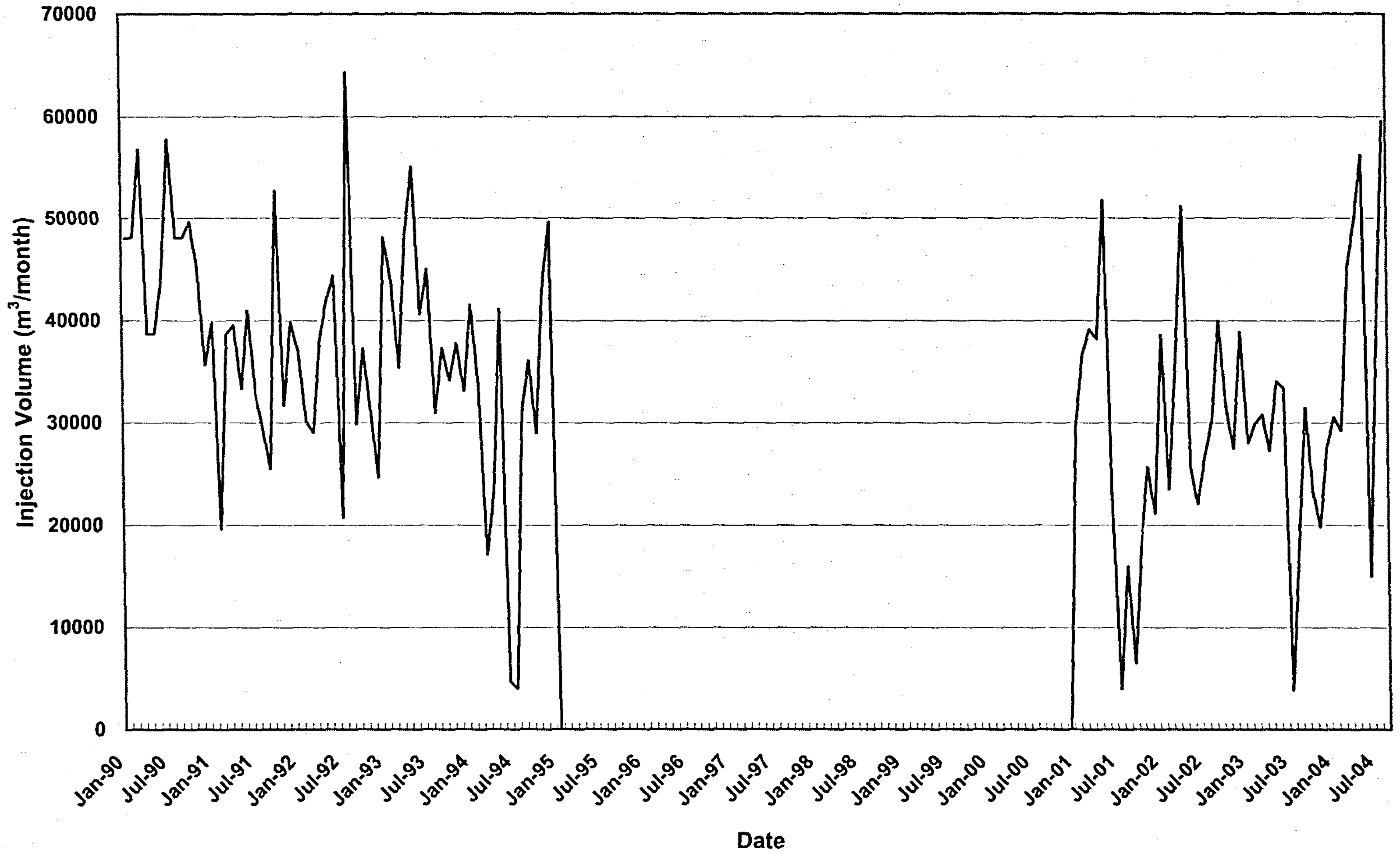

Figure 4.7. Time series plot of monthly injection volume of AGU REDWATER 10-17-56-21.

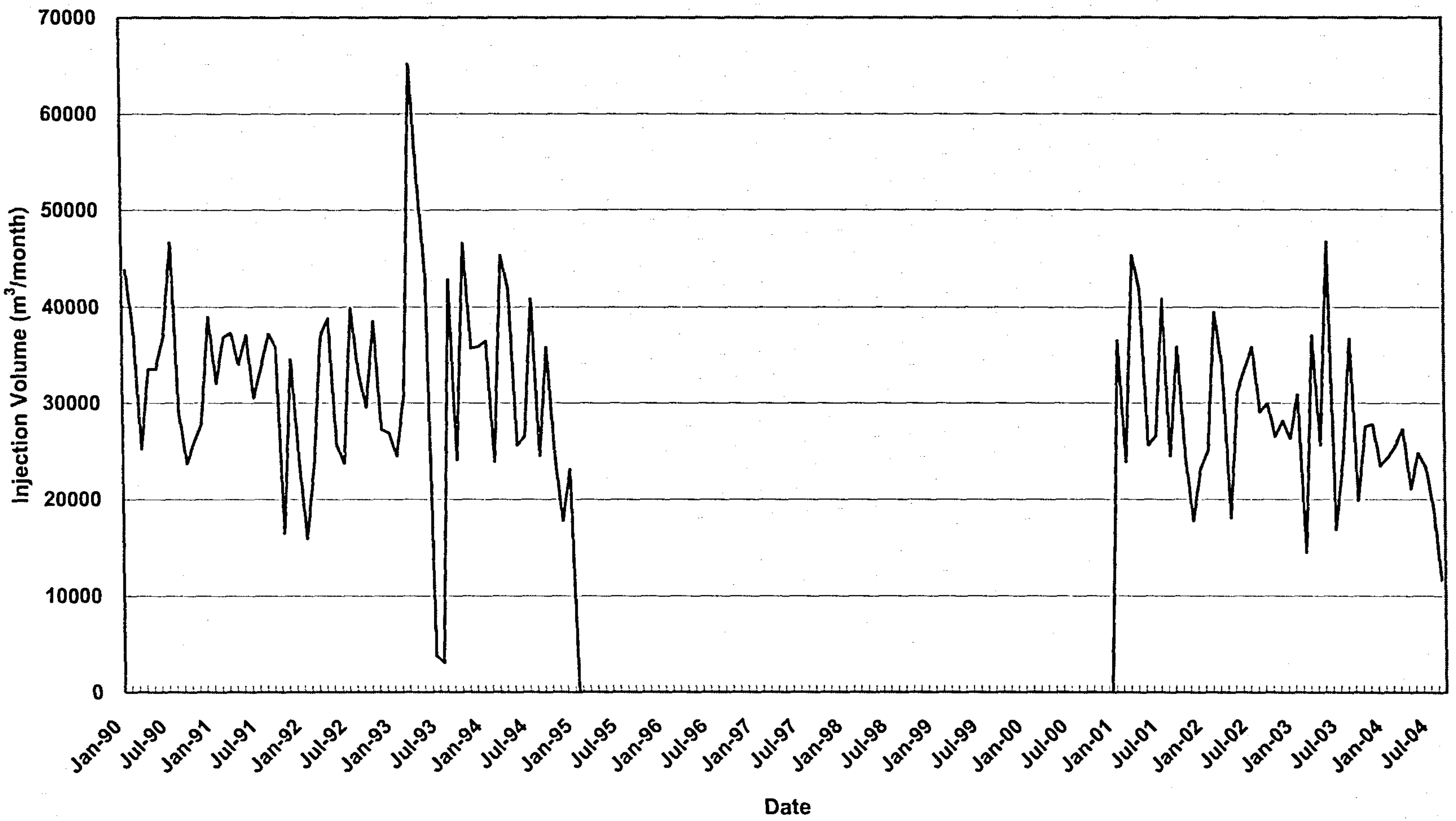

Figure 4.8. Time series plot of monthly injection volume of AGU REDWATER 6-17-56-21.

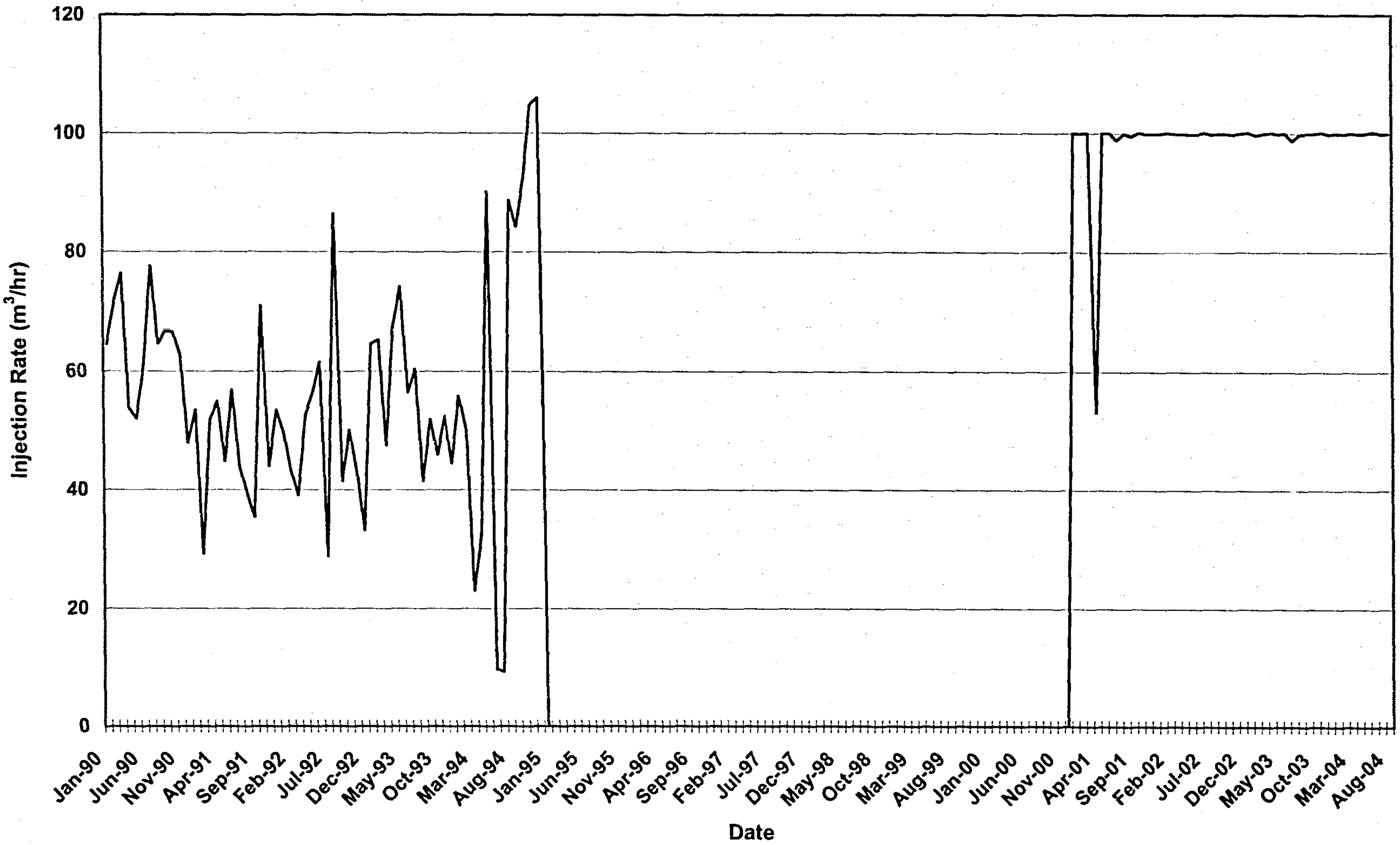

Figure 4.9. Time series plot of hourly injection rate of AGU REDWATER 10-17-56-21.

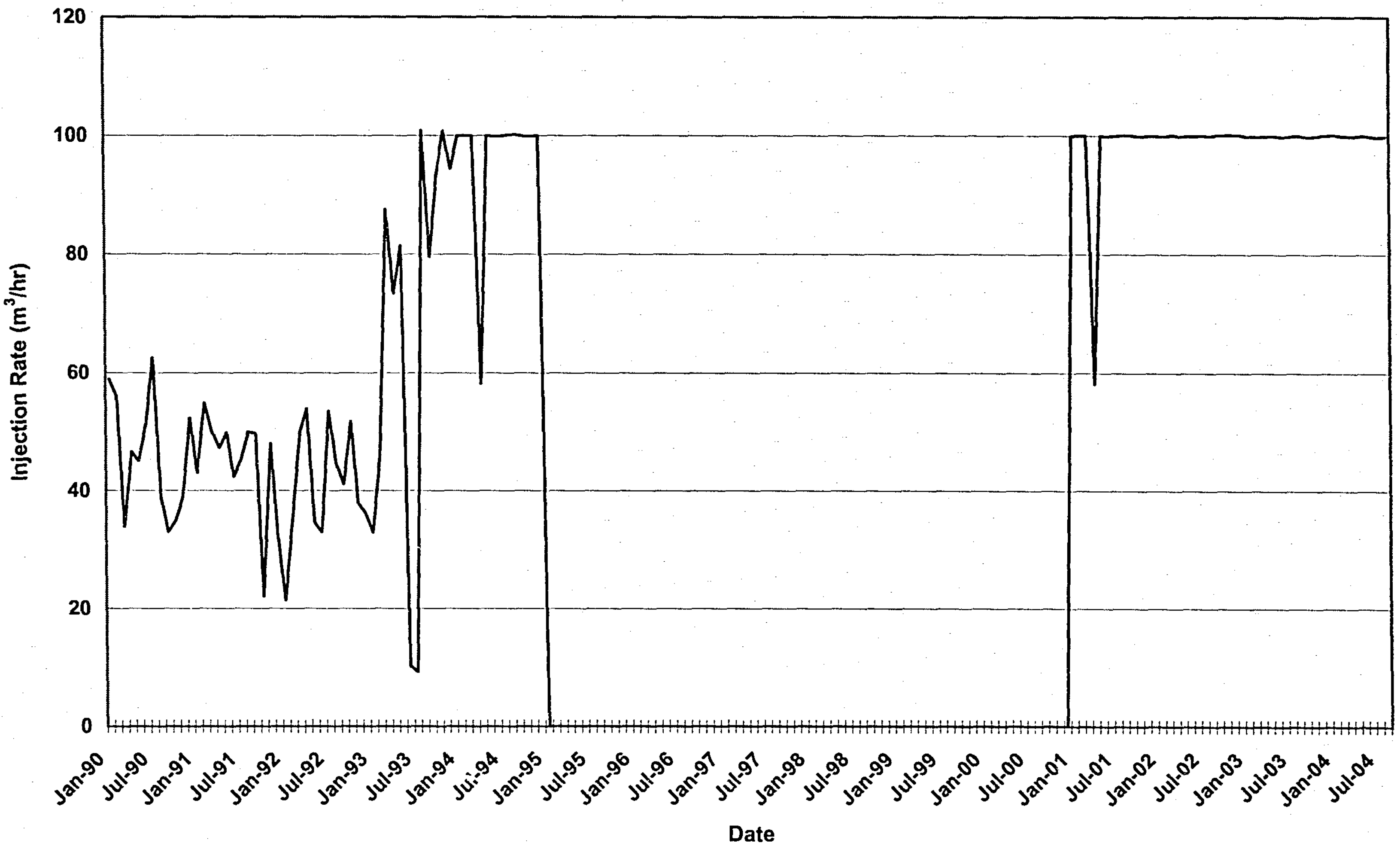

Figure 4.10. Time series plot of hourly injection rate of AGU REDWATER 6-17-56-21.

Table 4.3. Production units and respective production capacities of Redwater Fertilizer Plant.

Unit	Production Capacity (tonnes/day)
Ammonia Unit No. 1	685
Ammonia Unit No. 2	1600
Nitric Acid Unit	521
Ammonium Nitrate Unit	669
Sulphuric Acid Unit No. 1	1790
Sulphuric Acid Unit No. 2	1088
Urea Synthesis Unit	1500
Phosphoric Acid Unit	907
Ammonium Phosphate Unit	1891

Table 4.4. Summary of environmental monitoring survey of Redwater Fertilizer Plant effluent in January 1980.

Parameter	Concentration (mg/L except pH)
NO_3^-	88
NH_3	184
PO_4^{3-}	4.8
Cr^{6+}	3.1
TSS	27.0
pH	8.5

Table 4.5. Composition of Canada Redwater Fertilizer Plant effluent in 1983 (mg/L, except pH).

Month	NO_3^-		NH_3		PO_4^{3-}		Cr^{6+}	
	avg	range	avg	range	avg	range	avg	range
Jan	176	88-343	328	131-672	14	5-40	32	16-48
Feb	322	76-910	445	81-1231	17	6-50	16	2-47
Mar	320	91-812	411	119-1161	18	7-52	18	9-57
Apr	691	194-1175	1021	101-1521	15	5-67	22	14-35
May	955	453-1494	1924	156-2203	8	1-43	21	11-30
Jun	1060	95-1960	1523	653-2376	4	1-24	22	10-43
Jul	912	37-1565	1284	450-2132	1	1-7	28	6-24
Aug	462	34-1555	569	44-1594	11	1-23	17	8-36
Sep	405	97-992	634	23-1329	11	1-43	17	1-40
Oct	397	80-1330	768	402-1322	8	1-43	23	14-41
Nov	483	158-690	742	218-1023	18	3-55	33	13-44
Dec	362	53-614	623	344-1074	24	6-115	33	19-55

Table 4.5. Composition of Canada Redwater Fertilizer Plant effluent in 1983 (mg/L, except pH) (continued).

Month	CO_3^{2-}		SO_4^{2-}		Susp. Solids		pH
	avg	range	avg	range	avg	range	range
Jan	305	72-422	9100	5000-14,800	246	246	7.1-10.2
Feb	305	231-465	5200	4400-6200	363	45-693	6.8-9.4
Mar	451	352-666	5500	4900-5400	384	152-1741	6.2-9.6
Apr	476	253-554	8200	6100-10100	49	18-93	7.1-8.8
May	892	788-1051	13300	10800-17000	33	26-42	7.4-8.8
Jun	764	596-1006	18700	14200-25,100	45	34-55	3.2-8.2
Jul	316	438-1294	11500	5500-14500	15	10-21	7.0-8.8
Aug	349	75-730	8920	6100-16300	85	10-261	6.0-9.9
Sep	243	131-320	6000	1100-6500	54	5-159	6.7-9.7
Oct	223	142-457	6600	4300-10400	10	4-24	7.1-8.9
Nov	209	187-235	7400	6500-8700	30	5-54	3.1-9.1
Dec	203	150-183	7200	4500-7600	5	4-6	6.9-9.0

4.3 Approval No. 5737

Approval No. 5737 was issued to Shell Canada Resources on November 25, 1988. It included two wells: SHELL FTSASK 1-31-55-21 and SHELL FTSASK 8-31-55-21. The general properties of these wells are provided in Table 4.6, while time series plots of monthly injection volumes and hourly injection rates are depicted in Figures 4.11 to 4.14.

4.3.1 SHELL FTSASK 1-31-55-21

Approval No. 5737 indicates that this well was used to dispose of waste liquids produced in conjunction with the operation of the Shell Canada Limited Scotford Refinery. Approval No. 5737 also indicates that the schemes of disposal were described in Application No. 820188 dated February 16, 1982 from Shell Canada Resources Limited to EUB. However, that application was not provided.

According to actual injection records, the average monthly injection rate of this well was 35,800 m^3/month for the time period in question. This number was calculated from volume records for 1985 and for the period 1993 to 2004 inclusive. Injection volumes were not reported between 1986 and 1992. The subject well began operating on September 15, 1984. However, no volume was reported until 1985. As shown in Figure 4.11, the monthly injection volumes were not constant. From 1997 to 2001, approximately 50,000 m^3/month of wastewater was injected into the well.

According to Figure 4.13, hourly injection rates were about 70 m^3/hr in years during which volume records were provided, except June 1994. In that month, 720 m^3 waste were disposed into the well per hour, a rate substantially higher than at other times. Given this large difference, the original records should be checked for typographical errors. Characteristics of the waste liquids were not provided.

4.3.2 SHELL FTSASK 8-31-55-21

As indicated by Approval No. 5737, this well has the same waste source as SHELL FTSASK 1-31-55-21. According to actual injection records, the average monthly injection rate was 36,800 m^3/month. This number was calculated from data for the periods 1984 to 1985 and 1987 to 2001 inclusive. Injection volumes were not reported in 1986 or during the period 2002 to 2004 inclusive. The subject well began operating on May 24, 1984.

As shown in Figure 4.12, the monthly injection volumes were not constant. For the periods of May to August inclusive 1990, July to August inclusive 1998, and April 1985, more than 50,000 m^3/month of waste were injected into the well.

4.3.3 Recommendations

The average monthly volume of waste liquids produced in conjunction with the operation of the Shell Canada Limited Scotford Refinery for disposal was about 35,000 m^3 to each of two wells, which is considered to be a large amount. Unfortunately, the chemical characteristics of the source were not available to assess the potential for treatment and reuse. Given these conditions, the following recommendations are made in order to better assess the potential for treatment and reuse as an alternative to injection:

- Because of the large amounts indicated for wastewater injected, the records of SHELL FTSASK 1-31-55-21 for June 1994 should be checked for typographical errors.
- Application No. 820188 dated 16 February 1982 from Shell Canada Resources Limited to EUB should be provided for reviewing the disposal schemes.
- Because virtually no historical data exist on the type and amounts of chemicals parameters, an up-to-date chemical analysis of the source liquids injected in these wells should be provided.

Table 4.6. General properties of the wells included in Approval No. 5737.

Approval #	EUB Appl #	Field	Formation	Approval Holder	Scheme type	G 51 type	Well Name	Unique Identifier
5737	881087	Redwater	Nisku	Shell Canada Resources	Disposal	Class Ia	SHELL FTSASK 1-31-55-21	00/01-31-055-21W4/0
							SHELL FTSASK 8-31-55-21	00/08-31-055-21W4/0

Well Name	Top of Injection Interval Measured Depth (metres KB)	Minimum Packer Setting Depth (metres KB)	Maximum Wellhead Injection Pressure, kPa (gauge)
SHELL FTSASK 1-31-55-21	367.7	345.0	9,000
SHELL FTSASK 8-31-55-21	365.7	345.0	9,000

Well Name	Injection Started	Time Series Plot of Monthly Injection Volume	Time Series Plot of Hourly Injection Rate	Average Annual Injection Rate (m^3/yr)	Average Monthly Injection Rate (m^3/month)	Cumulative Injection Amount to Aug, 2004 (m^3)
SHELL FTSASK 1-31-55-21	September 15, 1984	See Figure 4.11	See Figure 4.13	3,440,000	35,800	276,000
SHELL FTSASK 8-31-55-21	May 24, 1984	See Figure 4.12	See Figure 4.14	4,450,000	36,800	4,710,000

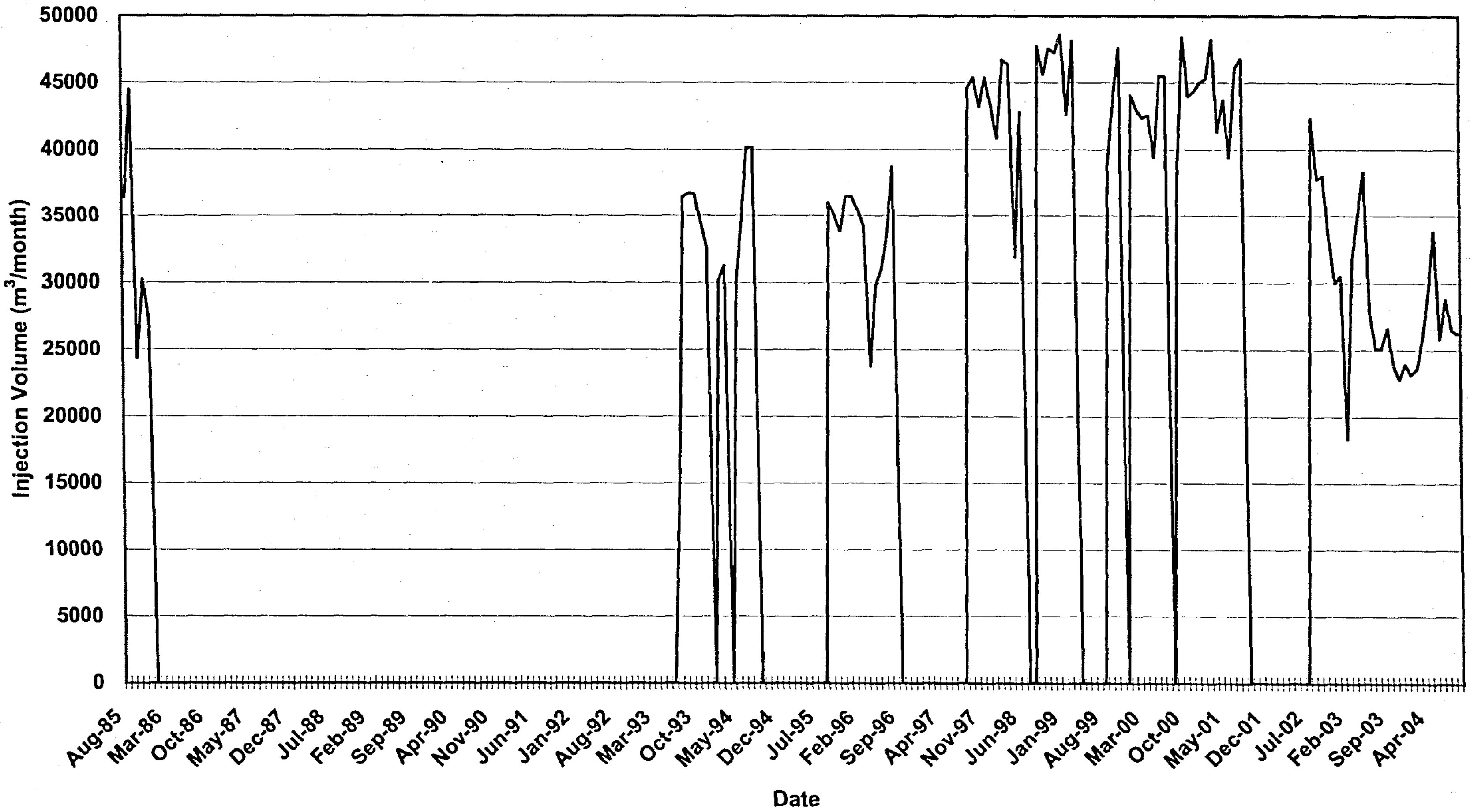

Figure 4.11. Time series plot of monthly injection volume of SHELL FTSASK 1-31-55-21.

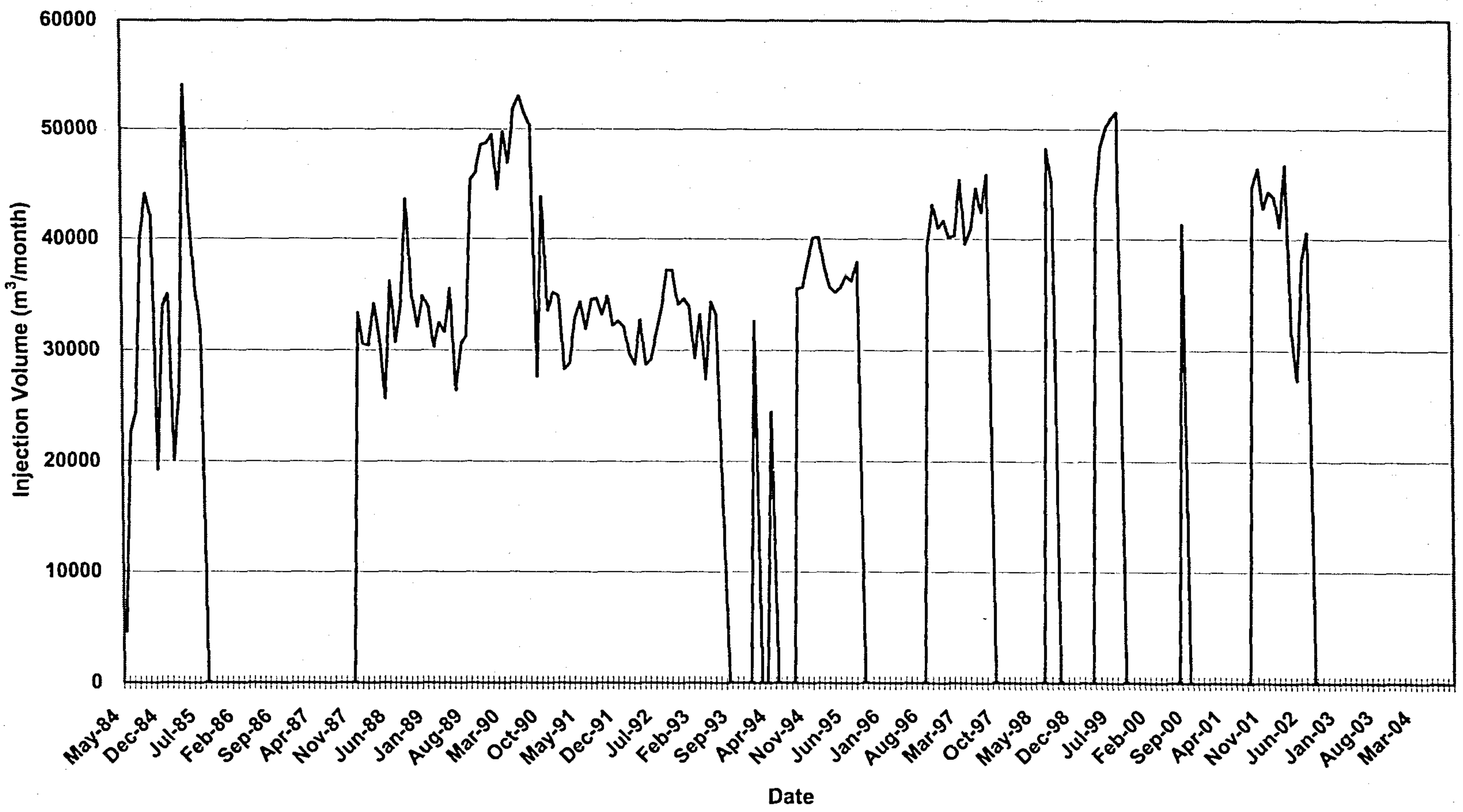

Figure 4.12. Time series plot of monthly injection volume of SHELL FTSASK 8-31-55-21.

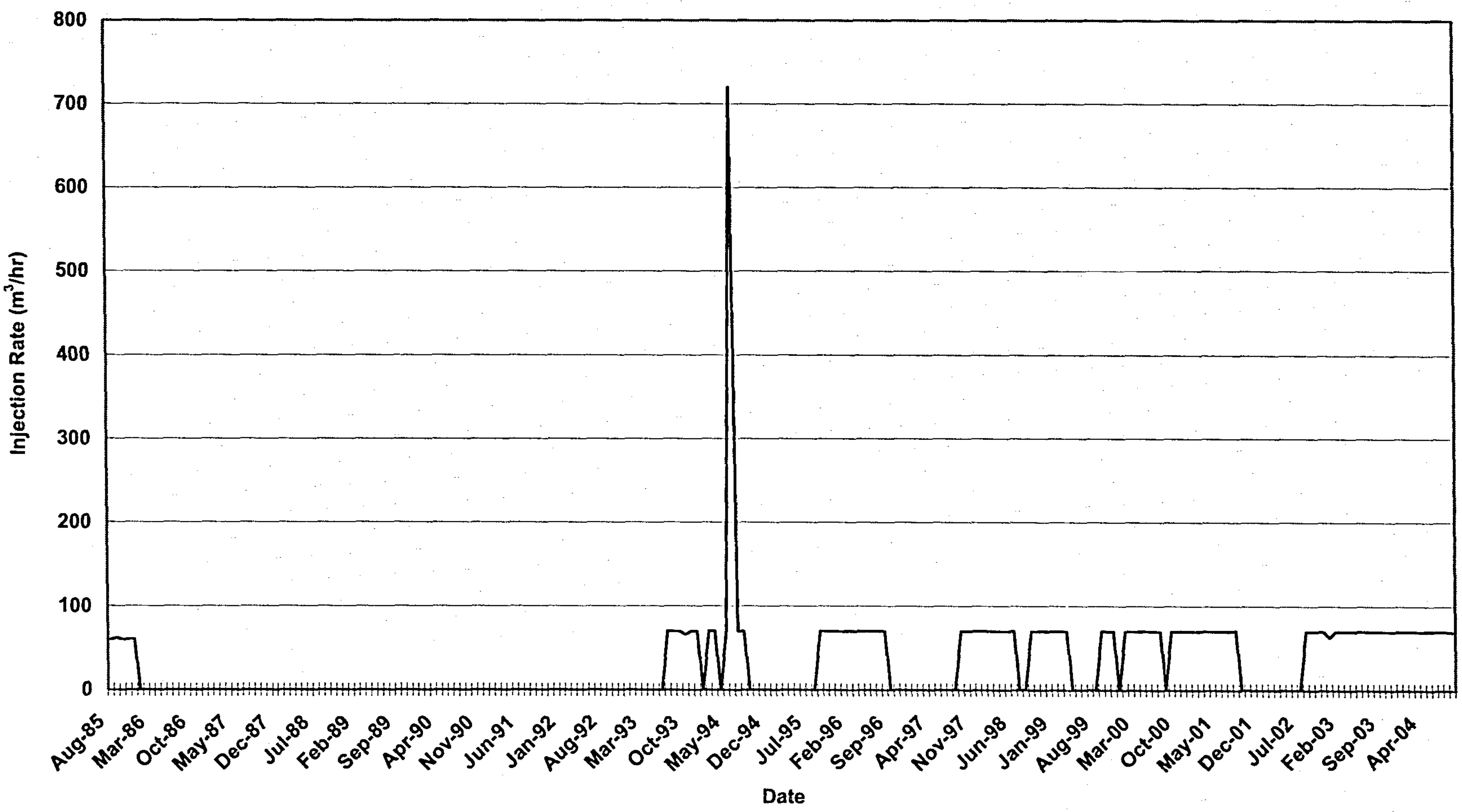

Figure 4.13. Time series plot of hourly injection rate of SHELL FTSASK 1-31-55-21.

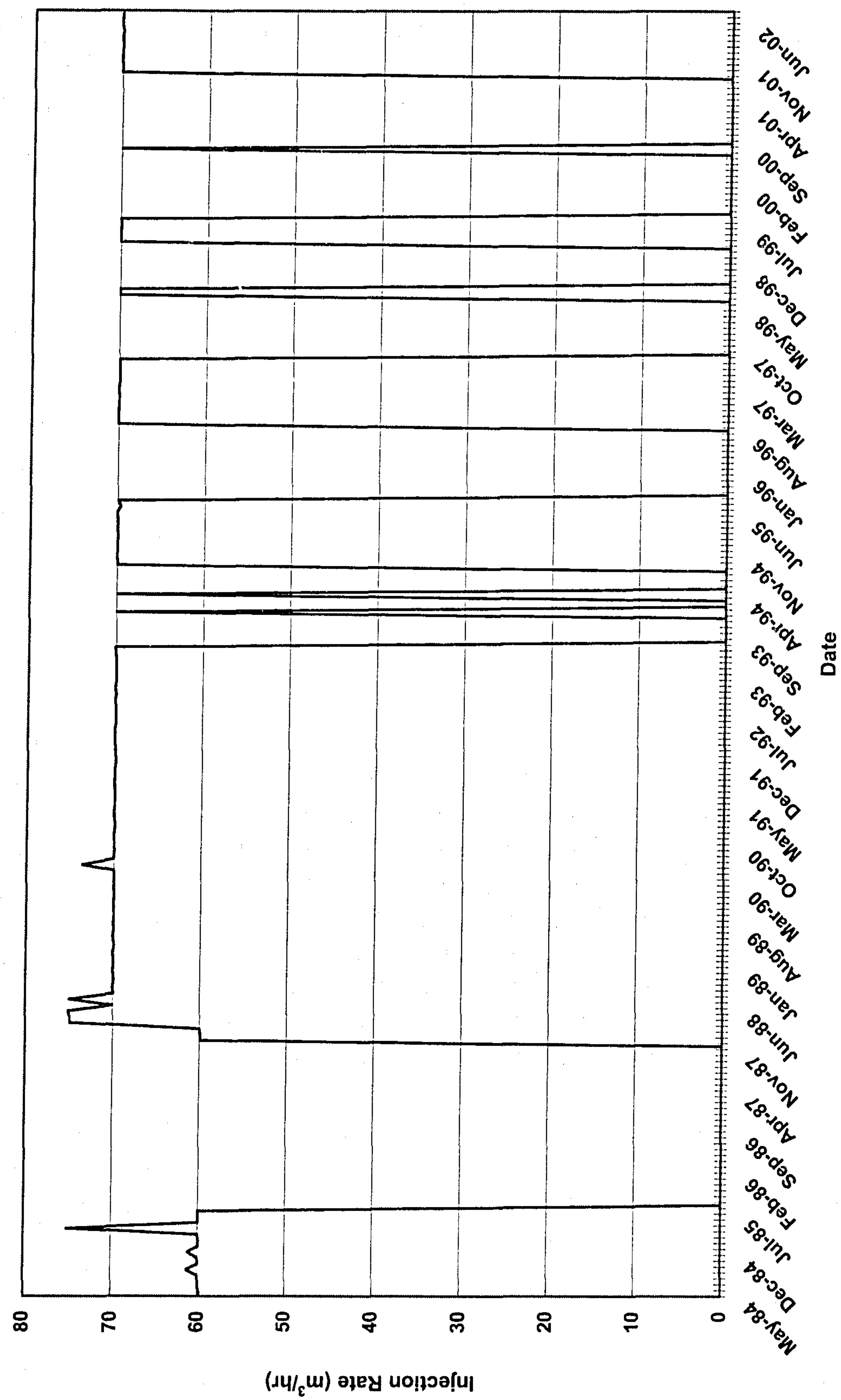

Figure 4.14. Time series plot of hourly injection rate of SHELL FTSASK 8-31-55-21.

4.4 Approval No. 6114

Approval No. 6114 was issued to Laidlaw Environmental Service (Ryley) Ltd. on December 22, 1992. It included only one well: NEWALTA MORINV 8-15-54-26. The general properties of the well are provided in Table 4.7. Time series plots of monthly injection volumes and hourly injection rates of the well are depicted in Figures 4.15 and 4.16, respectively.

4.4.1 NEWALTA MORINV 8-15-54-26

Approval No. 6114 indicates that this well was used for the disposal of water produced in conjunction with oil or gas from the Province of Alberta plus the disposal of 3,330 m^3/month of industrial waste liquids from the sources listed in Table 4.8. The well began operating on March 3, 1990. According to actual injection records, the average monthly injection rate of this well was 1,360 m^3/month. This number was calculated from data for the period 1990 to 2004 inclusive.

As shown in Figure 4.15, monthly injection volumes of this well were not constant. The highest monthly injection volume was 4,050 m^3, in October 2000. As shown in Figure 4.16, peak hourly injection rates were 119 m^3/hr, 107 m^3/hr and 136 m^3/hr in April 1990, June 1990 and May 1991, respectively. The hourly injection rates were less than 25 m^3/hr at other times.

Application No. 890835 indicates that waste liquids with the following characteristics were proposed for disposal to the subject well:

- Potential organic contaminants in aqueous solutions were to be at concentrations between 2% and 5% (by volume). Those contaminants included xylene, monoethanolamine, diethanolamine, ethylene glycol, triethylene glycol, tetraethylene glycol, gasoline, methanol and iso-propanol.

- Non-organic contamination from industrial processes could have concentrations between 2% and 5% (by volume) of sodium hydroxide in an aqueous solution.
- Some of the wastewater could have contaminant concentrations of between 0.01 and 10 mg/l of boron, fluoride, cyanide, nitrogen, phenol, arsenic, sulfide, cadmium, chromium, aluminum, copper, iron, zinc, barium, manganese, lead, nickel, vanadium, molybdenum, selenium and mercury.
- Substances with concentrations in excess of 10 mg/l could include calcium (as $CaCO_3$), magnesium (measured as $CaCO_3$), sodium (as Na), chemical oxygen demand, chloride (as NaCl), sulphate (as SO_4), phosphate (as PO_4), biological oxygen demand and biochemical oxygen demand.

Application No. 890835 also indicates that the disposed wastewater should be analyzed semi-annually for all metals and monthly for chemical oxygen demand, nitrogen, total phosphates, fluoride, total organic carbon, threshold odour number, and total suspended solids. However, records of these analyses have not been provided. As provided by Application No. 890835, an analysis of pond water is listed in Table 4.9. However, the origin of this pond water was not indicated. The waste characteristics of Source No. 6 and Sources No. 9 to 16 inclusive were not provided by EUB. The characteristics of other waste sources listed in Table 4.7 will be discussed in the following section.

Source 1: As provided by Application No. 890835, the oil content of this source was 2.0%. The organic contaminants in the oil were sodium isopropyl xanthate, isopropyl-ethyl-thionocarbanate and n-butyl-methyl-thionocarbanate. Application No. 890835 also provided the composition of this waste as listed in Table 4.10. Table 4.10 shows that this waste material was composed of water, oil and sediment.

Source 2: As provided by Application No. 890835, the oil content of this source was

1.35%. The organic contaminants in the oil were ethylene glycol, diethylene glycol, triethylene glycol, monoethanolamine, diethanolamine and triethanolamine; The results from chromatographic analyses of these organics are listed in Table 4.11. The level of total suspended solids of this source was 1400 mg/L, while pH was 8.4.

Source 3: As provided by Application No. 890835, the organic contaminants in this source were solexol and oil. Solexol is the dimethyl ether of polyethylene glycol. The oil content of this source was 0.29%. Application No. 890835 also provided the composition of this waste source (Table 4.12). As shown in Table 4.12, this waste material was composed of water, oil and solids.

Source 4: As provided by Application No. 890835, the oil content of this source was 11.95%. The organic contaminants in the oil were methanol, isopropanol, ethylene glycol, diethylene glycol, triethylene glycol, tetraethylene glycol, monoethanolamine and xylene. The results of chromatographic analyses of these organics are listed in Table 4.13. Application No. 890835 also provided the composition of this waste (Table 4.14). As shown in Table 4.14, this waste material was composed of water, oil and sediments.

Source 5: As provided by Application No. 900255, the oil content of this source was 8 ppm. The majority of the contamination was inorganic, the level of which was 218 ppm. A compositional analysis of this source is presented in Table 4.15.

Sources 7 and 8: As provided by application No. 900733 and 900893, compositional analyses of these two sources are included in Table 4.16 and Table 4.17, respectively.

Sources 17 and 18: As provided by Application No. 920878 and 920899, these two waste sources had the properties listed in Table 4.18 and Table 4.19, respectively.

4.4.2 Recommendation

The average monthly volume of liquids injected into NEWALTA MORINV 8-15-54-26 was 1,360 m^3 for the period in question. This is considered a small quantity, and the well receives waste liquids from multiple sources (18). Given these conditions, it is recommended that it would not be economical to pursue an investigation of the potential of the source liquids for treatment and reuse as an alternative to injection.

Table 4.7. General properties of NEWALTA MORINV 8-15-54-26.

Approval #	EUB Appl #	Field	Formation	Approval Holder	Scheme type	G 51 type	Well Name	Unique Identifier
6114	920899	Morinville	Wabamun	Laidlaw Environmental Services	Disposal	Class Ia	NEWALTA MORINV 8-15-54-26	00/08-15-54-26W4/2

Top of Injection Interval Measured Depth (metres KB)	Minimum Packer Setting Depth (metres KB)	Maximum Wellhead Injection Pressure, kPa (gauge)
571.4	551	9,900

Injection Started	Time Series Plot of Monthly Injection Volume	Time Series Plot of Hourly Injection Rate	Average Annual Injection Rate (m^3/yr)	Average Monthly Injection Rate (m^3/month)	Cumulative Injection Amount to Aug, 2004 (m^3)
March 3, 1990	See Figure 4.15	See Figure 4.16	16,100	1,360	236,000

Table 4.8. Sources of wastewater disposed to NEWALTA MORINV 8-15-54-26.

Source Number	Company Name	Waste Source	Proposed Injection Volume (m^3/month)
1	Prospec Chemicals	tank and floor washing at company's Edmonton chemical blending plant	150
2	Rempel Trial	tank washing of bulk fluid carriers at company's Edmonton facility	550
3	Sherritt Gordon Limited	washing of Solexol product storage tanks at company's Edmonton chemical blending plant	100
4	Harcross Chemicals	tank and floor washing at company's Edmonton chemical blending plant	25
5	Aichem Inc.	tank and floor washing at company's Edmonton chemical blending plant	450
6	Turbo Resources	the refining of lube oil at its Edmonton facility	80
7	Esso Resources Canada Limited	tank and floor washing generated from company's chemical plant in the East Airdrie Industrial Park, Edmonton	10
8	Linde Industrial Services:	tank and floor washings at company's Edmonton chemical plant	1
9	Canadian National Railways	sump collection from the washing of rail transport cars which contained diesel oil at company's Calder Yard, Edmonton	25
10	Ward Chemical	process waste water from the chemical blending plant at company's Fort Saskatchewan facility	400
11	Sherritt Gordon Limited	flushing of storage tanks from a chemical blending tank at company's Fort Saskatchewan facility	1
12	Northwestern Utilities Ltd.	sodium hydroxide and water from washing of an absorber tower from a dehydration unit at company's Edmonton facility	11
13	Canwell Enviro-Industries Ltd.	spent Cansweet 200, 300, 300SX and 500 hydrogen sulphide scavenger from various facilities	200
14	Novacor Chemical Limited	ammoniated citric wash and spent degasser solution from washing of new tanks and pipelines at company's Joffre chemical plant	1000
15	Iron Horse Compressor Ltd	a desiccant used to remove water produced from natural gas at various gas plant facilities	20
16	Laidlaw Environmental Services (Ryley) Ltd	precipitation waste water collection in a primary collection system at the secure landfill site from company's Ryley, Alberta facility	275
17	Baker Performance Chemicals	wash water generated from the washing of vessels used in the production of oilfield chemical at company's facility located at Calgary, Alberta	25
18	United Enerchem Ltd	wastewater generated from a wash sump used for rinsing of vessels and equipment at company's facility located at Nisku, Alberta	2.5

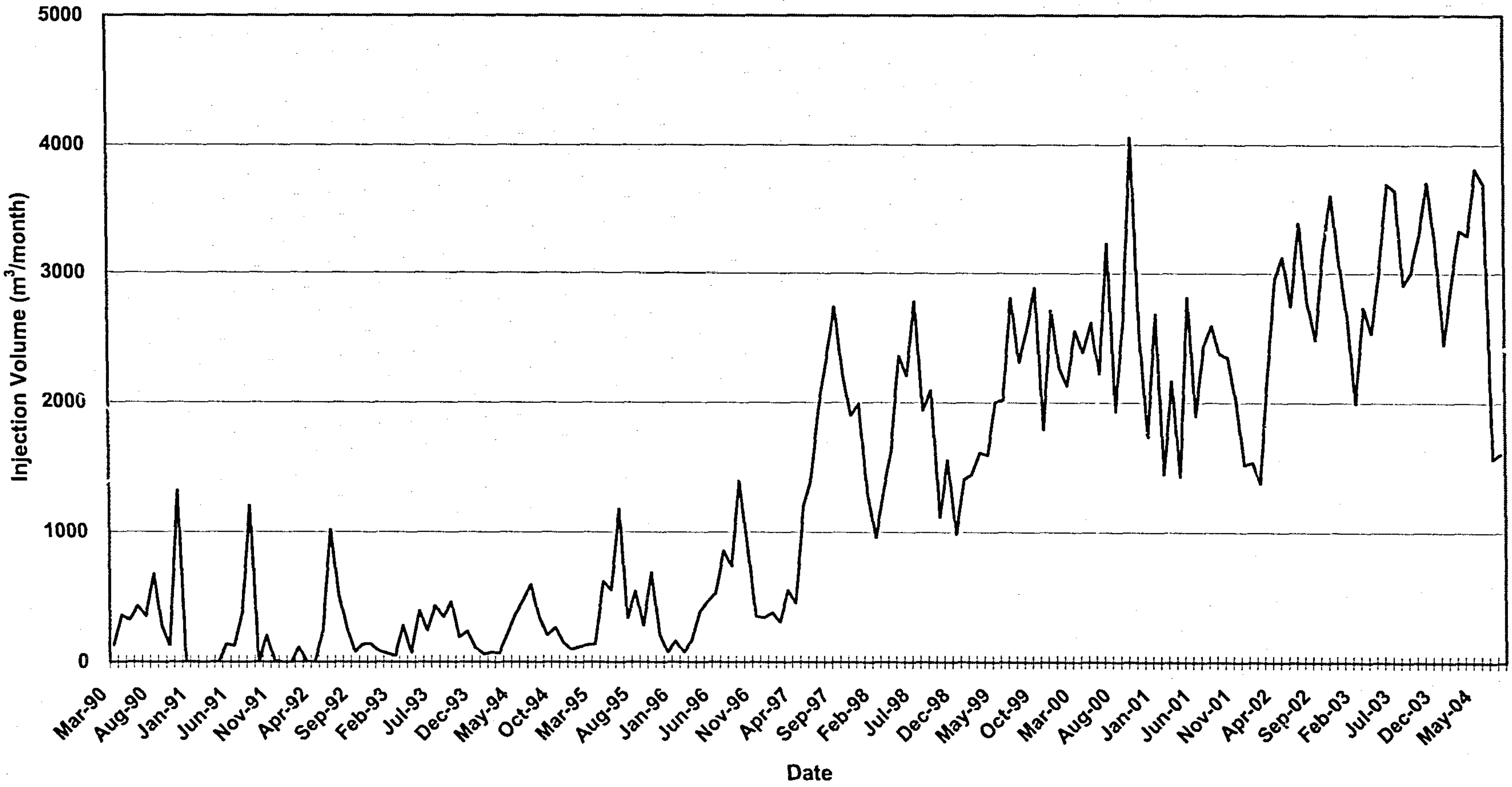

Figure 4.15. Time series plot of monthly injection volume of NEWALTA MORINV 8-15-54-26.

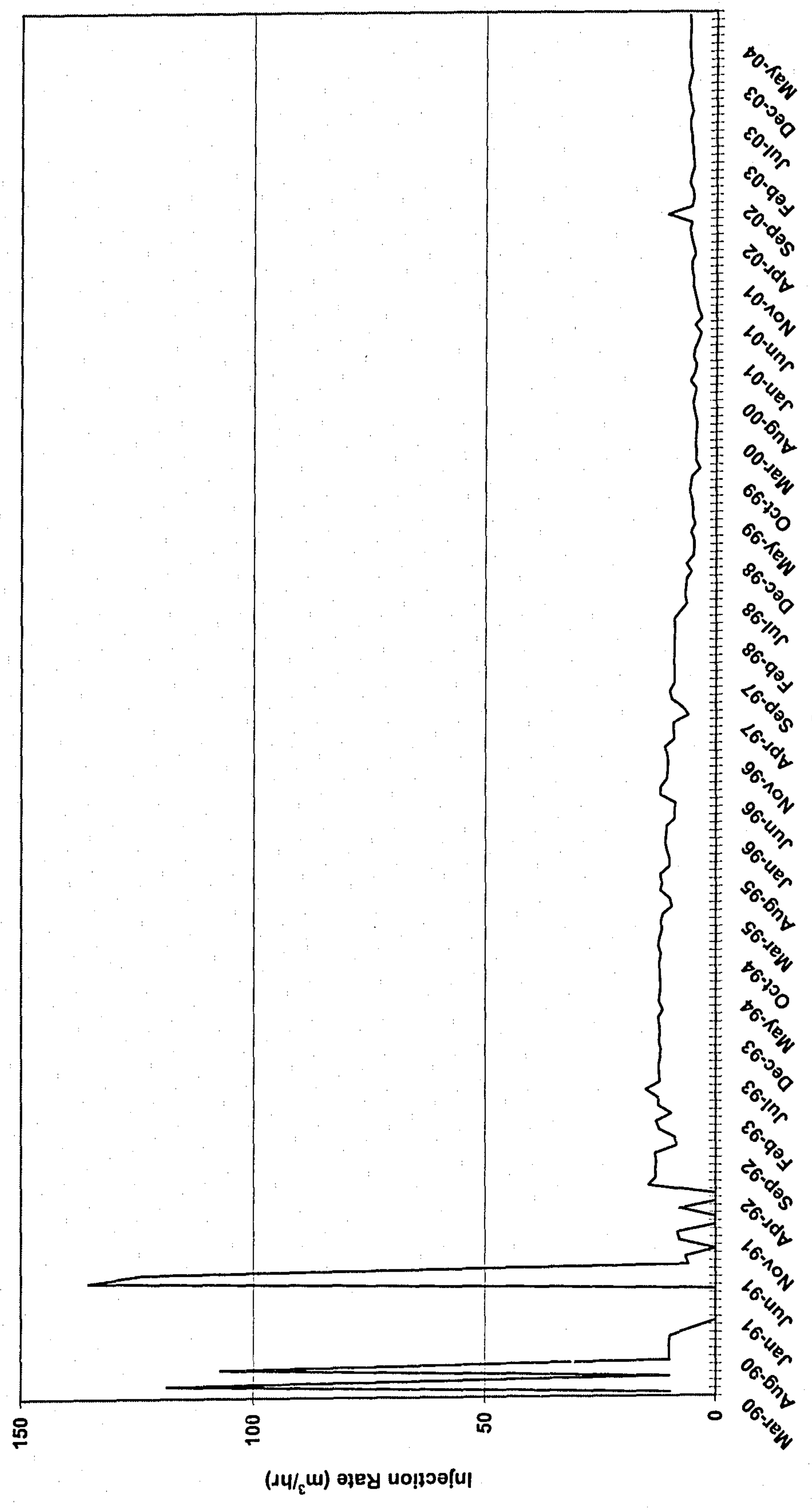

Figure 4.16. Time series plot of hourly injection rate of NEWALTA MORINV 8-15-54-26.

Table 4.9. Analysis of pond water (October 24, 1988).

Parameter	Concentration (mg/L)
Conductivity (dS/cm)	4350
Suspended Solids	68
Calcium (as $CaCO_3$)	40
Magnesium (as $CaCO_3$)	18
Sodium	1200
COD	1800
Boron	0.1
Fluoride	<0.2
Cyanide	<0.02
Alkalinity, P (as $CaCO_3$)	1391
Alkalinity, OH (as $CaCO_3$)	304
Alkalinity, H (as $CaCO_3$)	2478
NaCl	343
SO_4	70
TKN	8
Phenol	0,12
Arsenic	<0.01
PO_4	81
Sulfide	0.2
Cadmium	<0.1
Chromium	0.6
Al	--
Cu	<0.1
Fe	4.2
Zn	1.2
Barium	0.4
Manganese	0.1
Lead	<0.1
Freon	22
pH	10.9
Turbidity (as NTU)	--
Nickel	1
Vanadium	0.1

Table 4.10. Composition of waste source No. 1 (October 4, 1989).

Composition Substance	% Weight
Water	97.4
Oil	2
Sediment	0.6

Table 4.11. Chromatographic analysis of waste source No. 2.

Organic Compound	Organic Contaminant Level (% WT)
Ethylene Glycol	<0.1
Diethylene Glycol	0.5
Triethylene Glycol	<0.1
Monethanolamine	<0.1
Diethanolamine	0.45
Triethanolamine	<0.1

Table 4.12. Composition of waste source No. 3 (September21, 1989).

Composition Substance	% Weight by Volume
Water	98.87
Oil	0.29
Solids	0.64

Table 4.13. Chromatographic analysis of waste source No. 4 (September 22, 1989).

Organic Compound	Organic Contaminant Level (% WT)
Methanol	3.3
Isopropanol	0.4
Ethylene Glycol	3.3
Diethylene Glycol	<0.1
Triethylene Glycol	8
Tetraethylene Glycol	<0.1
Monethanolamine	7.3
Xylene	0.5

Table 4.14. Composition of waste source No. 4 (September 22, 1989).

Composition Substance	% Weight
Water	88
Sediment	0.05
Oil	11.95

Table 4.15. Compositional analysis of waste source No. 5 (May 5, 1989).

Parameter	Concentration (mg/L)
COD	4245
BOD	86
Fluoride	0.3
TKN	31
Phenol	<0.5
Phosphate Total (as PO_4)	27
Sulphate Total (as SO_4)	<0.05
Oil and Grease	8
Turbidity (as NTU)	1200
TSS	100
Mercury	0.017
pH	5.7

Table 4.16. Compositional analysis of waste source No. 7 (March 21, 1990).

Parameter	Concentration (mg/L)
Calcium	13.2 mg/L
Magnesium	0.6 mg/L
Sodium	39000 mg/L
Potassium	38 mg/L
Chloride	1815 mg/L
Sulphide	220 mg/L
PP Alkalinity as $CaCO_3$	2280 mg/L
Total Alkalinity as $CaCO_3$	9270 mg/L
pH	10.6
Carbonate	2708 mg/L
Bicarbonate	8555 mg/L
Oil and Grease	882 mg/L
Benzene	<1 ppm
Toluene	34 ppm

Table 4.16. Compositional analysis of waste source No. 7 (March 21, 1990) (continued).

Parameter	Concentration (mg/L)
Ethyl Benzene	10 ppm
Xylenes	104 ppm

Table 4.17. Compositional analysis of waste source No. 8 (May 5, 1990).

Parameter	Concentration (mg/L)
pH	7.6
Colour	60
BOD	627 mg/L
COD	1430 mg/L
Oil and Grease	1098 mg/L
Total Nitrogen	12.3 mg/L as N
Phosphorous as PO_4	19 mg/L
Fluoride	1.2 mg/L
Sulphide	0.35 mg/L
Cyanide	0.003 mg/L
Phenols	0.67 mg/L
Arsenic	0.233 mg/L
Barium	8.21 mg/L
Boron	0.7 mg/L
Cadmium	0.281 mg/L
Chromium	0.993 mg/L
Copper	2.1 mg/L
Iron	641 mg/L
Lead	2.53 mg/L
Manganese	14.3 mg/L
Mercury	<0.0001 mg/L
Selenium	0.009 mg/L
Silver	<0.02 mg/L
Zinc	7.03 mg/L
Total Coliform Bacteria	$1.5*10^4$
Fecal Coliform Bacteria	$2.4*10^4$

Table 4.18. Properties of waste source No. 17.

Property	Value
pH	7-8
Specific Gravity	0.97
Chloride	0.7%
Methanol	15-20%
Water	80-85%

Table 4.19. Properties of waste source No. 18.

Property	Value
pH	3.2
Heat Value	1400 kJ/kg
Ash	0.4%
Flashpoint	>61°C

4.5 Approval No. 6660

Approval No. 6660 was issued to Seller's Resources Ltd. on April 14, 1993. It included only one well: OKALTA-LEDUC NO. 13 WELL. The general properties of the well are presented in Table 4.20. Time series plots of monthly injection volumes and hourly injection rates of the well are depicted in Figures 4.17 and 4.18, respectively.

4.5.1 OKALTA-LEDUC NO. 13 WELL

Approval No. 6660 indicates that this well was used for the disposal of water produced in conjunction with oil or gas from the Province of Alberta and approximately 900 m^3/month of industrial waste liquids from the sources listed in Table 4.21. The subject well began operating on May 1, 1984. According to actual injection records, the average monthly injection rate was 2,200 m^3/month for the period in question. This number was calculated from volume records for 1984 and for the period of 1991 to 2004 inclusive. Injection volumes were not reported between 1985 and 1990. As shown in Figure 4.17, monthly injection volumes were not constant. The highest monthly injection volume of the well was 5,420 m^3 (in June 1996).

The waste characteristics of Sources No. 3, 5, 8, 10 and 11 were not provided by EUB. The characteristics of other waste sources listed in Table 4.21 are discussed below.

Source 1: Application No. 880053 indicates that the composition of this waste fluid was 70% H_2O, 20% methanol, 3% surfactant, and 2% amine salt.

Source 2: As provided by Application No. 881976, a hazardous waste landfill analysis of waste disposal tanks of this source is included in Table 4.22. The maximum acceptable concentration of methanol for hazardous waste landfill was 1000 mg/kg (Application No. 881976). The methanol concentrations from the 240-barrel tank and 40-barrel tank of this source were 1,432 mg/kg and 2,605 mg/kg, respectively.

Source 4: Application No. 880679 indicates that this waste fluid included 7.5% hydrochloric acid, 0.2% CH_{50} (acid inhibitor), 5% sodium hydroxide, 3% CC3919, 0.2% CS969 (surfactant) and 0.5% sodium nitrate.

Source 6: Application No. 910170 indicates that this source of waste was comprised of fluids used in industrial cleaning (ammoniated citric wash and hydrochloric acid wash). The composite of those two washes is presented in Table 4.23.

Source 7: Application No. 911059 indicates that this waste source had a pH from 6.5 to 7.5 and PCB concentration less than 50 ppm.

Source 9: As provided by Application No. 890659, the trace metals analysis of this source is presented in Table 4.24. Analyses of the untreated and neutralized wastewater of this source are presented in Table 4.25.

4.5.2 Recommendations

The average monthly volume of liquids injected to OKALTA-LEDUC NO. 13 WELL was 2,200 m^3 for the period in question. Although this is considered a small amount, the well received waste liquids from multiple sources (11). Given these conditions, it is recommended that it would not be economical to pursue an investigation of the potential of the multiple source liquids for treatment and reuse as an alternative to injection.

Table 4.20. General properties of OKALTA-LEDUC NO. 13 WELL.

Approval #	EUB Appl #	Field	Formation	Approval Holder	Scheme type	G 51 type	Well Name	Unique Identifier
6660	930310	Leduc-Woodbend	Leduc	Seller's Resources Ltd.	Disposal	Class Ia	OKALTA-LEDUC NO. 13 WELL	00/12-28-049-26W4/0

Top of Injection Interval Measured Depth (metres KB)	Minimum Packer Setting Depth (metres KB)	Maximum Wellhead Injection Pressure, kPa (gauge)
926.9	915.0	12,150

Injection Started	Time Series Plot of Monthly Injection Volume	Time Series Plot of Hourly Injection Rate	Average Annual Injection Rate (m^3/yr)	Average Monthly Injection Rate (m^3/month)	Cumulative Injection Amount to Aug, 2004 (m^3)
May 1, 1984	See Figure 4.17	See Figure 4.18	25,900	2,200	353,000

Table 4.21. Sources of wastewater disposed to OKALTA-LEDUC NO. 13 WELL.

Source Number	Company Name	Waste Source	Proposed Injection Volume (m^3/month)
1	Champion Northwest Chemicals	water chemical solution from a sump at Calgary facility	25
2	Nowaco Well Service Ltd.	Crude oil, water and methanol solution from its endless tubing unit	16
3	Raylo Chemicals	liquid waste defined as Magnesium Carbonate Slurry and Imidazole Hydro-chloride from its Edmonton facility	16
4	Ceda- Reactor Ltd.	neutralized acids and based from the chemical cleaning of separators, treaters, dehydration units, contactors, package boilers and new piping	90
5	QEC Canada Corp.	waste liquid from a paint stripping operation located at the Cooking Lake airport	6
6	Eveready Industrial Services 88 Ltd.	neutralized acids and bases from its cleaning operations	80
7	Chem-Security (Alberta) Ltd.	sump water collected at the Nisku Special Waste Handling Facility (PCB) concentration less than 5 parts per billion)	210
8	Nalco Canada Inc.	wastewater generated from its facility located at Edmonton. Alberta	
9	Alchem Inc.	tank and floor washing at company's Edmonton chemical blending plant	450
10	Laidlaw Environmental Services (Ryley) Ltd.	precipitation waste water from its primary leachate collection system at its landfill in Ryley, Alberta	N/A
11	Imperial Oil, Chemical Division	surface rain water collected from its blend plant facility at Nisku, Alberta	N/A

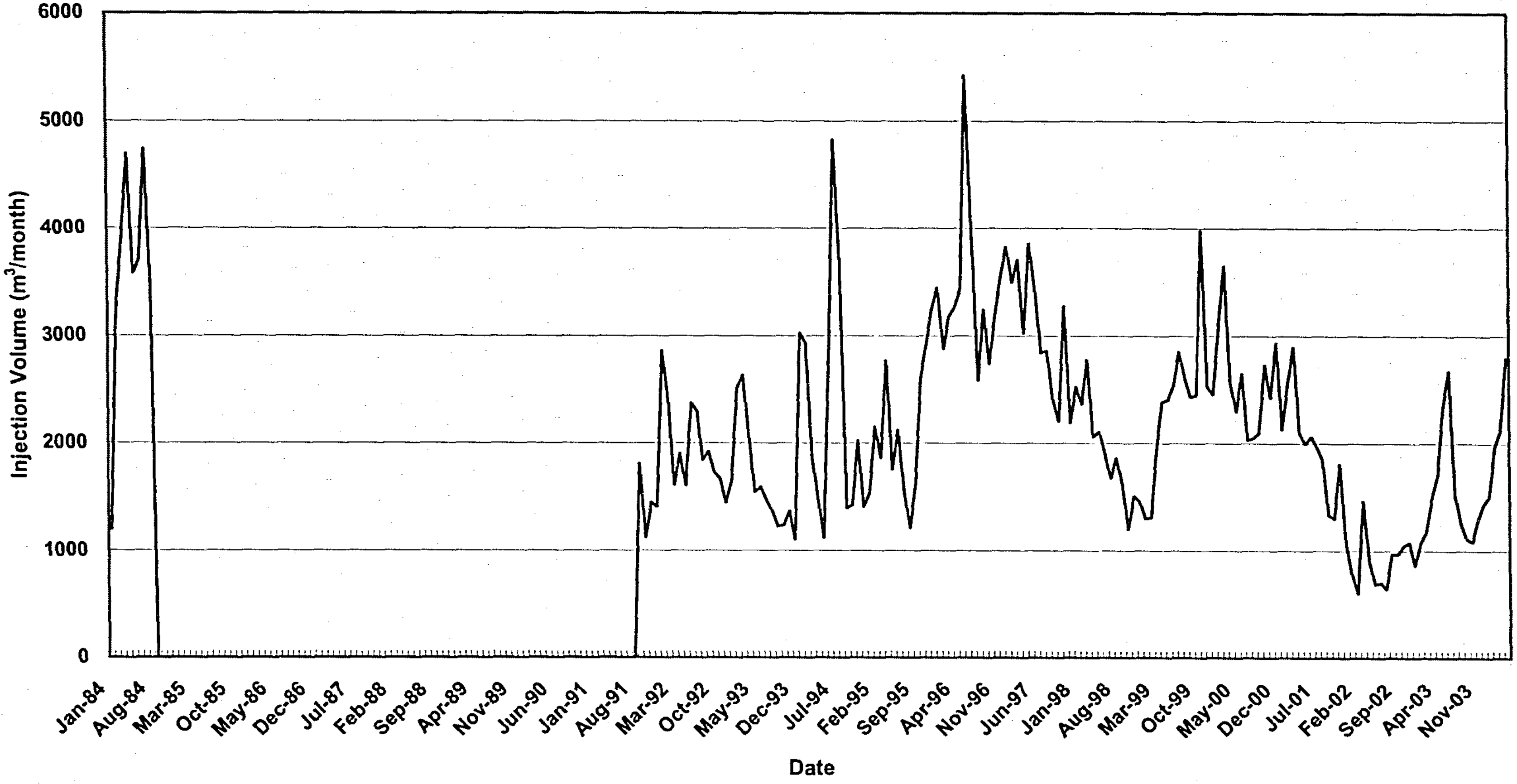

Figure 4.17. Time series plot of monthly injection volume of OKALTA-LEDUC NO. 13 WELL.

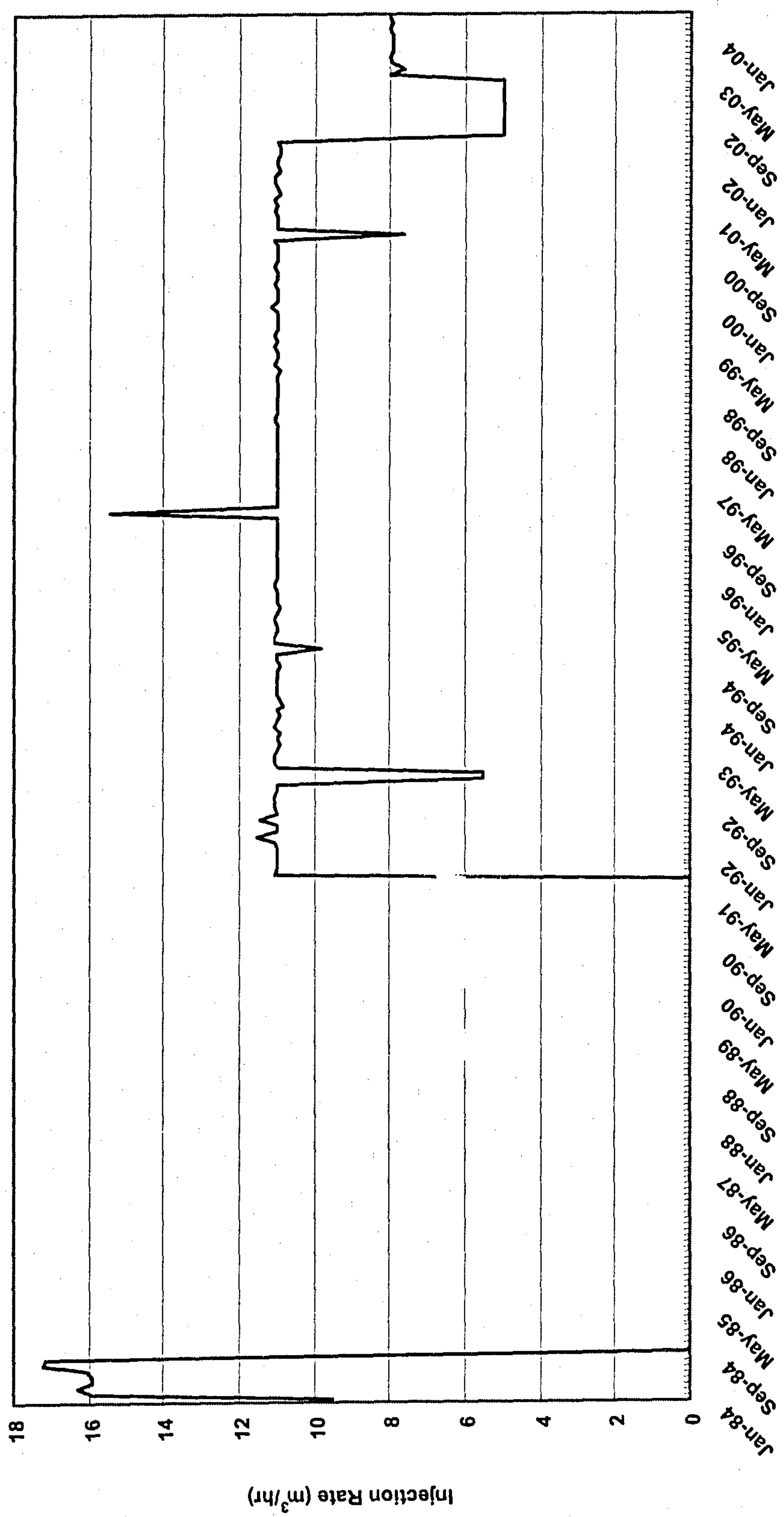

Figure 4.18. Time series plot of hourly injection rate of OKALTA-LEDUC NO. 13 WELL.

Table 4.22. Hazardous waste landfill analysis of Source No.2 (September 30, 1988).

Sample Point: 240 Barrel Tank		Sample Point: 40 Barrel Tank	
Organics	**mg/kg**	**Organics**	**mg/kg**
Cresols and Cresylic Acid	3.8	Cresols and Cresylic Acid	15
Cyclohexanone	2	Cyclohexanone	5
Sobutanol	303	Sobutanol	15
Methanol	1432	Methanol	2605
Methylene Chloride	5	Methylene Chloride	30
Xylene	>1	Xylene	>1
pH	4.76	pH	4.95

Table 4.23. Analysis of composition of ammoniated and hydrochloric acid wash of Source No. 6.

Chemical Composition	Ammoniated Citric Wash	Hydrochloric Acid Wash
	Concentration (mol/L)	
Anion/Cation	0.125/0.477	2.59/0.568
OH^-	0.561	--
Citric acid	0.0793	0.561
Chloride	$5.6*10^{-4}$	0.72
Silicate	0.0297	0.0355
Phosphate	0.0203	0.058
Sulphate	$4*10^{-4}$	0.0151
Carbonate	0.0031	0.798
Ammonia	0.238	0.02
Nitrate/Nitrite	0.0097/0.0145	--
Total Hardness	0.028	0.0957
Total Iron	0.0257	0.087
Manganese	0.009	0.0057
Phenol/Deriv	--	--
Cadmium/Zinc	<1 ppm	<1 ppm
Chromium	--	--
Surfactant	--	--
Oil-in-water	--	--

Table 4.24. Trace metals analysis of Source No. 9.

Element	Concentration (mg/L)
Aiuminum	18
Arsenic	0.13
Barium	0.12
Beryllium	<0.001
Boron	0.46
Cadmium	0.004
Calcium	8.2
Chromium	4.2
Cobalt	0.83
Copper	0.021
Iron	1.5
Load	<0.03
Magnesium	2.5
Manganese	0.045
Molybdenum	3.2
Nickel	0.56
Phosphorous	8.8
Potassium	5.8
Selenium	<0.05
Silicon	1.1
Silver	<0.05
Sodium	160
Thallium	<0.05
Tin	0.05
Titanium	0.015
Vanadium	<0.005
Zinc	1.5

Table 4.25. Analyses of untreated and neutralized wastewater of Source No. 9.

Ion	Concentration of Untreated Wastewater (mg/L)	Concentration of Neutralized Wastewater (mg/L)
Na^+	180	180
K^+	7	7
Ca^{2+}	0	0
Mg^{2+}	0	0
SO_4^{2-}	177	109
Cl^-	0	191
CO_3^{2-}	164.0	0.0
HCO_3^-	36	119
pH	10	7.1

4.6 Approval No. 7070

Approval No. 7070 was issued to Canadian Oil Reclamation (COR) on July 13, 1993. It included only one well: NEWALTA MORINVILLE 12-19-54-25. The general properties of the well are presented in Table 4.16. Time series plots of monthly injection volumes and hourly injection rates are depicted in Figures 4.19 and 4.20, respectively.

4.6.1 NEWALTA MORINVILLE 12-19-54-25

Approval No. 7070 indicates that this well was to be used for the disposal of waste liquids generated from COR's recycling operation and runoff water collected from the plant site. Application No. 841049 indicates that this well would dispose 3,000 m^3 per month of waste fluids.

According to actual injection records, the average monthly injection rate of this well was 156 m^3 per month for the period in question. This number was calculated from data for the period 2001 to 2002 inclusive. No injection volumes were reported for 2003 and 2004. The subject well began operating on January 1, 1986. However, no volume was reported until 2001. As shown in Figure 4.19, the monthly injection volumes have not been constant. The highest monthly injection volume was 293 m^3 (in both January and February of 2001). No information on chemical analysis of the waste liquids and runoff water was provided.

4.6.2 Recommendation

The average monthly volume of waste liquids and runoff water from COR injected into NEWALTA MORINVILLE 12-19-54-25 was 156 m^3. Although chemical characteristics of the individual sources are unknown, this is considered a very small amount. Given this situation, it would not be useful to pursue an investigation of the potential of the source liquids for treatment and reuse as an alternative to injection.

Table 4.26. General properties of NEWALTA MORINVILLE 12-19-54-25.

Approval	EUB Appl #	Field	Formation	Approval Holder	Scheme type	G 51 type	Well Name	Unique Identifier
7070	950029	Morinville	Leduc	Newalta Corporation	Disposal	Class Ia	NEWALTA MORINVILLE 12-19-54-25	00/12-19-054-25W4/0

Top of Injection Interval Measured Depth (metres KB)	Minimum Packer Setting Depth (metres KB)	Maximum Wellhead Injection Pressure, kPa (gauge)
1638.5	1599	18,000

Injection Started	Time Series Plot of Monthly Injection Volume	Time Series Plot of Hourly Injection Rate	Average Annual Injection Rate (m^3/yr)	Average Monthly Injection Rate (m^3/month)	Cumulative Injection Amount to Aug, 2004 (m^3)
January 1, 1986	See Figure 4.19	See Figure 4.20	468	156	46,800

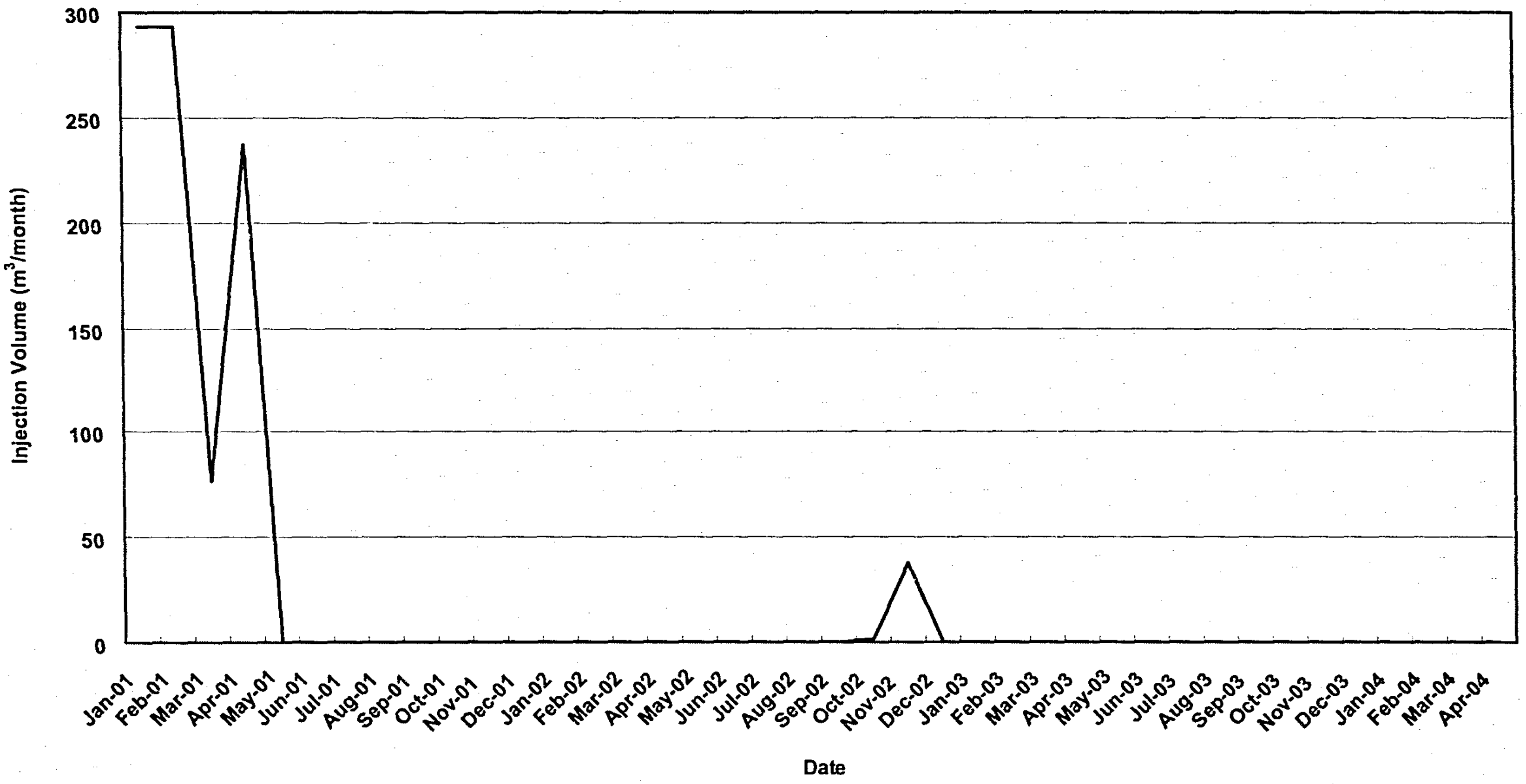

Figure 4.19. Time series plot of monthly injection volume of NEWALTA MORINVILLE 12-19-54-25.

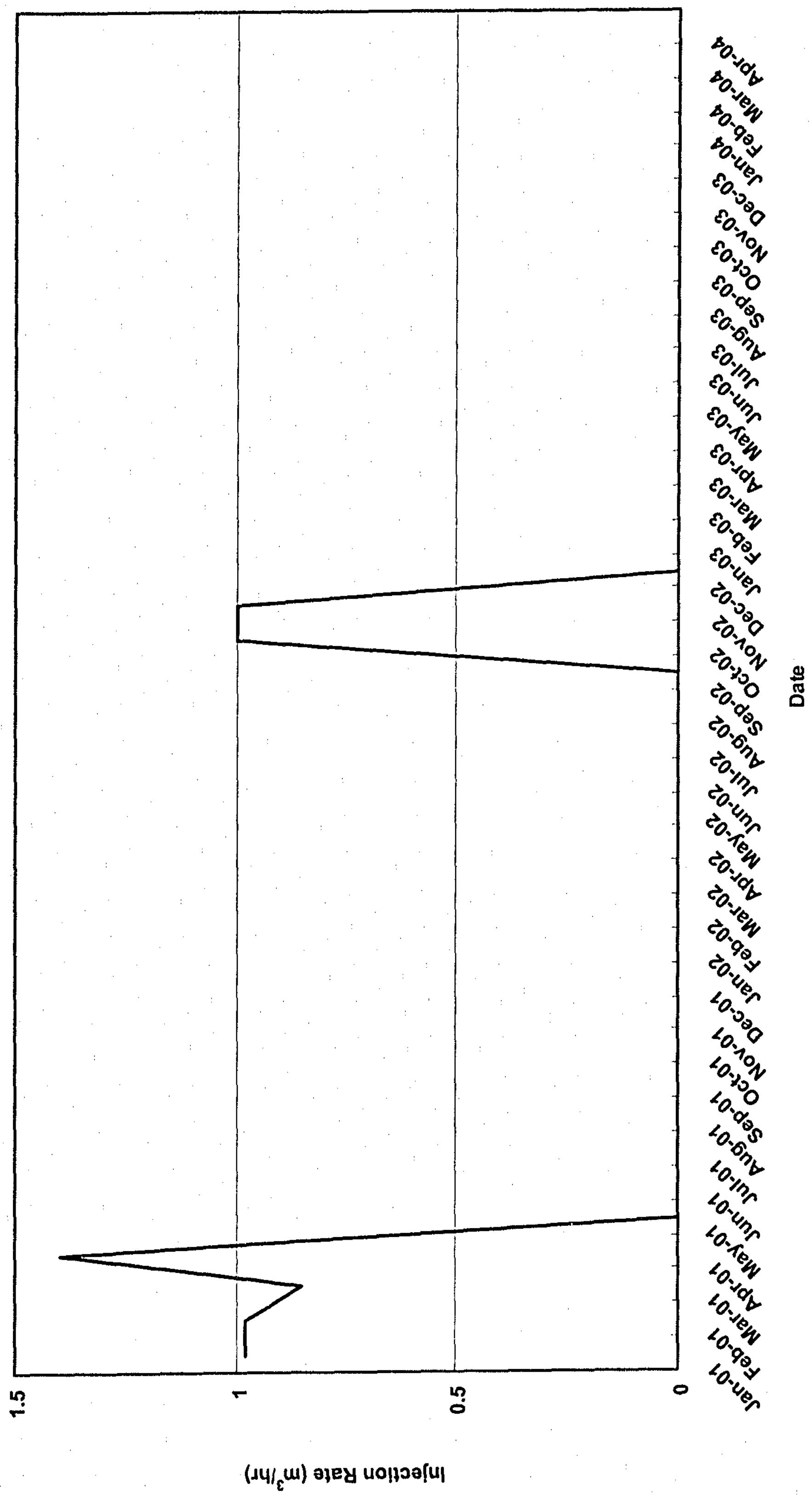

Figure 4.20. Time series plot of hourly injection rate of NEWALTA MORINVILLE 12-19-54-25.

4.7 Approval No. 7290

Approval No. 7290 was issued to Chevron Canada Resources Limited on November 1, 1993. It included only one well: CHEVRON MGSU 1 MITSUE 7-20-72-4. The general properties of the well are presented in Table 4.27. Time series plots of monthly injection volumes and hourly injection rates are depicted in Figures 4.21 and 4.22, respectively.

4.7.1 CHEVRON MGSU 1 MITSUE 7-20-72-4

Approval No. 7290 indicates that this well was used for the disposal of water produced in conjunction with oil and gas from the Province of Alberta and 12,000 m^3/month of waste liquids as specified in Table 4.28.

According to actual injection records, the average monthly injection rate of this well was 10,400 m^3/month. This number was calculated from data for the period 1985 to 2004 inclusive. The subject well began operating on May 20, 1985. As shown in Figure 4.21, monthly injection volumes have not been constant. The highest monthly injection volume was 95,800 m^3 (in June 1986).

The results of analyses of API pond, API sludge and API sludge leachate of Chevron Canada Resources are presented in Tables 4.29 to 4.31. Analyses of other waste sources were not provided.

4.7.2 Recommendation

The average monthly volume of liquids injected to CHEVRON MGSU 1 MITSUE 7-20-72-4 was 10,400 m^3. While this is considered a large amount, there appears to have been negligible amounts injected during the past ten years. No recommendations are put forward for these liquids.

Table 4.27. General properties of CHEVRON MGSU 1 MITSUE 7-20-72-4.

Approval	EUB Appl #	Field	Formation	Approval Holder	Scheme type	G 51 type	Well Name	Unique Identifier
7290	931118	Mitsue	Wabamun	Chevron Canada	Disposal	Class Ia	CHEVRON MGSU 1 MITSUE 7-20-72-4	00/07-20-072-4W5/0

Top of Injection Interval Measured Depth (metres KB)	Minimum Packer Setting Depth (metres KB)	Maximum Wellhead Injection Pressure, kPa (gauge)
765	745	3,700

Injection Started	Time Series Plot of Monthly Injection Volume	Time Series Plot of Hourly Injection Rate	Average Annual Injection Rate (m^3/yr)	Average Monthly Injection Rate (m^3/month)	Cumulative Injection Amount to Aug, 2004 (m^3)
May 20, 1985	See Figure 4.21	See Figure 4.22	86,400	10,500	2,420,000

Table 4.28. Waste sources of CHEVRON MGSU 1 MITSUE 7-20-72-4.

Waste Type	Waste Source	Volume (m^3/year)
Neutralized/Spent Acid	Chevron Mitsue Plant/Field	20
Drilling Mud	Chevron Mitsue Field	200
Oil Spill Fluids	Chevron Mitsue Field	1000
Plant Wastewater	Chevron Mitsue Plant	20
Spent Amine	Chevron Mitsue Plant	10
Spent Ethylene Glycol	Chevron Mitsue Plant	5
Spent Methanol	Chevron Mitsue Plant	5
Vessel Drainage	Chevron Mitsue Plant	50
Floor/Equipment Washing	Chevron Mitsue Plant	16
Turnaround Wastes	Chevron Mitsue Plant	70
DADS Sludge	Chevron Obed	200
DADS/Iron Sulphide Sludge	Chevron Obed	80
DADS/DMDS Sludge	Gulf Ricinus	25
DADS/DMDS Sludge	Bow Valley Resources, Rocky Mountain House	10
DMDS Sludge	Petro-Canada, Hanlon Robb	20
API Separator Sludge	Chevron Kaybob South No.3	1200 m^3 (once only)
Process Wastewater Pond Sludge	Amoco Kaybob 1/2 Gas Plant	4000 m^3 (once only)
Soil/Sulphur Mixtures	Chevron Kaybob South No.3	10000

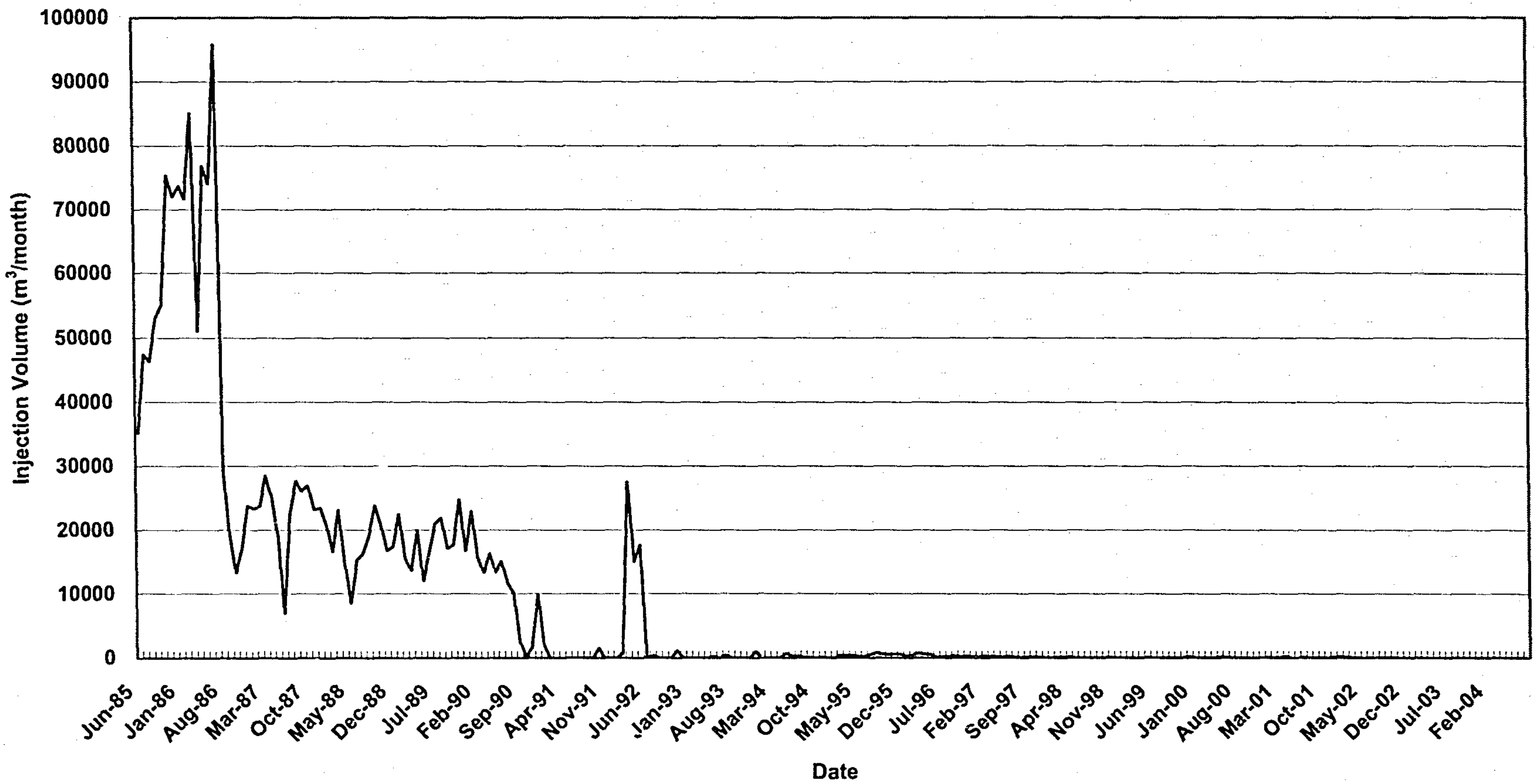

Figure 4.21. Time series plot of monthly injection volume of CHEVRON MGSU 1 MITSUE 7-20-72-4.

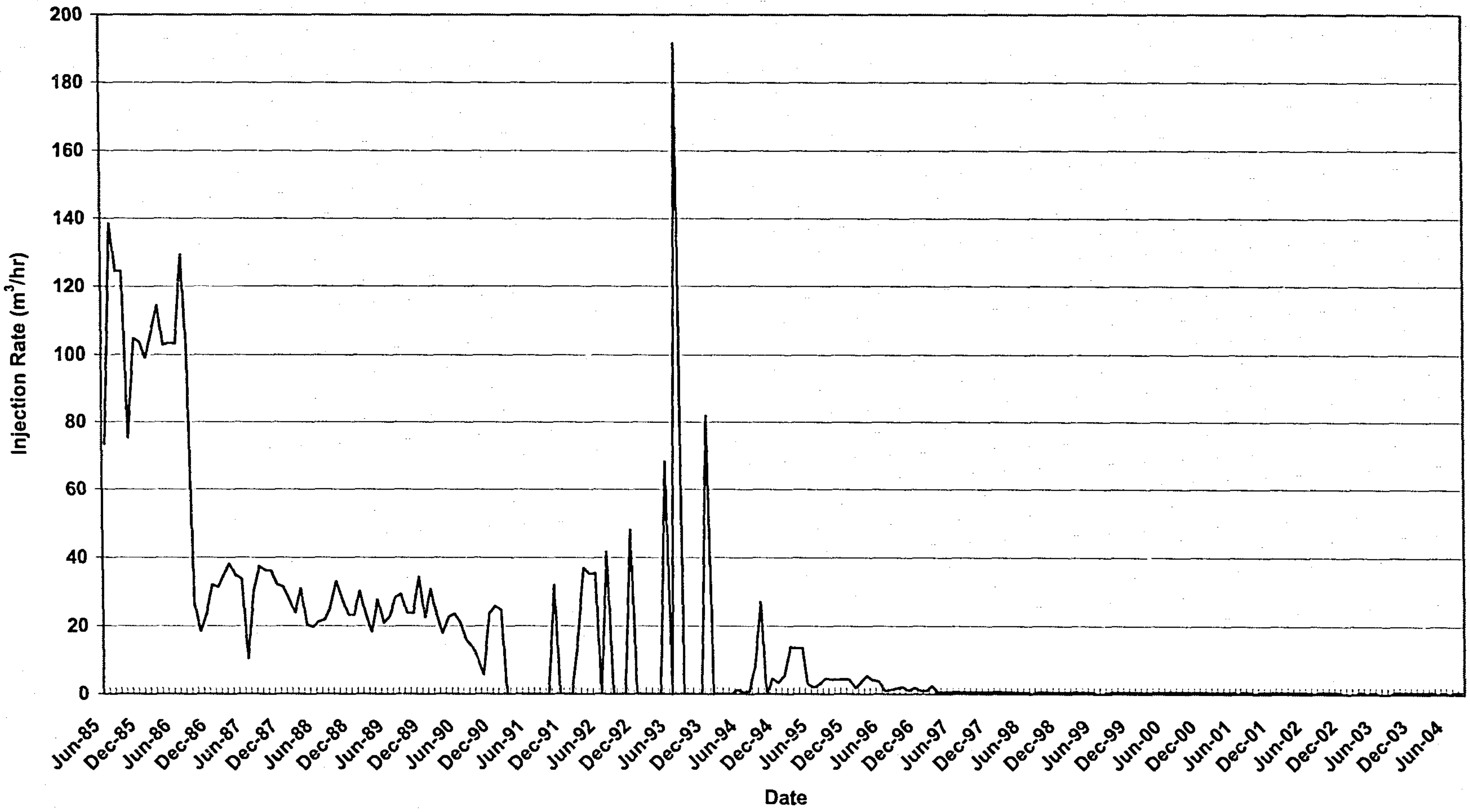

Figure 4.22. Time series plot of hourly injection rate of CHEVRON MGSU 1 MITSUE 7-20-72-4.

Table 4.29. Analysis of API pond of Chevron Canada Resources.

Parameter	Concentration
Density	1346 kg/m^3
Flash Point	26°C
Paint Filter Test	0 mL/kg
pH	8.9
Iron Sulphide	6.8 W_L%
Chromium	3350 ppm
Benzene	48.1 mg/kg
Toluene	313 mg/kg
Ethylbenzene	37 mg/kg
M & P-Xylene	382 mg/kg
O-Xylene	132 mg/kg

Table 4.30. Analysis of API sludge of Chevron Canada Resources.

Parameter	Concentration
Water Content	65.8 W_L%
Solids Content	29.9 W_L%
Oil & Grease	4.3 W_L%
TOC	15.86 W_L%
Dietholamine	<50 mg/kg
Cresols & Cresylic Acid	<50 mg/kg
1,1,1 & 1,1,2 Trichloroethylenes	<20 mg/kg
Total Metals	
Cd	36 mg/kg
Cr	1800 mg/kg
Ni	32 mg/kg
Pb	106 mg/kg
Zn	700 mg/kg
Non-halogenated Volatiles	
Benzene	<0.1 mg/kg
Toluene	203.2 mg/kg
Ethylbenzene	44.4 mg/kg
M & P-Xylene	211.8 mg/kg
O-Xylene	169.8 mg/kg
Methylethylketone	<300 ppm

Table 4.31. Analysis of API sludge leachate of Chevron Canada Resources.

Parameter	Concentration (mg/L)
Arsenic	0.045
Barium	2.9
Boron	0.9
Cadmium	<0.005
Hexavalent Chromium	<0.006
Lead	<0.007
Mercury	0.001
Nickel	0.15
Silver	<0.005
Thallium	<0.001
Uranium	0.001
Cyanide	0.009
Nitrate+Nitrite	<1
Nitrite	<0.005

4.8 Approval No. 7547

Approval No. 7547 was issued to Byram Industrial Services Ltd. on November 22, 1994. It included only one well: NEWALTA PEMBINA 8-23-48-8. General properties of the well are presented in Table 4.32. Time series plots of monthly injection volumes and hourly injection rates of the well are depicted in Figures 4.23 and 4.24, respectively.

4.8.1 NEWALTA PEMBINA 8-23-48-8

As indicated by Application No. 921157, the well was to be used for disposal of the following waste streams:

- Water produced in conjunction with the sites at Pembina Oil Separators (POS) Main Plant and POS Treating Facility within the Province of Alberta.
- Sweet and sour waters from typical oil field production processes from the Province of Alberta.
- Non-typical liquid waste streams from both the oil field and outside the oil field within the Province of Alberta.

Application No. 921157 indicates that the above liquid waste streams could be from the following sources: acid water, blowdown water, caustic water, scrubber liquids, knockout liquids, filter backwash liquids, hydrostatic test fluids, pigging fluids, process waste waters, the liquid portion of process sludges, water treatment fluids, water and solvent wash fluids, sweet and sour produced waters and well workover fluids.

Application No. 921157 also indicates that total disposal volumes to this well were proposed to be in the range of 100 to 400 m^3/day. According to actual injection records, the amount of waste fluids disposed has been approximately 170 m^3/day. This number was estimated from the average monthly injection rate of the well.

According to actual injection records, the average monthly injection rate for the period in question was 4,940 m^3/month. This number was calculated from data for the period 2001 to 2004 inclusive. The subject well began operation on April 1, 1993. However, no volume was reported until 2001. As shown in Figure 4.23, the monthly injection volumes have not been not constant. The highest monthly injection volume of the well was 8,930 m^3 (in February 2003). No information on chemical analyses of waste sources was provided.

4.8.2 Recommendations

The average monthly volume of liquids injected to NEWALTA PEMBINA 8-23-48-8 WELL was about 5,000 m^3. While this is considered a small amount relative to other wells in Alberta, the well receives waste liquids from many sources. Given these conditions, it may not be economical to pursue an investigation of the potential of the source liquids for treatment and reuse as an alternative to injection.

Table 4.32. General properties of NEWALTA MORINV 8-15-54-26.

Approval #	EUB Appl #	Field	Formation	Approval Holder	Scheme type	G 51 type	Well Name	Unique Identifier
7547	941190	Pembina	Pekisko	Byram Industrial Services Ltd	Disposal	Class Ia	NEWALTA PEMBINA 8-23-48-8	02/08-23-048-08W5/0

Top of Injection Interval Measured Depth (metres KB)	Minimum Packer Setting Depth (metres KB)	Maximum Wellhead Injection Pressure, kPa (gauge)
2,040.5	2,020.0	17,370

Injection Started	Time Series Plot of Monthly Injection Volume	Time Series Plot of Hourly Injection Rate	Average Annual Injection Rate (m^3/yr)	Average Monthly Injection Rate (m^3/month)	Cumulative Injection Amount to Aug, 2004 (m^3)
April 1, 1993	See Figure 4.23	See Figure 4.24	58,000	4,940	217,000

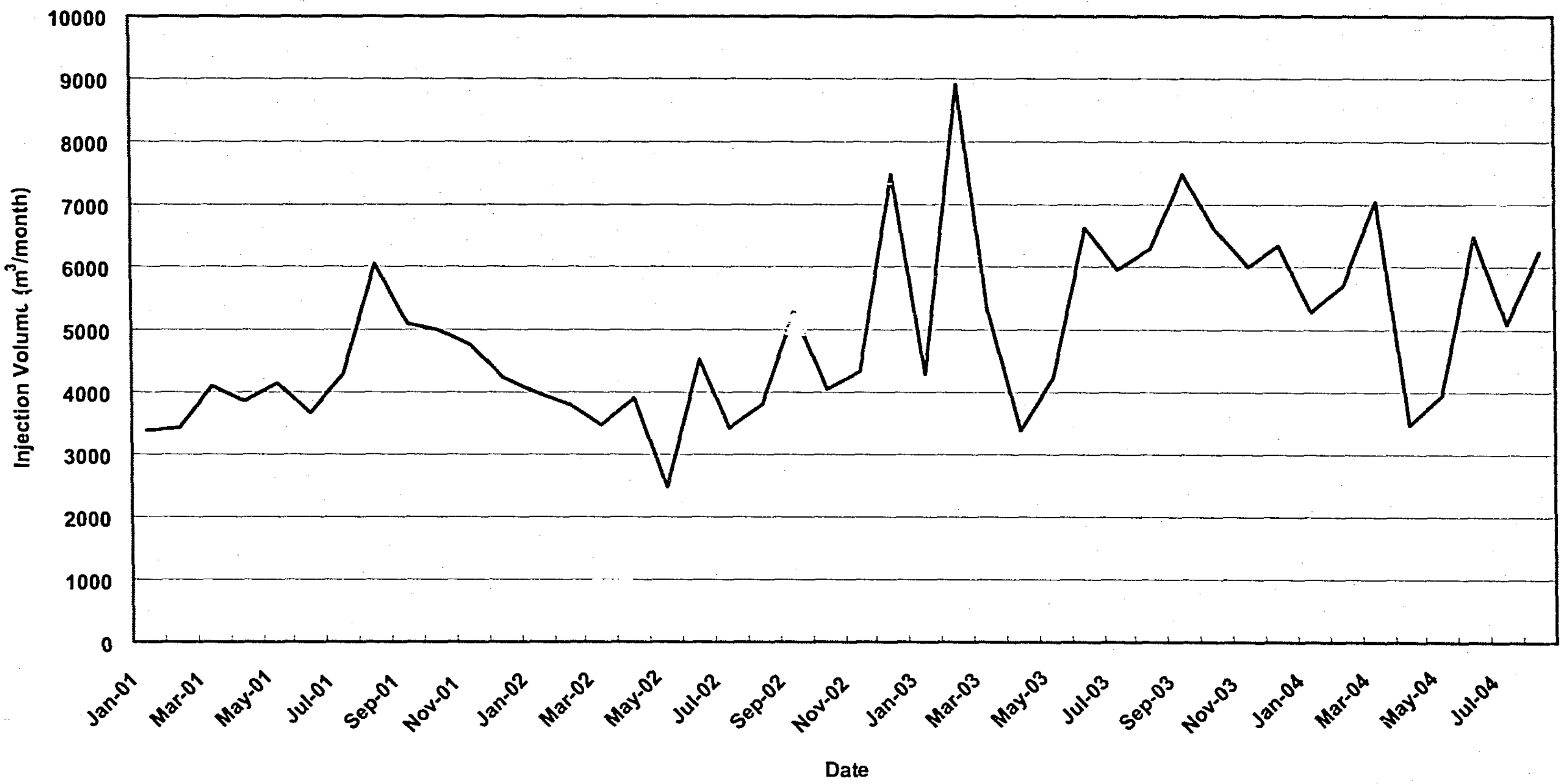

Figure 4.23. Time series plot of monthly injection volume of NEWALTA MORINV 8-15-54-26.

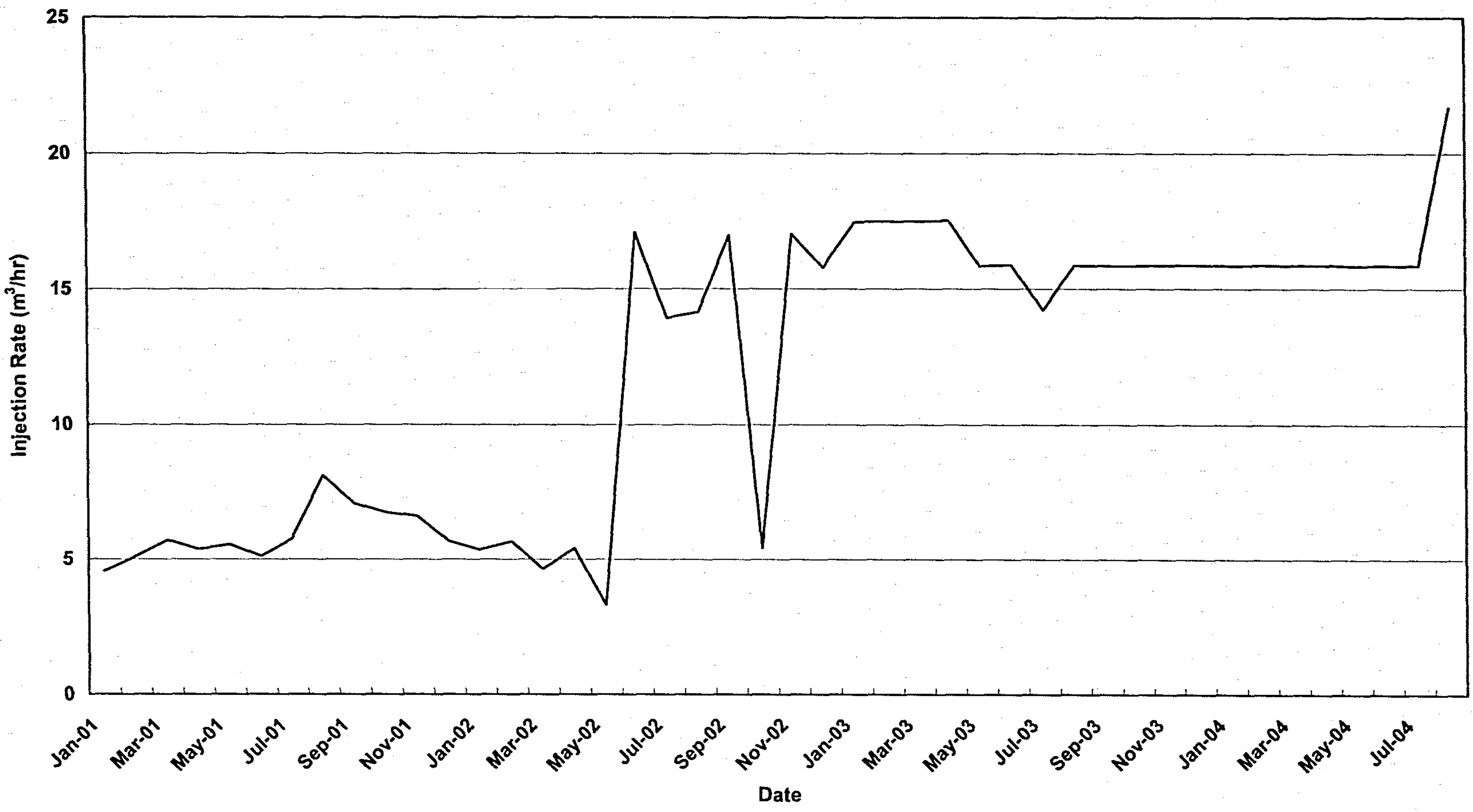

Figure 4.24. Time series plot of hourly injection rate of NEWALTA MORINV 8-15-54-26.

4.9 Approval No. 7742

Approval No. 7742 was issued to Alberta Infrastructure on January 11, 2001. It included two wells with the same well name: CSL ETHEL 13-6-67-8, but each with a different identifier: 00/13-06-067-08W5/0 and 00/13-06-067-08W5/2. The general properties of these wells are presented in Table 4.33. Time series plots of monthly injection volumes and hourly injection rates are depicted in Figures 4.25 to 4.28. Characteristics of the waste injected into these wells are listed in Tables 4.34 and 4.35.

4.9.1 CSL ETHEL 13-6-67-8

Application No. 990087 indicates that wastewater disposed to the two wells had the same sources and characteristics. Application No. 941328 indicates that fluid injected into the disposal wells came from three sources: storm water retention ponds, incinerator blowdown and filtrate from the filter press located in the physical and chemical treatment plant of Alberta Special Waste Treatment Centre.

Application No. 990087 indicates that the annual injection volume was approximately $130*10^3$ m^3. According to actual injection records, the average annual injection rate of the two wells was $100*10^3$ m^3/year. This number was calculated from the sum of the average annual injection rates of the two wells.

According to actual injection records of the well with unique identifier 00/13-06-067-08W5/0, the average monthly injection rate during the period in question was 3,890 m^3/month. This number was calculated from the volume records for1989 and for the period 2001 to 2004 inclusive. No injection volume was reported between 1990 and 2000. This well began operating on April 3, 1987. However, no volume was reported until 1989.

According to actual injection records of the well with unique identifier 00/13-06-067-08W5/2, the average monthly injection rate of this well has been 3,320 m^3/month. This number was calculated from data for the period 2001 to 2004 inclusive. The well began operating on October 5, 1990. However, no volume was reported until 2001.

As shown in Figure 4.25 and Figure 4.26, the monthly injection volumes were not constant for both wells. The highest monthly injection volume of the well with unique identifier 00/13-06-067-08W5/0 was 10,800 m^3, in August 1989 (Figure 4.25). As shown in Figure 4.26, the highest monthly injection volume of the well with unique identifier 00/13-06-067-08W5/2 was 7,000 m^3, in August 2001.

Application No. 861064 indicates the following criteria were to be used in determining whether a batch of liquid was suitable for disposal to the two wells:

- Temperature: Ambient up to 77°C.
- Specific Gravity: 1.0 to 1.3.
- pH: 0.5 to 7.0, typically 1.0.
- Inorganic Acids: Maximum 1.0% HCl.
- TSS: Up to 1.5 % by weight of less than 80% mesh material; typically clays, silicone and aluminum oxides.
- TDS: Primarily soluble calcium and sodium salts of inorganic acids; up to 30% by weight, typically 10% by weight and trace amount of soluble metals less than 200 ppm.
- TOC: 2% average, 4.5% maximum; based on M.W. of 60 at 60% carbon.
- Treated single-phase aqueous waste containing soluble organic components (oxygenated organics and amines) and soluble chlorinated hydrocarbons up to 200 ppm.

Application No. 941328 indicates that fluid from three sources (storm water retention ponds, incinerator blowdown and filtrate from the filter press located in the physical and chemical treatment plant) were pH-adjusted between 4.0 and 8.0. Samples for analysis were obtained from the pH-adjust tank. pH, total dissolved solids, total suspended solids, total organic carbon and specific gravity of waste samples were analyzed. The results are summarized in Table 4.34, while Table 4.35 summarizes metal concentrations for fluids injected between July 21 and August 9, 1994. These analyses indicate that disposal well fluids had high TSS and TDS.

4.9.2 Recommendations

The average monthly volume of wastewater from the three sources of Alberta Special Waste Treatment Centre for disposal was about 3,500 m^3 for each well. This is considered a small amount, and the wells receive waste liquids from three sources. Waste characteristics indicate that certain chemicals would require specific treatment in these sources. Given this situation, it may not be economical to pursue an investigation of the potential of the source liquids for treatment and reuse as an alternative to injection.

Table 4.33. General properties of the wells included in Approval No. 7742.

Approval	EUB Appl #	Field	Formation	Approval Holder	Scheme type	G 51 type	Well Name	Unique Identifier
7742	1083119	Ethel	Wabamum	Alberta Infrastructure	Disposal	Class Ia	CSL ETHEL 13-6-67-8	00/13-06-067-08W5/0
							CSL ETHEL 13-6-67-8	00/13-06-067-08W5/2

Unique Identifier	Top of Injection Interval Measured Depth (metres KB)	Minimum Packer Setting Depth (metres KB)	Maximum Wellhead Injection Pressure, kPa (gauge)
00/13-06-067-08W5/0	1833.0	1775.0	690
00/13-06-067-08W5/2	1911.5	1775.0	690

Unique Identifier	Injection Started	Time Series Plot of Monthly Injection Volume	Time Series Plot of Hourly Injection Rate	Average Annual Injection Rate (m^3/yr)	Average Monthly Injection Rate (m^3/month)	Cumulative Injection Amount to Aug, 2004 (m^3)
00/13-06-067-08W5/0	April 3, 1987	See Figure 4.25	See Figure 4.27	49,200	3,890	218,000
00/13-06-067-08W5/2	October 5, 1990	See Figure 4.26	See Figure 4.28	40,800	3,320	146,000

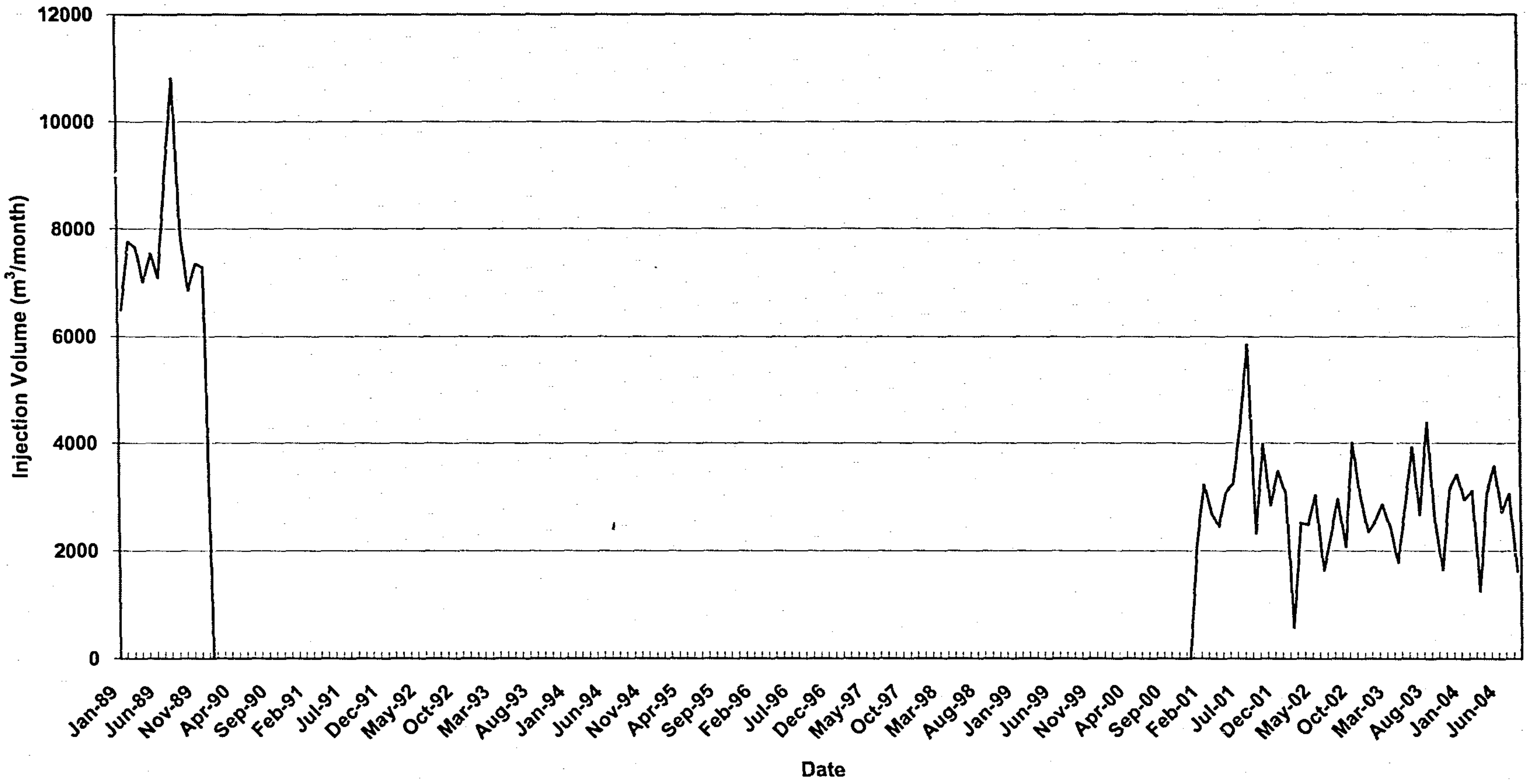

Figure 4.25. Time series plot of monthly injection volume of 00/13-06-067-08W5/0.

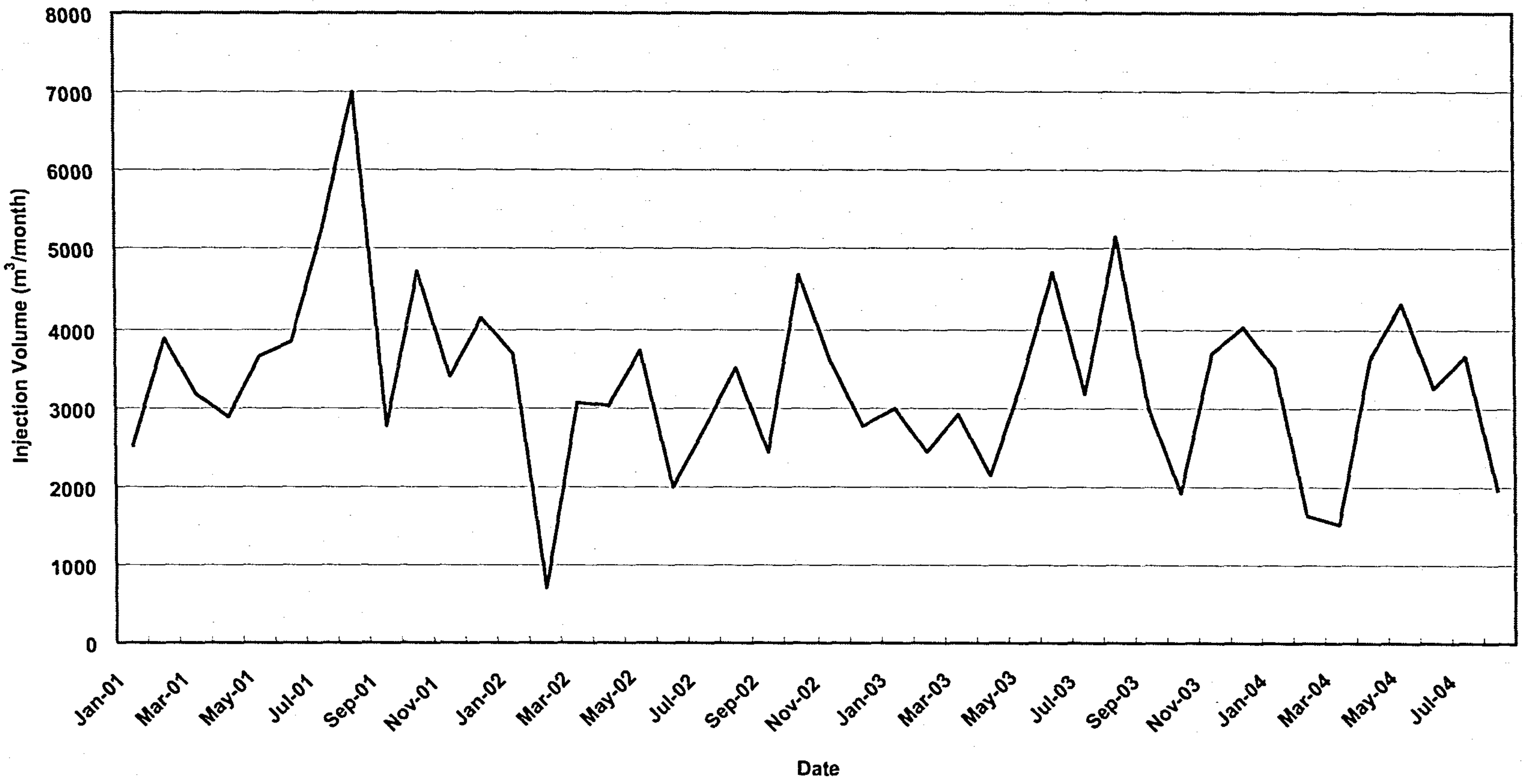

Figure 4.26. Time series plot of monthly injection volume of 00/13-06-067-08W5/2.

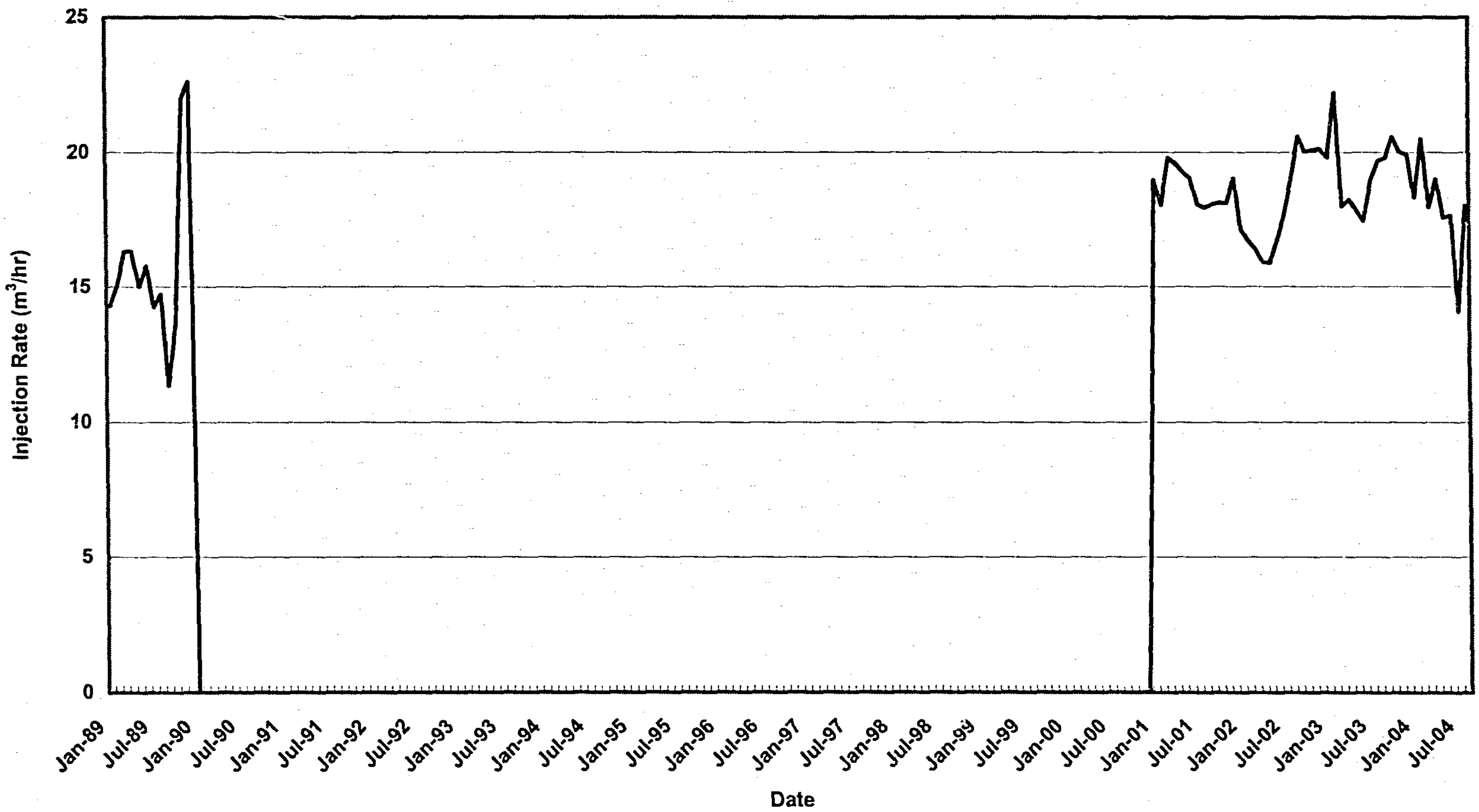

Figure 4.27. Time series plot of hourly injection rate of 00/13-06-067-08W5/0.

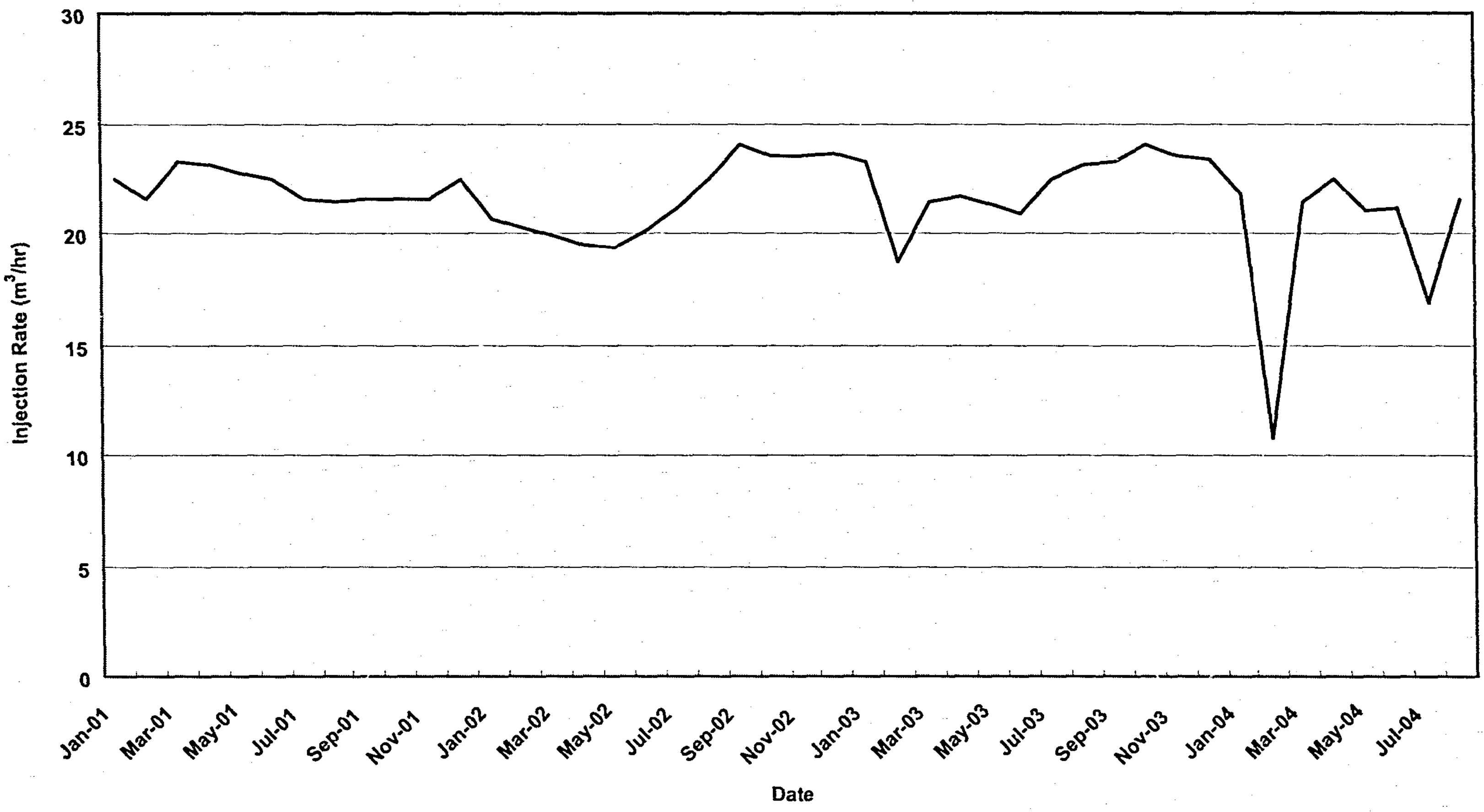

Figure 4.28. Time series plot of hourly injection rate of 00/13-06-067-08W5/2

Table 4.34. Disposal well CSL ETHEL 13-6-67-8 Fluid Analysis.

Parameter	Criteria	Operation Average of 1994					
		Jan	Feb	Mar	Apr	May	Jun
TSS	<15,000 ppm	2469	4146	1904	4615	2749	3838
TDS	<300,000 ppm	9422	12742	16326	35247	20960	24265
pH	4.0-8.0	4.55	4.97	5.17	5.18	5.26	4.83
TOC	<20,000ppm	103	238	80	53	56	56
Specific Gravity	1.0-1.3	1.01	1.02	1.01	1.03	1.02	1.02

Table 4.35. Metal concentrations for disposal well CSL ETHEL 13-6-67-8 fluid.

Metal	Criteria (mg/kg)	Concentration (mg/kg) July 21 to July 27, 1994	Concentration (mg/kg) July 28 to August 9, 1994
Arsenic	500	0.3	2.8
Beryllium	100	0	0
Cadmium	100	2.8	0.6
Chromium	500	0	1.5
Lead	500	28.1	124.3
Mercury	20	<0.1	<0.1
Nickel	500	0.7	0.8
Selenium	200	3	1
Silver	100	0.1	0
Thallium	200	0.5	0
Uranium	100	N/A	N/A
Trichlorobenzene	--	<0.1	<0.1
Polychlorinated Biphenyls	50	2	0

4.10 Approval No. 7842

Approval No. 7842 was issued to AT Plastics Inc. on December 18, 2001. It included only one well: AT PLASTICS CHEM IN 14-36-52-24. The general properties of this well are presented in Table 4.36.

4.10.1 AT PLASTICS CHEM IN 14-36-52-24

Application No. 941351 indicates that AT Plastics Inc. proposed to use this well to dispose the following waste streams of AT Plastics Inc.:

- Filter backwash;
- Boiler blowdown;
- Softener backwash;
- API separator effluent;
- Cooling tower blowdown;
- Treated sanitary sewage; and
- Oily sewer.

No information on volume records of this well was provided. As provided by Application No. 941351, the analyses of wastes of this well from 3 sample points of AT Plastics Inc. are included in Table 4.37.

4.10.2 Recommendation

There is no information on volume records of well AT PLASTICS CHEM IN 14-36-52-24. The analyses of wastes of this well show that it is lowly contaminated. While no volume records are available, the source liquids may be suitable for treatment and reuse as an alternative to injection. However, injection volume records would be required for this well.

Table 4.36. General properties of the wells included in Approval No. 3924.

Approval #	EUB Appl #	Field	Formation	Approval Holder	Scheme type	G 51 type	Well Name	Unique Identifier	Top of Injection Interval Measured Depth (metres KB)	Minimum Packer Setting Depth (metres KB)	Maximum Wellhead Injection Pressure, kPa (gauge)
7842	941351	Edmonton	Nisku	AT Plastics	Disposal	Class Ia	AT PLASTICS CHEM IN 14-36-52-24	00/14-36-052-24W4/0	1284.7	1250.0	4,200

Table 4.37. Analyses of wastes of well AT PLASTICS CHEM IN 14-36-52-24 (mg/L, expect pH).

Parameters	Sample Point # 1: Disposal Well	Sample Point #2: Power House	Sample Point #3: Sanitary Sewer
pH	7	7.2	7.1
TSS	81	63	67
TDS	2838	2640	2430
BOD	126	100	97
TOC	163	142	107
Total Sulfides	3.6	11.3	2.2
Arsenic	0.0014	0.0019	0.0018
Cobalt	0.02	0.016	0.015
Copper	0.02	0.01	0.011
Chromium	0.721	1.17	1.19
Lead	0.01	0.01	0.01
Mercury	0.0001	0.0001	0.0001
Molybdenum	0.148	0.028	0.018
Nickel	0.017	0.008	0.004
Selenium	0.0004	0.0002	0.0002
Vanadium	0.023	0.021	0.021
Zinc	0.424	0.616	0.548

4.11 Approval No. 8133

Approval No. 8133 was issued to Nova Chemical Ltd. on May 21, 1997. It included only one well: AGEC JOFFRE 6-32-038-25W4/0. The general properties of this well are presented in Table 4.38. Time series plots of monthly injection volumes and hourly injection rates of the well are depicted in Figures 4.29 and 4.30, respectively.

4.11.1 AGEC JOFFRE 6-32-038-25W4/0

Applications No. 790267 and 840326 indicate that this well was to be used for disposal of waste from the following sources:

- Approximately 2,400 m^3/month of plant effluent produced in conjunction with construction and operation of the Alberta Gas Ethylene Company Ltd. Joffre Plant.
- Maximum total volume of 192 m^3/day of plant effluent obtained from Alberta Gas Ethylene Company Ltd.'s second ethylene plant at Joffre.

According to actual injection records, the average monthly injection rate of this well was approximately 5,700 m^3/month. This number was calculated from data for the periods 1979 to 1980 inclusive and 2001 to 2004 inclusive. No injection volume was reported between 1981 and 2000. The subject well began operating on August 2, 1979. As shown in Figure 4.29, the monthly injection volumes have not been constant. The highest monthly injection volume of the well was 10,872 m^3 (in February 2004).

Application No. 921492 indicates that the "plant effluent" was a weak caustic stream generated through the process of removing CO_2 from the cracked gas stream produced in ethylene manufacturing plants. As shown in Table 4.39, the caustic well analysis of this stream was provided by Application No. 921492. According to the analysis, the waste stream contained large amounts of VOCs and had a high pH.

4.11.2 Recommendation

The average monthly volume of liquids injected into AGEC JOFFRE 6-32-038-25W4/0 was about 5,700 m^3. This is considered a small to intermediate amount. This well received waste liquid from two sources with characteristics that indicate they are highly contaminated. Given this situation, it may not be economical to pursue an investigation of the potential of the source liquids for treatment and reuse as an alternative to injection.

Table 4.38. General properties of AGEC JOFFRE 6-32-038-25W4/0.

Approval #	EUB Appl #	Field	Formation	Approval Holder	Scheme type	G 51 type	Well Name	Unique Identifier
8133	951632	Joffre	Leduc	Nova Chemical Ltd	Disposal	Class Ia	AGEC JOFFRE 6-32-038-25W4/0	00/06-32-038-25W4/0

Top of Injection Interval Measured Depth (metres KB)	Minimum Packer Setting Depth (metres KB)	Maximum Wellhead Injection Pressure, kPa (gauge)
2,075.0	2,050.0	13,000

Injection Started	Time Series Plot of Monthly Injection Volume	Time Series Plot of Hourly Injection Rate	Average Annual Injection Rate (m^3/yr)	Average Monthly Injection Rate (m^3/month)	Cumulative Injection Amount to Aug, 2004 (m^3)
August 2, 1979	See Figure 4.29	See Figure 4.30	49,400	5,660	346,000

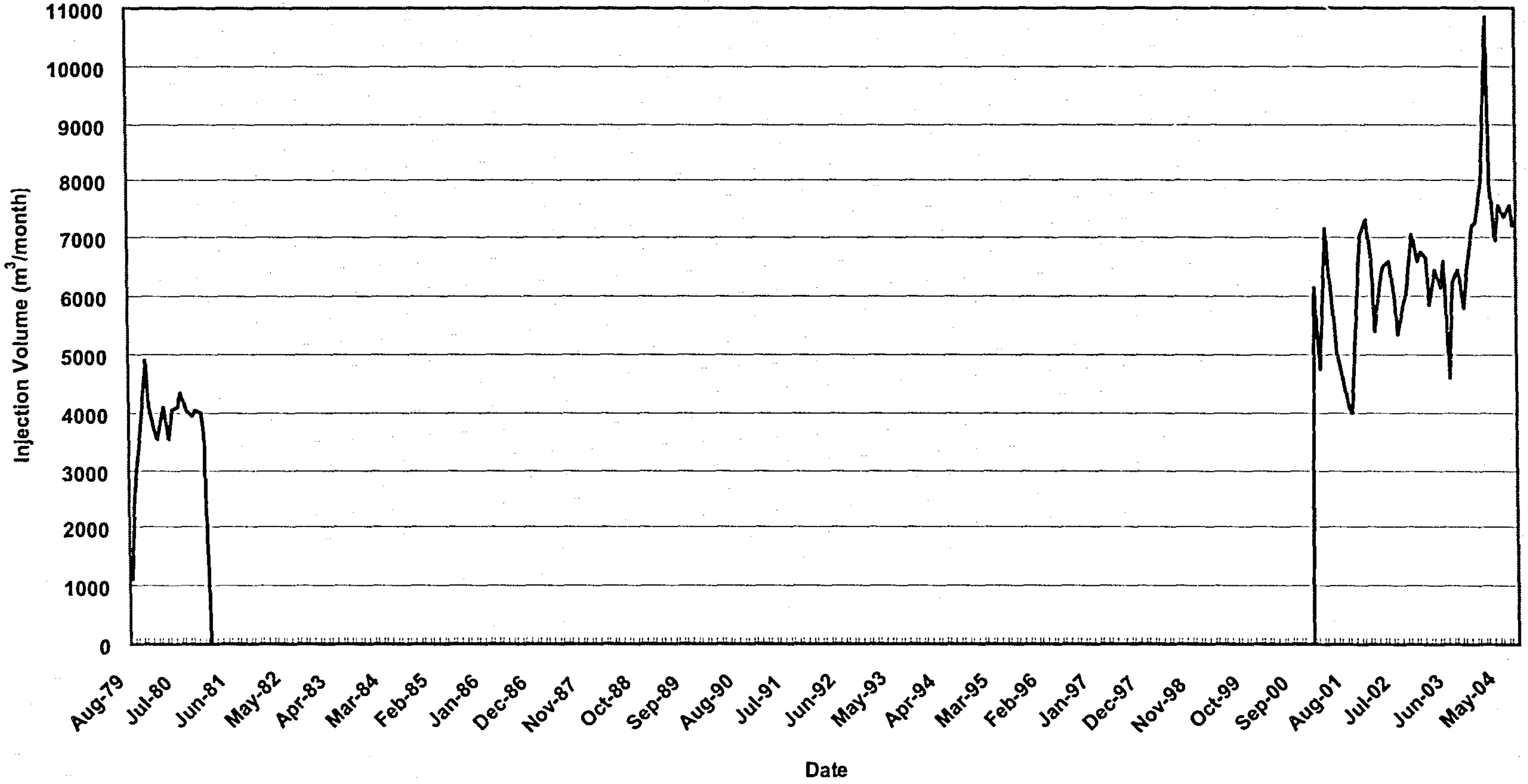

Figure 4.29. Time series plot of monthly injection volume of AGEC JOFFRE 6-32-038-25W4/0.

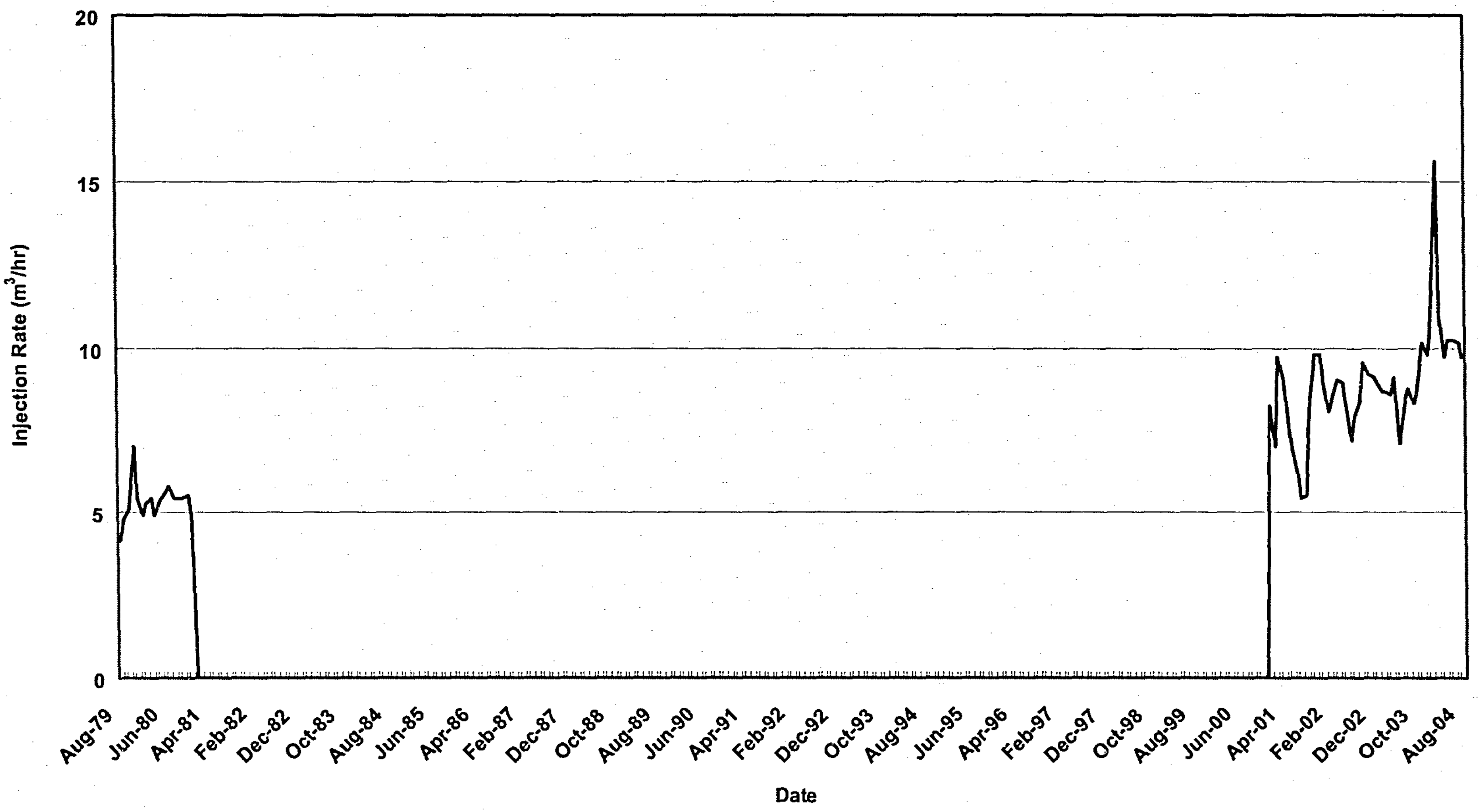

Figure 4.30. Time series plot of hourly injection rate of AGEC JOFFRE 6-32-038-25W4/0.

Table 4.39. Caustic well analysis of headspace.

Headspace Analysis (ppm wt.)	06/11/95	01/06/95	02/22/93	02/01/93	01/04/93	11/25/92	10/27/92	09/25/92	08/17/92	07/22/92	05/04/92
C-1 to C-4's	5.9	55.9	6.36	8.63	0.18	7.17	11.57	4.92	64.4	3.53	36.15
1-4 Pentadiene	0.4	0.2	0.66	<0.01	<0.01	<0.01	<0.01	<0.01	0.47	--	<0.01
Pentene-1	--	2.6	<0.01	0.52	<0.01	1	1.84	0.34	0.22	0.36	1.58
Isoprene	--	1.4	0.07	0.27	<0.01	0.23	0.22	0.11	1.84	0.19	0.78
Cyclopentadiene	7.3	30.4	2.92	3.88	0.05	3.94	9.61	3.63	23.11	2.78	14.75
Cyclopentene	0.3	2.1	0.09	0.37	<0.01	0.71	0.58	0.24	4.47	0.28	1.06
t-Hexene-2	--	0.7	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	2.53	--	0.52
c-Hexene-2	--	0.6	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	2.08	--	0.17
Benzene	136.3	301.2	95.1	91.58	2.57	136.24	262	63	367.8	50.73	194.76
Toluene	10.5	26.1	5.19	5.86	0.15	8.81	10.85	6.12	63.02	5.65	15.34
Eth-Benzene	--	--	--	0.22	<0.01	0.36	--	--	--		
X-Xylene	--	--	--	--	--	--	--	--	--	0.45	
m/p-Xylene	0.4	1.3	<0.01	0.15	<0.01	0.27	0.29	0.42	8.69	--	0.76
o-Xylene			<0.01	<0.01	<0.01	<0.01	0.21	0.36	7.07	0.4	1.09
Styrene	5.3	9.8	2.77	3.33	0.1	3.53	2.33	4.23	38	4.6	9.11
Dicyclopentadiene	3.5	14.1	0.29	0.66	0.07	1.99	1.37	0.74	26.6	1.3	3.36
Indene	--	--	0.19	0.3	0.01	0.15	0.19	1.05	8.01	1.14	0.2
C-10+	--	--	<0.01	--	--	--	--	43.2	--	--	
C-11+	13.6	14.1	--	0.47	0.25	8.46	--	--	--	--	
C-12+	--	--	--	--	--	--	11.4	--	237	10.35	4.51

Table 4.40. Caustic well analysis of TOC, TDS, NaOH, Na_2CO_3 and pH.

Date	06/11/95	01/06/95	02/22/93	02/01/93	01/04/93	11/25/92	10/27/92	09/25/92	08/17/92	07/22/92	05/04/92
Total Hydrocarbon (ppm wt.)	198.2	494.7	118	118.58	3.61	176.88	315.7	131.4	909	85.51	296
TOC ppm	130	330	320	120	185	500	120	42	610	66	232
TDS %wt	0.6	4.3	3.83	10.3	3.8	2.9	2.7	1.31	3.18	2.1	3.3
NaOH %wt	0.3	0.8	1.08	0.4	1.1	1.6	1.26	0.5	1.45	0.6	1.99
Na_2CO_3 %wt	0.53	2.6	2.34	1.8	2.4	2.9	1.11	0.42	1.98	<0.5	1.05
pH	14	14	14	14	14	14	13.8	13.5	14	12.2	13.2

4.12 Approval No. 8185

Approval No. 8185 was issued to Viridian Inc. on August 13, 1997. It included only one well: VIRIDIAN FTSASK 4-10-55-22. The general properties of this well are presented in Table 4.40. Time series plots of monthly injection volumes and hourly injection rates of the well are depicted in Figures 4.31 and 4.32, respectively.

4.12.1 VIRIDIAN FTSASK 4-10-55-22

Application No. 9600991 indicates that the well was to be used for disposal of waste from three sources. Table 4.41 shows the wastewater sources and their injection requirements of VIRIDIAN FTSASK 4-10-55-22.

According to actual injection records, the average monthly injection rate of this well has been approximately 4,580 m^3/month. This number was calculated from data for the period 1997 to 2004 inclusive. The subject well began operating on July 28, 1997. As shown in Figure 4.31, the monthly injection volumes have not been constant. The highest monthly injection volume of the well was 16,500 m^3 (in April 1999).

As provided by Application No. 960991, water analyses for each waste stream are listed in Table 4.42. Each analysis included the following chemical parameters: daily volume, pH, conductivity, total alkalinity, total hardness, total dissolved solids, total iron, total manganese and total suspended solids. The comparison of the waste streams to the Class Ia disposal criteria are shown in Table 4.43. It indicates that the waste streams met criteria for a Class Ia disposal well.

4.12.2 Recommendation

The average monthly volume of liquids injected to VIRIDIAN FTSASK 4-10-55-22 for the period in question was about 4,580 m^3. This is considered a small quantity. The well receives waste liquids from three sources, which includes contaminated groundwater. Given this situation, it is recommended to pursue an investigation of the potential of the source liquids (i.e., the groundwater) for treatment and reuse as an alternative to injection.

Table 4.41. General properties of VIRIDIAN FTSASK 4-10-55-22.

Approval #	EUB Appl #	Field	Formation	Approval Holder	Scheme type	G 51 type	Well Name	Unique Identifier
8185	960991	Fort Saskatchewan	Nisku	Viridian Inc.	Disposal	Class Ia	VIRIDIAN FTSASK 4-10-55-22	00/04-10-055-22W4/0

Top of Injection Interval Measured Depth (metres KB)	Minimum Packer Setting Depth (metres KB)	Maximum Wellhead Injection Pressure, kPa (gauge)
1,045.5	1,025.0	3,950

Injection Started	Time Series Plot of Monthly Injection Volume	Time Series Plot of Hourly Injection Rate	Average Annual Injection Rate (m^3/yr)	Average Monthly Injection Rate (m^3/month)	Cumulative Injection Amount to Aug, 2004 (m^3)
July 28, 1997	See Figure 4.31	See Figure 4.32	49,800	4,580	398,000

Table 4.42. Wastewater sources and injection requirements of VIRIDIAN FTSASK 4-10-55-22.

Wastewater Source	Initial Maximum Daily Injection Requirements (m^3/d)	Long-term Maximum Daily injection Requirements (m^3/d)
Phosphate Pond Inventory	262	-
River Road Wells	262	249
119 Street Wells	-	308
Total	524	655

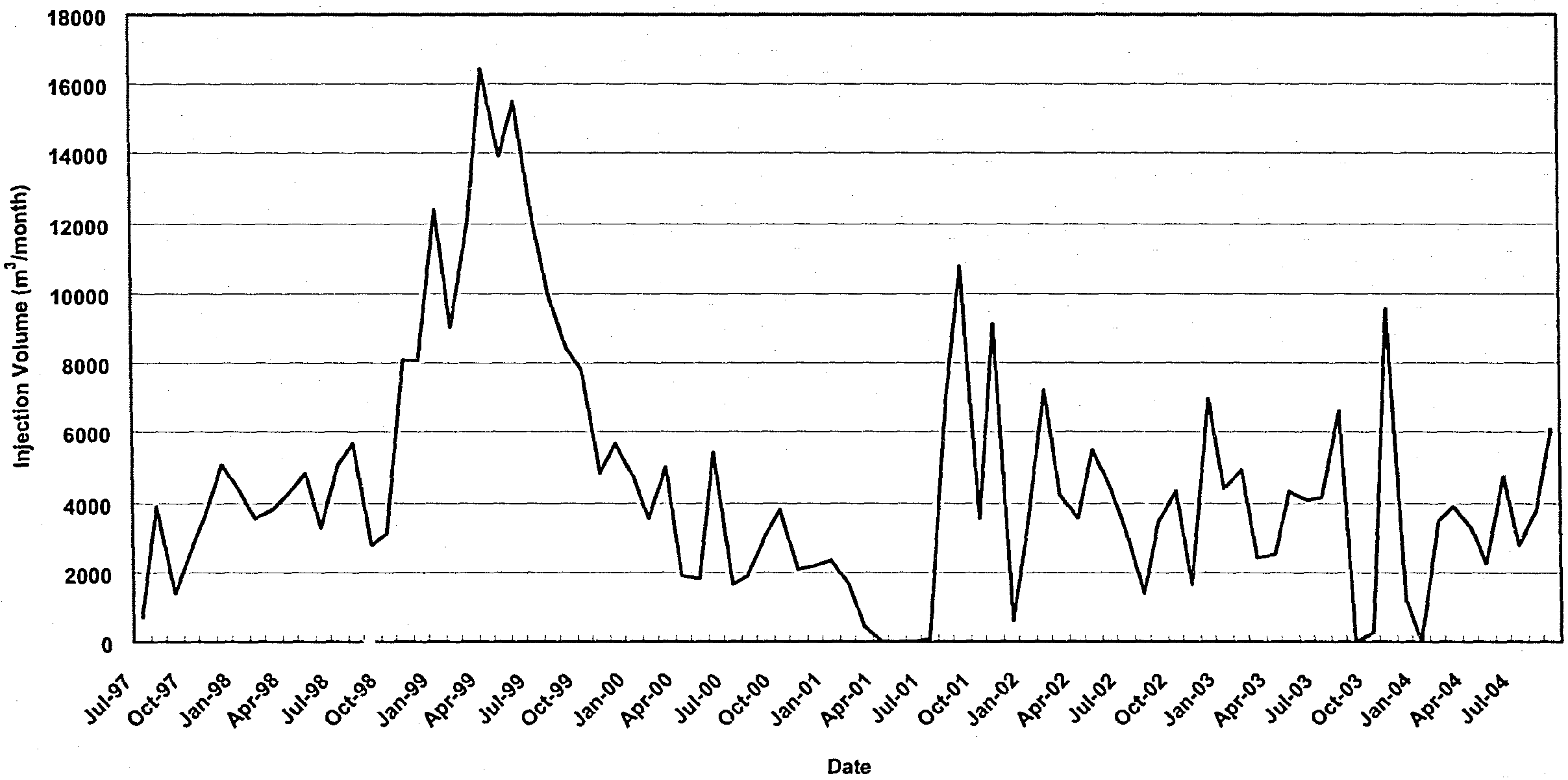

Figure 4.31. Time series plot of monthly injection volume of VIRIDIAN FTSASK 4-10-55-22.

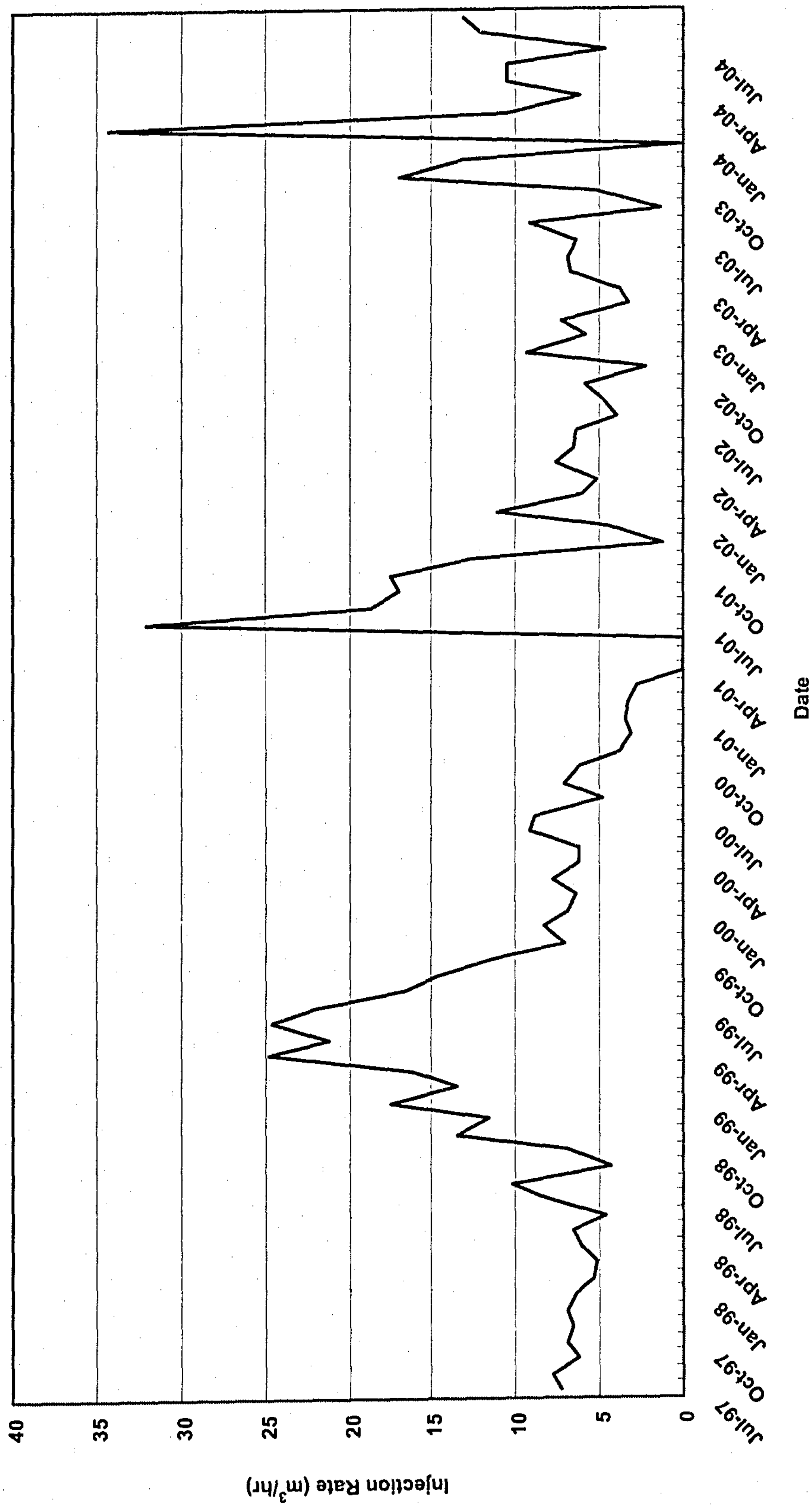

Figure 4.32. Time series plot of hourly injection rate of VIRIDIAN FTSASK 4-10-55-22.

Table 4.43. Water analyses of waste streams disposed to VIRIDIAN FTSASK 4-10-55-22.

Chemical Parameters			Water Streams		
Substance	**Chemical Formula**	**Units**	**Phosphate Pond**	**River Road Water Wells**	**119 Street Water Wells**
Volume	-	m^3/d	98	249	308
pH @ 23 C	-	-	4	7.7	8.45
Conductivity	EC	dS/m	-	-	-
Carbonate	CO_3^{2-}	mg/l	-	-	653
Bicarbonate	HCO_3^-	mg/l	0	6642	16407
Chloride	Cl-	mg/l	504	1093	7167
Sulphate	SO_4^{2-}	mg/l	32000	17000	17000
Calcium	Ca^{2+}	mg/l	338	388	0
Magnesium	Mg^{2+}	mg/l	14	54	0
Sodium	Na^+	mg/l	1240	510	1360
Potassium	K^+	mg/l	245	420	1000
Total Dissolved Solids	TDS	mg/l	344400	25100	43600
Total Iron	Fe	mg/l	-	<0.1	-
Total Maganese	Mn^{2+}	mg/l	-	1.2	-
Total Suspended Solids	TSS	mg/l	6	-	870

Table 4.44. Comparison of the waste streams disposed to VIRIDIAN FTSASK 4-10-55-22 to the Class Ia disposal criteria.

Parameter	Criteria	Phosphate Pond	River Road Water Well	119 Street Water Wells
pH<4.5 or >12.5	Y/N	Y	N	N
Industrial Sewage	Y/N	N	N	N
Contaminated Surface Run-off (unsuitable to discharge to watershed)	Y/N	Y	Y	Y
Lube Oil or Spent Solvent	Y/N	N	N	N
Contains Reactive Anoins (fluoride, hypochlorite, bromate)	Y/N	N	N	N
Non Halogenated Organic Fraction> 10% mass	Y/N	N	N	N
One or more Halogenated Organic Component > 1000 mg/kg	Y/N	N	N	N
Polychlorinated Biphenyl (PCB)>50 mg/kg	Y/N	N	N	N
Treatment Technology Exists	Y/N	N	N	N
Acid or Caustic Solution	Y/N	N	N	N
Heavy Metals Exceed Criteria Concentration	Y/N	N	N	Y
Pesticide Wastewater	Y/N	N	N	N
Herbicide Wastewater	Y/N	N	N	N
Pharmaceutical Wastewater	Y/N	N	N	N
Liquid Tannery Wastewater	Y/N	N	N	N
Phenolic Wastewater	Y/N	N	N	N
Oil Refinery Wastewater	Y/N	N	N	N
Chemical Process Wastewater	Y/N	Y	N	N
Asbestos Slurry	Y/N	N	N	N
Alum & Gypsum Slurry	Y/N	N	N	N
Metal (Heavy & Non) Slurry	Y/N	N	N	N
Spent Photofinishing Solution	Y/N	N	N	N

Table 4.43. Comparison of the waste streams disposed to VIRIDIAN FTSASK 4-10-55-22 to the Class Ia disposal criteria (continued).

Heavy Metal	Schedule I - Heavy Metal Criteria Level	Phosphate Pond Conc.	River Road Water Well Conc.	119 Street Water Wells Conc.
	(mg/kg)	mg/L	mg/L	mg/L
Arsenic	500	0.92	<0.01	0.8
Beryllium	100	0.01	<0.0005	<0.01
Cadmium	100	0.3	<0.0005	<0.01
Chromium	500	0.26	<0.0008	0.084
Lead	500	<0.04	0.003	0.007
Mercury	20	<0.002	<0.002	0.294
Nickel	500	52.6	0.02	0.2
Selenium	200	0.11	<0.003	0.02
Silver	100	<0.02	<0.001	<0.02
Titanium	200	<0.08	<0.004	<0.08
Vanadium	100	<1.0	<1.0	<1.0

4.13 Approval No. 8251

Approval No. 8251 was issued to Imperial Oil Resources Limited on February 12, 1998. It included two wells: IMP REFINERY DISPOSAL IN 9-1-53-24 and IMP REF DISP STRATHCONA 8-1-53-24. The general properties of these wells are presented in Table 4.44. Time series plots of monthly injection volumes and hourly injection rates of these wells are depicted in Figures 4.33 to 4.36.

4.13.1 IMP REFINERY DISPOSAL IN 9-1-53-24

Application No. 7164 indicates that this well is to be used for disposal of liquid wastes from the Strathcona Refinery. The application indicates that the liquid wastes could be from following sources:

- Spent caustic (10M barrels per month)
- Sour phenolic water (170M barrels per month)
- Surface runoff from Restricted Areas (50M barrels per month)
- Sodium fluoride solution (0.4M barrels per month)
- Other sources of liquid waste (0.6M barrels per month)
- Water coalescers
- Water form amine regeneration
- Water from tar neutralization
- Water from the disulphide separator
- Condensed steam from Light Ends operations

According to actual injection records of this well, the average monthly injection rate has been 16,500 m^3/month. This number was calculated from the volume records of 1967, 1976, 1985 and 1989 and the period 2000 to 2001 inclusive. No injection volumes were reported between 1968 and 1975, 1977 and 1984, 1986 and 1988, 1990 and 1999, 2002 and 2004. The subject well began operating on June 22, 1960. However, no volume was reported until 1967.

As shown in Figure 4.33, monthly injection volumes have not been constant. The highest monthly injection volume was 50,526 m^3 (in August 2001). The analysis of wastewater in the subject well as provided by Application No. 951711 is listed in Tables 4.45 and 4.46. According to these tables, the oil, NH_3 and H_2S contents of the wastewater in this well were high, which indicate it is contaminated.

4.13.2 IMP REFINERY DISPOSAL IN 8-1-53-24

Application No. 790087 indicates that, due to the declining disposal capacity of IMP REFINERY DISPOSAL IN 9-1-53-24, an additional disposal well IMP REFINERY DISPOSAL IN 8-1-53-24 was required to maintain disposal capacity of wastewater from Strathcona Refinery. The wastewater injected in the subject well has the same source as IMP REFINERY DISPOSAL IN 8-1-53-24.

According to actual injection records of this well, the average monthly injection rate has been 34,300 m^3 per month. This number was calculated from volume records of 1985 and 1989, and the periods of 1975 to 1976, 1978 to 1979 and 2000 to 2004. No injection volumes were reported in 1977 and between 1980 and 1984, 1986 and 1988, and, 1990 and 1999. The subject well began operating on March 21, 1975.

As shown in Figure 4.34, the monthly injection volumes have not been constant. The highest monthly injection volume was 87,400 m^3 (in November 2002). The analysis of wastewater in the subject well as provided by Application No. 951711 is listed in Tables 4.47 and 4.48. According to these tables, the oil, NH_3 and H_2S content of the wastewater in this well is high.

4.13.3 Recommendation

The average monthly volume of wastewater from Strathcona Refinery for disposal to the two wells is about 50,000 m^3, which is considered a large amount of waste. However, the periods when injection occurs appear to be very irregular. The waste characteristics show that it is highly contaminated. Given this situation, it may not be economical to pursue an investigation of the potential of the source liquids for treatment and reuse as an alternative to injection.

Table 4.45. General properties of the wells included in Approval No. 8251.

Approval #	EUB Appl #	Field	Formation	Approval Holder	Scheme type	G 51 type	Well Name	Unique Identifier
8251	951711/ 960519	Chamberlain	Nisku	Imperial Oil Resources Limited	Disposal	Class Ia	IMP REFINERY DISPOSAL IN 9-1-53-24	00/09-01-053-24W4/0
							IMP REF DISP STRATHCONA 8-1-53-24	00/08-01-053-24W4/0

Well Name	Top of Injection Interval Measured Depth (metres KB)	Minimum Packer Setting Depth (metres KB)	Maximum Wellhead Injection Pressure, kPa (gauge)
IMP REFINERY DISPOSAL IN 9-1-53-24	1,263.4	1,245.0	4,200
IMP REF DISP STRATHCONA 8-1-53-24	1,270.4	1,250.0	4,200

Well Name	Injection Started	Time Series Plot of Monthly Injection Volume	Time Series Plot of Hourly Injection Rate	Average Annual Injection Rate (m^3/yr)	Average Monthly Injection Rate (m^3/month)	Cumulative Injection Amount to Aug, 2004 (m^3)
IMP REFINERY DISPOSAL IN 9-1-53-24	June 22, 1960	See Figure 4.33	See Figure 4.35	176,000	16,500	1,180,000
IMP REF DISP STRATHCONA 8-1-53-24	March 21, 1975	See Figure 4.34	See Figure 4.36	418,000	34,300	432,000

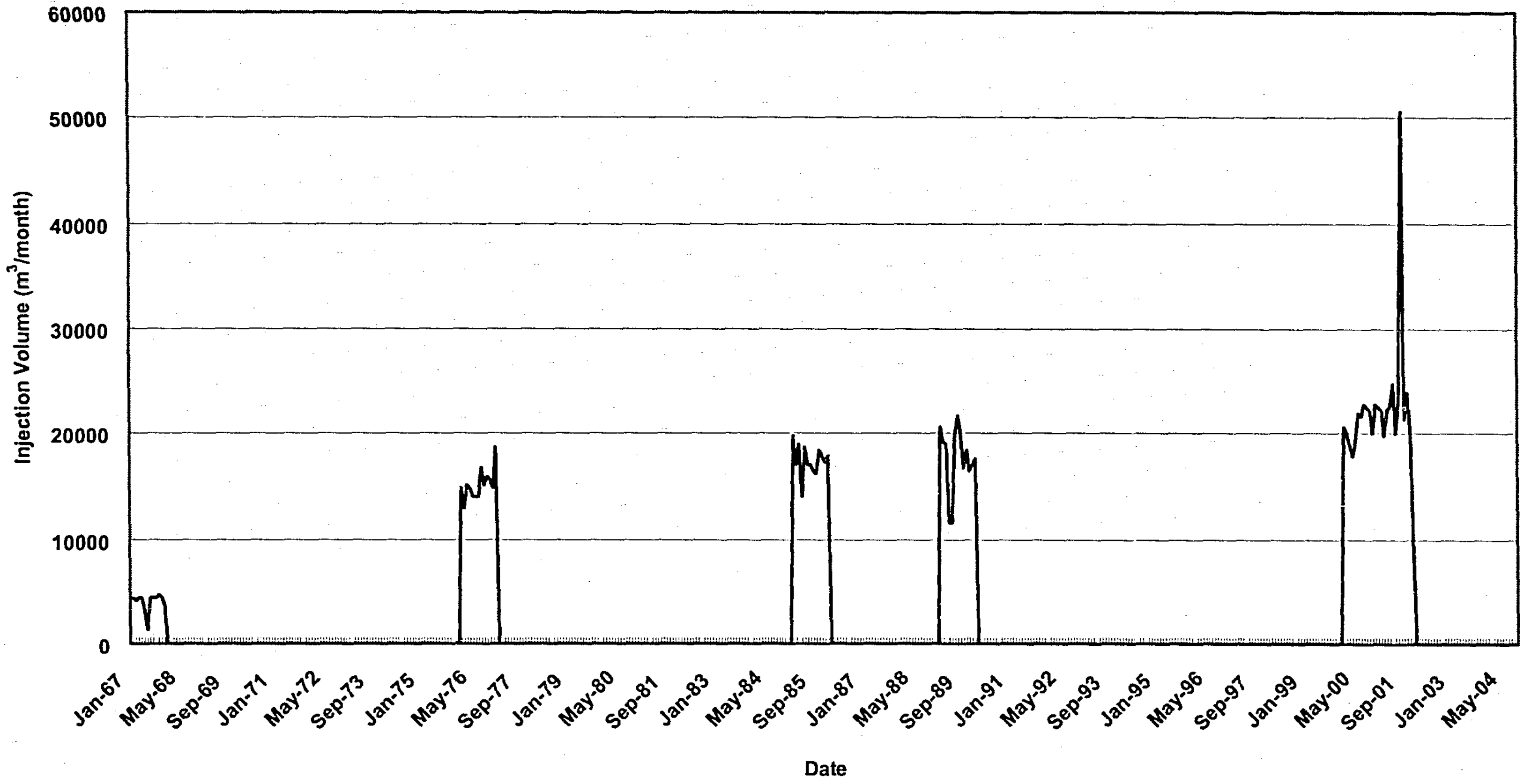

Figure 4.33. Time Series plot of monthly injection volume of IMP REFINERY DISPOSAL IN 9-1-53-24.

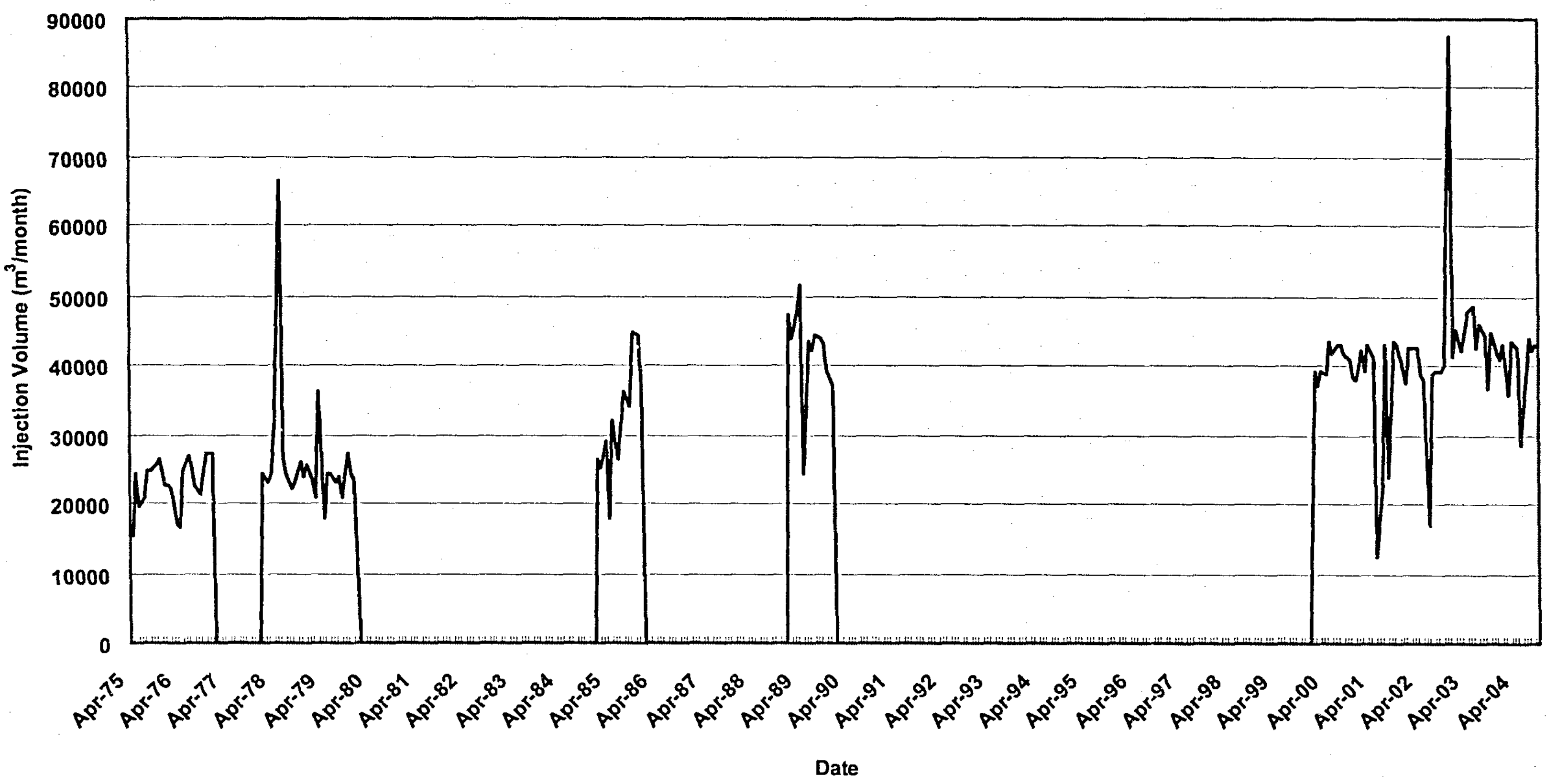

Figure 4.34. Time series plot of monthly injection volume of IMP REF DISP STRATHCONA 8-1-53-24.

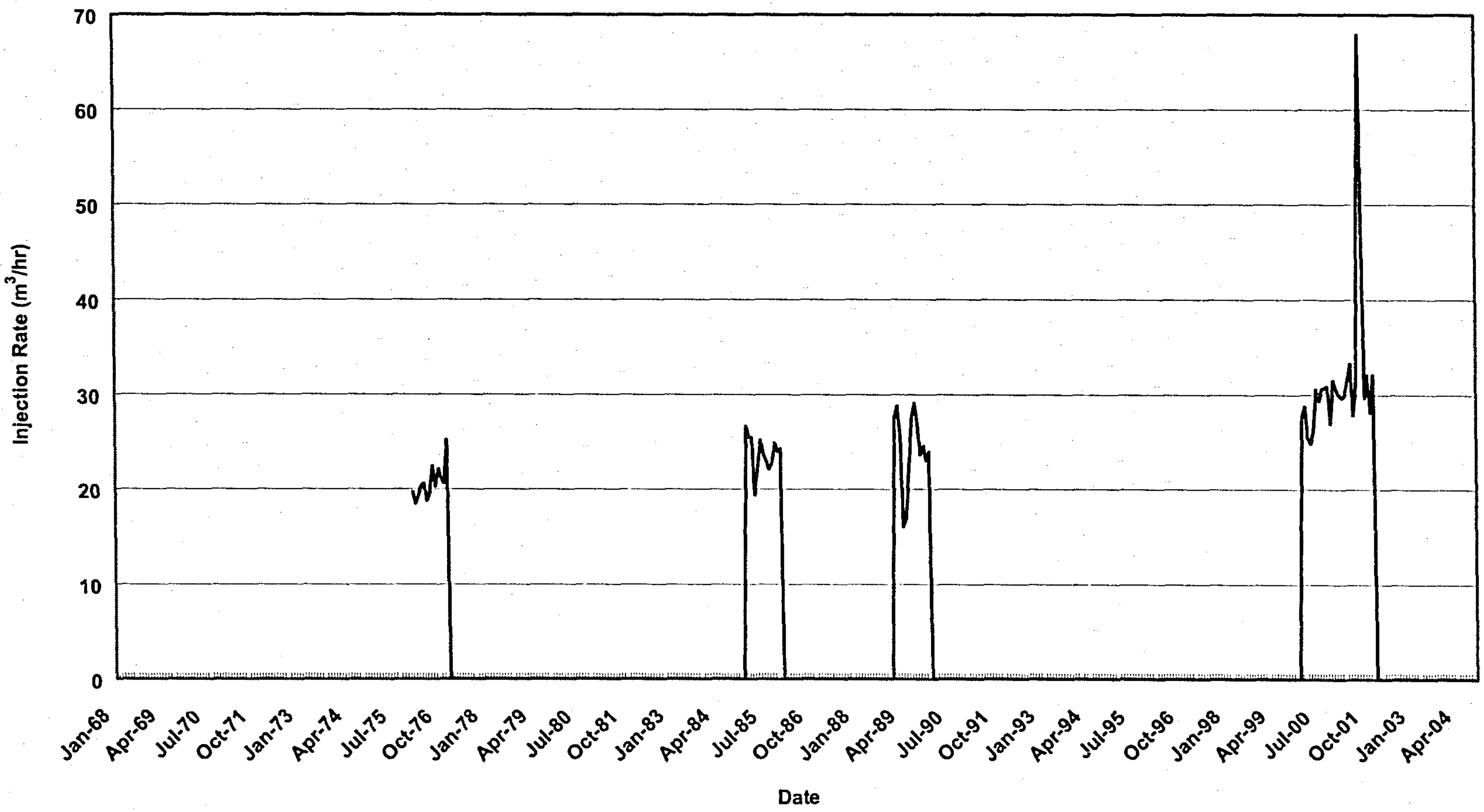

Figure 4.35. Time series plot of hourly injection rate of IMP REFINERY DISPOSAL IN 9-1-53-24.

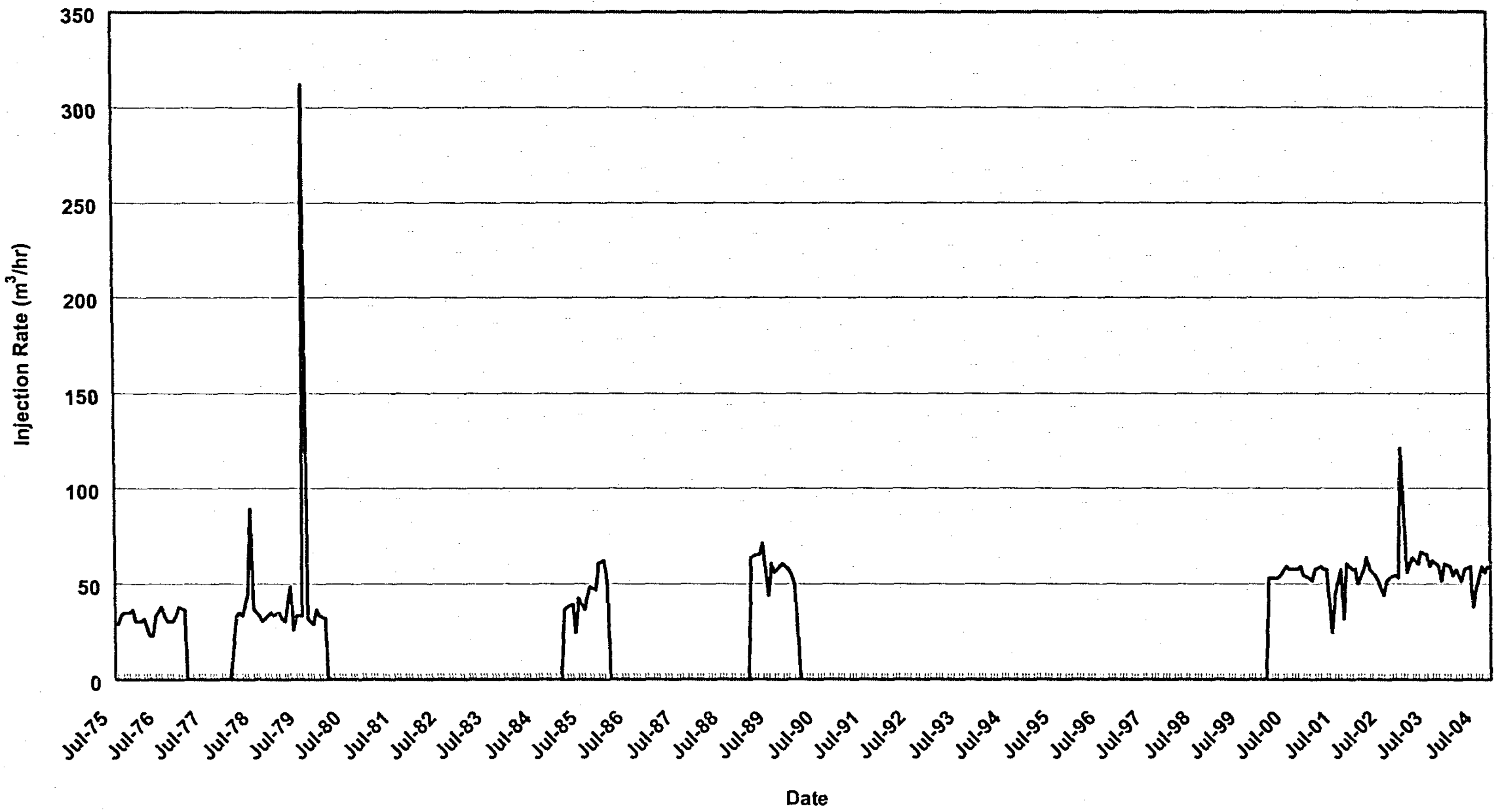

Figure 4.36. Time series plot of hourly injection rate of IMP REF DISP STRATHCONA 8-1-53-24.

Table 4.46. Analysis of wastewater in IMP REFINERY DISPOSAL IN 9-1-53-24.

Date	COD (mg/L)	Solids (mg/L)	Oil (ppm)	NH_3 (mg/L)	H_2S (ppm)	pH
Jan, 1995	-	11.2	2.7	4000.0	8000.0	9.4
Feb, 1995	-	526.4	4.3	3200.0	0.0	9.6
Mar, 1995	-	99.2	109.6	3500.0	220.0	11.3
Apr, 1995	-	4.2	6.5	3500.0	180.0	9.6
May, 1995	-	41.7	31220.0	3000.0	800.0	9.8
Jun, 1995	-	63.0	247.0	2200.0	21000.0	9.6
Jul, 1995	-	28.2	1003.0	2000.0	1200.0	7.1
Aug, 1995	-	80.0	139.5	40000.0	2400.0	-
Sep, 1995	-	58.4	165.1	3000.0	3000.0	9.2
Oct, 1995	-	-	-	-	-	-
Nov, 1995	-	-	-	-	-	-
Dec, 1995	-	-	-	-	-	-
Average	-	99.1	3655.3	7166.6	4088.9	9.5

Table 4.47. Analysis of wastewater in IMP REFINERY DISPOSAL IN 9-1-53-24.

Date	Benzene	Toluene	Ethylbenzene	Xylene
	wt. ppm	wt. ppm	wt. ppm	wt. ppm
1993-11-30	4.0	2.0	1.0	2.0
1995-5-17	5.5	3.7	0.2	1.7
1995-6-8	5.9	2.4	0.4	2.6
1995-7-11	4.9	3.3	0.1	1.2
1995-8-16	0.6	0.3	0.0	0.2
Average	4.2	2.3	0.3	1.6

Table 4.48. Analysis of wastewater in IMP REF DISP STRATHCONA 8-1-53-24.

Date	COD (mg/L)	Solids (mg/L)	Oil (ppm)	NH_3 (mg/L)	H_2S (ppm)	pH
Jan, 1995	-	7.0	10.7	10.0	50.0	8.8
Feb, 1995	-	123.5	20.3	7.0	0.0	8.3
Mar, 1995	-	83.0	44.4	18.0	8.0	7.2
Apr, 1995	S.D.	S.D.	S.D.	S.D.	S.D.	S.D.
May, 1995	-	29.2	111.6	10.0	0.0	8.2
Jun, 1995	-	13.1	32.3	6.0	12.0	8.7
Jul, 1995	-	52.0	1003.0	300.0	3000.0	9.1
Aug, 1995	-	130.9	187.8	3000.0	187.8	6.9
Sep, 1995	-	200.9	123.0	300.0	1.0	7.1
Oct, 1995	-	-	-	-	-	-
Nov, 1995	-	-	-	-	-	-
Dec, 1995	-	-	-	-	-	-
Average	-	79.8	191.6	456.4	407.4	8.0

Table 4.49. Analysis of wastewater in IMP REF DISP STRATHCONA 8-1-53-24.

Date	Benzene	Toluene	Ethylbenzene	Xylene
	wt. ppm	wt. ppm	wt. ppm	wt. ppm
1993-11-30	12.0	9.0	1.0	5.0
1995-5-17	1.1	1.2	0.3	2.4
1995-6-8	17.4	12.3	1.3	7.0
1995-7-11	1.4	1.0	0.1	0.1
1995-8-16	0.8	1.0	0.1	0.7
Average	6.5	4.9	0.6	3.0

4.14 Approval No. 8317

Approval No. 8317 was issued to Dow Chemical Canada on May 21, 1988. It included 3 wells, which are DOW 3 FTSASK NACL 10-10-55-22, DOW 4 FTSASK NACL 7-10-55-22 and DOW 5 FTSASK NACL 15-10-055-22. The general properties of these wells are presented in Table 4.49. The time series plots of monthly injection volumes and hourly injection rates are depicted in Figures 4.37 to 4.39 and Figures 4.40 to 4.42, respectively.

4.14.1 DOW 3 FTSASK NACL 10-10-55-22 and DOW 4 FTSASK NACL 7-10-55-22

Applications No. 8513 and 770952 indicate that these two wells completed in the Nisku Formation were to be utilized for disposal of water produced in conjunction with the construction of brine caverns of the Dow Chemical Plant. It was indicated by Application No. 800905 that approximately 47,696 m^3/month of produced water was proposed to be disposed to the two wells. According to actual injection records, the amount of waste fluid disposed to the two wells has been approximately 57,100 m^3 per month.

According to actual injection records of DOW 3 FTSASK NACL 10-10-55-22, the average monthly injection rate of this well has been 26,800 m^3/month. This number was calculated from data for the period 1977 to 2004 inclusive. The subject well began operating on April 24, 1975. However, no volume was reported until 1977. As shown in Figure 4.37, the peak monthly injection volumes were approximately 60,000 m^3 during June 1979, July 1982, August 1982 and August 1986.

According to actual injection records of DOW 4 FTSASK NACL 7-10-55-22, the average monthly injection rate of this well was 30,500 m^3/month. This number was calculated from data for the period 1977 to 2004 inclusive. The subject well began operating on November 5, 1977. As shown in Figure 4.38, the highest monthly injection volume of DOW 4 FTSASK NACL 7-10-55-22 was 94,500 m^3, in June 1980.

As provided by Application 950195, the results of analysis of water produced in conjunction with the construction of brine caverns of the Dow Chemical Plant are shown in Table 4.50. The analysis included the following parameters: hypochlorite, pH, dissolved solids, TOC and suspended solids.

4.14.2 DOW 5 FTSASK NACL 15-10-055-22

Application No. 910408 indicates that this well was added to supplement the above two wells. It is used for disposal of plant waste fluids produced from the operation of the Dow Chemical Plant.

According to actual injection records of DOW 5 FTSASK NACL 15-10-055-22, the average monthly injection rate of this well was 14,100 m^3/month. This number was calculated from data for the period 1991 to 2004 inclusive. This well began operating on December 9, 1991. As shown in Figure 4.39, monthly injection volumes have not been constant. The highest monthly injection volume was 84,200 m^3, in October 1997.

As provided by Application No. 950195, the results of analysis of plant waste fluids produced from the operation of Dow Chemical Plant are shown in Table 5.51. The analysis included the following parameters: hypochlorite, pH, dissolved solids, TOC and suspended solids.

4.14.3 Recommendation

The average monthly volume of wastewater from Dow Chemical Plant injected into the three wells was about 70,000 m^3. This is considered a large amount. Characteristics of the wastes indicate that they contain very high dissolved solids (associated with construction of brine caverns). Given these conditions, it is recommended that the source liquids in question are not practical for treatment and reuse as an alternative to injection.

Table 4.50. General properties of the wells included in Approval No. 8317.

Approval #	EUB Appl #	Field	Formation	Approval Holder	Scheme type	G 51 type	Well Name	Unique Identifier
8317	881087	Fort Saskatchewan	Nisku	Dow Chemical Canada	Disposal	Class Ia	DOW 3 FTSASK NACL 10-10-55-22	03/10-10-055-22W4/2
							DOW 4 FTSASK NACL 7-10-55-22	02/07-10-055-22W4/2
							DOW 5 FTSASK NACL 15-10-055-22	00/15-10-055-22W4/2

Well Name	Top of Injection Interval Measured Depth (metres KB)	Minimum Packer Setting Depth (metres KB)	Maximum Wellhead Injection Pressure, kPa (gauge)
DOW 3 FTSASK NACL 10-10-55-22	1,042.0	1,022.0	4,000
DOW 4 FTSASK NACL 7-10-55-22	1,040.6	1,020.0	4,000
DOW 5 FTSASK NACL 15-10-055-22	1,033.9	1,013.0	4,000

Well Name	Injection Started	Time Series Plot of Monthly Injection Volume	Time Series Plot of Hourly Injection Rate	Average Annual Injection Rate (m^3/yr)	Average Monthly Injection Rate (m^3/month)	Cumulative Injection Amount to Sep, 2004 (m^3)
DOW 3 FTSASK NACL 10-10-55-22	April 24, 1975	See Figure 4.37	See Figure 4.40	329,000	26,800	8,750,000
DOW 4 FTSASK NACL 7-10-55-22	November 5, 1977	See Figure 4.38	See Figure 4.41	379,000	30,500	9,790,000
DOW 5 FTSASK NACL 15-10-055-22	December 9, 1991	See Figure 4.39	See Figure 4.42	168,000	14,100	2,170,000

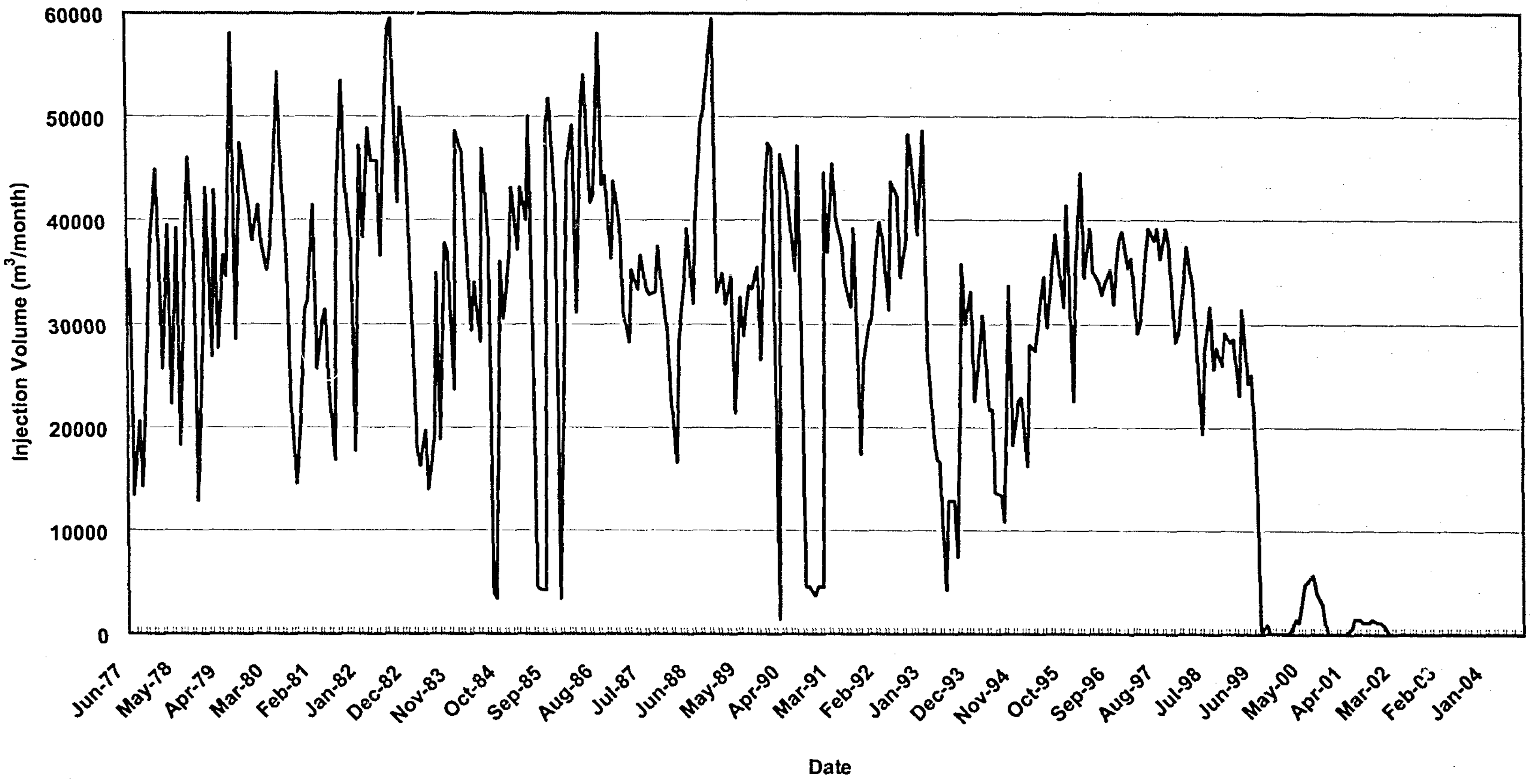

Figure 4.37. Time series plot of monthly injection volume of DOW 3 FTSASK NACL 10-10-55-22.

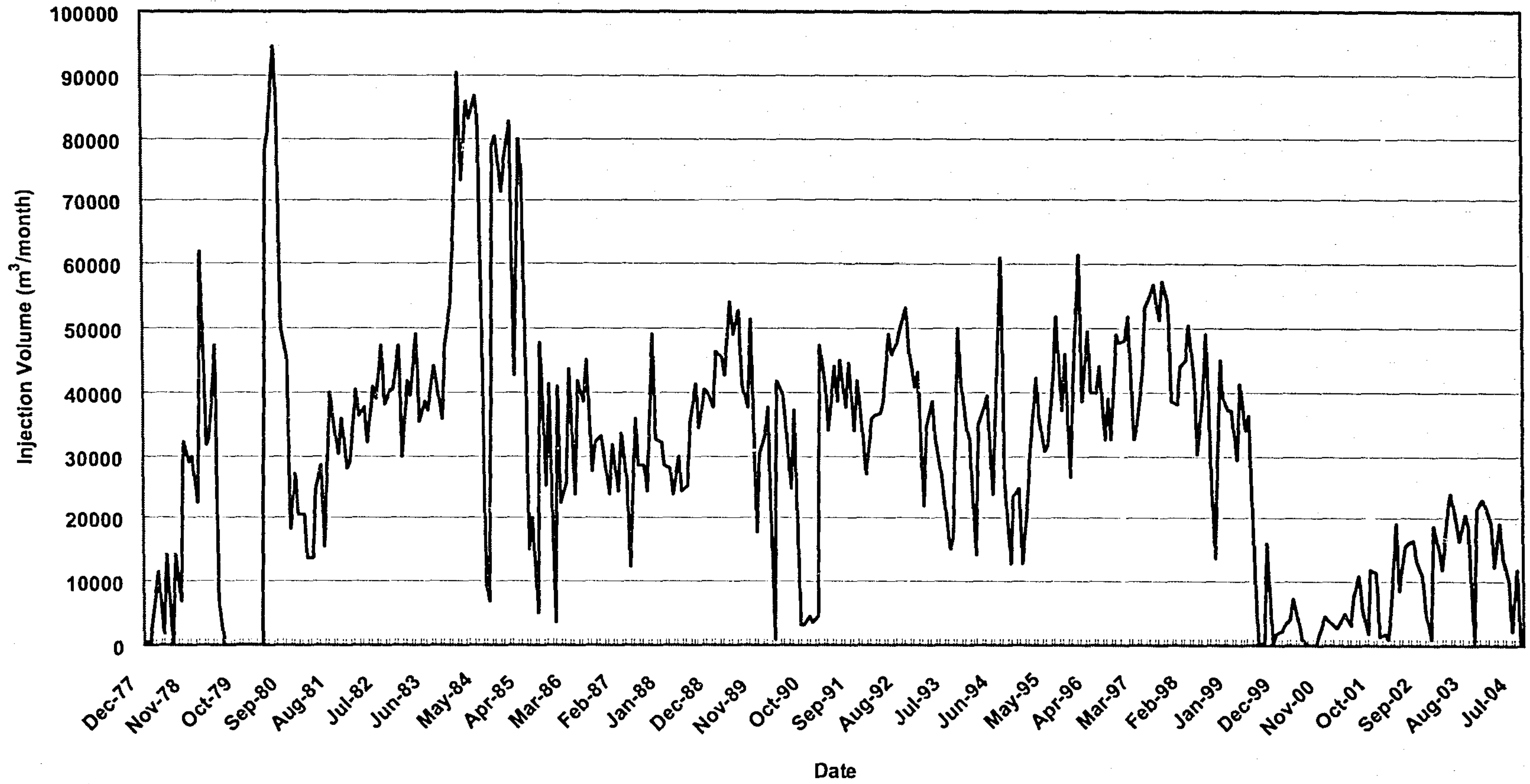

Figure 4.38. Time series plot of monthly injection volume of DOW 4 FTSASK NACL 7-10-55-22.

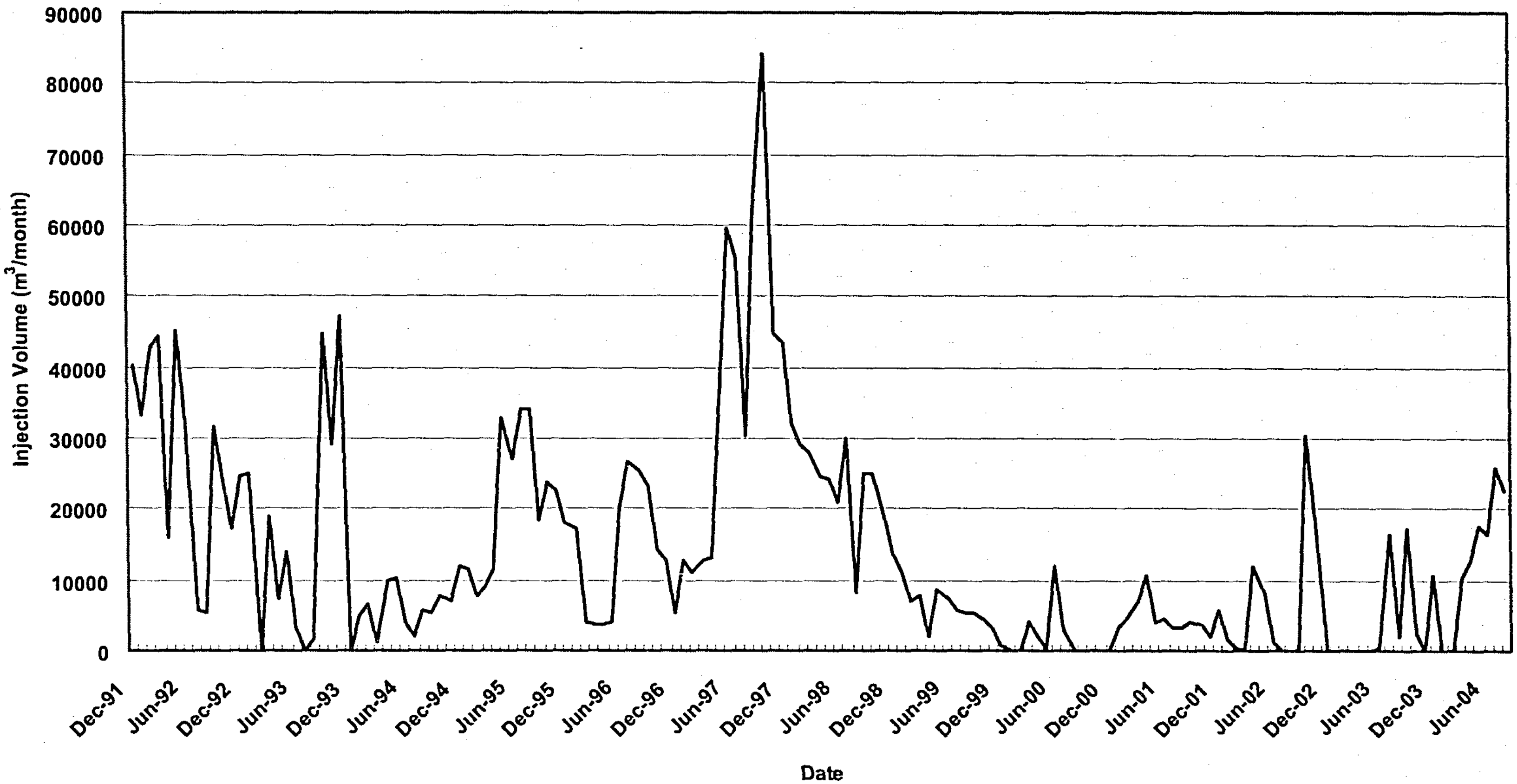

Figure 4.39. Time series plot of monthly injection volume of DOW 5 FTSASK NACL 15-10-055-22.

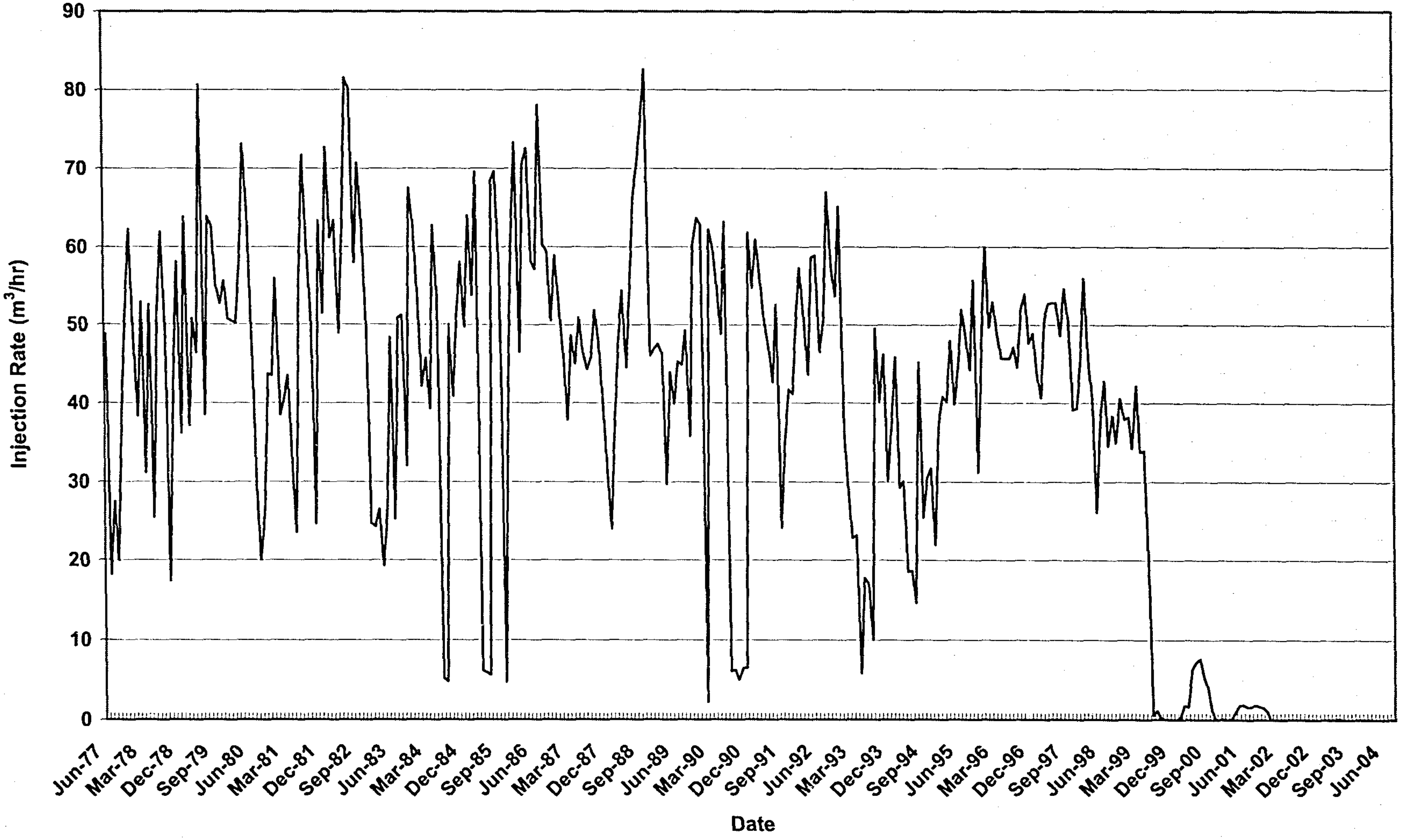

Figure 4.40. Time series plot of hourly injection rate of DOW 3 FTSASK NACL 10-10-55-22.

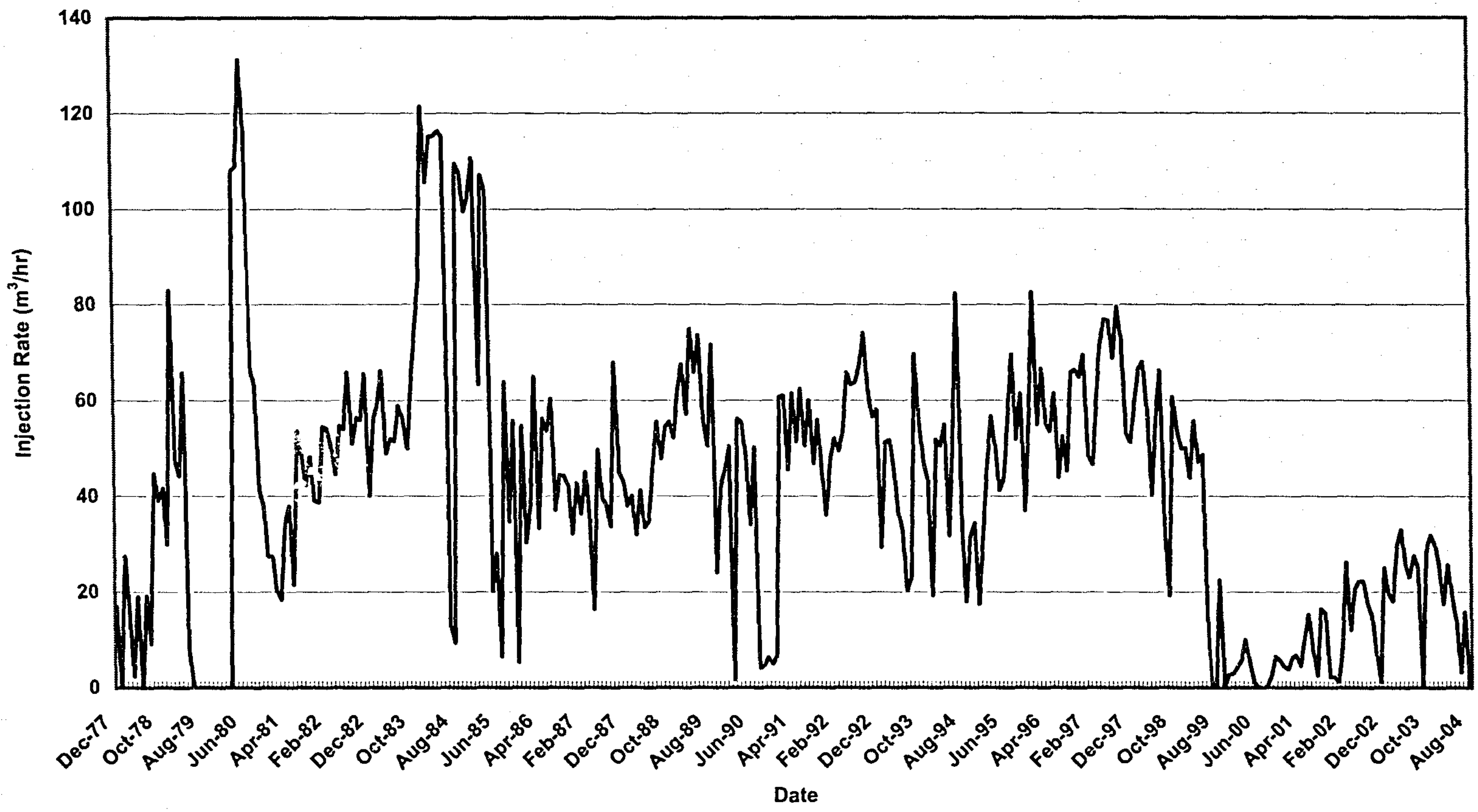

Figure 4.41. Time series plot of hourly injection rate of DOW 4 FTSASK NACL 7-10-55-22.

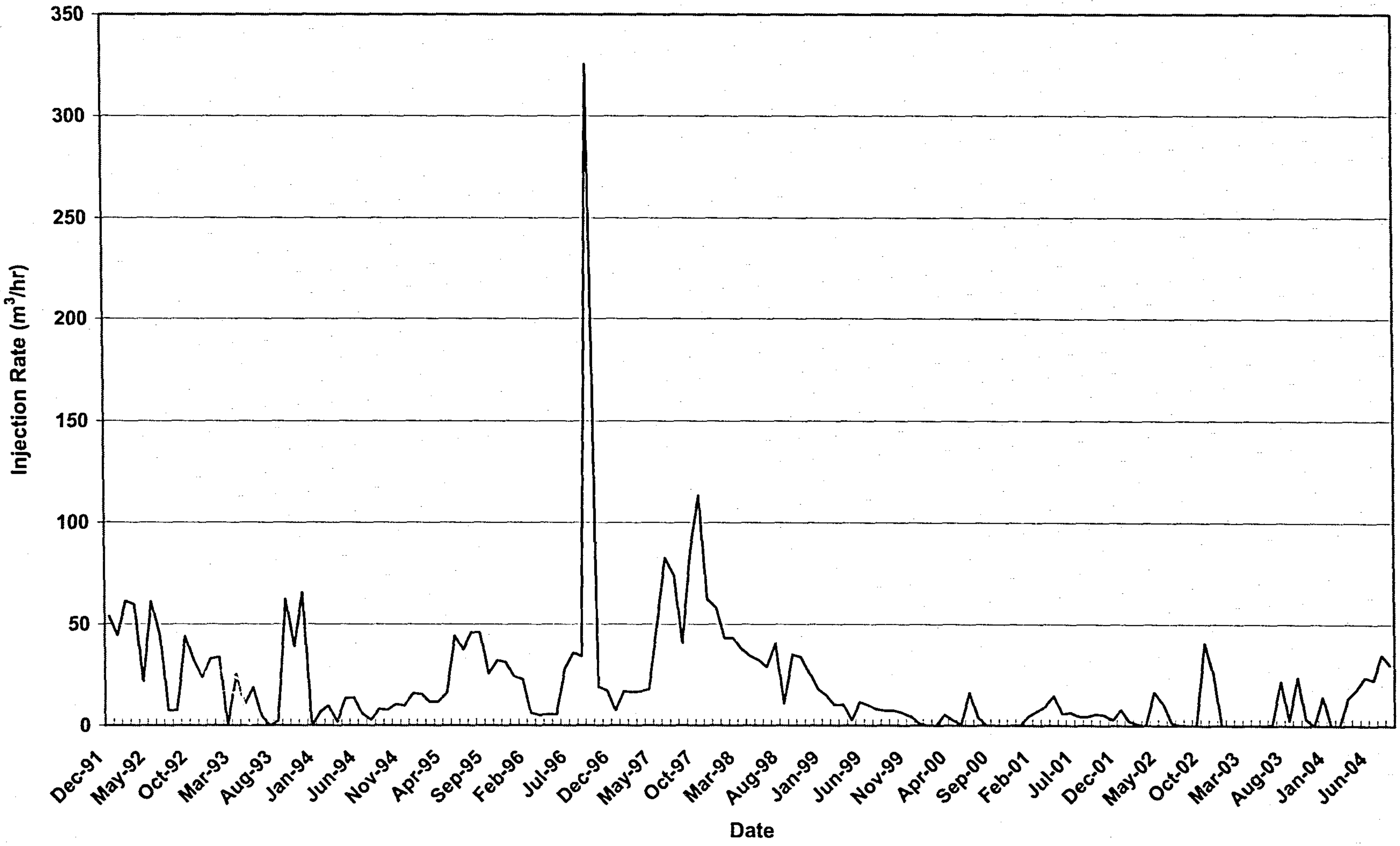

Figure 4.42. Time series plot of hourly injection rate of DOW 5 FTSASK NACL 15-10-055-22.

Table 4.51. Analysis of water produced in conjunction with the construction of Brine Caverns of Dow Chemical Plant.

Item	High	Low	Ave
Hypochlorite (mg/L)	N/D	N/D	N/D
pH	13.3	9.1	12.6
Dissolved solids (g/L)	273	58.2	169.5
TOC (mg/L)	50.5	N/D	20.8
Suspended solids (mg/L)	156	24	94.5

Table 4.52. Analysis of plant waste fluids from Dow Chemical Plant.

Item	High	Low	Ave
Hypochlorite (mg/L)	N/D	N/D	N/D
pH	12.8	8	10.2
Dissolved solids (g/L)	290.4	102	256.8
TOC (mg/L)	42.5	N/D	28.1
Suspended solids (mg/L)	245	31	98.8

4.15 Approval No. 8713

Approval No. 8713 was issued to Area 1 Reclaiming Ltd. on March 22, 2001. It included only one well: AIR B7-4 REDW IN 7-4-57-21. The general properties of the well are presented in Table 4.52. Time series plots of monthly injection volumes and hourly injection rates of the well are depicted in Figures 4.43 and 4.44, respectively.

4.15.1 AIR B7-4 REDW IN 7-4-57-21

As indicated by Application No. 910585, the well is used for disposal of water produced in conjunction with oil and gas from the Redwater Field and industrial waste liquids. Application No. 910585 indicates that the specific oilfield waste liquids were from following streams:

- Acid water (must be neutralized)
- KCL water
- Caustic water (must be neutralized)
- Cement water (no solids)
- Boiler blowdown water
- $CaCl_2$ water
- Fresh water produced in conjunction with spill clean-up or oilfield vessel washing

Approval No. 6909 indicates that the industrial waste liquids were from following sources:

- Wastewater generated from Dupont Canada Inc. Hydrogen Peroxide Plant located near Gibbons, Alberta.
- Sulphide-contaminated wastewater (mixed with less than 100 ppm BTEX components) generated from stripping of sulphides that pass through the caustic scrubber at Alberta Environfuels Inc.'s Edmonton facility. The expected volume was 250 m^3 per month.

According to actual injection records, the average monthly injection rate was 10,700 m^3 per month. This number was calculated from volume records between 1986 and 1988, and the periods of 1980 to 1984 and 1990 to 2004 inclusive. As shown in actual injection records, the well was suspended in 1985, 1987 and 1989. The subject well began operating on March 16, 1980. As shown in Figure 4.43, monthly injection volumes have not been constant. The highest monthly injection volume was 51,100 m^3, in April 1980.

Analysis of wastewater generated from Dupont Canada as provided by Application No. 920251 on the microfiche was difficult to read. The microfiche indicates that several parameters, including BOD, TSS, pH, ammonia nitrogen, total phosphorous, DOC, TOC, TKN, organic nitrogen, COD and oxidizers, were analyzed but actual quantities and concentrations were unreadable. An up-to-date detailed chemical analysis of the refinery waste would be useful in this case. As provided by Application No. 920819, the typical composition ranges of sulphide-contaminated wastewater are presented in Table 4.53.

4.15.2 Recommendation

The average monthly volume of liquids injected to AIR B7-4 REDW IN 7-4-57-21 has been about 10,700 m^3. This is considered a large amount. The well receives produced wastewater from many sources and industrial waste liquids from two sources. The actual injection volumes of the two industrial wastes injected into the well are unknown.

There is insufficient information on the chemical characteristics of the individual sources to determine their potential for treatment and reuse. Given this situation, the following is recommended in order to better assess the potential of the source liquids for treatment and reuse as an alternative to injection:

- An up-to-date chemical analysis of wastewater generated from Dupont Canada should be provided, as virtually no historical data exist on the type and amounts of chemicals parameters.
- The actual injection volumes of the two industrial waste liquids should be provided, as the amounts liquids of these two sources injected into the well are virtually unknown.

Table 4.53. General properties of AIR B7-4 REDW IN 7-4-57-21.

Approval #	EUB Appl #	Field	Formation	Approval Holder	Scheme type	G 51 type	Well Name	Unique Identifier
8713	1338131	Redwater	D-3	Area 1 Reclaiming Ltd.	Disposal	Class Ia	AIR B7-4 REDW IN 7-4-57-21	00/07-04-057-21W4/0

Top of Injection Interval Measured Depth (metres KB)	Minimum Packer Setting Depth (metres KB)	Maximum Wellhead Injection Pressure, kPa (gauge)
1,015.0	992.0	3,950

Injection Started	Time Series Plot of Monthly Injection Volume	Time Series Plot of Hourly Injection Rate	Average Annual Injection Rate (m^3/yr)	Average Monthly Injection Rate (m^3/month)	Cumulative Injection Amount to Aug, 2004 (m^3)
March 16, 1980	See Figure 4.43	See Figure 4.44	95,500	10,700	2,350,000

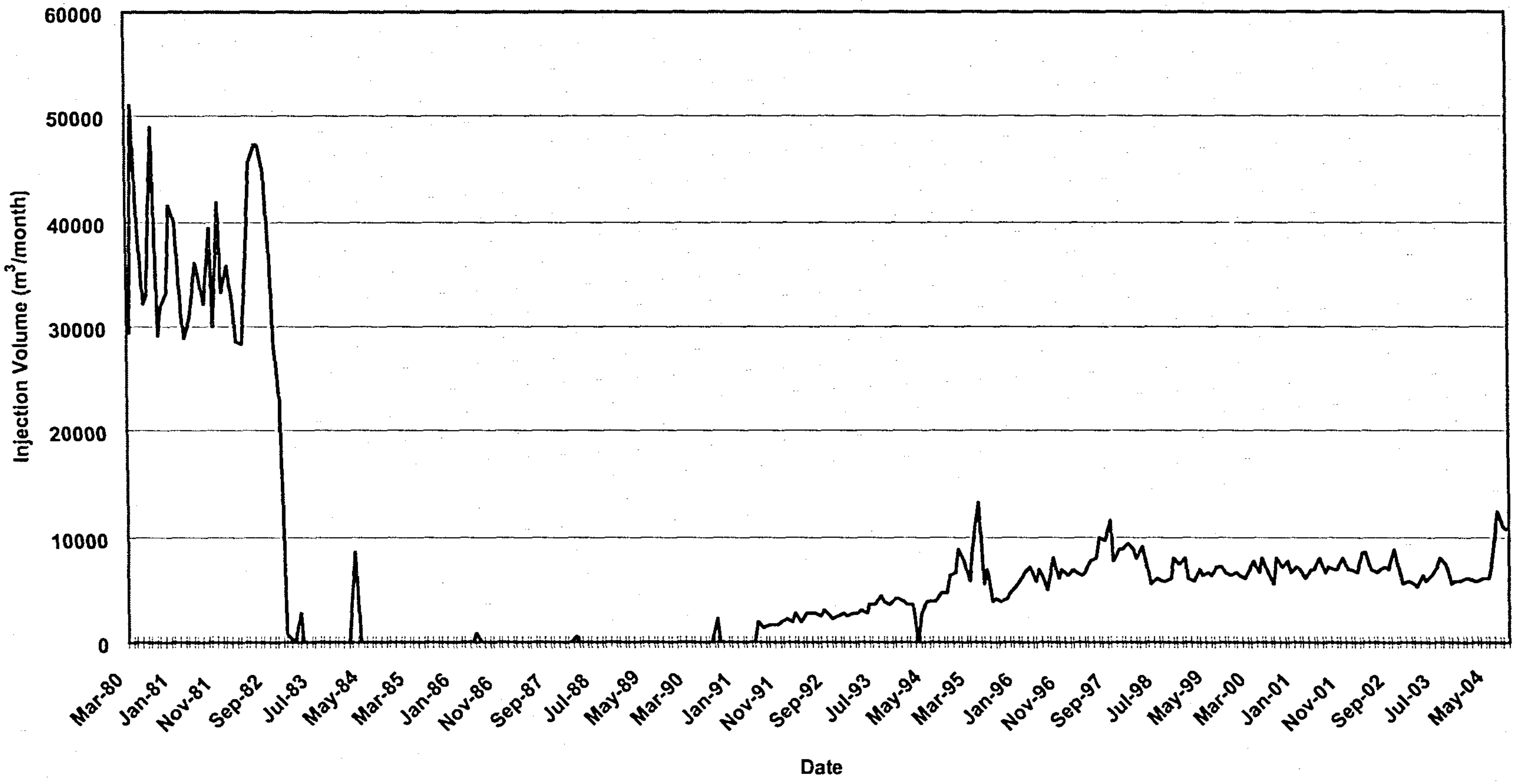

Figure 4.43. Time series plot of monthly injection volume of AIR B7-4 REDW IN 7-4-57-21.

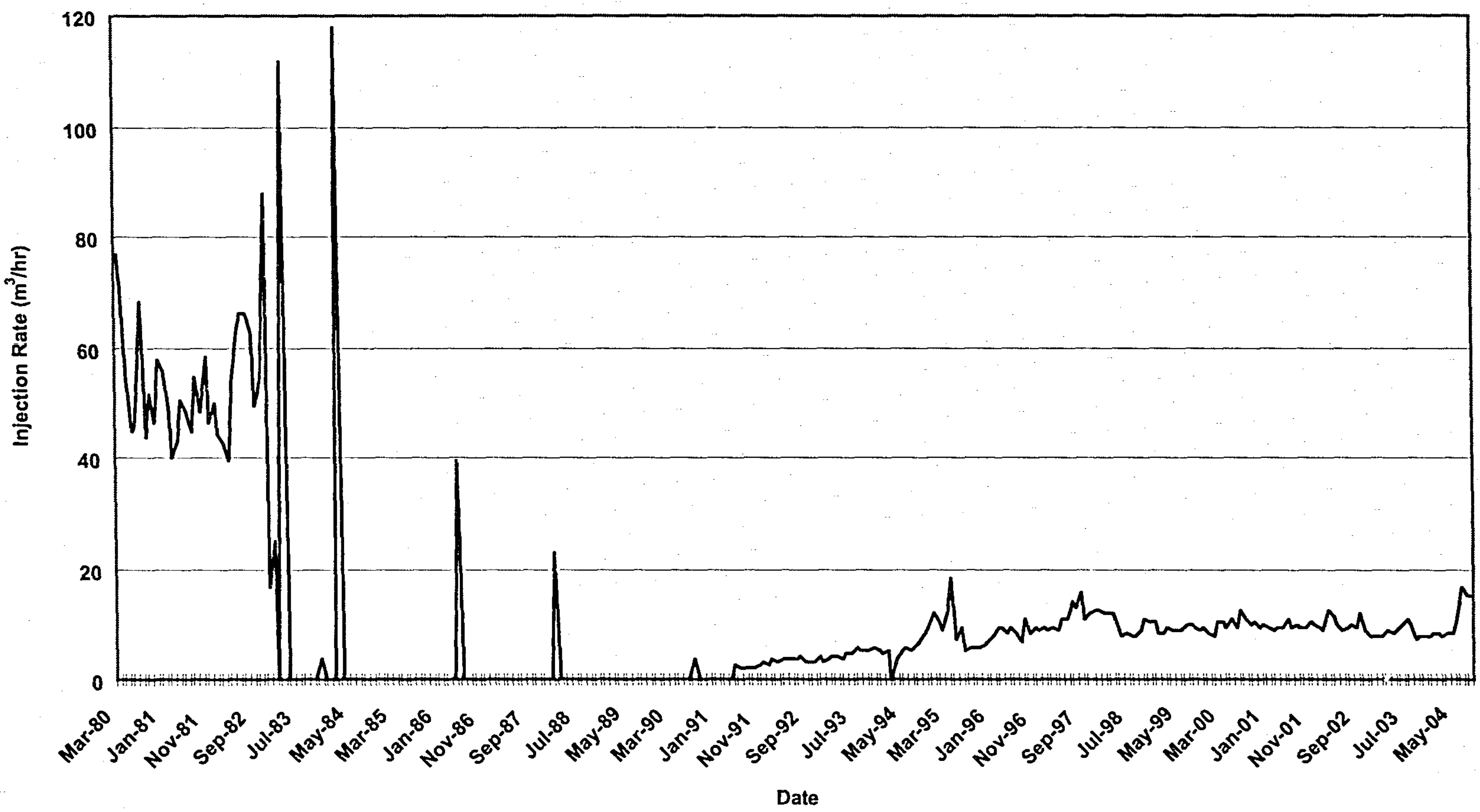

Figure 4.44. Time series plot of hourly injection rate of AIR B7-4 REDW IN 7-4-57-21.

Table 4.54. Typical composition range of sulphide-contaminated waste.

Parameter	Range
pH	>12
Caustic strength	1-15%
Sulphide content	1-10%
Flash point	>61°C

4.16 Approval No. 8784

Approval No. 8784 was issued to Petro-Canada on June 7, 2001. It included two wells: PCI REFINERY DISP EDMT 9-5-53-23 and PCI REFINERY DISP EDMT 15-5-53-23. The general properties of these wells are presented in Table 4.54. Time series plots of monthly injection volumes and hourly injection rates of these wells are depicted in Figures 4.45 to 4.48.

4.16.1 PCI REFINERY DISP EDMT 9-5-53-23

Application No. 851081 indicates this well was to be used for disposal of refinery wastes from the Gulf Edmonton Refinery. According to actual injection records, the average monthly injection rate of this well has been 49,200 m^3/month. This number was calculated from volume records of 1989 and the period 2001 to 2004 inclusive. No injection volumes were reported between 1990 and 2001. The subject well began operating on March 16, 1981.

As shown in Figure 4.45, monthly injection volumes have not been constant. The highest monthly injection volume of this well was 61,800 m^3, in March 2004. The results of analyses of waste injected into the well are presented in Table 4.55.

4.16.2 PCI REFINERY DISP EDMT 15-5-53-23

Application No. 800983 indicates that this well was to be used for disposal of 20,000 m^3/month of de-salted waste and also as a stand-by disposal well in case of difficulties at the PCI REFINERY DISP EDMT 9-5-53-23.

According to actual injection records, the average monthly injection rate of this well was 28,200 m^3/month. This number was calculated from volume records of 1989 and for the period 2001 to 2004 inclusive. No injection volumes were reported between 1990 and 2001. The subject well began operating on March 16, 1981.

As shown in Figure 4.46, monthly injection volumes have not been constant. The highest monthly injection volume of this well was 50,200 m^3, in December 2003. The results of analyses of the waste injected into the well are presented in Table 4.56.

4.16.3 Recommendation

The average monthly volumes of wastewater disposed to PCI REFINERY DISP EDMT 9-5-53-23 and PCI REFINERY DISP EDMT 15-5-53-23 were about 50,000 m^3 and 30,000 m^3, respectively. This is considered a large amount of liquid. Although original waste characteristics indicate the liquids are highly contaminated, these data date back over 20 years. It is recommended that an up-to-date chemical analysis of source liquids should be provided.

Table 4.55. General properties of the wells included in Approval No. 8784.

Approval	EUB Appl #	Field	Formation	Approval Holder	Scheme type	G 51 type	Well Name	Unique Identifier
8784	881087	Chamberlain	Nisku	Petro-Canada	Disposal	Class Ia	PCI REFINERY DISP EDMT 9-5-53-23	00/09-05-053-23W4/0
							PCI REFINERY DISP EDMT 15-5-53-23	00/15-05-053-23W4/0

Well Name	Top of Injection Interval Measured Depth (metres KB)	Minimum Packer Setting Depth (metres KB)	Maximum Wellhead Injection Pressure, kPa (gauge)
PCI REFINERY DISP EDMT 9-5-53-23	1,255.8	1,235.0	4,250
PCI REFINERY DISP EDMT 15-5-53-23	1,234.3	1,219.3	4,250

Well Name	Injection Started	Time Series Plot of Monthly Injection Volume	Time Series Plot of Hourly Injection Rate	Average Annual Injection Rate (m^3/yr)	Average Monthly Injection Rate (m^3/month)	Cumulative Injection Amount to Aug, 2004 (m^3)
PCI REFINERY DISP EDMT 9-5-53-23	March 16, 1981	See Figure 4.45	See Figure 4.47	590,000	49,200	2,160,000
PCI REFINERY DISP EDMT 15-5-53-23	March 16, 1981	See Figure 4.46	See Figure 4.48	205,000	28,200	1,240,000

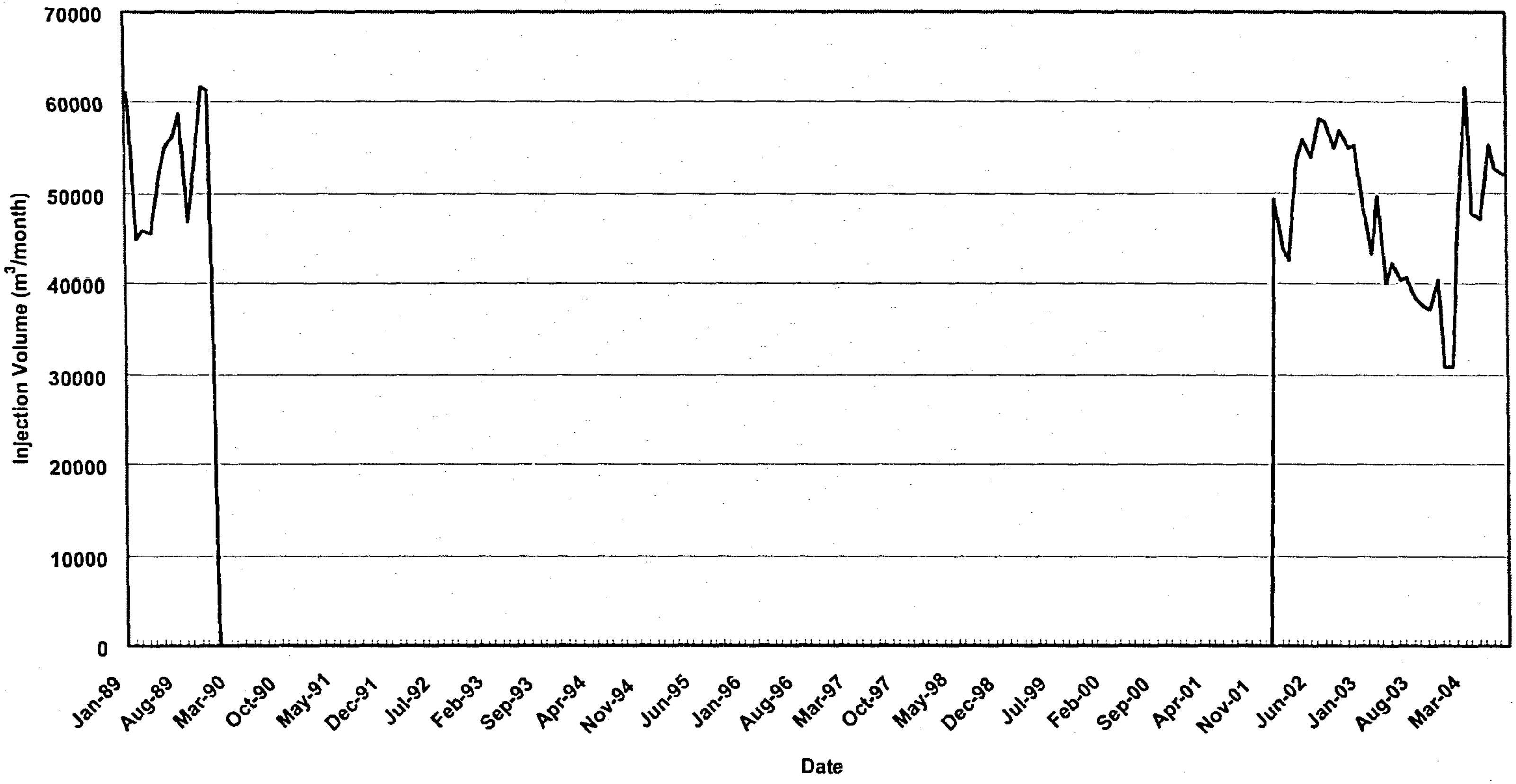

Figure 4.45. Time series plot of monthly injection volume of PCI REFINERY DISP EDMT 9-5-53-23.

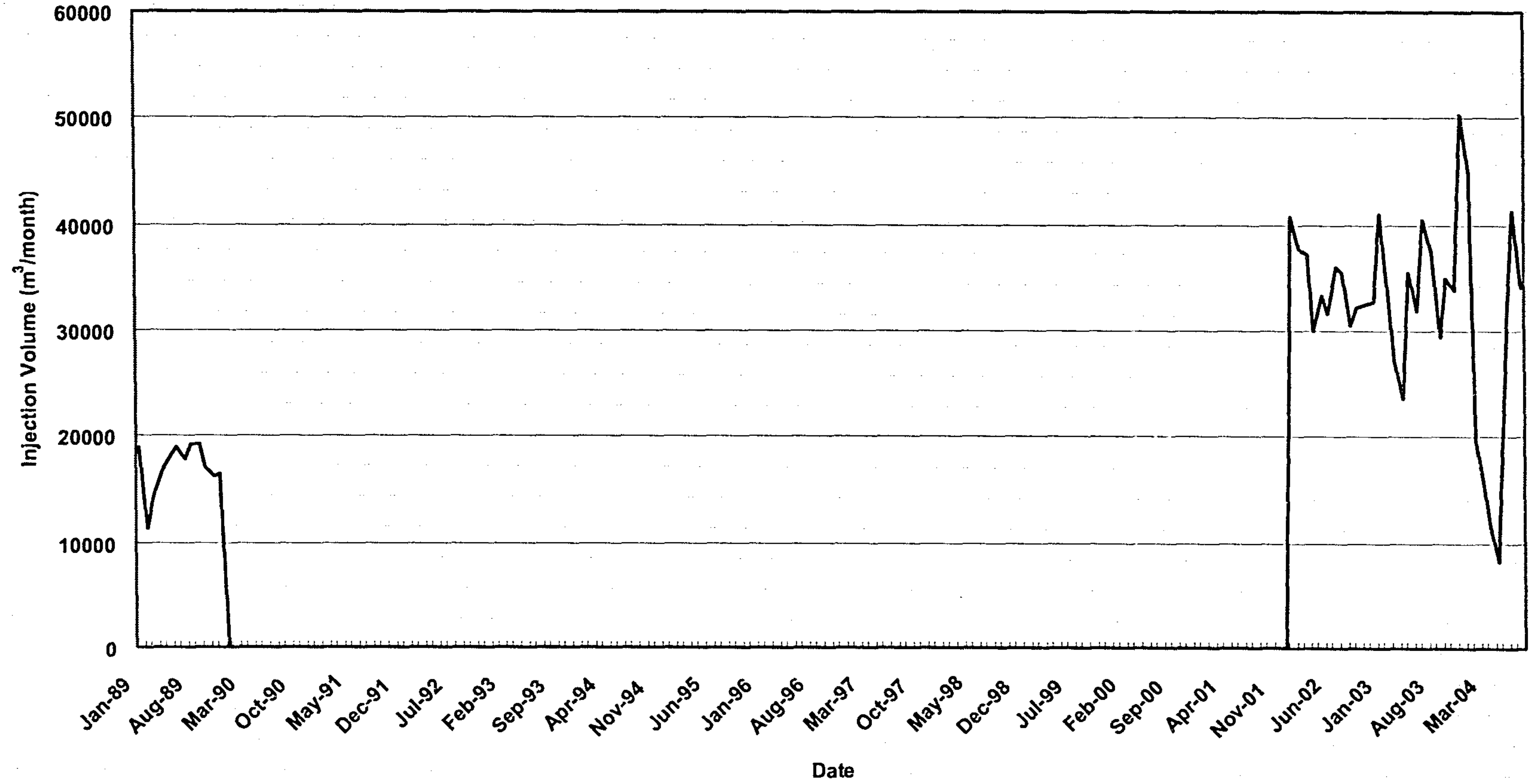

Figure 4.46. Time series plot of monthly injection volume of PCI REFINERY DISP EDMT 15-5-53-23.

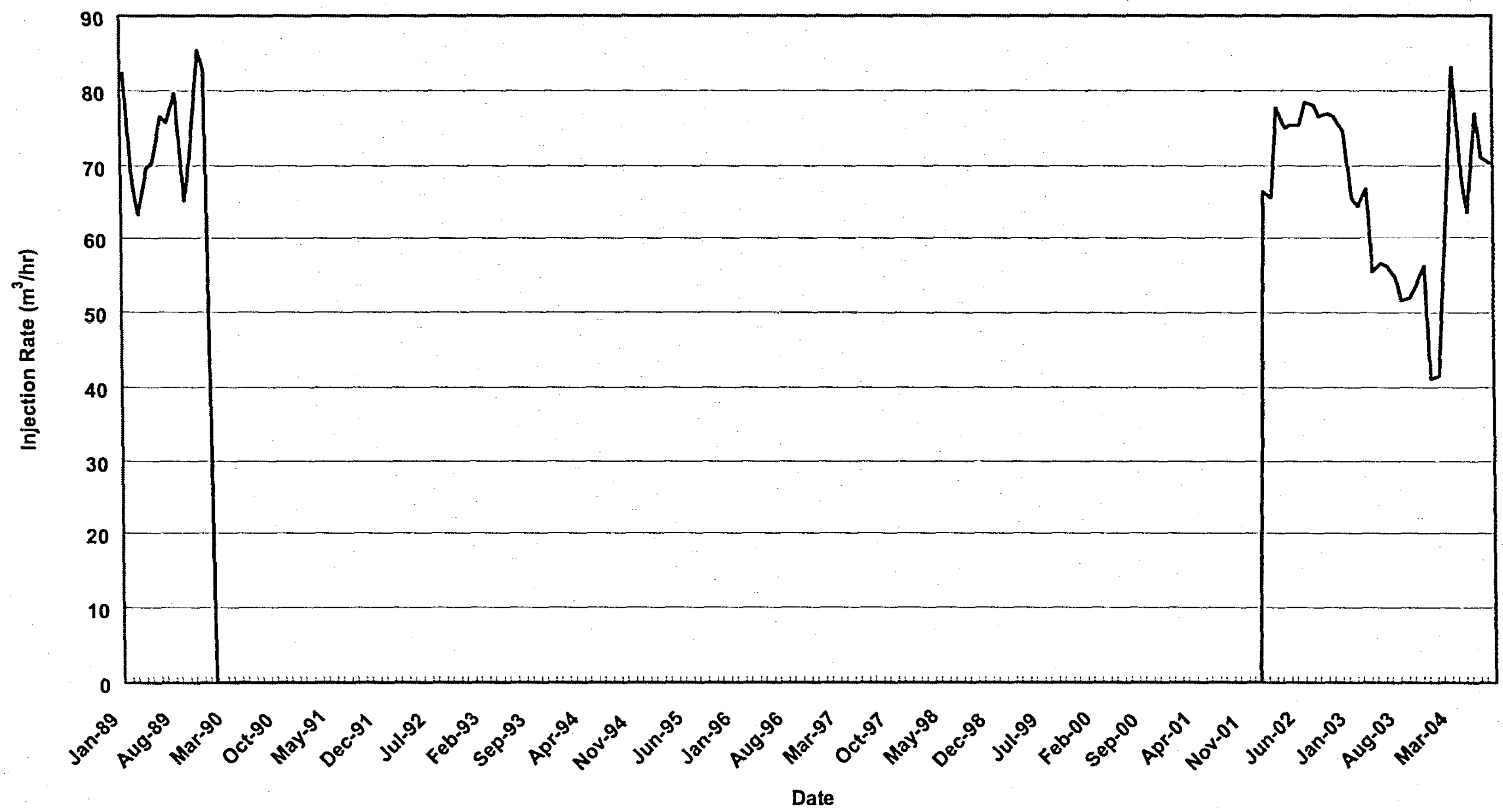

Figure 4.47. Time series plot of hourly injection rate of PCI REFINERY DISP EDMT 9-5-53-23.

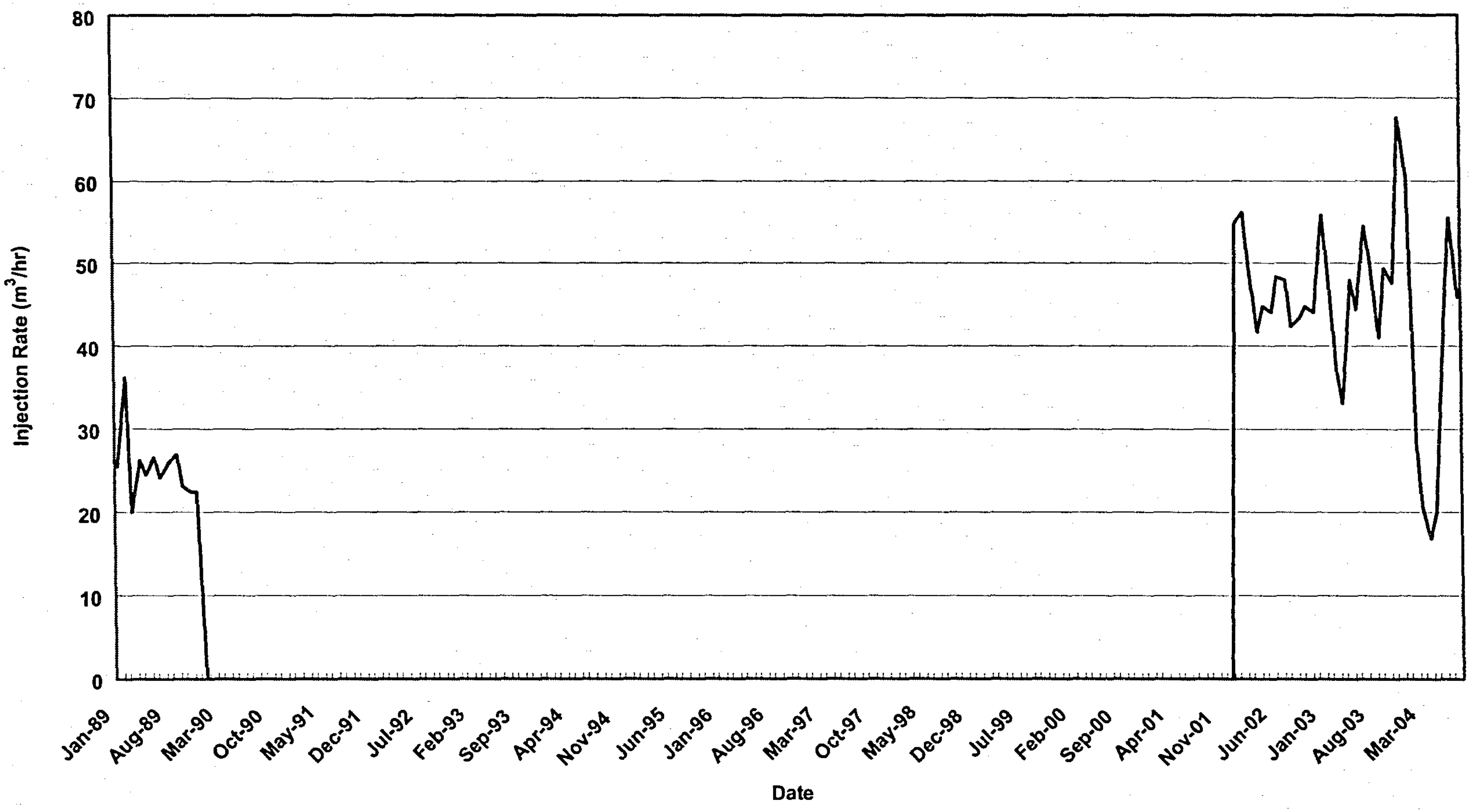

Figure 4.48. Time series plot of hourly injection rate of PCI REFINERY DISP EDMT 15-5-53-23.

Table 4.56. Analyses of wastes injected into PCI REFINERY DISP EDMT 9-5-53-23 (mg/L, except pH).

Parameters	10/17/1984	11/15/1984	12/12/1984	01/17/1985	12/14/1985	03/13/1985	04/24/1985	05/15/1985
pH	N/A	8.9	8.9	8.9	8.9	8.7	8.6	8.7
COD	N/A	9373	19,820	11,680	11,276	160	5,062	9,977
Oil	35.6	969	800	220	50,000	113	479	3
SS	192	622	22	185	35	85	1200	11
NH_3-N	1750	5000	1500	4500	3000	4375	3750	80
Sulfides	5280	4246	109	0	3443	3622	3326	2950
Phenols	160	300	2	10	135	13	128	630

Table 4.57. Analyses of wastes injected into PCI REFINERY DISP EDMT 15-5-53-23 (mg/L, except pH).

Parameters	12/12/1984	01/17/1985	12/14/1985	03/13/1985	04/24/1985	05/15/1985
pH	9.1	8.8	9	9	9.4	9.2
COD	575	1024	1,122	1,490	13,061	1,786
Oil	5.4	113	22.8	67	6	78
SS	14	61	120	176	40	35
NH_3-N	36	425	2500	200	100	87.5
Sulfides	70	60	93	25	115	158
Phenols	140	600	1	15	2.4	5.2

4.17 Approval No. 8926

Approval No. 8926 was issued to Husky Dow Chemical Inc. on December 18, 2001. It included seven wells with unique well identifiers as following: 03/01-10-055-22W4/0, 04/01-10-055-22W4/0, 00/16-10-055-22W4/0, 02/16-10-055-22W4/0, S0/01-15-055-22W4/0, 03/12-13-055-22W4/0 and 04/12-13-055-22W4/0. The names of these wells were not provided. Their general properties are presented in Table 4.57.

4.17.1 03/01-10-055-22W4/0 and 04/01-10-055-22W4/0

Application No. 800818 indicates that Dow Chemical of Canada Limited proposed to use these two wells to dispose non-dangerous oilfield solid wastes and fluids from following sources:

- Drill cutting from well drilling operations carried out by Dow Chemical Canada Inc.
- Brine treatment solids generated in process operation.
- Inorganic solid sludge, mostly sodium chloride contaminated mud, resulted from normal operation of Fort Saskatchewan Operation.

No information on volume records of these wells was provided. Analyses of wastes in these two wells are included in Table 4.58. No information on wells with unique well identifiers 00/16-10-055-22W4/0, 02/16-10-055-22W4/0, S0/01-15-055-22W4/0, 03/12-13-055-22W4/0 and 04/12-13-055-22W4/0 was provided.

4.17.2 Recommendation

There is insufficient information on sources, volumes, and characteristics of the individual waste streams of the wells included in Approval No. 8926. Given this situation, the following is recommended in order to better assess the potential of the source liquids for treatment and reuse as an alternative to injection.

- Volume records of these seven wells should be provided.
- An up-to-date chemical analysis of the source liquids injected into wells with unique well identifiers 00/16-10-055-22W4/0, 02/16-10-055-22W4/0, S0/01-15-055-22W4/0, 03/12-13-055-22W4/0 and 04/12-13-055-22W4/0 should be provided.

Table 4.58. General properties of the wells included in Approval No. 8926.

Approval #	EUB Appl #	Field	Formation	Approval Holder	Scheme type	G 51 type	Unique Identifier
8926	930310	Fort Saskatchewan	Lotsberg	Husky Dow Chemical Inc	Disposal	Class Ia	03/01-10-055-22W4/0
							04/01-10-055-22W4/0
							00/16-10-055-22W4/0
							02/16-10-055-22W4/0
							S0/01-15-055-22W4/0
							03/12-13-055-22W4/0
							04/12-13-055-22W4/0

Unique Identifier	Top of Injection Interval Measured Depth (metres KB)	Minimum Packer Setting Depth (metres KB)	Maximum Wellhead Injection Pressure, kPa (gauge)
03/01-10-055-22W4/0	1948.7	-	11000
04/01-10-055-22W4/0	1943.6	-	11000
00/16-10-055-22W4/0	1842.3	-	8000.0
02/16-10-055-22W4/0	1821.0	1805.5	8000.0
S0/01-15-055-22W4/0	1921.0	-	11000.0
03/12-13-055-22W4/0	1926.0	-	11000.0
04/12-13-055-22W4/0	1752.0	-	8000.0

Table 4.59. Analyses of wastes in wells 03/01-10-055-22W4/0 and 04/01-10-055-22W4/0.

Component	Average WT%
$Mg(OH)_2$	2.4
$CaCO_3$	2.7
Iron	0.2
NaCl	11.2
Acid Insoluble Components (silica, minerals...)	8.0
Total Organic Compounds	0.02 (211 ppm)
Water	75.5
Total	100.0
Other Chemical Parameters	
pH	12.3-12.5
Total chlorinated organics	<1.5
1,2 dichloroethane, ppm (1.5 ppm quantification limit)	<1.5
Chloroform (0.5 ppm DL)	N/D
Dioxins and Furans TEQ ppb	16.0

4.18 Approval No. 8951

Approval No. 8951 was issued to Imperial Oil Strathcona Refinery on June 25, 2001. It included only one well: IMP 102 STRATHCONA 9-1-53-24. The general properties of the well are presented in Table 4.59. Time series plots of monthly injection volumes and hourly injection rates of the well are depicted in Figures 4.49 and 4.50, respectively.

4.18.1 IMP 102 STRATHCONA 9-1-53-24

As indicated by Application No. 1092592, the well was to be used for disposal of waste fluids, such as sour water and caustic, from Imperial Oil Strathcona Refinery. The application also indicates that the anticipated daily volume of waste fluids injected into this well was to be 900 m^3 per day.

According to actual injection records, the average monthly injection rate has been 23,300 m^3/month. This number was calculated from data for the period 2001 to 2004 inclusive. The subject well began operating on Dec 13, 2001. As shown in Figure 4.49, monthly injection volumes have not been constant. The highest monthly injection volume was 45,200 m^3, in November 2002.

Analysis of reservoir water, as a source for this well (provided by Application No. 1092592), was difficult to read, except that pH was 6.5. The microfiche indicates that several parameters, including Cl^-, CO_3^{2-}, HCO_3^-, SO_4^{2-}, OH^-, I^-, Ca^{2+}, Mg^{2+} and Na^+, were analyzed but actual quantities and concentration units were unreadable. An up-to-date detailed chemical analysis of the refinery waste would be useful in this instance.

4.18.2 Recommendation

The average monthly volume of liquids injected into IMP 102 STRATHCONA 9-1-53-24 has been about 23,300 m^3. While this is considered a large amount, there is insufficient information on chemical characteristics of the individual sources. Given this situation, an up-to-date chemical analysis of the source liquids injected into the well is recommended.

Table 4.60. General properties of NEWALTA MORINV 8-15-54-26.

Approval #	EUB Appl #	Field	Formation	Approval Holder	Scheme type	G 51 type	Well Name	Unique Identifier
8951	1092592	Edmonton	Nisku	Imperial	Disposal	Class Ia	IMP 102 STRATHCONA 9-1-53-24	02/09-01-053-24W4/0

Top of Injection Interval Measured Depth (metres KB)	Minimum Packer Setting Depth (metres KB)	Maximum Wellhead Injection Pressure, kPa (gauge)
1265.0	1250.0	3800

Injection Started	Time Series Plot of Monthly Injection Volume	Time Series Plot of Hourly Injection Rate	Average Annual Injection Rate (m^3/yr)	Average Monthly Injection Rate (m^3/month)	Cumulative Injection Amount to Aug, 2004 (m^3)
December 13, 2001	See Figure 4.49	See Figure 4.50	284,000	23,300	769,000

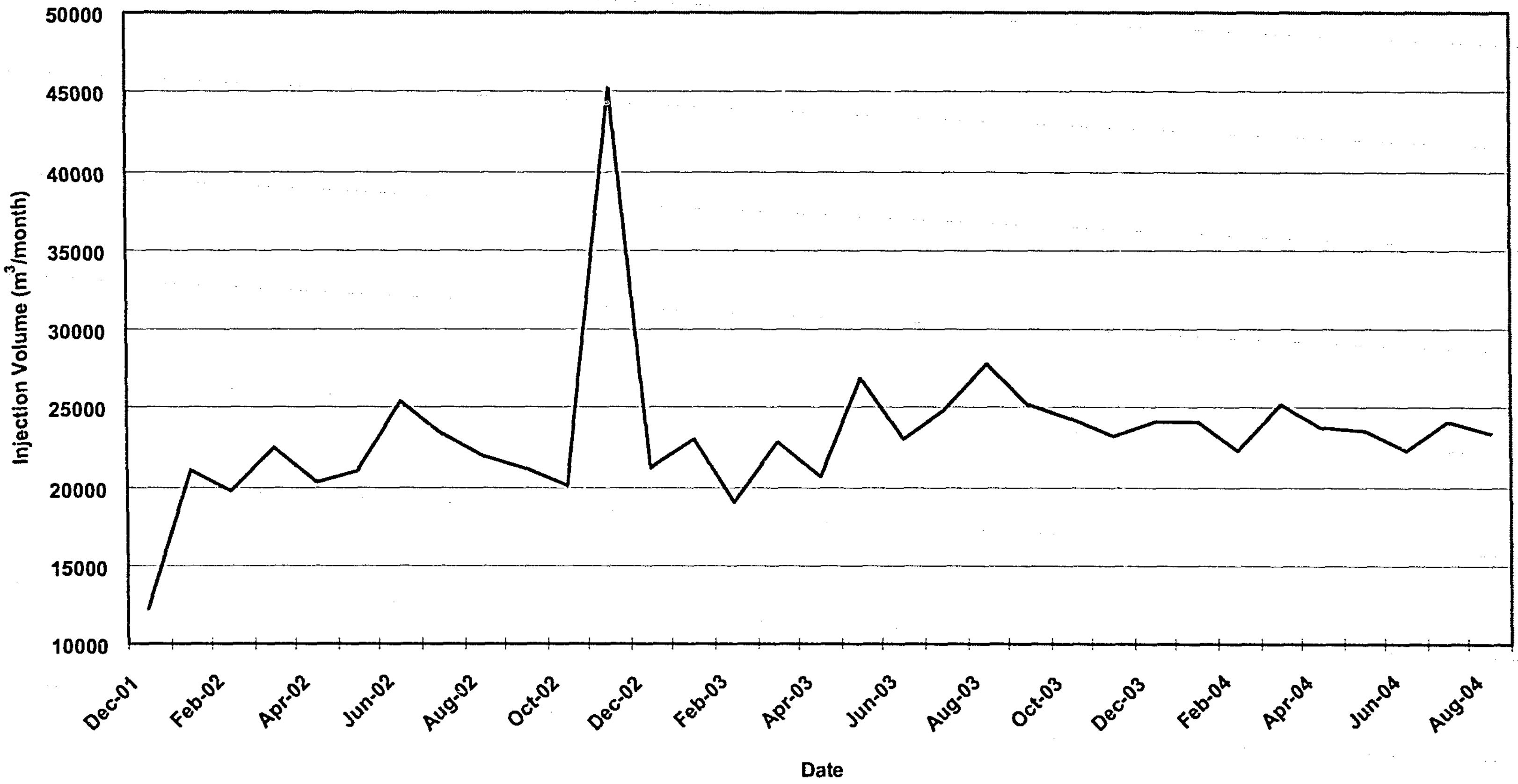

Figure 4.49. Time series plot of monthly injection volume of IMP 102 STRATHCONA 9-1-53-24.

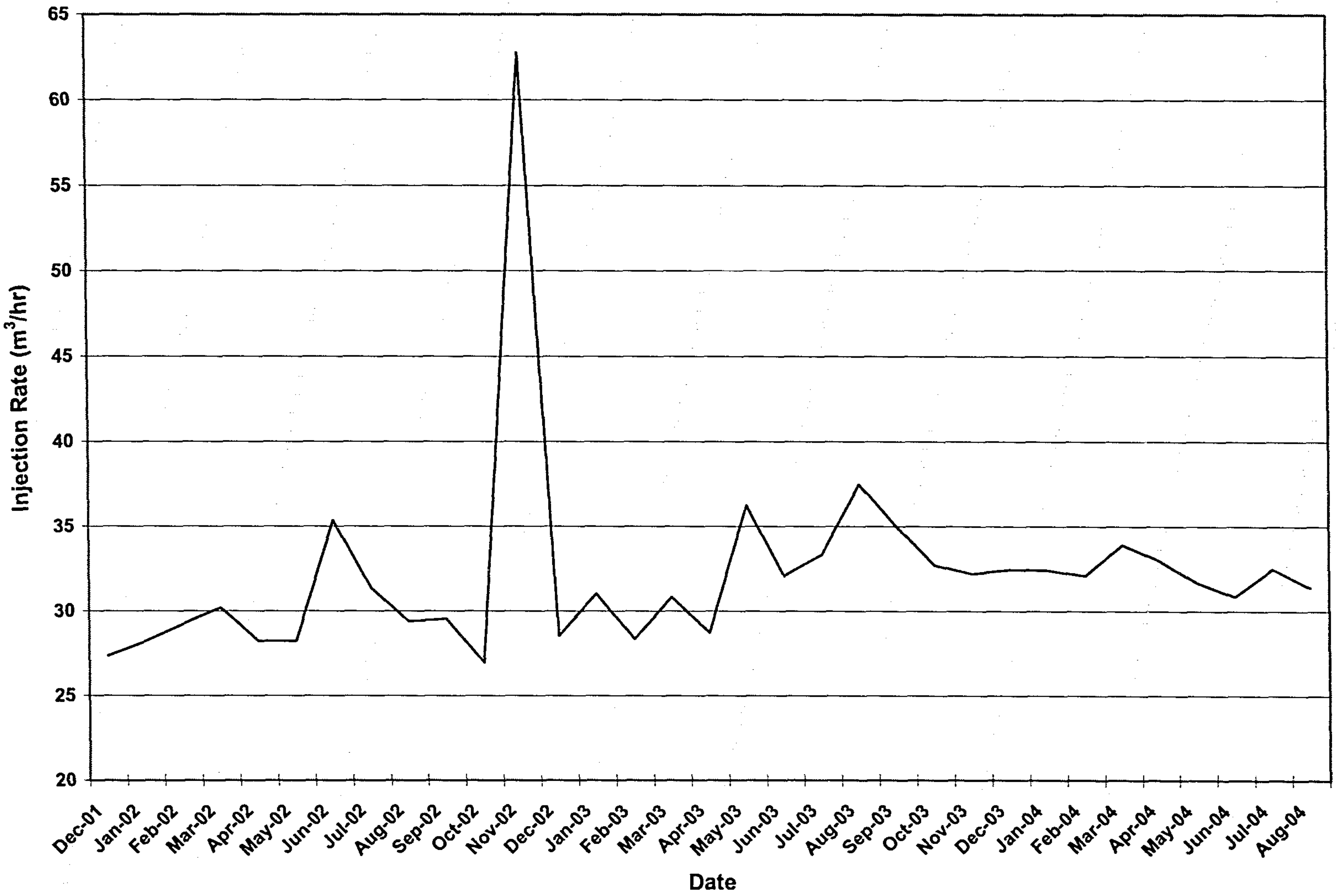

Figure 4.50. Time series plot of hourly injection rate of IMP 102 STRATHCONA 9-1-53-24.

4.19 Approval No. 9013

Approval No. 9013 was issued to Newalta Corporation on April 4, 2002. It included only one well: NEWALTA 102 BANTRY 1-25-18-14. The general properties of the well are presented in Table 4.60. Time series plots of monthly injection volumes and hourly injection rates of the well are depicted in Figures 4.50 and 4.51, respectively.

4.19.1 NEWALTA 102 BANTRY 1-25-18-14

Approval No. 1250509 indicates the fluids disposed into this well are to be oilfield brines and the following industrial wastes in the Brooks area:

- Saline fluids as obtained from oilfield waste processing facilities, oilfield tank washing operations, oil spill containment and recovery, or similar operations
- Boiler blowdown water
- Liquid fraction of drilling muds
- Spent workover or stimulation fluids
- Glycol solutions
- Methanol or hydro-test solutions
- Acid or caustic solutions
- Gas scrubber or adsorption tower bottom liquids (neutralized)
- Washing wastewater
- Corrosion inhibitor solutions
- Oxygen scavengers
- Metal finishing solutions
- Chemical process waste water
- Contaminated surface run-off water that is untreatable and unsuitable for return to the watershed
- Wastewaters from Newalta's Hazardous Recyclable Processing Facilities

- Other waste streams that have been classified that meet the General Criteria outlined in Guide 51:
    - pH between 4.5 and 12.5
    - Does not meet surface discharge criteria
    - Has a non-halogenated organic fraction of less than 10 per cent by mass (100,000 mg/kg), unless:
        - i) it is an untreatable sand or crude oil/water emulsion; or
        - ii) it is an antifreeze or dehydration fluid that contains greater than 60 per cent water by mass
    - Has one or more halogenated organic compounds in total combined concentration less than 1000 mg/kg
    - Has a polychlorinated biphenyl (PCB) concentration of less than 50 mg/kg

Approval No. 1250509 also indicates that the anticipated daily disposal volume was 250 to 300 m^3 per day. According to actual injection records, the average monthly injection rate of this well has been 7,000 m^3 per month. This number was calculated from data for the period 2001 to 2004 inclusive. The subject well began operating on November 3, 2001. As shown in Figure 4.50, the monthly injection volumes have not been constant. The highest monthly injection volume was 20,400 m^3, in December 2002. No information on chemical analysis of the wastewater was provided.

4.19.2 Recommendation

The average monthly volume of waste liquids injected into this well was 7,000 m^3 per month (daily disposal volume ~ 235 m^3 per day). This is considered a small to intermediate amount. In addition, the well receives industrial waste liquids from many sources in the Brooks area. Given this situation, it is recommended that it is not economical to pursue an investigation of the potential of the source liquids for treatment and reuse as an alternative to injection.

Table 4.61. General properties of NEWALTA 102 BANTRY 1-25-18-14.

Approval	EUB Appl #	Field	Formation	Approval Holder	Scheme type	G 51 type	Well Name	Unique Identifier
9013	1250509	Bantry	Nisku & Leduc	Newalta	Disposal	Class Ia	NEWALTA 102 BANTRY 1-25-18-14	02/01-25-018-14W4/0

Top of Injection Interval Measured Depth (metres KB)	Minimum Packer Setting Depth (metres KB)	Maximum Wellhead Injection Pressure, kPa (gauge)
1,316.0	1,301.0	14,400

Injection Started	Time Series Plot of Monthly Injection Volume	Time Series Plot of Hourly Injection Rate	Average Annual Injection Rate (m3/yr)	Average Monthly Injection Rate (m3/month)	Cumulative Injection Amount to Aug, 2004 (m3)
November 3, 2001	See Figure 4.51	See Figure 4.52	85,200	6,930	236,000

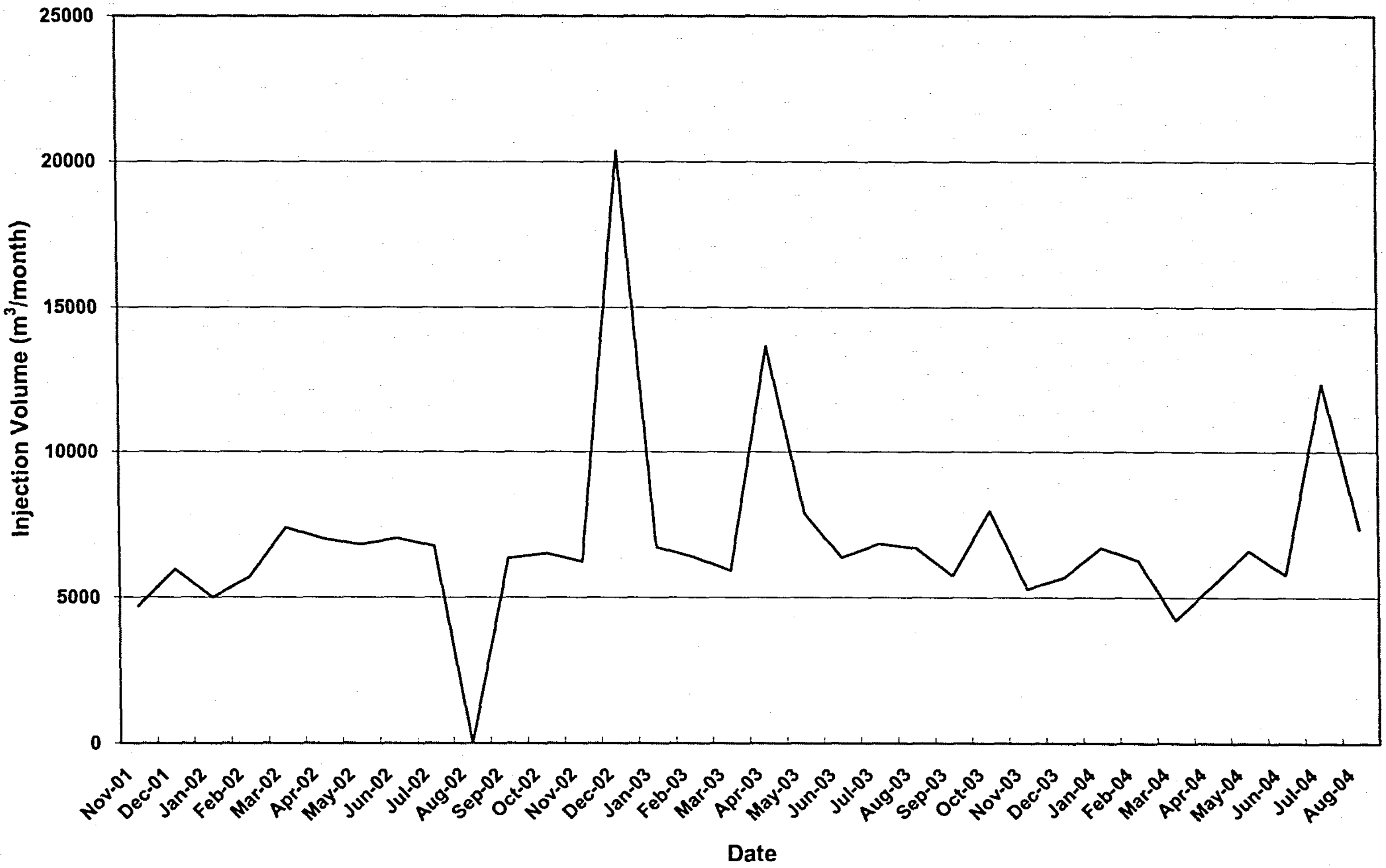

Figure 4.51. Time series plot of monthly injection volume of NEWALTA 102 BANTRY 1-25-18-1.

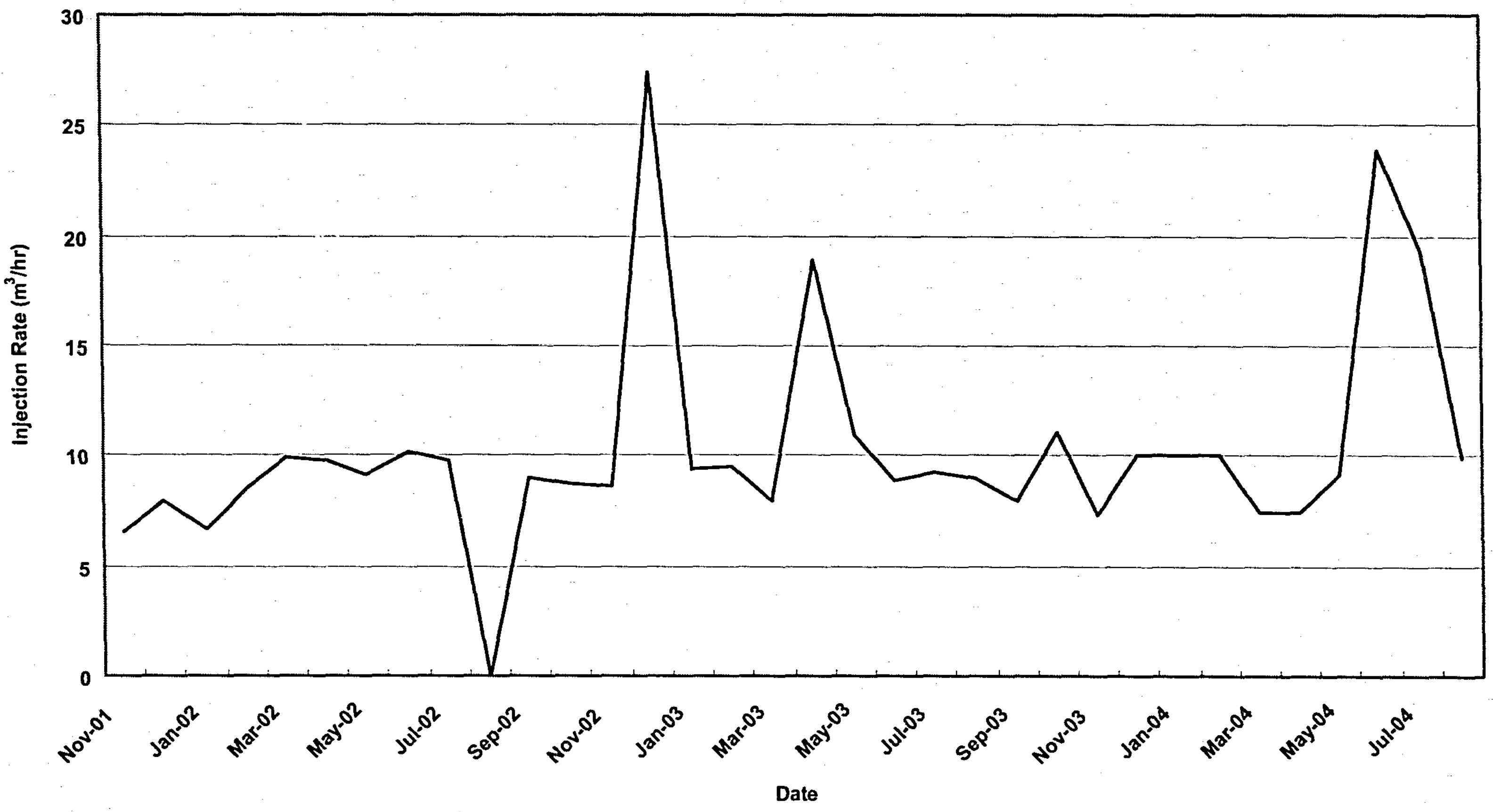

Figure 4.52. Time series plot of hourly injection rate of NEWALTA 102 BANTRY 1-25-18-1.

4.20 Approval No. 9699

Approval No. 9699 was issued to Celanese Chemicals on February 23, 2004. It includes two wells: CHEMCELL DISP CLOVER IN 10-17-53-23 and CHEMCELL DISP CLOVER IN 11-17-53-23. The general properties of these wells are presented in Table 4.61. Time series plots of monthly injection volumes and hourly injection rates of these wells are depicted in Figures 4.53 to 4.56.

4.20.1 CHEMCELL DISP CLOVER IN 10-17-53-23

Application No. 1312265 indicates this well was to be used for disposal of waste streams listed in Table 4.62. Process wastewater and groundwater recovery streams were sent to the City of Edmonton Gold Bar Waste Treatment Plant on a year-round basis (Application No. 1312265). During winter months, a slipstream of the effluent flow to Gold Bar was sent to the deep wells to help maintain their operation (Application No. 1312265).

It was also indicated by Application No. 1312265 that the proposed daily injection volume of this well was 3,250 m^3/day. According to actual injection records, the average monthly injection rate was 52,500 m^3/month. This number was calculated from data for the periods 1988 to 1991 and 2002 to 2004 inclusive. No injection volumes were reported between 1992 and 2002. The subject well began operating on October 12, 1968. However, no volumes were reported until 1988. As shown in Figure 4.53, monthly injection volumes have not been constant. The highest monthly injection volume was 106,000 m^3, in August 1989. No information on chemical analysis of the wastewater was provided.

4.20.2 CHEMCELL DISP CLOVER IN 11-17-53-23

Application No. 1312265 indicates this well was to have the same waste sources and proposed injection volumes as CHEMCELL DISP CLOVER IN 10-17-53-23. According to actual injection records, the average monthly injection rate was 65,800 m^3/month. This number was calculated from data for the periods of 1989 to 1991 and 2002 to 2004 inclusive. The subject well began operating on June 10, 1970. However, no volume was reported until 1989. As shown in Figure 4.54, the monthly injection volumes have not been constant. The highest monthly injection volume was 12,000 m^3, in April 1984.

4.20.3 Recommendation

The average monthly volume of liquids injected into the two subject wells was approximately 120,000 m^3. While this is considered a very large amount, there is no information on the chemical characteristics of the individual sources to determine their potential for treatment and reuse. Given these conditions, it is recommended that an up-to-date chemical analysis of the source liquids injected into these two wells should be provided, as virtually no historical data exist on the type and amounts of chemicals parameters.

Table 4.62. General properties of the wells included in Approval No. 9699.

Approval #	EUB Appl #	Field	Formation	Approval Holder	Scheme type	G 51 type	Well Name	Location
9699	1312265	Chamberlain	Chamberlain	Celanese Chemicals	Disposal	Class Ia	CHEMCELL DISP CLOVER IN 10-17-53-23	00/10-17-053-23W4/0
							CHEMCELL DISP CLOVER IN 11-17-53-23	00/11-17-053-23W4/0

Well Name	Top of Injection Interval Measured Depth (metres KB)	Minimum Packer Setting Depth (metres KB)	Maximum Wellhead Injection Pressure, kPa (gauge)
CHEMCELL DISP CLOVER IN 10-17-53-23	1,232.9	1,222.9	700
CHEMCELL DISP CLOVER IN 11-17-53-23	1,210.4	1,188.7	700

Well Name	Injection Started	Time Series Plot of Monthly Injection Volume	Time Series Plot of Hourly Injection Rate	Average Annual Injection Rate (m^3/yr)	Average Monthly Injection Rate (m^3/month)	Cumulative Injection Amount to Aug, 2004 (m^3)
CHEMCELL DISP CLOVER IN 10-17-53-23	October 12, 1968	See Figure 4.53	See Figure 4.55	659,000	52,500	3,570,000
CHEMCELL DISP CLOVER IN 11-17-53-23	June 10, 1970	See Figure 4.54	See Figure 4.56	850,000	65,800	3,490,000

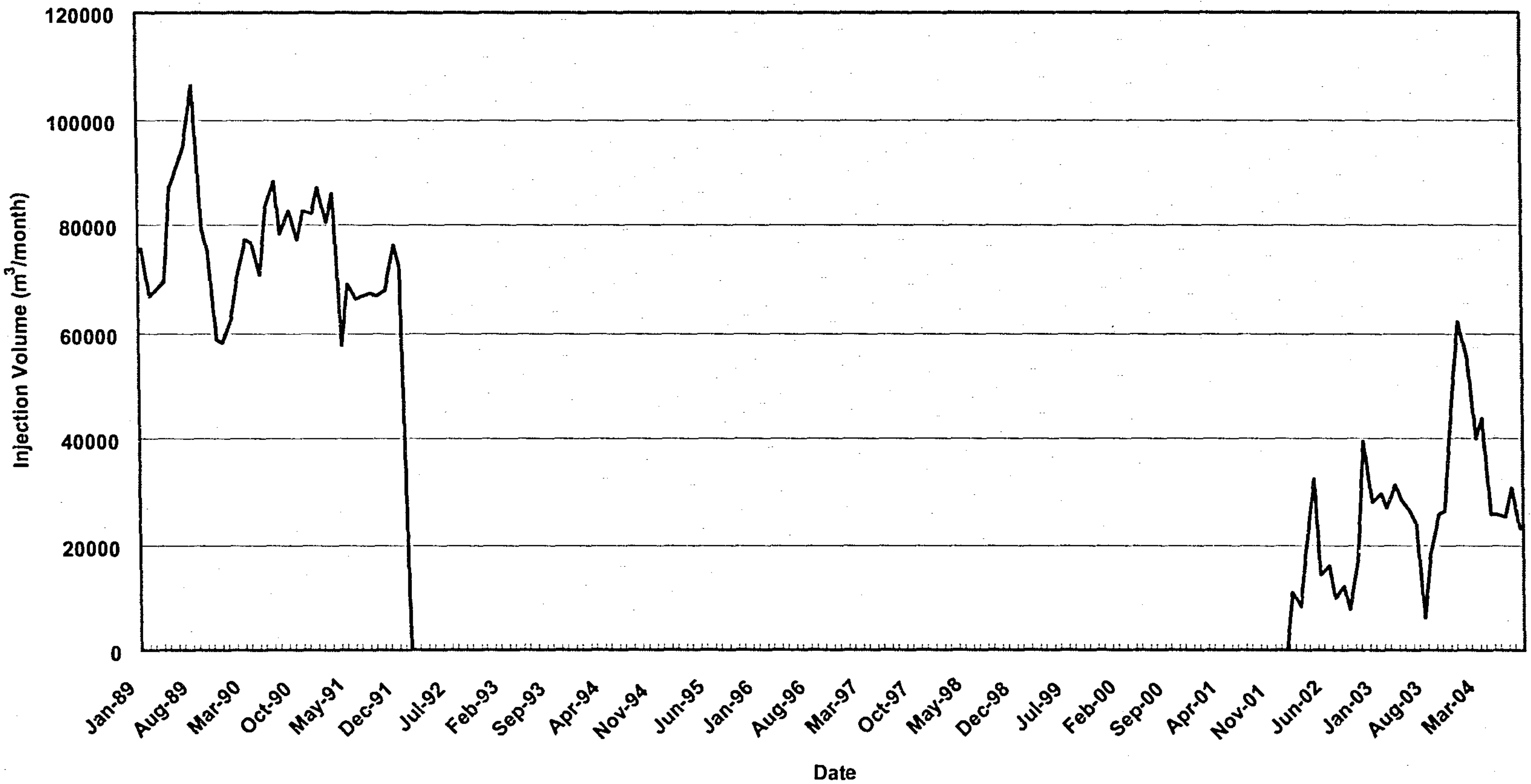

Figure 4.53. Time series plot of monthly injection volume of CHEMCELL DISP CLOVER IN 10-17-53-23.

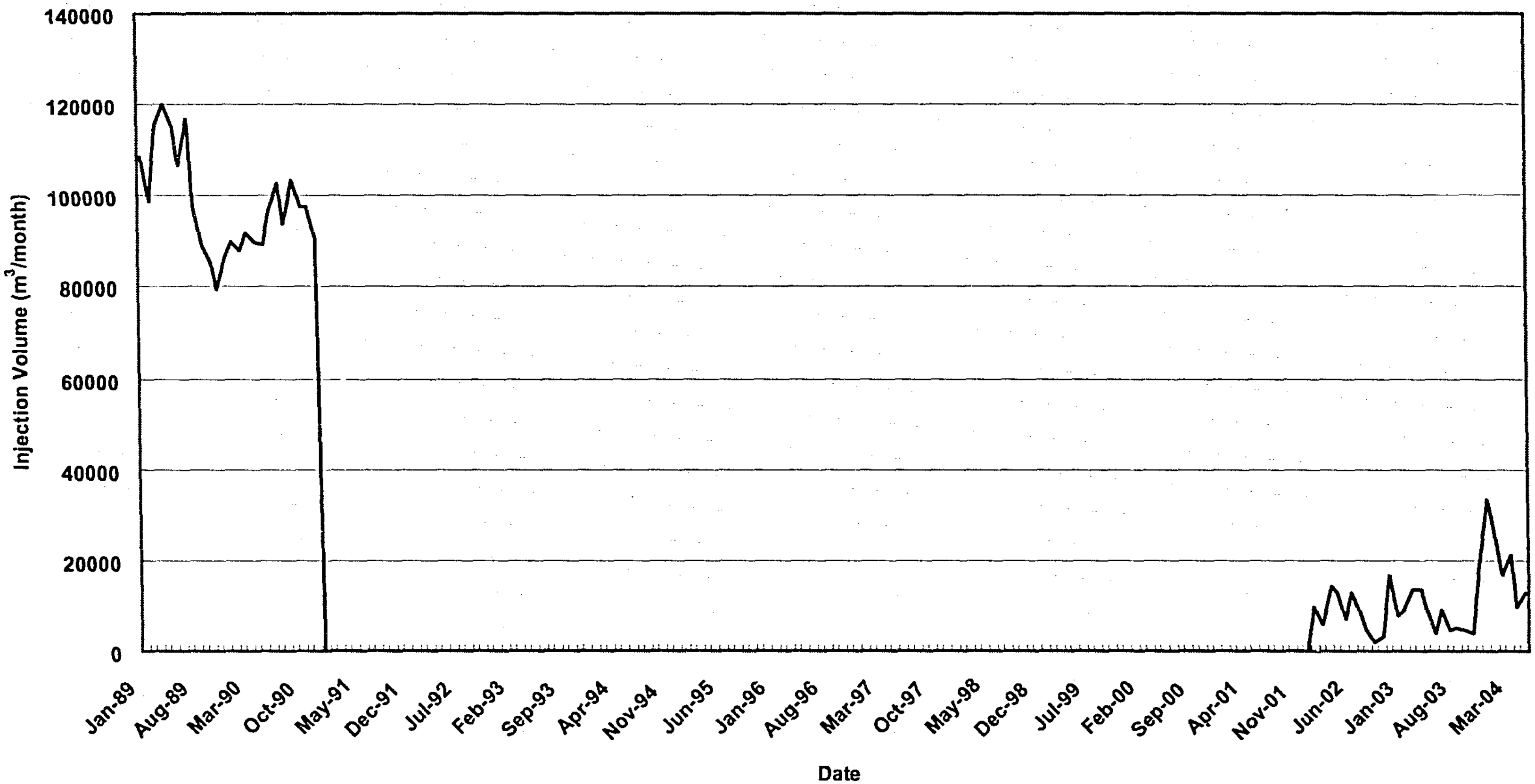

Figure 4.54. Time series plot of monthly injection volume of CHEMCELL DISP CLOVER IN 11-17-53-23.

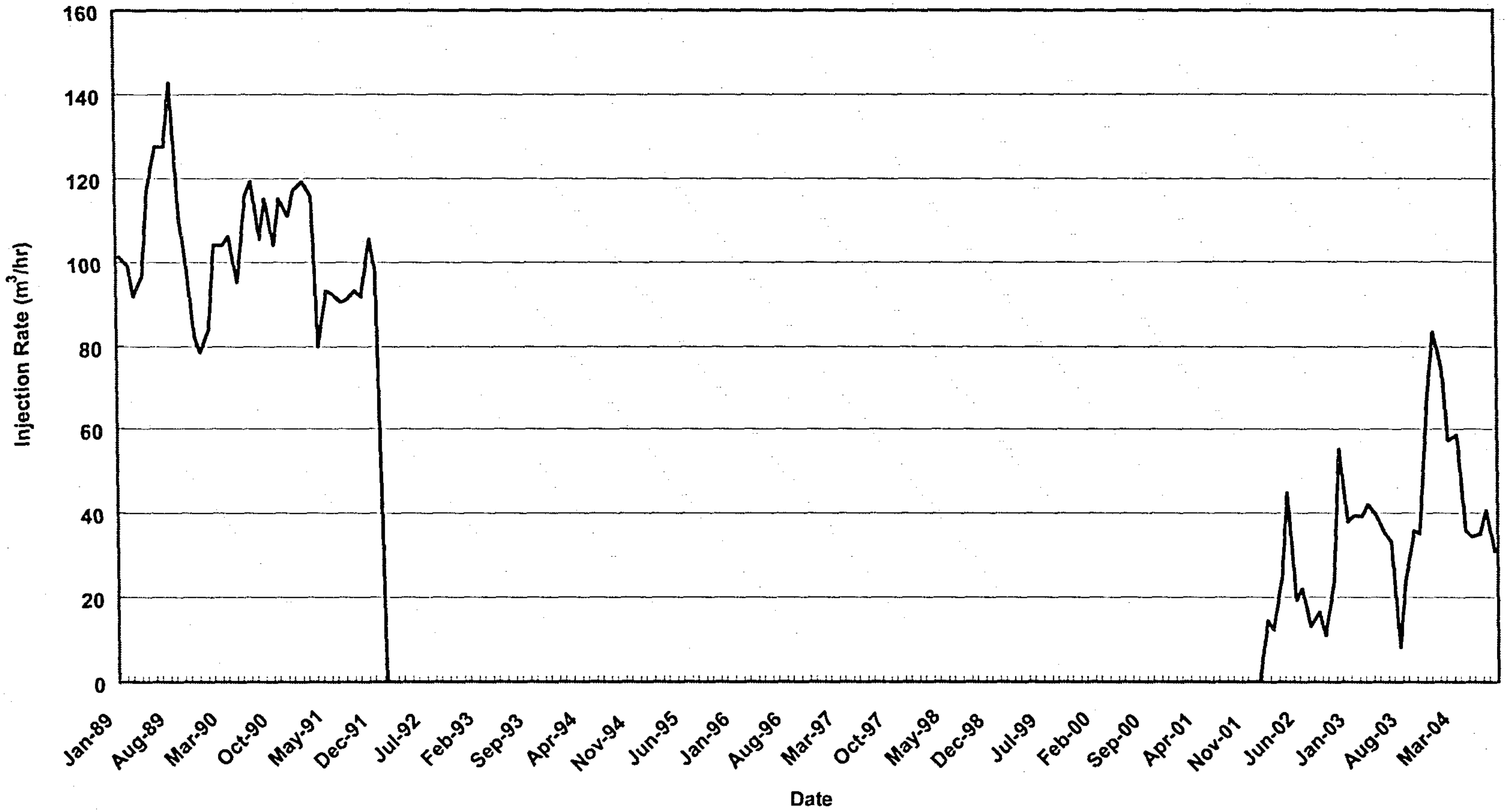

Figure 4.55. Time series plot of hourly injection rate of CHEMCELL DISP CLOVER IN 10-17-53-23.

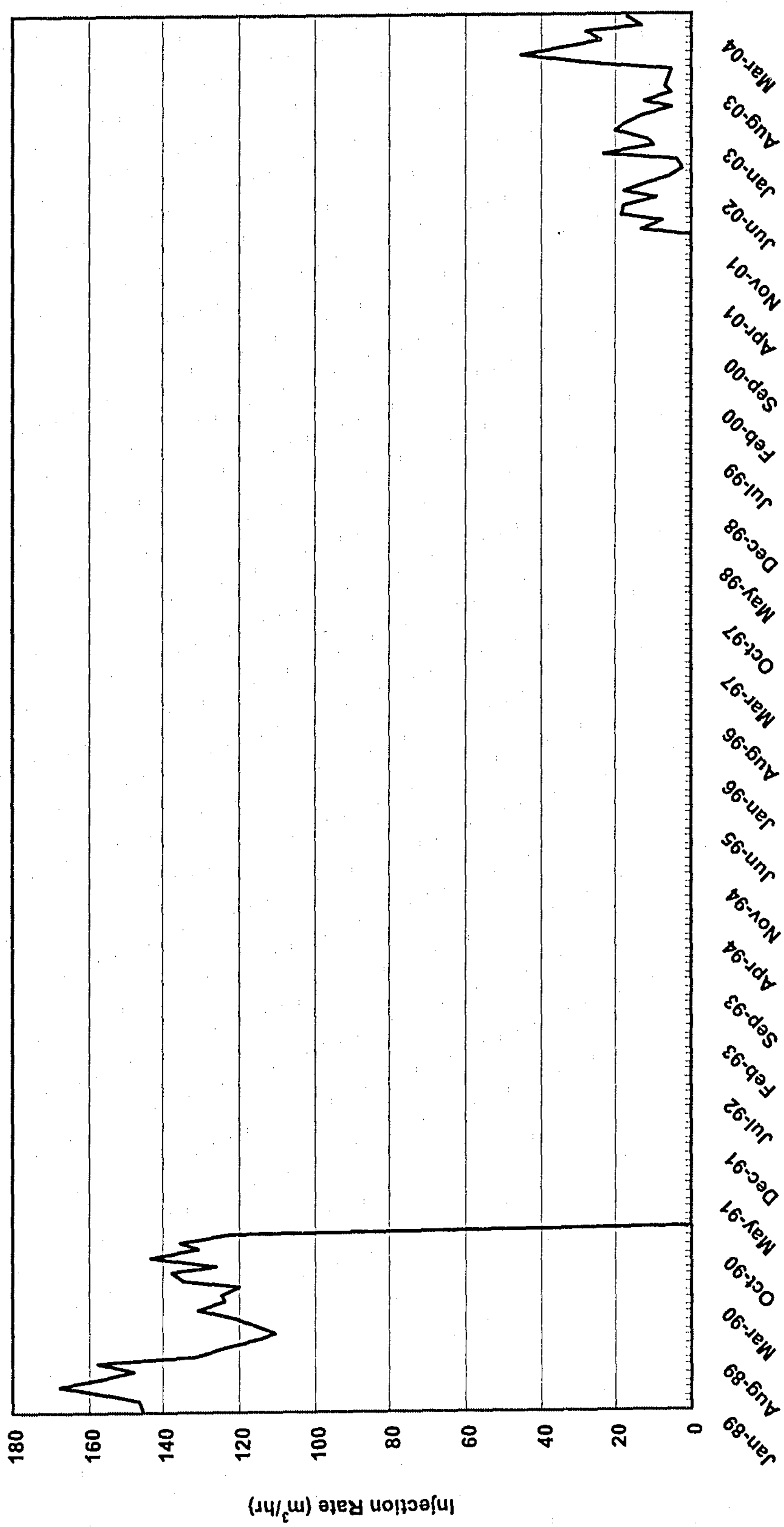

Figure 4.56. Time series plot of hourly injection rate of CHEMCELL DISP CLOVER IN 11-17-53-23.

Table 4.63. Waste streams and sources.

Source	Stream	Disposal Period
Acid Recovery Unit	Stripping Still Scrubber Base	Continuous
Methanol Synthesis Unit	Neutralization Basin Regeneration Flow	Yearly-batch basis
GWR Solid Waste Pond	Recovered Ground Water	April thru October-batch basis
Acid Recovery Unit	Process Waste Water	October thru April-Continuous
Cellulose Acetate Unit	Process Waste Water	October thru April-Continuous
Filter Products Unit	Process Waste Water	October thru April-Continuous
Methanol Oxidation Unit	Process Waste Water	October thru April-Continuous
Methanol Synthesis Unit	Process Waste Water	October thru April-Continuous
Utilities Unit	Process Waste Water	October thru April-Continuous
Ground Water Recovery (GWR) Flare Stack	Recovered Ground Water	October thru April-Continuous
GWR Tank Farm	Recovered Ground Water	October thru April-Continuous
GWR Zone C	Recovered Ground Water	October thru April-Continuous
GWR North Field	Recovered Ground Water	October thru April-Continuous

4.21 Approval No. 9700

Approval No. 9700 was issued to Crompton Co. on February 23, 2004. It included only one well: UNIROYAL CHAMBERLAIN 1-17-53-23. The general properties of the well are presented in Table 4.63. Time series plots of monthly injection volumes and hourly injection rates of the well are depicted in Figures 4.57 and 4.58, respectively.

4.21.1 UNIROYAL CHAMBERLAIN 1-17-53-23

Application No. 800613 indicates that this well was to be used for disposal of plant wastes from the Uniroyal Clover Bar Plant with an injection rate of 160 m^3/day. According to actual injection records, the average monthly rate has been 652 m^3/month. This number was calculated from volume records for 1981 and for the period 2002 to 2004 inclusive. No injection volumes were reported between 1990 and 2001. The subject well began operating on March 16, 1981. However, no volume was reported until 1989.

As shown in Figure 4.57, monthly injection volumes have not been constant. The highest monthly injection volume was 1,750 m^3, in July 2004. pH, conductivity, Cl^- (chloride), 2,4-D (2,4-dichlorophenoxyacetic acid), 2,4,5-T (2,4,5-trichlorophenoxyacetic acid), and phenols were monitored in plant wastes from the Uniroyal Clover Bar Plant. Average values of these parameters recorded during 2002 are shown in Table 4.64.

4.21.2 Recommendation

The average monthly volume of liquids injected to UNIROYAL CHAMBERLAIN 1-17-53-23 was 652 m^3. This is considered a small amount. Given this small volume, it is likely not economical to pursue an investigation of the potential of the source liquids for treatment and reuse as an alternative to injection.

Table 4.64. General properties of UNIROYAL CHAMBERLAIN 1-17-53-23.

Approval #	EUB Appl #	Field	Formation	Approval Holder	Scheme type	G 51 type	Well Name	Unique Identifier
9700	1310506	Chamberlain	Nisku	Crompton Co.	Disposal	Class Ia	UNIROYAL CHAMBERLAIN 1-17-53-23	00/01-17-053-23W4/0

Top of Injection Interval Measured Depth (metres KB)	Minimum Packer Setting Depth (metres KB)	Maximum Wellhead Injection Pressure, kPa (gauge)
1,222.0	1,207.0	9,450

Injection Started	Time Series Plot of Monthly Injection Volume	Time Series Plot of Hourly Injection Rate	Average Annual Injection Rate (m^3/yr)	Average Monthly Injection Rate (m^3/month)	Cumulative Injection Amount to Aug, 2004 (m^3)
March 16, 1981	See Figure 4.57	See Figure 4.58	7,170	652	28,700

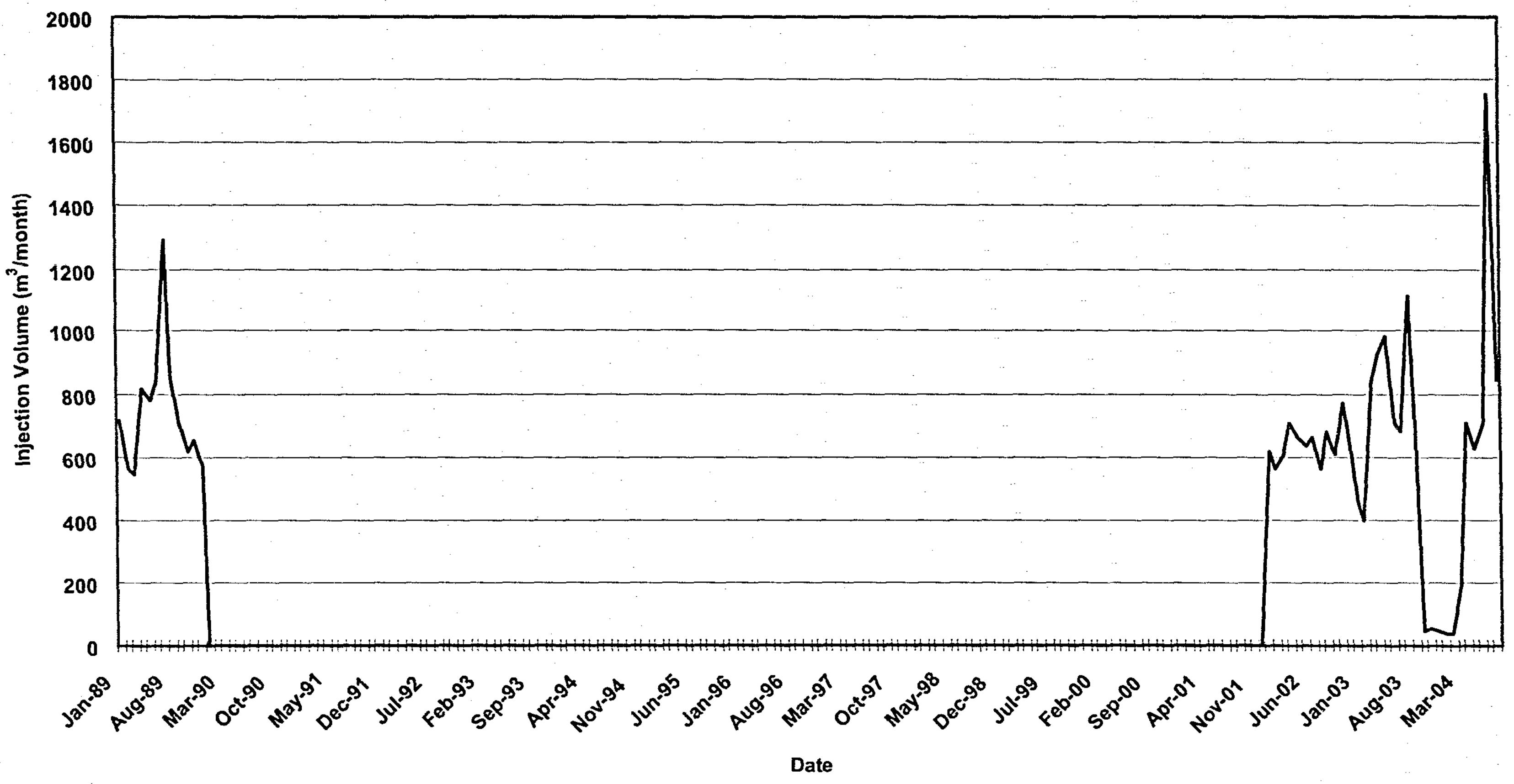

Figure 4.57. Time series plot of monthly injection volume of UNIROYAL CHAMBERLAIN 1-17-53-23.

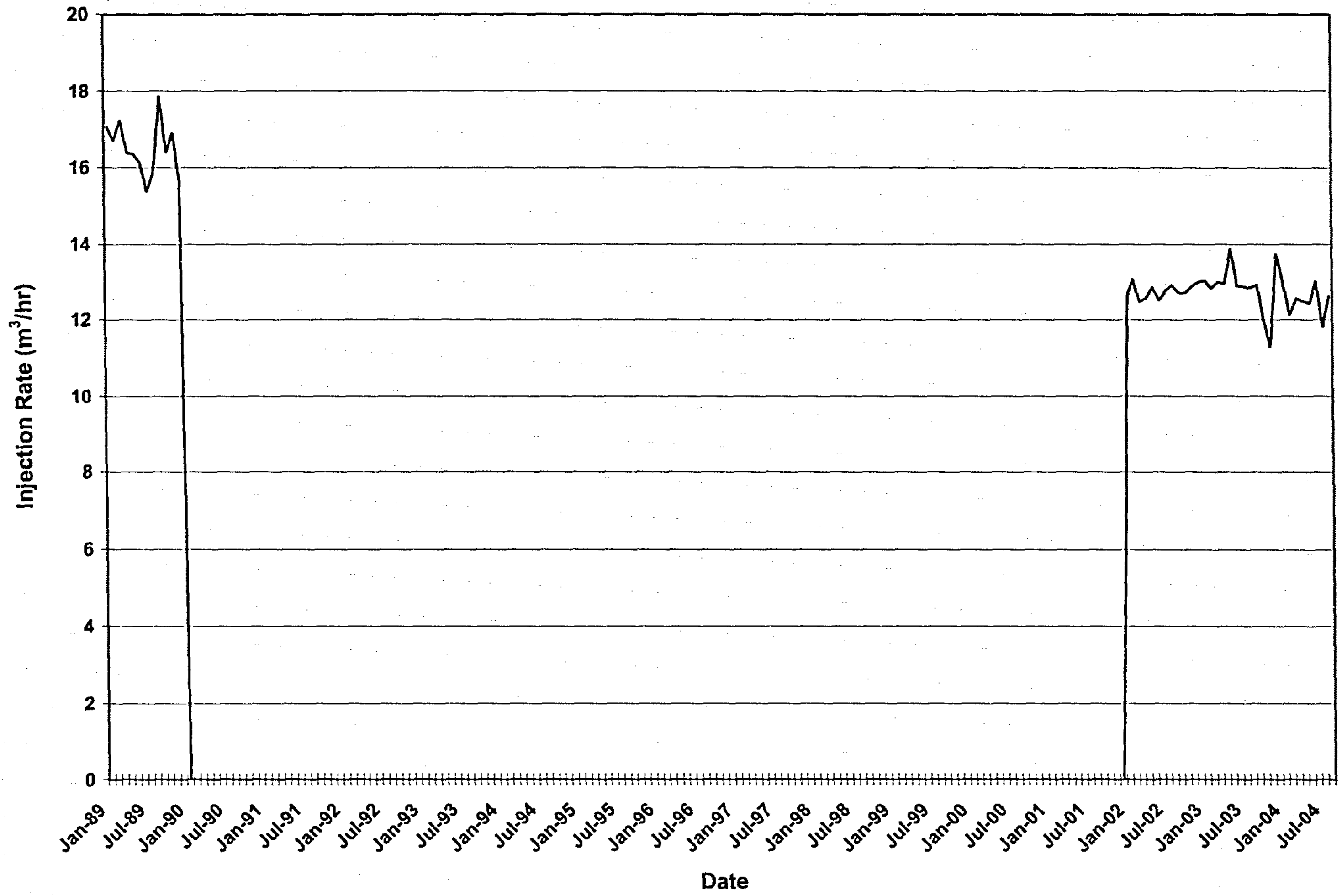

Figure 4.58. Time series plot of hourly injection rate of UNIROYAL CHAMBERLAIN 1-17-53-23.

Table 4.65. Average 2002 concentrations of monitored parameters of plant wastes from Uniroyal Clover Bar Plant.

Parameters	Concentrations
pH	7.16
E.C.	13.48 mS/cm
Chloride	5850 mg/L
2,4-D	17.6 mg/L
2,4,5-T	10.7 mg/L

5.0 DISCUSSION

Based on the information reviewed in the previous section, the 37 Class Ia wells were classified by categories identified in Section 3.3. Discussions applicable to them are described further below. Table 5.1 provides a summary of all wells classified by each category.

Category A Wells. The monthly disposal rates of Category A wells are less than 10,000 m^3/month. This was considered a low to intermediate rate using criteria identified in Section 3.3. Records indicated that waste streams injected into wells of this category are from multiple (or numerous) individual sources. These wells receive waste streams with small disposal volumes from many sources that are combined for disposal into an individual well. Further, records indicated that approval holders of the wells in this category are waste disposal companies. Industrial facilities pay these companies for disposal of small amount of untreated waste liquids.

According to the review, there was no information on the chemical characteristics of waster liquids disposed by these disposal companies. Although unknown, the treatment and reuse process of each individual sources would likely be different. It was concluded that is would not be economical to treat and reuse these multiple small volume sources with different chemical characteristics. Wells included in this category are from Approvals No. 6114, 6660, 7547, and 9013 (Table 5.1).

Table 5.1. Approved disposal wells organized by category.

Category	Well Approval No.	Well Name or ID
A	6114	NEWALTA MORINV 8-15-54-26
	6660	OKALTA-LEDUC NO. 13 WELL
	7547	NEWALTA PEMBINA 8-23-48-8
	9013	NEWALTA 102 BANTRY 1-25-18-14
B	7070	NEWALTA MORINVILLE 12-19-54-25
	7742	00/13-06-067-08W5/0
		00/13-06-067-08W5/2
	8133	AGEC JOFFRE 6-32-038-25W4/0
	9700	UNIROYAL CHAMBERLAIN 1-17-53-23
C	3924	HUSKY REFINERY NO. 3 & HUSKY REFINERY NO. 5
		HUSKY NO. 6 LLOYD 10C-1-50-1
	5737	SHELL FTSASK 1-31-55-21
		SHELL FTSASK 8-31-55-21
	8713	AIR B7-4 REDW IN 7-4-57-21
	8784	PCI REFINERY DISP EDMT 9-5-53-23
		PCI REFINERY DISP EDMT 15-5-53-23
	8951	IMP 102 STRATHCONA 9-1-53-24
	9699	CHEMCELL DISP CLOVER IN 10-17-53-23
		CHEMCELL DISP CLOVER IN 11-17-53-23
D	8317	DOW 3 FTSASK NACL 10-10-55-22
		DOW 4 FTSASK NACL 7-10-55-22
		DOW 5 FTSASK NACL 15-10-055-22
E	4779	AGU REDWATER 10-17-56-21
		AGU REDWATER 6-17-56-21
F	7842	AT PLASTICS CHEM IN 14-36-52-24
	8926	03/01-10-055-22W4/0
		04/01-10-055-22W4/0
		00/16-10-055-22W4/0
		02/16-10-055-22W4/0
		S0/01-15-055-22W4/0
		03/12-13-055-22W4/0
		04/12-13-055-22W4/0
G	8185	VIRIDIAN FTSASK 4-10-55-22
H	7290	CHEVRON MGSU 1 MITSUE 7-20-72-4
	8251	IMP REFINERY DISPOSAL IN 9-1-53-24
		IMP REF DISP STRATHCONA 8-1-53-24

Category B Wells. The monthly disposal rates of Category B wells are less than 10,000 m^3/month. Again, this was considered a low to intermediate rate using criteria identified in Section 3.3. Waste streams injected into wells of this category are from discrete (or few) individual sources. The number of sources combined for disposal into an individual well is less than three individual sources. Although the number of sources is much less than Category A well sources, it was concluded that volumetric disposal rates for these wells may not be high enough to make it economical to pursue treatment and reuse. Wells included in this category are from Approvals No. 7070, 7742, 8133, and 9700 (Table 5.1).

Category C Wells. The monthly disposal rates of Category C wells are more than 10,000 m^3/month. This was considered an intermediate to high rate using criteria identified in Section 3.3. Waste streams injected into wells of this category are from discrete (or few) individual sources. However, as discussed in Section 4, source characterization data of the wells in this category were unreadable or outdated (before 1970). These high volume waste sources may be economical to pursue treatment and reuse if source characterization data indicate the appearance of lowly contaminated liquids. In this case, provision of an up-to-date chemical analysis of source liquids is required in order to better assess the potential of the source liquids for treatment and reuse.

As a general recommendation, the analysis should at least include the following parameters:

- pH,
- specific gravity,
- total dissolved solids,
- total suspended solids,
- hardness (as $CaCO_3$),

- conductivity,
- nitrogen parameters,
- biochemical oxygen demand,
- chemical oxygen demand,
- major ions,
- metals (total and dissolved) if applicable,
- standard organic parameters (including oil and grease),
- complex organic and inorganic compounds if applicable, and
- biological organisms if applicable.

It is recommended to base the analysis on the original feedstock chemicals and corresponding industrial processes used to best determine what complex organic and inorganic compounds to analyze. Wells included in this category are from Approvals No. 3924, 5737, 8713, 8784, 8951, and 9699 (Table 5.1).

Category D Wells. The monthly disposal rates of Category D wells are more than 10,000 m^3/month. Again, this was considered an intermediate to high rate using criteria identified in Section 3.3. Waste streams injected into wells of this category are from discrete (or few) individual sources. In addition, source characterization data indicate the appearance of extensively contaminated liquids. For example, source liquids contain very high concentrations dissolved solids.

Although volumetric disposal rates for these wells are high enough to make it economical to pursue treatment and reuse, the cost of treatment – while unknown – may make it unfavorable. Ideally, these characteristics may well satisfy deep well injection as being the most environmentally sound alternative for disposal due to the nature of chemical contaminants. It was not recommended to pursue investigating treatment and reuse as an alternative to injection for these wells because of this. Wells included in this category are from Approval No. 8317 (Table 5.1).

Category E Wells. The monthly disposal rates of Category E wells are more than 10,000 m^3/month. Again, this was considered an intermediate to high rate using criteria identified in Section 3.3. Waste streams injected into wells of this category are from discrete (or few) individual sources. In addition, source characterization data indicated that individual contaminants – such as Cr^{6+}, NO_3^-, NH_3 and SO_4^{2-} – present in source liquids would require some form of specific treatment prior to general reuse.

Volumetric disposal rates for these wells are high enough to make it economical to pursue treatment and reuse. In addition, source characterization data indicated the appearance of lowly contaminated liquids requiring at least some form of specific treatment prior to general reuse. These waste streams clearly fell into a category requiring further investigation of treatment capabilities compared to other waste streams evaluated. Wells included in this category are from Approval No. 4779 (Table 5.1).

Category F Wells. Wells in Category F had no information on disposal rates. In addition, source characterization data were the same as that of category E – individual contaminants present in source liquids would require some form of specific treatment prior to general reuse. Although the characteristics of source liquids indicated the appearance of lowly contaminated, volumetric disposal rates were not available to indicate whether they are high enough to make it economical to pursue treatment and reuse. Injection volume data are required in order to better assess the potential of source liquids for treatment and reuse. Wells included in this category are from Approvals No. 7842 and 8926 (Table 5.1).

Category G Well. This category of wells is used to identify a special case where contaminated groundwater is extracted from the subsurface and injected into a disposal well. According to Underground Injection Control (UIC) Program of US EPA (2002), contaminated groundwater is not allowed to be injected into deep wells. Thus it is reasonable to recommend investigation of the potential of the contaminated groundwater for treatment and reuse. The well included in this category is from Approval No. 8185 (Table 5.1).

Category H Wells. Wells in Category H had negligible amounts of waste fluids injected during recent years and/or infrequent injection periods over the time in which data were available for review. For example, injection volumes for some of these wells were less than 1,000 m^3/month during the past ten years. No matter what level of contamination in the source liquid is, volumetric disposal rates for these wells may not be high enough to make it economical to pursue treatment and reuse. Wells included in this category are from Approvals No. 7290 and 8251 (Table 5.1).

6.0 RECOMMENDATIONS

The main limitation of this project was not having sufficient and detailed enough characterization data for waste streams currently being disposed of by deep well injection. The information that was available for review did not contain sufficient detail to allow more than the simple categorization scheme described in Section 3.3 for waste streams going to the wells. Based upon this categorization, the following recommendations are made for each well category:

Category A Wells. Category A wells (four) are classified as having low to intermediate disposal rates (<10,000 m^3/month) of waste streams from multiple (or numerous) individual sources. **It is recommended that these small volume sources are unlikely to be economical to pursue treatment and reuse as an alternative to injection for these four wells.**

Category B Wells. Category B wells (five) are classified as having low to intermediate disposal rates (<10,000 m^3/month) of waste streams from few individual sources. **It is recommended that the sources are unlikely to be economical to pursue treatment and reuse as an alternative to injection for these five wells.**

Category C Wells. Category C wells (ten) are classified as having intermediate to high disposal rates (>10,000 m^3/month) of waste streams from few sources, however source characterization data were unreadable or outdated (before 1970). **Provision of an up-to-date chemical analysis of source liquids is recommended in order to better assess the potential of the source liquids for treatment and reuse for these ten wells.**

Category D Wells. Category D wells (three) are classified as having intermediate to high disposal rates (>10,000 m^3/month) of waste streams from discrete or few sources. In addition, source characterization data indicate the appearance of extensively contaminated liquids. **It is not logical to pursue investigating treatment and reuse as an alternative to injection because of high contamination characteristics for these three wells.**

Category E Wells. Category E wells (two) are classified as having intermediate to high disposal rates (>10,000 m^3/month) of waste streams from discrete or few sources. In addition, source characterization data indicate that individual contaminants present in source liquids would require some form of specific treatment prior to general reuse. **Further investigation of treatment capabilities of waste streams is recommended for these two wells.**

Category F Wells. Category F (eight) wells are classified as having no information on disposal rates. In addition, source characterization data indicate that individual contaminants present in source liquids would require some form of specific treatment prior to general reuse. **It is recommended that injection volume records be obtained in order to better assess the potential for treatment and reuse for these eight wells.**

Category G Well. This category of well is used to identify a special case were contaminated groundwater it extracted from the subsurface and injected into a disposal well. **It is recommended that investigation of the potential of treatment and reuse be pursued for the contaminated groundwater source injected into this well.**

Category H Wells. Category H wells (three) are classified as having negligible amounts of waste fluids injected during recent years and/or infrequent injection periods over the time in which data were available for review. **It is recommended that these low volume sources are unlikely to be economical to pursue treatment and reuse as an**

alternative to injection for these three wells.

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