LANDFILL DESIGN - LEGAL LIABILITIES ARISING FROM GEOTECHNICAL AND HYDROGEOLOGICAL ISSUES

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Abstract

Minimum legislated standards for landfill design may be insufficient to protect the environment. Waste landfills can cause both immediate environmental impacts through geotechnical-related failures as well as long-term damage from leakage of unacceptable levels of contaminants. Careful consideration of a landfill's contaminating lifespan, as well as failures that could result from geotechnical-related causes, require engineering designs which provide a margin of safety if landfill design engineers wish to avoid substantial legal liabilities.

1.0 Legal Liabilities Created by Landfills

Waste disposal landfilling has the potential to create significant negative environmental impacts as well as considerable property damage and interference with the lives of communities. These impacts have been manifested both through unacceptable levels of contaminants being released from landfills, either slowly due to a failure of engineering systems, or quickly, such as in the case where there is a major slope failure. (see Rowe 1998, 1999). As a consequence of past problems, the disposal of waste by landfilling has become well controlled and regulated in many parts of the world (e.g. MoE (1998) in Ontario, Canada, TA Siedlungsabfall (1993) in Germany, DWAF (1994) in South Africa, US EPA (1994) in the USA, and many others). However, the presence of regulations does not necessarily imply that the landfills will provide adequate environmental protection or that geotechnical failure will not occur (e.g. see Rowe 1998, 1999). It is argued here that an engineer's responsibility both moral and legal) goes beyond meeting the requirements specified in regulations. Thus, this present paper, which is based on Estrin and Rowe (1997), discusses some potential legal implications for the design engineer in legal systems based on British common law.

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The contaminating lifespan of a landfill may be defined as a period of time during which the landfill produces contaminants which may have an unacceptable impact if discharged to the environment (Rowe & Fraser 1993a,b; MOEE 1994b). In order to prevent unacceptable levels of contaminants being released from landfills, the combined engineered system for the barrier must have a service life that is equal to or exceeds the contaminating lifespan of the landfill (MOEE, 1994b).

Engineering professionals today recognize that it is feasible to estimate a landfill's contaminating lifespan in order to provide for appropriate engineering design, maintenance and post-closure activities. Rowe (1991, 1995) described techniques that could be used to estimate the contaminating lifespan and it has been shown that even with modest to high infiltration rates, the contaminating lifespan of a large landfill may exceed 200 years.

However, not all jurisdictions and regulatory agencies clearly require that a landfill's contaminating lifespan be calculated and addressed in the design and approval stages. Most commonly a prescriptive standard (eg. specifying thickness and hydraulic conductivity of a liner or base) is provided, rather than a performance-based standard. Furthermore, some jurisdictions appear to limit the design period of concern to an arbitrary period (eg. 30 years). For example, in the United States, regulations promulgated under the Resource Conservation and Recovery Act (US EPA 1994) stipulate locational restrictions, operating criteria, design criteria as well as monitoring, closure and post-closure care and financial insurance criteria for municipal waste landfills. Under subtitle D, paragraph 258 of these regulations, one alternative design criteria provided is that a composite liner must be used meeting the following description:

> "Consisting of two components: the upper component must consist of a minimum 30 mil flexible membrane liner (FML), and the lower component must consist of at least a two-foot layer of compacted soil with a hydraulic conductivity of no more than 1×10^{-7} cm/s. FML components consisting of high density polyethylene (HDPE) shall be at least 60 mil thick. The FML component must be installed in direct and uniform contact with a compacted soil component (40 CFR, paragraph 258.40 (2) (b))."

The composite liner must be constructed with a leachate collection system that is designed and constructed to maintain less than a 0.3 m depth of leachate over the liner.

As discussed by Estrin and Rowe (1997), this US EPA design approach appears similar to the German Federal regulation (TA Siedlungsabfall 1993) and the proposed CEC (1995) directive insofar that all three specify a barrier system without defining the contaminating lifespan or identifying the service life of the engineered components of the system, and without identifying the effect of landfill size on potential impact. The authors have previously written as to how the application of this USA EPA minimum prescriptive design approach would not be sufficient, in the case of a proposed large landfill in the Metropolitan Toronto (Canada) area, for Ontario's Reasonable Use policy (MoEE 1994a), which requires "negligible" environmental impact, to be met (Estrin & Rowe 1995).

Similar concerns could be expected with respect to the German and proposed CEC directive. The CEC directive would require a thicker liner/geological barrier (1m vs. 0.6m) than the U.S. regulations. However, it may be anticipated that this will still not be sufficient to prevent potential unacceptable impact for large landfills. The German regulation has a greater likelihood of minimizing potential impact due to the migration of organic contaminants from large landfills (see Rowe et al 1996) but does not really address the issue of service life and, as shown by Rowe and Booker (1997), has the potential of causing large impacts when there is a failure of the leachate collection system (due to clogging or failure to operate as designed) and eventually, failure of the geomembrane liner (see Koch et al. 1988; Rowe et al. 1994).

Estrin and Rowe (1997) illustrated the significance of the thickness of the required compacted clay liner and geological barrier by comparing the calculated variation of the concentration in an aquifer beneath a 1000m long landfill (in direction of groundwater flow) for the US EPA (1994) minimum design (1.5mm HDPE geomembrane and 0.6m of compacted clay liner with $k \leq 10^{-9}$ m/s), the design that specified in the draft CEC (1995) directive (geomembrane over 1m of attenuation layer with $k \leq 10^{-9}$ m/s) and the German (TA Siedlungsabfall 1993) system (2.5mm geomembrane over 0.75m compacted clay liner with $k \leq 5 \times 10^{-10}$ m/s over a 3m geological barrier with $k \leq 10^{-7}$ m/s).

They showed that for similar assumed conditions other than the barrier system design, there was a very substantial difference in calculated impact, with the U.S. minimum design reaching the maximum acceptable concentration (MAC) after about 14 years and giving a peak impact almost four times the MAC after about 44 years. The CEC design took 35 years until the MAC was exceeded and gave a peak impact 65% above the MAC at about 70 years. In contrast the German design gave a calculated impact of only 0.2 μg/L at 150 years which is well below the MAC. While the actual numbers depend on the assumed condition, the relative effect of the different barrier systems is evident.

As noted earlier, some landfill regulations postulate a specific post-closure period for after-care. This unfortunately seems to be distorted by some regulatory agencies and proponents to define the period during which the landfill must perform. For example, in Denmark, a 30 year time horizon for active after-care was proposed, it being assumed that a properly designed active environmental protection system will perform for that period prior to being transformed into a passive environmental protection system (Johannessen et al. 1995). In the United States, the US EPA regulations and those of a number of other states specify a 30-year period (as a definitive or minimum period but subject to change by the Director of an approved state) following landfill closure for which aftercare funding is to be provided.

Lee and Jones-Lee (1992) stated that by specifying a 30-year post-closure care period for landfill maintenance, a myth has been created which now threatens groundwater quality protection. The myth is that within the 30-year period after closure, the buried waste will cease to represent a threat to groundwater quality and that therefore the owner/operator can be relieved of the responsibility for monitoring, maintenance and remediation. "This myth has been advanced and cited as fact by landfill applicants and even accepted by regulators in some states" (Lee & Jones-Lee 1992).

While the US EPA (1994) regulations state the regional administrator "may extend" the post-closure care period beyond 30 years, regulatory agencies, boards and staff and consultants on behalf of public and private landfill applicants continue to claim that within 30 years after closure landfills will be stabilized to a sufficient degree such that no further measures are needed to protect groundwater quality from the leachable chemical constituents from the solid wastes. As Lee and Jones-Lee (1992) have written:

> "Some landfill proponents go as far as to claim that after 30 years of post-closure care, the landfill could be converted to a botanical garden or some other highly beneficial use. ...The myth must be recognized as such and dispelled, and the realities of long-term responsibilities associated with landfilling of wastes properly addressed, or landfill companies, agencies and current society will profit from the legacy of groundwater pollution that will be left for the public of future generations to address."

In United Kingdom, the waste management licensing regulations of 1994 resulted in a requirement that the applicant for a landfill approval calculate the costs associated with developing, operating, restoring and maintaining the landfill. The Department of Environment issued a draft compliance cost assessment which was heavily criticized by the National Association of Waste Disposal Contractors, which represents most of the U.K.'s landfill operators. The Association believed that many of the estimates relating to costs were greatly underestimated. Perhaps one of the most critical underestimates was the assumption by the Department of Environment that the landfill would be in such a condition within 30 years that the site could receive a certificate of completion (ie. the licence could be surrendered). However, as pointed out above, a landfill receiving biodegradable wastes will have the potential to cause significant pollution for many decades and perhaps centuries (Merry & Rowan 1994).

Thus, while some jurisdictions recognize the need in a theoretical way to address long-term environmental liabilities and to require engineering measures to prevent these, the reality may be that prescriptive requirements of regulatory agencies and/or stipulated periods for after-care may in practice limit the effective design period to a time frame much less than the contaminating lifespan.

Similar issues can arise with regard to stability in geotechnical design failures. For example, if a regulatory guideline stipulates a certain number of borings should be taken and specifies the type of analysis to be provided, does this necessarily relieve the design professional from legal liability? The answer is most likely "no" as discussed in the following section.

In light of the very significant immediate as well as long-term potential liabilities posed by waste landfills, what is the appropriate legal obligations on landfill designers? Should they be designing to only meet the minimum requirements of regulations (eg. to have a specified configuration)? Should they assume that the engineering devices proposed will only have to work for 30 years after active landfilling has ceased? What if their design is both at and beyond the frontier of professional knowledge? We turn now, therefore, to an examination of these issues.

2.0 Engineer's Civil Liability for Insufficient Designs

Civil courts in the United Kingdom, Canada, the United States and Australia have ruled that professional designers, such as architects and engineers, owe a duty to use reasonable care and skill in undertaking the design of works and undertakings. Failure to utilize the appropriate degree of care and skill in their designs can result in the professional being found liable for compensation not only to the owner of the project but also to third parties who may suffer damage or are injured as a result of that lack of care and skill.

While an engineer's liability may at first appear limited to damages flowing from the terms of a contract between the engineer and the project owner, it is fundamentally important to appreciate that an engineer's civil liability is much broader.

The common law tort or cause of action in negligence allows not only the original project owner but potentially subsequent owners and other persons who may be injured or damaged as a result of the project to sue the engineer for failure to utilize appropriate care and skill in the design of the undertaking.

In 1995, the Supreme Court of Canada unanimously ruled (Winnipeg v. Bird*)* that engineers (as well as contractors, subcontractors and architects) who take part in the design and construction of a building owe a duty to subsequent purchasers of the building if it can be shown that it was foreseeable that failure to take reasonable care in constructing the building would create defects that pose substantial danger to the health and safety of the occupants.

> "... the duty to construct a building according to reasonable standards and without dangerous defects arises independently of the contractual stipulations between the original owner and the contractor because it arises from a duty to create the building safely and not merely according to contractual standards of quality."

The Canadian Supreme Court held that there is no logical reason for allowing a contractor or engineer to rely upon a contract with the original owner to shield him or her from liability to subsequent purchasers arising from a dangerously constructed structure. They endorsed the following proposition:

> "... It is clear that a builder or architect cannot defend a claim in negligence made against him by a third party by saying that he was working under a contract for the owner of the land. He cannot say that the only duty which he owed was the contractual duty to the owner. Likewise he cannot say that the nature of his contractual duties to the owner sets a limit to the duty of care which he owes to third parties."

In 1963, the High Court of Australia ruled (Voli v. Inglewoodshire) the fact that an architect's plans were approved by a government department did not exonerate the architect from civil liability for negligence when a person using the hall was injured as a result of the collapse of the platform in the hall.

The Australian High Court held that neither the terms of the architect's engagement nor the terms of the building contract can operate to discharge the architect from a duty of care to persons who are strangers to those contracts. The architect's duty of care extended to persons who had come to the hall to use it in the ordinary way.

The Court went on to hold that:

> "No doubt the fact that [the architect's] plans were approved by a public authority may, in some cases, be relevant in considering whether or not an architect was in fact negligent; but that is a very different thing from saying that by obtaining approval in this case the architect shed all liability for negligence. The approval of the Public Works Department was required because the building of the hall was to

> be financed in part by a subsidy from the state. The state treasury required that the plans be approved before it would advance the money. But that does not mean that the officers who examined the plans undertook to correct the architect's errors. In his evidence [the architect] said 'As these plans had to go to a final authority I thought that they should find anything that was untoward and that would be pointed out'. It was not an unnatural expectation. But it did not excuse a lack of care."

What of the liability of an engineer where the design is operating at the frontier of knowledge and there is no code of practice upon which the engineer/designer can rely? This issue was addressed by the House of Lords, the highest court of the United Kingdom (Independent Broadcasting Authority v. EMI and BICC). In this case, a 381 m (1250 ft.) high television mast collapsed. It was accepted that the design of such a cylindrical mast was "both at and beyond the frontier of professional knowledge" at that time.

In finding liability on the designers, one of the law lords (judges) said:

> "What is embraced by the duty to exercise reasonable care must always depend on the circumstances of each case. They may call for particular precautions. The graver the foreseeable consequences of failure to take care, the greater the necessity for special circumspection. Those who engage in operations inherently dangerous must take precautions which are not required of persons engaged in the ordinary routine of daily life. The project may be alluring. But the risks of injury to those engaged in it, or to others, or to both, may be so manifest and substantial and their elimination may be so difficult to ensure with reasonable certainty that the only proper course is to abandon the project altogether. Learned counsel for BICC appeared to regard such a defeatist outcome as unthinkable. Yet circumstances can and have at times arisen in which it is plain common sense and any other decision foolhardy. The law requires even pioneers to be prudent."

As Cornes (1994), an English solicitor and engineer put it:

> "It is clear that the judges in this case did not regard the fact that there was no precedent for a design of such a tall cylindrical mast as being any reason for excusing the designers when the mast collapsed. Indeed, the Court took the view that the designer needs to take added precautions in order to discharge his duty of reasonable skill and care in the circumstances of a novel design."

The case is of particular concern for a landfill design that proposes state-of-the-art measures. While courts usually assess negligence by reference to the state-of-the-art at the time of the design and not by later standards that might be different or higher, this case emphasizes liability can occur where the design is novel or at the frontiers of knowledge but nevertheless proves insufficient to prevent foreseeable harm or damage. If the harm is foreseeable and the design may prove to be insufficient, this case suggests it may be prudent (from a civil liability perspective) to not proceed with the project.

That engineers may be potentially liable for state-of-the-art designs which do not succeed is underlined by the American civil liability concept regarding those who engage in or who design ultra-hazardous activities. These design professionals may not be liable simply under the usual standard of care but may be held strictly liable.

As Beck (1995), an American lawyer, puts it:

> "Strict liability may also arise when the design professional is engaged in areas of ultra-hazardous or abnormally dangerous activities. Despite that fact that a design professional neither participates in the ultra-hazardous activity nor is financially responsible for the project, at least one court has held the professional liable. In Doundoulakis v. Town of Hempstead, the court held that all persons who intentionally undertake or join in an abnormally dangerous activity may be held strictly liable for damages to others. The court held that both the contractor and design engineer, as well as the owner, fell within the definition of "undertake or join in". Such a case represents a dangerous precedent for the design professional in blasting, pile driving, dredging, land filling and other similar activities."

In a recent Canadian decision (Homes v. Kellam), a firm of engineers was found to owe a duty of care by implication by provisions in a contract to which it was not a party. In this case, an engineering firm entered into an oral contract with the developer to design a septic system for a new condominium project. The firm designed a mound system for drainage during construction and advised the development manager that the mounds of soil had to be loose in order to drain properly and therefore should not be driven on. There was no discussion of supervision at the time the oral contact was made. A separate fee is customarily charged for supervision and was not included in this case. The contract between the developer and the owner stipulated that the engineers were to inspect the construction at intervals and provide certificates regarding the stages of completion of the project.

The developer ordered the mounds levelled and permitted heavy equipment to drive over them. A drainage problem developed and eventually led to a failure of the sewage system. The plaintiff sued the engineers who designed the system, the contractor responsible for its construction and the surety company that provided the performance bond for the contractor's work. One of the provisions of the contract stipulated that the engineer did not guarantee the contractor's work or undertake to check the quantity and quality of it.

In spite of this provision, and the fact that the engineers were not a party to the contract, the court concluded that the obligation to inspect the project implied an obligation to supervise it. Liability was apportioned equally among the engineers, the developers and the contractor.

2.1 Engineers' Negligence and Engineers' Professional Codes of Conduct

2.1.1 United Kingdom

In the United Kingdom, the Engineering Council regulates 290,000 registered engineers and technicians. The Board of Engineers' Regulation provides for Rules of Conduct regulating the activities and conduct of individuals on the Register as well as Codes of Practice.

S. 1 of the Rules of Conduct provide that:

"A registrant shall at all times and in all respects:

(a) take all reasonable care to avoid creating any danger of death, injury or ill health to any person or damage to property by any act or omission while carrying out his/her work or as a result or consequence of his/her work, save to the extent the creation of such danger is lawfully authorized;
(b) take all reasonable care to protect the working and living environments of himself/herself and others and to ensure the efficient use of materials and resources;
(c) conduct himself/herself so as to safeguard the public interest in matters of safety and health and in a manner consistent with the dignity and reputation of the engineering profession ... ."

Notes for the Guidance of Registrants that pertain to Rule 1 elaborate as follows:

> Rule 1(a) requires a registrant to "take all reasonable care to avoid creating any danger of death, injury or ill health to any person ..."
>
> This in an important requirement which bears upon a wide spectrum of engineering activities. It applies in all faces of engineering work, including investigation, <u>assessment</u>, planning, <u>design</u>, manufacture and construction, operation, maintenance and ultimate disposal [emphasis added]. Throughout, the registrant is advised to record formerly and to report explicitly those potential hazards, malfunctions, defects and failure modes which have been considered and the steps which have been taken to prevent them, and also to mitigate their effects should they be imposed by circumstances beyond the registrant's control eg. by operator errors.
>
> ... An engineer may not always be able to prevent the possibility of disaster arising from human errors on the part of an operator, but he or she still has a professional duty to minimize its probability to a practical minimum by "designing out" as far as is reasonably possible the opportunity for human errors.
>
> Rule 1(b) refers to the need to "... protect the working and living environments". This requires registrants to take steps to avoid pollution, or at least to minimize pollution within the limits of available technology.
>
> ... The hazards referred to in Rules 1(a) and 1(b) are those which are reasonably foreseeable, and which could be predicted with some confidence by a qualified engineer or other well-informed person, using the body of knowledge generally available to the engineering profession at the time of the decision."

The Engineering Council "Nine Point Code of Professional Practice on Environmental Issues " (1993) requires an engineer, among other things to:

- "use the body of knowledge generally available to the engineering profession at the time to anticipate environmental problems that could arise from your professional activities;
- assess projects to ensure that ... wastes can be ... rendered harmless and the discharges are controlled to minimize environmental impact;
- recognize that the impact on the environment might be so great that the project should be avoided altogether;
- be open-minded, seeking to comply fully with the law and regulatory framework but recognizing that you may need to go beyond compliance with the minimum standard which they may represent;
- recognize that your duty to the community takes precedence over personal interests;
- recognize the general duty ... to avoid creating danger or damage or waste of resources;
- accept your duty of care and do whatever is reasonably practical to respond to environmental issues including, where necessary, going beyond specific standards or codes of practice;
- bring major or potential environmental damage to the attention of those in authority in a responsible manner; and
- be aware that environmental review involves uncertainty and develop strategies to cope with this".[emphasis added]

2.1.2 Ontario, Canada

In Ontario, Canada, the engineering profession is governed by provincial legislation and professional Codes of Conduct authorized by statute. The definition of the practice of professional engineering in Ontario consists of a three part proposition: any active designing, composing, evaluating, advising, reporting, directing or supervising; that involves third-party concerns related to life, health, property and the public welfare (including the environment); and that requires the application of engineering principles. Engineering practitioners are expected to exercise their engineering skills in the interests of others, take professional responsibility and be accountable for their work.

In Ontario, it is recognized that engineering is the only profession where the primary responsibility is to the third party, "the public" in the true sense. The Rules of Professional Practice of Professional Engineers Ontario state that "ultimately, this overriding consideration subordinates the engineer's responsibility to the client (the second party)". (PEO, 1988, 1995)

Regulation 941 of the Professional Engineers Act, defines "professional misconduct" to mean:

"(a) negligence (which in turn is defined to mean "an act or omission in the carrying out of the work of a practitioner that constitutes a failure to maintain the standards that a reasonable and prudent practitioner would maintain in the circumstances");

(b) failure to make reasonable provision for the safeguarding of life, health or property of a person who may be affected by the work for which the practitioner is responsible;

(c) failure to act to correct or report a situation that the practitioner believes may endanger the safety or the welfare of the public ... ."

The PEO's "Environmental Guidelines for the Practice of Professional Engineering in Ontario" states that it is the role of the engineer with respect to the environment "to use knowledge not only of engineering, but also of the sciences, law and economics to have proper regard for the environment as it is affected by the engineer's work".

These Guidelines state that in executing their duties:

> "... members are in a unique position to influence the future. It is increasingly necessary for them to assess and communicate the broader implications of designs and activities in their practice of professional engineering with respect to such matters as:
>
> - public welfare;
> - environmental, health and safety impacts;
> - risk minimization and management ; and
> - social, economic and cultural values.
>
> These concerns must be considered by all members who are involved in the analysis and the evaluation of varying technologies, alternatives and cost benefit relationships that affect the environment."

The above appears to be consistent with the PEO "Code of Ethics" which, inter alia, states that an engineering practitioner shall "regard the practitioner's duty to public welfare as paramount".

2.2. American Professional Engineering Guidelines

The American Consulting Engineers Council has published "Professional and Ethical Conduct Guidelines". Adopted in 1980, these guidelines provide the following relevant Rules of Practice:

"1. Consulting engineers shall hold paramount the safety, health and welfare of the public in the performance of their professional duties:

(a) consulting engineers shall at all times recognize that their primary obligations is to protect the safety, health, property and welfare of the public ...

(b) consulting engineers shall approve only engineering work which, to the best of their knowledge and belief, is safe for public health, property and welfare and in conformity with acceptance standards."

3.0 Conclusions

Current engineering theory coupled with experience and contaminant modelling indicates that unless unusual restrictions are placed on waste that will be deposited at landfill sites, the contaminating lifespan of even a small site may be of the order of many decades - and perhaps several hundreds of years for a large site.

Despite the ability of engineers to predict the need to contain leachate for such long periods, many landfill regulatory regimes do not establish a clear obligation to design and monitor for such lengthy periods. Moreover, some regulatory regimes seem to arbitrarily set a very short time (eg. 30 years) as a design standard or for post-closure monitoring. When it can be predicted that leachate will continue to be generated for a long period of time - much longer than any arbitrary design or post-monitoring period - it would appear evident that professional and legal liabilities may accrue for landfill design engineers and landfill owners. Such legal liability may also accrue for regulatory authorities who close their minds to the inadequacy of designs which they approve and licence.

It would appear, based on common law judicial decisions in North America, England and Australia, that engineers who provide designs based on prescriptive or time limited standards could be civilly liable for environmental harm subsequently caused where it could be predicted that simply meeting such standards will not protect the environment.

The exhortation contained in professional engineering codes of practice, such as are found in the United Kingdom and Ontario, Canada, will likely guide judges called upon to decide such issues in the future. Certainly a United Kingdom judge called upon to determine civil liability of a design engineer in respect of damage caused either by a leaking landfill or one which suffered a slope or other geotechnical failure would be guided in determining liability by statements in the Engineering Council's Code of Professional Practice on Environmental Issues that stipulate an engineer must "anticipate environmental problems ...; assess projects to ensure that ... wastes can be ... rendered harmless ...; recognize that you may need to go beyond compliance with the minimum standard ...; do whatever is reasonably practical to respond to environmental issues including, where necessary, going beyond specific standards or codes of practice ... ."

Although less specific, the guidance provided in the Code of Ethics of Professional Engineers Ontario to the effect that a practitioner shall regard the practitioner's duty to the public welfare as paramount and it is professional misconduct "to fail to make reasonable provision for the safeguarding of life, health or property of a person who may be affected by the work for which the practitioner is responsible" would likely influence Ontario judges in concluding that a landfill design engineer must predict as accurately as possible the contaminating lifespan of a landfill and produce a design to prevent contaminants causing impacts both during the operational and reasonably estimated contaminating lifespan.

Judicial decisions from Australia, Canada and the United States underline that engineers involved in such design matters may be held to be strictly liable for the results of such inherently dangerous activities and that if a state-of-the-art design is not likely to safeguard against foreseeable impacts, it may be the course of prudence not to undertake the particular project.

Moreover, analogous judicial decisions would indicate that engineers cannot avoid civil liability by relying on government agency approval of a design which is inadequate to protect the environment.

Despite these conclusions, the authors do not advocate avoiding state-of-the-art landfill design. On the contrary, state-of-the-art contaminant modelling and engineering design are evidently required if environmental impacts from landfilling are to be avoided. This article, however, does emphasize that the precautionary and extra "margin of safety" principles contained in the UK Engineering Council Code of Practice on Environmental Issues should become more universally accepted as guidance for landfill design engineers if they wish to avoid potentially substantial legal liabilities.

4.0 References

Beck, S.P. in R. F. Cushman and G. C. Hedemann (Editors), Architecht and Engineer Liability: Claims against Design Professionals (2nd Edition, New York, 1995) at 139.

Commission of the European Communities, Common Position (ec) No. 496 adopted by the Council on October 6, 1995.

Cornes, D.L., Design Liability in the Construction Industry (4th Edition), (London, 1994) at 85-85.[?]

Department of Water Affairs and Forestry (1994). Minimum Requirements for Waste Disposal by Landfill. Waste Management Series, Vol. 1. Pretoria, South Africa: Department of Water Affairs and Forestry.

Estrin, D. and Rowe, R.K. (1995), Landfill Design and the Regulatory System, Proceedings Fifth International Landfill Symposium, Sardinia, Italy, Vol.3, at 15-26.

Estrin, D. and Rowe, R.K. (1997). Legal Liabilities of Landfill Design Engineers and Regulators, Proceedings, Sardinia '97, Sixth International Landfill Symposium, S. Margherita di Pula, Cagliari, Italy, October, Vol. 5, pp. 65-76.

Homes by Jayman Ltd. v. Kellam Berg Engineering and Surveyors Ltd. (1995) 20 C.L.R. (2d) 161.

Independent Broadcasting Authority v. EMI Electronics Limited and BICC Construction Limited (1980) 14 B.L.R.9.

Johannessen, L. M. (1995). Timeframe for Controlled Leachate Release from Landfills, Proc. Fifth International Landfill Symposium, Sardinia '95 Vol.1, p.35 at 36.

Koch, R. E. Gaube, J. Hessel, C. Gondro and H. Heil 1988. Langzeitfestigkeit von deponiedich-tungsbahnen aus polyethylene, "Mull und Abfall", 8: 348-361.

Lee, G. F. and Jones-Lee, A. (1992). Municipal Landfill Post-Closure Care Funding: The 30-year Post-Closure Care Myth, Report of G. Fred Lee & Associates, El Macero, CA, U.S.A.

Merry, G. and Rowan, S. (1994). The Financial Implications of the 1994 Waste Management Licensing Regulations for U.K. Landfill Operators, Environmental Claims Journal, Vol.7, No. 1, Autumn 1994, p.137 at 140.

MOEE 1994a. Ontario Ministry of Environment Guideline B-7. Incorporation of the reasonable use concept into MOEE groundwater management activities.

MOEE 1994b. Ontario Ministry of Environment Guideline C-13. Engineered Facilities at Landfills that Receive Municipal and Non-hazardous Wastes.

MoE (1998) Ontario Ministry of Environment Landfill Standards - A Guideline on the Regulatory and Approval Requirements for New or Expanding Landfilling Sites, see also Ontario Regulation 232/98.

Professional Engineers Ontario, Professional Practice Guideline, 1988 (revised 1995).

Rowe, R.K. (1991), Contaminant Impact Assessment and the Contaminant Lifespan of Landfills, Canadian Journal of Civil Engineering, Vol. 18, No.2, at 244-253.

Rowe, R.K. (1995), Leachate Characterization for MSW Landfills, Proceedings Fifth International Landfill Symposium, Sardinia, Italy, Vol.2, at 327-344.

Rowe, R.K. (1998), From the Past to the Future of Landfill Engineering through Case Histories, Proceedings, 4th International Conference on Case Histories in Geotechnical Engineering, St. Louis, pp. 145-166.

Rowe, R.K. (1999), Solid Waste Disposal Facilities for Urban Environments, Keynote paper, XI Pan American Conference on Soil Mechanics and Geotechnical Engineering, Brazil.

Rowe, R.K. and Booker, J.R. (1997a), POLLUTE v.6 - 1D Pollutant Migration Through a Non-Homogeneous Soil © 1983, 1990, 1994, 1997. Distributed by GAEA Environmental Engineering Ltd., 44 Canadian Oaks Drive, Whitby Ontario, Canada, Fax (905) 725-9657, e-mail: support@gaea.ca.

Rowe, R.K. and Booker, J.R. (1997b), Recent Advances in Modelling Contaminant Impact Due to Clogging, Keynote paper, 9th International Conference of the Association for Computer Methods and Advances in Geomechanics, Wuhan, China, November, Vol. 1, pp. 43-56.

Rowe, R. K. and Fraser, M. J. (1993a), Service Life of Barrier Systems in the Assessment of Contaminant Impact, Joint CSCE-ASCE National Conference on Environmental Engineering, Montreal, July, Vol. 2, at 1217-1224.

Rowe, R. K. and Fraser, M. J. (1993b), Long-term Behaviour of Engineered Barrier Systems, Proceedings of 4th International Landfill Symposium, Sardinia, Italy, at 397-406.

Rowe, R. K. Golder Associates, Fenco MacLaren and M. M. Dillon (1994). "Evaluation of Service Life of the Engineered Component of Landfills." Submitted to Interim Waste Authority (153 pages).

Rowe, R. K., Hrapovic, L. and Armstrong, M.D. (1996). "Diffusion of Organic Pollutants Through HDPE Geomembrane and Composite Liners and its Influence on Groundwater Quality", Proceedings, 1st European Geosynthetics Conference, Maastricht, October, pp. 737-742.

Rowe, R. K. Quigley, R.M. and Booker, J. R. (1995). "Clayey Barrier Systems for Waste Disposal Facilities", E & FN Spon (Chapman & Hall), London, 390 pp.

TA Siedlungsabfall (1993). Technische Anleitung zur Verwertung, Behandlung und Sonstigen Entsorgung von Siedlungsabfallen, Bundesanzeiger.

TA Siedlungsabfall (1993). German Federal Republic, The Third General Administrative Provision on the Waste Avoidance and Waste Management Act - Technical Instructions on the Recycling, Treatment and Other Management of Wastes from Human Settlements, May 14, 1993 German Gazette No.99, section 10.4.1.

US EPA (1994). Office of the Federal Register, National Archives and Records Administration, Code of Federal Regulations, Vol. 40, "Protection of the Environment", Parts 190-259, Revised as of July 1, 1994.

Voli v. Inglewoodshire Council (1963) 110 C.L.R. 74.

Winnipeg Condominium Corporation No.36 v. Bird Construction (1995) 121 D.L.R. (4^{th}) 193.