CHAPTER 15 TECHNICAL NOTE #6: LINER LEAKAGE VERSUS WASTE CONTAINMENT

August 5, 1993 revision, w/Addendum and w/letter of agreement by Rudolph Bonaparte

Chapter 15 requires that wastes in Class I and II waste management units be completely contained. Containment is to be accomplished by the use of clay and geomembrane liners, used alone or in combination, along with leachate collection and removal systems. Over the recent past, it has become evident that there is, within the State and Regional Boards, a growing contingent of adherents to an idea that the waste containment requirements of Chapter 15 cannot prevent ground water pollution from occurring because "all liners leak". This technote attempts to identify the source of the concept and examine its implications for waste containment.

"ALL LINERS LEAK..."

> ***"...one gets a somewhat different connotation when the statement is quoted in full: 'All liners leak, including geomembranes, but how much?'"***

The "all liners leak" concept seems to have been spread primarily by word-of-mouth and accepted as valid on Intuition alone. Further, it is clear that, at least in some Instances, provisions currently being written into waste discharge requirements are being influenced by this notion. Acceptance of the idea has even progressed to the point that there have been proposals to use it as the basis for rewriting. Chapter 15. Because of the apparent widespread acceptance of the idea and the enormous impact widespread acceptance would have on our current approach to waste management, we have attempted to trace its source and determine whether a change in approach to waste containment is justified.

The most likely source for the "all liners leak" statement appears to be a paper by J. P. Giroud and R. Bonaparte, two of the foremost authorities on liners. Their paper was published in two parts entitled "Leakage through Liners Constructed with Geomembranes--Part I. Geomembrane Liners", (published in Geotextiles and Geomembranes 8[1989] 27-67) and "Leakage through Liners Constructed with Geomembranes--Part II. Composite Liners", (published in Geotextiles and Geomembranes 8 [1989] 71-111). As Giroud has made presentations on liners a seminars attended by State andb Regional Water Board personnel, this paper may well be the most recent source for the idea.

The abstract of the paper contains the statement "All liners leak, . . . " However, one gets a somewhat different connotation when the statement is quoted in full: "All liners leak, including geomembranes, but how much?" The difference in meaning is reenforced within the text of the paper.

> ***"...the authors are deliberate in making a distinction between a liner and a liner system."***

Giroud and Bonaparte present the results of an exhaustive study examining the various aspects of leakage through geomembrane liners and composite liners. The mechanisms of leakage, including permeation through an intact geomembrane as well as the methods for determining how much leakage to expect under worst and best case conditions, are thoroughly discussed. Based on empirical data, the authors conclude that most holes in geomembranes occur at seams and that a realistic frequency of occurrence is one hole per acre. The authors then go on to analyze expected leakage from pin holes to mechanically induced large holes under various conditions of head and liner design options.

HOWEVER...! A careful reading of the text reveals that the authors are deliberate in making a distinction between a liner and a liner system. For example, the authors make the following statement: "Since no liner is impermeable, leakage control cannot result only from liners. Leakage control, however, can result from a combination of liners and drainage layers, performing complementary functions: . . ." Hence, the text makes it clear that it is inaccurate to conclude that liner systems cannot prevent water quality degradation. In fact, the authors conclude just the opposite. In their conclusion at the end of Part II of their paper, the authors make the following statement (emphasis added):

"Using these design liquid depths, Table 12 shows that unitized leakage rates through a well-constructed composite bottom liner can be anywhere between 10^{B4} lphd (10^{B5} gpad) and 0.2 lphd (0.02 gpad), **depending on the coincidence of the wetted portion of the leakage collection layer and the bottom liner geomembrane defects. The probability for such coincidence is small if the number of geomembrane defects is small (e.g., one hole per 4000 m^2 [1 acre]).**

> ***"...typically..., these leakage rate values should result in negligible pollutant discharges to the ground below the waste containment facility."***

"Considering that the concentrations of pollutants in landfill leachates are typically relatively low, these leakage rate values should result in **negligible pollutant discharges to the ground below the waste containment facility.** The situation is improved further when attenuation of pollutants in the compacted soil component of the bottom liner is considered. Thus, it appears that properly designed, constructed, and operated double liner systems with composite bottom liners can provide a very high level of environmental protection."

[Note: One hole per acre of liner is the frequency recommended by the authors for leakage calculations when adequate QA/QC is used. lphd = liters per hectare per day; gpad = gallons per acre per day]

CONSTRUCTION QA/QC AND GOOD DESIGN ESSENTIAL

The authors point out that the conclusions cited above assume good liner design and QA/QC. They also indicate that the performance of liners may be improved under certain conditions not assumed in their analysis. For example, leakage through a geomembrane top liner may be reduced if the geomembrane is overlain or underlain by a fine grained material. On the other hand, performance of a composite liner can be diminished or enhanced depending on whether and what kind of a geotextile is placed beneath the geomembrane.

FULL CONTAINMENT IS STILL A VALID GOAL

The significant point, however, is that although liners leak, the authors demonstrate that well designed, constructed, and inspected liner systems can protect ground water and that any impact will be negligible. Consequently, Giroud and Bonaparte affirm the basic approach to regulation of waste disposal and containment embodied in Chapter 15; although it is apparent that Chapter 15 should be updated in certain areas such as requiring composite liners.

In preparing their paper, Giroud and Bonaparte have presented a wealth of information that should prove valuable to anyone having to evaluate proposals for liner systems. We highly recommend this paper to Regional Water Board staff.

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> ***"...Giroud and Bonaparte reaffirm the basic approach to regulation of waste disposal and containment embodied in Chapter 15..."***

DR. BONAPARTE CONCURS

The discussion in Technical Note #6, as originally issued, was based on two papers entitled "Leakage through Liners Constructed with Geomembranes" Parts I and II published in 1989 and authored by J.P. Giroud and R. Bonaparte. These paper presented the results of a study on leakage through geomembrane liners. Dr. Bonaparte had an opportunity to review Technical Note #6 and was kind enough to communicate his concurrence with the discussion (**Attachment**).

Liquid in the LCRS below a composite liner does not always mean a release has occurred.

NEW PAPERS

With his letter, Dr. Bonaparte included two more recent papers which he coauthored with Dr. Giroud and others. These papers present the results of follow-up studies that complement the 1989 studies.

The first paper is entitled "Rate of Leakage through a Composite Liner due to Geomembrane Defects" by J.P. Giroud, K. Badu-Tweneboah, and R. Bonaparte published in Geotextiles and Geomembranes 11 (1992) 1-28. This paper expands on the work reported in the 1989 papers by including evaluation of leakage through defects in geomembranes subjected to large hydraulic headsXsuch as would be encountered in impoundments and damsXand by introducing a method for evaluating the rate of leakage through geomembrane defects that is applicable to long defects such as one could expect to find in defective geomembrane seams. The method is presented in the form of equations, tables, and charts that can be used for defects that range from small holes to long cracks.

The second paper is entitled "Field Behavior of Double-Liner Systems" by Rudolph Bonaparte A.M. and Beth A. Gross A.M. published in Proceedings of Symposium/GT Div/ASCE, ASCE National Convention, San Francisco, CA, November 6-7, 1990. This paper presents the results of a field study in which the authors investigated the quantity and origins of flow in the leachate collection systems of 30 landfills and surface impoundments constructed with double liner systems. The information gathered in this study provides a check on the assumptions and conclusions reached in the 1989 Giroud and Bonaparte studies.

REVISED CONCLUSIONS

The following are the conclusions reached by Bonaparte and Gross [1990], based on their field data. Of particular interest are their conclusions regarding sources, other than leakage through the top liner, of the liquid found in the leachate collection systems and the fact that the estimates of expected leakage through top liners of surface impoundments and the estimates of permeation through intact geomembranes assumed in the 1989 papers appear to have been overestimated.

- Leakage detection layers in double-liner systems frequently exhibit flows that may be due to leakage through the top liner or to other sources such as construction water, consolidation water, and infiltration water. Leakage detection layer flow rate data presented in Table A-3 and A-6, for landfills and surface impoundments, respectively, demonstrate the frequencies of occurrence and rates of flows from these sources.

- All of the double-lined landfill cells reviewed in this study that were constructed with geomembrane top liners appear to have exhibited top liner leakage. Based on the available data, the flow rates attributable to top liner leakage at active cells that had geomembrane top liners and CQA programs were frequently less than 200 lphd; the maximum measured flow rates, which were often associated with increased flow from the leachate collection layers shortly after storm events, were typically several times the average flow rates.

- Very little leakage detection layer flow was observed at double-lined surface impoundment ponds constructed with geomembrane top liners. The low flows may be attributed to the use of ponding tests and/or leak location surveys to identify geomembrane defects and allow their repair.

- The leakage calculation method presented by Giroud and Bonaparte [1989a,b (Parts I and II of their 1989 paper)] provided a reasonable upper bound of the observed flow rates attributable to top liner leakage at the Group I and II landfills. However, the method greatly overpredicted the liner leakage rates at the

Group I and II surface impoundments.

It appears that the primary reason for this overprediction is that the number and/or frequency of geomembrane holes assumed by Giroud and Bonaparte are too high. The surface impoundments described in this study were subjected to ponding tests and/or leak location surveys as part of their CQA programs. The use of ponding tests and/or leak location surveys reduces the frequency and/or size of geomembrane holes below those assumed by Giroud and Bonaparte. Furthermore, the absence of any flow from most of the Group I and II surface impoundments suggests that the rates of water permeation through intact geomembranes reported by Giroud and Bonaparte [1989] for large liquid head conditions are too high.

- The double-lined landfills and surface impoundments in this study having a layer of compacted clay as the soil component of a composite top liner almost always exhibited flows due to consolidation water. Measured flow rates attributable to consolidation water were in the range of 20 to 840 lphd. Only very small flows were observed from the leakage detection layers of cells where the soil component of the composite top liner was a prefabricated geotextile-bentonite mat.

- The calculation methods presented by Gross *et al.* [1990] for estimating consolidation water and construction water flow rates appear reasonable for facilities reported in this study.

- Based on the data in this study, an action leakage rate of 50 lphd is too restrictive and presents a performance standard that, if promulgated by USEPA, frequently will not be met by facilities that were constructed to present standards with rigorous third-party CQA programs. An action leakage rate of 200 lphd appears to be reasonable for landfills that have been constructed using rigorous third-party CQA programs. Even at this level, the action leakage rate may be temporarily exceeded at the start of operation of a facility, due to drainage of construction water. For surface impoundments with geomembrane top liners, ponding tests and/or leak location surveys will be required to meet a leakage detection layer performance standard of 200 lphd.

- The data presented in Tables A-3 and A-6 suggest that the double-liner systems evaluated in this study have performed well. Leakage rates through the top liners have been low or negligible in most cases and the leakage detection layers appear to be functioning effectively.

The content of both of these new papers are directly relevant to work being done in the Regions and should be useful to State and Regional Water Board staffs.