

# **J.P. Giroud**

## **Statement of Qualifications**

### **Liquid Impoundments**

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Dr. J.P. Giroud has 30 years of experience with liquid impoundments (also called “surface impoundments”, “ponds’, lagoons”, “reservoirs”). He is certainly one of the engineers who had the deepest influence on the design of liquid impoundments. Dr. Giroud, considered the “father of geosynthetic liner systems” by *Waste Age* magazine, developed many of the methods used for the design of geosynthetic liner systems for liquid impoundments such as: evaluation of leakage through liners, leakage detection system design, stability analysis of liner systems on slopes, liner anchor trench design, design of liner systems over weak foundations. He received the International Geosynthetics Society Award for the design method he developed for the evaluation of leakage through liners. As indicated by Richardson (*GFR*, March 1999, p. 21) “*Understanding and properly implementing the basic leakage equations developed by Giroud is key to the proper design of surface impoundments. [ . . . ] Rarely does a single engineer creatively affect a particular application as much as he has.*” The design methods developed by Dr. Giroud for liner systems have been published in more than 60 papers and are used worldwide.

Dr. Giroud has extensive experience in liner system design. He has designed, or conducted a performance analysis for, more than 100 liner systems. Dr. Giroud has originated innovative applications such as: the protection of geomembranes using geotextiles (1971), the double geomembrane liner system with granular leakage detection layer (1974), and the double geomembrane liner system with geosynthetic leakage detection layer, using a geonet (1980). He played a key role in the development of the use of geonets for leakage detection. Dr. Giroud is also recognized for his pioneering work in construction quality assurance of liner systems.

Dr. Giroud has unique experience in performing forensic analyses and performance evaluation of liquid impoundments. He has performed more than 30 of these forensic analyses and performance evaluations, and has presented several keynote lectures on the subject. Also, Dr. Giroud is currently working on a 1000-page book on the subject.

Dr. Giroud has actively participated in the development of regulations for liners. He was a consultant to the USEPA on the agency’s Liner Leak Detection Rule, Double-Liner Rule, and the related technical background documents. He also was a member of the task force developing the landfill rules for the Florida Department of Environmental Protection; his role in the task force was to develop a rationale for the liner system regulations. Dr. Giroud has also been asked on numerous occasions to develop “equivalency demonstrations” to

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show that an alternate solution for a liner system is equivalent to the liner system prescribed by regulations. He has written several papers on liner system comparison and equivalency demonstrations.

Dr. Giroud has extensive experience in teaching courses on liner systems: he has taught more than 50 courses on this subject for the USEPA, the Florida Department of Environmental Protection, the U.S. Bureau of Reclamation, the Association of State Dam Safety Officials, the Industrial Fabrics Association International, the Swedish Geotechnical Institute, and many other organizations. Dr. Giroud has been invited to present the prestigious Mercer Lecture series in 2005. The lecture, on “Contribution of geosynthetics to the geotechnical aspects of waste and liquid containment”, will be presented in Japan, in South Africa, and at the opening session of the International Landfill Symposium, in Sardinia.

Dr. Giroud’s experience in the field of liquid impoundments encompasses: (i) development of design methods and innovative designs for liquid impoundments; (ii) design of numerous liner systems for liquid impoundments; (iii) failure investigations and performance evaluations of liquid impoundments; (iv) technical assistance to the US EPA and other regulatory agencies; (v) construction quality assurance for liner systems for liquid impoundments; and (vi) training courses. Dr. Giroud’s experience in these six areas is described below.

## **Design Methods and Innovative Practice on Liquid Impoundments**

As a researcher, Dr. Giroud developed many methods of design for liner systems used in liquid impoundments:

- Evaluation of rate of leakage through liner systems.
- Design of drainage layers for leakage detection.
- Design method and charts for the determination of stresses and strains in geosynthetics caused by a localized subsidence of the supporting ground.
- Stability and differential movements of earth and concrete covers on geomembrane - geotextile - geonet systems.
- Design of structures connected with geomembrane liners.
- Uplift of geomembrane by wind.

Dr. Giroud is the principal author of three special issues of *Geosynthetics International*: “Design of Geomembrane Applications” (1995, 285 pages), “Control of Liquid Migration Using Geosynthetics Liner Systems” (1997, 251 pages), and “Liquid Collection Systems” (2000, 320 pages). These three volumes can be considered as the state of the art of liner system

design. In particular, these three volumes present the detailed methodology for liner system design and performance evaluation, and for the rational comparison of liner systems.

As a practicing engineer, Dr. Giroud developed the double liner concept, which he presented in a paper in 1973. He used a double liner in a project constructed in 1974, which has performed well ever since. This was the first double geomembrane liner ever constructed. Applications related to liner systems originated by Dr. Giroud include:

- First use of a geotextile associated with a geomembrane (1971).
- First use of a double geomembrane liner (1974).
- First use of a geonet associated with two geomembranes to form an entirely geosynthetic double liner system (1980).

In addition, Dr. Giroud has been instrumental in the acceptance of geonets and geocomposite drainage systems for leakage detection in the United States and in the acceptance of this technique by the U.S. Environmental Protection Agency (EPA) (1984-1985).

## **Design of Liquid Impoundments with Geosynthetic Liner Systems**

Dr. Giroud has designed liquid impoundments with geosynthetics since 1971, including a wide variety of projects with geosynthetic liner systems, such as: reservoirs for water and chemicals, waste water lagoons, evaporation ponds, brine ponds with floating covers, underground cavities, and secondary liner containment for underground fuel tanks. Typical projects include:

- Technical assistance for the design of a series of water reservoirs where geotextiles and geomembrane liners were associated for the first time (1971).
- Evaluation of effects of geomembrane liner uplift by wind, Pontho, Reunion Island (1972).
- Site investigations and design of Rhone-Progil Reservoir, which is a large industrial water reservoir on a steep slope, in Pont de Claix, France; this project included the first double geomembrane liner with intermediate drainage to detect leakage (1974).
- Site evaluation and liner design at Ain Djasser Irrigation Pond, Algeria (1974).
- Design of pond lining and dike reinforcement at Beaumont, Texas (1978-79).
- Review of liner system design for two evaporation ponds for a uranium processing plant, Narbonne, France (1980).

- Design of underground water reservoir liner system for the Proton Decay Experiment, Lake Erie, Ohio; this project included the first use of a geonet leakage detection layer between two geomembrane liners and was exceptionally difficult because of the shape, size and location of the cavity, which was excavated in a salt mine (1981).
- Conceptual and detailed design of a geomembrane/geotextile lined and reinforced large evaporation pond for sulfuric acid, Arlit, Niger (1981).
- Review of design of geomembrane-lined reservoirs with floating cover in Kirkuk, Iraq (1982).
- Conceptual design, review of detailed design, and quality control of installation of three reservoirs, including one with a double liner, in Aqaba, Jordan (1983-84).
- Conceptual design and detailed design of the lining system for a one million square meter (10 million square feet) reservoir, La Muela, Spain (1984-85).
- Review of conceptual design of a series of geomembrane-lined lagoons in Page, Arizona (1984-85).
- Review of design of a large dam and water reservoir for a pump-storage station, Kuriyama, Japan (1985).
- Design of the lining system for a large water reservoir, Djebel Zioua, Algeria (1985-86).
- Review of design of a hazardous liquid impoundment for a paper mill, Canton, North Carolina (1986).
- Review of the conceptual design of a large reservoir in Salt Lake City, Utah (1986).
- Analysis of the behavior of the lining system of an existing pond and recommendations for a new pond for a gold mine, near Nye, Montana (1987).
- Conceptual design for an ash pond for a utility company, Binghamton, New York (1988).
- Assistance for geomembrane selection and specifications for a lined potable water reservoir with floating cover, Nassau, Bahamas (1988).
- Conceptual design for a geomembrane-lined ashpond for a utility company, Binghamton, New York (1988).
- Review of construction quality audit for mine heap leach pad and associated ponds, Lawrence County, South Dakota (1988).
- Conceptual design of the rehabilitation of brine ponds using geomembrane liners, Fresno, California (1989).
- Technical assistance for the selection and specification of geomembrane for a large water reservoir in Ismailia, Egypt (1993).
- Design assistance for very large ponds lined with a geomembrane in Wilmington, North Carolina (1994).
- Design assistance for evaluation of wind effect on geomembrane-lined pond, Paris Airport, France (1995).
- Evaluation of the action of PCBs on HDPE geomembranes (1995).
- Liner system comparison, Tesoro tank farms, Alaska (1996).

- Design review for geomembrane-lined ponds, Anne Arundel County, Maryland, USA (1997).
- Design assistance for pond liner associated with above ground tanks, for BP, Algeria (1997).
- Design assistance for two large water reservoirs for pump-storage station, Afourer, Morocco (2003).
- Design review for a large geomembrane-lined water reservoir, Newark, Delaware (2004-2005).

As a result of his recognized expertise, Dr. Giroud has been involved in the design or the performance evaluation of liquid impoundments incorporating liner systems installed in unusual conditions, such as: liner systems installed on vertical concrete walls; liner systems installed in a very large underground mine cavity; liner systems located in extreme climates; etc.

## **Performance Evaluations and Forensic Analyses**

Dr. Giroud has extensive experience in performing forensic analyses and providing expert testimony. He has performed approximately fifty forensic analyses and performance evaluations. His first participation in a court case dates back to 1962. The first failure analysis of a geomembrane lined liquid impoundment by Dr. Giroud dates back to 1972. Since then, Dr. Giroud has investigated more than 30 failures of structures incorporating geosynthetics, including a number of liquid impoundments.

With his in-depth knowledge of geotechnical engineering and geosynthetics, Dr. Giroud is considered one of the foremost international authorities on the performance of geotechnical structures incorporating geosynthetics: keynote lecturer on geosynthetic failures at the conference “*Foundation of Success: Lessons Learned from Failures*” organized by the Colorado Section of the American Society of Civil Engineers (ASCE) (1992); keynote speaker on “*Lessons Learned from Failures Associated with Geosynthetics*” at the French Conference on Geosynthetics in Tours (France, 1993); keynote lecturer on “*Lessons Learned from Failures Associated with Geosynthetics*” at Geosynthetics ’99, the bi-annual conference of the North American Geosynthetics Society, held in Boston, USA, and author of the 66-page paper on the subject in the proceedings of the conference; keynote lecturer on “*Lessons Learned from Failures and Successes Associated with Geosynthetics*” at “Eurogeo 2”, the Second European Conference on Geosynthetics, held in Bologna, Italy, in 2000, and author of the 42-page paper on the subject in the proceedings of the conference. Also, Dr. Giroud is a frequently invited lecturer on the performance of structures incorporating geosynthetics and lessons learned from failures: “Kersten Lecture”, University of Minnesota/Minnesota Geotechnical Society, 1999; “Jack Hilf Memorial Lecture” The University of Colorado/US Bureau of Reclamation, 1999; and “The Nete Lecture”, Three Gorges Dam, China, 2000.

Dr. Giroud is currently working on a 1000-page book on failures associated with geosynthetics. In February 2005, Dr. Giroud presented the prestigious Vienna Terzaghi Lecture on “Geosynthetics engineering: successes, failures and lessons learned”.

Dr. Giroud has worked in many parts of the world. In particular, he has performed forensic analyses or performance evaluations on liner systems in various countries, such as Argentina, Jordan, Niger, France, the United States, etc. Furthermore, as President of the International Geosynthetics Society, or on other occasions, Dr. Giroud has chaired, or participated in, numerous international meetings and panels. As a result of this international experience, Dr. Giroud feels comfortable working everywhere in the world, and his authority and arbitration skills are instrumental in difficult situations, in particular when international participants are involved. Also, as a result of the work he has done for regulatory agencies (preparation of background documents to support regulations, report and manual preparation, training courses), Dr. Giroud is highly respected by representatives of governmental agencies, which is helpful in case problems linked to the performance of regulated facilities, such as liquid impoundments for leachate and industrial liquids.

Examples of liner system performance evaluation and forensic analyses include liquid impoundments lined with geomembranes such as butyl rubber, PVC, HDPE, CSPE (Hypalon), CPE, and bituminous geomembranes. Typical investigations performed by Dr. Giroud include:

- Investigation of failure and design of remedial measures for a geomembrane-lined reservoir subjected to intensive wind and wave action, Aire sur la Lys, France (1972).
- Investigation of failure and design of remedial measures for a geomembrane-lined reservoir on karstic terrain, Tancarville, France (1972).
- Investigation of failure (uplift by liquid and gas, defective seams) of two brine reservoirs in Hauterives, France (1978).
- Analysis of geotextile filter failure in a pond, Camacari, Brazil (1979).
- Forensic analysis of geomembrane failure (subsidence) and expert testimony, Avoriaz dam and reservoir, France (1980).
- Investigation of the malfunctioning (deterioration, uplifting, subsidence) of geomembrane-lined reservoirs for sulfuric acid and remedial measures, Arlit, Niger (1981).
- Investigation of failure (uplift by gas) of a manure pond in Groisy, France (1982).
- Investigation of failure (subsidence, deterioration) of a geomembrane-lined evaporating pond containing phosphoric acid, Aqaba, Jordan (1983).
- Experimental study of the aging of geomembranes exposed during four years in the Sahara desert, Niger (1983).
- Forensic analysis (surface cracking, deterioration) of geomembrane-lined waste water treatment ponds, Mountain Home, Idaho (1984).
- Review of performance of two lined reservoirs, Essex Junction, Vermont (1985).

- Investigation of malfunctioning of four reservoirs for sulfuric acid in San Onofre, California (1985).
- Analysis of the causes of malfunctioning (leakage, uplifting) of six geomembrane-lined concrete reservoir in Long Beach, California (1986).
- Analysis of the behavior of the lining system for concrete vaults to store low level nuclear waste placed in a liquid state, in Hanford, Washington (1987).
- Analysis of leakage rates of three lined ponds for a gold mine, Chesterfield County, South Carolina (1988).
- Analysis of the failure (stress cracking) of an installed geomembrane liner exposed to extremely cold temperatures, Delta, Utah (1989).
- Analysis of the failure of a geomembrane liner in a large waste water reservoir, Canton, Mississippi (1990).
- Analysis of failures of geomembrane seams and definition of remedial measures at a uranium mine pond, Blanding, Utah (1991).
- Preparation of remedial measures for a pond in Soldotna, Alaska (1993).
- Review of the analysis of the failure of a geomembrane liner in two wastewater lagoons, Ridgely, Maryland (1998).
- Performance evaluation of 16 evaporation ponds in Salar, Argentina (1998).
- Performance evaluation of two lagoons for deicing fluid, Dayton Aiport, Ohio (1999).

Dr. Giroud has also prepared:

- a report on the performance of geomembrane liners as part of a contract between Battelle Northwest Institute and the Nuclear Regulatory Commission (1982); and
- a report on “Assessment of Synthetic Membrane Performance at Waste Disposal Facilities” for the USEPA (1984).

Last, but not least, Dr. Giroud is working on a 1000-page book on “Lessons Learned from Failures Associated with Geosynthetics”, which will be the most comprehensive book on failures of geotechnical structures ever published, with more than 100 cases analyzed in detail, including many case histories of liquid impoundment failures.

Dr. Giroud has personal experience in providing expert testimony at administrative and judicial hearings. Dr. Giroud has also presented project descriptions and design concepts at public information meetings. Many of these hearings and meetings were related to liner systems.

## **Experience with US EPA and Regulatory Agencies**

Dr. Giroud has worked extensively with the US Environmental Protection Agency (US EPA) and other regulatory agencies regarding liquid impoundments, as indicated below:

- Report on the selection and installation of geomembranes to line experimental solar ponds, for the Solar Energy Research Institute, SERI (1981).
- Report on the performance of geomembrane liners as part of a contract between Battelle Northwest Institute and the Nuclear Regulatory Commission (1982).
- Preparation of “Guide Specifications for Geomembrane Installation in Hazardous Waste Disposal Facilities”, as part of a contract between the EPA and TRW (1983).
- Preparation of “Assessment of Synthetic Membrane Performance at Waste Disposal Facilities” for the US EPA (1984).
- Review of the “Permit Writer's Guidance Manual for Hazardous Waste Land Treatment, Storage, and Disposal Facilities”, as part of a contract between the EPA and GCA (1984).
- Participation in meetings with the US EPA for the revision of leachate collection and leakage detection rules to incorporate synthetic drainage layers (1984-1985).
- Review of “Construction Quality Assurance for Hazardous Waste Land Disposal Facilities”, as part of a contract between the EPA and the Research Triangle Institute (1985).
- Review of “Background Document: Bottom Liner Performance in Double-Lined Landfills and Surface Impoundments”, EPA/530-SW-87-013, April 1987, 301 p., Subcontract through NUS.
- Preparation (co-author) of the “Background Document: Proposed Liner and Leak Detection Rule”, EPA/530-SW-87-015, May 1987, 526 p., Subcontract through NUS.
- Review of “Background Document: Comparative Performance of Single-Liner and Double-Liner Systems”, October 1987, 76 p., Subcontract through NUS.
- Review of “Action Leakage Rates for Leak Detection Systems, Supplemental Background Document for the Final Double Liners and Leak Detection Systems Rule for Hazardous Waste Landfills, Waste Piles, and Surface Impoundments”, for the US EPA (1992).
- Participation in the preparation of the national guidelines on geomembrane construction quality assurance for the French environmental regulatory agency, ADEME (1996).

Also, Dr. Giroud has been a peer reviewer of the work by the GeoSyntec Consultants team that evaluated under contract for the US EPA monitoring data from more than a hundred landfill cells or liquid impoundments (1989-1997).

As a result of this work for the USEPA, Dr. Giroud is in a unique position to cooperate with regulatory agencies if this appears necessary for permit application or performance evaluation.

Dr. Giroud has also worked for the US EPA on geomembrane liner construction quality assurance and on liner performance evaluation, as mentioned below.

## **Quality Assurance of Liner System Installation**

Dr. Giroud became involved in quality assurance of liner system installation as early as 1980. The report “*Guide Specifications for Geomembrane Installation in Hazardous Waste Disposal Facilities*”, prepared by Giroud and Kastman in 1982 and published as part of a state-of-the-art report for the EPA, laid the foundations for modern geosynthetic quality assurance. Dr. Giroud also prepared a general quality assurance manual for the installation of geosynthetic liner systems for a major US waste management firm. Finally, Dr. Giroud was instrumental in forming, at GeoSyntec Consultants, a Quality Assurance Division which, from 1984 on, has been involved in more than 500 projects, totaling approximately 80 million square meters (875 million square feet) of geosynthetics.

Typical liquid impoundments where Dr. Giroud was personally involved in quality assurance field work include:

- Two evaporation ponds with a butyl rubber liner for a uranium processing plant, Narbonne, France (1980).
- A large evaporation pond for sulfuric acid, Arlit, Niger (1981).
- Geomembrane-lined brine reservoirs with floating covers in Kirkuk, Iraq (1982).
- A double-lined storage pond and two evaporation ponds for phosphoric acid, Aqaba, Jordan (1984).
- Tailing dam with a single geomembrane liner, Summitville, Colorado (1986).
- A very large gypsum pond in Rock Springs, Wyoming (1986).

## **Training Courses on Liquid Impoundments**

Dr. Giroud has taught training courses on liner systems for the personnel of the EPA and state regulatory agencies, including “Permit Writer's Training Seminar on Synthetic Liners”, presented to: EPA Region 4 in Atlanta, EPA Region 10 in Sacramento, EPA Region 3 in Philadelphia, EPA Region 2 in New York, and EPA Region 6 in Dallas (1985); EPA Region 7 in Kansas City, and EPA Region 5 in Chicago (1986).

In addition, Dr. Giroud has taught short courses or presented seminars as follows:

- Seminar on geomembrane liners for Envirosafe, a waste management company, Horsham, Pennsylvania (1982).
- Seminars on geomembrane liners for IBM, Austin, Texas (1985).
- Short course on geomembrane liners organized by the Industrial Fabrics Association International (IFAI), Cincinnati, Ohio (1985), and New Orleans, Louisiana (1987).
- Seminar on geosynthetic liner systems for Waste Management Inc., Chicago (1986, 1988).
- Five short courses on geosynthetic liner systems for the University of Wisconsin, Madison (1986, 1987, and 1988).
- Short courses on geosynthetic liner systems for the University of Lehigh (1986, 1987, 1988).
- Short course on geosynthetic liner systems for the U.S. Bureau of Reclamation, Denver, Colorado (1988).
- Short courses on liquid impoundments for the IFAI (1994).

## **Selected References of Publications Related to Liquid Impoundments**

### **Publications on Design Methods**

- Giroud, J.P., 1977, "Conception de l'etancheite des ouvrages hydrauliques par geomembranes", *Proceedings of the First International Symposium on Plastic and Rubber Waterproofing in Civil Engineering*, Vol. 1, Session 3, Paper 13, Liege, Belgium, Jun 1977, (in French), pp. III 13.1-III 13.17.
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- Bonaparte, R., Giroud, J.P., Wallace, R.B., Ah-Line, C., and Prillaman, J.G., 1987, "*Background Document on Proposed Liner and Leak Detection Rule*", EPA/530-SW-87-015, U.S. Environmental Protection Agency, Washington,
- Giroud, J.P. and Beech, J.F., 1989, "Stability of Soil Layers on Geosynthetic Lining Systems", *Proceedings of Geosynthetics '89*, Vol. 1, IFAI, San Diego, CA, USA, February 1989, pp. 35-46.
- Giroud, J.P. and Bonaparte, R., 1989, "Leakage through Liners Constructed with Geomembranes, Part I: Geomembrane Liners", *Geotextiles and Geomembranes*, Vol. 8, No. 1, 1989, pp. 27-67.
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## **Publications on Construction and Construction Quality Assurance**

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