

## PC WINDOWS FINITE ELEMENT MODELING OF LANDFILL GAS FLOW

Stephen R. Mull, Robert J. Lang, Samuel A. Vigil, Harold Cota  
Civil & Environmental Engineering Department  
California Polytechnic State University  
San Luis Obispo

### ABSTRACT

A two dimensional demonstration program, GAS, has been developed for the solution of landfill gas (LFG) flow problems on a personal computer (PC). The program combines a Windows™ graphical user interface, object oriented programming (OOP) techniques, and finite element modeling (FEM) to demonstrate the practicality of performing LFG flow modeling on the PC.

GAS is demonstrated on a sample LFG problem consisting of a landfill, one gas extraction well, the landfill liner, cap, and surrounding soil. Analyses of the program results are performed for successively finer grid resolutions. Element flux imbalance, execution time, and required memory are characterized as a function of grid resolution.

### INTRODUCTION

LFG is generated in a municipal landfill as a result of biological decay of the organic components of solid waste. The principal components of LFG are methane and carbon dioxide. Other trace gases, some toxic, make up the balance. Generation of LFG within any closed cell of a landfill varies with time, available moisture, and biodegradable organics present (Tchobanoglous et al, 1993). Simulation of LFG flow is important because:

- 1) LFG migration off-site can pose a public health risk.
- 2) LFG diffusion from a landfill cap can be a significant source of air pollution.
- 3) LFG can be burned to generate economically significant amounts of electricity.

Flow of the generated gases, principally due to convection, may be modeled by the following mass continuity partial differential equation (PDE), where  $\Phi$  is landfill porosity,  $C$  is gas

concentration,  $t$  is time,  $\rho$  is gas density,  $\bar{v}$  is the gas velocity vector, and  $G$  is the gas generation rate.

$$\Phi \frac{\partial C}{\partial t} = -\bar{\nabla} \cdot (\rho \bar{v}) + G \quad (1)$$

Analytic and finite difference solutions of this equation have been developed (Young, 1989), (Sumadhu, 1995), however, they are limited. Analytic solutions are constrained to the separate treatment of gas flow within any homogeneous portion of the landfill. These solutions cannot simultaneously describe the generation and flow of gas inside a landfill, its migration through semi-permeable liners, and its dispersion throughout soil surrounding the landfill. Analytic solutions are also limited by the assumptions underlying their formulation and those of their boundary conditions.

Finite difference solutions are limited by the typical requirement for a dense, evenly spaced grid. This spacing requirement limits the geometric flexibility of any general purpose model using finite difference formulations. For a given degree of accuracy, the modeling and computing resources required by finite difference techniques often limit the numerical computations to a workstation or mainframe computer.

### FINITE ELEMENT MODELING ON THE PC

To overcome the limitations of analytic and finite difference methodologies, finite element solution methods have been proposed to model landfill gas movement (Lang & Tchobanoglous, 1989b). FEM methods do not need uniform grid spacing, and physical properties can be defined on an element by element basis. Further, by implementing FEM processing using