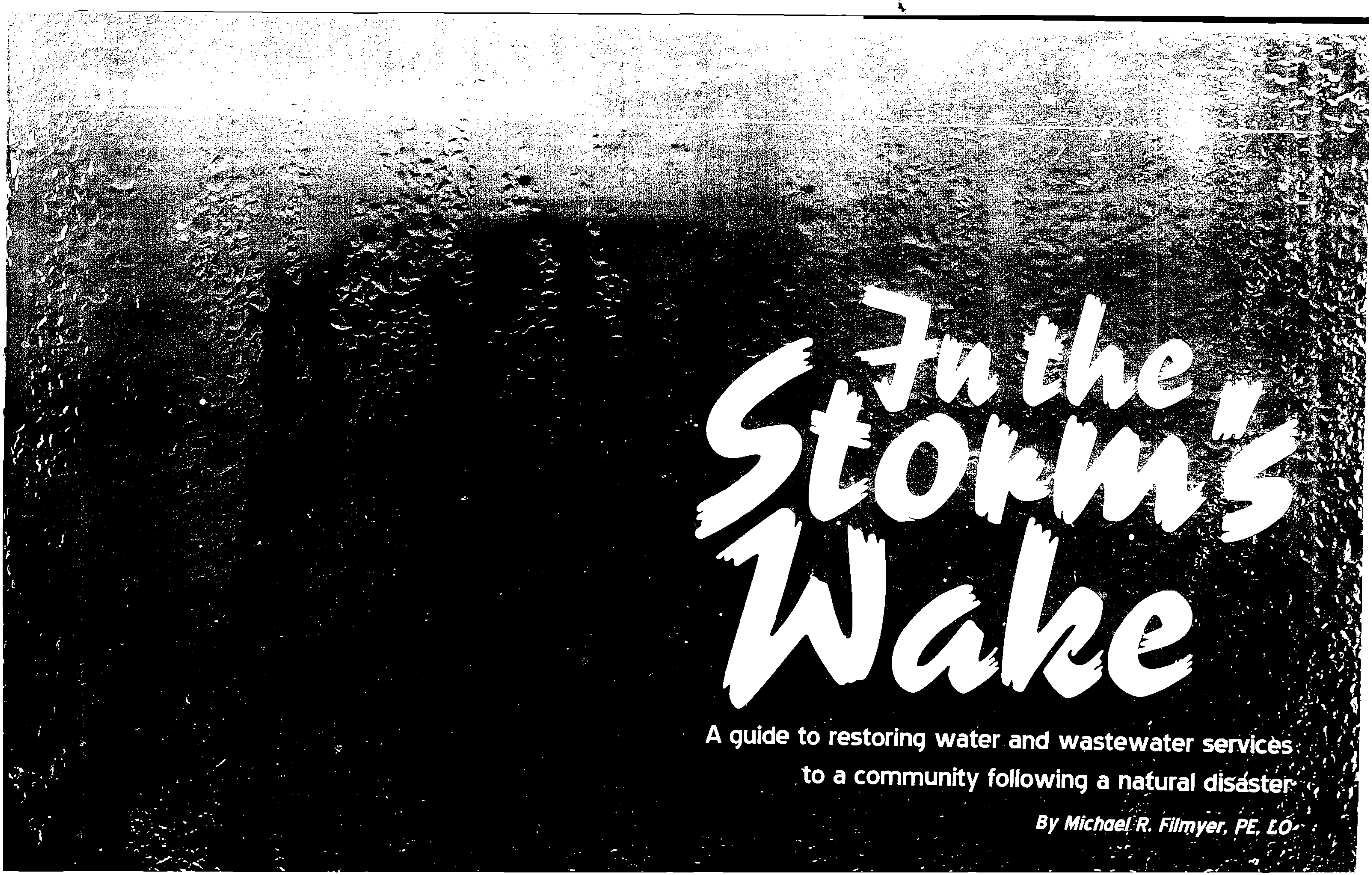


In the Storm's Wake

A guide to restoring water and wastewater services to a community following a natural disaster

By Michael R. Filmyer, PE, LO

When a natural disaster such as a hurricane or a major flood strikes, a typical first response is to evacuate quickly. Upon return and property review, the next priority is to find clean water to drink and use for washing and cleaning. The need for a functioning sanitary sewer system is of equal importance to bring a community back to normal functioning capacity. Communities also need to address safe disposal methods for wastewater generated from recovery efforts. These are just some of the many issues that have been brought to the fore because of the recent increase in natural disasters and flooding activities. This increase has prompted urban low-land communities with community water and sewer systems to incorporate more detailed water and wastewater restoration plans into their disaster-response efforts.

Central Water System Start-up Procedures

Central water systems are built in the ground away from view and constructed just under the frost line for most communities. This is a plus for starting up a system. After a disaster, it is likely that most, if not all, of the pipes will be full of water (potable or not) upon a restart of the system. When putting together a restoration plan, it is important to include the following key start-up procedures:

- Maintain communication with emergency coordinators, the public, and the state environmental agencies. Continue to issue "boil water" advisories until the system is fully functional;
- Make provisions to provide the public with an emergency source of drinkable water in areas where the systems do not have the ability to provide water;
- Inspect the water system's treatment and distribution facilities so that operators can assess immediate needs. Although it is not necessary to wait until all of the water recedes from the flooded areas, it is desirable. This step helps you seek out leaks or broken water lines from sink holes or wash-out areas left by the flooding. Although tenuous, your efforts may vary depending upon the size of your system and the accuracy of water maps. Yet, with experienced crews, you can achieve your objectives;
- Search out buildings or homes with heavy structural or foundational damage. Temporarily shut off water service from the street to avoid any further water damage due to broken pipes inside the structures. An organized program and good records are essential to this effort during and after the shut-off efforts;
- Once identified, quickly repair or isolate breaks until permanent repairs can be made to the facilities;
- Once the distribution system has been isolated and returned to working condition, rapidly flush the system. Your crews must take a fast-paced approach to their regular program of flushing and perform it as quickly as possible. Take grab samples from the flushing points and test them immediately. Levels of disinfection chemicals, such as chlorine, may have to be adjusted to higher than normal until the system is working properly. Maintain a chlorine residual level of 2.0 (milligrams per liter) mg/l or above in the flushed mains.
- Continue the program until operators feel comfortable that the distribution system is working adequately and safely. Obviously, a boil advisory needs to be in effect until the operators feel comfortable that the treatment and distribution systems are working properly.

Mechanical Component

The mechanical component of your system could involve more resources. Most water systems have booster stations and/or chemical-feed facilities throughout the system. This is where you need to reach out to your pump maintenance companies and local electricians for some assistance. If the stations have not been flooded, stop and treat yourself with a coffee and perhaps a donut, and thank your lucky stars it was constructed above the flood plain. But, if your stations have been damaged by the floodwaters, they will most likely need a complete overhaul and cleaning.

In order to expedite system startup, temporary generators, motor controls, circuit breakers, and starters need to be acquired. These can generally be provided by electrical contractors or equipment rental companies. The electricians should conduct a complete examination of the power system feed, any backup generator power, and any supply panels. Everything that was under water has to be checked, including items such as lights. Generally speaking, if a panel or power panel has been under water, it should be replaced. Motors may be saved, but they need to be sent out for baking prior to restart. You can prepare for these types of problems during system start up by having fast access to temporary motors and controls.

As for the pumps, generally the manufacturer can lend advice on damage, replacement, or other issues. Submerged pumps may require replacement or lubrication of the bearings, along with the motor work. As for the chemical-feed systems, they require a complete cleaning, and the chemicals should be replaced.

As elevated storage tanks are generally near a high point in the system, they most likely will not be affected by flooding. However, they may need to be disinfected prior to use if the system integrity was compromised. At a minimum, a mechanical inspection and an inspection from a structural engineer should be scheduled sometime in the aftermath of the flood. The engineer's inspection should address any potential or existing damage to the foundation.

flooding, permeameters, double-ring infiltrometers, borehole slug tests, and grain-size distribution analysis. One of the most cost-effective methods is field reconnaissance by an experienced geologist or hydrogeologist. Spending only a day or two in the field can reveal a wealth of information on areas of shallow bedrock, shallow groundwater, and soil characteristics, including drainage properties. This will help guide the more costly field investigations that follow.

Data Interpretation

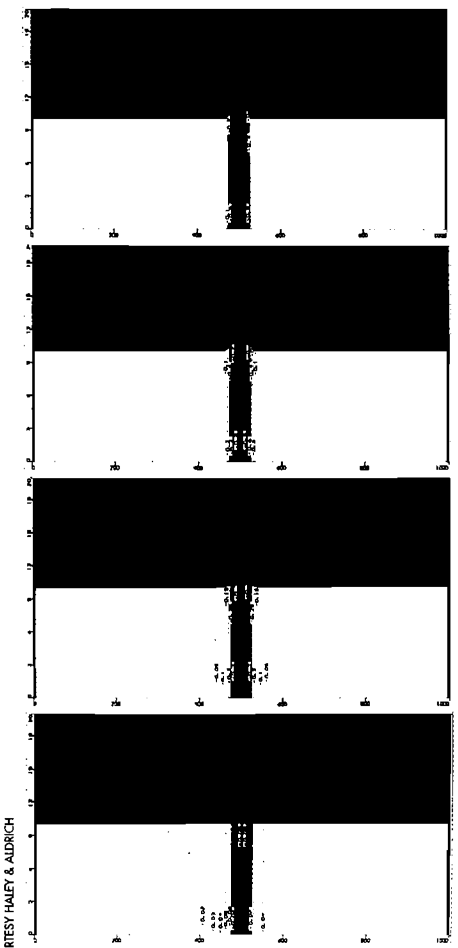
Stormwater infiltration is typically not controlled by pumps and valves, but rather by soil infiltration rates and infiltration area. The infiltration rate is the amount of water per surface area and time unit that penetrates the soil. Infiltration data needs to be comprehensive enough to inspire confidence in their validity, and they need to be interpreted with care. Infiltration rates — with appropriate safety factors to account for long-term clogging — and typical soil heterogeneity are critical for determining field dimensions and bottom elevations to comply with limits on stormwater runoff rates and/or volumes.

Above the water table, in the unsaturated zone where infiltration takes place, designers typically assume that infiltration occurs under a gradient of 1. Once the soil is saturated, however, the hydraulic gradient is typically a small fraction of 1 (often in the range of 0.001 to 0.01) and infiltration rates drop dramatically. If this is not considered, a system may be significantly undersized with respect to area. Conversely, if infiltration rates are underestimated, a system may be oversized such that more infiltration occurs than is necessary, putting neighboring structures at risk. Infiltration rates must be evaluated because, regardless of infiltration rates, restrictive features such as bedrock or low-permeability soils (i.e. silt and clay) may severely limit infiltration capacity. Thus, it is critical that testing data be interpreted in the context of the larger-scale site stratigraphy and regional geology.

Groundwater mounding may significantly influence an infiltration system design. If a stormwater system depends on infiltration rate rather than storage to control peak runoff rates or volume, excessive mounding may prevent infiltration and result in greater runoff. In these cases, the engineer must work closely with the hydrogeologist or groundwater hydrologist to come up with alternative designs to meet the overall objectives. This may involve increasing the infiltration system area, raising the elevation of the system to increase available subsurface storage; distributing the stormwater over multiple systems rather than concentrating it in a single area; or building adequate storage facilities to extend the infiltration period and reduce the infiltration rate.

While infiltration rates and areas, hydraulic conductivity, and depth to seasonal-high groundwater are critical variables, mounding analysis must also consider hydraulic boundaries. Barrier boundaries, such as areas with shallow bedrock or low-permeability soils, increase mound height because these transmit very little groundwater. Recharge boundaries, such as wetlands and surface waters, can serve as sinks for the infiltrating water, mitigating mound height between the recharge boundary and the infiltration system. The closer the boundary is to the infiltration area, the greater the effect it has on the extent and magnitude of groundwater mounding.

field-pilot testing. Simple analytical or numerical models, with assumptions applied based on professional experience, are indispensable tools. These simplified models can be used to "bracket" solutions within a reasonable range of hydraulic parameters and to evaluate the effects of design modifications on infiltration and groundwater mounding.



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Groundwater mounding in profile:

reduce runoff without creating or exacerbating groundwater seepage in neighboring structures. Ideally, geologic/hydrogeologic characterization will be conducted early in overall project planning since subsurface conditions drive the design of stormwater infiltration systems. By anticipating the site limitations early, minor adjustments can be made to impervious surface area, site grading, and layout to accommodate areas best-suited for infiltrating stormwater. Collaborating about project and site issues, regulatory compliance needs, and community expectations can resolve these issues to benefit the owner and the community.

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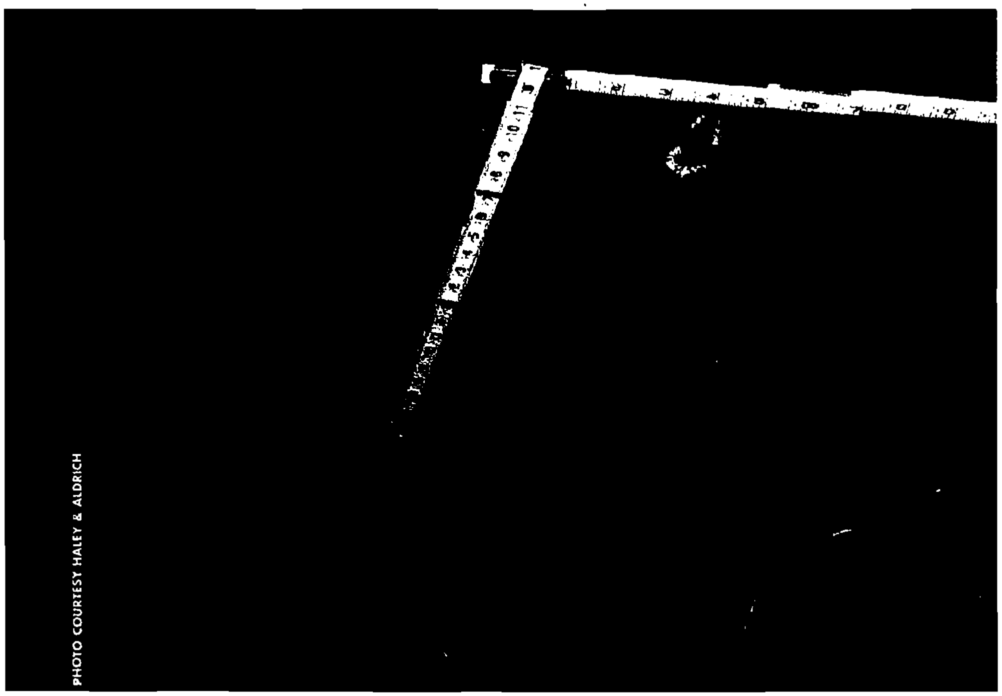
The scale of many small projects does not typically allow for support of a sophisticated groundwater flow model, an extensive network of observation wells, piezometers, and



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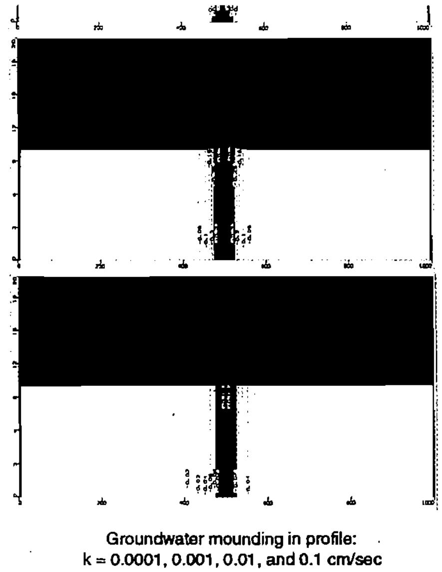
Typical percolation test setup for measurement of percolation rate of unsaturated soil.



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***Mounding Analysis* — Mounding analysis results from a simplified groundwater model illustrating predicted mound height and extent for four different hydraulic conductivity values, in profile for k = 0.0001, 0.001, 0.01, and 0.1 cm/sec**

Figure 1 is an example of mounding analysis results from a simplified groundwater model, illustrating predicted mound height and extent for four different hydraulic conductivity values. With increasing hydraulic conductivity, the mound height is smaller at the point of infiltration, but the effects of mounding are far more widespread. Thus, increased hydraulic conductivity allows for higher infiltration rates but increases the risk of groundwater mounding near neighboring structures.

Success Through Planning and Communication

Ongoing communication between the engineer, designer, and hydrogeologist is needed to address the often-conflicting goals of providing adequate storage, controlling outflow to storm drainage systems, and infiltrating sufficient water volume at a sufficient rate to

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