CHASTAIN-SKILLMAN, INC.

ENGINEERS • ARCHITECTS • SCIENTISTS • SURVEYORS

CONSULTANT'S UPDATE

ISSUE 25 JULY—SEPTEMBER 2007

CHANGES IN PHASE I ENVIRONMENTAL SITE ASSESSMENT STANDARDS IMPACT LANDOWNER LIABILITY PROTECTION

By Tom Lewis, PG, CFEA, LEP

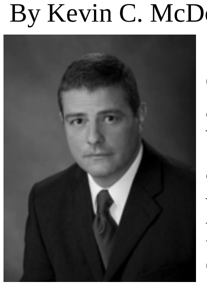
Phase I Environmental Site Assessments (Phase I's) are the most commonly used form of environmental due diligence, both for lending institutions and their borrowers. The concept of the Phase I arose in 1986 when The Superfund Amendments and Reauthorization Act (SARA) amended the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) to provide landowner liability protection to those who conducted "all appropriate inquiry consistent with good commercial practice". The purpose of the Phase I was therefore a tool used to permit the user to satisfy one of the requirements needed to qualify for this defense to CERCLA liability, now known as *innocent landowner* defense.

A Phase I consists of both a historical review and a present environmental qualitative evaluation of a property (without soil or groundwater sampling or analysis). Essentially, it is a snapshot in time without known analytical data. The five principle components of a Phase I are: (1) a review of public and private records relating to the property and surrounding properties; (2) a site visit to the property and surrounding properties; (3) interviews with the property's current owners and operators; (4) a review of historical sources of information related to the property

(Phase I—Continued on page 4)

SINK HOLES—THE BASICS

By Kevin C. McDowell, PE



Sinkholes are a common occurrence in Florida and an understanding of the basic types of sinkholes and the processes by which they form can be helpful to planners, developers, regulators, and the public in characterizing a site, determining what land uses are appropriate, and in better protecting our water supply. Homes, commercial buildings, landfills, and even courthouses are sometimes constructed without knowledge of the presence of underlying caverns and voids that cannot adequately support the weight of the structures. Taking appropriate measures before construction begins, or simply avoiding sinkhole-prone sites can save expensive repairs in the long run.

The process by which sinkholes form should not be confused with the formation of holes and surface erosion resulting from ruptured water mains and leaking storm sewers, which are sometimes mistaken for "sinkholes". The same basic process that drives the formation of sinkholes (dissolution of soluble rock material underlying surface sediments by acidic rainwater), is also responsible for formation of most of Florida's lakes, wetlands, shallow depressions, and (along with relict beach dunes and terraces) much of our "hilly" surface topography.

(Sink Holes—Continued on page 5)

EOH NEWS

EPA proposes new "Lead-Safe Work Practices" in light of two new lead dust studies

- *http://www.epa.gov/lead/pubs/renovation.htm*

OSHA Quick Cards - excellent safety program tool for tailgate safety meetings

- *http://www.osha.gov/OshDoc/quickcards.html*

EPA issues final Brake/Clutch brochure designed to reduce brake and clutch repair worker asbestos exposure

- *http://www.epa.gov/asbestos/pubs/brakesbrochure.html*

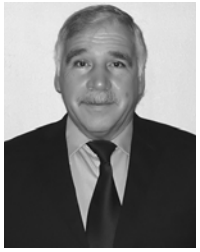
Neurology study "confirms" brain too slow for cell phone use while driving. Results found that, when it comes to handling two things at once, the brain is fast, but not fast enough. Findings were published in the December 21, 2006 issue of the neurology journal, Neuron.

- *http://www.neuron.org (use Author Search function "Dux")*

Inside this issue:

CHASTAIN-SKILLMAN, INC., FIFTY-SEVEN YEARS OF SURVEYING IN THE STATE OF FLORIDA AND HOW IT AFFECTS YOU, THE LANDOWNER

By Denis R. Pearson, PSM



Imagine it is 1824 at the General Land Office in Washington. On July 9, General Andrew Jackson makes a request to President James Monroe that you be appointed Surveyor of the Public Lands of Florida. You will become the first Surveyor General of the State of Florida. Your name is Colonel Robert Butler. William P. Duval was the appointed territorial Governor of Florida and George Graham was the Commissioner of the General Land Office in Washington. On July 10, George Graham would notify Governor Duval of the appointment. Your task will be to divide the State of Florida into Townships, six miles by six miles square, then divide each Township into thirty-six Sections, one mile by one mile square. This task, with today's technology and access by highways, streets, roads, etc., would be an enormous task and could take months or years to complete. In 1824, with the equipment of that era, and Florida being a vast and wild wilderness, it is hard to imagine a task of that magnitude. Keep in mind Florida was bounded by clear blue oceans and had clear springs, rivers, streams and lakes. The wildlife and plant life was extremely plentiful and not easy to enter, and the majority of the land was populated by Seminole Indians. Some of the early field notes from this era close with the following entries: "injuns and alligators too bad, we quit". This was to inform the Surveyor General that the Deputy Surveyor did not complete this portion of the survey and it was properly noted in the field notes why. Florida was an extremely exquisite area to behold but it was a very hostile environment in many ways.

Settlers were moving in and clearing land prior to the survey taking place, so Colonel Butler was under extreme pressure to get this started, and completed, as soon as possible. Lt. Governor Walton, in the absence of Governor Duval, instructed Colonel Butler to establish an Initial Point so the Capitol Building would be in the center of the first quarter section to the northwest. The quarter section to the northwest had been granted by the United States Government, as the seat of Government. The Initial Point is also known today as The Tallahassee Base, The Guide Meridian Marker, and The 0 Marker. It can be found just south of Gains Street and just west of Bloxham Street in Tallahassee, Florida. Colonel Butler appointed his most skillful surveyors to run the Tallahassee Base Line, west to the Perdido River. This task was completed by Benejamin Clements and James Exum, appointed by Colonel Butler. Colonel Butler received instructions to survey twenty townships in the vicinity of Tallahassee. Equivalent to 460,800 acres, this is an extreme task, even with today's technology. Colonel Robert Butler appointed Deputy Surveyors, as required, to expedite the subdivision of the Public Lands of Florida into Townships and Sections. These original surveys set up the surveying and identification system we use today: Section, Township and Range. This system is used in Florida and most of the United States.

In the late 1800's and early 1900's, the survey of the Public Lands of Florida was continued by several surveyors. The objective was to complete the subdividing and ensure the integrity of the original surveys of the Public Lands of Florida. As Florida continued to develop, the destruction of the original General Land Office corners was inevitable. The original monuments, in most cases, have been destroyed by the development of subdivisions, highways, streets, roads, etc. The destruction of historical and critical monuments continues today. Although it is illegal, the law is not enforced. As a landowner, the preservation of these and all monuments is essential to establish boundary lines. The continued destruction of the original corners and their accessories makes it harder for the surveyor to determine the correct boundary lines.

At Chastain-Skillman, the records of the past are preserved in what we, the Survey Department, call section, plat and project files. We are in the process of scanning this information and ensuring the integrity of the files for future use. These files include old government notes, old maps from the mining companies, old surveys performed by this firm from 1950 to 2007, old section breakdowns of areas with original section corners located and mapped, and a vast amount of information that can be reproduced in the field and staked by the field crews. This enables our surveyors to reproduce, on the ground, section and boundary corners that could otherwise be considered obliterated. As a landowner, this is beneficial in several ways: establishing the correct boundary line, locating or replacing lost corners, and resolving boundary disputes.

The Survey Department of Chastain-Skillman's Lakeland office consists of three Professional Surveyors and Mappers: Robert F. DuBois (Director of Survey, with over 21 years of survey experience), John Richard Noland, Jr. (Senior Project Manager, with over 19 years of survey experience), and Denis R. Pearson (Project Manager, with over 35 years of survey experience). Each Professional Surveyor and Mapper has assistant project managers with several years of field and office experience. The survey department has three CAD technicians and a senior CAD technician that oversees the CAD work. The senior CAD technician, Harry Greives, Jr., has 9 years of field surveying experience and over 11 years of CAD experience. We have five to eight field crews in the field, on any given day, depending on the projects scheduled. The field crews all have access to and knowledge of Global Positioning System, (GPS) - RTK network, the latest data collection equipment available and the latest CAD programs. In short, we keep abreast of the latest technology; have one of the best, if not the best, office support teams in the State of Florida, and continue in the tradition of the original surveyors. We do our best to ensure the integrity of all existing and new survey monuments set by others or this firm.

In 1950, one hundred and twenty-six years, after Colonel Butler started his division of the Florida Public Lands, Chastain-Skillman, Inc. was founded. Chastain-Skillman's records date back fifty-seven years, along with records received in the 1950's that date back even further. This vast supply of information is extremely important to the preservation of the land boundary lines, and essential to you as a landowner.

Denis Pearson serves as Project Manager in Chastain-Skillman's Lakeland office and has over 35 years experience in the survey profession. He can be reached at (863) 646-1402 or dpearson@chastainskillman.com.

WATER RESOURCES UPDATE

By Thomas E. (Tom) Jackson, PG

SWUCA. New rules relating to water use and resource protection for the Southern Water Use Caution Area (SWUCA) were implemented on January 1, 2007. The SWUCA encompasses a 5,100-square-mile area within eight counties in the southern part of the Southwest Florida Water Management District (SWFWMD). This area includes all of DeSoto, Hardee, Manatee, Sarasota, and portions of Charlotte, Highlands, Hillsborough and Polk counties. SWUCA water resource concerns include depressed aquifer levels which cause saltwater intrusion and contribute to reduced flows in the upper Peace River and lowered lake levels in upland Polk and Highlands counties. SWUCA Rules were featured in the 3rd Quarter 2006 issue of CSI's Consultant's Update newsletter (http://www.chastainskillman.com/downloads/articles/SWUCA_II.pdf). Additional information on the SWUCA, including the latest Draft SWUCA Recovery Strategy and the new SWUCA II Rules, is available online at the SWFWMD website at the following link: www.swfwmd.state.fl.us/waterman/swuca/SWUCA.htm. Water users in need of a Water Use Permit (WUP) modification, WUP renewal, or a WUP for a new use should ensure that their permitting plans and schedule take into account the new SWUCA II Rules and the SWUCA Recovery Strategy.

CFCA. The Central Florida Coordination Area (CFCA) encompasses Polk, Osceola, Orange, and Seminole Counties. Beginning last fall, the South Florida, Southwest Florida, and St. Johns River Water Management Districts (WMDs) held a series of informational and rulemaking meetings to better coordinate water supply regulation and planning. It now appears likely that total overall groundwater withdrawals in the CFCA region will be capped at the projected year 2013 demonstrated need for water. As such, it is critical that water users who are likely to contend with adverse impact issues or who will need additional water quantities beyond projected 2013 demand identify alternative sources of water to meet future needs. Alternative water supply projects typically take 6 to 10 years before the projects become operational; therefore it is critical to initiate this complex process without delay. Up-to-date information on the CFCA activities, including meeting dates and the proposed CFCA-related rules can be found at the following websites:

SWFWMD: http://www.swfwmd.state.fl.us/projects/cfca/

SJRWMD: http://sjr.state.fl.us/programs/watersupply.html

SFWMD: http://www.sfwmd.gov/site/

10-Year Water Supply Facility Work Plans. Nearly all local governments within areas of Florida that have Regional Water Supply Plans (RWSPs) are required to develop and submit their individual 10-Year Water Supply Facility Work Plans (Plans) to the Florida Department of Community Affairs (DCA) within 18 months of adoption of RWSPs by their respective WMD. Additionally, the Plans must be incorporated into the applicable Comprehensive Plan by this deadline. The purpose of the 10-year Plans is to identify sources of water and funding of water supply projects to meet future needs concurrently with growth. For local governments within SWFWMD, these 10-Year Plans are due by May 30, 2008, which is rapidly approaching. Additional information is available from DCA. Of particular note is DCA's Guidance Document, which is currently being updated and should be available soon online at the DCA website (www.dca.state.fl.us). Funding information and planning-related FAQs are also available at www.dca.state.fl.us/GrowthManagement2005/waterfaqs.cfm.

2007 Florida Springs Conference and Field Trips. The technical community is continuing efforts to better engage the public, elected officials, and decision makers in critical water-related educational and resource protection efforts in hope of sustaining the precious natural resources and quality of life we enjoy. The third Florida Springs Conference is scheduled to take place at the Innisbrook Golf and Tennis Resort (near Tarpon Springs) on October 10-13, 2007, with three concurrent all-day field trips planned for October 10, 2007. Ann Tihansky (USGS-St. Petersburg) is planning a trip to Tampa's Sulphur Spring and nearby Curiosity Creek; and to Crystal Springs and the nearby Zephyrhills Bottled Water facility. Dave Dewitt (SWFWMD) is organizing a trip to Weeki Wachee Springs, including a canoe trip down the spring run to view and discuss the numerous karst features. Tom Jackson (Chastain-Skillman) plans to lead a field trip to the Tampa Bay Regional Reservoir, Lithia Springs, and Buckhorn Springs (all in Hillsborough County); and to the historic site of Kissengen Spring within the Upper Peace River Karst Area (Polk County). All trips will be led by Professional Geologists with considerable knowledge of these sites and related resource issues. An understanding of the karst geology of west-central Florida is essential to water resource management and protection while addressing water supply, recreational, and environmental needs. We highly encourage the public and our decision-makers to participate and interact with the technical community on the field trips and at the Conference. Additional information, including registration forms, daily meeting agendas, and presentation abstracts, is available online at: http://4d.cmc-associates.com/Scripts/4Disapi.dll/4DCGI/events/67.html?Action=Conference_Detail&ConfID_W=67<a.

Please contact us here at Chastain-Skillman if you have any questions or require assistance with water use permitting, 10-Year Water Supply Facility Work Plans, and for the identification and development of alternative water supplies.

Tom Jackson is a Senior Project Manager/Professional Geologist in Chastain-Skillman's Lakeland Office. His work focuses primarily on water use permitting, water resources and geologic/hydrogeologic projects. Tom attended the University of Florida, and received his Bachelor (1987) and Master (1991) of Science degrees in Geology, and Certificate of Advanced Studies in Hydrogeology (1990), from the University of South Florida. He can be reached at (863) 646-1402 or tjackson@chastainskillman.com.

(Phase I—Continued from page 1)

and surrounding properties; and (5) compilation of all gathered information into a written report prepared by someone experienced in developing opinions and conclusions regarding conditions indicative of releases or threatened releases.

Subsequent amendments in 1996 to CERCLA clarified and affirmed a limited exemption from liability for commercial lenders under defined circumstances having to do with the lender's pre-loan *due diligence* and post-foreclosure activities. A key component of these requirements is that some form of comprehensive environmental due diligence be conducted prior to the closing of a real-estate-backed commercial lending transaction and to determine if any past or present environmental exposure exists. Because of this, there are two principal users of the Phase I: 1) the lending institutions, seeking true property valuation and due diligence protection; and 2) the purchaser, seeking environmental landowner liability protection.

ASTM (formerly known as the American Society of Testing and Materials), along with environmental professionals who specialized in the area of site assessments, began developing draft documents as far back as 1990 to provide standard operating practices for conducting Phase I's. The purpose of the resulting ASTM E 1527 Standards was to define "customary and good" practice for conducting a Phase I on a commercial real estate parcel within the scope of CERCLA and, therefore, permit the purchaser (user) to properly satisfy one of the requirements needed for the *innocent landowner* defense to CERCLA liability.

In 2002, the United States Congress passed the *Small Business Liability Relief and Brownfield Revitalization Act* (now commonly referred to as the "Brownfield Amendments") and, once again, amended CERCLA. As part of this Act, the EPA was required to finally establish a set of standards for the conduct of All Appropriate Inquiry (AAI). Prior to this, the federal government was strangely silent on the actual definition of AAI and the standards being used to comply with AAI. As a result of the 2002 amendment, the EPA released a new rule on November 1, 2005, defining the AAI that a prospective purchaser must undertake to qualify for landowner liability statutory defenses. This rule went into effect on November 1, 2006, and defers to the ASTM International Standard E1527-05 "Standard Practice for Environmental Site Assessment: Phase I Environmental Site Assessment Process" as the **only** industry standard to be used for compliance. Therefore, in simpler terms, as of November 1, 2006, all Phase I's must be conducted following the EPA's new requirements for AAI and using ASTM E 1527-05 in order to qualify for landowner liability protections available to CERCLA liability.

Though AAI must be made at the time of the transaction, it will control whether a potentially responsible party can later avoid CERCLA liability based on the diligent adherence to the ASTM E 1527-05 Standard and the actual inspection of the property. The largest change to the process is that an "environmental professional" must perform AAI. The final rule defines an environmental professional as one who "possesses sufficient specific education, training, and experience necessary to exercise professional judgment to develop opinions and conclusions regarding conditions indicative of releases or threatened releases on, at, or to a property." In addition, the environmental professional must also have one of the following:

- A professional license or certification in engineering, geology or environmental inquiries from a federal, state, or tribal government *and* three years of full time relevant experience;
- A baccalaureate or higher degree from an accredited institution in engineering or science *and* five years of full-time relevant experience;
- The equivalent of ten years of full-time relevant experience.

Though other individuals can assist with AAI, an environmental professional must supervise their activities.

Other changes to the scope of AAI include:

- mandatory interviews with current owners and past owners;
- increasing the historical review to when the property was first obviously developed or 1941 (whichever is earlier);
- documenting data gaps that prevent the environmental professional from fully rendering his or her opinion;
- documenting the purchase price and fair market value of the property;
- assessment of any specialized knowledge or experience of the user or landowner purchaser;
- an inquiry into the commonly known or reasonably ascertainable information about the property;
- documenting the degree of obviousness of the presence or likely presence of contamination at the property and the ability to detect contamination;
- conducting title searches for federal, state, tribal or local environmental clean-up liens against the property.

One final important change is that, under the new standards for conducting AAI, two new landowner liability protections are available to the purchaser in addition to the traditional *innocent landowner* defense.

The first new defense, *contiguous property owners*, is available for property owners who own property contiguous or otherwise similarly situated to a facility that is the only source of contamination found on the property. Such persons must demonstrate through the AAI process that they had "no reason to know", prior to purchasing the property, that any hazardous substances were released or disposed of on, in, or at the property.

The second new landowner liability protection is known as the *bona fide prospective purchaser* defense. Under this defense, prospective purchasers may buy property with knowledge of contamination if they purchased the property after January 11, 2002, and obtain landowner liability protection if they meet certain criteria set forth in CERCLA.

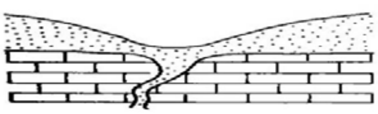
For both the lending institution seeking to secure the loan, and for the purchaser of commercial property seeking landowner liability protection, the November 1, 2006 changes to the Phase I process present both opportunity, when performed correctly, and danger, when conducted improperly. Consequently, both the purchaser and the financial institution should always ask if the Phase I is being conducted in accordance with ASTM E1527-05 and then clarify the qualifications and actual role of the environmental professional conducting the AAI.

Tom Lewis is a Senior Hydrogeologist in Chastain-Skillman's Tallahassee Office. His work focuses on environmental site assessment, environmental site rehabilitation and geologic/hydrogeologic projects. Tom received a Bachelor of Science Degree in Geology from The College of William and Mary in 1994, and a Master of Business Administration from Bellevue University in 2000. He can be reached at (850) 942-9883 or tlewis@chastainskillman.com.

(Sink Holes—Continued from page 1)

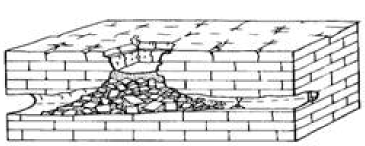
As rainfall combines with atmospheric carbon dioxide to form carbonic acid, it passes through decayed leaves and other plant material to form humic acid. The resultant low pH water percolates through soils and slowly dissolves the carbonate rocks that underlie surface sediments. This process can form vugs, conduits, and caverns in the carbonates, and the most rapid dissolution typically occurs along the easiest path (e.g., at exposed surfaces along fractures and joints), for the "aggressive" water to travel.

There are several basic types of naturally-occurring sinkholes, and these can also be induced by man's activities. *Solution Sinkholes* typically form where sediment cover is either thin or absent above the carbonates, as occurs along much of Florida's Gulf Coast north of Tampa Bay through the Big Bend area. *Subsidence Sinkholes* develop slowly where the overlying soil and rock are thin and surface water often accumulates. The acidic water seeps through the overlying soil to the limestone beneath. This water moves slowly down through the limestone, dissolving the limestone as it moves further down, and taking with some dissolved carbonates and some of the overlying soils. The result is typically a bowl-shaped sinkhole, technically called a *doline*. Water often fills this type of sinkhole, creating ponds or lakes. In fact, most of Florida's lakes are formed by individual and/or coalescing sinkhole activity.



Solution Sinkhole Formation Diagram
(Jennings, 1985)

Cover-Collapse Sinkholes begins to form when a fracture or cavity in the limestone bedrock is enlarged by water dissolving the limestone. As the bedrock is dissolved and carried away underground, the soil erodes into the developing void. Once the underlying cavity or fracture becomes large enough, if the weight of the overlying soil and rock can no longer be supported, a fairly sudden, often catastrophic collapse may occur. The famous Winter Park sinkhole is an example of this. The process is often triggered by new rainfall (added weight to the overburden) and/or by excess pumping of our aquifers (no hydrostatic support within the cavity).



Cover Collapse Sinkhole Formation Diagram
(Jennings, 1985)

Sinkholes are a commonly occurring geologic phenomenon, and not just in Florida. They are depressions or holes in the land surface. They can be shallow or deep, small or large, but—in Florida—they are virtually all a result of the dissolving limestone. Fortunately, there are a number of ways to identify the possible formation of a sinkhole.

- New exposure of foundations, or fence posts.
- Leaning fence posts or trees.
- Cracks in walls, floor, pavement, or the ground surface.
- Muddy water in wells.
- Circular patches of wilting vegetation.
- The accumulation of storm water, where storm water did not accumulate in the past.
- Doors and windows that do not close as they have in the past.

We can all imagine the devastating impact a sinkhole could have on our lives. However, our treatment of sinkholes can have an adverse effect on a much larger community. Sinkholes are a connection to the water aquifers from which many of us, in Florida, obtain our drinking water. Contaminates can easily enter the drinking water through a sinkhole. As an example of the ease of contamination and its far reaching effect, a report conducted by Hillsborough County Environmental Protection Commission (EPC) stated "…Subsequent bacteriological analysis of approximately 200 residential wells indicates that many of the wells were contaminated with total and fecal coliform bacteria. In response to a reported increase in the groundwater contamination over the next 3 to 4 months, the Southwest Florida Water Management District, the Hillsborough County Health Department, and the EPC of Hillsborough County conducted a tracer dye study to ascertain that a sinkhole, approximately 200 feet from the southeast corner of Lake Grady, was the source for contaminated surface water transport to the groundwater….". The report went on to state that approximately 50 million gallons of surface water flowed into the new sinkhole. Obviously, sinkholes should never be considered trash receptacles, as they often provide a direct pathway to our precious water supply aquifers.

Kevin McDowell is a Senior Project Manager in the Civil Department in Chastain-Skillman's Lakeland office. Kevin specializes in civil engineering design for all phases of Site Development. Kevin graduated Magna Cum Laude with a Bachelor of Science Degree in Civil Engineering from the Lawrence Technological University. He can be reached at (863) 646-1402 or kmcdowell@chastainskillman.com

RECENT PROJECTS AND CONTRACTS OF INTEREST

- Chastain-Skillman's Tampa office will be performing **Home Depot Supply** Industrial Hygiene/OSHA personnel exposure evaluations in Minneapolis, MN, Mobile, AL, Houston, TX and St. Louis, MO.
- The spotlight falls on the civil group this quarter as they remain feverishly busy. Sitework development engineering has been performed for Polk County's newest High School (**Saddle Creek**) in northeast Lakeland. Also the engineering, permitting and approval have been completed and construction begun on the new Publix-anchored **Town Center** in Highlands City (between Bartow and Lakeland). It will provide a great place to stop for lunch while on a Fort Frasier Trail outing!
- Additionally the intersection improvements at **Beacon Road and Lincoln Avenue** in Lakeland are under construction. Along with utility improvements, this project involved the resurfacing of several thousand feet of roadway.
- **School House Road** is being widened and improved as a result of the new Krenson Woods Subdivision going in just across from Medulla Elementary School; part of the burgeoning growth in the southwest Lakeland area.

HYDRAULIC TRANSIENTS: PERIL FOR PUMPS AND PIPES

By James R. Chastain, Jr., PhD, PE, MPH

One of the essential features of a modern urban society is the ability to efficiently distribute potable water to end users and collect and transfer wastewater away from them. These transfer operations depend on a complex network of pumps and pipes. Properly estimating the necessary community flows and appropriately sizing the pumping systems, reservoirs and piping network are primary tasks of civil and environmental engineers.

These design efforts can be challenging. Engineers are taught to perform these computations based on **steady-state** flow assumptions. In simple language "steady-state" means that the mean (average) velocity of water flowing through the system is constant. The purpose of this approach is two-fold: (1) provide the desired flow and pressure at specific locations within the system, and (2) configure the delivery components so as to minimize the expense. Guidelines and techniques based on this approach have allowed engineers to reliably design facilities for communities they serve.

But what happens in a system that experiences **unsteady flow** during the course of its operations? Unsteady flow, of course, refers to situations where the mean velocity in the pipes is not constant. This, in fact, occurs routinely (if not constantly) in fluid systems. Unsteady flow gives rise to **hydraulic transients** (also known as waterhammer or surge). Transients consist of pressure waves that very quickly move through the system. These would be of little interest if the transient waves were small and inconsequential. However, many times this is not the case and, in certain situations, transients can have catastrophic consequences. Interestingly, analysis of transient conditions is all too often neglected in the design process. This article will explore the basic characteristics of hydraulic transients, their analysis and some of the routine methods of controlling them. Transients can occur in both open channel and pressure flow situations. Only pressure pipe transients will be addressed here.

Basic Factors Affecting Transient Formation

Transients can be described by basic state equations, which result from the physical characteristics of water and the fundamental relations of physics. In essence, the mathematical effort attempts to model a system where the energy from the changing velocity is simultaneously trying to compress the water and stretch the conduit circumferentially. Water has a couple of properties that accentuate its ability to create these pressure waves.

First, water has a high density. Because pipelines are typically long relative to diameter, the water column (volume) is significant. Due to water density, this means that the mass, momentum and kinetic (active) energy can be quite large.

Second, water is, for all intents and purposes, incompressible. This makes water a very effective energy transfer medium. Therefore, whenever a pressure wave is formed, there is negligible dampening due to water compression.

Given these characteristics, when a moving column of water is abruptly stopped or started, a pressure wave is formed. The magnitude and speed of the pressure wave is mathematically defined by two differential equations that satisfy the Conservation of Mass and Conservation of Momentum criteria. While computer simulations are required for actual design, some simplified equations can provide an indication of the magnitude for non-complex systems.

The **Joukowsky equation** is many times used as a rough estimate of the magnitude of the pressure rise in the pipe. It is given by:

$$\Delta H = \frac{a}{g}\Delta v$$

where: ΔH = change in pressure
a = pressure wave propagation speed
g = acceleration of gravity
Δv = change in velocity

To compute this, the propagation speed of the transient must be calculated. The equation governing this takes several forms depending on the pipe material and construction characteristics. A general form of this equation is:

$$a = \sqrt{\frac{\frac{K}{\rho}}{1+\left(\frac{KD}{Ee}\right)}}$$

where: K = bulk modulus of elasticity of water
ρ = mass density of water
E = Young's modulus of elasticity for the pipe material
e = pipe wall thickness

After performing these computations over time, what one finds is that it is not unusual to see a pressure rise in the hundreds of pounds per square inch (psi) in unprotected systems (for reference the typical water system pressure is between 55 to 75 psi). The wave speed is incredibly fast, traversing the system at a speed on the order of 3,000 to 4,500 feet per second (roughly equivalent to 3,000 miles per hour).

With the intensity of these pressure swings, significant damage can occur to pipes, pumps, valves, as well as end user equipment and appurtenances if left unmanaged. In addition, recent studies have shown that water quality can actually deteriorate in systems that have significant transient problems. This is hypothesized to occur as a result of disturbance of biofilms within the distribution system, and possibly even aspirating small volumes of external (contaminated) water during negative pressure phases of the transient wave.

What Causes Hydraulic Transients?

Waterhammer can result from a wide array of system events that makes it difficult to completely eliminate from occurring. Per the definition, anything that causes a change in the mean velocity of the water column in a pipe will develop a pressure wave. The magnitude of the transient, then, is a result of the magnitude of the velocity change, the volume (mass) of water in movement, and the characteristics of the pipe. Typical operating conditions that result in changes in the water column velocity include:

(Transients—Continued on page 7)

(Transients—Continued from page 6)

1. Changes in valve settings. Opening or closing a valve within the pipeline system will obviously change the velocity within a pipe.
2. Starting or stopping a water supply or booster pump. It's common to associate waterhammer with stopping fluid flow, but it must be remembered that surge effects also result from starting or introducing a flow.
3. Change in demand conditions. User demand changes result in adjustment within the distribution system to meet the demand. A clear example of this is the large flow demand change that might occur at the start or conclusion of firefighting.
4. Changes within the transmission system. This occurs whenever a pipe ruptures or a new pipe is first put into service, causing a re-leveling of pressures within the system.
5. Changes in storage tank operation. Whenever an elevated storage tank begins to fill or drain, transients can occur. Normally, these pressure gradients are more gradual, but occasionally they can cause concern.
6. Air accumulation within pressure pipes. While this might not seem like much of an issue, air can in fact cause many problems. Air can actually restrict flow in variable ways and, in certain conditions, can cause column separation that can result in vacuum development. Depending on the situation, this vacuum can collapse pipes and attached storage tanks if not properly vented.

It is clear from looking at this list that pressure waves can occur almost continuously within a water or wastewater pressure system because system changes are constantly occurring. Since hydraulic transients can't be eliminated, designers and operators must look for ways to minimize their magnitude and effect.

<u>How Can Hydraulic Transient Effects Be Minimized?</u>

The first step in minimizing transient effects is to recognize that they will occur in most every pipe system to one extent or another. With that knowledge, during the design process, one should look for situations where the magnitude and/or frequency of these pressure waves can be deleterious to the system. For example, it is prudent to look for situations where large changes in elevation or pressure occur. When this condition arises it is likely that a change in flow condition will create a pressure wave due to the energy associated with the water. Conversely, when one sees a long, flat pipeline care must be exercised in this situation too. These pipelines can have a considerable amount of energy associated with them due to the mass of the water column and the pumps driving the flow may require considerable power to overcome the pipe friction to meet the design flow condition. Turning those pumps off and on (not to mention valve closures) can create the potential for hydraulic transients.

Another red flag is design of systems within hilly terrain. Actually, the hills don't have to be extremely large to be an incipient transient generator. Pipe systems should be designed to minimize the ability for air pockets to form, thus, they should be laid with an eye toward them being as horizontal as practicable. Where this is not possible, the profile should be examined to cause the air to collect in a controlled location, then removed by an appropriate device such as an air or air/vacuum relief valve.

In an operational setting, workers should be trained to never quickly open or close valves, especially on large pipes. This would include firefighters, operational personnel at large water users, etc. that can cause significant changes in the demand upon a pressure system through changes in valve settings. Actually, for specified conditions, it is possible to compute the allowable valve closure rate to keep a transient within acceptable range.

A number of techniques and devices have been developed to assist the designer or operator to manage transient events. Examples of devices commonly encountered include surge tanks, air cushioned surge tanks, air/vacuum relief valves, pressure relief valves, and by-pass lines. In addition, there are various pump and valve controllers that have been shown to effectively minimize the formation of pressure waves when properly designed and implemented.

The take away message of this article is that water and wastewater pressure systems are not static entities. Anything that changes the velocity of flow in the piped system (a pump is engaged/disengaged, a valve closes, a significant new demand occurs, etc.) creates an opportunity for a hydraulic transient to form. Mathematical analysis and field experience indicates that these transients can result in situations that are destructive, if not appropriately managed. Therefore, the design phase should be based not only upon the steady state conditions but should also consider the likelihood of unsteady flow regimes and consider their implications. The design should seek to configure the system in such a way as to minimize the transients but, if that is not possible, utilize the appropriate devices to suppress the waterhammer to levels that are not harmful. Further, operational practices should be enforced which protect the system from functional damage (ex. quick valve closure after firefighting, water main repair, etc.). These efforts will pay for their consideration many times over, especially as our utility systems age.

Additional Reading:

Jung, B.S., B.W. Karney, et al. (2007). "The Need for Comprehensive Transient Analysis of Distribution Systems." <u>JAWWA</u> **99**(1): 112-122.

Martin, C.S. (1999). Hydraulic Transient Design for Pipeline Systems. <u>Hydraulic Design Handbook</u>. L.W. Mays. New York, NY, McGraw-Hill: 12.1-12.32.

Streeter, V.L. and E.B. Wylie (1967). <u>Hydraulic Transients</u>. New York, NY, McGraw-Hill.

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PLEASE JOIN US AS WE WELCOME OUR NEW ASSOCIATES

It has been a busy spring season of adding new staff to our ever-growing team. Lakeland's civil department has added **William "Ed" Munson, PE** as Senior Project Manager, and **Kendel "Ken" Vanterpool** as Drafting Designer. Lakeland's Environmental department has added **David Edmunds** as Project Designer. Also joining us in Lakeland are **Lisa Willig**, Assistant Accountant, **Samuel Lee**, Computer Technician, and **Tavi Fontana**, Engineer Aide.

In Tampa, **Kelly Drapeza** will be assisting the Tampa office with filing needs.

In Tallahassee, **Thomas "Tom" E. Lewis, P.G.** has come aboard and will fill the role of Senior Hydrogeologist.

This newsletter is provided solely for informational purposes and presents only highly condensed summaries relating to the topics presented. Therefore, it should not be relied upon as a complete record for purposes of regulatory compliance, nor is it intended to furnish advice adequate to any particular circumstances. For additional information on any of the topics in this newsletter, please contact the author, or Allan Duhm, (863) 646-1402, or e-mail us.

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