Virginia Water Central

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FEATURE ARTICLE

What's New—and Old—in Drinking-water Treatment

Virginia has about 1300 community public drinking-water systems (those that serve at least 25 people or 15 service connections year-round). About 135 of these *water works* use surface water sources, and over 1100 use groundwater.

Looking back over the last hundred years of history for Virginia's water works, we see some recurring themes—waterborne disease prevention, filtration effectiveness, and disinfection alternatives. Consider the 1929 Conference on Operation of Water Purification and Sewage Treatment Plants in Richmond. On that program were such topics as chlorination, filter run lengths, plant record-keeping, and equipment maintenance. Similar topics were covered at local and national conferences held just last year (for example, during the 2000 Water Works Operations Conference in Staunton).

Does this mean the water industry is stagnant? At first glance it might appear that there's not much new at the water plant. A closer look, however, reveals that while the basic concerns have not changed much over the last century, much progress has occurred.

Waterborne Disease and Public Health Protection

[Ed. note: Certain terms are defined on page 5; they are printed in bold when first used.]

The connection between drinking-water treatment and public health was not widely appreciated until just over a century ago. Up until about 1890, water-treatment operations,

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Virginia Tech
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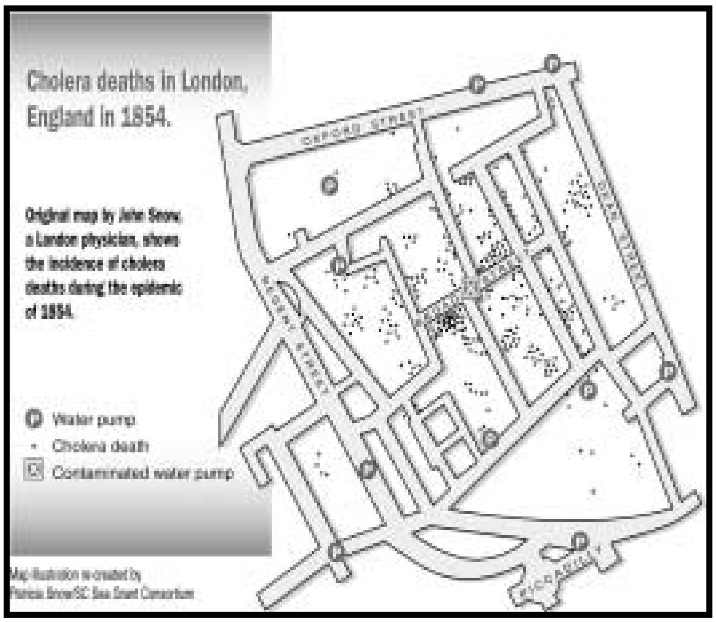
when practiced at all, generally focused on improving water's appearance and taste.[1] With water supplies subject to contamination from privies and faulty sewers, **enteric diseases**, such as **typhoid** and **cholera**, were widespread; awareness of their causes and means of prevention, however, was not.

In 1855, John Snow surmised that cholera in London was spread by sewage-contaminated drinking water. The following diagram[2] shows how Snow mapped out deaths from cholera, leading him to implicate the Broad Street pump as the source of contaminated drinking water. At the time, though, the cholera-causing organism still had not been identified.



A wider realization that water treatment could prevent disease came only after the pioneering work in bacteriology of British surgeon Joseph Lister and German scientist Robert Koch in the 1870s and 1880s. They demonstrated that some microorganisms are **pathogens** and showed that they existed in water supplies.[3] The consequences of these discoveries were dramatic. In the late 1880s, 58 of every 100,000 people died of typhoid in the United States; by 1940, improvements in water treatment and sanitation helped reduce the incidence of typhoid in the United States to only 0.5 per 100,000.[4]

In 1974, potentially carcinogenic **by-products of disinfection** with chlorine were identified in drinking water. With this discovery, the emphasis in drinking-water treatment rapidly shifted from prevention of microbial waterborne illness to placing limits on disinfection by-products. As a result, some complacency with regard to protection against microbial contamination prevailed for a time. Following outbreaks of **giardiasis** in the 1980s and 1990s and a major outbreak of **cryptosporidiosis** in Milwaukee in 1993, however, the drinking-water community recognized that the challenge of microbial contamination is *not only* a thing of the past.

Today, water-utility managers continue to work toward the protection of public health through safe drinking water, but in doing so they must attempt to balance the risk of *acute* disease from pathogenic microbes with the risk of *chronic* disease from disinfection by-products. This "risk-risk trade-off" underlies sweeping microbial and disinfection by-product (M/DBP) regulations that will soon affect all drinking-water utilities. In addition, water utilities and public health officials are increasingly aware of the need to protect the health of individuals who may be more sensitive than the general population to drinking-water contaminants.[5]

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[1] Baker, M.N., and Michael J. Taras. 1981. *The Quest for Pure Water, 2nd Edition, Volumes I and II*. American Water Works Association. Much of the information presented in this article was gleaned from this comprehensive history of water treatment.

[2] This map has been reproduced from *Coastal Heritage*, Vol. 13, No. 3 (Winter 1998-99), with permission from the South Carolina Sea Grant Consortium, Charleston.

[3] Hall, Ellen and Andrea Dietrich, "A Brief History of Drinking Water," *Virginia Section AWWA Newsletter*, October 1999.

[4] Web-site of the Chlorine Chemistry Council (www.c3.org), Jan. 16, 2001.

[5] The U. S. Environmental Protection Agency (EPA) is conducting studies to identify sensitive groups, which may include infants, children, pregnant women, the elderly, or people with chronic illness. See *EPA Studies on Sensitive Subpopulations and Drinking Water Contaminants,* Report to Congress, December 2000, EPA 815-R-00-015.

Filtration—Still Good, Getting Better

As early as the 1700s in France and England, various schemes to filter drinking water from polluted surface sources were attempted, with varying levels of success. The first filter for a municipal water supply in the United States was built in 1832 in Richmond (at that time, only 44 U.S. cities had water-treatment facilities *of any sort*). Unfortunately, Richmond's filter was far too small to be effective for treating the highly turbid waters of the James River, and it was apparently soon abandoned. No other U. S. city even attempted to build filters for another 20 years.

Eventually, advances in technology made filtration feasible and successful enough for U.S. cities to adopt it widely. In addition, comparisons of typhoid incidence in towns and cities along the Hudson River with filtered and unfiltered water supplies provided more convincing evidence linking filtration and disease prevention. By 1890, "even the majority of the skeptics had recognized that, instead of being a mere straining process for the removal of suspended matter, filtration removed deadly germs of disease."[6]

Slow-sand filtration was well-established in England and Scotland before 1861, but that success was not repeated on this side of the Atlantic until 1872. Once introduced in Poughkeepsie, N.Y., slow-sand filtration quickly predominated in the United States. Soon, though, U.S. companies perfected "*rapid*" *filtration*, using mechanical innovations such as surface wash jets, reverse-flow wash, and stirrers. Because it allowed much higher rates of water production than slow-sand filtration, rapid filtration became the norm in the United States by 1900.

The economic advantage of processing more water using less space continues to be exploited today, as utilities demonstrate the ability to meet stringent turbidity and particle-count limits at ever-higher filtration rates. For instance, the Va. Department of Health (VDH) has permitted "super-high rate" filtration (5—8 gallons per minute per square foot) at several facilities.[7] Most of Virginia's filtration facilities employ rapid filters, but some alternatives have been allowed by VDH for specific applications; these alternatives include cartridge filters, bag filters, and diatomaceous earth filters. In addition, Virginia has seen soaring popularity for *membrane filtration*, which uses synthetic membranes under low pressures to remove turbidity and bacteria.

At the beginning of the 21st century, filtration's critical role as one of the **multiple barriers** to waterborne disease for surface water systems remains nearly undisputed.[8] Some of the most far-reaching drinking-water regulations in recent years highlight filtration.[9] Nearly 200 years after Paisley, Scotland, became the first town known to filter a municipal water supply, and about 100 years after filtration became widely accepted as a key to disease prevention, optimized filtration is still one of the best available means of preventing waterborne disease outbreaks. Moreover, as our understanding of filtration principles continues to evolve, we are developing better techniques (such as particle counting) to measure filtration's effectiveness for removing a growing list of pathogens.

Disinfection's Past and Present

Natural waters, especially those from surface sources, generally contain bacteria and viruses, even after filtration. Some groundwater sources are also susceptible to

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6 Baker and Taras (1981), *The Quest for Pure Water*, p. 118.

7 Virginia water works using super-high filtration are located in Albemarle County, Dickenson County, Fairfax County, Harrisonburg, Hopewell, Newport News, Roanoke County, and Stafford County.

8 Some significant exceptions exist. The EPA is battling in the courts to require filtration by cities, such as Boston, that have avoided filtration because of their extremely high-quality sources.

9 For example: The EPA's 1989 Surface Water Treatment Rule, and Long Term Enhanced Surface Water Treatment Rules (LT1ESWTR anticipated early 2001; LT2ESWTR anticipated May 2002).

contamination from fecal matter or other sources.[10] To help prevent waterborne outbreaks of enteric disease, therefore, drinking water from all but the most pristine sources is disinfected to destroy or inactivate disease-causing microbes.

Chlorine disinfection is the most widely practiced disinfection technology in the United States. Yet, surprisingly enough, the history of using chlorine for water treatment does not go back even 100 years. And currently popular "alternative" disinfectants—such as **chloramine**, **ozone**, **ultraviolet radiation**, and **chlorine dioxide**—are not really new at all. In fact, ozone was the first disinfectant used for a municipal supply, in 1906 in Nice, France.

But as renowned sanitary engineer Abel Wolman remarked in *The Quest for Pure Water*, "perhaps the greatest scientific advance in the purification of water was in the demonstration of the remarkable qualities of chlorine, initially adopted on a large scale in 1908." In that year, chlorine—in the form of dissolved sodium hypochlorite—was applied to a municipal supply in Jersey City, N.J. *Pure* liquid chlorine was first used experimentally in Ft. Meyer, Va., in 1910. By early 1941, 4590 of the 5372 U.S. water works using any kind of water treatment used chlorine disinfection.

The adoption of tighter standards for **trihalomethanes** and other disinfection by-products in the 1990s has contributed to a shift from chlorine to alternative disinfectants. In the last several years, many Virginia water works have begun reducing the formation of by-products by using chloramine as the *residual* disinfectant—that is, after an initial period of contact with chlorine, chloramine is added as finished water enters the distribution system. As with ozone, the use of chloramine is not new. It was first used in 1917 in Ottawa, Canada, and in Denver, Colorado; it has been used since 1934 in Richmond.

While ozone's popularity in Europe and Canada continued after its introduction in 1906, only a few U.S. utilities used ozone throughout most of the 20th Century. Ozone's capacity to inactivate protozoan cysts (such as from *Giardia*) has fueled a resurgence in its use in the United States in the last decade. In Virginia, ozone has been approved for use at five water-treatment plants currently under construction (two in Fairfax County, one in Henrico County, and two in Newport News).

Ultraviolet radiation (UV), one of the hottest "new" disinfectants for drinking water, was first used in municipal supplies between 1916 and 1928 (in Henderson, Kentucky; Berea and Perrysburg, Ohio; and Horton, Kansas). UV was largely discredited as a drinking-water disinfectant because of several practical limitations, but it has recently been shown to inactivate resistant *Cryptosporidium* cysts, perhaps much more economically than alternatives. This finding, and the U.S. EPA's endorsement of UV in its new "toolbox" of technologies listed to meet emerging M/DBP regulations, has spurred a renewed enthusiasm among equipment manufacturers and the drinking-water research community to overcome limitations and make UV technology available.

Looking Back and Looking Ahead

Key developments in the history of drinking water—such as elucidating the relationship between water treatment and disease prevention, and inventing treatment technologies for filtration and disinfection—were made at the end of the 19th and beginning of the 20th centuries. During most of the 20th Century, drinking-water engineers and scientists were not introducing brand-new ideas; instead, they were slowly but firmly establishing the engineering and scientific bases for treatment practices.

How will drinking-water treatment change in the 21st Century? Most likely, change will continue to come slowly. We have yet to develop fully many of the concepts that were first introduced a hundred or more years ago. At the same time, even agreeing upon a definition of acceptably clean water

[10] The EPA plans to finalize in Summer 2001 the Ground Water Rule, which specifies the appropriate use of disinfection in groundwater and addresses other public-health aspects of using groundwater as a drinking-water source.

has become more complex because of our increased ability to detect very small amounts of contaminants. From time to time, though, there may be a significant technological breakthrough that will revolutionize the water industry. UV disinfection may prove to be just such a breakthrough, if technological hurdles can be cleared and if the technique proves to be as cost-effective as predicted.

Costs are always a factor in whether treatment practices change or not. The relative costs of alternative treatment technologies depend on many site-specific factors: the quality of a water works' source water; space constraints; the margin of safety a given water works desires in selecting equipment; and the health risk that is acceptable by the utility, the public it serves, and the agencies that regulate it. For these reasons, we will probably continue to see different water works choose different combinations of acceptable practices.

Water-utility managers today, of course, face many more diverse challenges than the strictly scientific and engineering topics discussed in this article. Regulatory compliance, business pressures, source-water protection, public information, decaying infrastructure—to name a few—are concerns that water managers of yesteryear may not have felt so keenly. As with the scientific and engineering advances, it is likely these aspects of the drinking water industry will see slow, steady changes, with perhaps an occasional, dramatic development.

—By Anne Spiesman

Anne Spiesman is an environmental engineer at Camp Dresser & McKee, Inc., in Annandale, Va. *The author thanks Hugh Eggborn and Gerald W. Peaks, both of the Va. Dept. of Health, for contributing to this article. Water Central thanks the South Carolina Sea Grant Consortium for permission to reprint the map of the 1854 cholera epidemic in London.*

Disinfection Terms

Chloramine—A weak disinfectant formed by combining a chlorine solution with ammonia.
Chlorine Dioxide—A relatively strong disinfectant that is sometimes used in drinking water treatment.
Disinfection By-product—Chemicals that result from side reactions when drinking water is disinfected. Examples include trihalomethanes (see below) and bromate (a by-product of ozone disinfection).
Multiple Barriers—Combining practices in source-water protection, treatment, and distribution to prevent microbial contamination of drinking water.
Ozone—A strong disinfectant formed by combining three oxygen atoms.
Pathogen—A disease-causing organism.
Trihalomethanes—The most common class of disinfection by-products created when chlorine reacts with natural organic materials.
Ultraviolet Radiation—Energy from a portion of the electromagnetic spectrum that has been shown to disinfect some pathogens.

Waterborne Disease Terms

Cholera—A disease caused by bacterium *Vibrio cholerae.*
Cryptosporidiosis—A disease caused by the parasitic protozoan *Cryptosporidium*.
Enteric Diseases—Intestinal diseases.
Giardiasis—A disease caused by the parasitic protozoan *Giardia*.
Typhoid—A disease caused by the bacterium *Salmonella typhi*.

References and Further Reading

Baker, M. N., and M. J. Taras. 1981. *The Quest for Pure Water, 2nd Edition*, Volumes I and II, American Water Works Association, 1981.

Hall, Ellen, and Andrea Dietrich. "A Brief History of Drinking Water," *Virginia Section AWWA Newsletter*, October 1999

Further Reading on the World Wide Web

Va. Dept. of Health/Office of Water Programs: www.vdh.state.va.us/owp/;
Virginia Section, American Water Works Association: www.awwa.org;
Centers for Disease Control and Prevention: www.cdc.gov;
EPA Office of Groundwater and Drinking Water: www.epa.gov/OGWDW/.

SCIENCE BEHIND THE NEWS

What's the Meaning of This…Data?!

[This article is Part 2of *Water Central*'s look at statistics; Part 1 ran in the June-August 2000 issue (p. 8).]

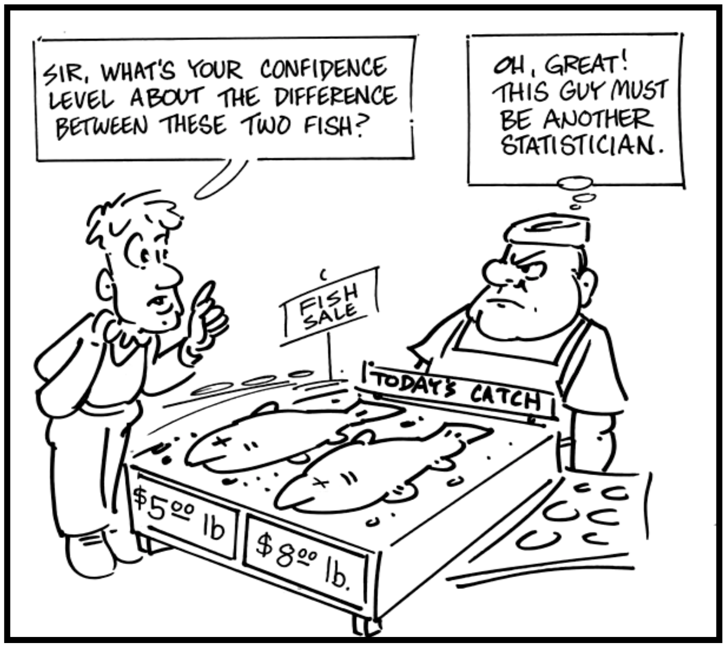
Good old Statistical Sample Stanley. He already gave us—in Part 1 of this series on statistics—two examples of *gathering* data: one based on observations of lake water quality; the other an experiment to test people's taste perception of tap water. Now Stanley is back to remind us that gathering valid data is only one step in using statistics to answer important questions; just as important is how one *analyzes* data.

At the Water Center's Virginia Water Research Symposium in November, 2000, Robert Ward, director of the Colorado Water Resources Institute, emphasized the timeliness of this topic. He said, "There's a whole new effort underway to question the statistics used in water-quality data analysis."

Data analysis consists of two main parts: *examining* data and *making inferences* from data. Examining data includes using tables and graphs to summarize and illustrate data, along with calculating **sample statistics** (numbers that describe a sample from a population). Specific tests using the sample statistics then allow for justifiable and defensible **statistical inferences**: reasoning based on certain assumptions and using systematic statistical procedures. To explore these topics, we'll investigate *made-up* data about the price of fish and the quality of Virginia's waters.

Summarizing and Describing Data

When the grumpy fish seller in the cartoon above told Stanley, "The more expensive fish is Rainbow Trout. It's leaner than Lake Trout, the cheaper one," he didn't intend to become part of an illustration of statistics. But Statistical Sample Stanley knows a good example when he sees one, so he devised a test of the fish seller's assertion. He posed this question: Is there less fat in the fish seller's Rainbow Trout than in his Lake Trout?



Stanley was on hand when the next deliveries of Rainbow Trout and Lake Trout arrived. He took **random samples** of 25 fish of each type, and he determined the fat content of each individual fish (in percentage of body weight). Stanley then created the table at the top of page 7 as his first data summary.

The table shows a **range** of values for each species. Assuming Stanley's measurements were accurate, the range of values represents natural, **random variation**. When sample units are chosen randomly, characteristics of those units that can take on different values differ randomly. In this example, fat percentage is a **continuous random variable**—it can take on an unlimited number of values. The uncertainty that this variability introduces into any sample is known as **random error**.[11]

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[11] Kenneth E. Osborn, in *Water Environment and Technology* (Nov. 2000), provides the following good description of **random** vs. **systematic** error:

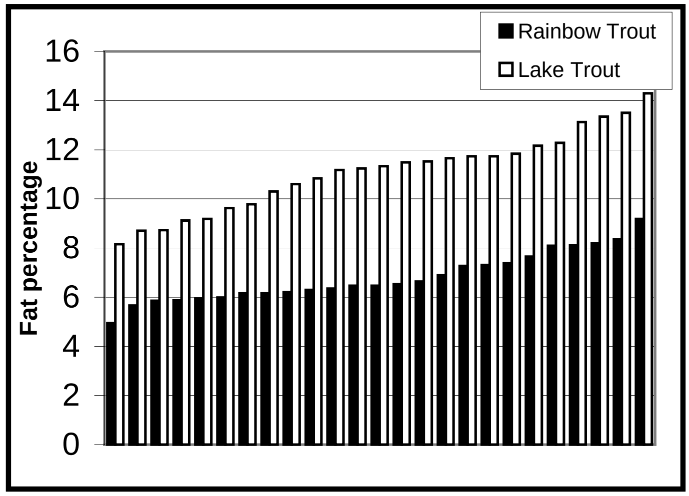
"Sources of systematic error [are] constant from one observation to the next [for example, improper instrument calibration]…Random errors vary from one observation to the next [and] have an equal likelihood for increasing or decreasing a measurement value…[They are] unpredictable."

Rainbow Trout Fat % (lowest to highest)	Lake Trout Fat % (lowest to highest)
4.94	8.15
5.66	8.70
5.86	8.73
5.87	9.12
5.94	9.18
5.98	9.63
6.15	9.78
6.15	10.30
6.20	10.60
6.30	10.83
6.35	11.18
6.47	11.24
6.47	11.33
6.53	11.49
6.63	11.53
6.90	11.65
7.27	11.73
7.31	11.73
7.39	11.84
7.65	12.16
8.09	12.28
8.10	13.13
8.20	13.34
8.35	13.50
9.19	14.29

Showing data in a table is useful for documenting detailed results, but Stanley wanted more concise summaries. **Graphs**, or **charts**, create a *picture* of data; in so doing, they bring out patterns more prominently than do tables of numbers. The statistician's term for the variation of values in a population or a sample is the **distribution** of the data.

The following (top of next column) is a **column chart** of the fish-fat data. It plots the fat-percentage value on the y-axis, with the lowest percentage on the far left of the x-axis and the highest percentage on the far right.

The chart clearly shows the variation among individuals of each species that was shown by the data table. The chart also shows clearly that most of the Lake Trout had higher fat percentages, although a few of the values overlapped between the two species.



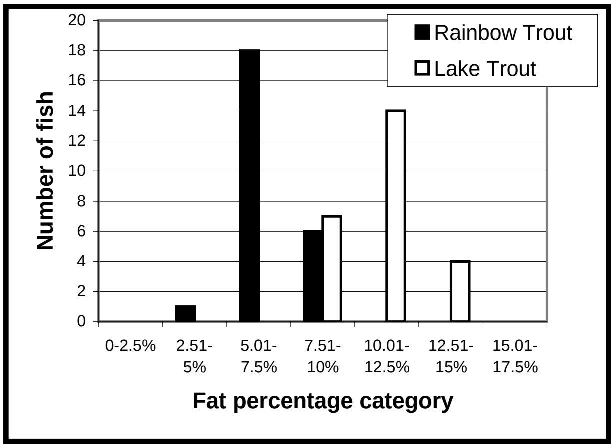
Stanley next employed a relatively simple but effective summary tool: a **frequency analysis**. He created categories for the ranges of values and counted the number of individuals in each category.[12] The following table shows his frequency analysis:

Category	# of Rainbow Trout	# of Lake Trout
0—2.5%	0	0
2.51—5 %	1	0
5—7.5 %	18	0
7.51—10 %	6	7
10.01—12.5 %	0	14
12.51—15 %	0	4
15.01—17.5 %	0	0

From the numbers in the table we can see the distribution pattern emerging: Most of the Rainbow Trout (24) had a percentage between 5 and 10, while most of the Lake Trout (21) had a percentage between 7.5 and 12.5. Once again, Stanley depicted the data with a column chart (top of next page). This chart is called a **histogram**. It has the *categories on the x-axis* and the *number of individuals in each category on the y-axis*.

This level of analysis is probably adequate to settle the basic question of which species in the sample had less fat. But, given the substantial price per pound difference, Stanley wanted to know *how much* difference there was. So it was time to calculate some **descriptive statistics** for the distributions.

[12] Choosing useful categories for data takes some thought so that the categories are neither to large nor too small. Category widths should be equal.



Descriptive Statistics

Calculating numbers to describe the distribution of data is a key part of data analysis. In most data analysis, the two most important aspects are the data distribution's **central tendency** and its **variation**. For samples of random variables in the natural sciences (such as the fishes' fat percentage), the most commonly used measure of central tendency is the **sample mean**. The **mean** (commonly called the average) is the sum of all values, divided by the number of values. The most common measure of variation around the central tendency is the **sample standard deviation**.[13] The more-complicated formula for the **standard deviation** is in any basic statistics book, but hand calculators and computers do it for you. Here are those statistics for Stanley's sample:

Statistic	R. Trout	L. Trout
Mean fat %	6.80	11.10
Std. dev.	1.02	1.61

From these statistics we see that, on average, the Rainbow Trout was only 2/3 as fat as the Lake Trout. If fat-percentage is the main price criterion, the price difference between Rainbow Trout and Lake Trout is justified *for the batch of fish Stanley sampled*. But the fish seller gets a new delivery every day, so how can Stanley determine if his results hold true for fish he might buy from on any given day? That question brings us to statistical inference.

[13] There are many other measures used to describe data. The **median**, for example may often be more appropriate for identifying the center of a distribution, especially if the data have some very high or very low values.

From Sample Data to Population Conclusions

A sample or an experiment gives us data and knowledge about the units actually measured or observed. This type of information—based on actual observations, not on probability or theory—is called **empirical**. Stanley has empirical data from his sample of Rainbow Trout and Lake Trout to show that the 50 fish he examined differed by species in fat percentage. But Stanley cannot get empirical information about *all* Rainbow Trout and Lake Trout, as it would be impossible and senseless to measure the whole population. To be truly useful, a sample has to allow valid inferences about the population. Systematic methods of statistical inference are the tools for doing so.

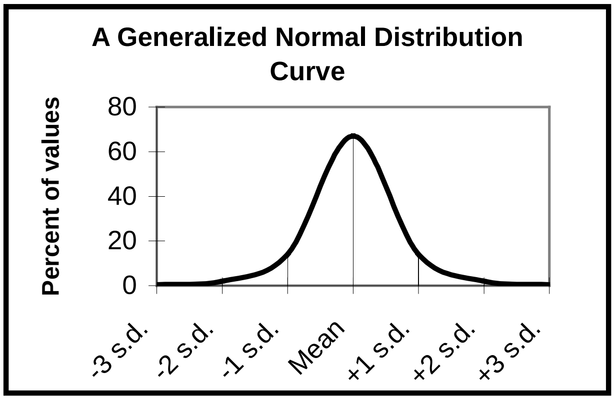
The two main types of statistical inference are **hypothesis testing** and **estimation**. Both are based on laws of probability about what would happen if a sample or experiment were repeated many times. In our example, Stanley wants first to *test a hypothesis* about whether there was statistically significant difference in fat-percentage between Rainbow Trout and Lake Trout. Second, he wants to *estimate* the expected fat percentage for a given sample of each species.

Stanley's inferences will apply to the population that Stanley sampled *randomly*. We know that he randomly selected fish from a day's delivery, so his statistical tests will at least be valid for all the fish on that day. But if Stanley wants to make any inferences to *all* the fish delivered to the fish seller, he would have had to select randomly his sampling day (or days), as well. Statistical inferences are valid only to the level of population one has randomly sampled, because the inferences are based on comparing empirical results to what could happen over repeated trials, simply by chance.

Comparing Data to Random Chance

Statistical reasoning asks this fundamental question: Are one's empirical results significantly different from what one could expect to occur simply by chance? If they are, then we rightly infer that something other than chance caused the results. In practice, this question is asked by comparing the empirical data's distribution to an appropriate **probability distribution** based on an assumption of randomness.

Statisticians have developed various probability distributions appropriate for different types of data. To illustrate statistical inference with our fish-fat example, we will be comparing out data to the **normal distribution**.[14] Randomly collected data from many naturally occurring continuous variables—people's height, for instance—fit, or nearly fit, this distribution. The distribution is illustrated by a bell-shaped curve:



The diagram illustrates that a normal distribution has the following features:

- the values are symmetrical about the mean;
- about 67 percent of values fall within one standard deviation (s.d.) of the mean;
- about 95 percent of the values fall within two standard deviations of the mean; and
- about 99 percent of the values fall within three standard deviations of the mean.

Hypothesis Testing

Let's assume that Stanley's sample was properly randomized to represent the fish seller's regular supply. Our inferences from Stanley's one-day sample, then, will be valid for any given day that the fish seller's source of supply remains essentially the same.

To determine if there is a statistically significant difference in fat-percentage between Rainbow Trout and Lake Trout, Stanley first proposes a **null hypothesis** that he can test with his data. In statistical literature, the symbol for null hypothesis is H_o. Typically, in a test of whether two values are different, the null hypothesis is that there is *no* difference.

For the hypothesis test, Stanley used the descriptive statistics we calculated above. Stanley tested whether there was a statistical difference between the *means*; the *standard deviations* were needed for calculations. Stanley's null hypothesis was follows:

H_o: L. Trout % — R. Trout % = 0.

(Recall that the sample data showed an *empirical* difference of 4.3 percent.)

Stanley now performed a very commonly used procedure known as a **t-test** (using **the t-distribution**) to establish the probability that his null hypothesis (no difference) is true.[15] From a reference table of t-distribution values (or a computer program), Stanley found that, if in fact the null hypothesis *were* true, a sample the size of Stanley's would find a difference as large as his result *only five percent of the time due to chance alone.*

The five-percent value is called the **significance level**. From this result, Stanley rejected his null hypothesis, and concluded that there was indeed a **statistically significant difference** in the mean fat percentages between the two populations he sampled randomly. Stanley must maintain a note of caution, however: His rejection of the null hypothesis has a five-percent chance of being wrong.

Estimation

Stanley wanted to know whether he could expect, with a known degree of confidence, an equivalent difference in fat percentage for repeated samples done the same way. To find out, he used another very common tool of statistical inference: **estimation of a confidence interval**. A confidence interval is a range of values about a sample mean. The **confidence level** (similar in concept to the significance level discussed above under hypothesis testing) is the percentage of time that the method used for the sample will produce a confidence interval that contains the true *population* mean. Here are Stanley's results for estimation of a confidence interval at the 95-percent level:

[14] The term "normal" can misleadingly imply that other distributions are "abnormal." A more accurate interpretation is that the normal distribution is the most widely used statistical distribution.

[15] A t-distribution *approximates* a normal distribution. T-tests are commonly used because they require knowing only the standard deviation one's *sample*, not that of the population itself.

Statistic	Rainbow Trout Data	Lake Trout Data
Mean fat %	6.80	11.10
95% conf. Int.	6.8 +/- 0.4	11.1 +/- 0.6

This means that Stanley has a 95-percent chance that the true population mean falls within his sample's confidence interval. In any similar sample from this population, there is a 95-percent chance that the mean fat percentage for Rainbow Trout will be 6.4—7.2, and that of Lake Trout will be 10.5—11.7.

Margin of error—one of the most widely seen statistical terms in the news but also one of the most easily misunderstood—is related to confidence intervals. It is a statement about the *precision* of sample methods. In the example above, the margin of error for the Rainbow Trout mean is 0.4; for Lake Trout, 0.6. The confidence level, as described above, is the sampler's confidence in the margin of error.[16]

A Different Distribution, Variable, and Water-quality Problem

Stanley has a final example, based on a **binomial distribution** rather than the normal distribution. The binomial distribution applies to the many real situations where the data are from *repeated trials* with *only two possible outcomes* in each trial. The data in such cases measure **categorical variables** (usually referred to as "success" or "failure"), rather than continuous variables.

The most familiar example of a phenomenon with a binomial distribution is tossing a coin. Each trial (tossing) has only two possible outcomes (heads or tails), each of which has a constant probability of occurring in a given trial (0.5, or a 50-percent chance). Because tossing a coin follows the binomial distribution, we can find (by formula or by reference tables) the probability for different combinations of outcomes (two heads in a row; three heads followed by two tails; etc.). Knowing the probabilities for random events in a binomial distribution, we can compare those random probabilities to the rate of occurrence seen in data from any real-life events that fit a binomial distribution.

The binomial distribution is the focus of a recent issue among water-quality regulators in Virginia and at the U. S. Environmental Protection Agency. In 1998, the Va. Department of Environmental Quality (DEQ) elected to use a binomial distribution method for assessing water-quality data. They chose the binomial over a simple percentage method (number of violations over number of samples) to determine if assessed waters exceeded water-quality standards more than 10 percent of the time (the rate recommended by the U. S. EPA to indicate impaired waters). But Va.'s Joint Legislative Audit and Review Commission, which asserted that the binomial procedure underestimates the violation rate, criticized the DEQ's use of this method in report. This statistical-methods debate potentially has significant consequences, as noted in the following quote:

> An inference that water quality is impaired initiates [a costly planning and pollution-control process]. Falsely concluding that a water segment is impaired results in unnecessary...costs. On the other hand, falsely concluding that a segment is not impaired may pose a risk to human health [or aquatic life]."[17]

Stanley has made up a water-quality example to help us understand the type of data to which this debate applies. He devised a simulation for the following question: "Ten percent or more of the time, is the level of bacteria in a lake greater than the state's standard for swimming?"[18] He simulated a lake-sampling program of five samples dates per year, 10 sites on each date. On each date,

[16] A confidence level should accompany any statement of a margin of error, but it often remains unstated, such as in many reports of opinion polls.

[17] Smith, Eric P., *et al.* 2000. "Assessing Violations of Water Quality Standards Under Section 303(d) of the Clean Water Act." Va. Water Center Special Report SR18-2000.

[18] The U. S. EPAA recommends waters be designated as "impaired" if ten percent of samples over a given period exceed a state's standard for fecal coliform bacteria. Virginia's bacterial standard for surface waters used other than shellfish waters is 1000 colony-forming units (CFU's) per 100 milliliters (ml) of water at any one time, and 200 CFU per 100 ml as a geometric mean of two or more samples over a 30-day period (*Virginia Administative Code*, 9 VAC 25-260-170).

the sample is either below the bacterial standard (pass) or above the standard (fail). Stanley simulated this by picking tags and from a hat containing "pass" and "fail" tags. Here are the data from 50 samples:

Days→	1	2	3	4	5	6	7	8	9	10
1	F	P	F	P	P	P	P	P	P	P
2	P	P	P	P	P	P	P	P	P	P
3	P	P	P	F	P	P	F	P	F	P
4	P	P	P	P	P	P	P	P	P	P
5	P	P	P	P	P	P	P	P	F	P
# Fail	1	0	1	1	0	0	1	0	2	0

The total number of failures in the made-up data is six, so a simple percentage test gives us a failure rate of 12 percent. The empirical percentage alone, however, does not tell us how *confident* we can be in making inferences about the population. Just as for other types of distributions, statistical tests have been developed for making inferences from binomially distributed data. In this case, a **test of binomial proportions** would allow us to test, at a given *significance level*, a null hypothesis that the true failure rate is actually 10 percent; that is, to test how often we could expect these results simply by chance.

Unfortunately, at this key moment, Statistical Sample Stanley ran off, saying there was less than a one-percent chance that he could adequately guide us further into the binomial distribution or its relation to Virginia's water-quality monitoring.

Conclusion

Statistics is the set of concepts and practices that help people collect, organize, and interpret data in scientifically valid and defensible ways. Statistics allows us to deal with uncertainty and probability, and to tell if the differences we observe are *real* and *significant* compared to chance.

Statistical inference depends on comparing the distribution of empirical data to standard probability distributions. In this article we have looked at three commonly seen probability distributions—the normal, binomial, and t-distributions. There are many other kinds, but familiarity with these three can help you better understand many water-related numbers.

We are constantly confronted with numbers or the need for them. Even if you remember no statistical terms or formulas, understanding the key concepts of variability, probability, and randomness will improve your ability to cope with a world overloaded with information, water-related and otherwise.

Two quotes from professional statisticians conclude our topic:

"The reasoning in statistical inference is subtle, and the principles at issue are complex…If you…do not fully grasp all the ideas…, you are in excellent company."[19]

"Statisticians looking at the same data [don't] always come to the same conclusions. But critical thinking, combined with good methods for collecting data, sound inferential procedures, and plain common sense, allow us to draw our own solid conclusions."[20]

—By Alan Raflo.

Water Central *thanks George Terrell and Jeff Birch, both of the Virginia Tech Statistics Department, for their assistance with this article.*

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[19] David Moore (1991), *Statistics: Controversies and Concepts*, p. 426.

[20] Teresa Amabile, (1989), "Against All Odds: Inside Statistics," Video Program #26, Annenberg/CPB Collection.

IN AND *OUT OF* THE NEWS
Newsworthy Items You May Have Missed

The following summaries are based on information in the source(s) indicated at the end of each item. Selection of this issue's items ended December 29, 2000. Unless otherwise noted, all localities mentioned are in Virginia.

In Virginia...

•**PCB levels in the Staunton and Dan rivers have dropped considerably since the 1970s,** the Virginia Department of Environmental Quality (DEQ) reported in October 2000. It isn't known whether the reduction is due to a breakdown of the chemicals or to cleaner sediment settling over more contaminated layers. The improvement has *not* caused the DEQ to change its recommendation for limited consumption of fish caught in these rivers. PCBs—suspected carcinogens—accumulate in fatty tissues of fish.

In a related story, the DEQ prepared a **list of possible sources of PCB pollution in the Staunton River** and released the list to the public in late October. The sites tested were in Altavista and Hurt, and included sites owned by furniture and textile manufacturers and small oil distributors; the site of a train wreck; and several properties owned by the towns. (Both stories in *Lynchburg News & Advance*, 10/24/00)

•**A summit on providing access to public water systems for residents of southwestern Virginia** was held in Abingdon in October 2000. Speakers estimated the costs of the current and planned public water projects in the region at about $172 million, and that some of the projects are as much as 20 years from completion. "Friends, it's the year 2000," said William Wampler, a state senator from Bristol. "Don't you think we can do a better job of establishing indoor plumbing throughout Southwest Virginia?" (*Bristol Herald-Courier*, 10/25/00)

•**A bacterial source tracking study** in Arlington County's Four Mile Run, conducted by Virginia Tech and the Northern Virginia Regional Planning District Commission, found that birds, raccoons, and even humans cause more bacterial pollution than dogs cause. Local officials suspected the large number of dogs exercised by their owners in proximity to the stream, and the waste many leave behind, would account for a high degree of fecal coliform pollution. But fecal counts tracked to dogs accounted for an estimated nine percent of the bacteria detected while waterfowl contributed 37 percent, raccoons 15 percent, and humans about 17 percent. (*Washington Post*, 10/26/00)

•A panel of Virginia and Maryland officials, crab fishers, seafood processors, and environmentalists agreed for the first time in October 2000 that **a limit should be placed on blue crab harvests in the Chesapeake Bay**, as both states prepared to close out a year in which harvest levels were at historic lows. The panel is recommending that annually 10 percent of the spawning potential of crabs should be protected. (Alliance for the Chesapeake's *Bay Journal*, November 2000)

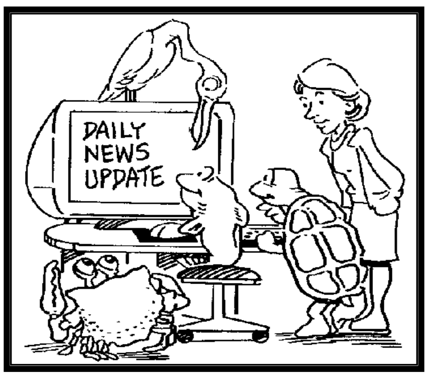
•**The Chesapeake Bay receives millions of tons of ballast water** each year from transoceanic freighters. According to a study recently published in the journal *Nature*, some of the water contains significant levels of microbes and viruses. Cholera-causing bacteria, for example, have been detected in the ballast of ships arriving in Baltimore and Norfolk over the past three years. The findings have bolstered concerns about invasive species being transported in ballast water, and some university marine programs have begun studying ways to clean ballast-water before it is dumped. (*Washington Post*, 11/02/00)

•Here are **three items on nutrient loads in the Chesapeake Bay watershed** (all from *Bay Journal*, December 2000):

*__Rockingham County has a new wastewater treatment plant__ and a new method for handling the waste it discharges. The plant takes in wastewater from two towns and two poultry processors. If all goes according to plan, the plant will keep at least 200,000 pounds of nutrients from discharging into the Shenandoah River each year by pumping them onto nearby farm fields as fertilizer. The plan is not without problems, though. Some state officials and environmental experts believe there's already too much nitrogen in Shenandoah Valley soils and that adding more could compromise groundwater. The DEQ is requiring extensive monitoring of the applications and, under certain conditions, may require discharging the wastewater to the river.

*__Nearly 50 industrial plants__ in the Bay watershed have **voluntarily been reducing their nitrogen discharges** or are planning to do so. Representing at least a dozen industries, these plants have instituted waste-treatment practices that have kept more than 17 million pounds of nitrogen from discharging into Bay tributaries since the mid-1980s. Reductions attributed to Virginia plants in this group represent half of the state's total *point-source* nitrogen reductions since that time.

*In 1999 Virginia **exceeded its nutrient-reduction goals for the Potomac and Shenandoah rivers**, largely through control of agricultural runoff. Since 1998, the federal government has paid $5 million, the state $15 million, and individuals $6 million to support runoff-control programs in these two basins. The programs have led to the retirement of more than 25,000 acres of agricultural land; 200 miles of stream fencing; 20 miles of stabilized stream banks; 422 acres of grass filter strips along waterways; nutrient-control systems at 725 poultry processors; and nutrient-management plans for 280,000 acres of farmland.



The Daily News Update at www.vwrrc.vt.edu—keeping the whole water gang informed.

•A **Northern Right Whale was sighted from a charter fishing boat off Virginia Beach** in November, 2000. Such a sighting is an increasingly rare event because only an estimated 300 No. Right Whales are still live in the North Atlantic. (*Roanoke Times*, 12/11/00)

•**Grundy, the Buchanan County seat, is moving downtown up the hill.** Three times in the last 60 years, the Upper Levisa River has flooded the downtown business district. Now local leaders, working with the Va., Department of Transportation and the U. S. Army Corps of Engineers, have begun using $177 million from the two agencies to demolish buildings in the old lowland area of town, with plans to reconstruct them on a level site the Corps is blasting out of a mountain just across the Upper Levisa. The plan will also allow for widening U. S. Route 460 atop a new floodwall through the original downtown site. (*Washington Post*, 12/28/00)

…and Outside of Virginia

•**A new generation of marine engines** promises to satisfy boating enthusiasts and regulators alike. In 1996, the U.S. Environmental Protection Agency (EPA) called for tighter emission restrictions and greater fuel efficiency for marine engines, which the agency says contribute about three percent of U.S. hydrocarbon emissions. The stricter standards mean phasing out popular but relatively inefficient carbureted, two-stroke engines nationwide by 2006. In response, manufacturers have developed fuel-injected, two- and four-stroke engines that appear to provide several benefits: significant reductions in hydrocarbon emissions, noise, smoke and fumes; more efficient fuel burning; and reduced chances for leakage of gasoline and additives. (*Water Connection*, NE Interstate Water Pollution Control Commission, Lowell, Mass., Fall, 2000)

•Along with population and economic activity, **the demand for water is increasing in the border regions between the United States and Mexico**. That's prompting concerns about rising consumption of groundwater. To address these concerns, the EPA recently funded **two studies of aquifers** along the borders of Texas, New Mexico, and Mexico. The New Mexico Water Resources Research Institute, the Texas Water Development Board, and two water agencies of the Mexican government worked together to map aquifer characteristics. The studies indicate adequate current amounts of water but low recharge rates. Preliminary results indicate water quality in these aquifers is good, though the character of the aquifers' rock types can lead to irregular concentrations of salinity. (*Divining Rod*, N.M. Water Resources Research Institute, November 2000)

•A voluntary effort may soon be under way to reduce significantly the **nitrogen run-off that has contributed to a Gulf of Mexico "dead zone,"** estimated to be the size of New Jersey. Scientists first noticed the "dead zone"—significant areas of oxygen depletion—in Gulf waters about ten years ago. The nitrogen-reduction plan calls for all Gulf-watershed states to agree to reduce run-off levels 30 percent by 2015. If that goal is met, the EPA estimates the size of the "dead zone" will shrink by half. A task force of representatives from the key states, interest groups, and Native American tribes agreed to the reduction targets last October, but implementation—expected to cost $1 billion or more per year—depends on Congressional funding. A draft of the action plan is available on-line at www.epa.gov/msbasin.fr-actionplan. (*Bay Journal*, November 2000)

•The U.S. Marine Corps is trying to notify anyone who lived on its **Camp LeJeune, N.C. base from 1968 to 1985** that they may have consumed **water contaminated with compounds linked to birth defects and leukemia**. The compounds are believed to have come from a dry-cleaning business on the base. In 1998 the federal Agency for Toxic Substances and Disease Registry published a report identifying a suspected link between the contamination and birth defects. In order to conduct health surveys, that agency has tried to contact people who lived on the base during the time of the contamination, but it has managed to reach less than half of the estimated 16,500 families that may have been exposed. The Marine Corps is encouraging anyone who lived on the base during the relevant years to call a toll-free number, **(800) 639-4270**, or to make contact through the Corps web site, at www.usmc.mil. (*Richmond Times-Dispatch*, 11/02/00)

•A Wheeling, West Virginia, high school student detected **low levels of antibiotics in water samples taken from the Ohio River** near her home in October 2000; she also found them in samples of Wheeling's tap water. The discovery won her the Stockholm, Sweden, Junior Water Prize. It's suspected that the detected penicillin, tetracycline, and vancomycin reached the river largely from agricultural sources, because these antibiotics are used regularly in livestock. The student's detection of the drugs in tap water suggests standard water-treatment practices may not effectively remove them. The worrisome note about the presence of antibiotics in the water supply is the possibility that bacteria exposed to them over long periods will develop resistance to the drugs. (*USA Today*, November 8, 2000)

•A University of Maryland study published in December said **more than 50 percent of the Chesapeake Bay's marshes are on their way to becoming open wate**r in the next few decades. There are several apparent causes: rising sea levels; the destructive habits of some wildlife species such as Canada Geese and Nutria (a fur-bearing mammal native to South America); artificial obstructions; and a natural sinking of the land surrounding the Bay. The impacts the study details can be seen most clearly at the Blackwater National Wildlife Refuge in Dorchester County, Md., where 7,000 of the marsh's 23,000 acres have been lost since the 1930s. The U.S. Fish and Wildlife Service hopes to restore the Blackwater Reserve to its condition in the 1930s and is studying how to eliminate Nutria from the marshes. (*Baltimore Sun*, 12/06/00)

•A Pentagon investigation determined in November that **three top officials at the U.S. Army Corps of Engineers manipulated the results of a study** into the feasibility and need for lock expansions on the Mississippi and Illinois rivers. The investigation comes as activities of the Corps are under increased scrutiny in Congress. The National Academy of Sciences is now studying the need for the lock expansions, while the Senate has promised to hold hearings in 2001 on Corps practices. (*Washington Post*, 12/07/00)

•If construction of the **Randleman Reservoir near Greensboro, N.C.**, is approved by the Army Corps of Engineers later this year, all of the 110-mile **shoreline will be off-limits to residential and commercial development**. The authority that would control the reservoir would own a 200-foot-wide buffer of undisturbed land. Both measures would seek to reduce polluted runoff reaching the reservoir. The lake would supply drinking water for Greensboro, three other cities, and two counties. (*Charlotte Observer*, 12/18/00)

•**Boston Harbor is cleaner than it has been for decades.** Marine mammals are now spotted regularly around the mouth of the harbor, and people are once again swimming in its waters. The improvement is credited to a better water-treatment plant serving 43 communities—the second-largest plant in the nation. Another factor is a 9.5-mile underground pipe that sends Boston's waste further out to sea, allowing it to be diluted before it drifts back toward the shallow harbor. That pleases Bostonians but troubles the people on Cape Cod, where the pipe points. The EPA has ordered extensive monitoring to allay concerns about the new discharge zone. (*Christian Science Monitor*, 12/20/00)

•Finally, here's a comment on those improvements to Boston Harbor's water, from an employee of the environmental group that first filed suit against the state to force action back in the early 1980s: **"[Now] it smells like an ocean, not like a sewer."** (*Christian Science Monitor*, 12/20/00)

—By David Mudd

TEACHING WATER
Especially for Virginia's K-12 teachers

This Issue and the Virginia Standards of Learning

Below are suggested Virginia Standards of Learning (SOLs) supported by this issue's Feature, Science, and For the Record sections. Water Central welcomes readers' comments on whether the articles actually do, in fact, help teachers with the standards listed or with others. Abbreviations: A=Algebra I; AII=Algebra II; BIO=biology; C/T=computer technology; CH=chemistry; ES=earth science; LS=life science; PS=physical science.

Feature Article—Drinking-water Treatment
Science SOLs: 6.11, LS.12, ES.9, CH.6
Social Studies SOLs: 6.2, 9.9.

Science Article—Statistics (Part 2; See Jun.-Aug. 2000 issue for Part 1)
Math SOLs : 4.19, 5.17, 5.18, 6.18, 6.19, 7.19, 7.20, 7.21, 8.13, A.18, AII.19.
Science SOLs: 4.1, 5.1, 6.1, 6.2, LS.1, PS.1, ES.1, ES.2, BIO.1, CH.1.

For the Record—Maps for Water Resources
Computer Technology SOLs: C/T5.3, C/T8.4.
Social Studies SOLs: 3.6, 7.10, 10.1, 10.2, 10.5, 10.7, 10.8, 10.9, 10.10, 10.15, 11.15.

Federal Agency Educational Resources for Schools

The U. S. Geological Survey (USGS), Environmental Protection Agency (EPA), and National Oceanic and Atmospheric Administration (NOAA) are all heavily involved with the nation's water resources. These three agencies make available various water-resource educational tools through their Web-sites.

The **USGS**'s "Water Science for Schools" (and for other people, too!) is located at ga.water.usgs.gov/edu/. The site has pictures, data, maps, and information on many water, plus a good glossary of water terms.

The **EPA** has collected educational resources at its "Adopt-a-Watershed" site: www.epa.gov/adopt/eduation.html. Available at this site are EPA's own "Office of Water Kids' Page" and "Kids Ecosystem Page," along with links to water-related educational programs by many other groups.

NOAA's Education Resources page at www.education.noaa.gov/ is organized into three main sections: "Specially for Teachers"; "Specially for Students"; and "Cool Sites for Everyone." Each section leads you to information on weather, climate, oceans and coasts, and space.

N O T I C E S

On the Public Calendar

•**Feb. 28**—Public hearing on proposed discharge permit for North River wastewater treatment facility in Rockingham County, 7 p.m., Va. Dept. of Environmental Quality's (DEQ's) Valley Office, Harrisonburg. For more information, contact Valerie Rourke, e-mail: varourke@deq.state.va.us, or by phone at the DEQ Central Office in Richmond, toll-free in Virginia, (800) 592-5482.

•**March 1 and 5**—Public meetings on notice of intent to conduct triennial review of water-quality standards. March 1: 2 p.m., Virginia War Memorial, Richmond; March 5: 2 p.m., DEQ West Central Office, Roanoke. For more information, contact Elleanore Daub, e-mail: emdaub@deq.state.va.us, or by phone at the DEQ Central Office in Richmond (see number above).

Proposed TMDL in Shenandoah River

The Va. DEQ will issue on Jan. 27, 2001, a public notice of a proposed Total Maximum Daily Load (TMDL) for PCB's in 41miles of the South and North Forks of the Shenandoah River. The public comment period will run until Feb. 28. For more information, phone Rod Bodkin at (540) 574-7801, or e-mail: rvbodkin@deq.state.va.us.

Have a Say about Environmental Educ.

Until March 1, 2001, the Va. Environmental Education Advisory Committee, created in 2000, is soliciting public input on the needs and priorities for environmental education in Virginia. For more information, phone Ann Regn at (804) 698-4442, or see the information on-line at www.vruec.org/enved.htm.

A Busy Spring Conference Season

•**Virginia Water Conference 2001.** The Va. Lakes and Watersheds Association's annual conference will be March 11—13 in Fredericksburg. For more information, contact the conference coordinator at (703) 642-5080, or e-mail: kyoung@gky.com.

•**"Sustainable Watersheds—Balancing Multiple Needs."** This year's Southeastern Lakes Management Conference will be held March 21—23 in Knoxville, Tenn. For more information, phone Sue Robertson at (423) 751-3747, e-mail: ssrobertson@tva.gov; or visit the North American Lake Management Society's Web-site at www.nalms.org.

•**Virginia Environment Symposium.** The 12th annual version of this conference will be held April 4—5 in Lexington. For more information, phone (540) 464-7750; Web-site: www.vmi.edu/ev.

•**Virginia Water Environment Association Conference.** "2001: An Ecological Odyssey" will be held April 29—May 2 in Williamsburg. For more information, phone Liz Christoff at (757) 595-1861; or e-mail: christoff@compuserve.com.

Water Quality in Two North Carolina Sounds

Albemarle and Pamlico sounds in North Carolina receive the waters of four major rivers in North Carolina and Virginia. This 1998 report summarizes findings from water-quality assessments during 1992—95. Available only on-line at water.usgs.gov/pubs/circ1157/.

USGS Report on Nutrients

The USGS has recently released "Nutrient Concentrations and Yields in Undeveloped Stream Basins of the United States." For an on-line version: water.usgs.gov/nawqa/nutrient.html. For a hard copy, please contact Amy Pekarik at the USGS in Reston, Va., phone (703)-648-5701.

At the Water Center

For more information about any item below, call the Water Center at (540) 231-5624; e-mail: water@vt.edu; or visit www.vwrrc.vt.edu

•**Request for Research Proposals**—Please see below.
•**Conference Announcement**—2001 Water Research Symposium, in Charlottesville, Nov. 14—16. For more information, please see page 17.
•**New Publications**

Conference Proceedings on CD-ROM: "Advances in Land and Water Monitoring Technologies and Research for Management of Water Resources," Tamim Younos, ed., 2000. Request VWRRC P6-2000.

Conference Proceedings on CD-ROM: "Integrated Decision-Making for Watershed Management—Processes and Tools," Darrell Bosch, ed., 2001. Request VWRRC P7-2001.

CORRECTION FROM THE PREVIOUS ISSUE OF *WATER CENTRAL*

The Feature Article in the November 2000 issue (Issue #14) did not mention that the Virginia Department of Environmental Quality provided helpful information and assistance for the article.

Request for Proposals and Fellowship Announcements

The Water Center has announced the following Request for Proposals and fellowships for Fiscal Year 2001 (July 1, 2001—June 30, 2002):

1. **Seed Grants**, Request for Proposals—Deadline March 30, 2001.
2. **USGS Competitive Grants**, Request for Proposals—Deadline March 19, 2001.
3. **William R. Walker Graduate Research Fellowship Award**—Deadline March 30, 2001.
4. **Undergraduate Research Summer Fellowship Awards**—Deadline March 9, 2001.

Guidelines for proposal preparation and fellowship application materials are posted on the Water Center's Web site, www.vwrrc.vt.edu; you can also obtain these materials by contacting the Water Center at (540) 231-5624. For additional information, please contact Dr. Tamim Younos at (540) 231-8039, or e-mail: tyounos@vt.edu.

Protecting Our Water Resources for the Next Generation

WHERE DO WE GO FROM HERE?

Virginia Water Research Symposium 2001

November 14—16, 2001
Charlottesville, Virginia

ABOUT THE SYMPOSIUM

The Virginia Water Research Symposium 2001 will assemble research scientists, educators, regulators, and environmental interest experts in a forum to discuss water issues facing Virginia and the region now and the future. Over the last half century, Virginia's landscape has changed significantly. Economic growth and population expansion have increased the demand for water use and water resources protection. Balancing the various water demands and ensuring a safe and affordable supply of water will become more critical in the coming decades. Issues such as water reclamation and reuse, water source protection, watershed management, and water management policies and regulations need to be re-examined and practical resolutions developed.

CALL FOR PAPERS

Research abstracts are being accepted for oral and poster presentations in all areas related to water environment, water supply, and water resources management. The abstract heading should include: Presentation title, author(s) name and affiliation, address, office phone and fax numbers, and email address. The body of the abstract should include a problem statement, research approach, major findings, and 3-5 keywords. Abstracts should not exceed 350 words. **The deadline for abstract submission is May 1, 2001.** Acceptance of a paper will be confirmed by email in early June and presenters will receive the author's guide for manuscript preparation and guidelines for oral and poster presentations. Abstracts not accepted for presentation will be invited to participate in a poster session. All posters must be mounted to easel-type boards that will fit on a 3' x 6' tabletop. Presenters must register for the symposium. **The deadline for submission of full manuscripts to be included in the symposium proceedings is August 1, 2001.**

Please email the abstract to jupoff@vt.edu. Abstracts may also be faxed (540)231-6673, or mailed to VWRRC, Virginia Tech, 10 Sandy Hall (0444), Blacksburg, VA 24061.

FOR THE RECORD
Sources for Selected Water Resources Topics

Maps for Water Resources

Maps are considered one of the most efficient ways ever devised to show information. Many kinds of maps inform us about the location, characteristics, and uses of water resources. This page identifies some main sources of maps and map-related information relevant to Virginia's water resources.

Sources of Water-related Maps

•U. S. Geological Survey (USGS) (maps of topography, land use, and much more): USGS Information Services, Box 25286, Denver, CO 80225; (800) USA-MAPS or (800) HELP-MAP; Web-site ask.usgs.gov. USGS maps are also available from many private vendors.
•Va. Dept. of Mines, Minerals, and Energy/Division of Mineral Resources (geological maps): DMME/DMR, P. O. Box 4667, Charlottesville, VA 22903; (804) 951-6340. The agency's Web-site describes the maps available: www.mme.state.va.us/DMR/home.dmr.html.
•National Atlas of the United States, on-line at nationalatlas.gov. Users can view existing maps or create maps showing various features.
•*Water Atlas of Virginia*, by Frits van der Leeden, Tennyson Press, Lexington, Va., 1993, 46 pp. This book contains maps showing basic facts about Virginia's water resources and water use.
•*Virginia Hydrologic Unit Atlas*, compiled by the Natural Resource Conservation Service and the Va. Dept of Conservation and Recreation (DCR), 1995. This book has maps of the hydrologic units, or watersheds, within each Virginia county. Available in libraries, or phone the DCR at (804) 786-2064 to request a copy.
•*Ground-Water Resources of the Untied States*, compiled by David K. Todd, Premier Press, Berkeley, Calif., 1983, 749 pp. This book, based on USGS reports, includes large-scale maps of geologic formations and other features.
•*Atlas of America's Polluted Waters*, U. S. Environmental Protection Agency, May 2000 (pub. no. EPA-840-B-00-002). The maps in this atlas show waters that do not meet state water-quality standards. Available in print free from the National Service Center for Environmental Publications, (800) 490-9198; available on-line at www.epa.gov/owow/tmdl/atlas.
•Oil Spill Cleanup and Response (OSCAR), an on-line mapping program developed by the Va. Institute of Marine Sciences. Users can create maps displaying many kinds of data, such as shoreline vulnerability to oil spills. Available at www.chesapeakebay.net.
•National Geographic Society web-site, www.nationalgeographic.com. Click on "Maps" then "Links" for descriptions of many useful sources of maps and geographic information.

Geographic Information Systems (GIS)

A GIS is a computer-based system for producing and storing maps and geographic data. Many public agencies and private firms have GIS capacities and inventories of GIS-based maps and data related to water resources.

The Virginia Geographic Information Network (VGIN), a division of the Department of Technology and Planning, is the state's lead agency for GIS. VGIN's Web-site, www.vgin.vipnet.org/index.html, has descriptions of GIS's available in Virginia. The VGIN coordinator's phone is (804) 786-8175.

A good introduction to GIS in general is the Winter 1998-99 issue of *Coastal Heritage* (Vol. 13, No. 3), available from the S.C. Sea Grant Consortium, 287 Meeting St., Charleston, S.C. 29401; (843) 727-2078; e-mail: dunmeyae@musc.edu.

Learning about Maps and Mapping

•*The Map Catalog, Third Edition*, Joel Makower, ed., Vintage Books, New York, 1992, 364 pp.
•*Keyguide to Information Sources in Cartography*, by A. G. Hodgkiss and A. F. Tatham, Facts on File Publications, New York, 1986, 253 pp.
•The USGS' National Mapping Program provides printed and electronic information about mapping programs and geographic data available in the United States. Phone toll-free 888-ASK-USGS, or visit the aks.usgs.gov Web-site.

Upcoming "For the Record" Schedule

Issue 16 – Groundwater Information Sources
Issue 17 – Coastal/Marine Information Sources
Issue 18 – Drinking-water Information Sources
Issue 19 – Water-quality Information Sources
Issue 20 – Water-quantity and Hydrologic Information Sources

Schedule subject to change

Guide to *Water Central* articles, June 1998—November 2000

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Loch, Lac, or Reservoir: There's More to Lakes than Water	Jun. 1999, p. 5
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