Certification Examination Study Guide

Laboratory Analyst
Grade IV

CALIFORNIA WATER ENVIRONMENT ASSOCIATION

California Water Environment Association

Grade IV Laboratory Analyst Study Guide

Technical Content by CGvL Engineers
6 Hughes, Suite 100
Irvine, CA 92618
www.cgvl.com

CGvL Project Team
Richard W. von Langen .... CGvL Project Manager
Heather Duckett...................... Author
Dr. Kenneth D. Kerri .... Technical Editor
Rhonda Barkey .... Word Processing Group
Jessie Lee .... Word Processing Group
Joy Gautier .... Word Processing Group
Lisa House .... Word Processing Group

Appendix A: You and Wastewater Math
Cheryl Ooten .... Author

CWEA Project Team
Chris Lundeen .... CWEA Project Manager/Editor
Nicole Schlosser...................... Editing Assistance
Lindsay Roberts .... Project Support

CWEA Technical Content Review
Marjorie Lopez Read............... California State Water Resources Control Board
Kacey Karmendy .... City of San Mateo
Kay Maksoud .... City of Modesto
Christine Kosmowski............... Battle Creek Michigan Water Treatment Plant
Victoria Shidell .... City of Benicia
Erich Delmas .... City of Tracy

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Important Notice: CWEA is pleased that you have purchased this book. We want to remind you that this book is one of many resources available to assist you, and we encourage you to identify and utilize the other resources in preparing for your next test.

Please send comments, questions, and suggestions to:
California Water Environment Association
7677 Oakport Street, Suite 600
Oakland, CA 94621 USA

Phone: 510-382-7800
Fax: 510-382-7810
Web: http://www.cwea.org
Email: tcp@cwea.org

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Section 1

Introduction

The California Water Environment Association (CWEA) Technical Certification Program (TCP) is voluntary; its purpose is to educate, prepare, and test an individual's knowledge within six vocations.

- Plant Maintenance Technology (with two parallel specialties in Electrical/ Instrumentation and Mechanical Technology)
- Laboratory Analysis
- Collection System Maintenance Technology
- Environmental Compliance Inspection
- Industrial Waste Treatment Plant Operations
- Biosolids Land Application Management

CWEA also assists in educating and training wastewater treatment plant operators for the State of California Operator Certification Tests. Upon qualifying and successfully completing a test, an individual is certified in that specialty at one of the grade levels. Levels within a specialty designate technical knowledge for the apprentice, journey, and management levels. Tests are designed to demonstrate minimum competence for a particular grade.

The purpose of this study guide is to provide a description of the knowledge, skills, and abilities (KSA) needed to pass the test. Also included are questions designed to assess candidates' strengths and weaknesses relative to their present KSA. Finally, the study guide provides references used to refresh subject knowledge, or to learn more about particular subject areas not completely understood.

Typically there are two to five primary references for each specialty area, which need to be read and understood. Test questions are generally based on information contained in these references. Secondary references give more information and often provide a different approach to a subject, making it easier to understand.

This study guide is not a compendium of all that may be on the test, so successfully answering questions contained in this guide does not guarantee passing. To successfully pass the Grade IV Laboratory Analyst (Lab Analyst) test, the reference materials presented in this study guide should be thoroughly understood.

This study guide can best be used to help identify strengths and weaknesses and to identify material that may need further study. Comments and suggestions to improve the study guide are always welcome and appreciated. Good luck on the test!

Section 2

Certification Program Information and Policies

CWEA's mission is to enhance the education and effectiveness of California wastewater professionals through training, certification, dissemination of technical information, and promotion of sound policies to benefit society through protection and enhancement of the water environment.

CWEA is a California nonprofit corporation, a Member Association of the Water Environment Federation (WEF), and a member of the National Organization for Competency Assurance (NOCA).

Technical Certification Program History

TCP was created to offer multilevel technical certification for individuals employed in the water quality field. Tests are written by vocational specialists and administered throughout the year in six different disciplines: Plant Maintenance Technology (with two parallel specialties in Electrical/Instrumentation and Mechanical Technology), Laboratory Analysis, Collection System Maintenance Technology, Environmental Compliance Inspection, Industrial Waste Treatment Plant Operation, and Biosolids Land Application Management.

CWEA first offered a certification program for wastewater treatment plant operators in 1937. The program was administered by CWEA until 1973 when the State of California assumed responsibility. During those 36 years, CWEA awarded 3,915 operator certificates.

The first committees were formed in 1975 to establish a voluntary certification program for water quality professionals specializing in disciplines other than plant operation. The Voluntary Certification Program (VCP) emerged offering specialized certificate programs for Collection System Maintenance Technology, Plant Maintenance Technology, Environmental Compliance Inspection, and Laboratory Analysis, with certifications first issued in April 1976. In the 1980s, two more disciplines were added: Electrical/Instrumentation and Industrial Waste Treatment Plant Operations.

Today, CWEA offers certification in six vocational programs with a total of 22 individual certifications. About 2,000 applications are processed annually and currently over 5,500 certificates are held by individuals in California and neighboring states.

Certification Process

To become certified, *all applicants* must complete the Application for Technical Certification, pay the application fee, have suitable experience and education, and pass the written test. Application instructions and fee schedules are listed on the application. After applications are received at the CWEA office, applicant information is compiled in a database, and reviewed by CWEA staff and Subject Matter experts for the respective vocation applied for. If approved, the applicant will receive an eligibility letter. If the application is rejected, the applicant will be notified and asked to supply more information if warranted.

After completion of the computer-based test and grading, applicants are mailed their official test results. Those who pass the exam are mailed certificates and wallet cards.

Test Administration

Test Dates and Sites

Tests are given throughout the year in California, Michigan, and Alaska (see Application for Technical Certification for test schedule). Applicants who are eligible to test will be mailed an acceptance letter and instructions on how to schedule their exam.

Test Site Admission

Certificate candidates are required to show at least one valid government-issued photo identification (state driver's license or identification, or passport). Only after positive identification has been made by the testing proctor may a candidate begin the exam. Candidates do not requir to show their eligibility letters to enter the test site.

Test Security

All tests are computer-based. No reference material, laptop computers, or cameras are allowed in the test site. Candidates will have access to an onscreen calculator, however, you they are welcome to bring their own pre-approved calculator (visit www.cwea.org/cert). Candidates are not allowed to take any notes from the test site. Candidates who violate test site rules may be asked to leave the site and may be disqualified from that test. All violations of test security will be investigated by CWEA and appropriate action will be taken.

Test Reschedule and Cancellation

To postpone your application you must submit a written request (a letter stating that you wish to postpone), to postpone to the adjacent testing window. You may only reschedule your application once without a fee. Additional postponement will require a $40 reschedule fee. There are no exceptions to this policy. If you have a scheduled exam with our testing administrator, Pearson Vue, you must contact them 24 hours in advance to avoid losing your exam fee.

To cancel your application you must submit a written request (a letter stating you wish to cancel your application) to CWEA. The written request must be received at the CWEA office no later than 2 weeks after the approved testing window. Full refunds, less the administrative fee, will be made within 4 weeks after the scheduled test date. There are no exceptions to this policy.

Test Result Notification

Test results are routinely mailed to certificate candidates approximately two weeks after the test date. Results are never given over the phone. All results are confidential and are only released to the certificate candidate.

Issue of Certificate/Wallet Card

Certificates and wallet cards are issued to all candidates who pass the test. Certificates are mailed about two to three weeks after result notifications are mailed.

Certificate Renewal

All certificates are renewed annually. The first renewal is due one year from the last day of the month in which the certification test was held. Certificate renewals less than one year past due are subject to the renewal fee plus a penalty fee of 100 percent of the renewal fee. Certificate holders more than one year past due will need to retest to regain certification. Renewal notices are mailed to certificate holders two months before the due date. It is the responsibility of certificate holders to ensure the certificate(s) remains valid.

Accommodations for Physical or Learning Disabilities

In compliance with the Americans with Disabilities Act, special accommodations will be provided for those individuals who provide CWEA with a physician's certificate, or its equivalent, documenting a physical or psychological disability that may affect an individual's ability to successfully complete the certification test. Written requests for special accommodations must be made with the test application along with all supporting documents of disability.

Test Design and Format

Test Design

All certification tests are designed to test knowledge and abilities required to perform the *Essential Duties* listed at the end of this section with minimal acceptable competence.

The *Essential Duties* and Test Content Areas for each certification were determined by a job analysis and meta-analysis of job specifications by two independent psychometric consulting firms. The studies gathered data from onsite visits of over 31 water and wastewater agencies, interviews with 110 water and wastewater professionals, and analysis of more than 300 job specifications. All research was conducted under the guidance of the TCP Committee, vocational sub-committees, and CWEA staff. All test questions are designed to measure at least one area of knowledge or ability that is required to perform an essential duty.

Test Delivery Mechanism

All tests are computer-based format and are written in the English language only.

Test Format

All TCP tests are in multiple choice format (see the sample test questions in this guide for an example). The multiple choice format is considered the most effective for use in standardized tests. This objective format allows a greater content coverage for a given amount of testing time and improves competency measurement reliability. Multiple choice questions range in complexity from simple recall of knowledge to the synthesis and evaluation of the subject matter.

Test Pass Point

The basic minimum score required to pass all tests is 75 percent of possible total points. However, the score may be adjusted downward depending on test complexity. It should be assumed that the passing score is 75 percent and candidates should try to score as high as possible on the test (in other words, always try for 100 percent). The pass point for each vocation and grade level is set independently. Also, each version or form of a test will have its own pass point. Different versions are given each time the certification test is administered.

How Pass Points Are Set

A modified *Angoff Method* is used to determine the pass point for each version of each test. The modified *Angoff Method* uses expert judgments to determine the test difficulty. The easier the test, the higher the pass point; similarly the more difficult the test, the lower the pass point.

The following is an outline of the modified *Angoff Method* (some details have been omitted):

1. A group of Subject Matter Experts (SMEs) independently rates each test question within a given test. The ratings are defined as the probability that an acceptably (minimally) competent person with the requisite education and experience will answer the question correctly. An acceptably (minimally) competent person is defined as someone who safely and adequately performs all job functions and requires no further training to do so.
2. The SMEs review each test question as a group. A consensus is reached for the rating of each test question. The SMEs also review comments submitted in writing by test-takers. Any test question that is judged to be ambiguous, has more than one correct answer, or has no correct answers is eliminated from the scoring process for that test. These test questions are then revised for future use, reclassified, or deleted from the test item bank.
3. After the data are refined, the final step is to calculate the mean, or average, of all the test question ratings. This becomes the overall pass point estimation.

Why Use Modified Angoff?

Each version of a given certification test uses questions from a test item bank. Each of these questions vary in difficulty. Because a different mix of questions is used in each test, the overall difficulty level is not fixed. Thus, it is important to make sure that the varying difficulty level is reflected in the pass point of each test to ensure that test results are reliable.

Test reliability is concerned with the reproducibility of results for each version of a given test. In other words, for a test to be reliable it must yield the same result (pass or fail) for the same individual under very similar circumstances.

For example, imagine taking a certain grade level test and passing it. Immediately after completing this test, a different version of the same grade level test is taken. If the test is reliable, the same result will be achieved: pass. If a passing grade is not achieved, it is likely that the test is not a reliable measure of acceptable (minimal) competency.

By taking into consideration the difficulty of the test, the modified *Angoff Method* significantly increases the reliability of the test. Also, since each test is adjusted for difficulty level, each test version has the same standard for passing. Thus, test-takers are treated equitably and fairly, even if a different version of the test is taken.

There are other methods for setting pass points. However, for the type of tests administered by CWEA, the modified *Angoff Method* is the best and most widely used.

Test Scoring

All tests are electronically scored by CWEA. Most test items are valued at one point. Some test items requiring calculations are worth multiple points varying from two to five (possibly more). After tests are scored, total points are compiled and an overall score is calculated as the sum of all points earned on the test. If the overall score is equal to or greater than the established pass point, the candidate has passed the test. Total points possible for each test vary, but the average is 100 points plus or minus 25.

Item Appeals

Candidates who wish to appeal a specific test item must do so by completing the Candidate Feedback Review Screen at the end of the exam. Item appeals will be evaluated and appropriate adjustments will be made to the test content. Candidtates submitting feedback will not be contacted in regards to the appeal.

Table 2-1 Eligibility Criteria for Grade IV Laboratory Analyst

Combination	Education and Certificates	+ Experience
A	None	8 full-time years in laboratory analysis with 1 of those years supervising others
B	Hold a Grade III Laboratory Analyst Certificate for 2 years	6 full-time years in laboratory analysis with 1 of those years supervising others
C	Hold an AA/AS degree in a related field	6 full-time years in laboratory analysis with 1 of those years supervising others
D	Hold a BA/BS, or higher, degree in a related field	5 full-time years in laboratory analysis with 1 of those years supervising others

Qualifying for the Test

Eligibility criteria are summarized in Table 2-1. Candidates may qualify by meeting either Education/Experience Combination A, B, C, or D. If you do not meet any of the combinations of experience and education, then you do not qualify for Grade IV.

It is recommended that Grade IV candidates have at least three years experience working as a Lab Analyst performing the *Essential Duties* listed below. Many candidates without the recommended experience have difficulty successfully completing the written test.

Essential Duties

Grade IV duties include the essential duties identified in the study guides for Laboratory Analyst Grades I, II, and III. In addition, the Grade IV Laboratory Analyst essential duties include:

- Manages laboratory division staff, including developing and implementing laboratory division plans, goals, and objectives consistent with agency goals and objectives.
- Directs, controls and implements laboratory services for the analysis of wastewater and industrial wastewater.
- Manages laboratory division budget, including: preparation of budget and staffing recommendations; initiating and/or approving purchase requests; adhering to purchasing policies and procedures; and monitoring expenditures to ensure that division expenses remain within budget.
- Manages monitoring programs, including discharge monitoring, receiving water monitoring, biosolids and residuals monitoring, and storm water monitoring, and ensures that all monitoring program reporting requirements are met.
- Ensures that the laboratory maintains current and appropriate certifications with the state Department of Health Services.
- Develops, plans, and implements field sampling and testing programs, including QA/QC.
- Keeps current on pertinent federal, state, and local regulation; prepares written comments and recommendations on proposed regulations.
- Reviews and approves staff recommendations on division work organization, assignments, work schedules, and training needs.
- Reviews and implements disciplinary actions.
- Prepares and approves technical reports and correspondence to regulatory agencies.
- Coordinates laboratory services with operations and pretreatment programs.

Section 3

Skill Sets

This study guide is aimed at the managerial, administrative lead/supervisory level candidate for Grade IV Lab Analyst certification. Grade IV Laboratory Analysts have many responsibilities that require a foundation of knowledge in mathematics, chemistry, microbiology, and instrumental analysis. Lab Analysts are expected to perform analysis in a safe and accurate manner, correctly interpreting *Standard Methods for Examination of Water and Wastewater (Standard Methods)*, EPA methods, and regulatory mandates. In addition to mastering all the wet chemistry methods and routine bacteriological determinations, Lab Analysts must demonstrate competency in advanced chemistry and instrumental analysis. These duties require great attention to detail.

Regardless of the size of the laboratory, or the specific duties that have been assigned, Lab Analysts have a responsibility to master certain concepts regarding the overall functioning of the laboratory that extend beyond chemical and microbiological analysis. In addition to having mastered the Grade I, II, and III skill sets, Grade IV Lab Analysts will need to develop supervisory skills. The knowledge, skills, and abilities that are required of Lab Analysts embody the professionalism that a career in chemistry and microbiology demands.

Grade IV Lab Analysts must demonstrate competency at the program manager level. A complete understanding of the entire spectrum of management practices and techniques is also necessary for success. Grade IV Lab Analysts are expected to possess and use good judgment and have ability to make sound decisions and implement and communicate these decisions to others. It is highly desirable that Grade IV candidates have strong written and oral communication skills along with interpersonal and public relations skills. This is the knowledge base on which Grade IV Lab Analysts will draw during their day-to-day duties.

Table 3-1, presented at the end of this section, cross-references each skill set with a specific chapter, section, and/or page of applicable references to assist the candidate in better understanding the subject matter. Please note that the first reference in Table 3-1, *Standard Methods for the Examination of Water and Wastewater, 18th Edition,* is not the most recent edition, but is the one referenced by EPA regulations, and therefore is the basis for developing the certification test questions.

Skill Set 1 Wet Chemistry

While developing their careers, Grade IV Lab Analysts are expected to have mastered wet chemical analysis including analytical techniques involving distillation, filtration, gravimetric, volumetric, titimetric, and colorimetric determinations, as well as pH, conductivity, turbidity and dissolved oxygen meters, as used for analysis of solids, chlorine, residual chlorine, chlorine demand, BOD, turbidity, alkalinity, and hardness.

Other areas of expected mastery include: use of ion-selective electrodes for fluoride, nitrate, ammonia and other ions; use of the spectrophotometer for sulfate, phosphate, and phosphorus; distillation of cyanide, volatile acids, total kjeldahl nitrogen, and ammonia; extraction of surfactants and grease and oil; the chemical oxygen demand (COD) method of digesting samples, followed by color development; analysis of phenols. These techniques should be reviewed by candidates for Grade IV certification.

In addition, Grade IV candidates are expected to have mastered reagent preparation using knowledge of atomic weights, molecular weights, molarity, normality, equivalents (valences); solution standardization using primary standards; mathematical calculations used for specific gravity, % weight to weight, proportional compositing, temperature conversions; and formulas used to calculate results for given lab data, using appropriate significant figures.

Skill Set 2 Instrumentation

Grade IV Lab Analysts are expected to be thoroughly familiar with the use of: variations of atomic absorption, including atomic emission, graphite furnace, hydride generation, and cold vapor technique; ICP/AES instrumentation; total organic carbon (TOC) analysis; ion chromatography and gas chromatography theory, as well as the various methods requiring different detectors and instrument setup. The theory, operation and maintenance of this instrumentation must also be understood.

Categories of questions Lab Analysts may ask themselves to assure familiarity with an instrument and its use are listed below:

3.1 Theory

- What is the name of the instrument?
- What does the instrument measure (metals, organics, volatiles, specific compounds, ions, etc.)?
- When is it an advantage to use this technology over others?
- What is the approximate detection limit?
- How do similar technologies compare (AA versus GFAA or ICP/AES)?
- What is the theory behind the instrument?

3.2 Instrument Components

- What are the components of the instrument (burner heads, columns, detectors)?
- What accessories are associated with the instrument?
- How are the results detected? Are there a variety of detectors to choose from?
- How and why are special gases, eluents or reagents used with the instrument?
- How is the sample introduced into the instrument so that it may be read by the detector? (For example, chromatography utilizes carrier gases; atomic absorption atomizes the sample with heat in the light path.)
- How are the instrument and its accessories maintained?

3.3 Calibration, Quantification, and Quality Control

- How is the instrument calibrated (standard curve)?
- How is quality control incorporated into the analysis (internal standards, surrogate standards)?
- How are the results qualified, and quantified (retention time, peak height, transmission/absorption, comparison to a standard curve, etc.)?
- Are blanks or background correction techniques used?

3.4 Sample Preparation

- How are the samples pre-treated (digestion, filtration, distillation, extraction, concentration, purge and trap, etc.)?
- How are difficult matrices dealt with (high dissolved solids, matrix modifiers)?
- What are the types of interferences and how are they corrected?
- Are there special sampling techniques (preservatives, zero-head space, holding time, etc.)?

Skill Set 3 Advanced Instrumentation

Lab Analysts should have advanced and continually expanding knowledge regarding mass spectrometry and “hyphenated” technology, such as gas chromatography-mass spectrometry (GS/MS) or inductively coupled plasma-mass spectrometry (ICP-MS). The theory, operation and maintenance of this instrumentation must be understood. Lab Analysts should be able to troubleshoot the instrument and understand its reactions to varying setup.

Lab Analysts should be knowledgeable about sampling technique and sample preparation for complex matrices, e.g., sludges or biosolids. Lab Analysts should understand that different matrices must be analyzed using appropriate EPA methods, and should know how to select the preferred instrument and best method for the matrix that is being analyzed, whether it is GC, GC/MS, or another technology.

Skill Set 4 Microbiology and Bacteriology

Lab Analysts should have complete familiarity with routine bacteriological analysis used to determine total and fecal coliform presence, including presumptive, confirmation, and completed tests, as well as membrane filter technique; indicators of positive results, such as colony appearance or presence of gas; stain techniques used to identify bacteria; and negative and positive controls used in quality control assessment.

Lab Analysts should develop knowledge of microbiological analysis by learning methods to identify fecal streptococcus and viruses.

Grade IV Lab Analysts are expected to have mastered sterile techniques such as streaking, pour plates, and serial dilutions; media preparation following approved criteria and conditions; the monitoring and maintenance of laboratory equipment, such as incubators, waterbaths, and autoclaves; and procedures such as the examination of laboratory water for suitability and the monitoring of dishwashing practices for soap residues.

Skill Set 5 Biomonitoring and Toxicity

Lab Analysts should have experience regarding toxicity testing using fish bioassays and three-species assays, and should be knowledgeable about various test methods, such as acute and chronic studies. Lab Analysts should be familiar with the terminology of toxicity testing and with quality control, including the use of reference toxicants or control organisms.

Lab Analysts should be knowledgeable about the use of toxicity tests and biomonitoring to conduct toxicity identification evaluations (TIEs), as well as toxicity reduction evaluations (TREs) to characterize the acute or chronic toxicity of effluents.

Skill Set 6 Process Control

Lab Analysts must be knowledgeable about current technological developments in wastewater treatment and control, including principles and practices as applied to the treatment and disposal of wastewater and biosolids. Lab Analysts should be familiar with treatment processes and should be able to analyze, interpret and effectively apply the results of laboratory analysis, as well as recognize and pursue atypical results and treatment process performance. Lab Analysts should strive to create positive working relationships between the lab and the plant operators, and are also responsible for coordinating laboratory services with operations and pre-treatment programs.

Many of the tests performed by the laboratory are used to manage plant operations. Lab Analysts are required to analyze and interpret lab data to provide support to operations staff. Analysts should be familiar with the stages of wastewater treatment, including which pollutants are removed at each stage of treatment and which pollutants remain in the effluent that is discharged to the environment.

The lab can help plant operation staff by analyzing digester gases and sludge to determine the health of the digester. Digester health is monitored using a variety of laboratory analyses, including gas analysis, pH, alkalinity and volatile acids. Lab Analysts must be familiar with the conditions that lead to anaerobic digester upset, as well as the regulations governing analyses required for sludge disposal or reuse of biosolids.

Lab Analysts must be able to use laboratory results to calculate MLSS, SVI, MCRT, F:M ratios, percent removal of sludge at various stages of treatment, and daily sludge production, and must be able to apply these calculated results to plant performance.

The microscopic analysis of sludge can show floc appearance, clarity of supernatant liquid, types and distribution of protozoa, and presence or absence of filamentous bacteria. The analyst should be familiar with common microorganisms found in the plant, and whether they indicate positive or negative trends in plant management, as well as the analysis of nitrogen to see if the plant is undergoing denitrification.

Lab data is used to calculate chlorine and sulfur dioxide feed rates, residual chlorine in lbs/day, and other disinfection/dechlorination-based calculations. Analysts should be familiar with various forms of chlorine, such as free and combined, and with the terminology associated with chlorination. Lab Analysts must assist operators and product vendors in conducting jar tests to assess dosage rates, and in analyzing products for specification verification.

A preliminary part of process control is the pretreatment program, or industrial waste source control. Lab Analysts must be knowledgeable about sampling, documentation, approved methods, and proper quality control, as well as the need to sample, handle and analyze industrial samples in a legally defensible manner.

Skill Set 7 Regulations

A central aspect of laboratory management is compliance with an ever-increasing body of regulations. Lab Analysts are responsible for ensuring that the laboratory maintains current and appropriate certification with the state Department of Health Services (or other accreditation agencies). Lab Analysts must know the federal, state and local laws and regulations applicable to analytical methodology and laboratory management, and must remain up-to-date by reading, interpreting, and applying pertinent regulations.

There are many regulations that affect the lab. These range from health and safety issues to complying with discharge permits. Regulations may be issued by federal, state, or local agencies including federal and regional Environmental Protection Agencies, the State Water Resources Control Board, the Department of Health Services, and OSHA. Programs may include emergency response plans, chemical hygiene plans, Lab Right-to-Know, MSDS, quality assurance programs, discharge permits, pre-treatment programs, and hazardous materials storage, handling, and disposal.

Lab Analysts must manage monitoring programs and ensure that all monitoring program reporting requirements are met. Monitoring programs include discharge permits (NPDES), receiving water, biosolids and residuals, industrial waste pre-treatment limits, and storm water monitoring. Regional or local regulations may require toxicity reduction evaluation (TRE) monitoring, and other watershed management programs.

Regulations regarding the storage, handling and disposal of hazardous materials have increased dramatically in the past years. Regulations include the quantities (volume) of wastes which may be stored in the lab, and the length of time permitted prior to disposal. Laboratories fall under special legal considerations due to the small quantities of wastes generated. Documentation regarding hazardous materials and hazardous wastes is an especially important aspect in laboratory management.

Skill Set 8 Laboratory Safety

Appropriate monitoring and maintenance of the laboratory equipment, such as hoods, deionized water, refrigerators, incubators, ovens, water baths, desiccators, safety equipment (showers, eye washes and fire extinguishers) are the responsibility of laboratory personnel. General knowledge of safe working practices, chemical storage, appropriate personal protective equipment, etc., is also required of all lab staff.

Lab Analysts bear much of the responsibility for the safe working environment of the supervised staff, part of which is training the staff to take responsibility for their own safety. Training may include knowledge of first aid, use of personal protective equipment and laboratory safety equipment, chemical waste management (what may be thrown away or down the sink, neutralized prior to disposal, or saved for a official hazardous waste disposal), understanding Material Safety Data Sheets, signs and labels, permissive exposure levels, safety in field sampling, and emergency response.

The responsibilities of Lab Analysts in ensuring a safe working environment are constantly increasing as new laws are promulgated. Laws, such as OSHA's Hazard Communication Standard, Chemical Hygiene Plan, Employee Right-to-Know, Emergency Response Plan and Injury and Illness Prevention Plan (IIPP), place an increased responsibility on the Lab Analyst to properly document training, accidents, chemical storage, chemical spills, equipment monitoring, etc. Most regulated programs, such as the chemical hygiene plan, require a mandatory set of requirements that each lab should incorporate into a plan customized to suit the specific needs of each facility.

Skill Set 9 Quality Assurance and Quality Control

Lab Analysts must ensure that the analytical results reported from the laboratory are scientifically valid. A quality assurance plan, incorporating quality control, is essential, not only for accurate and precise work, but also for laboratory accreditation.

Lab Analysts must know conventional quality assurance practices for the wastewater laboratory. These practices include establishing a quality assurance manual, monitoring quality control results using warning and control charts, establishing routine quality control analysis, such as blanks, spikes, duplicates and more advanced practices used in organic analysis, etc. Lab Analysts must have knowledge of analytical techniques, including advanced instrumentation, analytical methodology, sampling techniques, data interpretation, and statistical analysis. Quality control may include percent recoveries on spikes, relative percent differences for duplicates, standard additions for metals, method detection limits for instrumentation (and wet chemistry), holding times, etc.

Laboratory management involves report writing, submission of data, and discharge permit compliance. Data validation is crucial when submitting a report to regulating authorities. Quality control must be documented in requested format and must be available to accreditation inspectors and clients. Lab Analysts must also understand the general elements of contract lab procedure protocols.

Lab Analysts are called upon to address failures in quality control, to explain deviations from standard operating procedures, and to troubleshoot instrumental and technician failures. Proper training is essential to quality analysis.

Skill Set 10 Management

Candidates for Grade IV Lab Analyst certification must have a thorough understanding of and the ability to apply the general management skills used to run a smoothly operating laboratory or business. Although various management philosophies (such as “country club management style” or “five minute manager”) may come and go, candidates should focus their attention on acquiring the actual planning, organizing, staffing, leading, and controlling skills which have remained stable and reliable over the years.

The primary duty expected of Grade IV Lab Analysts is to manage laboratory resources, and to develop and implement laboratory plans, goals and objectives to best serve the agency’s (employer’s) goals and objectives. In addition to providing analytical results to operations staff for optimal plant performance, the Lab Analyst is expected to direct, control and implement monitoring programs to meet and comply with regulations regarding wastewater discharges, receiving water, industrial waste, storm water, and biosolids.

In order to meet these goals, Lab Analysts must hire lab staff, purchase supplies, plan budgets, write reports, justify capital purchases (instruments), schedule work assignments, and supervise training, evaluations, discipline and grievances. The knowledge, skills and abilities developed over a Lab Analyst’s career are all pulled together in management capability. Knowledge of wet chemistry, instrumentation, microbiology, biomonitoring, safety, regulations, quality assurance and process control applications are all used as a Lab Analyst customizes general management skills to best serve the employer and the laboratory staff.

Lab Analysts should be familiar with and be able to apply to the work setting principles and concepts of management covering such topics as managerial functions, communication, motivation, leadership, direction and delegation, decision-making, planning, time management, organizing, labor unions, employee selection, training, performance evaluations, diversity, building morale, resolving conflicts, controlling, and discipline.

Table 3-1 Grade IV Laboratory Analyst

		Primary References[a]				
No.	Skill Set	Standard Methods for the Examination of Water and Wastewater, 18th Edition	Lectures on Wastewater Analysis and Interpretation	Operation of Municipal Wastewater Treatment Plants	Operation of Wastewater Treatment Plants	Other (see footnotes)
1	Wet Chemistry					
1.0	**Surfactants (MBAS)**	5540 A, B	Lecture 15, pgs. 310–313			Methods[b] 425.1 Methylene Blue Active Substances (MBAS)
1.0	**Cyanide**	4500-CN^- A, B, C, E	Lecture 13, pgs. 245–259			Methods[b] 335.2 Cyanide Total –Colorimetric, Automated UV
1.0	**Phenols**	5530 A, B, D	Lecture 16, pgs. 321–328			Methods[b] 420.1 Phenolics, Total Recoverable–Spectrophot/MBTH
3	Advanced Instrumentation					
3.1	**Mass Spectrometry and "hyphenated" technology—MS, GC/MC, ICP/MS**		Lecture 5			
3.2	**Inductively Coupled Plasma (ICP)**	4110 A, B	Lecture 3 pgs. 62–73			
3.3	**Gas Chromatography**		Lecture 4			
3.4	**Pesticides, EPA Method 608**	6410 B				40 CFR 136[c] Appendix A, Method 608

a. Complete reference information given in Section 6.

b. *Methods for Chemical Analysis of Water and Wastes*

c. *40 CFR (CFR Title 40: Protection of Environment)*

Table 3-1 Grade IV Laboratory Analyst						
Primary References[a]						
No.	Skill Set	Standard Methods for the Examination of Water and Wastewater, 18th Edition	Lectures on Wastewater Analysis and Interpretation	Operation of Municipal Wastewater Treatment Plants	Operation of Wastewater Treatment Plants	Other (see footnotes)
3.5	**Polynuclear Aromatic Hydrocarbons (PAH)**	6440				40 CFR 136[c] Appendix A, Method 610
3.6	**Purge and Trap Sample Preparation Techniques**	6040, 6210, 6220, 6230				
3.7	**Quality Control for Organic Compounds**					Handbook[d] Chapter 8
3.8	**Sampling for Organic Compounds**	6010 A 1060	Lecture 2 pgs. 41–44			
4	Microbiology and Bacteriology					
4.1	**Viruses and Fecal Streptococci**	9230, 9510				Microbiologic-al Methods[e] Part III, Section D
4.2	**Inhibitory Residue Test**	9020 A, B especially B.3.a(2)				Microbiologic-al Methods[e] Part IV 5.1.3, pg. 199
4.3	**Water Suitability**	9020 A, B especially B.3.c(v)				Microbiologic-al Methods[e] Part IV 5.3, pg. 200
4.4	**Activated Sludge Microbiology**		Lecture 17 pgs. 341–342	Chapter 17 pgs. 564–567	Chapter 11, 11.93, 11.94, 11.95, 11.96	

a. Complete reference information given in Section 6.

c. *40 CFR (CFR Title 40: Protection of Environment)*

d. *Handbook for Analytical Quality Control in Water and Wastewater Laboratories*

e. *Microbiological Methods for Monitoring the Environment – Water and Wastes*

Table 3-1 Grade IV Laboratory Analyst							
Primary References[a]							
No.	Skill Set	Standard Methods for the Examination of Water and Wastewater, 18th Edition	Lectures on Wastewater Analysis and Interpretation	Operation of Municipal Wastewater Treatment Plants	Operation of Wastewater Treatment Plants	Other (see footnotes)
5	Biomonitoring and Toxicity					
5.1	**Toxicity, Acute Toxicity, and Chronic Toxicity**	8010 A, B, C, D, F (F.3), G (G.1, G.2) 8020 8910	Lecture 18	Chapter 14, pgs. 421–422		
5.2	**Fish Toxicity**	8910				Handbook[d] Chapter 13, Methods for Measuring[f] Section 9
5.3	**Toxicity Reduction Evaluation (TRE) and Toxicity Identification Evaluation (TIE)**	8910 D, Section 6.c as well as several references listed in Section 7		Chapter 6 pg. 123		Clean Water Act[g] 33 U.S. Code, Section 1317
6	Process Control					
6.1	**Wastewater Treatment**			Chapter 2 pgs. 9–16 Chapter 3 pgs. 43–47, 52 Chapters 14, 24, 25 Introductory paragraphs for all chapters	Chapter 3	
6.2	**Receiving Waters**				Chapter 13 13.0, 13.1, 13.3, 13.4	

a. Complete reference information given in Section 6.

d. *40 CFR (CFR Title 40: Protection of Environment)*

f. *Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms*

g. *The Clean Water Act*

Table 3-1 Grade IV Laboratory Analyst						
Primary References[a]						
No.	Skill Set	Standard Methods for the Examination of Water and Wastewater, 18th Edition	Lectures on Wastewater Analysis and Interpretation	Operation of Municipal Wastewater Treatment Plants	Operation of Wastewater Treatment Plants	Other (see footnotes)
6.3	**Chlorination and Dechlorination**	2350 A, B 4500-Cl A, B, D	Lecture 11 pgs. 219–234	Chapter 23 pgs. 819–823, 840–841, 847–848	Chapter 10 10.00–10.06, 10.6, 10.8, 10.810, 10.850, 10.851 Figure 10.2	
6.4	**Activated Sludge (F:M ratio, MCRT, MLSS<MLVSS <sludge age, SVI, microbiology, nocardia, normal operations and operational problems, denitrification, and nitrification)**	2710 A, C, D, F	Lecture 20 pgs. 369–373	Chapter 17	Chapter 11 11.0–11.051, 11.50, 11.51, 11.65, 11.70–11.74, 11.90–11.94, Table 11.67 Glossary Chapter 16 16.45	
6.5	**Anaerobic Digesters**	2720 A, C		Chapter 27 pgs. 961–966, 997–998, Table 27.9 (1, 2, 3)	Chapter 12 12.0, 12.2, 12.3, 12.43, Tables 12.2 and 12.44 (1, 2, 3) Chapter 16 16.46	
6.6	**Sampling for Liquid Processes**			Chapter 14		
6.7	**Sampling for Solid Processes**			Chapter 25		
6.8	**Sludge and Biosolids**		Lecture 19 pgs. 361–368	Chapters 24 and 25	Chapter 12 12.8	40 CFR 503[c] Test Methods[h]

a. Complete reference information given in Section 6.

c. *40 CFR (CFR Title 40: Protection of Environment)*

h. *Test Methods for Solid Waste, Physical/Chemical Methods, EPA Publication SW-846*

Table 3-1 Grade IV Laboratory Analyst						
Primary References[a]						
No.	Skill Set	Standard Methods for the Examination of Water and Wastewater, 18th Edition	Lectures on Wastewater Analysis and Interpretation	Operation of Municipal Wastewater Treatment Plants	Operation of Wastewater Treatment Plants	Other (see footnotes)
6.9	**Process Control Mathematics (Process control calculations and applying lab results to plant conditions: loading calculations, theoretical oxygen demand, clarifier overflow rate, sludge production, chlorine fee rate, lbs/day chlorine residual, gal/day hypochlorite, dechlorination dose)**		Lecture 20	Appendix: Example calculations for operators of wastewater treatment plants, and Chapter 22 pgs. 806–819	Volume II Appendix: How to solve wastewater treatment plant arithmetic problems	WSO Basic Science[i]
7	Regulations					
7.1	**NPDES Discharge Permit Monitoring**			Chapter 2 Chapter 6 pg. 122		40 CFR 133[c] Clean Water Act[g] 33 U.S. Code, Section 1342
7.2	**Industrial Waste Pretreatment Monitoring**			Chapter 4 Chapter 6 pgs. 123, 129		40 CFR 403[c]
7.3	**Receiving Water Monitoring (TRE)**			Chapter 6 pg. 123		Clean Water Act[g] 33 U.S. Code, Section 1317
7.4	**Biosolids and Residual Monitoring**					40 CFR 503[c]

a. Complete reference information given in Section 6.

c. *40 CFR (CFR Title 40: Protection of Environment)*

i. *Water Supply Operations (WSO) series Part V: Basic Science Concepts and Applications, Textbook*

g. *The Clean Water Act*

Table 3-1 Grade IV Laboratory Analyst						
Primary References[a]						
No.	Skill Set	Standard Methods for the Examination of Water and Wastewater, 18th Edition	Lectures on Wastewater Analysis and Interpretation	Operation of Municipal Wastewater Treatment Plants	Operation of Wastewater Treatment Plants	Other (see footnotes)
8	Laboratory Safety					
8.1	**General Lab Safety**			Chapter 5		Laboratory Safety Pocket Handbook[j]
8.2	**OSHA**			Chapter 2 pg. 8 Chapter 5		
8.3	**Hazard Communications (Standards, MSDS, signs and labels, hazard rating, Employee Right-to-Know)**			Chapter 2 pg. 8 Chapter 5 pgs. 85–86		Laboratory Safety Pocket Handbook[j] OSHA Regulations[k] 29 CFR 1910.1200
8.4	**Chemical Hygiene Plan**					OSHA Regulations[k] 29 CFR 1910.1450
8.5	**Emergency Response Plans**			Chapter 3 pgs. 33–38 Chapter 5 pgs. 86–87, 144–145		

a. Complete reference information given in Section 6.

j. *Laboratory Safety Pocket Handbook*

k. *OSHA Regulations (Standards – 29 CFR)*

Table 3-1 Grade IV Laboratory Analyst						
Primary References[a]						
No.	Skill Set	Standard Methods for the Examination of Water and Wastewater, 18th Edition	Lectures on Wastewater Analysis and Interpretation	Operation of Municipal Wastewater Treatment Plants	Operation of Wastewater Treatment Plants	Other (see footnotes)
9	Quality Assurance and Quality Control					
9.1	**Quality Assurance (QA plans and their components; Standard Operating Procedures (SOP); Quality Control Charts; Method Detection Limits (MDL); purpose of quality control samples and assessment of their results—measuring accuracy, precision, contamination)**	1010, 1020, 1030, 1040, 1050	Lectures 1, 2, 21, 22, 23	Chapter 14		
9.2	**Data Interpretation**		Lesson 21 pgs. 375–390	Chapter 6 pgs. 130–132		40 CFR 136[c] Appendix B Handbook[d] Chapters 6 and 7
9.3	**Report Writing**			Chapters 6 and 14		

a. Complete reference information given in Section 6.

c. *40 CFR (CFR Title 40: Protection of Environment)*

d. *Handbook for Analytical Quality Control in Water and Wastewater Laboratories*

Table 3-1 Grade IV Laboratory Analyst						
Primary References[a]						
No.	Skill Set	Standard Methods for the Examination of Water and Wastewater, 18th Edition	Lectures on Wastewater Analysis and Interpretation	Operation of Municipal Wastewater Treatment Plants	Operation of Wastewater Treatment Plants	Other (see footnotes)
10	Management					
10.1	**Motivational Style**			Chapter 3 pgs. 24–30		Utility Management[l] Chapter 2 Supervision[m] Chapters 4 and 16
10.2	**Directing and Leading**			Chapter 3 pg. 22		Utility Management[l] Chapter 2 Supervision[m] Chapters 5 and 1
10.3	**Planning**			Chapter 3 pgs. 18–21		Utility Management[l] Chapter 3 Supervision[m] Chapter 7
10.4	**Testing Programs**			Chapter 3 pgs. 20, 52–53		Supervision[m] Chapter 7
10.5	**Time Management and Scheduling Work Assignmens**					Supervision[m] Chapter 8 pgs. 209–324
10.6	**Organizing**			Chapter 3 pg. 21		Utility Management[l] Chapter 4 Supervision[m] Chapters 9 and 10

a. Complete reference information given in Section 6.
l. *Utility Management*
m. *Supervision: Concepts and Practices of Management*

Table 3-1 Grade IV Laboratory Analyst						
Primary References[a]						
No.	Skill Set	Standard Methods for the Examination of Water and Wastewater, 18th Edition	Lectures on Wastewater Analysis and Interpretation	Operation of Municipal Wastewater Treatment Plants	Operation of Wastewater Treatment Plants	Other (see footnotes)
10.7	**Labor Unions**					Utility Management[l] Chapter 5 Supervision[m] Chapter 12
10.8	**Hiring Staff and Orientation**			Chapter 3 pgs. 24–30		Utility Management[l] Chapter 5 Supervision[m] Chapter 13 pgs. 353–365
10.9	**Staff Training**		Lecture 23	Chapter 3 pgs. 24–30 Chapter 6 pgs. 141–142		Utility Management[l] Chapter 5 Supervision[m] Chapter 13 pgs. 369–373 Chapter 9
10.10	**Personnel Evaluations**			Chapter 3 pgs. 24–30		Utility Management[l] Chapter 5 Supervision[m] Chapter 14 pgs. 380–415
10.11	**Work Teams and Morale**			Chapter 3 pgs. 24–30		Supervision[m] Chapter 16
10.12	**Diversity and Harassment Policies**					Utility Management[l] Chapter 5 Supervision[m] Chapter 17 pgs. 485–511

a. Complete reference information given in Section 6.

l. *Utility Management*

m. *Supervision: Concepts and Practices of Management*

Table 3-1 Grade IV Laboratory Analyst						
Primary References[a]						
No.	Skill Set	Standard Methods for the Examination of Water and Wastewater, 18th Edition	Lectures on Wastewater Analysis and Interpretation	Operation of Municipal Wastewater Treatment Plants	Operation of Wastewater Treatment Plants	Other (see footnotes)
10.13	**Workplace Conflicts**					Utility Management[l] Chapter 5 Supervision[m] Chapter 18
10.14	**Controlling**			Chapter 3 pg. 23		Utility Management[l] Chapter 2 Supervision[m] Chapter 19
10.15	**Budgets**			Chapter 3 pgs. 38–43 Chapter 6 pgs. 142–144		Utility Management[l] Chapter 9 Supervision[m] Chapter 19
10.16	**Discipline**			Chapter 3 pgs. 24–30		Utility Management[l] Chapter 5 Supervision[m] Chapter 18 Chapter 20 pgs. 579–607

a. Complete reference information given in Section 6.

l. *Utility Management*

m. *Supervision: Concepts and Practices of Management*

Section 4

Test Preparation

This section provides tips on the how candidates should prepare for the test, information on the test question format and the math skills likely to be needed, and a table of equivalents and formulas.

Basic Study Strategy

To prepare adequately for the test, candidates need to employ discipline and develop good study habits. Ample time to prepare for the test should be allowed. Candidates should establish a study schedule and stick to it. One or two nights a week for one or two months should be sufficient in most cases. Spend one or more hours studying in quiet surroundings or in small groups of two or three serious candidates. Efforts should be directed to the test subject areas that are not being performed on a day-to-day basis.

It is especially important for candidates to obtain access to the reference materials listed under the Primary References heading in Section 6 of this study guide. Many of these materials are likely to be available in the work place and in technical libraries. Some references, such as codes and regulations, are available on-line as well. For a list of links to on-line resources, see the Certification Resource Links page on the CWEA website at www.cwea.org/tcp/resources.

Candidates should study at the certification level being sought after. There is no advantage to spending time studying material that will not be on the test. Refer to Section 3 of this study guide for topics that will be covered.

While using this study guide, be sure to understand the answers to all the sample and diagnostic test questions. It may also be helpful to use the skill set descriptions in Section 3 to devise additional questions for further study. Discuss the questions with others. Not only is this a good study technique, it is also an excellent way to learn.

It is not necessary, but it can certainly be helpful, to memorize all the formulas and equivalents used in working out the solutions for questions involving calculations. Table 4-1 lists many, but not all, of these formulas and conversion factors. When the test is administered, a sheet listing some, but not all, of the relevant formulas and equivalents will be provided as part of the test materials. So that candidates may determine which formulas and equivalents will actually be on the sheet included with the test booklet, copies of these sheets are provided on the CWEA website at www.cwea.org/tcp/resources. (The set of equivalents and formulas on the sheet provided with the test may not be exactly the same as the set included in Table 4-1.)

Multiple Choice Questions

All test questions are written in multiple-choice format. At first glance, the multiple-choice problem may seem easy to solve because so much information is given, but that is where the problem lies. The best answer must be chosen from the information provided. Here are some tips that may help solve multiple-choice problems.

1. Read the question completely and closely to determine what is being asked.

2. Read all the choices before selecting an answer.

3. Look for key words or phrases that often, but not always, tip off correct or incorrect answers:

   Absolute Words

   (Suspect as a wrong choice)

Always	Never	None
Totally	All	

   Limiting Words

   (Often a correct choice)

Few	Occasionally
Some	Generally
Often	Usually
Many	Possible

Table 4-1 Laboratory Analyst

General Information

Element Symbols and Atomic Weights[a]

Element	Symbol	Atomic Weight
Aluminum	Al	27
Arsenic	As	75
Calcium	Ca	40
Carbon	C	12
Chlorine	Cl	35.5
Chromium	Cr	52
Copper	Cu	63.5
Hydrogen	H	1
Iodine	I	126.9
Magnesium	Mg	24
Nickel	Ni	59
Nitrogen	N	14
Oxygen	O	16
Phosphorus	P	31
Potassium	K	39
Silver	Ag	108
Sodium	Na	23
Sulfur	S	32

a. Source: *Standard Methods, 18th Edition*

Conversion Factors

1 gal. = 8.34 lbs.
1 cu. ft. = 7.48 gal.
1 lb. = 454 grams

MPN

Dilutions: 10 mL, 1.0 mL, 0.1 mL

Combination of Positives	MPN Index
5 - 3 - 0	80
5 - 5 - 3	900
5 - 5 - 5	> 1600

Abbreviations

AA = Atomic Absorption
AE = Atomic Emission
mL = Milliliter
mg = Milligram
L = Liter
g = Gram
GC = Gas Chromatography
F = Formal
M = Molar
N = Normal
MGD = Million Gallons per Day

4. Never make a choice based on the frequency of previous answers. If the last ten questions have not had a "b" answer, don't arbitrarily select "b". Instead use logic and reasoning to increase the chances of choosing the best answer.

5. Reject answers that are obviously incorrect and choose from the remaining answers.

   Example

   The straight line distance from the center of a circle to the outer edge is called the:

   a. diameter

   b. circumference

   c. chord

   d. radius

   It is possible to reason out the answer by having some knowledge of geometry and studying the questions and the four provided answers. The question is asking for the name of a line or distance that is inside of the circle. Circumference is the distance around the outside of the circle, so this is an obvious incorrect answer.

6. Make an educated guess.

   Never reconsider a choice that has already been eliminated. This means that answer "b" should not be considered. Look for key phrases or words that give a clue to the right answer. Chord, answer "c," chord refers to a straight line inside of the circle, but it does not necessarily go through the center of the circle, so this answer can be eliminated.

   Answers "a" and "d" are distances that are measured as straight lines and either start or go through the center of a circle. The diameter goes through the center rather than starting from the center. Radius, answer "d" is the correct answer and is defined as the straight line distance from the center to the outer edge of a circle.

7. Skip over questions that are troublesome. Mark these questions for later review.

8. When finished with the test, return to the questions skipped. Now think! Make inferences. With a little thought and the information given, the correct answer can be reasoned out.

9. Under no circumstances leave any question unanswered. There is no penalty for incorrect answers. However, credit is given only for correct answers.

   NO ANSWER=WRONG ANSWER

10. Keep a steady pace. Check the time periodically.

11. Remember to read all questions carefully. They are not intended to be "trick questions"; however, the intent is to test candidates' knowledge of and ability to understand the written language of this profession.

Math Problems

Math problems on the certification tests are meant to reflect the type of work encountered in the water quality field. Although there is no specific math section on the test, many questions will require some calculations such as volume, ratios, and conversion of units. By far, the greatest number of applicants who fail the certification tests do so by failing to complete the math problems. Completing the math problems will be greatly simplified by using a calculator and the approach suggested in the following paragraphs.

Calculators

A scientific calculator may be used during the test; however, a four-function (add, subtract, multiply and divide) calculator is adequate for completing any of the certification tests. Additional functions (e.g., square root) are not necessary, but may be helpful in some situations. The most important factor in effectively using a calculator is the candidate's familiarity with its use prior to the time of the examination. Confidence in the calculator and a full understanding of how to properly operate it are a must. The best way to gain confidence is to obtain the calculator early and use it frequently.

Completing the sample problems in this section as well as the diagnostic test in Section 5 will improve proficiency. Additional use will also help. For example, calculate the gas mileage when filling a vehicle's tank. Check the sales tax calculation on each purchase. Balance a checkbook, or check a paycheck. The calculator chosen should have large enough keys so that the wrong keys are not accidentally punched. Be certain there are new batteries in the calculator, or use a solar powered calculator with battery backup.

Approach

The solution to any problem requires understanding of the information given, understanding of what is being requested, and proper application of the information, along with the appropriate equations to obtain an answer. Any math problem can be organized as follows:

Given or Known
All information provided in the problem statement that will be used to get the correct answer.

Find
A description of the answer that is being requested.

Sketch
If possible, sketch the situation described in the problem statement showing size and shape (dimensions).

Equation
A listing of the equation or equations that will be used to generate the answer.

Assumption(s)
Stated assumptions of key information needed to answer a math problem with missing information. This occurs frequently on higher-grade tests.

Answer
This is where the answer is clearly identified.

Advantages to using this approach to organize math problems are that it helps to organize thoughts, breaks the problem solution into a series of smaller steps, and reduces chances of making errors.

Solutions

Solutions to math problems are like driving routes from Los Angeles to San Francisco: there are many different routes that can be taken. Some routes are shorter or less complicated than others. Only certain routes end up in San Francisco.

Solutions to sample problems given in this study guide are the most common solutions. If a different solution arrives at the correct answer, then it can be used as well.

Equivalents and Formulas

Familiarity with the equivalents (conversion factors) and formulas in Table 4-1 is important. Pay special attention to the units of measure that are used in the formulas. A correct answer will not be obtained unless the correct units of measure are used.

Check the units, arithmetic, and answer so that:

1. the units agree;
2. the answer is the same when the arithmetic is repeated; and
3. the answer is reasonable and makes sense.

Dimensional Analysis

When setting up an equation to solve a math problem, the trick is to have clearly in mind what units the answer should be in. Once the units have been determined, work backwards using the facts given and the conversion factors known or given. This is known as dimensional analysis, using conversion factors and units to derive the correct answer.

Remember, multiplying conversion factors can be likened to multiplying fractions. The denominator (the number on the bottom of the fraction) and the numerator (the number on the top of the fraction) cancel each other out if they are the same, leaving the units being sought after.

Example

If a company runs a discharge pump rated at 50 gallons per minute all day, every day for a year, what is the discharge for the year in millions of gallons per year (MGY)?

Given: pump rating = 50 $\frac{\text{gal}}{\text{min}}$

Find: discharge = __?__ MGY

Calculations
Convert gal/min to million gal/yr, convert gallons to million gallons, and minutes to years.

What is known about minutes and years? There are 60 minutes in an hour, 24 hours in a day, and 365 days in a year. Put that into an equation, and multiply each conversion factor so the unneeded units are cancelled out:

$$50\,\frac{\cancel{\text{gal}}}{\cancel{\text{min}}} \times 60\,\frac{\cancel{\text{min}}}{\cancel{\text{hr}}} \times 24\,\frac{\cancel{\text{hr}}}{\cancel{\text{day}}} \times 365\,\frac{\cancel{\text{days}}}{\text{yr}} \times 1\,\frac{\text{MG}}{1{,}000{,}000\,\cancel{\text{gal}}} = 26.28\text{ MGY}$$

Sample Questions

The following sample math problems are intended to demonstrate unit conversion techniques. Although they are general wastewater problems, the questions may not be specific to any vocation.

1. How many gallons of water will it take to fill a 3 cubic foot container?

   $$3 \cancel{\text{cubic feet}} \times 7.48 \frac{\text{gallons}}{\cancel{\text{cubic feet}}} = 22.4 \text{ gallons}$$

2. If a gallon of gasoline weighs 7.0 pounds, what would be the weight of a 350 gallon tank full of gasoline?

   $$350 \cancel{\text{gallons}} \times 7.0 \frac{\text{pounds}}{\cancel{\text{gallon}}} = 2{,}450 \text{ pounds}$$

3. The rated capacity of a pump is 500 gallons per minute (GPM). Convert this capacity to million gallons per day (MGD).

   $$500 \cancel{\text{GPM}} \times 1 \frac{\text{MGD}}{694 \cancel{\text{GPM}}} = 0.72 \text{ MGD}$$

4. A chemical feed pump is calibrated to deliver 50 gallons per day (GPD). What is the calibrated chemical feed in gallons per minute (GPM)?

   $$\frac{50 \text{ gal}}{\cancel{\text{day}}} \times \frac{1 \cancel{\text{day}}}{24 \cancel{\text{hr}}} \times \frac{1 \cancel{\text{hr}}}{60 \text{ min}} = 0.035 \text{ GPM}$$

5. A chemical feed pump delivers 50 mL per minute (mL/min). Determine the chemical feed in gallons per day (gpd).

   $$\frac{50 \cancel{\text{mL}}}{\cancel{\text{min}}} \times \frac{1 \cancel{\text{L}}}{1000 \cancel{\text{mL}}} \times \frac{1 \text{ gallon}}{3.785 \cancel{\text{L}}} \times \frac{60 \cancel{\text{min}}}{\cancel{\text{hr}}} \times \frac{24 \cancel{\text{hr}}}{\text{day}}$$

   =19 GPD

6. A cyanide destruction process is designed to treat 30 pounds of cyanide per 24-hour operational day. How many pounds of cyanide can be treated during an 8-hour shift?

   $$\frac{30 \text{ lbs CN}}{\cancel{\text{day}}} \times \frac{8 \cancel{\text{hr}}}{\text{shift}} \times \frac{1 \cancel{\text{day}}}{24 \cancel{\text{hr}}} = 10 \text{ lbs CN/shift}$$

Math Skills

Grade IV Lab Analyst candidates must be skilled in arithmetic, statistics, and algebra. Lab Analysts must be able to build upon the skills learned for Grades I, II, and III to perform more complex calculations for work-related tasks in general chemistry, preparing standard solutions, reporting laboratory data, assisting plant operations, and any other job-related math task that may fall within the Skill Sets listed in Section 3.

Grade IV general chemistry problems will require Lab Analysts to understand how to determine:

- Weight (g) of a dry reagent required to make a solution, given the molecular formula, molecular weights, and the final concentration of one of its elemental constituents.
- Concentration of diluted solution in mg/L or ppm following serial dilutions on an initial concentration.
- Volume of concentrated acid that contains a specified weight (g) of pure acid, given specific gravity, % weight to weight, and molecular weights for the elements in the acid.
- Solubility product of a saturated solution, given the grams of solute per liter and the molecular weight.

Problems using laboratory data will require Lab Analysts to memorize the formulas in *Standard Methods* for the analytical methods outlined in the skill sets covered in Section 3 of this study guide. These types of problems will require Lab Analysts to determine:

- BOD concentration, given the initial and final DO concentrations. Lab Analysts must memorize the acceptance criteria for DO depletion in the blank and in the diluted samples, and the calculations used for seeded or non-seeded samples.
- Residual chlorine by back-titration given the lab data necessary to use the formula given in *Standard Methods*.
- Chloride, hardness, alkalinity, sulfates, chlorine demand, nitrogen, phosphorous, fluoride, and TOC.

- Concentration of an unknown solution, given absorbance versus concentration information from a standard curve.
- Concentration of bacterial counts from a serially diluted sample, given the serial dilutions and the final plate (colony) counts.

Problems using information to monitor plant operations require Lab Analysts to determine:

- Sulfur dioxide (lbs/day) required, given molecular weights, plant flow (MGD), and desired chlorine residual (mg/L).
- Chlorine feed rate (lbs/day), given plant flow (MGD), chlorine demand (mg/L), and desired residual chlorine (mg/L).
- Hypochlorite flow rate (gal/day), given chlorine dosage (lb/day), percentage of compound that is chlorine, and solution density (lb/gal).
- Dosage of alum (lbs/MG), given plant flow (gallons/day) and feed rate of alum (lbs/hour).
- Sludge production (cubic feet/day), given population, influent settleable solids (mL/L), per capita contribution to total flow (gals/day), and the conversion factor 7.48 gal = 1 cubic foot.
- Concentration of a constituent of a composite of two influent lines, given the concentration and the flow of each line.

A thorough review of the types of mathematics required for the test is beyond the scope of this study guide. Consult an appropriate text (see Section 6, References) if there is unfamiliarity with any specific math skills. Appendix A provides general strategies for approaching math problems and math anxiety, as well as resources for remedial study.

Arithmetic

Candidates should be able to understand and perform the following calculations either manually or with a calculator:

1. Addition and subtraction of whole numbers, fractions, and decimals.
2. Multiplication and division of whole numbers, fractions, and decimals.

Be prepared to apply these basic skills to work-related problems. The following example problem requires application of chemistry knowledge, application of basic arithmetic, and the ability to convert units.

Example

Potassium dichromate ($K_2Cr_2O_7$) is to be used in the COD test. How many grams would it take to make 2.0 liters of 0.5 N solution?

Molecular weights: K=39, Cr=52, O=16

Hint:
$6Fe^{++} + Cr_2O_7^{=} + 14H^{+} = 6Fe^{+++} + 2Cr^{+++} + 7H_2O$

To determine the answer to this problem, Lab Analysts must understand oxidation-reduction reactions and normality. From the equation given, it can be determined that each chromate ion accepts a total of six electrons. A 1.0 normal solution would contain 1/6 gram molecular weight of potassium dichromate per liter. A 0.5 normal solution would contain 1/2 of the above weight. Calculate as follows.

Determine the molecular weight: $K_2Cr_2O_7$

$(39 \times 2) + (52 \times 2) + (16 \times 7)$
$= 294 \text{ g } K_2Cr_2O_7\text{/mole}$

Then set up a unit factor equation:

$$\frac{294 \text{ g } K_2Cr_2O_7}{1 \text{ mole}} \times \frac{1 \text{ mole}}{6 \text{ equivalents}}$$

$$\times \frac{0.5 \text{ equivalent}}{1 \text{ L}} \times 2.0 \text{ L} = 49 \text{ g } K_2Cr_2O_7$$

Sequential Situations

Mathematics skills often require an understanding of sequential thought. Examples of this type of problem include serial dilutions in the laboratory, and serial removal of pollutants as wastewater is processed through sequential levels of treatment (primary, secondary, and tertiary).

Example

A bacterial culture was sampled and serially diluted prior to spread-plating onto triplicate plate-count agar plates. The dilutions were as follows. One mL of the original sample was added to 99 mL of solution B. One mL of solution B was added to 9 mL of solution C. Five mL of solution C was added to 5 mL of solution D. This final mix was plated in triplicate at 0.1 mL per plate. The plates were incubated at 25°C for 2 days before colonies were counted. The counts obtained were 57, 61, and 48 colonies per respective plate. Using the plate counts obtained, calculate the original concentration of the bacterial culture in CFU/mL.

First, calculate the dilution factor by multiplying together each serial dilution:

1 mL of A in 99 mL of B = 1:100 or 10^{-2} dilution

1 mL of B in 9 mL of C = 1:10 or 10^{-1} dilution

5 mL of C in 5 mL of D = 1:1 or 0.5 dilution

0.1 mL of D per plate is 1:10 or 10^{-1} dilution

$10^{-2} \times 10^{-1} \times 0.5 \times 10^{-1} = 0.5 \times 10^{-4}$

Second, find the average of the colony counts:

$$\frac{57 + 61 + 48}{3} = 55 \text{ colonies}$$

Third, divide the colony counts by the dilution:

$$\frac{55 \text{ colonies}}{0.5 \times 0.0001} = 1 \times 10^{6} \text{ CFU/mL}$$

Algebra

Candidates should be able to perform basic applied algebra such as solving for one unknown in an equation. Remember that the unknown must be in the numerator and by itself on one side of the equation with all knowns on the other side.

Example

A treatment plant receives 90 MGD of flow from Influent Line #1 and 10 MGD of flow from Influent Line #2. The flow from Influent Line #1 has a BOD of 300 mg/L and a suspended solids of 500 mg/L. The Influent Line #2 flow has a BOD of 2,000 mg/L and a suspended solids of 5,000 mg/L. What are the resultant BOD and suspended solids concentration of the mixture?

There are at least two ways this problem can be worked. One way is to compute the separate mass contributions by each flow, total them, and calculate the resultant concentration from the combined flow. The example below shows this method and is followed by a method using ratios.

First, calculate the pounds of BOD/day of the combined flow.

Influent Line #1: 300 mg/L x 90 MGD x 8.34 = 225,180 pounds BOD/day

Influent Line #2: 2,000 mg/L x 10 MGD x 8.34 = 166,880 pounds BOD/day

Total = 391,980 pounds BOD/day

Second, calculate the concentration of BOD in mg/L.

$$\frac{391{,}980 \text{ pounds BOD/day}}{8.34 \times 100 \text{ MGD}} = 470 \text{ mg/L}$$

Repeat these steps for suspended solids.

First, calculate the pounds SS/day of the combined flow.

Influent Line #1: 500 mg/L x 90 MGD x 8.34 = 375,300 pounds SS/day

Influent Line #2: 5000 mg/L x 10 MGD x 8.34 = 417,000 pounds SS/day

Total = 792,300 pounds SS/day

Second, calculate the concentration of SS in mg/L.

$$\frac{792{,}300 \text{ pounds SS/day}}{8.34 \times 100 \text{ MGD}} = 950 \text{ mg/L}$$

A shorter way to work this problem is to use ratios. The combined flow is 100 MGD (90 MGD + 10 MGD). 90/100 of the total flow is from Influent Line #1 and 10/100 comes from Influent Line #2 flow.

Calculate the BOD in mg/L for the combined flow.

$$\frac{90 \text{ MGD}}{100 \text{ MGD}} \times 300 \text{ mg/L} = 270 \text{ mg/L}$$

$$\frac{10 \text{ MGD}}{100 \text{ MGD}} \times 2000 \text{ mg/L} = 200 \text{ mg/L}$$

270 + 200 = 470 mg/L

Calculate the SS in mg/L for the combined flow.

$$\frac{90 \text{ MGD}}{100 \text{ MGD}} \times 500 \text{ mg/L} = 450 \text{ mg/L}$$

$$\frac{10 \text{ MGD}}{100 \text{ MGD}} \times 5{,}000 \text{ mg/L} = 500 \text{ mg/L}$$

450 + 500 = 950 mg/L

Section 5

Diagnostic Test

Introduction

This section provides a diagnostic test to assist those studying for the Grade IV Lab Analyst certification test in evaluating their current knowledge level in the skill sets presented in Section 3.

The example questions in the diagnostic test represent the type of knowledge that may be required to successfully pass the certification test. They are based on information contained in Section 6, References, and are arranged according to the skill sets presented in Section 3. However, passing the diagnostic test does not guarantee passing the certification test.

Note that this diagnostic test can be used to help Lab Analysts create additional questions for further study. For example, if a question asks about the components of an atomic absorption spectrophotometer, the Lab Analyst can inquire about the components of other types of instruments. A question that asks for the definition of a specific term used for toxicity analysis may prompt a Lab Analyst to become familiar with toxicity terminology in general.

Diagnostic test answers, the applicable skill sets, and selected solutions are presented at the end of this section. Candidates should take the diagnostic test, mark wrong answers, and record the skill sets for questions missed. Using Table 3-1, candidates should review the references to improve their knowledge of the subjects, especially in areas where they answered diagnostic test questions incorrectly.

Skill Set 1 Wet Chemistry

1. In the cyanide determination, which one of the following is not an interference?

   a. Sulfides

   b. Hydrogen cyanide

   c. Fatty acids

   d. Carbonates

2. Standard addition is best if the addition increases analyze:

   a. 0.3 to 0.6 times its original concentration.

   b. 1.5 to 3 times its original concentration.

   c. 3 to 6 times its original concentration.

   d. 15 to 30 times its original concentration.

3. Advantages of ion-selective electrodes do not include:

   a. wide-range of linear response.

   b. being unaffected by color or turbidity.

   c. interferences.

   d. short response time.

Skill Set 2 Instrumentation

1. Which gas chromatography detector(s) could be used for selective trace analysis of halogen-containing compounds?
   a. Hall Electrolytic Conductivity Detector (HECD)
   b. Thermionic Selective Detector (TSD)
   c. Electron Capture Detector
   d. Both “a” and “c”

2. In atomic absorption, a method not used for background correction is:
   a. beam chopping.
   b. Zeeman correction system.
   c. doppler broadening correction system.
   d. Deuterium lamps.

3. In chromatography:
   a. the greater ratio of partition coefficients between mobile and stationary phases, the greater the separation between two components of a mixture.
   b. the greater the ratio of partition coefficients between mobile and stationary phases, the smaller the separation between the two components of a mixture.
   c. the greater the ratio of partition coefficients between two components of a mixture, the greater the separation between the mobile and stationary phases.
   d. the smaller the ratio of partition coefficients between two components of a mixture, the greater the separation between the mobile and stationary phases.

Skill Set 3 Advanced Instrumentation

1. A mass spectrometer is an instrument:
   a. containing a hollow graphite rod that can be heated electrically to about 25,000°K to decompose and atomize a sample for analysis.
   b. which measures a sample that has been bombarded with electrons to produce charged molecular fragments that are separated according to their mass in a magnetic field.
   c. in which an electric potential exists at the junction between two different electrolyte solutions or substances.
   d. in which the analyses are immediately accelerated by a powerful radiofrequency field that oscillates about a load coil at a frequency of 27 MHz.

2. In gas chromatography:
   a. a mobile phase (a gas carrier) and a stationary phase (column packing or capillary column coating) are used to separate individual compounds.
   b. a sample is injected into an effluent stream and passed through a series of ion-exchanging columns.
   c. molecules are separated by size, and there is no attractive interaction between the stationary phase and the solute.
   d. a liquid mobile phase transports a sample through a column containing a liquid stationary phase.

3. Inductively coupled plasma (ICP) is desirable in comparison to Atomic Absorption (AA) for the following reasons, with the exception of:
   a. the high temperature and stability in ICP eliminate much of the interference encountered with AA.
   b. ICP is less expensive to purchase and operate.
   c. atomization in ICP is more complete.
   d. ICP is remarkably free of background radiation where the sample emission is observed.

Skill Set 4 Microbiology and Bacteriology

1. The genera that does not contain members of the coliform group is:
   a. *Enterobacter.*
   b. *Klebsiella.*
   c. *Aeromonas.*
   d. *Citrobacter.*

2. An organism associated with activated sludge treatment problems is the:
   a. *Sphaerotilus.*
   b. *Streptococcus.*
   c. *Salmonella.*
   d. *Rotifer.*

3. Particular problems associated with the detection of viruses of public health interest in the aquatic environment do not include:
   a. the small size of virus particles.
   b. the high virus concentrations in water and the variability in amounts and types that may be present.
   c. the various dissolved and suspended materials in water that interfere with virus detection.
   d. the present limitations of virus estimation and identification methods.

Skill Set 5 Biomonitoring and Toxicity

1. Chronic toxicity tests:
   a. are generally of shorter duration than acute tests.
   b. expose organisms under flow-through conditions.
   c. measure sublethal effects.
   d. are more precise than acute tests.

2. Toxicity Reduction Evaluation (TRE) is a phased approach that:
   a. characterizes the acute or chronic toxicity of an effluent.
   b. identifies the toxicant(s) of concern.
   c. confirms toxicity.
   d. identifies the species most vulnerable to the toxicant(s) of concern.

3. Toxicity Identification Evaluation (TIE) achieves which function during a Toxicity Reduction Evaluation study?
   a. Characterizes the acute or chronic toxicity of an effluent
   b. Identifies the toxicant(s) of concern
   c. Confirms toxicity
   d. Identifies the species most vulnerable to the toxicant(s) of concern

Skill Set 6 Process Control

1. Calculate the chlorine demand using the following data: the chlorinator is set at 250 lbs/day, the flow is 2.4 MGD, and the residual chlorine is 1.4 mg/L.
   a. 222 lbs/day
   b. 236 lbs/day
   c. 245 lbs/day
   d. 278 lbs/day

2. A sample of wastewater from a city of 50,000 population with an average flow of 100 gallons per capita per day contains 10 mL/L settleable solids. The cubic feet of solids produced per day is:
   a. 70,600 cu ft.
   b. 6.68 cu ft.
   c. 6,684 cu ft.
   d. 374,000 cu ft.

3. A treatment plant has the following characteristics of suspended solids removal: the primary clarifier removes 39% of the applied suspended solids; the biological treatment removes 85% of the applied suspended solids; the secondary clarifier removes 16% of the applied suspended solids. The plant flow is 18.2 MGD. The wastewater influent has 215 mg/L suspended solids. Assuming that results can be reported to three significant figures, what is the amount of solids, in pounds/day, removed in the process?
   a. 11.4 pounds removed per day
   b. 4,054 pounds removed per day
   c. 11,400 pounds removed per day
   d. 30,100 pounds removed per day

Skill Set 7 Regulations

1. A Quality Assurance/Quality Control document is a necessary component of the Environmental Laboratory Accreditation Program. Of the following, the least important area to be covered in the document is:
   a. organization and responsibility.
   b. sampling procedures.
   c. assessment of precision and accuracy.
   d. standard operating procedures for each analysis.

2. The methods of analysis that are promulgated for use on most wastewater samples are found in:
   a. 20 CFR 1910.1450.
   b. 40 CFR 136.
   c. 40 CFR 403.
   d. 40 CFR 503.

3. Of the following, which section of the Code of Federal Regulations determines the concentrations of toxins, heavy metals, pathogens, and other pollutants found in sewage sludge?
   a. 20 CFR 1910.1450
   b. 40 CFR 136
   c. 40 CFR 403
   d. 40 CFR 503

Skill Set 8 Laboratory Safety

1. A toxicant concentration producing death of test organisms, usually defined as a median value of 50%, is known as:
   a. a dose response concentration.
   b. an acute toxicity concentration.
   c. an LC_{50} value.
   d. an EC_{50} value.

2. As a laboratory supervisor, you must see that someone is primarily responsible for safety supervision. The most appropriate method of assigning this duty would be:
   a. to rotate the responsibility to someone new each month so everyone will feel involved in laboratory safety issues.
   b. to pick a permanent safety supervisor so that the individual can provide planning continuity and follow-up attention to reported hazards.
   c. to ask for a volunteer because volunteers tend to be more conscientious and capable because they have expressed an interest in the job.
   d. as a laboratory supervisor, you are ultimately responsible for laboratory safety and are unable to delegate this important responsibility.

3. When developing an Emergency Response Plan, the first step is to:
    a. inventory all chemicals in the laboratory.
    b. identify the tasks assigned to each group responding to emergency situations.
    c. identify the line of authority in an emergency.
    d. identify the hazards and dangers faced by the plant.

Skill Set 9 Quality Assurance and Quality Control

1. If a laboratory reports unacceptable data in a Proficiency Testing Study:
    a. the laboratory must determine the cause of the failure and perform corrective action prior to participation in another study.
    b. the laboratory must wait for the next Proficiency Testing Study to determine the cause of the failure.
    c. the laboratory must determine the cause of the failure, perform corrective action, and repeat another Proficiency Testing Study within 30 days.
    d. the laboratory must write a letter requesting leniency prior to participation in another study.

2. An application for laboratory accreditation (ELAP or NELAP) includes:
    a. laboratory information; personnel qualifications for the lab director and the quality assurance officer; fields of testing; invoice for fees; and the submission of a quality assurance manual.
    b. laboratory information; personnel qualifications for the lab director, the emergency response team leader, and the quality assurance officer; fields of testing; and the submission of a quality assurance manual.
    c. laboratory information; personnel qualifications for the lab director and the quality assurance officer; fields of testing; and the submission of a quality assurance manual and the standard operating procedures manual.
    d. laboratory information; personnel qualifications for the lab director, the quality assurance officer, and the safety officer; fields of testing; and the submission of a standard operating procedures manual.

3. The difference between duplicate determinations on randomly-selected routine samples is used in the development of quality control charts. One approach used to calculate the control limit specifies the following formula:

   UCL = D_4R, where D_4 = 3.27 is used for duplicates and R = the average difference of each of the duplicate samples.

   Ten duplicate determinations for a constituent is µg/L are as follows:

152 and 160	163 and 158	148 and 154	142 and 151
150 and 160	160 and 154	145 and 149	162 and 155
156 and 157	159 and 151		

   The duplicate analyses for a wastewater sample were 180 and 167 µg/L. Calculate the upper control and determine whether the analytical results for the plant sample are under control.

   a. The UCL = 6.3 µg/L and the wastewater sample duplicate analysis is in control.

   b. The UCL = 6.3 µg/L and the wastewater sample duplicate analysis is out of control.

   c. The UCL = 20.9 µg/L and the wastewater sample duplicate analysis is in control.

   d. The UCL = 20.9 µg/L and the wastewater sample duplicate analysis is out of control.

4. Calculate the method detection limit given the following information.

   A standard solution was analyzed 7 times with the following results in mg/L:

0.0356	0.0380
0.0352	0.0360
0.0371	0.0374
0.0346	

   Calculated mean = 0.0362

   Calculated standard deviation = 0.00125

   T Scores
   Level of Certainty

N	90%	95%	99%	99.5%
1	3.078	6.314	31.821	63.657
2	1.886	2.920	6.965	9.925
3	1.638	2.353	4.541	5.841
4	1.533	2.132	3.747	4.604
5	1.476	2.015	3.365	4.032
6	1.440	1.943	3.143	3.707
7	1.415	1.865	2.998	3.499
8	1.397	1.860	2.896	3.355

   a. 0.00393 mg/L

   b. 0.00375 mg/L

   c. 0.109 mg/L

   d. 0.114 mg/L

Skill Set 10 Management

1. In the management-by-exception concept:
   a. objectives are non-specific.
   b. tasks are closely managed.
   c. all activities are reported in detail.
   d. standard routines are not reported.

2. When an employee has made a mistake or error, the least important of the following is:
   a. obtain all the facts.
   b. maintain calmness.
   c. have the employee admit the error.
   d. keep a record of the event.

3. The most effective way to obtain an employee's cooperation on a plan is to:
   a. let the employee know you will assume full responsibility.
   b. let the employee know that he or she will be held personally responsible for the plan.
   c. let the employee know his or her role in originating the plan and/or the part he or she will play in implementation.
   d. let the employee know your availability in the implementation of the plan.

4. An organization chart for a utility can be helpful for several reasons. Which of the following is the least valid objective of an organization chart?
   a. To establish proper chain-of-command authority
   b. To help develop a budget
   c. To help in making up project schedules
   d. To help in scheduling emergencies

5. Successful communication requires mutual:
   a. agreement.
   b. confusion.
   c. transmission.
   d. understanding.

6. When a great deal of authority is delegated on many levels, an organization may be described as:
   a. authoritarian.
   b. centralized.
   c. decentralized.
   d. unstructured.

7. Recognition and job security are indications of:
   a. a good organization.
   b. a good supervisor.
   c. external morale factors.
   d. internal morale factors.

8. Generally, as an individual progresses upward in management, reliance on personal technical skill:
   a. changes to the more complex.
   b. decreases.
   c. increases.
   d. remains the same.

9. How can the supervisor be certain that scheduled maintenance is completed?
   a. Ask the workers
   b. Hire someone to inspect completed work
   c. Use a form that compares work assigned with work completed
   d. Wait and see if there are any failures

10. Word has just come down from the upper management that operating funds are being cut. How should this be handled?
    a. Cut the supplies and repairs in order to balance the budget
    b. Fire some of the less productive old employees
    c. Keep it quiet and do what you have to do—the less said the better
    d. Let the other personnel know what the situation is and ask for their help

11. One opening has become available which would be an advancement to any one of three qualified employees. How should this situation be handled?
    a. Hire an outsider to fill the position
    b. Pick one and notify all personnel of the change
    c. Split the work between the three and leave the position open
    d. Talk to the three as a group, explain the situation and make your selection, and then notify all personnel of the change

12. One of the employees in your crew complains about having to do a hard job. The proper thing to do is:
    a. explain that all employees must do their fair share of the hard work as well as the easier tasks.
    b. ignore the complaint.
    c. promise that the next assignments will be easier ones.
    d. tell the employee to shut up and work or quit and go home.

13. Occasionally some of the people on a work crew will indulge in active horseplay. This should be:
    a. discouraged because some of the workers might not like it.
    b. encouraged because it promotes good fellowship.
    c. permitted as it is a form of relaxation.
    d. stopped immediately because it is likely to cause an accident.

14. The managerial function which involves devising an appropriate system of pay is:
    a. controlling.
    b. organizing.
    c. planning.
    d. staffing.

15. The span of supervision is the:
    a. average length of time required to be in the organization before making supervisor.
    b. number of levels between the lowest employee and the boss.
    c. number of subordinates for each manager.
    d. number of supervisors in an organization.

16. If an organization's departments are organized by jobs to be done, this is known as departmentation by:
    a. customer.
    b. function.
    c. product.
    d. territory.

17. Decentralized authority describes the process of:
    a. changing an organization from centralized to decentralized.
    b. delegating authority to one's superiors instead of one's subordinates.
    c. delegating power for decisions to lower levels.
    d. retracting authority that has been previously delegated and probably changing functions and duties.

18. What term means that the employee reports to one specific supervisor, and that the delegation of authority comes from one particular supervisor to the employee?
    a. Unity of command
    b. Span of supervision
    c. Organizational chart
    d. Formal organization

19. The term “control” in management practices is:
    a. backward-looking.
    b. concentrating on the present.
    c. forward-looking.
    d. not connected to the other managerial functions.

20. If you are supervisor of two lead workers, one whose work is exceptionally good and a second whose work is substandard, what should you do?
    a. Demote the substandard foreman and bring up a replacement from the ranks
    b. Discuss the problem with the substandard foreman and offer to help before any other action is taken
    c. Find a replacement and then fire the substandard foreman
    d. Wait to see if the substandard foreman does better

21. Recruiting of new employees falls within which category?
    a. Directing
    b. Organizing
    c. Planning
    d. Staffing

22. The managerial function, which includes the guiding, teaching, motivating and supervising of Laboratory Analysts is:
    a. staffing.
    b. planning.
    c. organizing.
    d. directing.

23. “Essence of control” is:
    a. written records.
    b. testing.
    c. evaluation.
    d. action.

24. In the evaluation of an applicant for employment, which of the following may enter into your decision?
    a. Age
    b. Education level
    c. Minority classification
    d. All of the above

25. Why are good records important?
    a. To demonstrate a pattern of lawful behavior over time
    b. To polish your report-writing skills
    c. To record all uncritical events
    d. To give bookkeepers a job

26. What is the meaning of the term “paper screening”?
    a. Additional analysis of qualified applicants
    b. Elimination of applicants not qualified for the job
    c. Filing of unsuccessful applicants’ paperwork for future job openings
    d. Review of research papers submitted by a job applicant

27. Which one of the following questions is an acceptable interview question?
    a. Who is your religious leader?
    b. What is the nationality of your parents or spouse?
    c. What is your age?
    d. What is your technical background?

28. What is the best approach to solving a discipline problem?
    a. Accept the employee’s solution to the problem
    b. Form a committee of peers to make a recommendation
    c. Ignore the problem and it will go away
    d. State the problem and then ask employee to suggest a solution

29. What is the best way to prevent sexual harassment?
    a. Ignore any accusations
    b. Require victims to prepare a written document
    c. Set an example by your own behavior
    d. Tell people sexual harassment is wrong

30. Why is written communication more demanding than oral communication?
    a. Ideas must be expressed clearly
    b. Important information may be missed
    c. It requires the use of highly technical terms
    d. There is no chance to clarify and explain ideas in response to an audience

31. What kinds of behavior are considered sexual harassment?
    a. Humiliating, offensive, happy, and invited
    b. Annoying, hostile, humiliating, offensive, and invited
    c. Inoffensive, annoying, hostile, humiliating, and uninvited
    d. Annoying, hostile, humiliating, offensive and uninvited

32. When an employee breaks the rules and requires discipline, who is responsible for administering it?
    a. Fellow employees
    b. The personnel office
    c. The Supervisor
    d. Upper management

33. You are asked to determine the cost per test of the COD analysis. Use the following information:

    The base salary of an analyst is $30,000; employer paid benefits add 35% to the base salary; administrative overhead adds another 45% to the base salary; there are 10 paid holidays, 15 days paid vacation leave and 12 days paid sick leave per year; the hourly salary is determined by dividing the monthly salary by 174. Each COD test requires an average of 20 minutes of labor from sample preparation to cleanup. Costs for chemicals, glassware, and equipment use average $1.00 per test. Disposal costs average $2000/year for reagents from 1,000 tests.

    What is the total cost per test?
    a. $11.62/test
    b. $8.62/test
    c. $20.24/test
    d. $13.04/test

34. You must select one of two approved methods for performing an analysis. Method A requires 30 minutes of analyst time per test and uses no special instruments. Method B requires 10 minutes of analyst time per test and uses an instrument costing $30,000. Base salary for the analyst is $2,600 per month, employer paid benefits add 35% to the base salary, and overhead adds another 45%. Assume there are 2,080 working hours per year. The instrument has a one-year full warranty; maintenance and repair costs for subsequent years are estimated to be $1,000 per year. The instrument has an eight-year service life. The test is now run on one sample at each of three locations, five days per week. Regulatory requirements may add one or two more sampling locations to the present requirements. The justification for expenditure for an instrument must show at least a 20% cost saving. (Assume there is no inflation in the salary for this example.) The recommendation you make is to:

   a. remain with Method A.
   b. purchase the equipment with the present requirements.
   c. purchase the equipment if one more sample location is added.
   d. purchase the equipment if two more sample locations are added.

Test Answer Key

Skill Set 1 Wet Chemistry

No.	Answer	Skill Set
1	b	1.0
2	b	1.0
3	c	1.0

Skill Set 2 Instrumentation

No.	Answer	Skill Set
1	d	2.0
2	c	2.0
3	a	2.0

Skill Set 3 Advanced Instrumentation

No.	Answer	Skill Set
1	b	3.0
2	a	3.0
3	b	3.0

Skill Set 4 Microbiology and Bacteriology

No.	Answer	Skill Set
1	c	4.0
2	a	4.0
3	b	4.0

Skill Set 5 Biomonitoring and Toxicity

No.	Answer	Skill Set
1	a	5.0
2	d	5.0
3	d	5.0

Skill Set 6 Process Control

No.	Answer	Skill Set
1	a	6.0
2	c	6.0
3	d	6.0

Skill Set 7 Regulations

No.	Answer	Skill Set
1	d	7.0
2	b	7.0
3	d	7.0

Skill Set 8 Laboratory Safety

No.	Answer	Skill Set
1	c	8.0
2	b	8.0
3	d	8.0

Skill Set 9 Quality Assurance and Quality Control

No.	Answer	Skill Set
1	a	9.0
2	a	9.0
3	c	9.0
4	a	9.0

Skill Set 10 Management

No.	Answer	Skill Set
1	d	10.0
2	c	10.0
3	d	10.0
4	d	10.0
5	a	10.0
6	c	10.0
7	a	10.0
8	b	10.0
9	c	10.0
10	d	10.0
11	d	10.0
12	a	10.0
13	d	10.0
14	c	10.0
15	c	10.0
16	b	10.0
17	c	10.0
18	d	10.0
19	b	10.0
20	b	10.0
21	d	10.0
22	d	10.0
23	c	10.0
24	b	10.0
25	a	10.0
26	b	10.0
27	d	10.0
28	d	10.0
29	c	10.0
30	d	10.0
31	d	10.0
32	c	10.0
33	a	10.0
34	d	10.0

Selected Problem Solutions

Skill Set	6	Process Control

1. Calculate the chlorine demand using the following data: the chlorinator is set at 250 lbs/day, the flow is 2.4 MGD, and the residual chlorine is 1.4 mg/L.

   First convert the residual chlorine concentration to mass, and then subtract it from the mass output of the chlorinator.

   $$\frac{2.4 \text{ MG}}{\text{day}} \times \frac{8.34 \text{ lbs}}{\text{gal}} \times \frac{1.4 \text{ parts}}{\text{M parts}} = 28 \text{ lbs/day}$$

   250 lbs/day - 28 lbs/day = 222 lbs/day

2. A sample of wastewater from a city of 50,000 population with an average flow of 100 gallons per capita per day contains 10 mL/L settleable solids. The cubic feet of solids produced per day is:

   Calculate the flow in cubic feet (cu ft)/day using the population and the flow "per capita" or per person.

   $$\frac{100 \text{ gal}}{\text{capita/day}} \times 50{,}000 \text{ capita} \times \frac{1 \text{ cu ft}}{7.48 \text{ gal}}$$

   = 668,449 cu ft/day

   The settleable unit mL/L is the same as parts/1,000 parts (p per k-p). Calculate the daily volume of settleable solids as follows:

   $$\frac{10 \text{ p}}{\text{k-p}} \times 668{,}449 \text{ cu ft} \times \frac{\text{k-p}}{1{,}000 \text{ p}} = 6{,}684 \text{ cu ft}$$

3. A treatment plant has the following characteristics of suspended solids removal: the primary clarifier removes 39% of the applied suspended solids; the biological treatment removes 85% of the applied suspended solids; the secondary clarifier removes 16% of the applied suspended solids. The plant flow is 18.2 MGD. The wastewater influent has 215 mg/L suspended solids. Assuming that results can be reported to three significant figures, what is the amount of solids, in pounds/day, removed in the process?

   Applied suspended solids refers to the influent load. Solids added by biological growth in the biological treatment are ignored. The solids remaining in the effluent of each treatment unit become the solids applied to the next treatment unit. First, use the removal efficiencies across each treatment unit to calculate the solids remaining in the secondary effluent.

   215 mg/L x (1 - 0.39) x (1 - 0.85) x (1 - 0.16)

   =16.52 mg/L

   Calculate the mass of solids removed across the plant.

   $$\frac{(215 - 16.52)}{\text{M}} \times \frac{8.34 \text{ lbs}}{\text{gal}} \times \frac{18.2 \text{ MG}}{\text{day}}$$

   = 30,126 lbs/day

   Round answer to three significant figures:

   30,100 lbs/day

Skill Set	9	Quality Assurance and Quality Control

3. The difference between duplicate determinations on randomly-selected routine samples is used in the development of quality control charts. One approach used to calculate the control limit specifies the following formula:

UCL = D_4R, where D_4 = 3.27 is used for duplicates and R = the average difference of each of the duplicate samples.

Ten duplicate determinations for a constituent is µg/L are as follows:

152 and 160	163 and 158	148 and 154	142 and 151
150 and 160	160 and 154	145 and 149	162 and 155
156 and 157	159 and 151		

The duplicate analyses for a wastewater sample were 180 and 167 µg/L. Calculate the upper control and determine whether the analytical results for the plant sample are under control.

Using the formula given above, calculate the upper control limit by summing the difference between each set of duplicate analyses, divide by the number of duplicates, and multiply by D_4.

$$\frac{8 + 5 + 6 + 9 + 10 + 6 + 4 + 7 + 1 + 8}{10}$$

x 3.27 = 20.9 = upper control limit

The difference between the duplicates for the wastewater sample is 180 - 167 = 13. Thirteen is less than the upper control limit, therefore, the duplicate analysis on the wastewater sample is in control.

4. Calculate the method detection limit given the following information.

A standard solution was analyzed 7 times with the following results in mg/L:

0.0356	0.0380
0.0352	0.0360
0.0371	0.0374
0.0346	

Calculated mean = 0.0362

Calculated standard deviation = 0.00125

T Scores
Level of Certainty

N	90%	95%	99%	99.5%
1	3.078	6.314	31.821	63.657
2	1.886	2.920	6.965	9.925
3	1.638	2.353	4.541	5.841
4	1.533	2.132	3.747	4.604
5	1.476	2.015	3.365	4.032
6	1.440	1.943	3.143	3.707
7	1.415	1.865	2.998	3.499
8	1.397	1.860	2.896	3.355

Standard Methods states: Analyze seven portions of this solution and calculate the standard deviation. Compute MDL from replicate measurements one to five times the actual MDL. From a table of the one-sided t distribution, select the value of t for 7 - 1 = 6 degrees of freedom at the 99% level; this value is 3.14. The product 3.14 times the standard deviation is the desired MDL.

3.14 x 0.001252 = 0.00393

Skill Set 10 Management

33. You are asked to determine the cost per test of the COD analysis. Use the following information:

The base salary of an analyst is $30,000; employer paid benefits add 35% to the base salary; administrative overhead adds another 45% to the base salary; there are 10 paid holidays, 15 days paid vacation leave and 12 days paid sick leave per year; the hourly salary is determined by dividing the monthly salary by 174. Each COD test requires an average of 20 minutes of labor from sample preparation to cleanup. Costs for chemicals, glassware, and equipment use average $1.00 per test. Disposal costs average $2000/year for reagents from 1,000 tests.

What is the total cost per test?

Determine the total cost of the analyst's time:

$$\frac{\$30{,}000 + (\$30{,}000 \times 0.35) + (\$30{,}000 \times 0.45)}{1 \text{ year}}$$

= $54,000/year

$$\frac{\$54{,}000}{\text{year}} \times \frac{1 \text{ year}}{12 \text{ mos}} \times \frac{1 \text{ month}}{174 \text{ hrs}} = \$25.86/\text{hr}$$

At 20 minutes analyst time per test:

$$\frac{\$25.86}{\text{hr}} \times \frac{1 \text{ hour}}{60 \text{ mins}} \times \frac{20 \text{ mins}}{\text{test}} = \$8.62/\text{test}$$

(analytical labor cost)

Disposal costs:

$$\frac{\$2{,}000}{1{,}000 \text{ tests}} = \$2.00/\text{test}$$

Reagent costs = $1.00/test

Total costs per COD test:
$8.62 + $2.00 + $1.00 = $11.62

34. You must select one of two approved methods for performing an analysis. Method A requires 30 minutes of analyst time per test and uses no special instruments. Method B requires 10 minutes of analyst time per test and uses an instrument costing $30,000. Base salary for the analyst is $2,600 per month, employer paid benefits add 35% to the base salary, and overhead adds another 45%. Assume there are 2,080 working hours per year. The instrument has a one-year full warranty; maintenance and repair costs for subsequent years are estimated to be $1,000 per year. The instrument has an eight-year service life. The test is now run on one sample at each of three locations, five days per week. Regulatory requirements may add one or two more sampling locations to the present requirements. The justification for expenditure for an instrument must show at least a 20% cost saving. (Assume there is no inflation in the salary for this example.) The recommendation you make is to:

Determine total cost of analyst's time:

$$\frac{\$2{,}600 + (\$2{,}600 \times 0.35) + (\$2{,}600 \times 0.45)}{\text{month}}$$

= $4,680/month

$$\frac{\$4{,}680}{\text{month}} \times \frac{12 \text{ months}}{1 \text{ year}} \times \frac{1 \text{ year}}{2{,}080 \text{ hrs}} = \$27.00/\text{hr}$$

Method A:

Cost/sample (Analyst's time) =

$$\frac{\$27.00}{\text{hr}} \times \frac{1 \text{ hr}}{60 \text{ mins}} \times \frac{30 \text{ mins}}{\text{sample}}$$

= $13.50/sample

Present workload = 15 samples/week

15 samples/week x $13.50/sample
= $202.50/week

With 1 additional sample point
= 20 samples/week

20 samples/week x $13.50/sample
= $270.00/week

With 2 additional sample points
= 25 samples/week

25 samples/week x $13.50/sample
= $337.50/week

Method B:

Cost/sample (Analyst's time) =

$$\frac{\$27.00}{hr} \times \frac{1\ hr}{60\ mins} \times \frac{15\ mins}{sample} = \$6.75/sample$$

Present workload = 15 samples/week

15 samples/week x $6.75/sample
= $101.25/week

With 1 additional sample point
= 20 samples/week

20 samples/week x $6.75/sample
= $135.00/week

With 2 additional sample points
= 25 samples/week

25 samples/week x $6.75/sample
= $168.75/week

Instrument costs:

$30,000 + (7 years x $1,000/year maintenance) = $37,000 over 8 years

$$\frac{\$37{,}000}{8\ years} \times \frac{1\ year}{52\ weeks} = \$88.94/week$$

Method B present workload
= $101.25 + $88.94 = $190.19/week

Method B with 1 additional sample point
= 20 samples/week = $135.00 + $88.94
= $223.94/week

Method B with 2 additional sample points
= 25 samples/week = $168.75 + $88.94
= $257.69/week

Method A / Method B relative costs:

Present workload = $\frac{\$190.19}{\$202.50}$ = 0.94

With 1 additional sample point =

$\frac{\$223.94}{\$270.00}$ = 0.83

With 2 additional sample points =

$\frac{\$257.69}{\$337.50}$ = 0.76

The addition of two sample points would justify the expenditure due to a cost savings of >20%.

Section 6

References

This section provides titles and information on primary and secondary references found useful in obtaining Grade IV Laboratory Analyst certification. Because primary references contain most of the information needed for the certification test, it is recommended that candidates obtain access to them for personal use.

Many of these publications may be reviewed and purchased on-line from their publishers or from electronic book retailers. Others may be found in a wastewater treatment plant library or in a college or university library. In addition, see the CWEA Certification Resource Links page at www.cwea.org/tcp/resources for links to resources available on-line and any updates or changes to the information and URLs listed below.

Primary References

Standard Methods for the Examination of Water and Wastewater, 18th Edition
Water Environment Federation
601 Wythe Street
Alexandria, VA 22314-1994
800/666-0206
www.wef.org

Please note that the 18th Edition is not the most recent edition, but is the one referenced by EPA regulations, and therefore is the basis for developing the certification test questions.

Lectures on Wastewater Analysis and Interpretation
Genium Group, Inc.
1171 Riverfront Center
Amsterdam, NY 12010
800/842-1843
genium@genium.com

Operation of Municipal Wastewater Treatment Plants – MOP 11, 5th Edition (3 volumes)
Order No: M05110WW
Pub Date: 1996
Water Environment Federation
601 Wythe Street
Alexandria, VA 22314-1994
800/666-0206
www.wef.org

Operation of Wastewater Treatment Plants, Volumes I and II
Office of Water Programs
California State University, Sacramento (CSUS)
6000 J Street
Sacramento, CA 95819-6025
916-278-6142
http://owp.csus.edu

Methods for Chemical Analysis of Water and Wastes
U.S. Environmental Protection Agency, Revised March 1983
EPA-600/4-79-020
NTIS Order No: PB84128677
National Technical Information Service (NTIS)
5285 Port Royal Road
Springfield, VA 22161
800/553-6847 (order by phone)
www.ntis.gov
Online version available at
www.epa.gov/clhtml/pubtitle.html

40 CFR (CFR Title 40: Protection of the Environment)
Available on-line at:
www.epa.gov/epahome/cfr40.htm

Section 6: References

Handbook for Analytical Quality Control in Water and Wastewater Laboratories
U.S. Environmental Protection Agency, 1979
EPA-600/84-79-019
NTIS Order No: PB297451
National Technical Information Service (NTIS)
5285 Port Royal Road
Springfield, VA 22161
800/553-6847 (Order by phone)
www.ntis.gov

Microbiological Methods for Monitoring the Environment – Water and Wastes
Edited by R.H. Bordner, J.A. Winter, and P.V. Scarpino
U.S. Environmental Protection Agency, 1978
EPA-600/8-78-017
NTIS Order No: PB290329
National Technical Information Service (NTIS)
5285 Port Royal Road
Springfield, VA 22161
800/553-6847 (Order by phone)
www.ntis.gov

Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms, 4th Edition, August 1993
U.S. Environmental Protection Agency
EPA-600/4-90-027F
NTIS Order No: PB94114733
National Technical Information Service (NTIS)
5285 Port Royal Road
Springfield, VA 22161
800/553-6847 (Order by phone)
www.ntis.gov
Online version available at
www.epa.gov/OST/WET/disk2/

The Clean Water Act: 25th Anniversary Edition
Order No: PO7110WW
Pub. Date: 1997
Water Environment Federation
601 Wythe Street
Alexandria, VA 22314-1994
800-666-0206
www.wef.org

Test Methods for Evaluating Solid Waste, Physical/Chemical Methods
EPA Publication SW-846
Available online at
www.epa.gov/epaoswer/hazwaste/test/sw846.htm

Water Supply Operations (WSO) series Part V: Basic Science Concepts and Applications, Textbook
ISBN 0-89867-796-3
Catalog No: 1959
American Water Works Association (AWWA)
6666 W. Quincy Avenue
Denver, CEO 80235
800/926-7337
www.awwa.org

Laboratory Safety Pocket Handbook
Genium Publishing Corporation
1171 Riverfront Center
Amsterdam, NY 12010
800/243-6486
genium@genium.com

OSHA Regulations (Standards – 29 CFR)
Available online at:
www.osha-slc.gov/pls/oshaweb/
Available in print or on CD from:
Government Institutes, Inc.
4 Research Place, Suite 200
Rockville, MD 20850
301/921-2300

Utility Management
Office of Water Programs
California State University Sacramento (CSUS)
6000 J Street
Sacramento, CA 95819-6025
916-278-6142
www.owp.csus.edu

Supervision: Concepts and Practices of Management, 8th Edition
Raymond L. Hilgert and Edwin C. Leonard, Jr.
ISBN 0-324-01389-2
Pub Date: 2001
South-Western College Publishing
a division of Thomson Learning
5101 Madison Road
Cincinnati, OH 45227-1490
800/543-0487
www.swcollege.com

Grade IV Lab Analysts are expected to have mastered the skills learned for Grades I, II, and III, and candidates may wish to review the math and chemistry problems outlined in the CWEA study guides for Grades I, II, and III.

Secondary References

The information contained in the Primary References listed above provides a solid base of knowledge for the Lab Analyst. The additional sources of information listed below may also be helpful for candidates seeking to broaden or refresh their knowledge in specific areas.

Chemical Technicians' Ready Reference Handbook
Gershon Shugar and Jack Ballinger
ISBN 0070571864
Pub Date: June 1, 1996
McGraw-Hill Professional Publishing Group
800/722-4729
www.books.mcgraw-hill.com

Chemistry
John McMurry and Robert C. Fay
ISBN 0-13-057677-8
Pub Date: December 2000
Prentice-Hall
Pearson Education Company
One Lake Street
Upper Saddle River, NJ 07458-1813
201/236-7000
www.pearsonptg.com or other online booksellers

Quantitative Analytical Chemistry, 5th Edition
James S. Fritz and George H. Schenk
ISBN 025104800
Pub. Date: January 1987
Prentice-Hall
201/236-7000
Purchase through amazon.com
barnesandnoble.com or other online booksellers

Instrumental Methods of Analysis, 7th Edition
Hobart Hurd Willard, Frank A. Settle,
John A. Dean, and Lynne L. Merritt
ISBN 0534081428
Pub. Date: October 1995
available through various online booksellers

Microbiology, An Introduction
Gerard Tortora, Berdell Funke,
and Christine Case
ISBN 0-8053-7597-X
Benjamin Cummings (publisher)
Pearson Education Company
One Lake Street
Upper Saddle River, NJ 07458-1813
201/236-7000
www.pearsonptg.com or other online booksellers

Brock's Biology of Microorganisms
Michael T. Madigan, John M. Martinko,
and Jack Parker
ISBN 0-13-081922-0
Prentice-Hall
Pearson Education Company
One Lake Street
Upper Saddle River, NJ 07458-1813
201/236-7000
www.pearsonptg.com or other online booksellers

Effective Supervisory Practices: Better Results Through Teamwork
ISBN: 0-87326-176-3
ICM International
City/Council Management Association
800/745-8780
www.icma.org

Section 6: References

Math Text for Water and
Wastewater Technology, 2nd Edition
Wright's Training
P.O. Box 515
Elmira, CA 92625
707/448-3659
Download form to order:
www.wrights-trainingsite.com

Applied Math for Wastewater Plant Operators
Joanne Kirkpatrick Price
ISBN 0877628092
CRC Press
800/272-7737
www.crcpress.com

A p p e n d i x A

You and Wastewater Math

by Cheryl Ooten, Mathematics Professor, Santa Ana College, Ooten_Cheryl@rsccd.org

Example math problems found in Appendix A are representative of general wastewater math and are designed to illustrate a math problem solving strategy, not specific math skills. Examples given in this appendix may not be like the problems given on the test for your discipline. However, the problems are typical of types of problems you may encounter, including, but not limited to, basic algebra (solving one equation for one unknown), story problems, and plane and solid geometry (area and volume problems). For specific kinds of math skills and problems you may encounter on the certification test, please review Sections 3, 4, and 5 of this study guide.

Introduction

Now is the time for you to begin preparation for the math portion of your technical certification exam. This Appendix provides suggestions to take charge of:

- Your math skills
- Your attitudes toward math
- Your test-taking skills

By doing this, you can improve your performance in successfully completing the math questions on the certification exam.

Two Facts to Consider

First, since early childhood, you have used math mostly without giving it a second thought. Knowing your age, counting, comparing sizes and shapes, adding your money, and subtracting to get change are math skills.

You drive the streets judging distances, speeds, and times. You estimate if you can afford a vacation or a car and when you can retire. You compare volumes and areas as you build and do jobs around the work site. You even measure volume in putting toothpaste on your toothbrush. You use statistics as you watch sports and consider things like RBIs in baseball or field goal percentages in basketball. All of these are mathematical skills many people take for granted.

Second, if you think math is hard, please know that math becomes hard for *everyone* at some point. You are not alone. There are math problems that have been unsolved for hundreds of years even though they have been attempted by competent, well-informed mathematicians who may work at them for decades. Those are not the problems you need to work unless you are curious. When you work at your appropriate level, you find a combination of easy ideas and hard ideas.

You may get discouraged comparing your speed and understanding in math with others. Those people who appear to do math easily have, most likely, done those specific problems, or ones like them, many, many times.

You will want to study and progress at your "growing edge"—the skill level where you have a bit of discomfort with new material, but where you are not totally overwhelmed. You can expect challenges that trouble you, but that can be overcome. Instead of saying "I cannot do math," decide now to begin learning enough math to make work and test-taking easier.

Move Beyond the Math You Know

To move beyond your routine skill level in math, consider the following points:

You Have Skills.
You already have many math skills and can build on that base. It is best and easiest to build on what you already know.

Basics are Important.
Going back over the basics of what you know will build confidence and help you progress and add new math skills to your ability to solve math problems.

Math Progresses Logically.
There are many different areas of math and each builds on itself as well as on the others. If you cannot do a particular problem, it may be because you have missed something basic to that one area along the way. Working your way up slowly and cumulatively in math is the fastest way to gain skills.

Words Count.
Each and every word and symbol in math means something. You need to find out those meanings and then practice them. If you do not know what "mgd" or "psi" means, or which units measure "flow", it is harder to do problems involving them. It can seem like a foreign language.

Brains are Unique.
Each individual brain is wired differently, causing each person to think and learn differently. The more you know about the way you as a specific individual learn, the more you will permit yourself to do what it takes to learn math. Some people need to do many written repetitions. Some need to walk or move around as they do math. Some need to talk out loud. Others need to draw pictures. Some need to work problems with other people. Some need to use words and some need to use symbols. In order to focus on how to move forward, think about what works for you or where learning has been difficult for you.

If you are an independent learner, you might find a basic math book at your library to work through on your own. You may be able to study with your own children to learn some math together or with your friends and colleagues. You may have an old math book you used a long time ago that could be helpful, and you may come to remember what you learned from it.

Assessment Helps.
Assess your skill level honestly. Math placement tests are available at your local college and through private educational agencies to help you determine where your skills are and where you can best get help to make comfortable progress.

You are Not Alone.
No one promises that math will always be easy or interesting for you. For most people, working on math is a challenge. Persevering and pushing personal limits allows you to experience the satisfaction of success.

Get help when you get discouraged or experience confusion. Remember this is just a momentary problem in a sequence of ideas that you are confronting. Do not buy into the myth that you have to do math alone. Do not believe it is demeaning for you to admit you do not understand. You can have fun if you lighten up as you progress. Working with others is an outstanding way to improve math skills.

Questions are Essential.
Make a list of people with whom you feel comfortable discussing your math questions. They may be your colleagues, teachers, fellow students, friends, or family members—even your children. Do not ask just anybody; pick people who are helpful and positive or non-judgmental about your questions.

Mistakes Happen.
Expect mistakes up front. As you learn anything new, you will make errors. Do not blame your mistakes on math itself! In any new endeavor you need to allow yourself to crawl before you can walk. Successful people in all fields know this. Trial and error is the basis of all learning.

You can learn more from your mistakes than from repeated successes. Making errors gives you feedback by showing you what you do not understand. Learn to value and accept those errors and use them to find out what areas of your learning need more work. Correct them and then move on with new knowledge.

Learning Math is Not a Competitive Game.
Physicist Albert Einstein, politician Winston Churchill, and inventor Thomas Edison were all considered slow in school. Musical composer Ludwig Van Beethoven and scientist Louis Pasteur probably had learning disabilities. What all five certainly had was determination and patience to persevere. Only compete with yourself, pushing yourself forward, in learning math.

There is Hope for Those with Learning Disabilities.
If you really have a hard time learning, you might ask your local college or a private learning specialist to assess you for a learning disability. Many colleges and universities do free testing and training for their students. You can also purchase this kind of assistance from private consultants. Much is now known about learning disabilities and how to help people who have them. Learning

disabilities often become just learning differences as students learn to honor and use their own thinking and learning styles.

Math Success and Test-Taking Success are Not the Same.
Many math students understand and can work math problems, but have difficulty in test-taking situations. It is possible to know math and still fail exams. These people may find Section 4, Test Preparation very helpful. Conscious practice of both math skills and test-taking skills can make a big difference in your score.

Resources are Available.
Resources exist for all types of math. You will need to decide whether you will work on your math skills independently or with the help of some structure such as a math course or a tutor. Different strategies may work better at different stages in your progress.

Your local community college has inexpensive math courses. Some colleges even have math courses specifically for water and wastewater professionals. Professional organizations sponsor training conferences and seminars which include math courses specific to the field. Many agencies can provide in-house training and many agencies will provide individual help with all aspects of test taking.

Community Colleges
Community colleges offer several types of services including:

- Math Placement Testing
- Math Courses
- Water Utility Science Courses
- Math Anxiety Reduction Courses
- Testing and Training for those with Learning Disabilities

Professional Organizations
Organizations such as the California Water Environment Association (CWEA), American Water Works Association, and American Public Works Association also provide opportunities to practice your math skills and network with others:

- Technical Certification Training Classes and Annual Conferences
- CWEA Study Guides

At Work
Ask for help and suggestions from others who have taken math courses or are skilled in the work area similar to the one you are trying to prepare or improve. Ask your supervisor for advice on how to prepare and how much time on the job you can have to prepare. Ask your supervisor to provide training classes for the areas that you are wanting to improve. Ask those managing other departments, agencies, or local professional organizations for help in getting the training you need.

Materials
Any basic math book or instructional manual that you can beg, borrow, or buy, including:

- Courses from Ken Kerri, Office of Water Programs, California State University, Sacramento, 6000 J Street, Sacramento, CA 95819
- Price, Joanne Kirkpatrick. *Basic Math Concepts for Water and Wastewater Plant Operators, 2nd Edition.* Lancaster, Pennsylvania: Technomic, 1991; currently CRC Press LLC.
- Smith, Richard Manning. *Mastering Mathematics: How to Be a Great Math Student,* 3rd Ed. Pacific Grove, CA: Brooks/Cole, 1998.
- Zaslavsky, Claudia. *Fear of Math.* New Brunswick, NJ: Rutger University Press, 1994.

Practice Problem Solving Strategies

Wastewater math deals with only a handful of basic types of problems that involve moving liquids and semi-solids from place to place, and manipulating, storing, and treating these substances along the way.

So basically, understanding area, volume, slope, rates, concentrations, costs, and time elements that occur in wastewater treatment 24 hours per day, 365 days per year, pretty much covers what you need to know.

Units and Arithmetic

All wastewater math problems can be solved by simple arithmetic—adding, subtracting, multiplying, and dividing. You can become proficient with wastewater math by paying careful attention to the units in the problems as you write down your strategies, and then using a calculator to do the needed arithmetic.

Units
Units such as cubic feet, gallons, gpm, and mgd are important in wastewater math problems. Paying attention to the units will tell you whether to multiply or divide. Also, the units will often help you know what numbers to multiply or divide.

Notice in each example that doing math operations on the units produces the correct units in the answer. Many people do the math on the units first to figure out the correct procedure before they ever do the math on the numbers.

Multiplying
Multiplying is important. There are several symbols for multiplication. They are •, x, and ()().

For example,

$2 \bullet 3 = 2 \times 3 = (2)(3) = 6$

Dividing
Dividing is important to wastewater math because units often used such as MGD, cfs, ppm, GPM, psi, mg/L, GPD/sq ft, and % are really division problems.

"Per" stands for "divided by."

$$\text{MGD} = \frac{\text{millions gallons}}{\text{day}}$$

$$\text{cfs} = \frac{\text{cubic feet}}{\text{second}}$$

$$\text{ppm} = \frac{\text{parts}}{\text{million}}$$

$$\text{GPM} = \frac{\text{gallons}}{\text{minute}}$$

$$\text{psi} = \frac{\text{pounds}}{\text{square inch}}$$

$$\text{mg/L} = \frac{\text{milligrams}}{\text{Liter}}$$

$$\text{GPD/square foot} = \frac{\text{gallons/day}}{\text{square foot}}$$

$$10\% = \text{ten percent} = \frac{10}{100}$$

Example Problems

Example 1

Plant No. 1 measured a flow of 3.5 million gallons in half a day. If the peak flow (hydraulic) capacity of the plant is 8 mgd, is there need for concern?

Using the conversion factor

$$\text{mgd} = \frac{\text{million gallons}}{\text{day}}$$

divide 3.5 million gallons by half a day.

$$\text{mgd} = \frac{3.5 \text{ million gallons}}{.5 \text{ day}} = 7 \text{ mgd}$$

7 mgd is less than the peak flow capacity, 8 mgd. There is no need for concern yet.

Example 2

a. Find the number of gallons in 10 cubic feet.

Since we can pour 7.48 gallons into a 1 cubic foot container, that means that 7.48 gallons = 1 cubic foot. We can use either factor:

$$\frac{7.48 \text{ gal}}{1 \text{ cu ft}} \text{ or } \frac{1 \text{ cu ft}}{7.48 \text{ gal}}$$

to convert cubic feet units into gallons or vice versa

$$\frac{10 \text{ \sout{cu ft}}}{1} \times \frac{7.48 \text{ gal}}{1 \text{ \sout{cu ft}}} = \frac{(10 \text{ \sout{cu ft}})(7.48 \text{ gal})}{1 \text{ \sout{cu ft}}}$$

= 74.8 gal

Notice that using the first factor allows the unit "cu ft" to cancel out leaving the answer in gallons.

b. Find the number of cubic feet in 10 gallons. Notice that using the second factor allows the unit "gal" to cancel out leaving the answer in cubic feet.

$$\frac{10 \text{ \sout{gal}}}{1} \times \frac{1 \text{ cu ft}}{7.48 \text{ \sout{gal}}} = \frac{(10 \text{ \sout{gal}})(1 \text{ cu ft})}{7.48 \text{ \sout{gal}}}$$

= 1.34 cu ft

You will notice how important it was in these examples to consider the units in deciding whether to multiply or divide by 7.48.

Example 3

a. Find the detention time for a basin with 675,460 gal if the flow is 1,000,000 gal/day.

Flow is always a rate which is division. Units like gpd or cfs are both division.

The formula for the basin detention time is:

$$Dt = \frac{\text{volume}}{\text{flow}}$$

$$Dt = \frac{675{,}460 \text{ } \cancel{\text{gal}}}{1{,}000{,}000 \text{ } \cancel{\text{gal}}/\text{day}}$$

$$= \frac{675{,}460 \text{ } \cancel{\text{gal}}}{1} \times \frac{\text{day}}{1{,}000{,}000 \text{ } \cancel{\text{gal}}} = 0.675 \text{ days}$$

b. Find the detention time for a 426 cubic foot basin if the flow is 1,000 cfs.

$$Dt = \frac{426 \text{ cu ft}}{1{,}000 \text{ cfs}} = \frac{426 \text{ } \cancel{\text{cu ft}}}{1{,}000 \text{ cu ft/sec}}$$

$$= \frac{426 \text{ } \cancel{\text{cu ft}}}{1} \times \frac{\text{sec}}{1{,}000 \text{ } \cancel{\text{cu ft}}} = 0.426 \text{ sec}$$

Example 4

Find the number of gallons of an 11% polymer needed to produce 100 gallons of a 0.75% solution.

Use the formula $C_1V_1=C_2V_2$ where C=concentration or % and V=volume.

You can let the volume you are looking for (i.e. the number of gallons of 11% polymer) be represented by V_1. Then C_1=11% or 0.11, C_2=0.75% or 0.0075, and V_2=100 gallons.

Using the formula $C_1V_1=C_2V_2$, you have $(0.11)(V_1) = (0.0075)(100)$

Notice to find V_1, you do the opposite of multiplying (i.e. dividing) by 0.11 on both sides. You then have

$$\frac{(\cancel{0.11})(V_1)}{\cancel{0.11}} = \frac{(0.0075)(100)}{0.11}$$

and using a calculator, V_1=6.82. So, the amount needed is 6.82 gallons.

Example 5

How many hours will it take to empty a 43,000 cubic foot tank if it empties at a rate of 2.7 cubic feet per second?

Notice that dividing 43,000 cubic feet by 2.7 cubic feet per second would make the cubic feet unit cancel out. This would give us the time in seconds. To convert seconds into hours, use the factors

$$\frac{1 \text{ min}}{60 \text{ sec}} \text{ and } \frac{1 \text{ hr}}{60 \text{ min}}$$

The work is given below. Notice how the units cancel out leaving the answer in hours.

$$\text{Time} = \frac{43{,}000 \text{ } \cancel{\text{cu ft}}}{2.7 \text{ } \cancel{\text{cu ft/sec}}} \times \frac{1 \text{ } \cancel{\text{min}}}{60 \text{ } \cancel{\text{sec}}} \times \frac{1 \text{ hr}}{60 \text{ } \cancel{\text{min}}}$$

= 4.42 hr

Example 6

Find the number of gallons of water in a rectangular basin 200 feet long, 50 feet wide, and 12 feet deep.

First, find the volume of the rectangular basin by multiplying length by width by height. Volume = (200 ft)(50 ft)(12 ft) = 120,000 cubic feet or cu ft or ft^3.

You now have a problem similar to Example 2. How many gallons are there in 120,000 cubic feet? Use the factor

$$\frac{7.48 \text{ gal}}{1 \text{ cu ft}}$$

to convert cubic feet into gallons.

$$\text{Volume} = \frac{120{,}000 \text{ } \cancel{\text{cu ft}}}{1} \times \frac{7.48}{1 \text{ } \cancel{\text{cu ft}}}$$

= 897,600 gal

Example 7

A cylindrical tank is full to 3 feet below the top at 10 a.m. and empty at 4 p.m. If the tank is 50 feet tall with a diameter of 70 feet, find the volume (in gallons) of the liquid at 10 a.m. and the rate of flow from the tank in gallons per minute.

For a math problem with many words, I recommend always first writing down what you are trying to find:

(1) First, find the number of gallons of water in the tank at 10 a.m.

(2) Second, find the rate of flow in gal/min.

Drawing a sketch helps some people understand the problem and helps to keep track of the data.

I also like to write down and interpret the details that are given to me like:

Full to 3 ft below the top at 10 a.m.

Empty at 4 p.m.

Takes 6 hours to empty

a. First, to find the volume in gallons at 10 a.m., use the formula for volume of a cylindrical tank which is V=(area of the base) times (height).

To find the area of the base of the tank which is a circle, multiply 0.785 times the diameter squared.

So, the area of the base = $0.785(70^2)$
= 3,846.5 sq ft.

The height at 10 a.m. is 47 feet because the tank is filled to 3 feet below the top.

Volume = (area of the base)(height)
= $(3846.5\ ft^2)(47\ ft) = 180{,}785.5\ ft^3$

However, you want the volume in gallons so use the factor

$$\frac{7.48\ gal}{1\ cu\ ft}$$

to convert.

Volume in gallons = $180{,}785.5\ \cancel{ft^3} \times \frac{7.48\ gal}{1\ \cancel{ft^3}}$

= 1,352,275.54 gal

b. Second, to determine the rate of flow in gallons per minute, divide the number of gallons by the number of minutes it took the tank to empty. It took 6 hours to empty. To convert 6 hours to minutes, use 60 min = 1 hr or factors

$$\frac{60\ min}{1\ hr} \text{ or } \frac{1\ hr}{60\ min}$$

to convert. You want the hour unit to cancel out, so you will use the first factor. The time becomes:

$$\frac{6\ \cancel{hrs}}{1} \times \frac{60\ min}{1\ \cancel{hr}} = 360\ min$$

Rate of flow in gal per minute =

$$\frac{1{,}352,\ 275.54\ gal}{360\ min} = 3{,}756.32\ gal\ per\ min$$

Take Charge of Your Success

The key to progress with math is to consciously take charge of your thoughts and actions. Then, instead of letting math control you, you control math and you take charge of your success.

Recommendations

Ask Questions.
Be active and assertive. Learning is not a spectator sport. You cannot learn well from the sidelines. Get involved. Work problems and keep asking questions until they become clear. In classes and seminars, ask questions on confusing procedures.

Take It Easy.
When you get stuck working problems, hang in for a while and then take a break. Go back later, begin at the beginning with a clean sheet of paper and a different point of view. Just because you do not understand at first does not mean understanding will not come. Math learning requires time to settle into your brain. Being able to live with uncertainty for a while is a good math skill to have.

Keep a List.
Write down your resources (books, tutors, people to answer questions, people who understand) so that you can consult them when you get discouraged. You are not alone. Find helpful people with whom you are comfortable. Form a network with others working toward the same goals as you.

Find Yourself.
Discover your own unique ways of learning. Experiment with new ones. If a method does not work, find others. Ask different people how they learn math or do a problem. They will often feel honored and pleased that you asked them and you might get a breakthrough idea.

Be Positive.
Listen to what you say to yourself inside your head. It is difficult to work well if you are saying, "I will never get this" or "I cannot do math." Change those negative messages to neutral ones like "I have not learned this *yet*" or "I cannot do this particular problem *yet*."

Reward Yourself.
Acknowledge your progress—every little bit! Pat yourself on the back for each and every problem you work. Notice what you know now that is new that you did not know two weeks ago. Maybe even write it down to document your growth.

Learn From Mistakes.
Remember that errors are part of the learning process. Pay attention to them and figure out where they happened and how to fix them.

Keep It Real.
Be realistic with your expectations of yourself—your math level, your life commitments, and your time constraints. Do not beat yourself up for being a human being.

Use Technology.
Learn to use a calculator and use it appropriately for calculations with large numbers and decimals. Each brand of calculator is different, so keep your manual for reference. Take spare batteries to exams.

Start Easy.
Practice the easier math problems to warm up each time you begin your math study. This builds confidence and strengthens those math pathways in your brain.

Use Paper.
Keep scratch paper available and expect to use it for your math work. You need empty space on paper to think and do calculations.

Promote Emotional Well Being.
Patience, self-care, and humor will make your math work so much easier. Your brain will work better too.

Be Healthy.
You are making new connections in your brain as you practice math, so sufficient sleep and healthy foods are important. Having fresh drinking water available and breathing fresh air also helps you think better.

Test-Taking Strategies

There are many actions you can take before, during, and after exams that will improve your test-taking performance and outlook. Remember that math skills and test-taking skills are different from each other. This section will help you become conscious of your thoughts and actions regarding test preparation. Use these suggestions to take charge and approach your test confidently.

If you find yourself thinking negative thoughts about your coming exam, skip to the last section and read "Negative Thinking about Exams" first.

Before the Exam

Work Problems.
Diligently prepare and practice. Repeat solving problems to gain speed and confidence. This takes work and time—sometimes many hours, even days. Going in to an exam with the knowledge that you have worked lots of problems boosts confidence. Prep time is invaluable.

Relax.
Practice relaxation daily for about at least ten minutes using breathing. Sitting or lying comfortably, breathe slowly in through your nose counting to five and then out through your mouth counting to ten. If you feel dizzy, breathe normally for a while. Deep breathing activates chemicals in your body that help you relax and feel better. Any type of regular meditation, yoga, or slow stretching while breathing deeply can help facilitate your relaxation response. Practicing daily will help you control your adrenaline level during your exam. Using relaxation consciously during an exam frees up the thinking part of your brain. (Do not practice these deep breathing exercises while you are driving.)

Stay Active.
Daily walks or biking or whatever aerobic exercise you use consistently prepares your body for your exam by relieving stress and keeping your state of mind positive. Your mind and your body are connected so tightly that they are nearly the same.

Rehearse.
Do a dress rehearsal for your exam. Write or have someone assist you in writing a practice test with problems and questions that you think might be on the real exam. Use questions from the diagnostic test in Section 5 of this study guide. Give yourself this practice test in an environment as close to your testing situation and schedule as possible. Time it and then correct it to learn from your errors.

Plan Ahead.
Plan ahead carefully so that you will get to the exam early—do not be in a rush. Know exactly how to get there and what you will wear so that you are comfortable. You might want to wear your "lucky" shirt or bring a photograph of people who care about you and believe in you. WHATEVER you can do to increase your sense of comfort and security, do it. Ahead of time, pack a Testing-Taking Kit with sharp pencils, pens, a ruler, erasers, tissues or handkerchief, a bottle of water, extra calculator batteries, and anything else you think you might need that is allowed at the test.

Care For Your Body.
Optimal food and rest are individual preferences. Plan these ahead of time. Some research has shown that a brisk walk before an exam has raised test results. Some research has shown that eating a few candies (not chocolate) right before an exam has raised test results. Protein appears to be essential for clear thinking. Be in charge of what happens to you before the exam. Do not let outside influences take charge of you for this little time before your test.

At the Exam

Do a Data Dump.
Bring a short list of formulas or facts you find difficult to remember. Look at them before the test. Visualize them going into a holding tank in your brain. Practice making them subject to recall. If you are not allowed to use notes on the exam, be sure to put the list away so that your honesty is not questioned. When you receive your test, quickly write these formulas or facts on your exam paper. Now you do not have to expend any energy trying to recall them later when you need them.

Ignore Others.
Ignore all of the other people at the exam—before, during, and maybe even after. Different people have different ways of dealing with their anxiety during tests. Some people get a little hyper and try to rub off their anxiety on everyone else. Do not take on someone else's anxiety. Your test is not a competition, so what other people do will not affect your score. Often the first person to leave an exam gets a very low score, while the last person to leave gets a very high score. Take your time. Pay no attention to other people's behavior.

Breathe.
When you feel stuck or tense, take a deep breath. Let it all go as you expel the air. (The more you have practiced relaxation and deep breathing before the exam, the more you will relax during the test.)

Take Time Out.
Take short breaks during the exam to close your eyes, breathe deeply, and stretch your neck and arms. Massaging your temples, scalp, and the back of your neck will increase blood flow with oxygen to your brain to help you think better. A few isometric exercises can release tension too.

Use Your Subconscious Mind.
If a problem makes no sense, read it and go on. Ideas will come to you as the problem sinks into your subconscious mind while you continue with the test.

Trust.
Let each question reach into your mind for the answer. Remind yourself that you know everything you need to know for now.

Strategize.
Do the easy problems and questions first. Make pencil marks by the questions to which you want to return.

Use Time Wisely.
Do not work on one problem for a long time. Often a question further into the exam will act as a "key" to unlock a previous problem. Tell yourself that you have all of the time you need. Let go of the rest of your life during the exam. You can deal with all that later.

After the Exam, Let the Results Go.
You have used a lot of energy and may be low and off balance. You may wish to pass up discussing the exam with others so you can take care of yourself. Going to the bathroom, drinking some water, and eating something can help you feel normal again. You may have set much of your life aside to prepare for this exam. Refresh yourself and get your life back. You can deal with the test results later when your priorities are in order again.

Negative Thinking About Exams

Here are negative thoughts math students often think before test-taking. Put a check mark by the examples familiar to you. Recognizing the distorted thinking in each example can help you change negative thoughts to neutral or positive ones. If you need more assistance with overwhelming negative thoughts, I recommend the book *Feeling Good* by David Burns (WholeCare, 1999).

"I Will Fail."
Unless you have a crystal ball and can see into the future OR unless you have made a definite plan NOT to prepare for the test OR unless you plan to "freeze up" during the exam, you have no way of knowing whether you will fail or not. Worrying about the future only takes energy from today.

"I Will Panic During the Test."
It is not uncommon to be excited. An exam is a process during which you will experience many thoughts, feelings, and body sensations. Actors get nervous, yet they still perform. If you do panic, let panic leave you. It will. No one dies from panicking during an exam.

Preparation by practicing problems, asking questions, and reviewing gives you confidence and skills that you need. Taking a dress rehearsal test and trying to panic can help you practice dealing with out-of-control feelings. Learning some relaxation techniques to use before and during the exam calms you and aids clear thinking. The more you prepare yourself ahead, the more you are in charge and feel relaxed.

"I Cannot Do Math."
Math is a very broad subject involving many different skills. If you can recognize shapes, tell time, and know where the front and back of a classroom are, you can already do math. There are many more math skills that you have and many that you do not have YET. There are also many that you will never choose to acquire. Instead of thinking so absolutely about math, find areas where you can grow and learn new skills instead of paralyzing yourself with this broad generalization.

"I Am Stupid."
Name calling is seldom productive. Occasionally you may feel stupid because you do not know something or you mess up. What really is happening is that you are being human and humans are not stupid. Educators recognize the need to change how everyone thinks about intelligence. They recognize that there are many different kinds of intelligence including:

- bodily/kinesthetic
- verbal/linguistic
- naturalist
- logical/mathematical
- visual/spatial
- interpersonal
- intrapersonal
- musical/rhythmic

This comes from the work of Howard Gardner. (Gardner, Howard. *Multiple Intelligences: The Theory in Practice.* New York: Basic Books, 1993.)

You are a wonderful combination of these talents—not just an IQ number. IQ Tests are limited because they only measure a few types of intelligence and ignore the rest. We are not all the same and cannot possibly know all there is to know in every situation. Between now and the exam, there are many questions you can get answered as well as many new skills you can practice and master if you use the skills and intelligence that you have.

"I Will Forget Everything."
Forgetting does not mean something is gone from your mind forever. The right cue will often help you remember what you need to know. Your exam will be filled with cues—words and symbols—that will trigger formulas and ideas you have practiced.

Expecting to forget "everything" is foretelling the future and making a broad generalization. Even most people with amnesia caused by illness or injury do not forget "everything." If you are extremely worried about your memory, *The Great Memory Book* by Karen Markowitz and Eric Jensen (The Brain Store, 1999) can be of assistance to you.

"Math Tests Are Tricky."
Math students who rely on memorizing the material rather than understanding it are usually the ones who think tests are tricky. You will use your memory to add to your understanding of how to do the math. Your math problems will contain many units such as mgd or ft^3 or psi. Learning how to skillfully convert back and forth between units of measure will take a lot of the trickiness away from your test problems. Practicing using your calculator will help too.

"There Is So Much I Do Not Know."
This will always be the case the rest of your life. It is the human condition. Taking a deep breath and finding the level where you can begin to learn will improve your feelings and your confidence.

Appendix B

Glossary of Technical Terms

Accuracy: The nearness of a number to true value.

Acid: A compound which liberates hydrogen ions, and has a pH below 7.

Aliquot: A portion of a sample with an exact volume.

Alkalinity: The measurement of a sample's capacity to neutralize acid.

Amperometry: The measurement of electrical current.

Analyte: The element or ion compound that is being measured; the element of interest.

Atomic Weight: The sum of the number of protons and the number of neutrons in the nucleus of an atom. Atomic weights of elements are found on periodic tables.

Autoclave: The instrument used to sterilize samples and equipment by use of heat and steam under pressure.

Base: A compound which liberates hydroxide ions and has a pH above 7.

Batch: A group of samples prepared and analyzed at the same time.

Blank: A sample (usually deionized water) that is taken through all the steps of analysis to monitor for contamination in the process.

Calibration: The use of known standards to create an analytical curve based on the measured characteristic (e.g. absorbence) of the standards. The calibration is used to determine the measured characteristic of unknown samples.

Calibration Standards: A sequence of standard solutions of known concentration used to create a calibration curve.

Celsius: Temperature measurement scale where the freezing point of water is 0° and the boiling point of water is 100°. On this scale, room temperature is about 21°C, while on the Fahrenheit scale it is about 70°F.

Clean Water Act (CWA): The federal Clean Water Act sets the framework for the imposition of industrial wastewater control programs on municipalities and the regulation of industrial users. Sections 307(b) and (c) of the CWA set the authority for the U.S. EPA to establish pretreatment standards for existing and new sources discharging industrial wastewater to POTWs.

Coliform: A bacteria used as an indicator organism for tests of bacteriological purity.

Colorimetric: An analysis technique that compares color density to concentration. Color developing chemicals are added to both known standards and unknown samples.

Composite Sample: A collection of individual samples obtained at regular intervals, based either on flow or time. The individual samples are combined proportionally.

Compound: A substance composed of two or more different chemical elements.

Conductivity: The reciprocal of electrical resistivity, related to electrical current density. In water samples dissolved salts contribute to conductivity.

Culture Medium: The nutrient material prepared for growth of microorganisms in a laboratory.

Density: The relationship between weight and volume, e.g., grams per centimeter or pounds per gallon.

Desiccant: A chemical, such as calcium chloride, used in a desiccator to absorb moisture.

Desiccator: An airtight cabinet filled with desiccant, which provides a low-humidity environment in which samples may cool without absorbing atmospheric water.

Dilution: The process of reducing the concentration of a solution.

Duplicate: A second aliquot of a sample, which is treated the same as the first to determine the precision of the method.

Filtration: An analytical technique that is used to separate suspended solids from liquids (including dissolved solids). The solids (residue) are retained on the filter. The liquid (filtrate) passes through the filter.

Grab Sample: An individual sample collected to represent the flow at a given moment in time.

Gravimetric: An analytical technique that uses weight (mass) as the primary measurement to make lab determinations.

Hot Air Sterilization: Sterilization by the use of an oven at 170° for approximately 2 hours.

Inoculation: The act of introducing microorganisms into a culture medium.

Linear Range: The range of concentrations through which an analytical curve is linear.

Log/Work Book: A written record of sample receipt, preparation of standards, or documentation of other actions taken in the laboratory.

Material Safety Data Sheets (MSDS): Sheets providing information about manufactured chemicals, as required by the Hazard Communication Rule.

Media, Medium: The nutrient material prepared for growth of microorganisms in a laboratory.

Microorganism: A living organism too small to be seen with the naked eye, e.g., bacteria, fungi, protozoa, microscopic algae, viruses.

Molarity: Moles per liter, a measure of concentration.

Molecular Weight: The sum of the atomic weights of all atoms making up a molecule.

Most Probable Number (MPN): A statistical determination of the number of coliform per 100 mL of water.

National Pollutant Discharge Elimination System (NPDES): The federal permitting program designed to control all discharges of pollutants from point sources into U.S. waterways, as required under CWA, through the issuance of permits by either a federal or a state agency. NPDES permits regulate discharges into navigable waters from all point sources of pollution, including industries, municipal wastewater treatment plants, sanitary landfills, large agricultural feedlots, and return irrigation flows.

Normality: A measure of the concentration of a solution.

pH: The hydrogen ion (H+) concentration; the measure of the relative acidity or alkalinity of a solution on a scale from 0 (acidic) to 14 (basic).

Pathogen: A disease-causing organism.

Potentiometric: The measurement of the electric potential difference of a cell (voltage).

Pour Plate Method: A method of inoculating a solid nutrient medium by mixing bacteria in the melted medium and pouring the medium into a Petri dish to solidify.

Precision: The agreement of results for a sample and its replicates (duplicates).

Reagents: Chemicals and the solutions made from them.

Relative Percent Difference (RPD): The difference between two numbers divided by their mean. RPD statistically compares two values for closeness.

Reproducibility: The ability to reproduce the same results using an analytical method.

Serial Dilution: The process of diluting a sample several times in a sequential manner.

Spectrophotometer: An instrument used to measure the absorbence of light.

Standard Curve: The curve which plots concentrations of known standards versus measured characteristics (e.g., absorbence). The curve is used to determine the concentration of unknown samples based on their measured characteristics.

Standard Deviations: A statistical measurement of how closely data are clustered about the mean value.

Streaking: The technique (streak plate method) of isolating a culture by spreading microorganisms over the surface of a solid culture medium.

Titration: An analytical technique that involves the use of a standard of known concentration and volume to determine the concentration of a sample with known volume. This technique utilizes a buret.

Turbidimeter: The instrument used to measure the cloudiness of a sample. The instrument, also called a Nephelometer, provides results in NTUs (Nephelometric Turbidity Units).

Appendix C

Glossary of Management and Supervision Terms

Acknowledgement/Credit: Many of the terms and definitions found in this glossary have been taken from the 6th Edition of *What Every Supervisor Should Know,* by L. Bittle and J. Newstrom. These definitions are reproduced, in part or in whole, with permission of The McGraw-Hill Companies. Most of the remaining terms and definitions have been taken from the 1st Edition of *Utility Management: A Field Study Training Program,* prepared by L. Lindsay for the California State University Sacramento Foundation. These definitions are copyrighted and reproduced by permission of the Office of Water Programs, CSUS.

Ability: The quality of being able to perform; a natural or acquired skill or talent.

Accident: Unplanned or uncontrolled event in which action or reaction of an object, material, or person results in personal injury.

Accountability: Non-assigned liability for the manner in which an organizational obligation held by a supervisor is discharged, either personally or by subordinates.

Active listening: Conscious process of securing information through full attention, intent listening, and alert observation.

Affirmative Action: In-company program designed to remedy current and future employment inequities.

Americans with Disabilities Act (ADA): Prohibits employment discrimination based on a person's mental or physical disability.

Appraisal interview: Meeting held between a supervisor and an employee to review performance rating and, using the evaluation as a basis, to discuss overall quality of work performed, and methods of improvement, if necessary.

Arbitration: Labor dispute or employee grievance settlement by an impartial umpire selected through mutual agreement by organization and worker's union.

Attrition: Gradual reduction in a work force due to natural events and causes, (e.g., retirement, death, resignation), as opposed to planned reductions (e.g., discharges, layoffs, early retirement).

Authority: The power needed to do a specific job, or to carry out one's responsibilities, usually handed down from immediate bosses or superior.

Body language: Nonverbal body movements, facial expressions and/or gestures that project or reveal underlying attitudes and sentiments.

Budget: Plan, or forecast, especially of allowable expenses in operation of a department.

Budgetary control: Planning and reporting system incorporating standards for operating conditions and results, as well as costs and expenses, within a single document.

Certification Exam: An examination administered by a state or professional association that candidates take to indicate a level of professional competence.

Chain-of-Command: Formal channels in an organization that distributes authority from top down.

Code of Federal Regulations (CFR): A publication of the United States Government that contains all of the proposed and finalized federal regulations, including environmental.

Collective bargaining: Process of give-and-take engaged in by management and collective employees representatives to reach formal, written agreement about wages, hours, and working conditions.

Communication process: Giving and receiving information and understanding, such as between a supervisor and an employee, leading to a desired action or attitude.

Computerized Maintenance Management System (CMMS): A computerized system to assist with the effective and efficient management of maintenance activities through application of computerized elements including: work orders, routine standard jobs, bills of materials, application parts, and lists of numerous other features.

Competition: Relatively healthy struggle among individuals or organizational groups to excel in striving to meet mutually beneficial goals.

Conflict: Disruptive clash of interests, objectives, or personalities, between individuals or groups within an organization.

Control: To exercise authoritative influence over; the authority or ability to manage and/or direct.

Cost-benefit analysis: Technique for weighing pros and cons of alternative actions, in which both intangible benefits as well as costs are assigned dollar values.

Cost variance report: Listing of allowable expenses compared with actual expenses incurred.

Decision-making: Part of the problem-solving process that entails evaluation of alternative solutions and a choice of an effective action.

Delegation: The act in which power is given to another person in the organization to accomplish a specific job.

Differential treatment: The act of treating a minority or protected group member differently from other applicants or employees.

Discipline: Imposition by management—in such a manner as to encourage more constructive behavior—of a penalty on an employee for infraction of a rule, regulation, or standard.

Discrimination: Managerial action or decision based on favoring or disfavoring one person or group member over another on the basis of race, color, ethnic or national origin, sex, age, handicap, Vietnam era war service, or union membership.

Division of work: Principle that performance is more efficient when a large job is broken down into smaller, specialized tasks.

Due process: Employee's legal entitlement to a fair hearing, usually before an impartial party and with appropriate representation, before discipline can be metered out.

Employee turnover: Measure of how many people come to work for an organization and do not remain employed by that organization, for whatever reason.

Ergonomics: Study of how workers react to their physical environment; used in design of more comfortable and productive workstations.

Equal Employment Opportunity (EEO): System of organizational justice, stipulated by law, that applies to all aspects of employment; intended to provide equal opportunity for all members of the labor force.

Feedback: Process of relaying measurement of actual performance back to an individual or unit, so that action can be taken to correct, or narrow, the variance.

Gantt Chart: Chart that enables a planner to schedule tasks in the most productive sequence, and that also provides a visual means for observing and controlling progress.

Geographical Information System (GIS): An integrated system of computer hardware, software, and trained personnel linking topographic, demographic, utility, facility, images, and other resource data that are geographically referenced.

Grievance: Job-related complaint stemming from an injury or injustice, real or imaginary, suffered by an employee, for which relief or redress from management is sought.

Grievance procedure: Formalized, systematic channel for employees to follow in bringing complaints to the attention of management.

Hazard: Potentially dangerous object, material, condition, or practice present in the workplace, to which employees must be alert and from which they must be protected.

Hostile Work Environment: Conditions such as harassment, offensive speech, or unwelcomed conduct, that are severe or persuasive enough to create an abusive, antagonistic, or inhospitable work place.

Information Management System (IMS): System comprised of data processing devices, programs, and people, that collects, analyzes, exchanges, and delivers information to an organization in such a manner as to aid managers in making the best possible decisions.

Information: Dates, past or present facts, observations, or conclusions, collected in numbers and words that have been selected, arranged, and analyzed (processed) to make them useful for a specific human (managerial) activity.

Injury Illness Prevention Plan: Plan required by California Senate Bill (SB) 198 to establish, implement, and maintain an effective program helping assure employee safety while on the job. It includes eight elements: management assignments and responsibilities, safety communications system with the employees, system assuring employee compliance with safe working practices, scheduled inspections and compliance system, accident investigation, health and safety training and instruction, and record-keeping and documentation.

Job breakdown analysis: Segmentation of a job into key elements, or steps, which require an employee to perform, induce, or supervise an action that advances work toward completion.

Job evaluation: Systematic technique for determining job worth, compared with other jobs in an organization.

Just cause: Reason for a disciplinary action that is accurate, appropriate, well founded, deserved and meets the test of prior notification of unacceptable behavior and its penalty.

Knowledge: Information that can be learned from reading, listening to an expert, or keenly observing a situation; often a prerequisite to skill development.

Management: Process of obtaining, deploying, and utilizing a variety of essential resources in support of an organization's objectives.

Management by objectives (MBO): Planning and control technique where supervisors and their immediate superiors agree on goals to be attained and/or standards to be maintained.

Management development: Systematic program for improving the knowledge, attitudes, and skills of supervisors and managers.

Management principles: Set of guidelines established for carrying out the management process.

Management process: General sequence of five unique functions—planning, organizing, staffing, directing or activating, and controlling—provided by managers for any organization.

Manager: An individual who plans, organizes, directs, and controls work of others in an organization.

Material Safety Data Sheets (MSDS): Sheets providing information about manufactured chemicals, as required by the Hazard Communication Rule (HCR).

Mentor: Knowledgeable, often influential, individual who takes an interest in, and advises, another person concerning that person's career.

Morale: Measure of the extent of voluntary cooperation—as well as the intensity of desire—to meet common work goals, as demonstrated by an individual or work group.

Motivation: Process that impels someone to behave in a certain manner in order to satisfy highly individual needs.

Networking: Informal process of getting to know, and create confidence among others who—through mutual exchange—help advance one's career.

Non-managerial employees: Workers who receive direction from managers, who perform specific, designated tasks, and who are responsible only for their own performance.

Organizing: Deciding who does what work and delegating authority to the appropriate person.

Organization: Structure derived from systematically grouping tasks to be performed, and from prescribing formal relationships that strengthen the ability of people to work together more effectively.

Performance appraisal: Formal and systematic evaluation of how well a person performs work and fills an appropriate role in the organization.

Penalty: Punishment or forfeiture imposed as discipline by management on an employee .

Personality: An individual's unique way of behaving and of interpreting events and the actions of others.

PERT Chart: Graphic technique for planning a project in which a large number of tasks must be coordinated, by showing the relationship between tasks and critical bottlenecks that may delay progress towards completion.

Policies: Broad guidelines, philosophy, or principles which management establishes and follows in support of organizational goals.

Procedures: Methods, prescribed by management, for the proper and consistent forms, sequences, and channels to be followed by individuals and units of an organization.

Productivity: Measure of efficiency that compares operational output value with cost of resources used.

Progressive Discipline: Providing increasingly harsh penalties for substandard performance or broken rules, as the condition continues or the infraction is repeated.

Quid pro quo: An equal exchange or substitution; e.g., as applied to sexual harassment, when a supervisor threatens to fire or not promote an employee if they do not provide sexual favors in return.

Regulations: Special rules, orders, and controls set forth by management, restricting the conduct of units and or individuals within an organization.

Reprimand: Severe expression of disapproval or censure by management of an employee, usually written as well as oral, and retained in an employee's personal file.

Responsibilities: Those duties one is held accountable for.

Responsibility: Duty or obligation to perform a prescribed task or service or attain an objective.

Reverse discrimination: Notion that implementation of affirmative action deprives qualified members of non-protected groups of their rightful opportunities.

Satisfaction: State that exists when motivating factors—such as interesting and challenging work, full use of one's capabilities, or recognition for achievement—are provided.

Schedules: Detailed assignments dictating how facilities, equipment, and/or individuals are used, according to times and dates, in accomplishment of organizational objectives.

Sexual Harassment: Unwanted sexual advances, requests for sexual favors, or other visual, verbal, or physical conduct of a sexual nature, which is conditioned upon an employment benefit, unreasonably interferes with an individual's work performance, or creates an offensive work environment.

Skill: The capacity to perform a job related action by blending relevant knowledge and physical or perceptual ability.

Specification: Collection of standardized dimensions and characteristics pertaining to a product, process, or service.

Stereotype: Characterization of an individual on the basis of a standardized, oversimplified view of characteristics believed to be held in common by a group to which the individual is assumed to belong.

Supervisor: Manager who is in charge of, and coordinates, activities of a group of employees engaged in related activities within a department, section, or unit of an organization.

Suspension: Temporary removal by management of an employee privilege (such as the right to report to work and receive pay for it) until proper actions have been determined and imposed.

Time budget: Charting technique for planning the systematic distribution of a supervisor's time.

Theory X: Negative approach to human relations in which a supervisor presumes most people don't like to work and thus need to be pushed or threatened.

Theory Y: Positive approach to human relations whereby a supervisor presumes that, given meaningful work, most people will try hard to achieve, especially when there is an opportunity to improve their self-regard.

Tolerance: Permissible deviation, or variance, from a standard.

Type A individual: Person characterized by high standards of achievement and an urgency to attain them, who is especially susceptible to stress.

Unfair labor practices: Practices engaged in by management or labor unions that are judged by federal labor law to be improper, especially when they interfere with the right to organize or when they discriminate against labor union activities.

Unity of Command: Principle that each individual should report to only one boss.

Unity of Direction: Principle that there should be a single set of goals and objectives that unites the activities of everyone in an organization.

Variance: Gap, or deviation, between actual performance, condition, or result and a standard of expected performance, condition, or result.

Warning: A reprimand so worded as to give formal notice to an employee that repetition of a particular form of unacceptable behavior will draw a penalty.

Worker's compensation: Financial reparations or awards granted by an employer to an employee who has suffered an on-the-job injury or illness that is judged to have permanently restricted the employee's earning capacity.

Appendix D

Common Acronyms and Abbreviations

AA	atomic absorption
AC power	alternating current
AC	acre
AF	acre-foot (feet)
AFY	acre-foot per year
AMSA	Association of Metropolitan Sewerage Agencies
ANSI	American National Standards Institute
APHA	American Public Health Association
AS	activated sludge
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWT	advanced wastewater treatment
AWWA	American Water Works Association
BECP	Business Emergency and Contingency Plan
BNR	biological nutrient removal
BOD5	biochemical oxygen demand after 5 days
BTU	British thermal unit
C	Celsius
Cal-OSHA	California Occupational Safety and Health Act
Cal-EPA	California Environmental Protection Administration
CBOD	carbonaceous biochemical oxygen demand
CCE	carbon chloroform extract
CCR	California Code of Regulations
cf	cubic feet (foot)
CFR	Code of Federal Regulations
cfs	cubic feet per second
CH_4	Methane
CIU	Categorical Industrial User
CM	common mode
CMOM	Capacity Management, Operations, and Maintenance
COD	chemical oxygen demand
CPU	central processing unit
CRWA	California Rural Water Association
CSP	confined-space permit
CT	current transformer
CWA	Clean Water Act
CWEA	California Water Environment Association
DAF	dissolved air flotation
DO	dissolved oxygen
DOHS	California Department of Health Services
DV/DT	($\Delta V/\Delta T$) The change in voltage per change in time.
DWF	dry weather flow
DWR	Department of Water Resources
EIS	Environmental Impact Statement
EMF	electromotive force or voltage
EPA	U.S. Environmental Protection Agency
F	Fahrenheit
F/M	food to microorganism ratio
ft	feet (foot)
ft^2	square foot
ft^3	cubic feet
FTU	formazin turbidity unit
GAC	granular activated carbon
gal	gallon

GFI	ground fault interrupter
GPD	gallons per day
GPM	gallons per minute
GTAW	gas tungsten arc welding
H_2S	hydrogen sulfide
HCP&ERP	Hazard Communications Program and Emergency Response Plan
hp	horsepower
HPLC	high-performance liquid chromatography
Hz	Hertz
IC	ion chromatograph
ICP	inductively coupled plasma
IEEE	Institute of Electrical and Electronics Engineers
IIPP	Injury and Illness Prevention Plan
IML	Interface Management Language
JTU	Jackson Turbidity Unit
K	Kilo, a prefix meaning 1,000
KVA	kilovolt amperes
kw	kilowatt
kwh	kilowatt hour
L	liter
lb	pound
M	Mega, a metric prefix meaning 1,000,000
m	meter
M	mole or molar
MA	millamps
MBAS	methylene blue active substance
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MCRT	mean cell residence time
MDL	method detection limit
MG	million gallons
mg	milligram
mg/L	milligrams per liter
MGD	million gallons per day
min	minute
MIS	Manufacturing Information System
mL	milliliter
MLSS	mixed liquor suspended solids
MLVSS	mixed liquor volatile suspended solids
MMI	Man Machine Interface
MOP	Manual of Practice
MPN	most probable number
MS	mass spectrometer
MSDS	Material Safety Data Sheets
MTBF	mean time between failures
MTTR	mean time to repair
N	normal
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NEPA	National Environmental Policy Act
NM	Normal Mode
NOCA	National Organization for Competency Assurance
NOD	nitrogenous oxygen demand
NPDES	National Pollutant Discharge Elimination System
NPSH	net positive suction head
NTU	nephelometric turbidity unit(s)
O&M	operation and maintenance
OCT	Operator Certification Test (State of California)
OMR	operations, maintenance, and replacement
OOC	Office of Operator Certification (SWRCB)
OSHA	Occupational Safety and Health Administration/Act
OTE	oxygen transfer efficiency
P	Pico, a metric prefix meaning one millionth of a millionth, or one trillionth (10^{-12})
PC	personal computer

PCB	polychlorinated biphenyls
pH	potential of hydrogen
P&ID	piping and instrumentation diagram
PID	proportional gain, integral action time and derivative action time
PLC	Programmable Logic Controller
POTW	Publicly Owned Treatment Works
PPB	parts per billion
PPE	Personal Protective Equipment
PPM	parts per million
prct	percent
psi	pound per square inch
PSIA	pounds per square inch absolute
PSID	pounds per square inch differential
PSIG	pounds per square inch gage
PVC	polyvinyl chloride (pipe)
QA/QC	quality assurance/quality control
RAS	return activated sludge
RBC	rotating biological contactor
RCP	reinforced concrete pipe
RFI	Radio Frequency Interference
RMS	root mean square
RTD	resistance temperature device
RWQCB	Regional Water Quality Control Board (State of California)
SCADA	Supervisory Control and Data Acquisition
SCR	semiconductor (or silicon) controlled rectifier
SD	standard deviation
SDI	sludge volume index
sec	second
SI	System Internationale D'Unites (metric units)
SS	suspended solids
SSO	sanitary sewer overflow
SVI	sludge volume index
SVR	sludge volume ratio
SWRCB	(California) State Water Resources Control Board
TAC	Technical Advisory Committee
TC	total carbon
TCP	Technical Certification Program
TDS	total dissolved solids
TF	trickling filter
THD	total harmonic distortion
TIC	total inorganic carbon
TMDL	total maximum daily load
TOC	total organic carbon
TOD	total oxygen demand
TS	total solids
TSS	total suspended solids
TU	turbidity unit
μ	micro, a metric prefix meaning one millionth
UPS	uninterruptible power supply
USB	universal serial bus
USEPA	United States Environmental Protection Agency
V	volt
VAC	volts of alternating current
VCP	vitrified clay pipe
VFD	variable frequency drive
VOC	volatile organic chemicals
VOM	volt Ohm meter
VSR	volatile solids reduction
VSS	volatile suspended solids
W	watt
WAN	wide area network
WEF	Water Environment Federation
WRP	water reclamation plant
WWF	wet weather flow
WWTF	wastewater treatment facility
WWTP	wastewater treatment plant (same as POTW)
yr	year

CWEA is pleased that you have purchased this book.

We want to remind you that this book is one of many resources available to assist you, and we encourage you to identify and utilize the other resources in preparing for your next test.

Your comments, questions, and suggestions are welcome.

California Water Environment Association

7677 Oakport Street, Suite 600
Oakland, CA 94621-1935
Ph: 510-382-7800
Fx: 510-382-7810
Em: tcp@cwea.org
www.cwea.org