DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

JAN 08 2004

FROM: HQ AFCESA/CESC
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SUBJECT: **Engineering Technical Letter (ETL) 04-6: Inspection of Drainage Systems**

1. Purpose. This ETL provides information and guidance for inspecting Air Force drainage systems. Various inspection and testing techniques and the effectiveness of each are described.

2. Application: All Air Force installations.

2.1. Authority: Air Force Policy Directive (AFPD) 32-10, *Installations and Facilities*.

2.2. Coordination: Major command (MAJCOM) pavement engineers.

2.3. Effective Date: Immediately.

2.4. Intended Users:

- Air Force MAJCOM pavement engineers and maintenance engineers.
- Base civil engineers (BCE) and other Air Force units responsible for the maintenance, rehabilitation, and renovation of Air Force facilities.
- U.S. Army Corps of Engineers (USACE) and Navy offices responsible for the rehabilitation and renovation of Air Force facilities.

3. References.

3.1. Code of Federal Regulations (CFR):

Title 29, CFR, Chapter XVII, Section 1910.146, *Permit-required confined spaces*, available online at
http://www.access.gpo.gov/nara/cfr/waisidx_03/29cfr1910_03.html

3.2. Federal Aviation Administration (FAA):

- FAA Advisory Circular (AC) 150/5320-5B, *Airport Drainage*, 1 July 1970, available online at http://www1.faa.gov/arp/pdf/5320-5b.pdf

3.3. Joint-Service:

- UFC 3-260-02, *Pavement Design for Airfields*, available online at http://65.204.17.188//report/doc_ufc.html
- Pavement-Transportation Computer Assisted Structural Engineering (PCASE) at http://www.pcase.com/go.html

3.4. Air Force:

- AFPD 32-10, *Installations and Facilities*, available online at http://www.e-publishing.af.mil/

3.5. Army:

- Engineer Instruction (EI) 02C202, *Subsurface Drainage for Pavements*, 2 October 1996, available online at http://www.hnd.usace.army.mil/techinfo/ei.htm
- Engineer Research and Development Center (ERDC)/Geotechnical Laboratory (GL) 90-15, *Backcalculation of Composite Pavement Layer Moduli*, September 1990

3.6. Navy:

- Naval Facilities Engineering Service Center (NFESC) Special Publication (SP) 2081-SHR, *Airfield Pavement Void Detection Technology*, available online at http://www.nfesc.navy.mil/pub_news/voiddetection/VoidDetd.PDF

3.7. National Association of Sewer Service Companies (NASSCO) (publications are available for purchase at http://www.nassco.org/publications.html):

- NASSCO *Inspector Handbook*
- NASSCO *Manual of Practices*, 2000 Edition
- NASSCO *Specification Guidelines*, latest edition
- *The Safe Operation of Remote Controlled Electrical Equipment*, NASSCO position paper, available online at http://www.nassco.org/pdf/safety.pdf

3.8. Private Industry:

- Technical Bulletin # R-01, *Locating Interior Pipe Deposits and Other Hidden Defects Using Robotic Visual Inspection*, published on the Nondestructive Testing Services website of East Coast Industries, Inc. at http://www.eci-ndt.com/tb_r_01.htm
- *Paving and Drainage Specialists*, the website of A.J. McCormack & Son, at: http://www.pavingexpert.com
- *Design and Implementation of Runoff Control Structures*, Jerald Fifield, Erosion Control, available online at http://www.forester.net/ec_0001_design.html

3.9. Other References:

- Tennessee Hydraulics Memorandum 09, *On Site Inspection Report*, Structures Division, Tennessee Department of Transportation, available online at http://www.tdot.state.tn.us/Chief_Engineer/assistant_engineer_design/struct~1/thmall.pdf
- *Soil Modification Studies for Enhanced Mine Detection with Ground Penetrating Radar*, Proceedings of SPIE - 1999, Joel T. Johnson, Jatupum Jenwatanavet and Nan Wang, ElectroScience Laboratory, Department of Electrical Engineering, The Ohio State University

4. Acronyms and Terms:

2-D	- two-dimensional
3-D	- three-dimensional
AC	- Advisory Circular
AFPD	- Air Force Policy Directive
BCE	- base civil engineer
CCTV	- closed-circuit television
cfm	- cubic feet per minute
CFR	- Code of Federal Regulations
COMDEF	- COMposite Pavements DEFlections
DCP	- dynamic cone penetrometer
ECP	- electronic cone penetrometer
EI	- Engineer Instruction
ERDC	- Engineer Research and Development Center
ETL	- Engineering Technical Letter
FAA	- Federal Aviation Administration
GL	- Geotechnical Laboratory
gpm	- gallons per minute
GPR	- ground-penetrating radar
HQ AFCESA	- Headquarters, Air Force Civil Engineer Support Agency
HWD	- heavy weight deflectometer
I/I	- infiltration / inflow
in	- inch
IR	- infrared
IRT	- infrared thermography
ISM	- impact stiffness modulus
MAJCOM	- major command
m	- meter
m^3/s	- cubic meters per second
mm	- millimeter
NASSCO	- National Association of Sewer Service Companies
NFESC	- Naval Facilities Engineering Service Center
OSHA	- Occupational Safety and Health Administration
PCASE	- Pavement-Transportation Computer Assisted Structural Engineering
PCU	- power control unit
PVC	- polyvinyl chloride
SP	- Special Publication
UFC	- Unified Facilities Criteria
USACE	- United States Army Corps of Engineers
VCR	- video cassette recorder
VHS	- vertical helical scan
SVHS	- super vertical helical scan

5. Background.

5.1. Inspection methods and record-keeping requirements vary with the specific purpose(s) of the inspection, which may include:

- Inspecting new pipe construction prior to acceptance.
- Assuring sound pipes prior to paving.
- Finding problems in troubled areas.
- Locating improper connections and/or sources of infiltration/inflow (I/I).
- Pinpointing the cause, source, and magnitude of I/I.
- Determining the suitability of various rehabilitation methods.

5.2. Technology has evolved in the sewer maintenance industry to meet the needs of system owners. In particular, closed-circuit television (CCTV) has emerged as the dominant tool for inspecting pipelines. These units have been commercially available since 1965, and NASSCO has estimated that there are now approximately 60,000 conventional CCTV pipeline inspection units in use. CCTV units also have an excellent safety record for people and property.

6. Data-gathering Methods. There are many different ways to gather information about the current condition of a drainage system. Before proceeding with any of these data-gathering techniques, however, the inspector should determine if there are any historical data that would help perform and/or guide the current inspection. If historical data are available, the inspector should be thoroughly familiar with such data before using any of the data-gathering techniques described in this ETL. The most common data-gathering methods are prioritized by usefulness into four groups: "primary," "secondary," "sometimes useful," and "rarely useful." These methods are described below.

6.1. Primary Data-gathering Methods:

6.1.1. Person-entry (Manual Inspection of Large Pipes). The main advantage of a person-entry inspection is that it uses the oldest and most reliable method of inspection: the human eye. The inspector can get first-hand information about internal pipe conditions that is impossible to obtain by any other method. Videotape records or photographs, guided directly by the inspector, can be used to supplement and document the inspector's findings. More than one person can participate so communication can be direct (although radio communication is also used for safety reasons). Measurements and samples can be taken on the spot. In every way, when practicable, person-entry is the best method of inspection. There are two obvious, and closely related, disadvantages to this method. The first is that most people do not like to go into drainage pipes, regardless of the size and condition of the pipe. The second is that safety considerations require that a pipe be of an appropriate size and condition before person-entry is allowed (see Occupational Safety and Health Administration [OSHA] rules on confined space entry, Title 29, Code of Federal Regulations, Chapter XVII, Section 1910.146).

6.1.2. Visual Inspection:

6.1.2.1. Observations at manholes can provide beneficial information, particularly with regard to corrosion. Typically, corrosion occurs at concrete structures due to the turbulence of flow. Erosion and/or breakout are indicators that the corrosion cycle has been initiated. In addition, most improper and/or illegal connections are present at manholes—unexpected I/I should be examined carefully.

6.1.2.2. Attachment 1 is a sample log form for an on-site hydraulic structure inspection (Section a) and an on-site catch basin, manhole, handhole, or drop inlet inspection (Section b).

6.1.2.2.1. Hydraulic Structures. For hydraulic structures other than pipelines, the key information can be determined visually and reported along with photographic documentation. In many cases, the condition of the floodplain will give the inspector more information than the channel itself. The form has space to add sketches and comments to document important features. The log form shown in Attachment 1 will not work well for every possible hydraulic structure, nor is it intended to—it is a model which gives a basic format and parameters which can be used as is, or adapted to meet the local needs of a given base or region. Hydraulic structures should be routinely inspected at least annually, but more frequently if local conditions (i.e., amount and intensity of rainfall) warrant it. Inspections during and after storms can prove invaluable in identifying problem areas.

6.1.2.2.2. Catch Basin, Manhole, Handhole, Drop Inlet. Section b of the form is self-explanatory and should work well for virtually any catch basin, manhole, or drop inlet. However, some handholes do not allow easy visual access, and in those cases an adapted log form should be used which includes relevant information based on the local conditions. The log form shown in Attachment 1 is intended to be a model which can be used as is, or adapted to meet the local needs of a given base or region. Catch basins, manholes, handholes, and drop inlets should be inspected in accordance with the schedule shown in Table 1. In areas where these structures may be subject to aircraft or heavy vehicular traffic, inspectors should pay particular attention to cracking, breakage, corrosion, or other visible defects that could make the load-carrying capacity of the structure suspect.

CAUTION

To prevent serious damage to aircraft or vehicles, any structures of questionable integrity should be closed to traffic until repairs are made.

Table 1. Schedule of Inspections for Catch Basins, Manholes, Handholes, and Drop Inlets

Inspection Type	Early Wet Season Inspection	Late Wet Season Inspection	Mid-Dry Season Inspection
Cleanliness	✓	✓	✓
Pollution	✓	✓	✓
Cover/grate	✓	✓	✓
Frame and top slab			✓
Structural condition			✓
Ladder			✓

6.1.3. CCTV.

6.1.3.1. Summary. CCTV has become the primary method for most drainage inspections. A short description, including the main advantages and disadvantages, is included in this section, and discussed in more detail in Attachments 2 through 7.

6.1.3.1.1. The biggest advantage of CCTV is that it is the **only** proven technology for internal inspection of small pipes. A key factor for the success of a CCTV inspection is establishing proper reference points so the video can be tied to exact locations in the pipe being inspected. The biggest disadvantage of CCTV is that the quality of the data is highly dependent on the operator's experience. In addition, and particularly when videotape is used for analysis, the results are highly dependent on the quality of the equipment, their degree of maintenance, and timeliness of hardware and software updates. An unfortunate disadvantage is that most CCTV systems for pipe inspection use analog cameras and recorders rather than digital video equipment. Even with the same video cassette recorder (VCR), a digital video camera will provide a much clearer recording. And a pure digital system (both camera and recorder) provides a tremendous boost in picture quality that will not degrade over time or with copying.

6.1.3.1.2. If a pipe is not freely flowing, pipe cleaning should be attempted before a CCTV inspection. If the pipe cleaning is unsuccessful the inspection may proceed, but extra care must be taken since the camera system could be damaged or lost during the inspection.

6.1.3.1.3. CCTV inspection should be required before any pipe rehabilitation. A post-rehabilitation CCTV inspection should also be performed to determine if the rehabilitation was completed properly.

6.1.3.2. Guidelines for CCTV Inspection. Attachment 2 contains a reprint of the NASSCO CCTV Guidelines. The guidelines are useful not only for the information they contain, but also because the "boilerplate" language can be used in writing contracts.

The specification writer must still use care, however, because the NASSCO guidelines are written primarily for civilian systems, and for both drainage/stormwater and sanitary/wastewater systems.

6.1.3.3. CCTV Log Sheet and Coding. Attachment 3 explains data logging with a CCTV log sheet and the use of data codes to speed up and increase the accuracy of CCTV data logging. Attachment 3 also references Attachment 4, a model CCTV inspection log sheet; Attachment 5, a model pipe identification matrix; and Attachment 6, a model problem identification matrix.

6.1.3.4. Supplement to CCTV Guidelines. Attachment 7 contains additional information about CCTV inspections to supplement the NASSCO Guidelines in Attachment 2.

6.1.4. Ground Surface Condition. Documenting the ground surface condition above the pipeline route can provide important information for the current inspection and is often invaluable for future inspections. When practical, the route should be walked. If walking is impractical (e.g., a system-level inspection), the route should be driven, preferably with a motorized cart or all-terrain vehicle that allows the inspector clear visual access. During this phase of the inspection, surface anomalies and unusual geologic conditions should be noted. Washouts and holes may indicate erosion and/or infiltration/exfiltration problems. Conditions that might impact pipelines or manholes include large swales, surface drainage, adjacent water bodies, types and volume of traffic, and pavement subsidence. Videotape or photographs should be used to document areas of particular interest.

6.2. Secondary Data-gathering Methods. Secondary data-gathering methods should not routinely be included in an otherwise routine drainage inspection, but should be included if specific subsurface conditions (primarily voids) are suspected which would affect the outcome of the drainage inspection and might cause structural problems. In addition, if these secondary data are readily available from a prior evaluation, the drainage inspector should review the past data for anomalies that might be related to drainage problems. Secondary data-gathering methods include:

6.2.1. Ground-Penetrating Radar (GPR). GPR is a key tool for rapidly determining the existence and extent of major structural defects (particularly voids) in drainage systems. GPR surveys are not routinely performed in drainage inspections, so the drainage inspector needs to know if GPR results will be of sufficient value to justify the cost. Therefore, a conceptual understanding of GPR data and where it comes from is important to the inspector, even if someone else will do the actual data interpretation.

6.2.1.1. The source of the GPR signal is a high-frequency antenna that sends radar waves into the soil. Returning energy is detected by a receiver and comes from reflections of the signal at interfaces that are perpendicular to the signal (i.e., horizontal) and where the material above the interface has a contrast in dielectric properties with the material below the interface. In the case of a rounded “target,” only that energy which hits the target at points where the tangent of the target is perpendicular to the signal’s direction will be reflected back—this is why Stealth aircraft have rounded surfaces. The ability to “see” a target with GPR is a function of the dielectric constant of the target, the dielectric constant of the material above the target, and the geometry of the target. So, while a box-shaped metal pipe might be easy to "see" with GPR, a rounded pipe with very little dielectric contrast from the surrounding soil (e.g., vitrified clay) might be almost "invisible" to the GPR.

6.2.1.2. The returning signal from a single GPR test, if plotted, would yield a two-dimensional (2-D) graph of signal intensity versus return time. If assumptions are made about the dielectric properties of the soil, then the return time can be converted to depth, so that the 2-D data is converted to intensity versus depth. A GPR "sweep" is a series of GPR tests at regular distance intervals (usually done with a GPR van), so that the data becomes three-dimensional (3-D). The output from a GPR sweep is usually displayed on a color monitor or printed on a color printer, with the vertical axis representing depth, the horizontal axis representing horizontal distance, and the graph's color representing the intensity of the returning signal. This color graph is commonly called "GPR data." The closely spaced data in a GPR "sweep" gives far more information to the GPR interpreter than a like number of tests at random locations. For example, the location of a rounded pipe might be inferred by a drop in return intensity compared to immediately adjacent areas.

6.2.1.3. Once the choices of antennas, location, and speed of travel (i.e., sampling rate) are made, the actual data collection using a GPR rig is relatively straightforward. The interpretation of that data, however, is sometimes more art than science—an experienced GPR engineer/technician can collect a great deal of information from a graph that is meaningless to an untrained individual.

6.2.1.4. GPR can be a valuable tool for a drainage inspector if its advantages and shortcomings are understood. GPR is very good at locating large voids because there is a great contrast in dielectric constant between air and soil, and a large void tends to have a somewhat horizontal interface. GPR can sometimes locate rounded pipes, but does so by inference based on a drop in intensity compared to adjacent areas. This emphasizes one of the big shortcomings of GPR: once the radar wave is completely reflected or completely dispersed, there is no further return signal to interpret. Therefore, a problem can be "hidden" by another anomaly above it (which reflects all the energy upwards). Similarly, problems at greater depths might be overlooked, because the radar wave has lost its energy due to normal dissipation during the wave propagation. In addition, soil saturation can sometimes cause unpredictable results in GPR data, since water tends to increase the contrast in dielectric properties but also tends to increase the energy loss during wave propagation.

6.2.1.5. Even with its shortcomings, GPR can quickly provide information to the drainage inspector that no other nondestructive test can. GPR is generally not used routinely for drainage inspection because of cost, but armed with an understanding of what GPR is (and is not), the drainage inspector can make an informed decision as to whether the cost of GPR is justified for a particular problem. The biggest cost in most GPR surveys is mobilization, so once the inspector decides to bring in GPR for a particular problem, a large test area can usually be included at a relatively small additional cost.

6.2.2. Electronic Cone Penetrometer (ECP). The ECP, a vehicle-mounted penetrometer with a variety of electronic-measuring cone-tips, is a valuable tool for investigating underground structures. The ECP is mainly used by a drainage inspector to determine subsurface soil strength properties, and can be used directly (e.g., inspecting an earth dam) or indirectly (e.g., void detection). Other ECP measurements of interest to a drainage inspector might include water table location and chemical intrusion detection.

6.2.3. Dynamic Cone Penetrometer (DCP). The DCP is a hand-held penetration testing system used to determine subsurface soil strength properties. Like the ECP, the DCP can be used directly by the drainage inspector (e.g., inspecting an earth dam) or indirectly (e.g., void detection); however, the DCP cannot make electronic measurements.

6.2.4. Heavy Weight Deflectometer (HWD). The HWD (or its predecessor, the falling weight deflectometer) is another method of assessing subsurface soil strength properties. An advantage of the HWD is that the subsurface soil does not have to be exposed (i.e., testing can be done on the upper paving layers). As with cone penetration, soil strength data can be used directly by the drainage inspector (e.g., inspecting an earth dam) or indirectly (e.g., void detection); however, for void detection, a method that uses all HWD sensors should be used, such as the following:

- PCASE (Pavement-Transportation Computer Assisted Structural Engineering): Software developed by the Army, Navy, and Air Force for seven-sensor backcalculation of rigid or flexible pavements.
- COMDEF (COMposite Pavements DEFlections): Software developed by the Air Force for seven-sensor backcalculation of composite (asphalt over concrete) pavements. For further information, see Engineer Research and Development Center (ERDC)/Geotechnical Laboratory (GL) 90-15, *Backcalculation of Composite Pavement Layer Moduli*.
- ISM1-7: Navy method of comparing normalized impact stiffness modulus (ISM) for seven sensors to aid in detecting voids (a large variation in one or two sensors could indicate voids). For further information, see Naval Facilities Engineering Service Center (NFESC) Special Publication (SP) 2081-SHR, *Airfield Pavement Void Detection Technology*.

Note: The use of seven-sensor backcalculation (PCASE or COMDEF) requires a further inference that low soil strengths in a particular test area are related to voids, whereas the Navy method (ISM1-7) was developed specifically to locate voids.

6.2.5. Infrared Thermography (IRT). IRT has been used, with varying degrees of success, to locate voids around drainage pipelines. An IRT scanner measures temperature differences in the surface above the sewer, which may be significantly influenced by void areas. IRT scanners can be mounted on a permanent structure, but are commonly used on portable overhead equipment (e.g., cherry-picker), or even mounted on aircraft. The main advantage of IRT is the ability to survey relatively large areas in a short time. The main disadvantage of IRT is that any suspected problem must be verified by other methods (e.g., boring). In addition, the method is generally effective only for relatively shallow pipelines due to the 2-D aspect of the collected data.

The depth of a possible problem cannot be determined from 2-D thermographs, so even if a void is correctly detected in a given area, it might not be in the vertical vicinity of a deeper pipeline. The use of IRT still has definite advantages over purely random test borings in areas where voids are suspected because large areas may be surveyed in a relatively short time and the "screening" thermography tests are completely nondestructive.

6.3. Sometimes Useful Data-gathering Methods:

6.3.1. Smoke Testing. Smoke testing may be used to test new construction, pipeline rehabilitation or reconstruction projects, and to locate rainfall-dependent I/I. Smoke testing is not usually performed routinely in drainage inspections.

6.3.1.1. Specific sources of rainfall-dependent I/I that can be readily detected by smoke testing may include roof, yard, and area drain connections, catch basins, and broken or perforated service lines. Using an air blower, a nontoxic, nonstaining "smoke" (typically a zinc chloride mist) is forced through a manhole. The smoke then surfaces through open pipe connections and defects. Indications of defects are photographed and tabulated, and the amount of I/I is approximated (if possible). Smoke testing can usually be used in pipe sections up to 180 meters (600 feet) in length. The pipe length that can be tested is even longer if the pipeline is airtight (or nearly airtight).

6.3.1.2. Smoke testing has some significant limitations. It is completely ineffective if the pipeline is flowing full, groundwater is above the pipe, or the pipe has sags or traps that hold standing water. In addition, a defect may be either undetected or underestimated if wind quickly disperses the smoke at the surface.

6.3.1.3. In addition to the questionable effectiveness of indirect testing for I/I, there are several issues to be addressed before any smoke testing should be undertaken. First, the smoke has the possibility of damaging some types of pipe (particularly those with retrofit liners). There is also the possibility that the smoke can combine with chemicals in the pipe walls (more likely with retrofit liners) to form environmentally unfriendly compounds. While neither of these scenarios has a high probability of occurrence, the manufacturer of the pipe or pipe liner should be consulted before testing. Any nearby fire department (including the on-base fire department) should be notified of intended smoke testing.

6.3.2. Dye-water Testing. Dye-water testing, sometimes called flooding, can be done alone or in conjunction with color CCTV (dye-water testing cannot be used effectively with black-and-white CCTV). The dye commonly used is Rhodamine B, which is usually in a tablet form to minimize contact with personnel.

6.3.2.1. The simplest type of dye-water testing is for a pipe that is suspected of either being totally obstructed at some point or physically disconnected from the system. In the first case, if the dye fails to appear at a downstream manhole the obstruction/disconnection is confirmed. Similarly, the dye may be put in an upstream drainage component (such as an area drain or catch basin), and the appearance of dye at a downstream manhole would confirm that the upstream component is physically connected to the drainage system. Dye-water testing can also be useful in identifying cross-connections between pipes. In more sophisticated analyses, a dye "plume" in the area around the pipe may be used to indirectly determine the existence and extent of exfiltration from the pipe into surrounding strata. Additionally, for some pipe types (generally the more porous materials), the exfiltrating dye-water will impregnate an otherwise undetectable crack to create a "highlight" of dye that is visible to the naked eye or color CCTV. This is particularly useful if cracks are known to exist but cannot otherwise be located.

6.3.2.2. Dye-water testing is commonly used to inspect sanitary/wastewater systems (sometimes in conjunction with smoke testing), but not commonly used for drainage inspections. An example that clearly points out the difference is a pipe defect that allows exfiltration. Environmental contamination may be a major concern for a wastewater system, and a dye-water plume might be the ideal test to locate the defect and assess the extent of damage. Exfiltration from a drainage pipe, however, is rarely considered a problem if there is no other related difficulty (e.g., washout).

6.3.3. Groundwater Monitoring. In cases where the water table always stays below the level of the drainpipes, the depth to groundwater is typically not an issue. In other cases, the depth of groundwater—and particularly unusual fluctuations in groundwater depth—should be identified along pipeline alignments before any rehabilitation/renovation or reconstruction. In some instances, locating the groundwater table can identify I/I problems that may be corrected with a spot repair, rather than a complete overhaul of the system. Spot repairs at the high groundwater point are not recommended due to minimal effectiveness. The best method for determining groundwater level is with monitoring wells, but a low-cost substitute that often works in older systems is to find a manhole with a leaky crack.

6.4. Rarely Useful Data-gathering Methods:

6.4.1. Sonic Caliper. The sonic caliper, developed in 1983, is passed through a pipeline to determine the degree of corrosion at the crown of the pipe (i.e., the depth of corrosion from the pipe surface), and also the depth of debris in the bottom of the pipe (e.g., the depth of deposited silt). The sonic caliper is typically used to supplement CCTV after the CCTV has detected the existence and 2-D extent of corrosion or debris. The sonic caliper is a relatively fast test that can proceed at a rate of about 30 meters per minute (100 feet per minute), but this is a new and largely unproven technology for drainage inspection. This device has been shown to work well under controlled conditions and is highly praised by vendors, but most researchers agree that there is insufficient validation testing under actual field conditions to verify the vendors' claims.

6.4.2. Pumping/Lift Station Inspection. Pumping/lift station inspections are very site-specific and/or equipment-specific, and not well suited for a generalized methodology of inspection. In addition, pumping/lift stations used in drainage typically do not have the clogging problems associated with sanitary/wastewater systems, so pumps tend to fail gradually from internal wear. Routine inspections and performance testing are the most effective means of determining this wear. For portable systems, performance testing may simply be a pass/fail test, whereas more sophisticated systems use pressure or flow-rate measurements to detect drops in performance. Performance testing is generally more effective when incorporated into an ongoing routine maintenance program, rather than a non-routine, one-time inspection.

6.4.3. Flow Monitoring. Flow monitoring, as described in this ETL, is the overall pipe flow rate, not the measurement of inflow due to structural defects. Inflow rates related to structural defects are usually estimated visually (either directly or by CCTV).

6.4.3.1. Flow monitoring is usually omitted in a stormwater drainage system inspection because accurate data is difficult to obtain, is costly, and is of limited value to the inspector.

6.4.3.2. Flow monitoring is often critical in the monitoring of sanitary/wastewater systems. In wastewater systems, flow monitoring is used to estimate the I/I rates in different sections of pipe, since I/I has a very direct effect on treatment volume. Flow measurements are also used to infer pipe roughness (commonly backcalculated from the Manning formula) that can dramatically affect system performance.

6.4.3.3. In sharp contrast to sanitary/wastewater systems, flow determination has very limited utility for the drainage inspector and should not be routinely performed.

6.4.3.3.1. Localized reduction in flow, not I/I, is usually the key interest of the drainage inspector. Unlike the typical sanitary/wastewater system, most drainage systems can handle a reasonable amount of I/I without adverse effects. In addition, the most common problems caused by I/I in drainage systems are structural in nature (e.g., backfill washout, pipe deterioration) and are generally easier to detect by more direct inspection methods rather than inference from flow rate data.

6.4.3.3.2. Pipe roughness is generally not a problem in drainage systems, unless the roughness is related to pipe deterioration or flow is significantly reduced; this is easier to detect by more direct methods.

6.4.3.3.3. The exception to the utility of flow measurement in drainage systems is for sealed systems that are used to move large amounts of stormwater from one area to another (particularly pressurized systems). In these cases, flow measurement may be more important, especially for system-wide inspections. Note that the stormwater system would then hydraulically approximate a wastewater system (although the levels of contaminants should be significantly lower), so the “exception” is more semantic than actual.

6.4.3.4. Types of flow-monitoring equipment that can be used in pipes include:

6.4.3.4.1. Weirs. In general, weirs are considered a poor method of flow monitoring, particularly for longer-term monitoring. Along with calibration difficulties, weirs have problems with clogging and obstruction of the weir crest—the clogging may be transitory and inaccuracies can go completely undetected. Nevertheless, some manufacturers make claims of 95 percent (or better) accuracy of flow rate with weirs. Weirs can be calibrated to provide workable data as a quick way to estimate I/I in a section of pipe, particularly since the measurements are taken manually (downstream rate minus upstream rate equals inflow rate).

6.4.3.4.2. Flumes. Flumes are not usually used in pipeline inspections. In general, flumes provide more accurate flow information than weirs, but they are not as suited to a rapid flow measurement in a pipeline situation. For long-term measurements, clogging can be a problem. An upstream stilling well may be needed for accurate measurement in pipes that carry water with a significant amount of suspended solids.

6.4.3.4.3. Microprocessor-based Recording Systems. When long-term flow rate data is needed, microprocessor-based recording systems that record flow depth (and sometimes flow velocity) are quickly becoming the standard for flow monitoring. These systems are generally more accurate than mechanical systems, do not impede flow during measurement, and use sensing systems that are relatively easy to calibrate. The output data from microprocessor-based recording systems are usually in the form of calibrated flow versus time, either as a continuous graph or as a table of discrete data points that can be plotted or analyzed statistically.

7. Point of Contact. Recommendations for improvements to this ETL are encouraged and should be furnished to: HQ AFCESA/CESC, 139 Barnes Drive, Suite 1, Tyndall AFB, FL 32403-5319, Attention: Mr. James Greene, DSN 523-6334, commercial (850) 283-6334, FAX DSN 523-6219, E-mail james.greene@tyndall.af.mil.

JEFFREY L. LEPTRONE, Colonel, USAF
Director of Technical Support

Atchs
1. On-site Visual Inspection Logs
2. Guidelines for CCTV Inspections
3. CCTV Log Sheet and Coding
4. CCTV Inspection Log
5. Pipe Identification Matrix
6. Problem Identification Matrix
7. Supplement to CCTV Guidelines
8. Distribution List

ON-SITE VISUAL INSPECTION LOGS

a. On-Site Hydraulic Structure Inspection Log

Base: ______________________________ Date: _______________ Time: ____________

Runway/Hwy ID: ________________________ Drain Line ID: ___________________________

Channel / Hydraulic Structure

Depth of Channel / Structure: __________________________	Sketch of Channel / Hydraulic Structure
Width of Channel / Structure: __________________________	
Depth of Flow (if any): ______________________________	
Material in Channel Bed: _____________________________	
Vegetation on Banks: ________________________________	
Estimated "N" Factor of Channel: ________________________	
Are Channel Banks Stable? ____________________________	
Type and Size of Bed Material: __________________________	
Skew of channel with Runway / Hwy: ____________________	Comments

Floodplain

Skew Same as Channel? ______________________________	Sketch of Floodplain
Symmetrical about Channel? __________________________	
Type of Vegetation in Floodplain: ________________________	
Left Upstream: ____________________________________	
Right Upstream: ___________________________________	
Left Downstream: __________________________________	
Right Downstream: _________________________________	
Is Runway/Hwy Lower than Structure? ____________________	
Are any Buildings in Floodplain? ________________________	
Approx. Floor Elevation: ____________________________	
Historical Flood Information: ___________________________	Comments

Bridge / Overpass

Type of Structure: __________________________________	Sketch of Bridge / Overpass
Skew: ____	
Length: # of Spans: ________________________________	
Width (out to out): Opening Area: ______________________	
Approach Material Type: ______________________________	
Superstructure Depth: ______________________________	
Substructures in the Channel? __________________________	
Indications of Overtopping: ____________________________	
High-water Marks: __________________________________	
Local Scour: _______________________________________	
Stream aggradation/degradation? ________________________	
Drift or Drift Potential? ______________________________	
Obstructions: ______________________________________	Comments

Photographic Documentation Checklist

Elev. View of Structure Opening: __________________ Upstream Channel: ___________ Downstream Channel: __________

Upstream Floodplain - Right: _______ Left: _______ Downstream Floodplain - Right: _______ Left: _______

Centerline - Forward: _________ Backward: _________ Other: ____

b. On-Site Catch Basin, Manhole, Handhole, or Drop Inlet Inspection Log

Base: ____________________ Runway/Hwy ID: ____________________

Structure ID: ____________________ Structure Type: ____________________

Date: ______________ Time: ______________ Wet or Dry Season? ______________

Cleanliness Inspection

Trash / debris	Approximate depth of debris below bottom of lowest pipe entering or exiting structure?	__________ inches
Sediment	Is sediment visible in inlet/outlet pipes?	Yes / No (circle one)
Root Intrusion	Maximum length of root intrusion?	__________ inches

Pollution Inspection

Vegetation / debris	Is there any vegetation or debris on the cover/grate?	Yes / No (circle one)
Chemicals	Identify any chemicals present (for example, solvents, gasoline, diesel fuel, jet fuel, paint, natural gas, etc.).	__________ __________ __________

Frame and Top Slab Inspection

Alignment	Maximum that the frame extends past the curb face or runway surface?	__________ inches
Holes	Maximum hole in the top slab?	Width = __________ inches Length = __________ inches
Cracks	Maximum crack size in the top slab?	Width = __________ inches Length = __________ inches
Flushness	Maximum separation between the frame and the top slab?	__________ inches

Structural Condition

Cracks	Width and length of the worst crack (inches)?	Width = __________ inches Length = __________ inches
Holes	Size of largest hole / missing brick (inches)?	Width = __________ inches Length = __________ inches
I/I	Is there unexpected infiltration / inflow?	Yes / No (circle one)

Cover / Grate Inspection

General condition	Is cover/grate OK, only partially in place, damaged, or missing?	OK / Partially in Place / Damaged / Missing (circle one)
Corrosion	Is cover / grate badly corroded (possible structural problems)?	Yes / No (circle one)
Corrosion	Is cover / grate mildly corroded (more than surface rust but no structural problems)?	Yes / No (circle one)
Opening	Can cover / grate be opened by one person?	Yes / No (circle one)
Locking	Are any locks or locking bolts missing or damaged?	Yes / No (circle one)
Buried	Is cover / grate buried?	Yes / No (circle one)

Ladder Inspection

Damage	Are ladder rungs missing or damaged?	Yes / No (circle one)
Alignment	Are ladder rungs misaligned?	Yes / No (circle one)

Photo Documentation	Comments / Defects Not Listed Herein
Photo(s) taken / No photos needed (circle one)	______________________________

GUIDELINES FOR CCTV INSPECTIONS

Reprinted courtesy of the National Association of Sewer Service Companies (NASSCO) from *Closed Circuit Television Guidelines*, Manual of Practices, 2000 Edition, Chambersburg, PA, 2000.

GENERAL

The content of this chapter is to supplement the NASSCO Standard on closed circuit televising. The items discussed should be reviewed for information and used for additional input for project specifications.

1. The work consists of furnishing all labor, materials, accessories, equipment, tools, transportation, services and technical competence for performing all operations required to professionally execute the internal inspection of sewers in strict accordance with the specification and applicable drawings, and subject to the terms and conditions of the contract. All Federal and State safety requirements will be followed.

2. Information concerning depths of flow, manhole depths, air quality in the sewers, accessibility of manholes, traffic conditions, and other safety considerations are to be the sole responsibility of the Contractor to obtain and to incorporate the necessary provisions into the overall contract price to complete the specified work under the conditions existing in the sewers to be inspected.

3. Closed Circuit Television (CCTV) Inspection will be required prior to sewer line rehabilitation to document the condition of the pipeline and to verify that the pipeline was cleaned per NASSCO Manual Specification Guidelines, “Sewer Line Cleaning”. A post installation CCTV inspection should be performed to determine if the rehabilitation method selected was installed per the contract documents and that all laterals have been re-established, as required.

4. After cleaning, the Contractor should televise the pipeline during optimum low flow level conditions, per NASSCO Specification Guidelines, “Sewer Flow Control” or preapproved by the Engineer. The television camera utilized should be specifically designed and constructed for sewer inspection. The camera should be operative in one hundred percent (100%) humidity conditions. Lighting for the camera should minimize relative glare. Lighting and picture quality should be suitable to provide a clear, in-focus picture of the entire periphery of the pipeline for all conditions encountered during the work.

5. Lighting for the camera will be suitable to allow a clear picture of the entire periphery of the pipe. The camera, television monitor, and other components of the video system must be capable of producing picture quality to the satisfaction of the Owner’s Representative.

6. Documentation and Reports

a. Videotape recordings should include an audio track, recorded by the Inspection Technician during the actual inspection work, describing the line being inspected (i.e., location, depth, diameter, pipe type, date, time), as well as describing connections, defects and unusual conditions observed during the inspection. All videotapes should be professionally labeled, showing the Owner's name, the lines recorded on the tape, and the name of the Contractor. Other recording media, such as optical discs, may be utilized as they become available. These new recording devices offer increased storage capacity and faster location of data.

b. Printed inspection reports may be prepared by the Contractor for each sewer line inspected during the actual field inspection activities. These field logs should then be reviewed by the Contractor's technical staff, along with reviewing the associated video record, as a means of ensuring that no defects or entries are omitted or incorrect, and as a means of gaining a second opinion as to the condition of each sewer line. Edited field logs should then be reprinted or typed per Owner requirement for use in the final project reports. During the data review, detailed, one-page summaries should also be available for each line section inspected, presenting the Engineer's synopsis of the general line condition and the relative severity of observed defects. These summaries should also be included in all field report copies immediately before each associated inspected report to further assist the Owner in understanding and using the results of the inspection project. Direct submittal of copies of the Inspection Technician's field logs, without this secondary review and summary pages, may not be acceptable.

c. Television Inspection Logs: Printed location records should be kept by the Contractor and clearly show the location in relation to an adjacent manhole of each infiltration point observed during inspection. In addition, other points of significance such as locations of building sewers, unusual conditions, roots, storm sewer connections, broken pipe, presence of scale and corrosion, and other discernible features should be recorded and a copy of such records should be supplied to the Owner.

d. Photographs: Instant developing, 35 millimeter (mm), or other standard-size photographs of the problems may be taken by the Contractor upon request of the Owner's Representative, as long as such photographing does not interfere with the Contractor's operations or as agreed upon.

e. Videotape Recordings: The purpose of tape recording should be to supply a visual and audio record of problem areas of the lines that may be replayed. Videotape recording playback should be at the same speed that it was recorded. Slow motion or stop-motion playback features may be supplied at the option of the Contractor as approved by the Owner. Title to the tape should remain with Contractor, unless the Owner requires ownership per contract specifications. The

Contractor should have all videotapes and necessary playback equipment readily accessible for review by the Owner during the project.

f. Video Printer: Video images can be reproduced as hard copy prints by incorporating a video printer into the CCTV system. The video printer can reproduce any of the color images seen on the monitor in about four seconds. The print serves as a durable hard copy print that can be included with the written report to graphically show the exact nature of the defect or any observation.

g. Data Printer: Software programs are available to record the observations and defects viewed on the monitor. Many of the programs provide standard menus that allow the TV operator to quickly record observations by type and degree. At any time, the data can be printed either by using a standard printer on board the CCTV truck, or by a printer located in the Engineer's or the Maintenance Department's offices.

7. The camera should be pulled through the sewer line in either direction at a speed not greater than 30 feet per minute, stopping as necessary to permit proper documentation of the sewer's condition. If, during the inspection operations, the inspection camera cannot pass through the entire manhole section, the Contractor should reset his equipment so that the inspection can begin at the opposite manhole. If the camera again fails to pass through the entire manhole section, the inspection should be considered complete, unless the Owner requires / permits spot repair for completing the CCTV work. In instances where manual or remote power winches are used to pull the camera through the sewer (i.e., where the Recording Technician does not directly control the winch), constant two-way communication should be set up between the two manholes of the line being inspected to permit the Recording Technician to communicate clearly with the crew member controlling the camera's movement.

8. Post-Rehabilitation: Documentation consisting of a color videotape, log sheets, and a written report detailing the post rehabilitation condition of the pipeline and lateral connections/openings, should be submitted to the Engineer for approval. Any rejected work should be repaired, then re-televised. Additional Owner requirements for performing CCTV inspection should be noted on the Plans or in the Special Provisions.

TELEVISION REQUIREMENTS

Small Diameter Sewers (24-inch and less)

1. The remote reading footage counter should be accurate to less than one percent (1%) error over the length of the particular section of pipeline being inspected. The distance is measured from the centerline of the manhole to the centerline of the next manhole. The camera and television monitor should produce a minimum 350 line per inch resolution or greater, as required. Telephones, radios, or other suitable means of communication should be set up to ensure that adequate communication exists

between members of the crew. The CCTV inspection system to be utilized on the project should be approved by the Owner, prior to the work being performed.

CCTV inspection should be performed utilizing one of the following Video camera systems:

a. Remote focus stationary lens cameras;
b. Rotating lens cameras; or
c. Pan and tilt cameras.

The Video camera should be mounted on a skid, floatable raft system, or transporter, based on the conditions of the pipeline to be televised.

2. The importance of accurate distance measurements is emphasized. Measurement for location of defects should be above ground by means of a meter device. Marking on the cable, or the like, which would require interpolation for depth of manhole, will not be allowed. Accuracy of the distance meter should be checked by use of a walking meter, roll-a-tape, or other suitable device, and the accuracy must be satisfactory to the Owner's Representative.

Large-Diameter Sewers (27-inch and larger)

1. Procedures and Equipment

a. Four basic methods of internal pipe inspection should be made available by the Contractor for the project.

i. Conventional color inspection cameras specifically designed for use in sewer line inspection work, mounted on conventional camera skids, tractors, or push skids.

ii. Conventional color inspection cameras specifically designed for use in sewer line inspection work, mounted on floating skids or rafts.

iii. Special industrial grade color inspection cameras, contained in waterproof housings, and mounted on floating skids or rafts.

iv. Special industrial grade color inspection cameras, either hand-held or contained in waterproof housings, and carried manually through the sewer during inspection work.

b. The Contractor may be required to submit sample video recordings from recently completed projects, demonstrating the picture quality obtained with each available inspection system for pipe diameters ranging from 27 to 108 inches. The intent is to insure that the best possible picture quality is made available to the Owner/Client.

c. All cameras used should be color units specifically designed or modified for use in large-diameter sewer inspection work. The cameras should be operable in one hundred percent (100%) humidity conditions. The camera lens should have not less than a 65-degree viewing angle and have either automatic or remote focus and iris controls. Adequate lighting is required. Camera lighting should be sufficient for use with color inspection cameras, and for diameters larger than 48 inches. In all cases, the complete video system (camera, lens, lighting, cables, monitors and recorders) should be capable of providing a picture quality acceptable to the Owner.

d. Manual inspections may be required in lines where conditions will allow the Contractor’s inspection crew to safely walk through the sewer. No remote inspection work may proceed until the process has been reviewed and approved by the Owner. It is required that the Contractor complies with the Confined Space Permit and Safety requirements of OSHA Federal Regulation 29 CFR 1910 or latest revision thereof.

e. Manual pipe inspections (walk-through inspections) should be conducted in such a manner as to transmit the video signal to an above-ground viewing room to permit the Owner’s Representative to watch the inspection work live on a color monitor in the viewing facility. In addition, direct voice communication between the Owner’s Representative, the in-pipe inspection personnel, and the Recording Technician in the above-ground unit should be maintained at all times during the manual inspection work. Video recording equipment should also be located above ground in the inspection truck and accurate, continuous footage readings should be super-imposed on the video recording for permanent record. Camcorders should not be permitted for use as the sole means of obtaining video records, unless approved by the Owner.

During manual inspections, 35-mm color photographs may be required as instructed by the Owner’s Representative, or as deemed necessary by the in-pipe technicians, to document line conditions, should the Inspector not request specific photos.

Safety of the in-pipe inspection crew (minimum of two men in the pipe is required) is of prime concern. Adequate ventilation should be provided and this is normally in the range of two 6800 cubic feet per minute (cfm) or larger air movers. In addition, both exhaust and blower type air movers should be available to provide push-pull ventilation for the sewer line being inspected by manual methods. Each of the technicians in the pipe should also have safety equipment and lifelines as required by OSHA regulations.

f. Remote pipe inspections, using either electric or manually operated winches to pull the inspection camera through the sewer line, should be permitted in cases where conditions are agreed to be unsafe or impractical for manual inspections and where acceptable picture quality can be obtained by the Contractor.

As with manual inspections, accurate and continuous footage readings should be superimposed on the video recording for each line inspected by remote inspection methods. Also shown, should be the date of inspection and an identification manhole number designation for each manhole on the line section inspected.

g. Lines scheduled for inspection should be inspected in their existing condition. The Contractor should be responsible for having the necessary camera skids, floats, and rafts available to allow for inspection of these lines under live flow conditions in a manner acceptable to the Owner.

2. Documentation and Reports

a. The 35-mm photographs taken during manual, walk-through inspections should be properly mounted and labeled on 8.5 x 11-inch paper for inclusion in the final project reports. One copy of the final reports should contain the original 35-mm photos, on fully laminated pages, and the remaining requested copies should contain copies of these photo pages. The photo pages will be presented immediately following the inspection report for the line section in which they were taken.

b. Photographs taken from the video monitor for remote TV inspections should also be presented in the same manner as described in 2.a. If the Owner desires photos of all significant defects observed during remote inspection work where manual inspections are not performed, still photos from the monitor may not be possible.

c. Original videotapes for the project should be forwarded to the Owner with final report submittal and should become the property of the Owner. Additional copies of the videotapes, if requested, should be made by the Contractor on professional tape duplication equipment.

d. The required copies of the final project report should be submitted to the Owner within the time frame specified by the Owner. One of the four copies should contain the original photos as required under 2.a. and 2.b.

e. An overall summary narrative should be provided in each Owner's report, describing the overall conditions found in each associated line section grouping. To assist the Owner in subsequent project reviews, detailed summary tables should also be compiled showing those lines where major and significant defects were located.

3. Suggested Criteria

The following general criteria should be followed:

a. Where flow depths exceed fifty percent (50%) of the pipe diameter, no inspections should be performed without prior approval of the Owner.

b. The maximum flow depth for remote inspection work is thirty-three percent (33%) of the pipe diameter. The Contractor may be required to perform inspections during off-peak hours (night inspections), if specifically requested by the Owner, to achieve this maximum flow standard.

c. No maximum flow depth has been established for manual (walk-through) inspections; however, depths in excess of one-third (1/3) of the pipe diameter will probably make such inspection methods unsafe.

d. Lines 60 inches in diameter and larger, and having flow depths of less than twenty percent (20%) of the pipe diameter, can be manually inspected unless the Contractor provides the Owner with reasons for deeming manual inspections to be impractical or unsafe.

Note: The Contractor should submit a listing of actual measured flow depths and times of measurement, at a sufficient number of locations, to indicate the flow depths that could be expected during inspection work. A minimum of one flow depth measurement should be provided for each line section at no additional cost to the Owner.

Additional off-peak flow measurements (i.e., night flow measurements) may be requested by the Owner at various locations, also, at no additional cost to the Owner.

f. A pre-startup meeting should be scheduled with the Owner, the Contractor, and the Owner's Representative, prior to beginning any internal pipe inspection work, to review the Contractor's proposed inspection methods for each of the line section groupings. At that time, the Contractor should have available the necessary flow depth data described above, as well as the overall listing of proposed inspection methods in each area.

g. The stated time for contract completion should include the time needed for obtaining the required flow depth measurements and the time for the pre-startup meeting. In addition, the Contractor should execute the field work in a continuous manner and not leave the project for more than four consecutive days without prior written approval of the Owner. Delays due to extended adverse weather conditions should be permitted and time extensions be granted in writing at the written request of the Contractor.

4. Measurement for Payments:

a. Project mobilization/demobilization should be paid at the lump-sum price bid for this item. Seventy percent (70%) should be paid on the first pay request, with the remaining thirty percent (30%) being paid after all field activities have been successfully completed and approved by the Owner. Project mobilization/

demobilization should not normally exceed five percent (5%) of the total bid price for the project.

b. Internal pipe inspections and video recordings of the sewer lines should be paid for at the unit price bid per linear foot of each size pipe. Payment should be made only for the actual feet of pipe inspected, as measured from the center of the manholes.

c. Reverse setups (i.e., resetting the inspection equipment to begin inspections from the opposite manhole) should be paid at the unit price bid per reverse setup, for the actual number of reverse setups required, as approved by the Owner.

d. The original set of videotapes and all required photographs should be incidental to the bid unit costs for the actual inspection work. Extra copies of the videotapes should be paid at the unit cost bid for duplicate videotapes for the actual number of duplicate tapes requested by the Owner or as included in the overall bid proposal.

e. Final project reports should be paid at the lump-sum price bid for this item at the time the final reports are received and accepted by the Owner. This bid item should normally be no less than five percent (5%) of the total bid price for the project.

CCTV LOG SHEET AND CODING

A3.1. Attachment 4 is a sample log sheet for CCTV inspection. The inspector can rapidly log pipe and joint information, as well as defects, by using codes. The sample log sheet should be adequate for most CCTV inspections, but can be modified if needed. With the exception of the coding, the log sheet is straightforward and self-explanatory.

A3.2. Attachment 5 is a pipe identification matrix and Attachment 6 is a problem identification matrix. The matrices provide the coding numbers for the CCTV log sheet. By comparing the following examples to the attachments, the reader should be able to use the CCTV log without further instruction.

> Example 1: Consider a circular drainage pipe made of polyvinyl chloride (PVC), with O-ring joints: the pipe type code would be *c-21* (for PVC); the pipe use code would be *a-3* (for a drainage pipe); the pipe geometry code would be *b-2* (for circular); the joint type code would be *d-3* (for O-ring).
>
> Example 2: During the CCTV inspection, a horizontally misaligned joint, that is pulled about 12 millimeters (0.5 inch), is found; it also has longitudinal cracks, but no evidence of I/I. The following codes would apply: *g-10* (for misalignment); *h-6* (for pulled joint, 12.7 to 25.4 millimeters [0.5 to 1 inch]); *i-6* (for longitudinal cracks); and *m-8* (for no evidence of I/I). The full entry would be: *g-10 h-6 i-6 m-8*.

A3.3. Attachments 5 and 6 are intended as models, and can be adapted to meet the needs of a particular base or region. Any number of additional pipe types and/or defects can be added. While the numbered entries in each group are listed alphabetically in Attachments 5 and 6, they could be reordered in a more efficient way. However, once a given set of codes is used for a particular installation they should never be changed (additional codes can always be added). The inspector should be thoroughly familiar with the codes that will be used in the CCTV inspection **before** beginning the CCTV inspection—particularly if another person is logging the codes.

A3.4. The pipe identification matrix of Attachment 5 has code letters which start with the letters *a* through *e*. To avoid confusion, the problem identification matrix of Attachment 6 continues the letters (starting with the letters *f* through *t*). In addition, some letters were intentionally omitted because they are easily confused when handwritten (especially for entries with multiple codes, as illustrated in Example 2 of paragraph A3.2.). There is no *l* code, because it can be easily confused with an *i* (particularly if the *i* is capitalized). There is no *o* code, because it can be easily confused with a zero. There is no *q* code, because it can be easily confused with *p*. And finally, there are no *v* or *w* codes, because they can be easily confused with *u*. The omitted letters can be added if they are needed, but the inspector should be especially careful about the legibility of the logs in that case.

A3.5. The use of coding may appear to be cumbersome, and, in fact, it will slow down the process unless the data logger is thoroughly familiar with the codes. However, as the logger becomes more and more familiar with the codes, the time saved during logging is dramatic. More importantly, the use of codes is particularly conducive to computer data entry by a clerical worker to allow for more sophisticated analyses. In the near future, all logging will be done directly on laptop computers. In addition to the ability to perform analyses, one benefit of entering the codes on a computer is that the computer can generate a complete narrative description in easy-to-understand text based on the code numbers, with far fewer mistakes than a secretary trying to transcribe hand-written field notes.

CCTV INSPECTION LOG

Base: ________________________ Date: ___________ Inspector: _____________ Crew Chief: _____________ Time Start: ___________ Time End: ________________ From MH # _____, located at: _____________________ To MH # _________, located at: ____________________ Flow Direction: ________ CCTV Direction: ___________ Pipe Type: ____ Pipe Use: ____ Pipe Geom. ________ Depth: ______ Diameter: ______ Length: ___________ Joint Type: __________ Joint Spacing: _____________ Manhole Condition:______________________________	Sketch or Extra Comments

Footage	Tape Time	Defect Code(s)	Comments

PIPE IDENTIFICATION MATRIX

a. Pipeline Use	
1	Combined (drainage & sanitary)
2	Culvert
3	Drainage pipe
4	Force main/pressurized pipe
5	Natural flow channel/creek
6	Open channel/ditch
7	Overflow
8	Siphon
9	Trunk/connector pipeline
b. Pipeline Geometry	
1	Arch-top
2	Circular
3	Irregular
4	Natural channel
5	Oval, vertical
6	Oval, horizontal
7	Phillip egg
8	Rectangular, closed
9	Rectangular, open
10	Semi-elliptical
11	Trapezoidal open-channel
c. Pipeline Material Type	
1	Acrylonitrile butadiene styrene (ABS)
2	Asbestos cement (AC)
3	Brick pipe (BP)
4	Cast iron pipe (CIP)
5	Clay pipe
6	Corrugated aluminum pipe (CAP)
7	Corrugated metal pipe (CMP)
8	Concrete pipe, unreinforced (CP)
9	Concrete pipe, reinforced (RCP)
10	Cured-in-place pipe (CIPP)
11	Ductile iron pipe (DIP)
12	Fiberglass reinforced pipe (FRP)
13	Glass reinforced plastic (GRP)
14	High-density polyethylene (HDPE)
15	Orangeburg
16	Polybutylene (PB)
17	Polyethylene (PE)
18	Polypropylene (PP)
19	Plastic-lined pipe
20	Plaster pipe
21	Polyvinyl chloride (PVC)
22	Reinforced concrete box
23	Reinforced plastic mortar pipe (RPMP)
24	Spirolite HDPE
25	Truss
26	Steel pipe (SP)
27	Vitrified clay pipe (VCP)
28	Vitrified segment duct
29	Wooden pipe (WP)
30	Other (indicate type)
d. Joint Type	
1	Asphaltic/bituminous
2	Cement mortar
3	Compression gasket/O-ring
4	Friction/gasketless
5	Solvent weld (usually ABS or PVC)
6	Thermal weld (usually PE)
e. Lateral	
1	Dead/unused
2	Defective connection
3	Hammer tap
4	Protruding (< 13 mm [1 in])
5	Protruding (13 to 50 mm [1 to 2 in])
6	Protruding (> 50 mm [2 in])
7	Protruding (no pass)
8	Saddle tap
9	Sanitary connection
10	Tee
11	Wye

PROBLEM IDENTIFICATION MATRIX

f. Alignment (vertical)	
1	25-mm (1-in) sag
2	50-mm (2-in) sag
3	75-mm (3-in) sag
4	100-mm (4-in) sag
5	125-mm (5-in) sag
6	Sag ≥ 150 mm (6-in)
7	6-mm (0.25-in) diameter sag, begin
8	6-mm (0.25-in) diameter sag, end
9	12-mm (0.5-in) diameter sag, begin
10	12-mm (0.5-in) diameter sag, end
11	Camera underwater, begin
12	Camera underwater, end
13	See comments
g. Condition	
1	Broken
2	Cracks (open) - add i. code
3	Cracks (visible) - add i. code
4	Crushed/collapsed
5	Deterioration, heavy
6	Deterioration, intermediate
7	Deterioration, light
8	Fair
9	Good
10	Misalignment – add h. code
11	Missing pieces
12	Poor fitting
13	Satisfactory
h. Joint Condition	
1	Dropped joint (> 90% diam. clear)
2	Dropped joint (80 - 90% diam. clear)
3	Dropped joint (< 80% diam. clear)
4	Leaking at joint
5	Pulled joint (0 to 12 mm [0 to 0.5 in])
6	Pulled joint (12 to 25 mm [0.5 to 1 in])
7	Pulled joint (> 25 mm [1 in])
8	Shifted joint (> 90% diam. clear)
9	Shifted joint (80 - 90% diam. clear)
10	Shifted joint (< 80% diam. clear)
11	Typical joint
12	Visible gasket
13	Visible joint material
14	See comments
i. Cracks	
1	0 to ½ inch
2	½ to 1 inch
3	> 1 inch
4	Circumferential
5	Combination
6	Longitudinal
7	Pipe, hole in
8	Pipe wall missing (≤ 60°)
9	Pipe wall missing (> 60°)
10	See comments
j. Leak Type	
1	Clean-out broken
2	Clean-out plug defect
3	In drainage channel
4	Manhole bench
5	Manhole cover
6	Manhole ring
7	Manhole riser
8	Manhole wall/cone
9	No smoke from drop inlet
k. Leak Size	
1	Smoke test, heavy
2	Smoke test, intermediate
3	Smoke test, light
4	Video, large leak
5	Video, medium leak
6	Video, small leak
7	See comments

m. Infiltration	
1	Evidence of I/I (great)
2	Evidence of I/I (medium)
3	Evidence of I/I (small)
4	I/I, heavy (> 0.0006 m^3/s [10 gpm])
5	I/I, high (0.0003 to 0.0006 m^3/s [5 to 10 gpm])
6	I/I, medium (0.00006 to 0.0006 m^3/s [1 to 5 gpm])
7	I/I, small (< 0.00006 m^3/s [1 gpm])
8	No evidence of I/I
9	See comments

n. Corrosion	
1	Major (steel bar gone)
2	Medium (steel bar showing)
3	Minor (aggregate showing)
4	Severe (holes through pipe)

p. Debris	
1	General debris, major
2	General debris, medium
3	General debris, minor
4	Grease/sludge, major
5	Grease/sludge, medium
6	Grease/sludge, minor
7	Large rocks/bricks
8	Rocks/gravel
9	Sand/grit
10	Soil (clayey)
11	Soil (silty)

r. Roots	
1	Blockage
2	Extreme growth
3	Heavy growth
4	Heavy to medium growth
5	Medium growth
6	Medium to minor growth
7	Minor growth

s. Erosion	
1	Major (rebar missing)
2	Medium (rebar showing)
3	Minor (aggregate showing)
4	Severe (holes in pipe)

t. Structural Damage	
1	Bricks missing, minor
2	Bricks missing, moderate
3	Bricks missing, severe
4	Collapsed
5	Deflection, minor (< 5%)
6	Deflection, moderate (5 to 10%)
7	Deflection, severe (> 10%)
8	Four-hinged break

u. Utility Damage	
1	(Other) utility duress
2	(Other) utility failure

x. Street Damage	
1	Building collapse
2	Curb and gutter cracks
3	Curb and gutter settlement
4	Pavement cracks
5	Pavement settlement
6	Street collapse

SUPPLEMENT TO CCTV GUIDELINES

To supplement the NASSCO CCTV Guidelines in Attachment 2, this attachment contains general information that is helpful to the inspector in preparing and carrying out a CCTV inspection.

A7.1. CCTV units. Table A7.1 summarizes commonly available CCTV units and their general characteristics:

Table A7.1. Common CCTV Inspection Equipment

Camera Type	Camera Subtype	Most Common Cable Type	Typical Cable Lengths in Linear Meters (Linear Feet)	Typical Pipe Sizes
Micro-mini Camera	Color	Coaxial	15 to 30 (50 to 100)	≤ 101 mm (≤ 4 in)
	Black & white	Coaxial	30 to 60 (100 to 200)	≤ 152 mm (≤ 6 in)
Mini-camera	Color	Coaxial	60 to 90+ (200 to 300+)	101 to 610 mm (4 to 24 in)
	Black & white	Coaxial	60 to 150+ (200 to 500+)	
Conventional Cameras	Multi-conductor	Coaxial	300[a] to 450[b] (1000[a] to 1500[b])	152 to 3048 mm (6 to 120 in)
	Single conductor	Coaxial	600[a] to 1500[b] (2000[a] to 5000[b])	
	Well cameras	Coaxial	600[a] to 3000[b] (2000[a] to 10,000[b])	Well casings
Special Inspection Units	Coaxial with amplifiers	Coaxial	900 to 1800 (3000 to 6000)	1219 to 3658 mm (48 to 144 in)
	Fiber-optic unit	Fiber optic	1500 to 3000 (5000 to 10,000)	

[a] Commercially available units [b] Specially designed or modified units

A7.2. Components of CCTV Inspection System. The following paragraphs describe the components (i.e., the personnel and equipment) that are needed for a professional CCTV inspection.

A7.2.1. Personnel.

A7.2.1.1. The most critical component of any successful inspection is the person responsible for documenting observed field conditions. The final products of most CCTV inspections are the videotape narrated by the operator and a documenting field log, either prepared during the inspection or from notes and/or narration by the operator during the inspection. Operator experience is essential to a successful CCTV inspection, which provides not only information for the present time, but also baseline information for future inspections.

A7.2.1.2. Almost as important to the success of the inspection is the person responsible for the daily equipment maintenance. The best equipment, with the best operators, will give poor performance if the equipment is not properly maintained. Ultimately, it is the inspector's responsibility to see that equipment maintenance is completed at least daily, or more often if needed.

A7.2.2. Safety Equipment. A health and safety plan is critical for entry into manholes and large-diameter pipes. While health and safety issues are most often the purview of the contractor, it is the inspector's responsibility to ensure that the contractor has adequate health and safety guidelines and policies when working in confined spaces, and that those guidelines and policies are followed by field personnel.

A7.2.3. Ventilating Equipment. Special blowers and/or exhaust fans should be considered during manual inspection if long line lengths, unusual structures, or other conditions are encountered which might restrict air movement.

A7.2.4. Cameras.

A7.2.4.1. If available, a digital camera should be used. In any event, a high-resolution color camera (minimum resolution of 450 lines) should be used. The higher resolution camera will give the operator a better chance of locating defects during the test, and will provide a better quality videotape, even when the recorder has a lower resolution.

A7.2.4.2. Another important feature of the camera is the ability to operate in a low-light environment. Even if the system lighting is generally adequate, unusual circumstances may occur within the pipeline where the lights are shaded so the camera does not have full illumination for inspecting a particular feature. Video camera light sensitivity is rated with a "lux" number (the smaller the lux number, the higher the sensitivity).

A7.2.5. Lighting. Lighting is an often overlooked, but critical, component for CCTV pipeline units. Even the best cameras will not detect defects without proper lighting. While low-lux cameras can sometimes provide details in unusual situations, the use of a low-lux camera should never be considered a substitute for a good lighting system. On the contrary, the low-lux features of a camera should be treated as a bonus for those odd situations. For typical inspection situations, it is the lighting that will, in large measure, determine whether defects will be recognized. The inspector should ensure that the lighting is both adequate and maintained in optimum working order.

A7.2.6. Power Control Units (PCU). The exact features and configuration of the PCU is very system-dependent. In general, it allows the operator to remotely control the CCTV unit from a viewing room (typically a van or trailer). Typical PCU control features include lighting intensity, camera focus/iris setting, crawler speed/direction, and viewing angle for articulated head cameras. The inspector should ensure that the PCU is of state-of-the-art quality and properly maintained.

A7.2.7. Cables. Coaxial cable is the most common means of transmitting a CCTV signal from the camera to the viewing room. Video transmission with coaxial cable is typically limited to about 900 linear meters (3000 linear feet) for a conventional camera and much less for typical mini-camera systems. Signal degradation tends to increase as the transmission length of a coaxial cable increases, and commercially available CCTV systems generally have, at most, 600 linear meters (2000 linear feet) of coaxial cabling. Specially designed units have extended the useful transmission length for coaxial cables to 1500 linear meters (5000 linear feet), and with bulky line amplifiers that length can be extended to more than 1800 linear meters (6000 linear feet), but with a corresponding increase in cost and difficulty. Given the current trend toward digital technology, significant improvements in the useful transmission length of coaxial cables are not anticipated. In sharp contrast to coaxial cabling, signal degradation due to transmission length is usually not a problem for fiber-optic cabling. Commercially available digital CCTV inspection systems are typically equipped with 1500 to 3000 linear meters (5000 to 10000 linear feet) of fiber-optic cable. Digital CCTV inspections have been completed in pipe lengths greater than 4800 linear meters (16,000 linear feet), with little or no line loss. More importantly, digital data can be easily amplified without bulky equipment, so CCTV inspections with unlimited transmission lengths will be possible. Fiber-optic cabling will be used almost exclusively as digital CCTV systems replace analog CCTV systems for routine inspections. Fiber-optic cables are also well suited for two-way digital data transmission that can allow control of camera unit functions by a PCU. Even with the improvements in digital technology and recent reductions in the costs associated with digital technology, most current CCTV systems still rely on analog technology. However, for cases where transmission length is an issue, an all-digital system, equipped with fiber-optic cabling, is the best solution for CCTV inspections.

A7.2.8. Drum and Slip-Ring Assembly. Power and/or audio-video signals must pass through the drum and slip-ring assembly to allow the cable to be spooled and unspooled during inspections. Maintenance of the slip-ring configuration is critical, as problems in these mechanical systems can cause reductions in power output and/or picture quality. The slip-rings are obvious suspects when a loss of power or picture is encountered, but are rarely considered if, for example, the picture quality becomes slowly degraded over time. The inspector has ultimate responsibility to ensure that both the electronic and mechanical systems are maintained.

A7.2.9. Winches, Transporters, or Other Propulsion. A pipeline inspection requires that camera, lighting, and cabling be propelled through the pipeline in a manner that permits professional inspection results. Most standard equipment transporters use portable winches that are limited to pipe lengths of about 300 linear meters (1000 linear feet), although some transporters are capable of inspecting pipe lengths of 600 linear meters (2000 linear feet) or more. If pipe lengths of greater than 600 linear meters will be encountered, custom equipment will probably be required. The inspector should review all pipe lengths before starting the inspection to ensure the contractor's transporters are adequate for the entire job.

A7.2.10. Video Monitor. High-resolution monitors in the viewing room give the operator the best possible view of pipe conditions without actually being in the pipe. The operator must be able to see defects in order to properly log them—this is especially true for slight cracks, corrosion, or other hard-to-see defects. In addition, unless an all-digital system is used, the high-resolution monitor in the viewing room gives the best representation of the pipeline interior that will **ever** be seen, because analog video recording always causes loss of picture quality; therefore, the inspector should view areas of particular interest during the inspection, rather than reviewing the videotape at a later time. The videotape should be for documentation, not for discovery.

A7.2.11. Video Recording Equipment. The most detailed end-product of all CCTV inspections is a videotape record. At present, most video recordings are made in vertical helical scan (VHS) format, which is a relatively low-resolution format (240 lines). Particularly for VHS recordings, the type, age, and maintenance of the video recorder is critical for the best possible picture quality for documentation purposes. When available, higher quality recorders should be used. For example, super vertical helical scan (SVHS) format video recorders (400+ lines) will deliver significant improvements over VHS format, especially when copies of the videotape are needed. The best reproduction quality comes from an all-digital system (digital camera, digital-capable cabling, and digital recorder). In an all-digital system, the picture originally "seen" by the high-resolution camera can be reproduced at any time on a high-resolution monitor, even for comparison in future inspections. In fact, the exact same picture quality can be reproduced from a copy of the videotape. However, even without an all-digital system, an analog-to-digital video recorder can provide a much better videotape record and one that will not degrade as copies are made.

A7.2.12. Two-way Voice Communication. For manual (person-entry) inspections, two-way voice communication must be maintained at all times for the safety of the inspector. Two-way communication is most often accomplished with two-way radios, but hard-wired systems (usually with fiber-optic cabling) are also used. The voice of the person(s) in the pipeline should be included on the videotape record. On systems that do not automatically include the pipeline voice(s), the audio recording is often accomplished by patching into an earphone jack on the receiving communication device, and splitting the audio signal so that it can be heard in the viewing room and simultaneously recorded onto the videotape. This arrangement can be enhanced even further by using a video recorder capable of recording a stereo audio signal, and then recording the two-way communication on one audio track, with additional comments from the viewing room operator on the other audio track.

A7.2.13. Photographic Documentation. Special low-light 35-mm film is usually required for still photos of areas of interest during manual (person-entry) inspections, along with additional lighting to give the proper depth to the photographs. If photographic documentation is needed, the inspector should plan in advance for the availability of appropriate equipment to make sure that the resulting photographs are satisfactory.

A7.2.14. Continuous Footage Count. Electronic distance meters should be used to count the footage during CCTV or manual inspections. The typical electronic footage counter reads the length of video cable that has been spooled off the cable drum, and then sends the signal to the video recorder for superimposed recording with the pipeline video signal. The inspector must ensure that the counter is properly calibrated (usually by hitting a "zero" switch, but sometimes by dialing in a starting value) on every pipe inspected. Any system that will not superimpose the footage count on the videotape should be avoided; however, in some cases, equipment failures may make manual footage measurement necessary. In those cases, the inspector must make sure that closely spaced footage counts (in addition to the footage for specific areas of interest), are included in the audio portion of the video recording.

A7.2.15. Character Generator. Character generators should be used when available. Character generators allow alphanumeric comments to be superimposed on the videotape recording. While a written log may be more helpful for the current inspection, future inspections may have to rely purely on the videotape for comparisons (videotapes tend to stay around offices longer than written notes). Even for the current inspection, adding superimposed video comments to the videotape is usually helpful because audio comments are usually not available during "cue" and "review" of the videotape (to aid in quickly finding a particular spot on the videotape).

A7.2.16. Special Support Equipment. The need for specialized transportation (e.g., pontoons, wagons, skid-rigs) is less likely for an inspector on an Air Force base, but is always a possibility. Specialized safety equipment may also be needed, particularly for person-entry inspections. Larger pipes tend to have variable conditions that may require special equipment to be fabricated to facilitate professional inspection results. As much as possible, the inspector should anticipate special support equipment needs before starting the inspection, and should be alert during the inspection for conditions that might need special equipment so fabrication can proceed quickly.

A7.3. Variables. The inspector should be familiar with the many variables that impact performance, production, and cost on any particular CCTV inspection. Some variables apply to each pipe section to be inspected.

- Locating, exposing, or removing manhole covers
- Access to manholes
- Type of terrain
- Traffic-control requirements
- Condition of the manholes (steps, cleanliness, structure)
- Depth of the manhole (difficulty and safety of entry)

- Depth and velocity of water flow
- Availability of water for threading a camera line (if the line is dry)
- Plugging requirements (ability to plug, necessity to bypass)
- Presence of explosive gas or combustible liquid
- Offset joints, intruding joint materials, intruding lateral (or service) connections, curved pipe, crushed pipe, and other obstructions which could prevent the passage of the camera
- Cleanliness of the pipe and the presence of root curtains or grease which could foul the camera lens
- Size of the pipe (150- to 200-millimeter [6- to 8-inch] pipe is tight and may cause equipment clearance problem; 250- to 530-millimeter [10- to 21-inch] pipe is best for inspection; 610- to 910-millimeter [24- to 36-inch] pipe may require special lights and skids)
- Production is sensitive to the number of setups required (it is possible to televise 300 meters in one direction from a single location when inspecting successive manhole sections, while random inspection of single manhole sections is more time consuming)
- Requirements for documentation (monitor photographs, videotape recording)
- Weather (rain and snow lower production rate; snow hides manholes)

A7.4. Distance Measurements. It is important to record reasonably accurate distance measurements for the purpose of locating defects. Distance measurements are made above ground by means of a meter device (footage meter) on the CCTV cable. Typically, footage meters have an error of about ± 2% or 600 millimeters per 30 meters (2 feet per 100 feet). Additional error can result from improperly calibrating the meter at the start of the pipeline inspected (calibration is usually accomplished by a “zero” button or dial, but could require reading an initial footage).

A7.4.1. The inspector should check that the crew sets the footage meter to indicate the distance from the center of the near manhole to the pipe location that is in clear focus on the television monitor. This is often done using the following procedure:

- Measure the distance to the first or second joint outside the manhole.
- Move the camera into the pipe and install the CCTV cable roller.
- Take the slack out of the CCTV cable and move the camera into the pipe until the measured joint appears in clear view and focus on the television monitor.
- Add the radius of the manhole to the measured joint distance and set this initial number on the footage meter.

A7.4.2. The inspector can and should check the accuracy of the distance measurements, particularly when corrective action may be required. The accuracy of the footage meter is best checked by taking a reading at the entrance to the away manhole and comparing with a surface measurement made with a steel tape or walking meter (Roll-A-Tape). The accuracy of the recorded distance measurement should be satisfactory to the inspector or corrective action should be taken.

A7.5. Documentation.

A7.5.1. Documentation of CCTV inspection should be performed concurrently with the actual CCTV inspection. The inspector should observe that all documentation (entering data on inspection logs) is being properly, accurately and legibly done during (**not after**) the CCTV inspection of each pipe section. CCTV reports can be assembled elsewhere, but good documentation must be completed in the field.

A7.5.2. Three methods of documentation that are often used in combination:

- Television Inspection Logs. Written records that show the location of each point of significance, in relation to an identified manhole, should be maintained at all times (knowing a problem exists is useless if you cannot find it again).
- Videotape Recordings. The purpose of tape recording is to obtain a visual and audio record of the pipe conditions that may be replayed at a later time. Clock times on the videotape, of each point of significance, should be hand-recorded to allow easy replay of key segments.
- Photographs. Polaroid or 35-mm photographs of the television picture of problems areas may be used to supplement the CCTV logs.

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