DSO-04-09

Final December 5, 2007

Guidance on Sampling, Transportation, and Analysis of Materials in Drains

Doug Hurcomb, Geologist, Earth Sciences and Research Laboratory Group

Introduction

The topic of monitoring seepage sediments in dams is a reoccurring one. There is no guidance on how to sample, transport, and analyze sediment samples from drains in any current Reclamation document. Examples of sediments that may be present in a drain are soils, clay to sand size sediments, biological growths and films, and precipitates.

Investigators often need guidance to estimate costs and specify sampling procedures for dam safety monitoring programs. Without guidance, investigators may sample critical material and handle it inappropriately, which requires re-sampling and loss of time and resources. This brief guidance document provides advice on how to effectively use the Technical Service Center (TSC) services to help you determine what is fouling a drain. This report includes a discussion of drains, inspections, materials, sampling, transportation, testing, costs, and TSC contacts.

This document should be used as a practical guide as the title suggests. It should not be considered complete or a definitive dissertation on microbiology and sampling.

Drains in dams

There are several drain types in dams and appurtenant structures. For a comprehensive reference on drains, refer to the Bureau of Reclamation **draft** publication "Drains for Dams and Associated Structures" published in 2001 and "White Paper on the Impacts of Aging of Seepage Control/Collection System Components on Seepage Performance", published in 2000 by McCook.

A few common drain types include:

Concrete dams
- formed drains
- cracks
- foundation drains
- drilled vertical drains

Embankment dams
- chimney drains
- downstream drainage blankets
- toe drains
- drainage trenches
- drainage tunnels
- pressure relief wells

Drainage systems for appurtenant structures
- drilled foundation drains

underdrains in trenches
backfill at base of walls

Inspection activities

It is likely that deposited materials will be discovered in drains during operation and maintenance (O&M) inspections and activities. Dam inspections are conducted by the Dam Safety Office, the Technical Service Center, and regional and area offices as part of the Comprehensive Facility Review (CFR) and Periodic Facility Reviews (PFRs) process. Annual Facility Inspections are performed in years in which a CFR or PFRs are not scheduled. Drain inspections are typically performed using closed circuit television (CCTV) equipment.

If deposited materials are present they will be revealed during inspections or monitoring of the drain. The sampling will typically be scheduled for a later date or routine O&M activities. Instructions to O&M personnel should be clear and concise. Figures 1 to 12 contain photographs submitted by Denise Hosler, D 8220, and Chuck Cooper, D-8130, show examples of biofouling, biofilms, bacterial growths, mineralization, sediments, and vegetation found in drains during inspections.

Material typically found in drains

Sediments – Sediments may be transported in seepage and collected at outfalls and drain outlets. Sediments may be evidence of piping or internal erosion of a structure, which may have serious structural consequences. Evidence of erosion of dam or foundation materials surrounding a drain requires immediate attention. Continued erosion could result in partial or complete dam failure. If piping is suspected, a sample of the suspected eroding material should be collected by drilling, or excavation.

Samples of any significant or unusual build up of sediments in a drain should be petrographically examined to provide evidence for piping with in the dam or foundation. This type of examination is most effective if accompanied by a companion sample of material adjacent to the drain for comparison.

Mineralization and encrustations – The accumulation of minerals deposited in a drain or the material surrounding a drain hinders water from exiting or being removed from a structure. An excellent discussion of mineralization and encrustation and groundwater constituents can be found in the Ground Water Manual, 1995, and Driscoll, 1986.

Biofilms and drains – Biofilms are composed of populations or communities of microorganisms adhering to environmental surfaces. These microorganisms form slime-like mats, which bacteria adhere to causing fouling. Biofilms may be found on essentially any environmental surface in which sufficient moisture is present. Their development is most rapid in low flowing systems where adequate nutrients are available, for example, drains. The following is a discussion of some biofilms that affect drains:

Iron-related bacteria –A common bacterially rich organic slime observed in Reclamation structures are composed of iron-related bacteria. Iron-related bacteria films can be sticky and cause drain blockage. The presence of iron-related bacteria or other microflora is suggested by any of the following symptoms:

1. Orange, red, brown, and black colored slime
2. Reduced water flow
3. Slimy deposits blocking main lines and laterals
4. Unpleasant odor in water
5. Slimy, rusty deposits in water collection systems
6. Severe staining on concrete surfaces
7. Oil like films on surface water
8. White flocking, like finely shredded tissue paper, floating in water

Iron related bacteria are a diverse group of microorganisms widely distributed in nature. They are found naturally in fresh and salt waters and in soils. Iron bacteria are a nuisance microorganism capable of transforming dissolved iron and manganese to an insoluble form that can cause severe fouling and plugging in pipes, plumbing, well pumps, treatment plants, and distribution systems.

They tend to grow much faster and in greater quantities when the temperature rises in a drain or when exposed to air. The result of the iron bacteria converting soluble iron, from a soluble state (Fe^{2+}), to the insoluble form (Fe^{3+}), is referred to as "red water". It is in this stage that iron, and manganese, become deposited on the outside of the bacteria cell sheaths and the slimes they produce. The bacteria cell sheaths and slimes become encrusted with iron and manganese.

Other microflora that may be found in drains and wells:

Sulfate reducing bacteria – Sulfate reducing bacteria live in oxygen-deficient water. They reduce sulfur compounds, producing hydrogen sulfide gas in the process. Hydrogen sulfide gas is foul-smelling and highly corrosive. Sulfur-reducing bacteria are more common than iron bacteria. The most obvious sign of a sulfur bacteria problem is the distinctive "rotten egg" odor of hydrogen sulfide gas. Bacteria respire oxygen in sulfate ion and create hydrogen sulfide gas. Sulfate reducing bacteria occur in waters where oxygen is absent and sufficient dissolved organic materials are present (Cullimore, 1992)

Iron bacteria may coexist with sulfate reducing bacteria. Iron bacteria and sulfate reducing bacteria contamination are often difficult to tell apart because the symptoms are similar. Sulfur reducing bacteria often live in complex symbiotic relationships with iron bacteria, so both types may be present.

Sulfur oxidizing bacteria - Sulfur oxidizing bacteria require oxygen to grow and convert sulfides to sulfuric acid or hydrogen sulfide to sulfates. They can be colorless, purple, or green bacteria.

Algae – Algae are small single or simple multicellular plant-like organisms which grow in the presence of light by photosynthesis. Algae occur in shallow wells or drains where there adequate nutrients.

Heterotrophic bacteria - Heterotrophic bacteria are able to utilize organic materials as their principle source of energy and carbon for survival, growth and synthesis.

Sampling

During the course of an inspection, it may be determined that drains are plugged or deposition of material in outfall or seeps is reducing the effectiveness of drains or otherwise causing a problem. Good digital photographs can help the field, office and laboratory personnel communicate.

A sampling plan should be developed by those who conduct drain maintenance in consultation with project engineers and field personnel. A discussion of the problem and how to implement the plan will help define the critical issues before sampling, so appropriate analyses can be made by the proper personnel. Often, the issue is - how much sample needs to be collected or under what conditions should the sample be shipped to provide the analyst with what he or she needs to conduct an effective analyses.

Information provided with submitted samples should include a clear statement defining the problem and/or what information is sought; names of Project, Area, Region, and/or Technical Service Center personnel familiar with the problem; sample location information including amount and location of the deposit; knowledge of the type of material previously taken from drains, if known; any other relevant data; and the required deadline for results.

Appropriate personnel in the Technical Service Center or your contract laboratory should be contacted with any questions concerning type, quantity, selection, preparation, and shipment of representative samples. Submitted samples should be representative of the material intended for analyses. The analyst should be able to provide a complete cost estimate for the recommended work to be performed.

Upon arrival of samples in the laboratory, the analyst will determine which tests are to be performed based on the purpose of the examination and previous communication with project personnel. Photographs of submitted samples will be provided upon request. Because more than one analysis may be performed on a sample, enough material for each procedure should be submitted.

Inorganic material - If the material contaminating the drain appears to be sediments (mineral and soil material), then there are usually no special precautions needed regarding holding times.

Every effort should be made to obtain a representative sample. That is, a sample or group of samples selected to typify the larger population.

If laboratory identification of a precipitate is required, a representative sample, at least 1 teaspoon or 50 grams, should be sent to a qualified laboratory for examination. Typically, calcium carbonate deposits can be easily identified by application of a mixture of 3:1 distilled water to hydrochloric acid as described in Reclamation's Engineering Geology Field Manual, second edition, volume 1, page 43. Calcium carbonate is also easily and inexpensively determined by microscopic examination.

Water carrying suspended sediments can be sampled by taking a water sample. The sample should be a sufficient volume to allow at least 1 teaspoon or 50 grams of sediment to settle.

Excessive amounts or unusual materials in a drain may require a sample. Insure that all particle sizes are represented by taking a sample large enough to insure an adequate population of all particle sizes. If only a limited amount of material is available, take everything. If abundant material is available then an average sample can be assembled by taking a scoop from 30 different parts of the sample to yield a representative sample free of grouping and segregation error.

Reclamation's Concrete Manual appendix, Eighth edition, designation 7, page 511, offers guidance on the amount of material required with respect to particle size. A typical sand sample, with particle sizes ranging from 0.074 to 4.75 mm, should weigh about 500 grams (1 pound) or equal about a pint of material. The weight or volume requirement increases with increasing particle size.

Organic material - If the material contaminating the drain is suspected to be organic, an analyst should be contacted in advance of field sampling to insure the sample is properly handled and preserved so that it survives the trip to the laboratory undamaged. Usually, the analyst is going to recommend that the organic material sample is placed in a clean container, transported in an insulated picnic cooler with sealed "blue ice" containers, and shipped to the laboratory as soon as possible to reduce the holding time. I think of it as transporting fresh lettuce a long distance. Planning needs to be done to insure the lettuce arrives in good condition. Planning should include making sure a qualified analyst is on duty to accept the shipment. About 500 mL (1 pint) of fresh material is required for a positive identification. Denise Hosler and Fred Nibling, D-8220, are the TSC's current analysts and contacts for biological identification.

Description of aseptic technique for sampling water from Denise Hosler, D-8220: Have latex gloves and isopropyl alcohol on hand. After putting on gloves, wash hands and sample bottle and top with some alcohol. Open the sample bottle as close to the sampling location as possible taking care not to contaminate the bottle top by facing the cap in the bottom up position or leaving the cap off for excessive time, to reduce the chance of airborne bacterial contamination. Triple-rinse the bottle with sample water then fill the bottle with sample water and cap. Label each bottle with the sample location and place in cooler. If requested in advance, D-8220 will prepare a cooler with sample bottles and send it to the collection site.

Water samples should be collected in clean, 500 mL nalgene bottles using aseptic techniques and placed in an iced cooler and shipped immediately to the laboratory. Collect the samples early in the work week so the water can be cultured upon arrival.

Biofilms and slimes should also be collected in clean, nalgene bottles or stout plastic bags using aseptic techniques and placed in an iced cooler and shipped immediately to the laboratory. Collect the samples early in the work week so the water can be microscopically examined upon arrival.

Transportation

Transporting inorganic materials to the Laboratory - Ship the samples by any reasonable means in a competent container directly to the U.S. Bureau of Reclamation Earth Sciences and Research Laboratory Group or your contract laboratory.

Earth Sciences and Research Laboratory Group (ESRL) (call for current laboratory location)
Mail code D-8340
Denver Federal Center
6th and Kipling
Denver CO 80225
(303) 445-2329

Transporting organic materials to the Laboratory - As soon as possible, store the labeled samples in a picnic cooler. Use sealed "blue ice" cartridges to chill the cooler and samples. Ship the samples OVERNIGHT EXPRESS directly to the U.S. Bureau of Reclamation Ecological Research and Investigations Group or your contract laboratory. It is necessary to contact the analyst prior to sampling and shipment to insure the sample is properly received in the laboratory.

Ecological Research and Investigations Group (ERIG) (call for current laboratory location)
Mail code D-8220
Denver Federal Center
6th and Kipling
Denver CO 80225
(303) 445-2200

Testing of inorganic materials

Soil and soil-like materials from drains are petrographically examined to determine mineralogical composition, organic fraction, and origin usually for documentation purposes. Soil and soil-like material in a drain is analyzed to identify the mineralogical composition and to detect the presence of minerals and rock types that determine origin, occurrence, and history of the sample. If a sample of the construction or foundation material surrounding the drain is submitted for examination, the samples can be compared for common mineralogical composition.

The petrographic examination of soils generally includes a description of the submitted sample and a determination of the mineralogical composition and estimated volume percentages.

The soil and soil-like material analysis results can be applied to the material in the field only to the extent that the submitted sample represents that material.

Testing or organic materials

Two approaches are generally considered. One is to sample the water that has passed over the biofilm using aseptic techniques to reduce sample contamination (Denise Hosler, personal communication). The second technique is to remove some of the slime or biofilm from the original site for microscopic examination.

The ERIG laboratory performs bacterial activity reaction tests and light microscope examinations. The ERIG laboratory performs analytical testing for water, solid samples, and hazardous wastes, research and special studies to solve environmental, operation and maintenance, and engineering problems.

Examples

Appendix A contains two memoranda of laboratory examinations of inorganic and organic materials as an example of the TSC work. Both technical memoranda were regarding material in a vault at Wasco Dam, Oregon. The first is an example of inorganic petrographic analysis of sediments and provides mineralogical composition and loss on ignition test results which indicates a significant organic content. The second is an example describing bacterial and light microscope results of filamentous bacteria. Both examples represent the quality of service provided by the TSC.

Costs

The website http://www.usbr.gov/tsc provides information regarding engineering services provided by the Technical Service Center as well as information on personnel, business practices, and billing rates. Please call for an estimate and personal service. The Client Business Services Office (D-8010) can facilitate the work and any financial arrangements.

2004 TSC Laboratory Contacts

Earth Sciences and Research Laboratory Group
U.S. Bureau of Reclamation
P.O. Box 25007, D-8340
Denver, CO 80225-0007
Group Manager Tom Lippert
(303) 445-2329
(303) 445-6341 FAX
Key personnel: Doug Hurcomb (2336) and Karl Krill (2338)

Ecological Research and Investigations Group
U.S. Bureau of Reclamation
P.O. Box 25007, D-8220
Denver, CO 80225-0007
Group Manager G. Chris Holdren
(303) 445-2200
(303) 445-6328 FAX
Key personnel: Denise Hosler (2195) and Fred Nibling (2202)

Client Business Services Office
P.O. Box 25007, D-8010
Denver, CO 80225-0007
Manager Tom Luebke
(303) 445-2594
(303) 445-6356 FAX

References

Cullimore, D. R., 1992, Practical Manual of Groundwater Microbiology, Lewis Publishers, Chelsea, Michigan, 412 pages

Driscoll, F.G, 1986, Groundwater and Wells, Second ed., Johnson Division, St Paul Minnesota, 1089 pages

Ford H. W., 1993, Iron Ochre and Related Sludge Deposits in Subsurface Drain Lines, Florida Cooperative Extension Service, Circular 671, http://edis.ifas.ufl.edu/BODY_AE026

Ground Water Manual, 1995, second edition, Bureau of Reclamation, U.S. Government Printing Office, 661 pages

Hem, J.D., 1985, Study and Interpretation of the Chemical Characteristics of Natural Water, Third ed., U.S.Geological Survey Water-Supply Paper 2254, 263 pages

Lennox, J. E, A Manual of Biofilm related exercises, A Biofilm Primer http://www.personal.psu.edu/faculty/j/e/jel5/biofilms/primer.html

McCook, D. K., 2000, White Paper on the Impacts of Aging of Seepage Control/Collection System Components on Seepage Performance, ASDSO/FEMA

University of Alaska Fairbanks, Water Treatment Plant, Iron Bacteria http://www.uaf.edu/fs/water/ironbact.html

Figures (separate file)

Appendix A - Drain samples submitted for examination and testing

Earth Sciences and Research Laboratory Referral No. 8340-03-17: Sediment Sample Physical Properties and Petrographic Examination Results – Wasco Dam, Oregon with selected figures

Ecological Research and Investigations Group Memorandum dated September 2, 2003, Report of Bacterial and Chemical Testing of the Vault at Wasco Dam with selected attachments

D-8340
PRJ-13.00

MEMORANDUM

To: Manager, Geotechnical Engineering Group 2, D-8312
Attention: J. Gagliardi

From: Doug. Hurcomb
Geologist, Earth Sciences and Research Laboratory Group

Subject: Sediment Sample Physical Properties and Petrographic Examination Results - Wasco Dam Sediment Monitoring – Wasco Dam, Juniper Division, Wapinitia Project, Oregon

Earth Sciences and Research Laboratory Referral No. 8340-03-17

Petrographic referral code: 03-05

INTRODUCTION

One sediment sample from the vault box left of outlet works, Wasco Dam, Oregon, was submitted to the Earth Sciences and Research Laboratory (ESRL) by J. Gagliardi, Geotechnical Engineering Group 2, for examination. The sediment was sampled in July 2002 during an annual examination of Wasco Dam after some earthquake activity near the dam-site. The material was deposited by the drain system and formed a cone of sediments. The dam safety office project plan document dated February 13, 2003, referred to "algae and iron bacteria" clouding the water in the vault. The sample was submitted to the ESRL in February 2003 and assigned the laboratory index No. 19S-73.

Physical properties tests and the petrographic examination were conducted in the ESRL.

The purpose of the petrographic examination was to determine the mineralogical composition of the sediment. Physical properties and loss on ignition (LOI) testing were performed on the sample. Advice on biological identification was requested.

PHYSICAL PROPERTIES TEST RESULTS

The physical properties tests were performed following procedures described in: USBR 5330, Performing Gradation Analysis of Fines and Sand Size Fraction of Soils, including Hydrometer Analysis; USBR 5350, Determining the Liquid Limit of Soils by the One-Point Method; USBR 5360, Determining the Plastic Limit and Plasticity Index of Soils; and USBR 5430, Determining Moisture, Ash, and Organic Content of Soils.

Sediment sample 19S-73 was determined to be Silty Sand (SM) with no plasticity. Figures 1 and 2 contain the particle size and grain size distribution test reports and selected physical properties (test results not included here).

PETROGRAPHIC EXAMINATION AND RESULTS

The submitted sediment was examined megascopically, microscopically, by X-ray diffraction and by some qualitative physical and chemical tests. The percent organic content of the sediment was determined by loss on ignition (LOI).

The as-received sediment sample 19S-73 was wet and grayish brown. When air dried the material was loose and sandy and forms friable aggregates. Sediments consist of silt and sand size particles up to about 1.5 mm in diameter. The angular to chiefly subrounded sand size particles were composed of glassy volcanic particles, altered volcanic particles, kaolin(?), feldspar, magnetite, and unidentified altered crystals with miscellaneous minerals in the finer sizes (figure 3). Examination of the unwashed silt size particles revealed high amounts of amorphous volcanic glass.

X-ray diffraction analysis results revealed kaolinite, feldspar, and tridymite with minor hematite and trace quartz.

LOI was determined in the petrographic laboratory using a method similar to USBR 5430, Determining Moisture, Ash, and Organic Content of Soils. About 50 gm of air dried sediment was held at 400 degrees C for 8 hours. The percent organic content was determined to be 8.0 percent.

BIOLOGICAL IDENTIFICATION

Biological identification of any organic materials in the submitted sample cannot be performed due to the condition of the sample. If a biological identification is desired, the Ecological Research and Investigations Group, D-8220, may be able to provide assistance. Contact Denise Hosler (303 445-2195) or Fred Nibling (303 445-2202) for more information.

Attachments

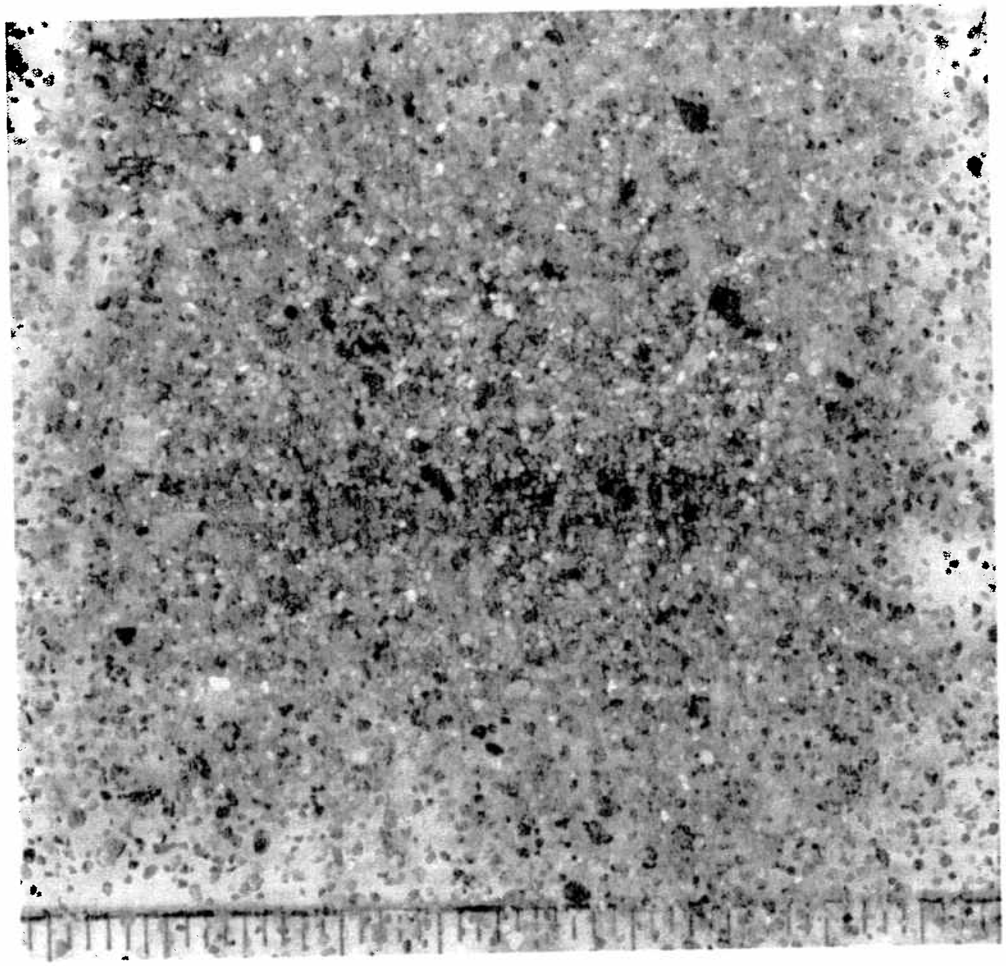

Figure 3. Washed Sand Size Sediments from ESRL Test Procedure USBR 5330. The scanned image provides visual documentation of the coarser sediments in sample 19S-73 for future reference. Note the millimeter scale.

Denise Hosler's Wasco Memo here (don't have electronic copy at this time)

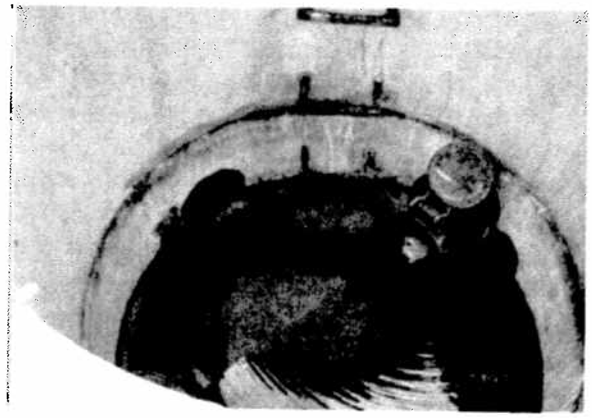

Figure 1. The manhole shows an example of biofouling

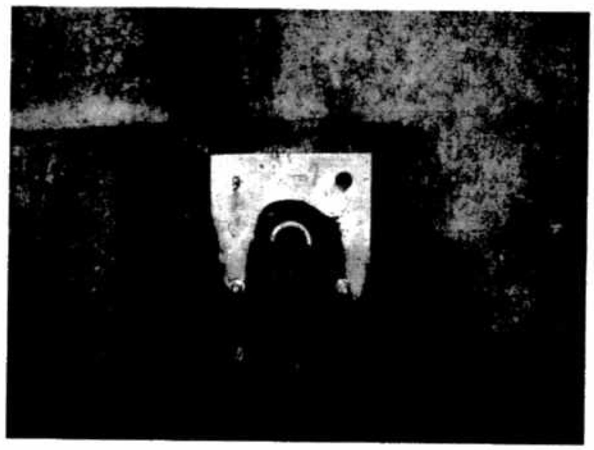

Figure 2. The weep shows an example of a sulfate (black) related biofilm

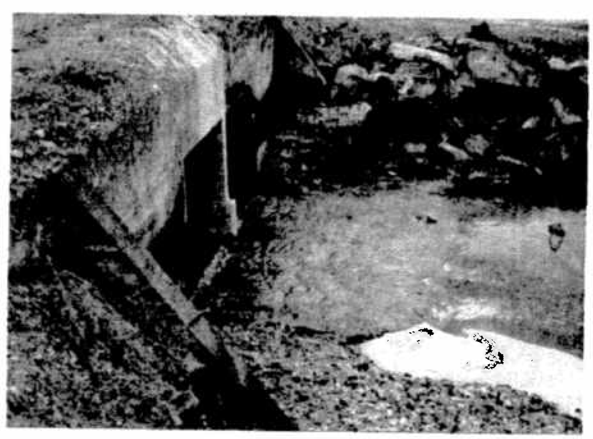

Figure 3. The outlet shows an example of biofouling.

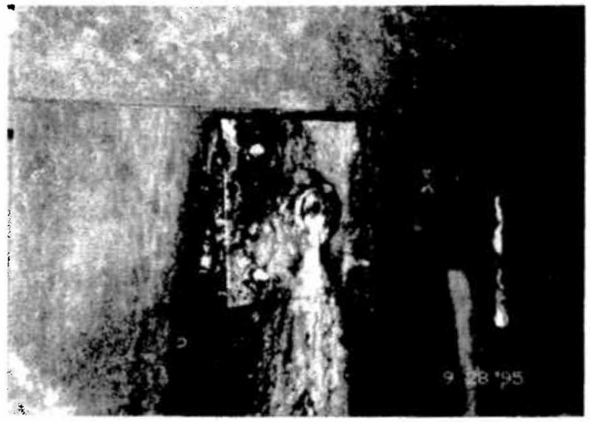

Figure 4 The weep hole shows an example of sulfur (yellow) and phosphorous (white) related biofilm.

Figure 5. The weir shows an example of biofouling.

Figure 6. The bacterial growth is partially covering the inside of 8-inch diameter HDPE pipe.

Figure 7. Bacterial grow is shown completely covering the 8-inch diameter HDPE pipe.

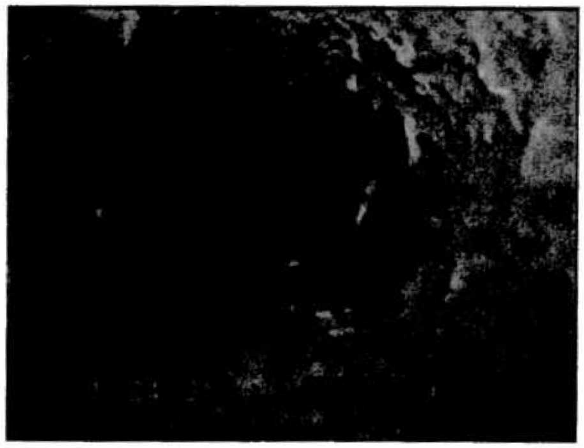

Figure 8. Bacterial grow is shown completely covering the 8-inch diameter HDPE pipe.

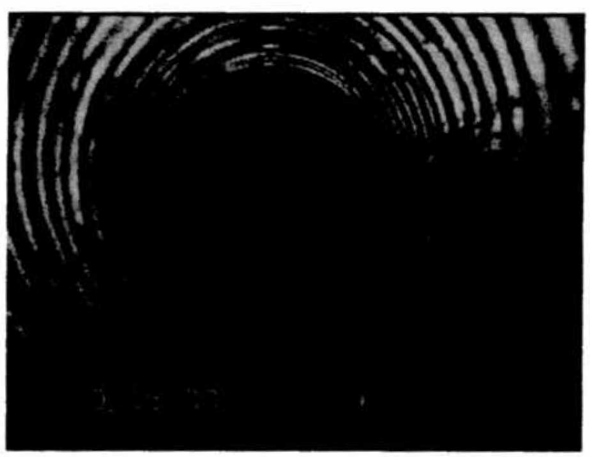

Figure 9. Bacterial growth is shown covering the 8-inch diameter HDPE pipe invert.

Figure 10. Calcium carbonate precipitate was observed covering the 18-inch pipe interior about 60 ft upstream of the outfall exit portal of a toe drain.

Figure 11. Sediments were observed fouling the invert portion of a 12-inch diameter HDPE pipe.

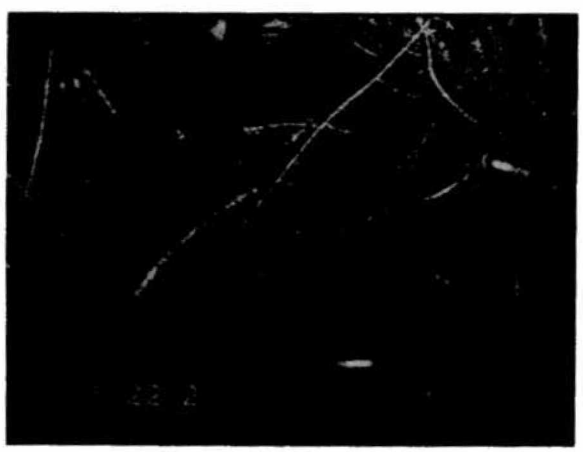

Figure 12. Vegetative growth shown fouling 8-inch-diameter HDPE pipe.