Lake Fork Reservoir BMP Implementation Project

Nonpoint Source Pollution Project

Texas State Soil and Water Conservation Board
FY93 CWA Section 319(h)

Final Report
December 1998

STATE SOIL AND WATER CONSERVATION BOARD

Lake Fork Reservoir Watershed NPS Project Final Report

Texas State Soil and Water Conservation Board

CONTRACT #994-592-4200000040
FY93 CWA SECTION 319(h)
DECEMBER 1998

ACKNOWLEDGEMENTS

The Texas State Soil and Water Conservation Board (TSSWCB) is especially indebted to Danny Coke and John Beezley, the two landowners that participated in the project. Without the patience of these two individuals, the implementation portion of the project would not have been successfully completed.

The TSSWCB also genuinely appreciates the dedication and hard work of the agencies involved in the project. Specifically, the TSSWCB would like to thank the Hopkins-Rains Soil and Water Conservation District (SWCD) and the Natural Resources Conservation Service (NRCS) for their assistance in the nonpoint source (NPS) pollution prevention activities throughout the course of the project. The SWCD, along with Jim Wyrick and his staff at the NRCS, have done an exceptional job in working to increase the voluntary adoption of BMPs in the Lake Fork Watershed. The Texas Institute for Applied Environmental Research (TIAER) is also to be commended for their diligent efforts in collecting and analyzing data and providing overall project guidance. The TSSWCB is privileged to work alongside an excellent organization such as TIAER. The TSSWCB would like to thank the Texas Agricultural Experiment Station (TAES) for their TEX*A*Syst educational activities in the watershed. The TSSWCB also sincerely appreciates the Texas Agricultural Extension Service (TAEX) for their preparation of the "Dairy Outreach Training Guides" and for hosting an educational workshop for dairy operators in the watershed. Last, and certainly not least, the TSSWCB wishes to thank Carol Whittington of the TNRCC for her excellent project oversight.

SUMMARY

The Lake Fork Reservoir (LFR) watershed is an approximate 575 square mile area located within the Sabine River Basin in Hopkins, Rains, Wood and Hunt Counties. The reservoir itself is approximately 40 square miles in size and was constructed as a drinking water supply and recreational reservoir. This watershed has a significant number of agricultural operations, primarily dairies.

This section 319(h) project was developed to promote the adoption of best management practices (BMPs) to reduce nonpoint source pollution in the Lake Fork watershed. The project was funded by the U.S. Environmental Protection Agency through the Texas Natural Resource Conservation Commission (TNRCC) and the Texas State Soil and Water Conservation Board (TSSWCB). Project participants included the Hopkins-Rains Soil and Water Conservation District (SWCD), the Natural Resources Conservation Service (NRCS), the Texas Institute for Applied Environmental Research (TIAER) at Tarleton State University, the Texas Agricultural Extension Service (TAEX) and the Texas Agricultural Experiment Station (TAES). In addition to the cooperating agencies, local citizens and technical experts provided necessary project input through coordinating committees established early in the project.

The primary tasks of the TSSWCB portion of the project included completing an inventory and GIS database in a sub-watershed of the Lake Fork watershed, pre- and post-BMP monitoring of two demonstration sites in the sub-watershed, NPS management activities in the sub-watershed (implementation of waste management systems), assessing the effectiveness and economics of implemented BMPs and education and technology transfer.

Based on data collected by TNRCC in Task 2.1, the Running Creek sub-watershed was chosen because of the relative impacts from agricultural activities in the watershed. NRCS and the SWCD installed a total of 12 Waste Management Systems during the course of the project in this watershed. Two of these systems were chosen as project demonstration sites. A complete listing of the BMPs that were implemented in the sub-watershed is included in the report prepared by NRCS (TASK 3.1).

Unfortunately, because of a delayed QAPP and weather constraints, the BMPs were not installed in time to collect post-BMP data. However, the pre-BMP data was collected and analyzed and is included in the report. Although post-BMP data was not collected to assess BMP effectiveness, these practices have been proven to be effective in the past. If they were not effective practices, they would not be listed in the *NRCS Field Office Technical Guide*.

The project accomplished several important objectives:

- 12 Waste Management Systems were installed in the sub-watershed, which include numerous BMPs designed to reduce nonpoint source pollution.

- A Lake Fork Reservoir Watershed and Running Creek Sub-Watershed Geographic Information System Data Report was generated which provides an excellent overview of the watershed characteristics. This will be very useful for any future work performed in the watershed.

- Pre-BMP data collected on two dairies in the Running Creek sub-watershed. This data is important because it depicts the impact of dairies on water quality prior to using BMPs. This information may be important in the development of TMDLs in watersheds that contain dairy operations.

- Document summarizing the overall economics and effectiveness of BMPs in general.

- Dairy Outreach Training Guide for non-permitted dairy producers was developed and used in a training program for dairy producers in the project area.

PROGRAM ELEMENT 3: LAKE FORK RESERVOIR BMP IMPLEMENTATION TEXAS STATE SOIL AND WATER CONSERVATION BOARD (ELEMENT COST: $375,000)

OBJECTIVE 1: Project Planning and Coordination at a cost not to exceed: $37,500

Task 1.1 Coordinate with Appropriate Interests

The TSSWCB will coordinate project activities with the TNRCC, Hopkins-Rains Soil and Water Conservation District, Texas Institute for Applied Environmental Research (TIAER), Natural Resources Conservation Service (NRCS), Texas Agricultural Experiment Station (TAES), Texas Agricultural Extension Service (TAEX) with regard to the agricultural aspects of this project.

Deliverables: Copies of minutes and attendance list of meetings

Milestones: August 1998

Task 1.2 Evaluate Available Information

The TSSWCB will complete an inventory and GIS database for the watershed including land use, soils information, streams, highways, location, size and types of dairies (permitted, 503 water quality management plans, unpermitted). Current management practices will be inventoried for the dairies in the Running Creek subwatershed. Data will be evaluated and used to support project activities and the implementation of BMPs.

Deliverables: Inventory of dairies, current management practices, and GIS database

Milestones: January 1998

Task 1.3 Quality Assurance Project Plan

The TSSWCB will prepare a quality assurance project plan (QAPP) for edge-of-field monitoring to determine the effectiveness of BMP implementation. QAPP will be submitted for review and approval prior to field implementation and monitoring.

Deliverables: QAPP to TNRCC and EPA

Milestones: March 1997

OBJECTIVE 2: Determine baseline conditions and prioritize subwatersheds with NPS loads at a cost not to exceed : $0

Task 2.1 Determine Baseline Conditions

The TSSWCB will obtain and develop data and other technical information pertaining to agricultural activities as necessary to assist TNRCC in identifying and quantifying NPS pollutant loads. Also, TSSWCB will provide concurrence to TNRCC on baseline condition determinations relating to agricultural activities.

Deliverables: Input to interim technical report developed by TNRCC that describes the baseline conditions.

Milestones: January 1996

Task 2.2 Prioritize NPS Pollution

Data and other technical information assimilated in Task 2.1 will be utilized and evaluated by TNRCC Region 5 project staff to determine a subwatershed with relative impacts from agricultural activities. TSSWCB will provide concurrence to TNRCC on the selected subwatershed.

Deliverables: Input to an interim technical report developed by TNRCC that describes the prioritized subwatershed with NPS Loads.

Milestones: January 1996

OBJECTIVE 3: Implement NPS Management Activities at a cost not to exceed: $225,000

Task 3.1 NPS Management Activities

In the Running Creek subwatershed, the TSSWCB will develop and implement dairy water quality management plans on a voluntary basis. BMPs standards established by the NRCS Technical Guide and adopted by the Hopkins-Rains SWCD will be used in the design of the water quality management plans. The TSSWCB and NRCS will work with the local SWCD to include in the water quality management plans appropriate BMPs and practice standards to address identified NPS impacts. Through the SWCD, dairy producers will be encouraged to develop and implement water quality management plans, utilizing technical assistance provided by the NRCS and TSSWCB. Water quality management plans will be approved by the district and certified by the TSSWCB as meeting appropriate practice standards and being consistent with State water law. Once plans are approved and certified, dairy producers will be provided technical and financial assistance to implement the water quality management plans. Water quality management plans will be implemented on dairies within the Running Creek subwatershed. On two of the dairies with water quality management plans, water quality monitoring will be conducted to determine the effectiveness of BMPs implemented.

Deliverables: Copy of water quality management plan developed and implemented in target subwatersheds.

Milestones: May 1998

OBJECTIVE 4: NPS Management Effectiveness Evaluation: Determine effectiveness of BMPs implemented; Examine operating cost, alternatives for financing BMPs and problems with the use of various BMPs at a cost not to exceed: $93,750

Task 4.1 NPS Management Evaluation

TSSWCB will assess best management practice implementation to determine the effectiveness with respect to:

(1) Water quality monitoring on two dairies with water quality management plans
(2) Capitol and operating costs
(3) Methods/alternatives for financing BMPs
(4) Problems/Constraints associated with the use of various BMPs

Deliverables: Preliminary and final technical reports showing effectiveness of BMPs implemented on two dairies. A report that assesses the performance of BMPs for each consideration listed above.

Milestones: January 1998
August 1998

OBJECTIVE 5: Information/Technology Transfer: Increase the Awareness of the Local and Effected Community Regarding NPS Pollution, NPS Prevention/Control Practices, and the Nature and Value of the Local Environmental Resources at a cost not to exceed; $18,750

Task 5.1 Information Transfer Activities

TSSWCB educational activities will be geared toward dairy owners in the Running Creek subwatershed. Educational activities will consist of the following:

(1) TSSWCB will work with TAEX in establishing and operating a dairy training program that includes appropriate curriculum/manuals on dairy waste management for small dairy owners in the targeted subwatershed, distributing manuals to dairy owners, conducting one workshop that makes dairy owners aware of how activities could contribute to NPS pollution.

(2) TSSWCB will work with TAES to complete a TEX*A*Syst program in the Running Creek subwatershed. Activities in this program will include: conducting an inventory of water wells in the subwatershed and determine the potential for contamination (improper storage of dairy manure, pesticides, etc.) for these well owners, distributing TEX*A*Syst materials to dairy owners, conducting two workshops that make dairy owners aware of how activities could contaminate groundwater resources.

Deliverables: Copies of dairy waste management manual, copies of distribution list for dairy waste management manuals, agendas and attendance list for workshops, copies of inventory of water well owners, copies of TEX*A*Syst materials. This information will be provided in quarterly reports and summarized in the last report of each fiscal year.

Milestones: August 1998

TASK 1.1 Coordinate with Appropriate Interests

The TSSWCB will coordinate project activities with the TNRCC, Hopkins-Rains Soil and Water Conservation District, Texas Institute for Applied Environmental Research (TIAER), Natural Resources Conservation Service (NRCS), Texas Agricultural Experiment Station (TAES), Texas Agricultural Extension Service (TAEX) with regard to the agricultural aspects of this project.

- Numerous meetings were held throughout the project to discuss the project details. Meeting minutes are attached.

First Meeting of the Local Coordinating Committee
for the
Lake Fork Reservoir Nonpoint Source Management Project

June 8, 1994
7:00 PM

MEETING MINUTES

Meeting convened at 7:15 PM

The meeting began with Dick Respess of the Texas Natural Resource Conservation Commission (TNRCC) introducing himself as well as introducing Bo Spoonts of the Texas State Soil and Water Conservation Board (TSSWCB). The meeting participants also introduced themselves to the other participants.

Dick Respess: Gave an overview of the purpose of the Lake Fork Reservoir (LFR) Nonpoint Source Pollution (NPS) program which is to gather baseline data, determine NPS areas in the Lake Fork Reservoir and implement Best Management Practices (BMP's).
Bo Spoonts: Explained the difference between TNRCC and TSSWCB and that this program would involve voluntary cooperation among all entities within the LFR watershed.

Dick Respess: EPA's responsibility is to provide project funding and insure that proper sampling procedures are followed. Dick then stated that TNRCC will conduct the baseline sampling for water quality monitoring and define which NPS sites will be part of the program. TSSWCB will then be responsibilble for implementing BMP's at these locations.
Bo Spoonts: TSSWCB is not a regulatory agency and would work in conjunction with the Texas Agricultural Extension Service (TAEX) and the Soil Conservation Service (SCS) and go up into the watershed to see what are possible causes of NPS pollution. The basic approach will be to involve landowners in the watersheds to develop waste management plans. Bo further explained BMP's and some of the practices in installing them to improve water quality. Hopefully, technology transfer will result.

Dick Respess: Stressed the importance of local cooperation to make this program a success.

Dave Koran: (Groundwater division at TNRCC) said he will be doing groundwater sampling during the baseline sampling period to determine problems.

Marilyn Long: TNRCC's Agriculture Permitting and Enforcement Section gave out handouts on TNRCC's Texas Watch, Citizen's Monitoring and Dairy Outreach programs.

Ed Hansalik: SCS and Lake Fork Creek HUA said that he and Billy Brown of TAEX were attending the meeting as citizen advisors to advise on innovative and economic ways to implement BMP's to producers who request assistance.

Dick Respess: The Local Coordinating Committee (LCC) was required by EPA as part of the program. The purpose of the LCC is to be the "eyes and ears" of the community to make sure that all community interest in the program are covered.

Bo Spoonts: Added it is important the LCC keeps TNRCC and TSSWCB informed of local historical data and local input into the project.

Dick Respess: Baseline monitoring will begin when EPA approves the Quality Assurance Project Plan (QAPP) in 60-90 days. Dick will keep the LCC informed of progress of the baseline sampling and everyone will meet again as soon as the data is collected.

Question and Answer Session:

1. Bill Elliot - When will the local media be notified of the program?
   Dick wanted the media informed after the QAPP had been approved and the sampling was underway.
   Bill wants the media informed of the same information that was presented at this meeting.
   Bobby McDonald added that he wants the media to know that this program is a cooperative effort and the LCC be involved in the media release.
   He would also like to introduce TNRCC sampling personnel to the local community to make them of aware of the reasons for sampling.

2. Ed Hansalik - What are incentives of producers to implement BMP's?
   Bo Spoonts said there were 2 incentives. First, there would be a 60/40 match to implement BMP's and possibly more through Senate Bill 503. Second, after the project is over, the ASCS and SCS may cost share additional funds.

3. Bobby McDonald - Who would help implement the BMP's?
   Bo said the TSSWCB Mt. Pleasant staff and/or subcontractors.
   Marilyn Long emphasized that the dairy outreach program is voluntary compliance and is to provide owner/operator assistance. Enforcement is the last resort.

4. Don Smith - Who is establishing the ground water baseline?
   Dick said EPA wants the ground water sampling done at same time as water quality sampling.
   Dave Koran said he will choose 25 water wells to sample but knew nothing more at this time.

Don Smith concerned about the short time period to sample, establish and implement BMP's (3 years).
Bo said that not everyday NPS will be addressed in the 3 year period but only the "hot spots". Bo also agreed that 3 years was not nearly enough time (more like 5-8 years was needed) but that EPA was mandated by Congress to show improved water quality within a 3 year time frame.

Meeting adjourned at 8:50 PM.

AGENDA
LAKE FORK RESERVOIR WATERSHED
COMPREHENSIVE NPS WATER QUALITY MANAGEMENT PROJECT
LOCAL COORDINATING COMMITTEE MEETING
JUNE ~~6~~ 8, 1994

Introductions (Respess)

Project Summary (Respess/Spoonts)

- EPA Responsibilities (Fisher)
- TNRCC Responsibilities
  - Nonpoint Source (Respess)
  - Field Operations (Respess)
  - Groundwater (Koran)
- TSSWCB Responsibilities (Spoonts)

Other Related Activities

- TNRCC, TEXAS WATCH, Citizen's Monitoring (Campbell)
- TNRCC, Dairy Outreach (Long)
- Lake Fork Creek Hydrologic Unit Project (Hansalik)
- Others????

Local Coordinating Committee Responsibilities

- Informed of Project Status & Direction
- Provide Local Input re Project Focus & Direction

What Next?????

- Evaluate Available Information
- Prepare Project Plans
- Baseline Monitoring
  - Low/normal flow water quality, sediment, & biological (20 sites)
  - Stormwater runoff water quality (8 sites)

Next Meeting?????

Newsletter of Project Status!!!!!

LFI LCC Meeting
6-8-94

Name		Telephone #
Richard O. Respess, TNRCC		[redacted]
Bo Spoonts, TSSWCB		
MARILYN LONG, TNRCC		
David Koran, TNRCC		
Bobby McDonald		
KEITH BLAIR	Lake Fork Marina	
Dennis Canoda	Lake Fork	
Randy Rushin	TIAER	
MIKE PRATER	TNRCC R-5	
TROY HENRY	SRA	
John Payne	SRA	
ANDREW LABAY	TPWD	
EDWARD K. HANSALIK	USDA-SCS	
LARRY HAUCK	TIAER	
Don Frost	Dairy + Beef Producer	
Suzanne Cardwell	TSSWCB	
Bill Elliott	Hop. Co. Chamber of Com	
Billy J Brown	TAEX	
Vera Harrington	Dairy Producer	

LAKE FORK RESERVOIR
LOCAL COORDINATING COMMITTEE MEETING MINUTES
SEPTEMBER 15, 1994

Meeting convened at 7:15 p.m.

The meeting began with introductions of all attendees. Three Local Coordinating Committee members were present in addition to Technical Advisory Committee members from several state, local and federal agencies.

DICK RESPESS (TNRCC) opened by giving an overview of the project and the respective roles of TNRCC and TSSWCB for the benefit of the committee members present. He also discussed TNRCC Region 5 representative Randy Rushin's role in collecting water, sediment,fish and benthic macroinvertebrate samples in several selected subwatersheds. Dick explained that results of Randy's activities will assist TNRCC/TSSWCB in determining the extent of nonpoint source problems in the region.

BO SPOONTS (TSSWCB) further discussed TSSWCB's role in working with local dairymen to promote the implementation of Best Management Practices (BMPs). In order to document improvement, the project must collect baseline data to determine the nature and extent of BMPs required. Bo stressed that voluntary participation is the Soil Board's objective. The TSSWCB has a 75/25 cost share incentive program which is in addition to the Lake Fork HUA cost share dollars which are also available.

BOBBY McDONALD (LCC) asked about the timeline for implementation of BMPs.

DICK RESPESS (TNRCC) stated that final selection of subwatersheds for the study will be completed in Spring of 1995.

H. D. POTTS (LCC) asked if the State would be soliciting the support of those dairymen in the selected subwatersheds.

BO SPOONTS (TSSWCB) replied affirmatively and reiterated that the project's goal is not to tie NPS pollution to a specific dairy for regulatory action, but to foster cooperation among local dairymen in improving water quality.

CLETIS MILLSAP (LCC) asked if the state would be investigating other sources of pollution such as fertilizers and septic systems.

RANDY RUSHIN (TNRCC) at this point distinguished between point source and nonpoint source pollution for those unfamiliar with the terminology.

[A side discussion followed at this time among several members of the Technical Advisory Committee concerning security with field sampling equipment.]

CLETIS MILLSAP (LCC) asked if the Lake Fork Reservoir currently has pollution problems.

DICK RESPESS replied that no one really knows at present.

GERALD SALA (Sabine River Authority) stated that the River Authority is presently engaged in doing assessments on the reservoir for the Clean Rivers Program which is to be completed next month. There is not a whole lot of water quality data existing at this time.

H. D. POTTS asked why is there a problem in the Lake Fork watershed.

GERALD SALA (SRA) replied that the problem exists in the **potential** of nonpoint source pollution given the density and presence of nutrient/coliform sources in the watershed. Tributaries with dairy operations may be contributing to a nps problem but much of the data is anecdotal. The river authority wants to determine if loading capacities are being exceeded and what is causing the problem.

RANDY RUSHIN (TNRCC) repeated that TNRCC does not want to see fines imposed on local dairymen. TNRCC wants to see dairymen comply with water quality protection on a voluntary basis.

BOBBY MCDONALD (LCC) stated that the future trend of the dairy business is toward a reduction in the number of dairies but an increase in herd size. He sees a need for technology for waste management to be adapted to accomodate herd sizes of up to 500 head. (The current local dairy averages about 175 milking head.)

Gerald Sala was asked at this point about the functions of the Sabine River Authority. Mr. Sala gave an overview of the River Authority and briefly discussed the Lake Fork Reservoir development. The SRA sees the concern that dairies could be a problem in the area but no hard data exists to support this assumption. The SRA is committed to helping solve water quality problems since the river authority's financial support is dependent on the sale of good quality water to its customers

DICK RESPESS (TNRCC) mentioned that he had seen some heavy emergent vegetation in the reservoir and wondered if there were any problems with vegetation.

ANDREW LABAY (TPWD) replied that he had not seen a water quality problem as a result of vegetation or algae in the Lake.

DICK RESPESS (TNRCC) next distributed handouts for the TNRCC TX Watch and Dairy Outreach programs and announced that TNRCC's new Dairy Outreach representative, Mr. Luis Aguirre, will be coming to Hopkins County in the near future. The Dairy Outreach representative will provide assistance to local dairymen to ensure compliance with TNRCC rules and regulations as well as provide information on BMPs. Dick also gave an update on the status of the Quality Assurance Project Plan.

[A discussion ensued here concerning cost sharing under the Dairy Outreach and ASC programs. If there is regulatory action against a dairy then no cost share assistance is available. As long as a dairyman is in compliance with an approved waste management plan then he is eligible for cost sharing. ASCS cost share dollars are restricted to the watershed.]

BOBBY McDONALD (LCC) asked if there was anything that TNRCC/TSSWCB wanted the LCC members to do in the meantime.

RANDY RUSHIN (TNRCC) requested the assistance of the LCC members to do what they could to inform the local dairymen about the purpose of his field work so that there would be no misunderstanding as to the intention of his activities in the local tributaries.

A final discussion of the meeting concerned potential problems surrounding the reception of the TNRCC Dairy Outreach representative, Mr. Aguirre, among local dairymen. The LCC members discussed several options of how to introduce Mr. Aguirre to the dairy community. Dick Respess encouraged the LCC Committee members to contact Mark McFarland with TNRCC who is the project manager for the Agricultural & Rural Assistance Division's portion of this project. Dick said that he would contact Mr. McFarland as well.

The meeting was adjourned at 8:55 p.m.

Lake Fork Coordinating Committee 9/15/

Carol Whittington	TNRCC	[redacted]
Suzanne Cardwell	TSSWCB	
Bo Spoonts	TSSWCB	
June Wolfe	TAES / Blackland Research	
Tim Jones	TIAER Stephenville	
[illegible]	Potts Feed Store	
Andrew Sabay	TPWD	
Cletis Millsap	Justice of the Peace (Hopkins Co.)	
Billy Brown	TAEX Lake Fork Creek HUA	
Troy Henry	Sabine River Authorit	
John Payne	Sabine River Authority	
Gerardo Sala	Sabine River Author.	
Randy Rushin	TNRCC - Tyler Region 5	
Richard O. Respess	TNRCC - Austin	
Bobby McDonald		

Meeting Minutes
October 2, 1996
Lake Fork Project Meeting

Attendees:

Carol Whittington (TNRCC)
Suzanne Cardwell (TSSWCB)
Bo Spoonts (TSSWCB)
Justin Hester (TSSWCB)

I. Project Extension is needed - 1 year extension. Carol had the extension approved through 1997, but accidentally forgot to send it to us. This caused the project to die and Carol must now "resurrect" the project. This will require a good deal of paper work. We have a revised workplan through September of 1997. Larry Hauck can not do any work for the project until he gets a copy of the extended contract.

II. Randy Rushin (TNRCC) is handling the surface water portion for the project. He is doing sampling from the Tyler field office. He has storm water stations in the priority watersheds. Five of them are in the priority watershed (Running Creek) and two are in the non-priority (Elm Creek). This surface water portion of the project has its own approved QAPP.

III. The edge of field samples (TIAER) that we will be collecting off of the dairy can not get underway until we get an approved QAPP.

IV. The ground water portion of the project (TNRCC) also has its own approved QAPP. They are using monitoring wells (lysimeters) to monitor the leakage from the lagoons. Cary Betz and Paul Reynolds are working on the ground water component.

V. Jim Wyrick is the D.C. for this area. He has found an additional dairy for the project. We will discuss this dairy in the upcoming meeting on the 17th.

Lake Fork Project Meeting
November 15, 1996

Attendees:
Dave Corran
Paul Reynolds
Brian DuBose
Larry Hauck
David Powell
Jim Wyrick
John O'Connor
Justin Hester

- Brian DuBose with TIAER is doing the sampling. TIAER will be monitoring before and after BMPs (lagoons). The QAPP needs to be in place before any monitoring can begin. Larry H. and I worked on the QAPP in October.
- Two dairies: Coke and Beasley – both of these will have BMPs in place.
- Paul Reynolds (TNRCC ground water team) said that they will be installing piezometers and lysimeters and look at the groundwater effects. They will not be monitoring the water sources.
- Discussed the workplan and budget revision – Carol W. got a 1 year extension but forgot to send it to us. Larry can not continue his work until the contract is in his hands. The additional one-year extension is also at EPA.

- What is the role of Experiment station? They have already completed their portion of the project. They performed TEX*A*Syst presentations.
- Extension's role is to prepare a non-permitted dairy producer training manual and provide

- TIAER will collect pre-bmp data (minimum of 6 months) and then collect post-bmp data. QAPP must first be approved. They are worried about being under a time constraint.

- Paul Reynolds will not be sampling potable water – but will be using piezometers for subsurface flow. He needs to revise his portion of the workplan and get his QAPP approved. LCRA is doing his lab work.
- Discussed the chances that we take when choosing dairies. They could be going out of business over the next 2 years. Milk prices have really started dropping and cheese prices have plummeted.
- Summer of next year the BMPs will hopefully be in place.
- Discussed the origin of the project, who came up with the idea, etc. It was decided that Clyde Bohmfalk, Dick Respess (retired) and James Moore were the originators. TNRCC said the project was two years behind schedule due to it being hung up in the grant process.

- Jim mentioned that the LAC meeting have not been too effective and we have not had anything to report to them.
- Bo had an idea of a local meeting in the area to let all interested people know everything that is going on in the watershed. The local SWCD will be the most effective folks to have at this meeting. If it satisfies the local SWCD it will most likely satisfy the majority of the locals.
- There are 33 dairies in the Running Creek Watershed and 29 of them have received some type of technical assistance. The majority of them are in different stages of conservation plans. The include waste storage ponds and everything else that relates to water quality.

- Discussed the QAPP and the amendment that Carol Whittington will get to us soon.

- Spoke with Paul Reynolds about a site visit in December.

Lake Fork Project Meeting
May 8, 1997

Attendees:
Carol Whittington
Richard Egg
Bo Spoonts
Paul Reynolds
Randy Rushing
Carl Hutcherson
Justin Hester

- Carol W. passed out the budget and expenditures and she offered up any unspent money.
- Randy Rushin discussed that this project came about because of politics – a democratic congressman was pushing for it. He also went over the data collect thus far by the Surface water team at TNRCC. Original concept was to find streams only impacted by dairies, impacted only by humans and unimpacted – this was impossible.
- Bo said that the main thrust was Source Identification – "share the blame"
- Randy says that you can get fecal coliform reproduction within the soil. So fecal coliform follows the hydrograph curve. So during a rainfall event, it was high and then returned to normal 24 hours later.

- The discussion the led to how to restructure the project with 1.5 years remaining – is this needed? Should we redirect the money to another project. Should we continue the project? We are not sure what to do

- Randy mentioned that the nutrients are hottest at the top of the watershed and seem to dilute as you move downstream. Carl mentioned using a GIS predictive model.
- How are we going to validate success?

- Noel mentioned that the DOPA program is hitting this watershed hard.

- Len mentioned an inspection team that completes an evaluation of what is needed in the watershed. This would involve going door-to-door. Pull the people together in a meeting and discuss this. Use the TAEX program mechanism. Len also mentioned putting together some type of kit that an inspector will utilize when going out (possibly door to door).
- Problems in the watershed – nutrients and fecal coliform.
- Where are the nutrients coming from? Dairies, fertilization application, on-site septic systems, and waste water outflows.
- Randy Rushin monitored below treatment plants and these don't seem to be a problem. Lake Fork was impounded in 1975 and has a high nutrient content. This has proved beneficial to the fish population, but the carrying capacity of the lake may be exceeded and cause a negative impact.

- Carl H. mentioned a heavy hitting outreach program. Show producers how the BMPs will pay off eventually. Control it now with 503 and 319 or pay more later. In order for this work we need the buy-in of stakeholders in the area.
- Next meeting in Tyler on June 5th.

Lake Fork Project Meeting
June 5, 1997

Attendees:

Len Pardee	Carol Whittington
Carl Hutcherson	Paul Reynolds
Byron Spoonts	Cary Betz
Justin Hester	Noel Luper
Richard Egg	Randy Rushin
Tim Jones	

(these are the attendees that I was able to write down)

- Randy Rushin discussed the 319 National Monitoring Program and that the Lake Fork project would lend itself well to this type of project. He handed out some information. This would include all components of the watershed.
- Discussed septic systems – TNRCC has enough work from complaints. Banks are now requiring TNRCC's septic system approval before they give the loan. TNRCC estimates that 90% of the septic systems in the watershed have not had any attention.
- Carl and Len questioned why we need the GIS/GPS component in the workplan, since we can already predict what is going to happened with predictive models. Much of this work has already been completed and it will provide a great map of the watershed.
- Len asked about a maintenance program for septic systems. How do we know that the systems are being maintained? TNRCC does not have the staff and septic systems on private property is a sticky issue. The TSSWCB does not want to deal with them; however, we are dealing with them in some of our current projects.
- There are 57 facilities in the entire watershed.
- Barbara Parmley (DOPA) – wants to know which dairies in the watershed have WQMPs and are in compliance. We discussed the TSSWCB regional office, NRCS and the complaint resolution program. 10% of WQMPs undergo Annual Status Reviews as well. In addition, we discussed that the producers have a grace period of two years to implement all practices.
- Discussed artificial liners – these are requirements in some waste storage ponds. All waste storage ponds with these liners must have monitoring wells – can piezometers be considered monitoring wells?
- I need to call Jim Wyrick and ask him about funds allocated for the two dairies involved in the project.
- Discussed an additional project in the watershed that uses 503 money as 319 money. Do we want to change the requirements under this separate possible project. No, it was decided that it was cause major problems with others if we give someone who has waited to install practices more than those who did the right thing and installed the practices a couple of years ago.
- We need to get feedback from Carol's regarding money, TSSWCB upper management and our upper management.
- Bo will call Randy R. about the pond liners.

Training Manaual meeting with TAEX
7/7/97

Attendees:
Sandy Stokes
John Sweeten
Lanny McDonald
Justin Hester
Richard Egg
Beade Northcutt
Bo Spoonts, Jr

- Discussed the Technical Assistance Project that may be forthcoming in the Running Creek Watershed.
- Discussed that an extension has been requested by TNRCC to EPA.
- Discussed when the workshop for the Traininn Manual will be held. A date of November or possibly even Spring will be fine.
- We also discussed not calling this a certification program. We will change this wording in the workplan and send to TNRCC and EPA for approval. In place of this, we will include a certificate of completion for all who attend the training. This will be included in their WQMPs. TAEX will complete these certificates.

- The main purpose of our meeting was to go through the draft training manual and discuss overall comments. Overall the manual was technical.
- TAEX will make all the changes we discussed and send it to us for another review. We will then approve it in house and send it to the State Board for their review and approval.

Lake Fork Meeting
February 4, 1998

Items to discuss:

1. Meeting on February 24, 1998 – Barbara Parmley
2. April 14 – Training Program for non-permitted dairies
3. TIAER – sample through June
4. If it dries up in April – do we go ahead and put the practices in or included that in the Phase II workplan?
5. Will the approximate $185,000 be attached to our FY98 dollars? If so, will we have to have an approved workplan for the Phase II project in order to receive the FY98 funds?
6. Need something in writing from Len-Carol-TSSWCB-Larry explaining the change in project focus.
7. QAPP revision – leave alone and use the post-bmp information for the Phase II project.
8. Groundwater – how to get equipment in? If we decided we are not going to put the practices in for this portion of the project and we tag those on to the Phase II portion, then we could possibly put this equipment in place.
9. Invoices

Lake Fork Conference Call
January 21, 1998

Those participating in the call: TNRCC, TSSWCB, EPA

- Carol Whittington explained that there is $237,000 federal dollars remaining in the account.
- Carl Hutcherson mentioned that we should get the people in the Running Creek Watershed together to discuss a possible implementation project.
- We discussed that although the Sabine River is not on the 303(d) list some poor water quality hits are being noted. This area would still be eligible for some pollution prevention work.
- We know that there is a need in the Running Creek watershed; however, we need to be able to show some short term results (trends).

What are we going to do about the FY93 project – the saturated conditions are going to prevent the BMP implementation soon enough to collect post-BMP results.

- Len mentioned spending money out of one project and paying for another. Freeing up newer money to designate to another project – this way the money will not expire. Not sure if we want to do this or not.
- Carl said that we could propose to TIAER that they could continue pre-BMP monitoring until their contract expires. Then under another project they could come back and collect additional data (post-BMP). We need a drop-dead date to have the WQMPs implemented.
- We could pick up the WQMP construction activities under another workplan (for the two dairies). We need to assure producers the cost-share will be made available to them, if not in this project, in the FY98 Running Creek workplan.
- How can TIAER change the scope without doing post-BMP data collection? TIAER will just complete the tasks that they can. We will not modify the workplan nor the QAPP to reflect these changes. We will just make note of them in the final report.
- Len said that he would send something in writing giving his approval on the project change in focus. This will be in lieu of official revisions.
- We will try and have a project meeting in February to discuss these issues.

Lake Fork Meeting
February 4, 1998

Attendees:
Carl Hutcherson
Len Pardee
Bobbie Stephens
Bo Spoonts
Justin Hester
Larry Hauck
Tim Jones
Barbara Parmley
Cary Betz
Paul Reynolds

- Carol Whittington passed out a financial update handout. Only 1/3 of the money has been spent thus far.
- Discussed TNRCC's deobligated money. We are going to spend that on a financial assistance project in the Running Creek Watershed. We will need to develop a workplan in order to get the deobligated funds.
- The Groundwater folks need information from Jim Wyrick. I (Justin) will call and remind Jim Wyrick. I communicated to these guys that they need to begin calling Jim themselves. They say they need to know 3 weeks in advance of BMP implementation – only Jim will be able to give them that information and depending on the weather, he may not even be able to provide that. They will be installing 5-10 temporary wells at both sites.
- Larry Hauck discussed the BMP evaluation portion of the project. Larry says there is going to be a problem obtaining post-BMP data since we have not installed BMPs and the project ends in a few months. The weather has been too wet. Should TIAER continue monitoring pre-BMP data? Larry H. suggested sampling through June so that TIAER does not have to fire employees in the field that are assigned to this project. TIAER will document things very closely. This will allow someone to come in and collect the post-BMP data with ease – if we decide to do this.

- WHAT ARE WE GOING TO DO?
  If we change the scope of the project how much money will we have to continue monitoring in the future (if we decide this is needed)? It was decided that we should not even try within this project to do the pre-BMP monitoring.

- Carl mentioned hiring a technician to work one-on-one with the landowners.

- As of now, the TSSWCB project money will be pooled (except for TIAER and TAEX) and this will possibly be deobligated for the Running Creek project. We will wait until August to make the decision.
- Carol W. will check to see whether or not she can deobligate the money. Because the practices are not in place and we are not sure it is going to dry out soon enough to get

them implemented within the confines of this project, we will need to be very careful that we do not lose this money. The dairy operators would be a bit peeved if they'd been promised BMP money and then us not come through on our promises. Carl mentioned a drop-dead date of ***August 10, 1998*** to have the BMPs implemented.

- We discussed that a new QAPP will not be needed for the remaining project, because the only thing that is changing is we will not be able to conduct as much sampling as we initially thought possible.
- We will revised the workplan to meet the deliverables.

RUNNING CREEK POTENTIAL PROJECT

- Discussed some details of this potential project. We will run it like the 503 program – 75% land-owner assistance, 25% land owner contribution
- Barbara Parmley says the timing for this project is important and she also thinks the landowners in the watershed will be interested in participating. She also thinks the technician will be a good use of the funds.
- Discussed having a stakeholder meeting in the watershed to discuss the project and get their input.
- Discussed having a meeting in the watershed the first of March to discuss the project.

Lake Fork/Running Creek Watershed Meeting
March 4, 1998

Attendees:
Barbara Parmley and 3 others from her staff
Justin Hester
Bo Spoonts
Bobbie Stephens
David Powell
John O'Connor
Jim Wyrick
Carl Hutcherson
Len Pardee

- This meeting was held at the NRCS office in the Hopkins-Rains SWCD in Sulphur Springs to discuss the completion of the FY93 Lake Fork project and continuing the implementation portion through another project.
- Basically came to the conclusion that approximately 10 dairies may participate and benefit from the project.
- According to Jim Wyrick, the problem will be getting the dairies involved in the project. Many of these dairies are just barely keeping their heads above water, if that.
- A question was asked if a de-watering system (honey wagon) could be purchased through the project to keep these ponds from over flowing. Someone in the meeting mentioned that there is already a guy in the area doing this. Hence, we could not use project money and compete with this guy.
- Jim mentioned that a technician is probably not needed he also said that we need to make sure we handle this just like the 503 program so that we don't give the appearance of giving special treatment to some dairies.
- There was also some discussion about adding some additional BMPs to already existing WQMPs.
- Roxanne and Barbara will be going out in the field together to get a feel of whether or not the dairy operators are interested in participating in the project.
- Bobbie discussed in-kind match information. She will get something to these guys regarding match.

Running Creek Watershed Meeting
March 4, 1998

Topic: Potential implementation assistance project in Running Creek Watershed

1. Will the SWCD be interested?
2. If so, can NRCS and Mt. Pleasant handle the additional workload?
3. How much money is available?
4. How much money is necessary for each dairy?
5. Where will the project be located – upper portion of the watershed? - BOTH
6. Who will be the lead for the project?
7. Who needs to be involved?
8. Who will be responsible for the technician payroll/project expenses/match calculations, etc.. } REGIONAL OFFICE
9. Who will supervise and train the technician?
10. Will the technician need a truck? } NO TECHNICIAN NEEDED

TASK 1.2 Evaluate Available Information

The TSSWCB will complete an inventory and GIS database for the watershed including land use, soils information, streams, highways, location, size and types of dairies (permitted, 503 water quality management plans, unpermitted). Current management practices will be inventoried for the dairies in the Running Creek subwatershed. Data will be evaluated and used to support project activities and the implementation of BMPs.

- TIAER, with help from NRCS, collected data through the use of a GPS unit for the GIS database. The complete inventory and report completed by TIAER is attached.

TIAER
WP 98-05

Lake Fork Reservoir Watershed and Running Creek Sub-Watershed Geographic Information System Data Report

August 1998

Scott Ewer and Nancy Easterling

Texas Institute for Applied Environmental Research
Tarleton State University · Box T0410 · Tarleton Station · Stephenville · Texas · 76402
(817) 968-9567 · Fax (817) 968-9568

Table of Contents

List of Tables

List of Figures

Introduction

The Lake Fork Reservoir (LFR) watershed covers approximately 575 square miles in Hopkins, Rains, Hunt and Wood counties in northeast Texas. The watershed, which is located in a post oak savannah ecological setting within the Sabine River watershed, is characterized by gently rolling topography and a temperate climate. There are eight major tributary streams to the Lake Fork Reservoir: Lake Fork Creek, Glade Creek, Running Creek, Carroll Creek, Caney Creek, Elm Creek, Birch Creek and Garrett Creek.

Due to the large number of dairy operations in the LFR watershed, the area is recognized on the State's Nonpoint Source (NPS) Assessment Report as having potential water quality problems. Local citizen complaints resulted in the watershed being included in the Texas State Soil and Water Conservation Board's "State of Texas Agricultural/Silvicultural Nonpoint Source Management Program" (March, 1995). Water quality data collected during stormwater runoff events by the Sabine River Authority (SRA), U.S. Geological Service (USGS), and Texas Natural Resource Conservation Commission (TNRCC) have documented elevated levels of nutrients and fecal coliform bacteria and depressed levels of dissolved oxygen in LFR tributaries. Inspections of wastewater discharges by TNRCC personnel and self-reporting information from area wastewater treatment facilities and marinas revealed that point source discharges from domestic wastewater treatment plants are not having a significant impact on stream water quality in the watershed; and the pollution in the streams appears to be nonpoint source related (TNRCC, 1994. Project Summary-LFR Watershed Comprehensive Nonpoint Source Water Quality Management Plan).

The U.S. Environmental Protection Agency funded Section 319(h) project entitled *Lake Fork Reservoir Implementation Project* is a multidisciplinary effort to identify and evaluate the effectiveness of selected best management practices (BMPs) in controlling NPS pollution from dairy operations in the Lake Fork Reservoir watershed. The Running Creek sub-watershed, which was identified by TNRCC as being affected by runoff from dairy operations, was targeted for development and implementation of water quality management plans for dairies. Located in the upper portion of the LFR watershed, the Running Creek sub-watershed was the focus of two demonstration projects to show the effects of typical BMPs for dairies as part of the 319(h) project. The Soil and Water Conservation District (SWCD) and US Department of Agriculture Natural Resources Conservation Service (NRCS) had primary responsibility for selecting and overseeing the installation of BMPs on the two targeted dairy operations. The TNRCC was responsible for monitoring streams in the LFR watershed and for subsurface monitoring in the vicinity of the two demonstration dairies. The locations of the Lake Fork Reservoir watershed and the Running Creek sub-watershed are shown in Figure 1.

The Texas Institute for Applied Environmental Research (TIAER) was responsible for assembling geographic information system (GIS) databases for the watershed. This report provides an overview of the GIS databases for the Lake Fork Reservoir watershed. The GIS databases were created from existing sources whenever feasible. Only the dairy location database was created specifically for this project. These databases will be described first at the LFR watershed level and secondly at the Running Creek sub-watershed level.

Lake Fork Reservoir Watershed GIS Data

The largest part of the LFR watershed is located in Hopkins County, the second highest dairy production county in Texas. Most Hopkins County dairies are small, family-owned operations that average about 165 acres in size with 175 milking cows. According to the USDA Natural Resources Conservation Service office in Sulphur Springs, 206 dairies were located within the boundaries of the LFR watershed as of June 1997 (Figure 2). Improved pasture is the predominant land use in the watershed. Much of the remaining land in the watershed is characterized as either unimproved pasture or forest and brush (Table 1 and Figure 3).

Table 1. Lake Fork Reservoir Watershed Land Use

CATEGORY	ACRES	%TOTAL
Improved Pasture	137,024	43.7
Unimproved Pasture	85,395	27.2
Forest and Brush	55,649	17.7
Water	27,898	8.9
Cropland	5,095	1.6
Barren & Roadways	1,596	0.5
Urban	1,149	0.4
TOTAL	313,808	100.0

Source: Private contractor using Landsat TM imagery, July 1996

Soils in the LFR watershed are mainly of the Woodtell-Freestone-Bernaldo and Crockett-Wilson-Cowen associations. These soils are deep, loamy to sandy in texture, slowly permeable and well drained. (Table 2 and Figure 4).

Table 2. Lake Fork Reservoir Watershed Soil Associations

SERIES	ACRES	%TOTAL
Woodtell-Freestone-Bernaldo	149,281	47.6
Crockett-Wilson-Cowen	83,011	26.4
Wolfpen-Pickton-Woodtell	29,578	9.4
Water	21,231	6.8
Bernaldo-Kirvin-Freestone	19,360	6.2
Nahatche-Crockett-Woodtell	9,627	3.1
Houston Black-Leson-Heiden	1,720	0.6
TOTAL	313,808	100.0

Source: State Soil Survey Geographic Data Base (USDA)

Note: there is a difference between land use and soil association databases in the amount of area characterized as water. Resolution of this difference is beyond the intent of this report.

Figure 5 presents elevation data (digital elevation map) for the LFR watershed.

Running Creek Sub-watershed GIS Data

The Running Creek sub-watershed encompasses an area of over 17,000 acres in Hopkins County, southeast of Sulphur Springs. Boundaries of the Running Creek sub-watershed are generally defined by State Highway 11 to the north, Farm Road 2560 to the west, Farm Road 1567 to the east and Lake Fork Reservoir to the south (Figure 6). Dry Creek drains the eastern portion of the sub-watershed and is a major tributary to Running Creek approximately six miles upstream from the point where Running Creek enters Lake Fork Reservoir.

Land use in the Running Creek sub-watershed is fairly typical of the entire LFR watershed, but has more improved pasture and less cropland and forest than the watershed average. The majority of the sub-watershed is characterized as improved and unimproved pasture (Table 3 and Figure 7).

Table 3. Running Creek Sub-watershed Land Uses

DESCRIPTION	ACRES	%TOTAL
Improved Pasture	9,301	52.7
Unimproved Pasture	4,431	25.7
Forest & Brush	3,356	19.0
Cropland	152	0.9
Water	361	2.0
Barren & Roadways	45	0.3
TOTAL	17,646	100.0

Source: Private contractor using Landsat TM imagery, July 1996

Soils in the area consist mostly of the Wolfpen-Pickton-Woodtell and Woodtell-Freestone-Bernaldo associations (Table 4 and Figure 8). Wolfpen soils are well drained and moderately permeable, while Woodtell soils are moderately well drained and slowly to very slowly permeable.

Table 4. Running Creek Sub-watershed Soil Associations

SERIES	ACRES	%TOTAL
Woodtell-Freestone-Bernaldo	12,882	75.5
Wolfpen-Pickton-Woodtell	4,764	24.5
TOTAL	17,646	100.0

Source: State Soil Survey Geographic Data Base (USDA)

This sub-watershed has a higher concentration of dairies than any other part of the LFR watershed. As of June 1997, there were approximately 44 dairy locations within the boundaries of the Running Creek sub-watershed (Table 5 and Figure 9). The number of dairies that are operating changes continuously due to economics, weather and other factors. Some dairy owners cease their own operations but lease their dairy location to other entities for varying lengths of time. As of summer 1998, approximately 27 of the 44 dairy locations were in operation. Several dairies had completed or were in the process of completing their SB503 waste management plan documentation, as noted in Table 5.

Figure 10 presents elevation data for the Running Creek sub-watershed.

Table 5 Running Creek Sub-watershed Dairies

	Dairy Name	Milking Herd	Total Herd	503 Plan	503 Plan Number and Additional Notes
1	[redacted]			N	Out of business
2	[redacted]			Y	[redacted]*/Operating
3	[redacted]			Y	[redacted]*/Out of business
4	[redacted]	245	245	N	Leased/Operating
5	[redacted]	66	107	N	Out of business
6	[redacted]	160	180	Y	[redacted]*/Operating
7	[redacted]			N	Not milking
8	[redacted]	510		N	Permitted dairy
9	[redacted]	150	150	Y	[redacted]
10	[redacted]			Y	[redacted]*/Operating
11	[redacted]			N	Out of business
12	[redacted]			N	Operating
13	[redacted]			N	
14	[redacted]			Y	[redacted]*/Operating
15	[redacted]	200	200	N	TNRCC plan/Out of business
16	[redacted]			N	Not milking
17	[redacted]	115	145	Y	[redacted]
18	[redacted]			N	Cons. Plan/Leased
19	[redacted]	85	115	N	Operating
20	[redacted]			Y	[redacted]*/Operating
21	[redacted]			N	Out of business
22	[redacted]			Y	[redacted]
23	[redacted]			Y	[redacted]
24	[redacted]			N	Leased
25	[redacted]				Operating
26	[redacted]			N	Operating
27	[redacted]				Operating
28	[redacted]	151	234	Y	Out of business
29	[redacted]				Operating
30	[redacted]				[redacted]/operating
31	[redacted]	97	109	N	Operating
32	[redacted]			N	Out of business
33	[redacted]	78	117	Y	[redacted]*/Operating
34	[redacted]	130	150	Y	[redacted]*/Operating
35	[redacted]	18	188	Y	[redacted]*/Operating
36	[redacted]	130		N	Canceled 503
37	[redacted]			N	Out of business
38	[redacted]			N	Permitted dairy/Out of business
39	[redacted]			N	Operating
40	[redacted]			N	Operating
41	[redacted]	200	200	Y	[redacted]*/Out of business
42	[redacted]			N	Sold
43	[redacted]	240	240	Y	[redacted]*/Out of business
44	[redacted]	150	150	N	Out of business

Source: NRCS Office, Sulphur Springs, Texas

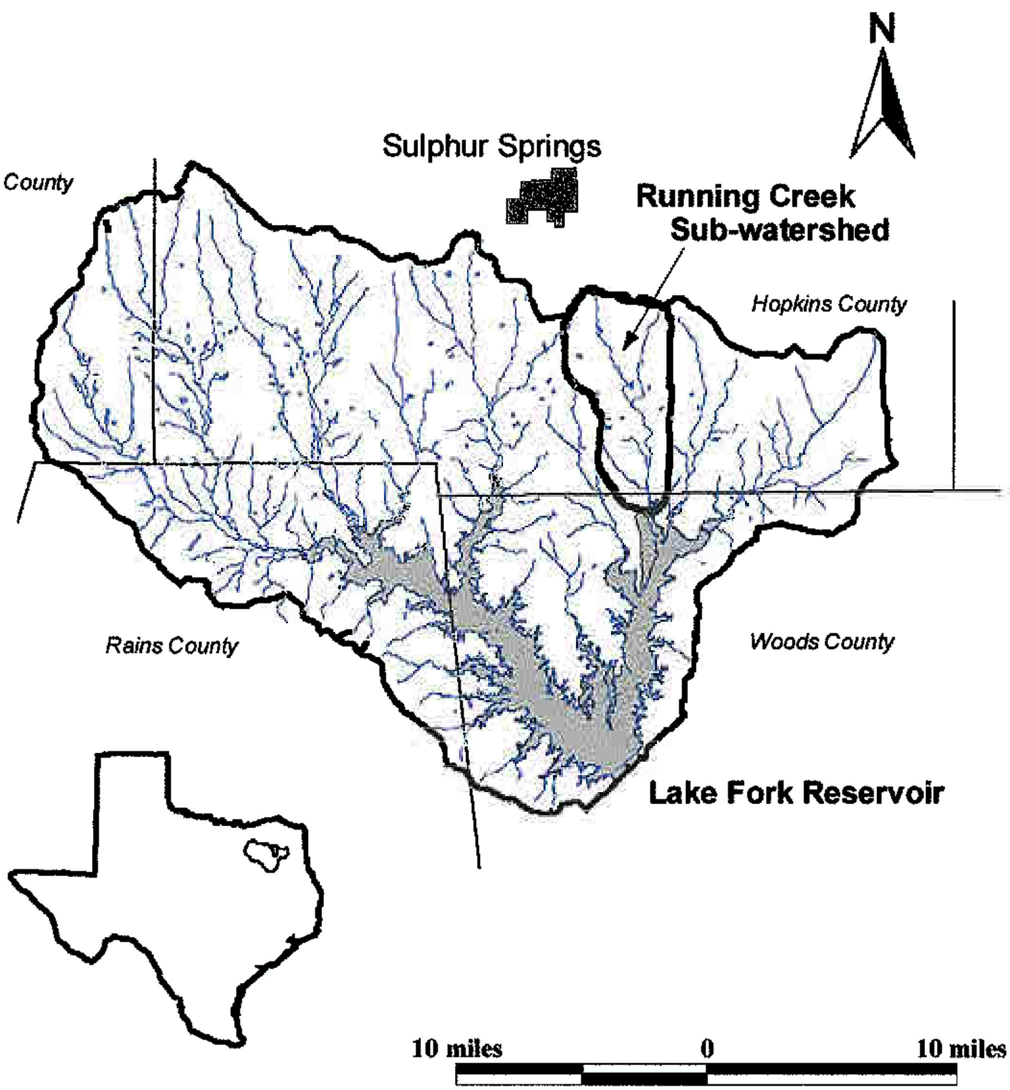
*503 plan number

LITERATURE CITED

TNRCC. Project Summary-LFR Watershed Comprehensive Nonpoint Source Water Quality Management Plan. 1994.

USDA, SCS, National Cooperative Soil Survey. State Soil Survey Geographic Data Base CD-ROM, GRASS v.4.13. October 1994.

Figure 1. Location of Lake Fork Reservoir Watershed and Running Creek Sub-watershed



Source: US Census TIGER files

Figure 2. Dairy Locations in Lake Fork Reservoir Watershed

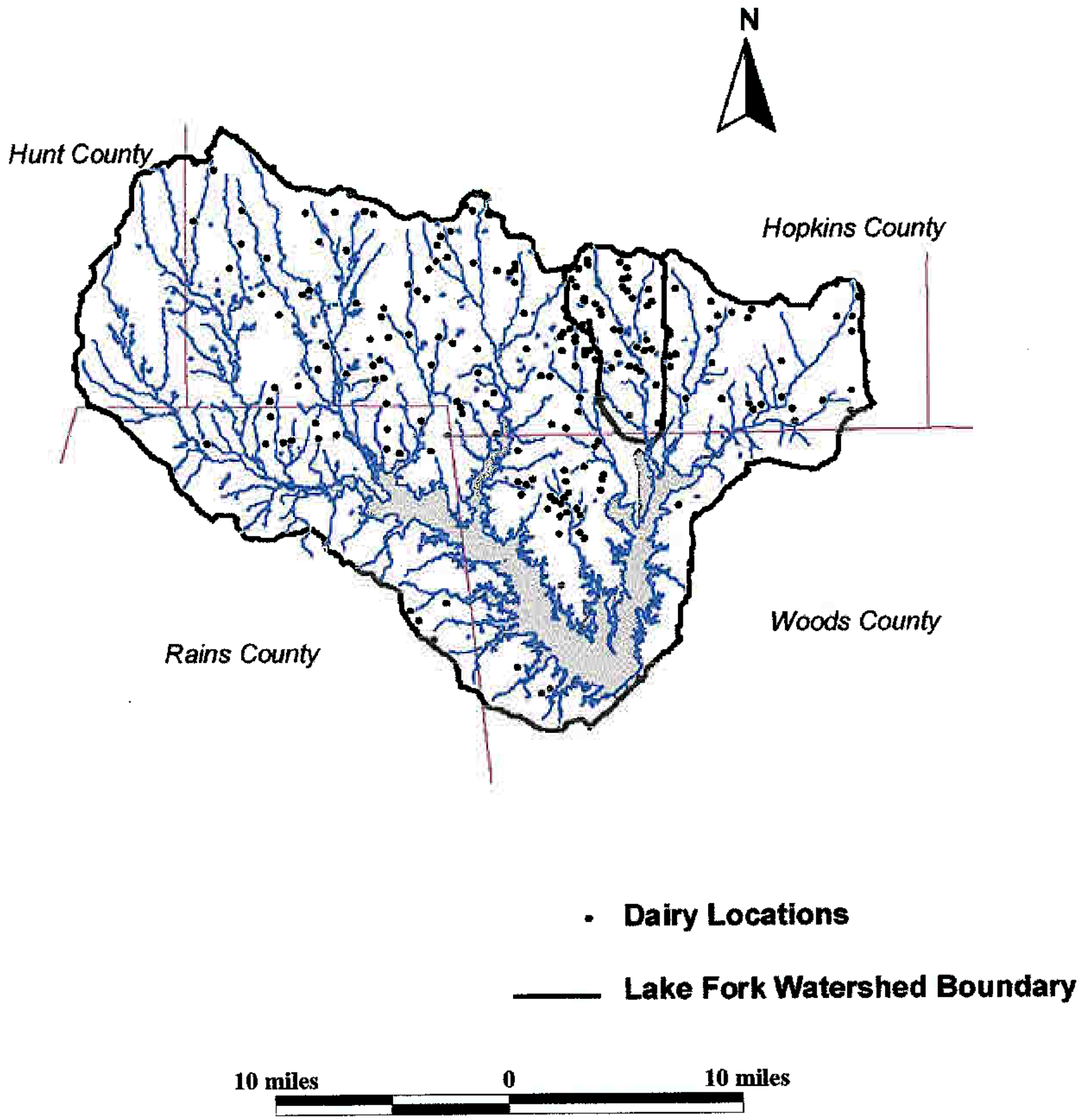
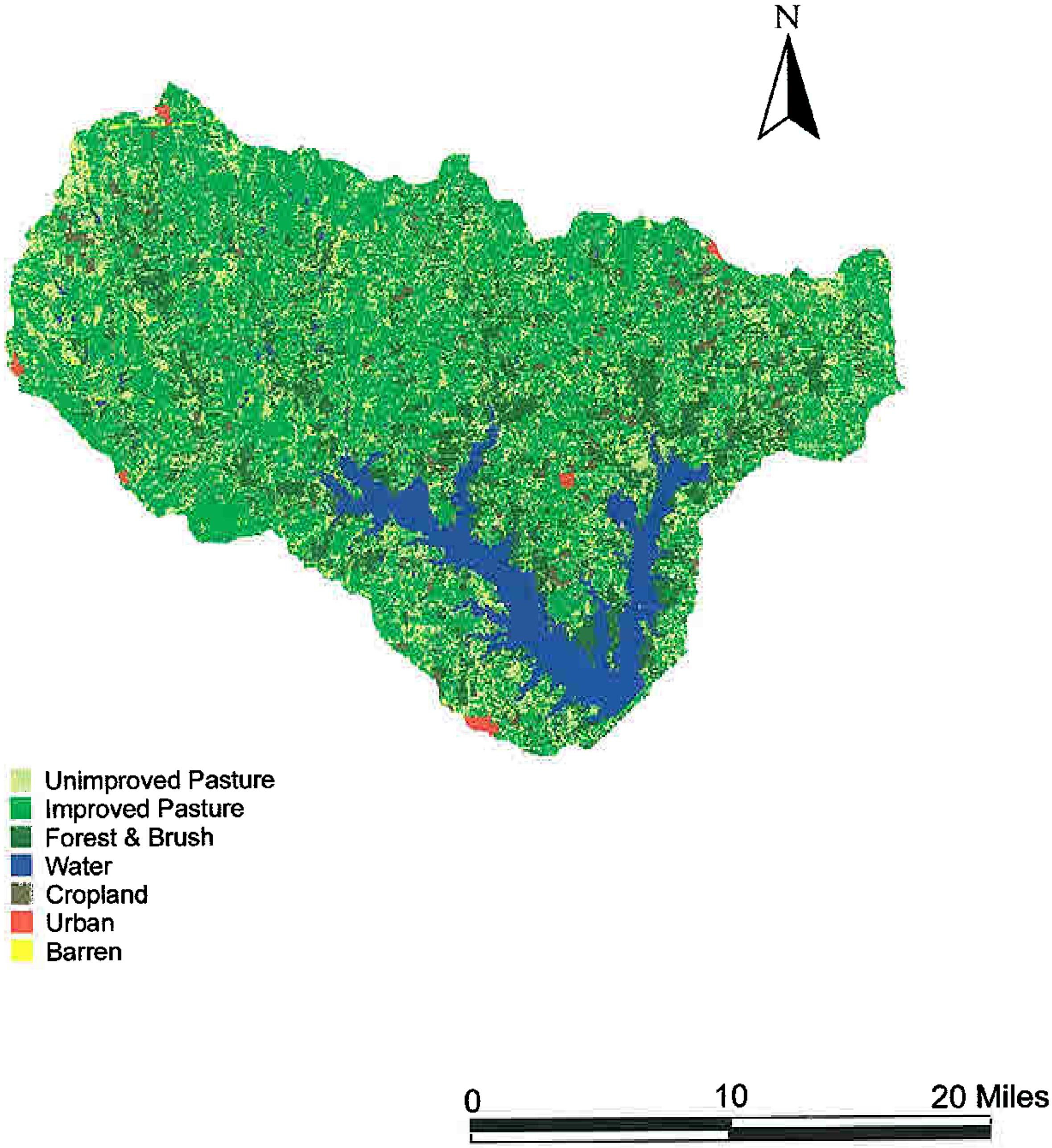
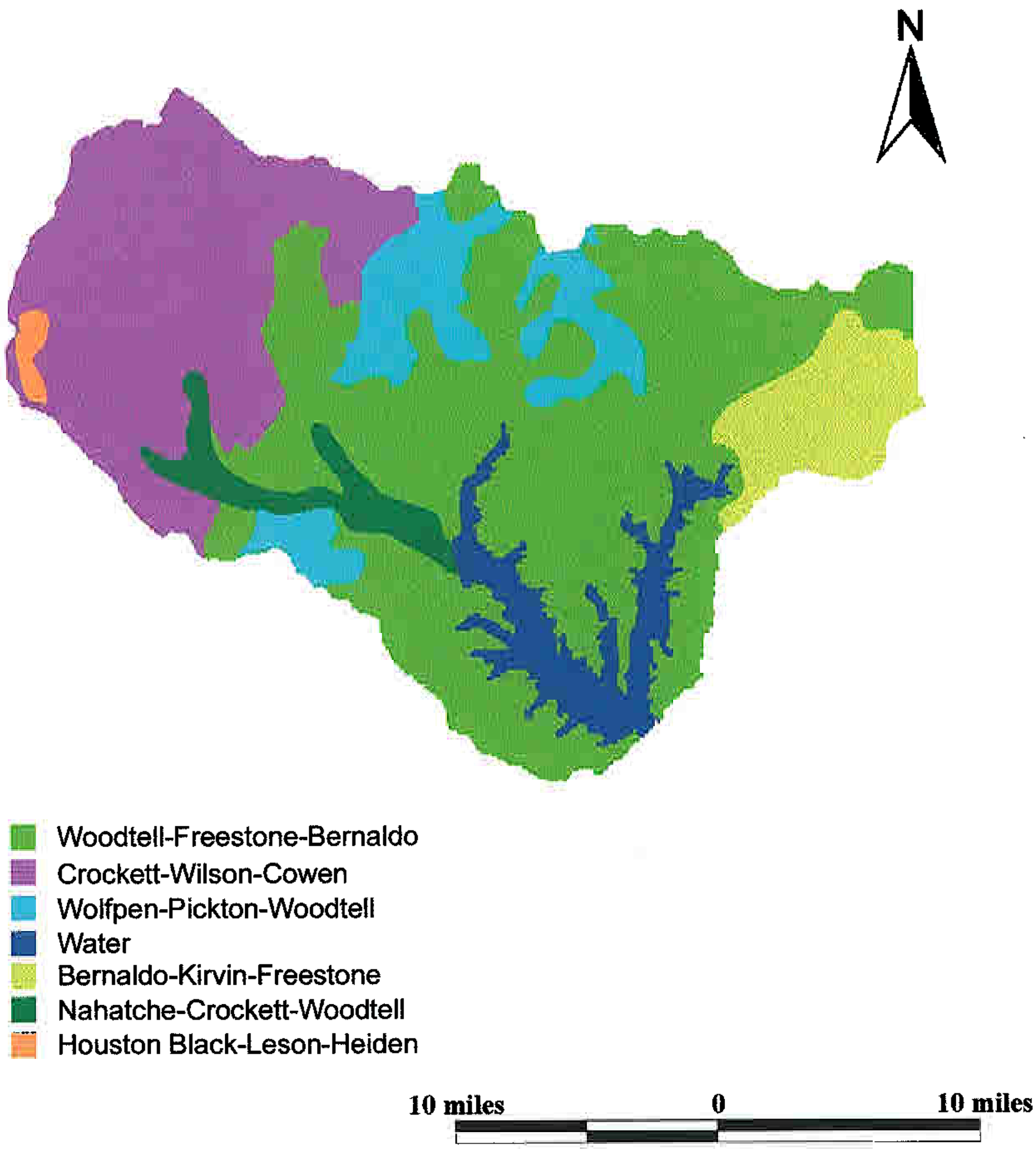


Figure 3. Lake Fork Watershed Land Use



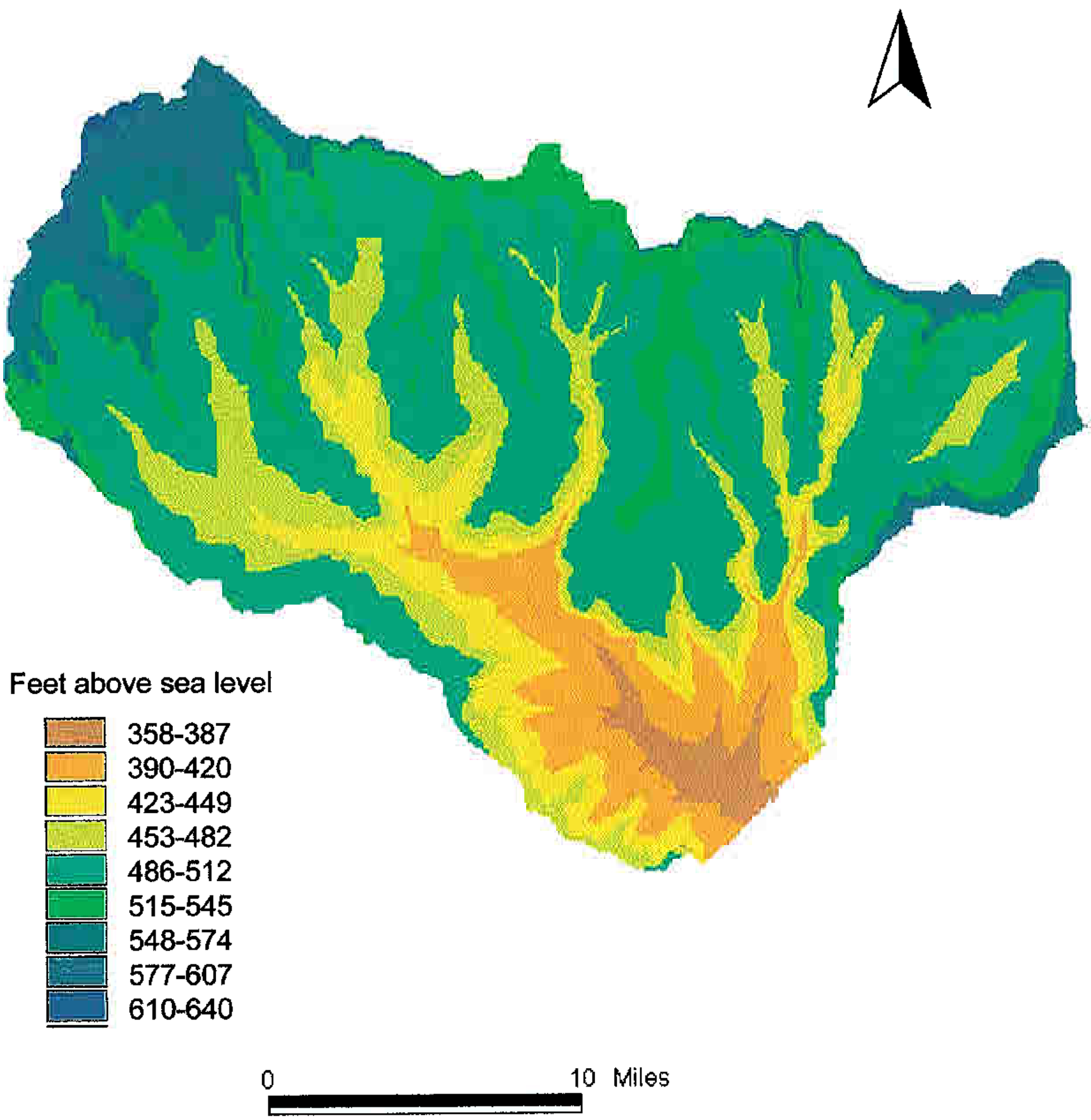
Source: Landsat TM Imagery

Figure 4. Lake Fork Reservoir Watershed Soil Associations



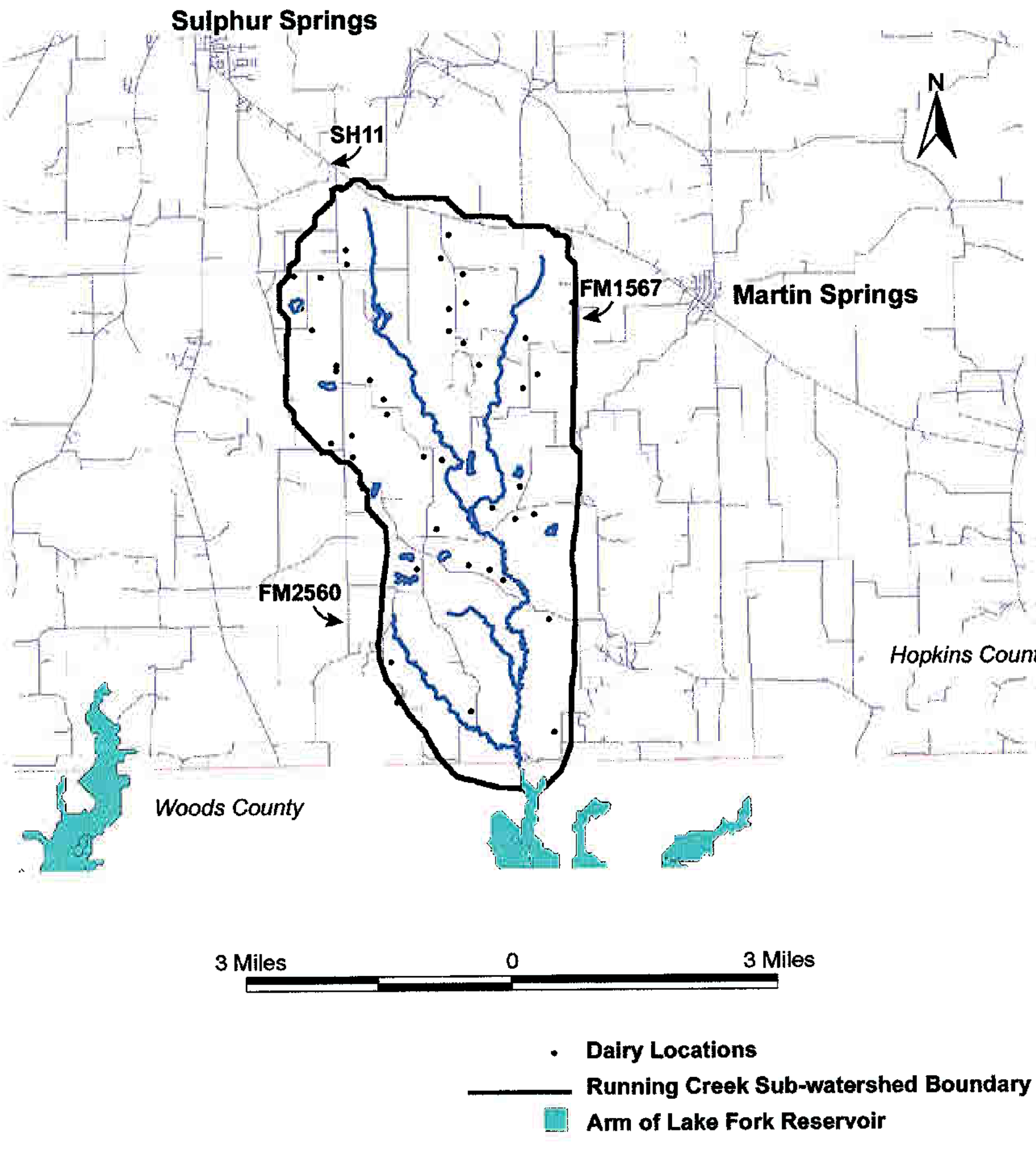
Source: Statsgo Soil Polygons

Figure 5. Digital Elevation Map for the Lake Fork Reservoir Watershed



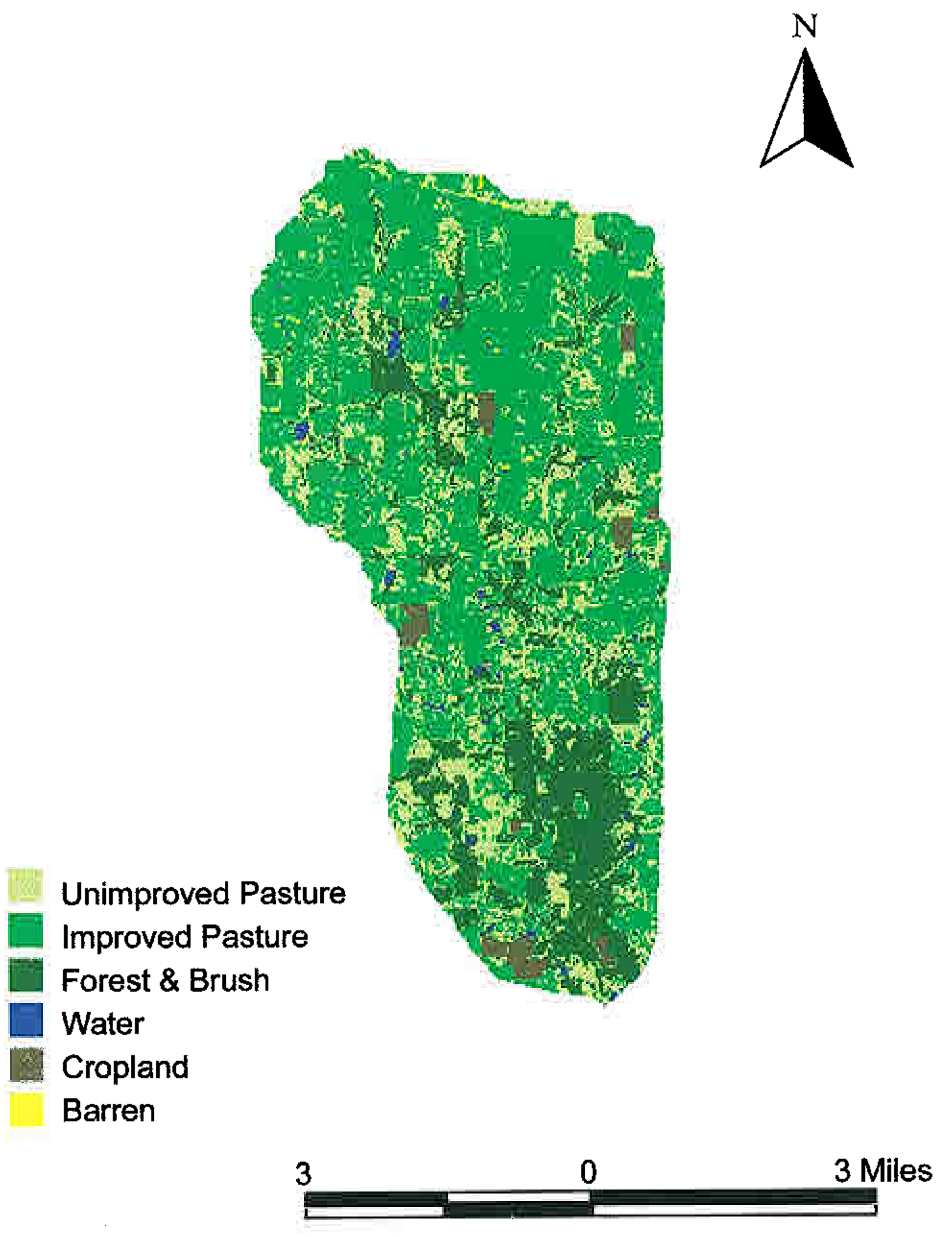
Source: USGS Digital Elevation Map
USGS 7½ Minute Quadrangle Maps
Digitized by NRCS

Figure 6. Location of Running Creek Sub-watershed



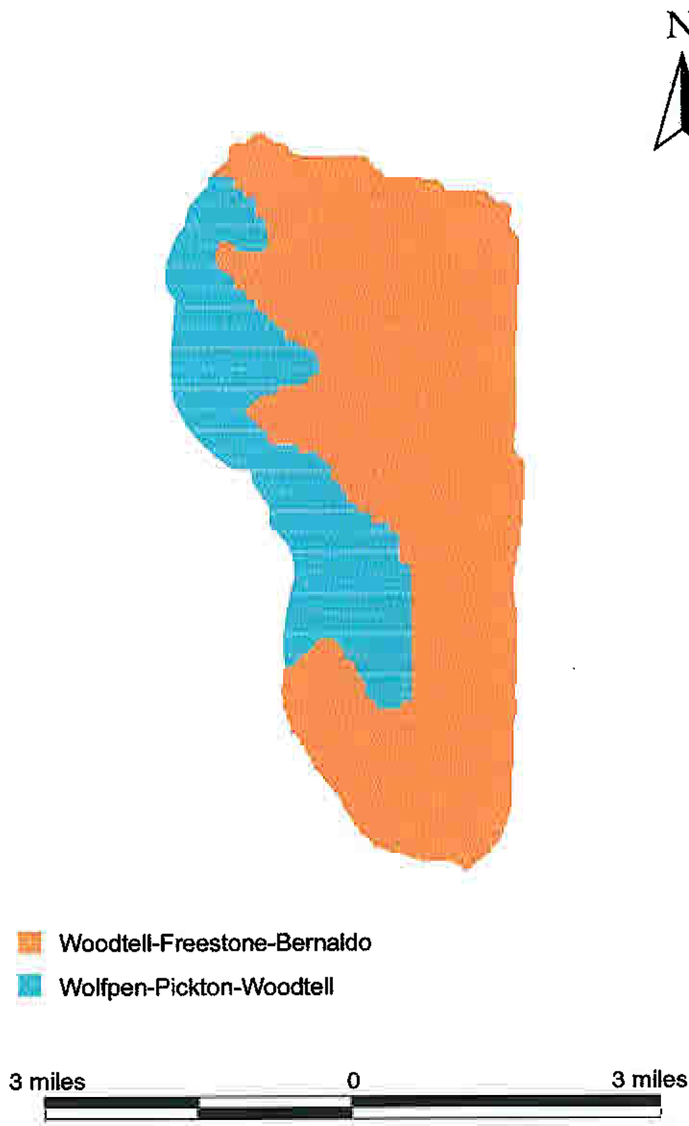
Source: US Census TIGER files

Figure 7. Running Creek Sub-watershed Land Use



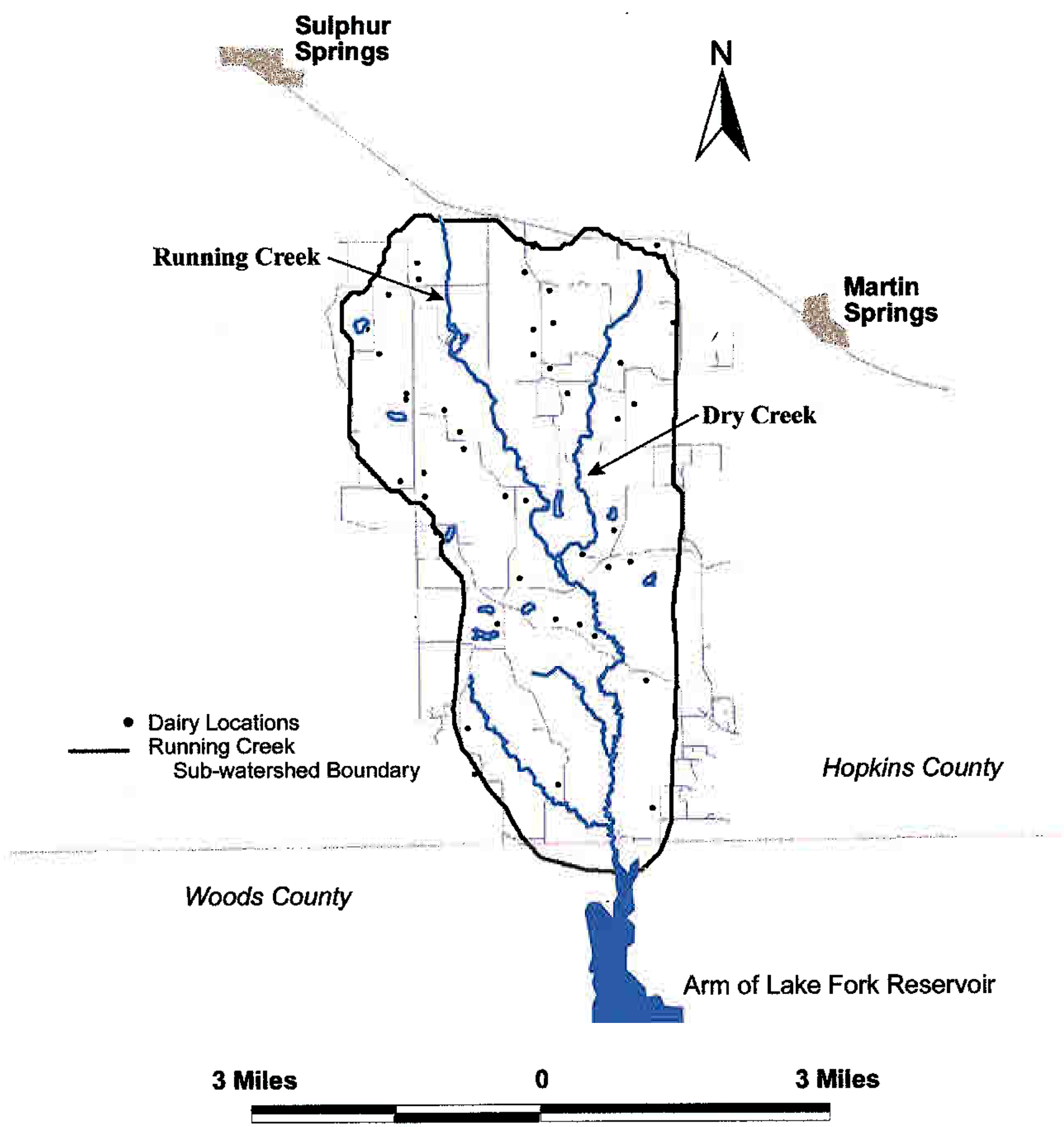
Source: Landsat TM Imagery

Figure 8. Running Creek Sub-watershed Soil Associations



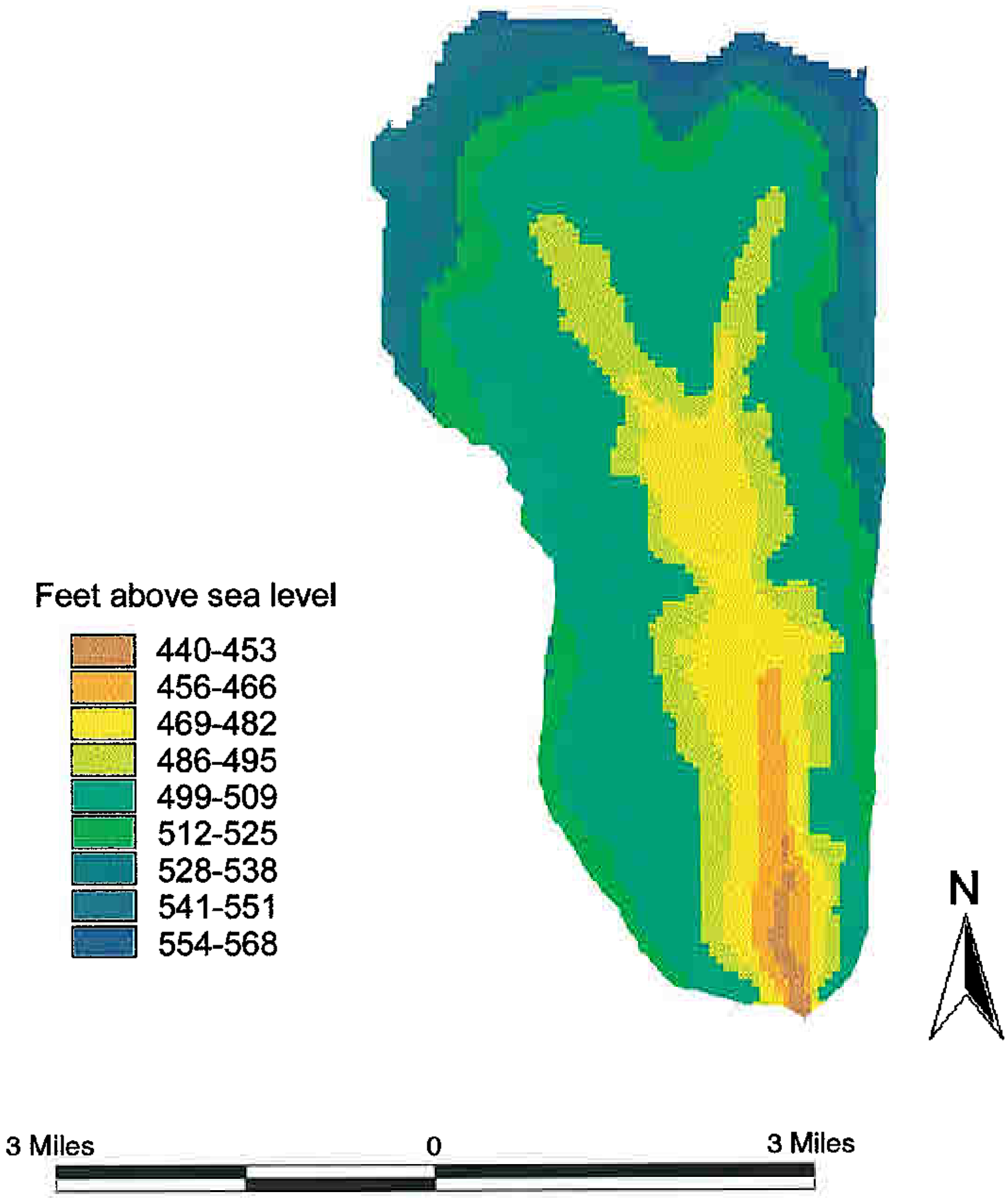
Source: Statsgo Soil Polygons

Figure 9. Dairy Locations in the Running Creek Sub-Watershed



Source: TIAER

Figure 10. Digital Elevation Map of the Running Creek Sub-watershed



Source: USGS Digital Elevation Map
USGS 7½ Minute Quadrangle Maps
Digitized by NRCS

TASK 1.3 Prepare Quality Assurance Project Plan

The TSSWCB will prepare a quality assurance project plan (QAPP) for edge-of-field monitoring to determine the effectiveness of BMP implementation. The QAPP will be submitted for review and approval prior to field implementation and monitoring.

- The QAPP was approved by the EPA on March 10, 1997 and is attached. Pre-BMP monitoring began not long after this date. The goal was to implement BMPs by September of 1997 in order to give TIAER sufficient time to collect post-BMP data. However, the difficulty in lining up local contractors and wet weather conditions impeded BMP implementation. The BMPs were not installed until the summer of 1998, which prevented TIAER from collecting post-BMP data.

Quality Assurance Project Plan for the

Environmental Measurement Activities Relating to Lake Fork Watershed NPS Project

Texas State Soil and Water Conservation Board

Temple, Texas

Quality Assurance Management Plan (TQ-96-051)

Texas State Soil and Water Conservation Board

United States Environmental Protection Agency, Region VI

Name: Leonard Pardee

Title: Texas Nonpoint Source Project Manager

Signature: Leonard G. Pardee Date: 3/6/97

Name: Richard G. Hoppers

Title: Chief of Assistance and Outreach Branch

Signature: Richard G. Hoppers Date: 3/10/97

Texas Natural Resources Conservation Commission

Name: Carol Whittington

Title: Program Administrator Nonpoint Source Program

Signature: Carol Whittington Date: 12/10/96

Name: Clyde E. Bohmfalk

Title: Quality Assurance Officer

Signature: Clyde E. Bohmfalk Date: 12/10/96

Texas State Soil and Water Conservation Board

Name: Byron Spoonts

Title: Agricultural Project Administrator

Signature: ____________________ Date: 11/19/96

Name: Justin Hester

Title: Agricultural Project Manager

Signature: ____________________ Date: 11/18/96

Texas Institute for Applied Environmental Research

Name: Larry Hauck

Title: Program Manager

Signature: ____________________ Date: 10/31/96

Name: Nancy Easterling

Title: Quality Assurance Manager

Signature: ____________________ Date: 10/31/96

Name: Mark Murphy

Title: Laboratory Manager

Signature: ____________________ Date: 10/31/96

Quality Assurance Project Plan for the Environmental Measurement Activities Relating to Lake Fork Watershed NPS Project

Texas State Soil and Water Conservation Board

Temple, Texas

Quality Assurance Management Plan (TQ-96-051)

Texas State Soil and Water Conservation Board

United States Environmental Protection Agency, Region VI

Name: Leonard Pardee

Title: Texas Nonpoint Source Project Manager

Signature: Leonard G. Pardee Date: 3/6/97

Name: Richard G. Hoppers

Title: Chief of Assistance and Outreach Branch

Signature: [signature] Date: 3/10/97

Texas Natural Resources Conservation Commission

Name: Carol Whittington

Title: Program Administrator Nonpoint Source Program

Signature: Carol Whittington Date: 12/10/96

Name: Clyde E. Bohmfalk

Title: Quality Assurance Officer

Signature: Clyde E. Bohmfalk Date: 12/10/96

Texas State Soil and Water Conservation Board

Name: Byron Spoonts

Title: Agricultural Project Administrator

Signature: ____________________ Date: 11/19/96

Name: Justin Hester

Title: Agricultural Project Manager

Signature: ____________________ Date: 11-18-96

Texas Institute for Applied Environmental Research

Name: Larry Hauck

Title: Program Manager

Signature: ____________________ Date: 10/31/96

Name: Nancy Easterling

Title: Quality Assurance Manager

Signature: ____________________ Date: 10/31/96

Name: Mark Murphy

Title: Laboratory Manager

Signature: ____________________ Date: 10/31/96

Section A2: Table of Contents

Section: Title Page

Section A3: Distribution List

Organizations, and individuals within, which will receive copies of the approved QAPP and any subsequent revisions include:

- United States Environmental Protection Agency, Region VI

  Name: Leonard Pardee
  Title: Texas Nonpoint Source Project Manager

  Name: Richard G. Hoppers
  Title: Chief of Assistance and Outreach Branch

- Texas Natural Resource Conservation Commission

  Name: Carol Whittington
  Title: Program Administrator

  Name: Clyde E. Bohmfalk
  Title: Quality Assurance Officer

- Texas State Soil and Water Conservation Board

  Name: Byron Spoonts
  Title: Agricultural Project Administrator

  Name: Justin Hester
  Title: Agricultural Project Manager

  Name: Suzanne Cardwell
  Title: Contract Manager

- Texas Institute for Applied Environmental Research

  Name: Larry Hauck
  Title: Program Manager

  Name Nancy Easterling
  Title: Quality Assurance Manager

  Name Mark Murphy
  Title: Laboratory Manager

Section A4: Project/Task Organization

The following is a list of individuals and organizations participating in the project with their specific roles and responsibilities:

Leonard Pardee, Texas Nonpoint Source Project Manager
United States Environmental Protection Agency (EPA), Region VI, Dallas. Responsible for overall performance and direction of the project at the Federal level. Approves the final products and deliverables.

Richard G. Hoppers, Chief of Assistance and Outreach Branch
United States Environmental Protection Agency (EPA), Region VI, Dallas. Responsible for determining that the Project Plan meets the Federal requirements for planning, quality control, quality assessment, and reporting.

Carol Whittington, Program Administrator
Texas Natural Resource Conservation Commission (TNRCC), Watershed Management Division, Nonpoint Source Program. Responsible for tracking project progress and expenditures. Reports project status to the EPA.

Clyde E. Bohmfalk, Quality Assurance Officer
Texas Natural Resource Conservation Commission (TNRCC), Field Operations Division. Responsible for determining that the project activities meet the federal Quality Assurance Project Plan (QAPP) requirements.

Byron Spoonts, Agricultural Project Administrator
Texas State Soil and Water Conservation Board (TSSWCB). Responsible for tracking project administration.

Justin Hester, Agricultural Project Manager
Texas State Soil and Water Conservation Board (TSSWCB). Responsible for overseeing the implementation of the proposed BMPs on targeted dairy operations.

Suzanne Cardwell, Contract Manager
Texas State Soil and Water Conservation Board (TSSWCB). Responsible for tracking project progress and expenditures

Larry Hauck, Program Manager
Texas Institute for Applied Environmental Research (TIAER), Tarleton State University. Responsible for coordinating and supervising the installation of monitoring equipment, collection of water samples, laboratory analyses.

Nancy Easterling, Quality Assurance Manager
Texas Institute for Applied Environmental Research (TIAER), Tarleton State University. Responsible for determining that the Project Plan meets the requirements for planning, quality control, quality assessment and reporting.

Mark Murphy, Laboratory Manager
Texas Institute for Applied Environmental Research (TIAER), Tarleton State University. Responsible for TIAER analytical laboratory operations for this project.

Technical Advisory Committee
This committee was formed to ensure that the technical activities of this project are properly addressed.

Local Coordinating Committee
This committee was formed to ensure that the citizens within the Lake Fork Creek Watershed are informed on the progress of the project and have a opportunity to provide input and express concerns on the activities and direction of the project.

Section A4: Project Organization Chart

- Leonard Pardee (EPA)
  - Richard Hoppers (EPA)
- Carol Whittington (TNRCC)
  - (TNRCC)
- Byron Spoonts (TSSWCB)
  - Justin Hester (TSSWCB)
  - Suzanne Cardwell (TSSWCB)
- Larry Hauck (TIAER)
  - Nancy Easterling (TIAER)
  - Mark Murphy (TIAER)
- Technical Advisory Committee
- Local Coordinating Committee

Section A5: Problem Definition/Background

The Lake Fork Reservoir (LFR) watershed is an approximate 575 square mile area located within the Sabine River Basin in Hopkins, Rains, Wood and Hunt Counties. The watershed is characterized by a gentle rolling topography, temperate climate, and a post oak woodland natural ecological setting. Eight major tributary streams comprise most of the drainage area and drain the basin in a southerly direction to LFR. The Lake Fork Reservoir is approximately 40 square miles in size and was constructed as a drinking water supply and recreational reservoir.

There are three communities in the watershed that have sewage treatment facilities. The Cities of Yantis, Point, and Como discharge treated wastewater into tributaries of the LFR. Based on results of wastewater treatment facility inspections by TNRCC personnel and self-reporting information, the point sources of pollution within the watershed are not having a significant impact on the water quality of the tributary streams of the LFR.

The watershed is experiencing significant growth in agricultural operations, primarily dairies. There are about 300 dairies in the watershed, most of which are small, family operations. Average dairy size is 175 milking head on an average of 165 acres. Hopkins County makes up most of the watershed and has approximately 205 dairies within the LFR watershed.

Water quality problems have been noted in the LFR watershed associated with bacteria, nutrients, and dissolved oxygen. LFR is recognized as having a potential water quality problem in the State's approved "NPS Assessment Report". Citizens' complaints and concerns about degraded water quality as a result of stormwater runoff from dairy operations resulted in the watershed being included in the State's "Agricultural and Silvicultural Nonpoint Source Pollution Management Program".

The Sabine River Authority (SRA), U.S. Geologic Service (USGS), and TNRCC water quality data collected during stormwater runoff events or as a result of pollution complaints following rainfall runoff, have documented elevated nutrient and fecal bacteria levels and depressed dissolved oxygen levels in LFR tributaries. This pollution appears to be related to nonpoint sources from dairy operations rather than human sources.

LFR is the premier trophy Largemouth Black Bass lake in Texas. As of January, 1993, the LFR had produced 8 of the top 10, 15 of the top 20, and 34 of the top 50 biggest bass ever caught in Texas. LFR is a very productive lake that obviously has the capability to support a quality fishery. The unique characteristic of the lake to produce trophy fish and its ability to attract tourists to the area are important beneficial uses. However, the pollutant loadings are affecting the water quality of the tributary streams and may also be detrimentally affecting the water quality of the reservoir. Hopefully controlling these pollutant loadings will help to maintain and sustain the productive bass fishing as well as other beneficial uses of the reservoir.

pollutant loadings will help to maintain and sustain the productive bass fishing as well as other beneficial uses of the reservoir.

The TNRCC enforces a statewide no discharge policy for confined animal feeding operations (CAFOs). Also, the TSSWCB, pursuant to legislation passed by the Texas Legislature that became effective in September, 1993, provides a voluntary water quality management plan development and implementation program for the abatement of NPS pollution from agricultural producers. Only a limited number of dairies in the LFR Watershed have waste management systems that meet the requirements of either program. All dairies need to install water quality management plans and/or meet TNRCC regulations. Nonpoint source pollution control from CAFOs in this area is one of the State's top priorities.

Based on information available and data gathered by TNRCC during the baseline condition evaluation, the Running Creek subwatershed shows some impact from dairy operations and will be targeted for the installation of water quality management plans by TSSWCB and the Hopkins-Rains Soil and Water Conservation District (SWCD). TSSWCB addresses the prevention or abatement NPS pollution through a Water Quality Management Plan (WQMP) program. A WQMP is a site-specific plan which includes appropriate land treatment practices, production practices, technologies and combinations thereof, and an implementation schedule. This program is administered by the TSSWCB and provides agricultural producers an opportunity to comply with State water quality laws through traditional voluntary incentive-based programs.

The TNRCC will continue to monitor the Running Creek subwatershed for dairy impacts during stormwater runoff events to provide vital information about the NPS pollutant loadings that the tributaries and lake are experiencing within the watershed. Physiochemical and biological monitoring under normal flow conditions will provide information regarding water quality degradation of the creek itself and any impairment of its beneficial use. Through the installation of water quality management plans it is expected that several of the dairies within the targeted subwatershed can be assisted in installing BMPs to reduce the amount of waste reaching the creek. Continued edge of field monitoring (conducted by TIAER) in conjunction with the installation of BMPs will define the effectiveness of NPS pollution control.

Section A6: Project/Task Description

The Lake Fork Reservoir Implementation Project is a multidiscipline effort to identify and evaluate the effectiveness of selected BMPs in controlling NPS pollution in targeted subwatersheds of the Lake Fork Watershed. The on-farm management component of this project is addressed by this QAPP.

The purpose of this project is to collect sufficient data in the Running Creek subwatershed to assess if the installation of BMPs significantly reduces the nutrient loading of dairy operations in this area. The effectiveness of the selected BMPs will be determined by comparing the concentration of nutrient levels before and after BMP installation.

Concentrated efforts were made and completed by TNRCC to identify a subwatershed within the Lake Fork Watershed which shows some impact from dairy operations. The subwatershed within the Lake Fork Watershed that was identified by TNRCC is the Running Creek subwatershed. The Running Creek subwatershed will be targeted by the TSSWCB for the implementation of water quality management plans. These management plans are developed at the Soil and Water Conservation District level through the combined effort of the NRCS and the TSSWCB's field offices to help producers identify practices which are necessary on their specific operations to help prevent or reduce NPS pollution. The plans are certified by the Texas State Soil and Water Conservation Board. A series of maps and data are currently being developed and compiled that will show the location of dairies and the current practices implemented on each dairy within the subwatershed. In this project, the SWCD and the NRCS will work with dairy owners in the subwatershed to implement water quality management plans.

Water quality management plans will be implemented on 7 or 8 dairies within the Running Creek subwatershed. Stormwater runoff and bi-weekly grab samples will be collected from two of these dairies to demonstrate the effectiveness of BMPs in preventing animal waste from entering nearby creeks and streams. The effectiveness of the BMPs will be evaluated on the two dairies based on either an "upstream-downstream" or a "paired watershed" study design. Under both of these methods one sample site serves as a control and a second site serves as the treatment to allow statistical analysis. Please refer to section B1 "Sampling Process Design (Experimental Design)" for more detail. Through the collection of water samples, and analyses based on one of these two methods, it will be possible to demonstrate the effectiveness of BMPs implemented on these two dairies. As results are available, education and transfer of information on the benefits of effective NPS pollution control measures will be provided to dairy owners and those entities that can effectively provide NPS control programs.

The SWCD and NRCS will be primarily responsible for selecting and overseeing the installation of BMPs on the targeted dairy operations. TIAER will be primarily responsible for the installation of monitoring equipment, water sample collection, and laboratory analysis of water samples. TIAER and TSSWCB will analyze the monitoring data and determine the effectiveness of the BMPs. Load reductions for nutrients and phosphates will be calculated for the targeted dairy operations in order to determine the effectiveness of the BMPs installed. Table A6-1 lists the monitoring plan milestones.

Table A6-1 Monitoring Plan Milestones

Aug	1996	Design QAPP for sampling and analyses.
Dec	1996	Approval of QAPP for sampling and analyses by EPA.
Jan	1997	Monitoring equipment installed and monitoring initiated
Jun	1997	Install BMPs on treated fields
Jun	1998	Conclusion of water quality sampling
Jul	1998	Draft Project report BMP effectiveness submitted.
Aug	1998	Final Project reports on BMP effectiveness submitted.

Section A7: Data Quality Objectives for Measurement Data

Nonpoint source pollution generated from the dairy industry has the potential for contaminating surface water resources in the Lake Fork Watershed. The project's data quality objective is to demonstrate water quality improvements from BMPs designed to reduce nutrient loadings from dairy operations. The project hosts a number of participants including:

1) US Environmental Protection Agency, Region VI (EPA)
2) Texas State Soil and Water Conservation Board (TSSWCB)
3) Texas Natural Resource Conservation Commission (TNRCC)
4) Texas Institute for Applied Environmental Research (TIAER)
5) USDA Natural Resources Conservation Service (NRCS)
6) Hopkins-Rains Soil and Water Conservation District (SWCD)
7) Local dairy owners

This project will demonstrate the effectiveness of selected BMPs to reduce nutrient loading of dairy operations to the Running Creek Subwatershed. For the sites where BMPs are implemented, when sufficient overland water flow exists, water samples will be collected from the sites. Load reductions for nutrients and phosphates will be calculated for the targeted dairy operations in order to determine the effectiveness of the BMPs installed. Please see section B1 "Sample Process Design (Experimental Design)" for more detail.

Dairy operations that have not implemented practices to control dairy waste from leaving their operations are often found to be contributors of water quality degradation. In order to assess the quality of water at the in-stream and edge of field sampling locations, automatic ISCO water samplers will be utilized to collect water samples during stormwater runoff events. Water samples will be analyzed and monitored for the presence of nitrates, orthophosphates, total suspended solids, pH, conductivity, dissolved oxygen and temperature. These parameters will be measured since they are good indicators of water quality. Water samples will be collected from the demonstration sites (a maximum of 300 samples per 18 months for each sampling point, flow permitting). Concurrent flow data, estimated by ISCO stream level data loggers, will provide information to locate the beginning, peak, and end of stormwater events. Water samples collected will analyzed if they meet preservation requirements and holding times. Datalogger printouts are checked to ensure that samples come from a rainfall event and not artificial flow from a wastewater treatment plant or some other anomaly. Samples will be analyzed within the estimated accuracy and precision limits of measured parameters to insure data quality (Table A7-1).

Table A7-1 Estimated Accuracy and Precision Limits of Measured Parameters

Nutrient/pollutant	Processing Agency	Estimated Precision Limits (PD)	Estimated Accuracy Limits	Estimated Practical Quantity Limits
Conductivity	TIAER	NA	± 1% of Range *	10 µs/cm *
Dissolved Oxygen	TIAER	NA	NA	1.0 mg/L
Water Temperature	TIAER	NA	NA	0.1 °C
Potential Hydrogen (pH)	TIAER	NA	NA	0.1 pH units
Total Suspended Solids	TIAER	10%	80-120%	50 mg/L
Chemical Oxygen Demand	TIAER	10%	80-120%	25 mg/L
Nitrate-nitrite Nitrogen	TIAER	10%	80-120%	0.08 mg/L
Orthophosphate - Phosphorous	TIAER	10%	80-120%	0.015 mg/L
Ammonia Nitrogen	TIAER	10%	80-120%	0.08 mg/L
Total Kjeldahl Nitrogen	TIAER	10%	80-120%	1.5 mg/L
Total Phosphorus	TIAER	10%	80-120%	0.55 mg/L

* Manufacture's specifications

Data collection and analyses will meet a 90 percent data completeness. These data will be presented as mean levels for evaluation. Statistical comparison of BMPs will include analysis of variance with a 90 percent level of confidence (α=.10). Although 100 percent of collected data should be available, accidents, insufficient sample volume, or other problems must be expected. A goal of 90 percent data completeness will be required for data usage. If less than 90 percent data completeness occurs, the Program Manager will initiate corrective action. Data completeness will be calculated as a percent value and evaluated with the following formula:

$$\% \text{ completeness} = \frac{SV}{ST} \times 100$$

Where: SV = number of samples with a valid analytical report

ST = total number of samples collected

The TIAER Laboratory will determine the precision of its analyses. This will be accomplished by repeating the entire analysis of a sample once per batch or once per 10 samples which ever is the greater frequency. Percent deviation (PD) of duplicate analyses will be calculated using the formula:

$$PD = \frac{(X_1 - X_2)}{(X_1 + X_2)} \times 100\%$$

Where: X_1 = first replicate value
X_2 = second replicate value

The accuracy of the analytical process will be monitored by determining the percent recovery of a spike quantity of the parameter in question. The following formula will be utilized to determine percent recovery:

$$\%\ Recovery = \frac{SSR - SR}{SA} \times 100$$

Where:
SSR = spiked sample result
SA = spike added
SR = sample un-spiked result

Data will be reviewed for abnormalities or any unusual results. Any of these that occur will be traced back looking for sources of error. In the event no error is found, the data will be assumed normal and appropriate for decision determinations. If an error is found and cannot be resolved then the data will be discarded.

The Program Manager will coordinate with the Laboratory Manager to ensure that proper protocols are utilized. Table A7-1 shows the study limits established for accuracy and precision.

Section A10: Documentation and Records

Reporting will include quarterly progress reports, reimbursement requests, and a final report at the culmination of the project.

Quarterly progress reports will note activities conducted throughout the quarter, items or areas identified as potential problems, and any variations or supplements to the QAPP. Problems encountered will be discussed by the project team and corrective actions implemented will also be included in the appropriate quarterly report. Corrective Action Report forms(CARs) will be utilized when necessary (Attachment A10-1).

Reimbursement requests for TIAER will be handled by the Tarleton State University accounting office in Stephenville.

The final report will include laboratory results with a summary of the data that was collected during the course of the project. Hard copies of all raw data, laboratory analyses, documentation records, calibration logs, and all original data will be archived by TIAER for at least 5 years.

Attachment A10-1 Corrective Action Report (CAR) Form

Corrective Action Report

CAR #: ________________

Date:____________ Area/Location:________________

Reported by:__________________ Activity:______________________

State the nature of the problem, nonconformance or out-of-control situation:

____

____

____

Possible causes:

____

____

____

Recommended Corrective Actions:

____

____

____

CAR routed to:_______________________

Received by:_________________________

Corrective Actions taken:

____

____

____

Has problem been corrected: YES NO

Quality Assurance Manager:___________________________

Program Manager:______________________________

Laboratory Manager:______________________________

Section B1: Sampling Process Design (Experimental Design)

This project is designed to implement water quality management plan BMPs on several dairies within the Running Creek subwatershed and determine the effectiveness of these BMPs to reduce the loadings of nutrients (nitrogen and phosphorus) and chemical oxygen demand leaving these dairies. Through the collection of water samples it will be possible to demonstrate the effectiveness of implemented BMPs. The waterborne constituents which will be measured to demonstrate BMP effectiveness are shown in Table B1-1.

Table B1-1 Waterborne Constituents

Parameter	Reporting Units
Potential Hydrogen	pH standard units
Dissolved Oxygen	mg/L
Temperature	°C
Conductivity	µs/cm
Chemical Oxygen Demand	mg/L
Total Suspended Solids	mg/L
Ammonia Nitrogen	mg/L
Total Kjeldahl Nitrogen	mg/L
Nitrate-Nitrite Nitrogen	mg/L
Orthophosphate Phosphorous	mg/L
Total Phosphorous	mg/L

In order to assess the overall water quality benefit or effectiveness of implemented BMPs, baseline water quality grab samples will be collected above and below the two dairy sites at approximately two week intervals. A maximum of 40 grab samples will be collected from each dairy site, flow permitting. Sampling on these sites will be completely weather dependent so the number of runoff events that may occur will vary. Either a paired watershed study design (EPA publication number 841-F-93-009) or an upstream/downstream study design (EPA publication number 440/5-85-001) will be used to demonstrate the effectiveness of implemented BMPs (see Appendix A and B). Both of these designs involve a period of calibration to establish a pre-BMP baseline and then a period of time to collect samples following appropriate NPS pollution control BMPs. Hence, water quality data collected pre-and post-BMP implementation will be compared to demonstrate BMP effectiveness.

Stormwater runoff will also be collected above and below the two dairy sites with ISCO automatic sampling devices during each rainfall event that is of sufficient intensity and duration to trigger the automatic sampling devices. A maximum of 300 and a minimum of 150 stormwater runoff samples will be collected from each sampling point on each dairy site. Sampling on these sites will be completely weather dependent so fewer runoff events may occur. The automatic sampler timers will be programmed with a sampling regime developed by TIAER on previous projects (see Table B1-2). These sampling times may be adjusted as individual collection sites warrant.

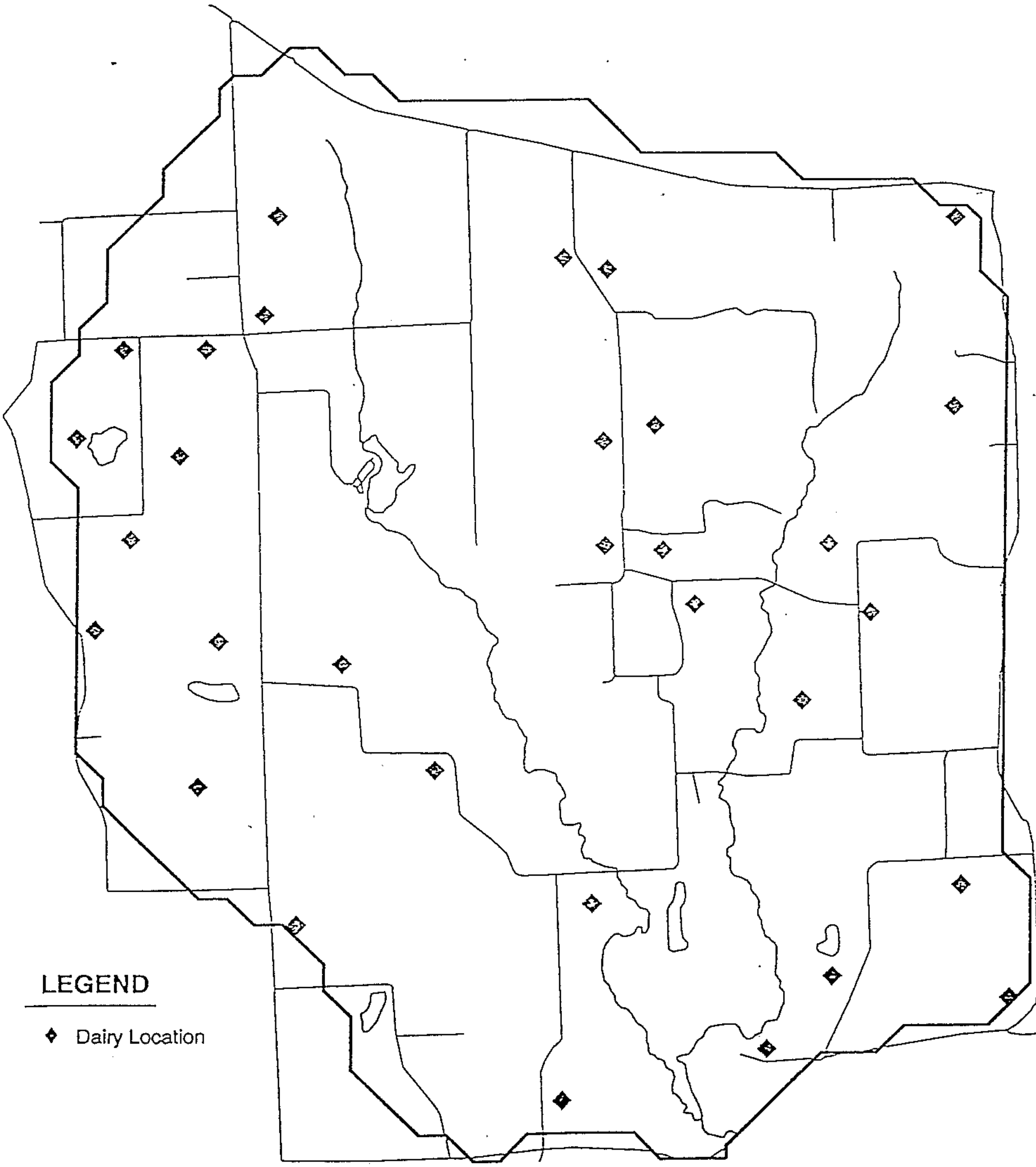
A map of the Running Creek Subwatershed (Attachment B1-3) is shown on page 19 of the QAPP. Activities are currently ongoing with TSSWCB and the SWCD to contact two dairy owners for potential monitoring sites.

This project will evaluate BMP effectiveness at a confidence level of 90 percent over the 18 month sampling period. Following the completion of the project, a report (which is the final report mentioned in Section A10) of BMP effectiveness will be distributed to all agencies participating in the project.

Table B1-2 Demonstration Sites Time Sampling Regimes

Sample Number	Elapsed Time, Hours
# 1	0.0 Hours
# 2	1.0 Hours
# 3	2.0 Hours
# 4	3.0 Hours
# 5	5.0 Hours
# 6	7.0 Hours
# 7	9.0 Hours
# 8	11.0 Hours
# 9	17.0 Hours
# 10	23.0 Hours
# 11 - 24	6.0 Hour intervals thereafter

* All times referenced to sampler activation time of 0.0 hours.



Attachment B1-3 Map for Running Creek subwatershed

Section B2: Sampling Methods Requirements

Emphasis during this project will be placed on stormwater runoff; however, measurements must be made to determine base flow nutrient levels leaving the dairy sites. Routine bi-weekly grab samples will be collected at the sites a maximum of 40 times over the 18 month sampling period. Upon collection, samples will be transported to the TIAER laboratory for analysis.

Stormwater runoff samples will be collected with automatic sampling equipment. Each unit will consist of a weatherproof, lockable instrument shelter; a solar / battery power system; timer controlled ISCO Model 3700 Water Sampler; and an ISCO Model 4230 or 3230 Bubble Flow Meter. The flow meter monitors and records water level in the stream channel and also activates the sampler when the water rises to a predetermined level which will be site specific. Automatic sampler times will be set as described in Table B1-2. Up to 24 samples may be collected as the ISCO 3700 water sampler contains a set of 24 one liter polyethylene bottles.

Water samples will be collected with the automated water samplers when the water level rises to a predetermined point. Flow will be estimated from water levels with standard open-channel flow equations such as the Chezy-Manning equation. The ISCO 3700 water samplers will be set up to catch the first flush of runoff from the sites when sufficient flow exist. The automatic sampler timers will be programmed with appropriate time sampling regimes for each demonstration site e.g., (Table B1-2).

All automatic sampling equipment will be inspected at least once a week and serviced as needed. Sample collection at the demonstration sites will be performed by the TIAER personnel. After a rainfall event, the ISCO samplers will be inspected within 24 hours to see if water samples have been collected. If the ISCO samplers properly collected water samples, then the samples will be transported to the TIAER laboratory for analysis.

Any problems encountered during the collection of water samples will be documented with a Corrective Action Report (See Attachment A10-1). Corrective Action Reports must be documented in writing and are the responsibility of the TIAER Project Manager or his representative.

Section B3: Sample Handling and Custody Requirements

Requirements for sample handling include collection, preservation, shipping, transfer of sample custody, and storage in a manner that does not compromise sample integrity or exceed holding times for analyses. Table B3-1 delineates sample container, preservation and holding time information for parameters of interest in this project. Dissolved oxygen, pH, water temperature and conductivity are not included because they are measured in situ. A sample COC is included in Attachment B3-2. The sampling team will, upon collection, labeling and preservation of the samples, complete the sample description, date/time of collection information and sign the COC to transfer custody. The COC, sealed in a water proof bag, will be packed with the samples in coolers with ice, sealed with tape and shipped to the laboratory. Custody seals on sample bottles and shipping coolers will not be used on this project because the potential for litigation or fines is not expected to exist. Shipment of samples from the Sulphur Springs area will be accomplished overnight to the Stephenville laboratory using Greyhound Bus Lines as the primary carrier. Federal Express and United Parcel Service priority shipments will be used as backup methods.

Once the samples are received at the laboratory, they will be inventoried against the accompanying COC, any discrepancies noted, and the COC will be signed for acceptance of custody. The sample numbers will then be recorded into a laboratory sample log, checked for preservation (as allowed by the specific analytical procedure), filtered or pretreated as necessary, and placed in a refrigerated cooler dedicated to sample storage.

The Laboratory Manager has the responsibility to ensure that all holding times are met. This is documented on COC for sample dates and times and on analytical run logs for analysis dates and times.

Table B3-1 Sample Preservation and Holding Times

Parameter	Method	Sample Size	Container	Preservation	Holding Time
Ammonia nitrogen	EPA 350.1	1 liter	HDPE	pH <2 H2SO4, 4C	28 days
Nitrate-Nitrite nitrogen	EPA 353.2	1 liter	HDPE	pH <2 H2SO4, 4C	28 days
Total Kjeldahl nitrogen	EPA 351.2	1 liter	HDPE	pH <2 H2SO4, 4C	28 days
Orthophosphate phosphorus	EPA 365.2	1 liter	HDPE	pH <2 H2SO4, 4C	48 hours
Total phosphorus	EPA 365.4	1 liter	HDPE	pH <2 H2SO4, 4C	28 days
Chemical Oxygen Demand	HACH 8000	1 liter	HDPE	pH <2 H2SO4, 4C	28 days

HDPE = High Density Polyethelene bottles
H2 SO4 = concentrated sulfuric acid
4C = 4 degrees centigrade

CHAIN O. JSTODY
Attachment B3-2

Project Name/No.	Project Manager/Person Requesting Sample	Samplers Name

Sample No.	Color Code	Date	Time Military	Size	Sample Type	Sample Interval	Comments

Relinquished By:	Date:	Time:	Received By:
Relinquished By:	Date:	Time:	Received By:
Relinquished By:	Date:	Time:	Received By:

SAMPLE TYPES: F = Flow Based Composite T = Time Based Composite S = Sequential G = Grab

Section B4: Analytical Methods Requirements

Only EPA approved methods shall be used for analytical data collection in accordance with 40 CFR 136. Documentary logs shall be maintained for instrument maintenance and calibration, sample extractions, standard and matrix spiking preparations. Table B4-1 delineates specific methods of analyses with equipment and instruments to be used and estimated method detection limits. Sample analysis will be performed by the Texas Institute for Applied Environmental Research, Tarleton State University, Stephenville, Texas. Glassware and labware shall be cleaned according to the specific method requirements. Corrective actions shall be initiated and resolved as described in section B5.

Table B4-1 Laboratory Analytical Methods

Parameter	Method	Equipment Used	Estimated MDL **
Ammonia nitrogen	EPA 350.1	Perstorp Analytical Autoanalyzer	0.015 mg/L
Nitrate-Nitrite Nitrogen	EPA 353.2	Perstorp Analytical Autoanalyzer	0.015 mg/L
Total Kjeldahl Nitrogen	EPA 351.2	Perstorp Analytical Autoanalyzer	0.299 mg/L
Orthophosphate phosphorus	EPA 365.2	Beckman DU 64 Spectrophotometer	0.003 mg/L
Total phosphorus	EPA 365.4	Perstorp Analytical Autoanalyzer	0.11 mg/L
Total Suspended Solids	EPA 160.2	Sartorius AC210P analytical balance, oven	10 mg/L
Conductivity	SM 2510.B	Hydrolab Datasonde	2.0 mmhos/cm
pH	EPA 150.1	Hydrolab Datasonde	± 0.2 pH units
Dissolved Oxygen	EPA 360.1	Hydrolab Datasonde	± 0.2
Water temperature	EPA 170.1	Hydrolab Datasonde	±0.15 °C
Chemical Oxygen Demand	HACH 8000	Hach DR 2000 COD system with digestors	5 mg/L

** Estimated MDL determined March 1996

Section B5: Quality Control Requirements

Automated samples shall be acquired using ISCO samplers with plastic bottles and silicon tubing. Grab samples are acquired with plastic bottles.

Data acceptance criteria shall be based upon precision and accuracy monitoring as described in Table B5-1. Method Detection Limit (MDL) estimates are listed in Table B4-1 above. MDLs are determined by analyzing a low level standard at 3-5 times the estimated MDL. This standard is analyzed 7 times using normal calibration and instrument operating conditions. The standard deviation of the 7 readings is determined and multiplied by 3.14 to obtain the MDL for the parameter of interest. Analytical precision shall be determined through the use of laboratory duplicate samples. The Percent Deviation (PD) is determined from the duplicate values. Sample matrix spiking, the addition of a known amount of the analyte of interest to a sample aliquot, is used to determine interferences present in the sample matrix. Accuracy is determined by percent recoveries of matrix spikes and of a Laboratory Control Sample (LCS) (known spike of deionized water). The quality control for blanks, duplicates, spikes and standard sample analyses are listed in Table B5-2. The use of method blanks, deionized water carried through all processes, will demonstrate that no contamination of samples occurs through laboratory handling or operation. Method blanks shall be used with every parameter in this project except conductivity, pH, temperature, and dissolved oxygen and will be done on a 10% basis. Spikes and duplicate analyses will be performed will be done on a 10% basis for each set of samples collected.

In the event that a situation arises which may indicate a compromise of sample integrity or data quality, a Corrective Action Report (CAR) shall be initiated (Attachment A10-1). The person who first identifies the out-of-control situation shall initiate a Corrective Action by completing the first portion of the form and presenting it to his/her immediate supervisor. Out-of-control situations include, but are not limited to: automated stormwater sampler malfunction, broken sample bottles, missed holding times, instrument malfunction, improper preservation, or acceptance criteria for precision and accuracy not met. An attempt shall be made to correct the problem at the source or supervisory levels. The Program Manager may decide on what action to take if further action is deemed necessary. CARs shall be included in the quarterly progress reports and final project report.

Table B5-1
QC Acceptance Criteria

Parameter	PD	spike recovery	LCS recovery
Total Suspended Solids	10%	N/A	80-120%
Conductivity	10%	N/A	80-120%
Ammonia Nitrogen	10%	80-120%	80-120%
Nitrate-Nitrite Nitrogen	10%	80-120%	80-120%
Total Kjeldahl Nitrogen	10%	80-120%	80-120%
Orthophosphate Phosphorus	10%	80-120%	80-120%
Total Phosphorus	10%	80-120%	80-120%
Chemical Oxygen Demand	10%	80-120%	80-120%

Once matrix effects have been established for parameters, control charts will be used to establish more narrow acceptance criteria for LCS, duplicates and spikes.

Table B5-2 Required Quality Control Analyses

Parameter	Blank	Standard	Duplicate	Spike
Total suspended solids	A	None	B	None
Ammonia nitrogen	A	A	B	B
Total Kjeldahl nitrogen	A	A	B	B
Nitrate/nitrite nitrogen	A	A	B	B
Orthophosphate phosphorous	A	A	B	B
Total phosphorous	A	A	B	B
Chemical Oxygen Demand	A	A	A	None

A - Where specified, blanks and standard shall be performed each day that samples are analyzed.
B - Where specified, duplicate and spike analyses shall be performed on a 10% basis each day that samples are analyzed. If one to 10 samples are analyzed on a particular day, then one duplicate and one spike analyses shall be performed.

Section B7: Instrument Calibration and Frequency

Instruments and laboratory equipment used in the analyses of these samples are listed in table B4-1 above. All instruments which require calibration prior to use are calibrated before each day's analysis. One exception is the Hach DR 2000 COD system which maintains a stored calibration curve and is functionally checked with a laboratory control standard prior to use. Calibration is normally performed with a 5 point standard curve. Another exception is for conductivity which uses a two point LCS check for the platinum cell electrode. The analytical balance for TSS also requires no calibration other than class "S" weights to check the balance.

Stock standards are made from ACS certified materials where possible. All certified standards are maintained traceable with certificates on file in the laboratory. Dilutions from all standards are recorded in the standards log book and given unique identification numbers. The date, analyst initials, stock sources with lot number and manufacturer, and how dilutions are made are also recorded in the standards log book.

All automatic sampling equipment will be inspected at least once a week and serviced as needed. After a rainfall event, the ISCO samplers will be inspected within 24 hours to see if water samples need to be collected. If the ISCO samplers properly collect the water samples, then the samples will be transported to the TIAER laboratory for analysis.

Section B9: Data Acquisition Requirements (Non-direct Measurements)

The evaluations of the BMPs used in this project will be based entirely on data collected from the dairy sites during the time-frame of this project. No additional data bases or literature files will be utilized to evaluate the BMPs implemented during this project.

Section C1: Assessments and Response Actions

The commitment to use approved equipment and approved methods when obtaining environmental samples and when producing field or laboratory measurements requires periodic verification that the equipment and methods are, in fact, being employed and being employed properly. This verification will be provided through an annual field and laboratory performance audit performed by TSSWCB. Individual field personnel will be observed during the actual field investigation to verify that equipment and procedures are properly applied. Any problems that are discovered in the monitoring procedures that would affect the quality of data collected at the demonstration sites will be addressed by the project participants and followed up with a Corrective Action Report. The TIAER laboratory has an internal system of quality assurance and assessment to ensure the quality of data produced. Also, TNRCC and EPA may conduct a performance audit for this project.

All laboratory analyses will have the precision and accuracy of data determined on the particular day that the data were generated. Depending on the analysis, certain methodologies require that water blanks, standards, and reagent blanks be analyzed to verify that no instrument or chemical problem will affect the quality of the data. The specific requirements are presented in Section B5 of the QAPP.

To minimize downtime of all measurement systems, all field measurement and sampling equipment, and all laboratory equipment must be maintained in a working condition. Also, backup equipment or common spare parts will be available if any piece of equipment fails during use so that repairs or replacement can be made quickly and the measurement tasks resumed.

Section C2: Reports to Management

The field measurement and sampling for the project will be done according to the QAPP. However, if the procedures and guidelines established in this QAPP are not successful, corrective action is required to ensure that conditions adverse to quality data are identified promptly and corrected as soon as possible. Corrective actions include identification of root causes of problems and successful correction of identified problem. Corrective Action Reports will be filled out to document the problems and the remedial action taken. Corrective Action Reports will be submitted to the TSSWCB on a quarterly basis and subsequently passed on to TNRCC and EPA.

Section D1: Data Review, Validation, and Verification

The program manager and monitoring team personnel will be responsible for reviewing, validating, and verifying the measurement and sample data and the routine assessment of measurement procedures for precision and accuracy.

The Laboratory Manager shall be responsible for reviewing raw data produced by the TIAER laboratory. The Laboratory Manager shall check calculations to verify that data is entered into the database correctly and be responsible for internal lab error corrections. Corrective Action Reports will be initiated in cases where invalid or incorrect data has been determined to have left the laboratory. The Quality Assurance Manager will review the project data prior to its usage in determining the effectiveness of BMP for abnormalities or any unusual results. Any of these that occur will be traced back looking for sources of error. Data outliers will be determined by constructing box plots and all data points that fall outside the inner fence will be checked for error in data transmission. Since most water quality data is not normally distributed, a natural log transformation on the data will be completed before construction of the box plots. Extreme outliers from the dataset (data points outside the outer fence) will be excluded from statistical analyses. Data determined to be non-detected shall be reported as less than the method detection limit and will be used in subsequent analyses as one-half the method detection limit level (Gilliom, R.J. and D.R. Helsel. 1986. Estimation of distributional parameters for censored trace level water quality data. 1. Estimation techniques. Water Resources Research 22:135-126).

Whenever the procedures and guidelines established in this QAPP do not meet the specified levels of data quality, corrective actions will be required. Corrective action shall be initiated if variances from proper protocol are noted. Implementation of corrective actions will be the responsibility of the Program Manager or Laboratory Manager. Each manager may also initiate corrective action on his own initiative, if situations arise that require immediate attention. Documentation of any corrective action procedures through the Corrective Action Report (Attachment A10-1) will be provided by the appropriate manager, along with the results of implemented changes.

Section D3: Reconciliation with Data Quality Objectives

Data completeness in this project will be relative to the number of stormwater events sampled as compared to the number of proposed sampling events. Unforeseen weather conditions or equipment unreliability may reduce the number of events sampled. Accidents in handling, shipping, and laboratory analysis may also reduce the completeness of the sampling program. It will be the goal of this project to achieve 90% completeness in data collected. The validity of data collected will be analyzed using a t-test. However the data may need to be transformed using a natural log transformation since most water quality data contains unequal variances (variances that increase with the size of the mean). Nonparametric tests such as the Wilcoxon test on median values could be used if there is a concern that the data does not meet the assumptions for parametric analysis even after transformation.

Representativeness and comparability of data, while unique to each individual collection site, is the responsibility of the Program Manager. By following the guidelines described in this QAPP, and through careful sampling design, the data collected in this project will be representative of the actual field conditions and comparable to similar applications. Representativeness and comparability of laboratory analyses is the responsibility of the Laboratory Manager.

The Program Manager will review the final data to ensure that it meets requirements as described in this QAPP.

Appendix A - Paired Watershed Study Design

United States Environmental Protection Agency

Office of Water Washington, D.C. 20460

841-F-93-009 September 1993

EPA

Paired Watershed Study Design

INTRODUCTION

The purpose of this fact sheet is to describe the paired watershed approach for conducting nonpoint source (NPS) water quality studies. The basic approach requires a minimum of two watersheds - control and treatment - and two periods of study - calibration and treatment. The control watershed accounts for year-to-year or seasonal climate variations, and the management practices remain the same during the study. The treatment watershed has a change in management at some point during the study. During the calibration period, the two watersheds are treated identically and paired water quality data are collected (Table 1). Such paired data could be annual means or totals, or for shorter studies (<5 yr), the observations could be seasonal, monthly, weekly, or event-based. During the treatment period, one watershed is treated with a best management practice (BMP) while the control watershed remains in the original management (Table 1). The treated watershed should be selected randomly by such means as a coin toss. The reverse of this schedule is possible for certain BMPs; the treatment period could precede the calibration period. For example, the study could begin with two watersheds in two different treatments, such as "BMP" and "no BMP". Later both watersheds could be managed identically to calibrate them. Since no calibration exists before the treatment occurs, this reversed design is considered risky.

Table 1. Schedule of BMP implementation.

Period	Watershed: Control	Watershed: Treated
Calibration	no BMP	no BMP
Treatment	no BMP	BMP

The basis of the paired watershed approach is that there is a quantifiable relationship between paired water quality data for the two watersheds, and that this relationship is valid until a major change is made in one of the watersheds. At that time, a new relationship will exist. This basis does not require that the quality of runoff be statistically the same for the two watersheds; but rather that the relationship between paired observations of water quality remains the same over time except for the influence of the BMP. Often, in fact, the analysis of paired observations indicates that the water quality is different between the paired watersheds. This difference further substantiates the need to use a paired watershed approach because the technique does not assume that the two watersheds are the same; it does assume that the two watersheds respond in a predictable manner together.

EXAMPLE

To illustrate the paired watershed approach, data taken from a study in Vermont will be used. The purpose of the study was to compare changes in field runoff (cm) due to conversion of conventional tillage to conservation tillage.

Selection of Watersheds

1. Watersheds should be similar in size, slope, location, soils, and land cover.
2. Watersheds should be small enough to obtain uniform treatment over the entire watershed.
3. Watershed outlets should have a stable channel and cross section for discharge monitoring, and should not leak at the outlet.
4. Each watershed should be in the same land cover for a number of years prior to the study so that they are at a steady-state.

Advantages

1. Climate and hydrologic differences over years are statistically controlled.
2. Can attribute water quality changes to a treatment.
3. Control watershed eliminates need to measure all components causing change.
4. Watersheds need not be identical.
5. Study can be completed in shorter time frame than trend studies.
6. Cause-effect relationships can be indicated.

Disadvantages

1. Response to treatment likely to be gradual over time which influences the variance.
2. Study vulnerable to catastrophes such as hurricanes.
3. Shortened calibration may result in serially correlated data.
4. Variances between time periods may not be equal due to drastic treatment.
5. Minimal change in the control watershed is permitted.
6. Requires similar watersheds in close proximity.

The west watershed was the control and was 1.46 hectares (ha) in area. The east watershed was the treatment field and was 1.10 ha. Conventional tillage was moldboard plow whereas conservation tillage was a single disk harrow. The calibration period was one year during which 49 paired observations of storm runoff were made. The treatment period was three years during which 114 paired observations of runoff were made. Data were log-transformed to approach normality based upon the Wilks-Shapiro (W) statistic. The equality of variances between periods was tested using the F-test. Residual plots were examined to check for independence of errors. The statistical package SAS® was used for all analyses.

CALIBRATION

The relationship between watersheds during the calibration period is described by a simple linear regression (Figure 1).

between the paired observations, taking the form:

$$treated_i = b_o + b_1(control_i) + e \quad (1)$$

where *treated* and *control* represent flow, water quality concentration, or mass values for the appropriate watershed, b_o and b_1 are regression coefficients representing the regression intercept and slope, respectively, and e is the residual error.

Three important questions must be answered prior to shifting from the calibration period to the treatment period: a) is there a significant relationship between the paired watersheds for all parameters of interest, b) has the calibration period continued for a sufficient length of time, and c) are the residual errors about the regression smaller than the expected BMP effect?

Regression significance. The significance of the relationship between paired observations is tested using analysis of variance (ANOVA). The test assumes that the regression residuals: are normally distributed, have equal variances between treatments, and are independent.

Hand calculations to test for the significance of the relationship are shown in Snedecor and Cochran (1980, p. 157) (Table 2). The values for Table 2 are calculated from:

$$S_y^2 = \Sigma Y_i^2 - \frac{(\Sigma Y_i)^2}{n} \quad (2)$$

$$S_x^2 = \Sigma X_i^2 - \frac{(\Sigma X_i)^2}{n} \quad (3)$$

$$S_{xy} = \Sigma X_i Y_i - \frac{(\Sigma X_i)(\Sigma Y_i)}{n} \quad (4)$$

$$S_{yx}^2 = \frac{S_y^2 - (S_{xy})^2/S_x^2}{n - 2} \quad (5)$$

Also, the regression coefficients and coefficient of determination are determined from:

$$b_1 = \frac{S_{xy}}{S_x^2} \quad (6)$$

$$b_o = \overline{Y} - b_1\overline{X} \quad (7)$$

$$r^2 = \frac{(S_{xy})^2/S_x^2}{S_y^2} \quad (8)$$

Table 2. Analysis of variance for linear regression.

Source	Degrees of freedom	Sum of squares	Mean squares	F
regression	1	$(S_{xy})^2/S_x^2$	$(S_{xy})^2/S_x^2$	$[(S_{xy})^2/S_x^2]/S_{yx}^2$
residual	n-2	$S_y^2-(S_{xy})^2/S_x^2$	S_{yx}^2	
total	n-1	S_y^2		

In order to perform the calculations by hand, initially calculate: ΣX_i, ΣY_i, $\Sigma X_i Y_i$, ΣX_i^2, ΣY_i^2, $\bar{X}$, $\bar{Y}$. The mean squares (MS) are determined by dividing the sum of squares by the degrees of freedom (df).

For the example above, the following was calculated by hand: ΣX_i = -123.403, ΣY_i = -180.704, $\Sigma X_i Y_i$ = 533.553, ΣX_i^2 = 381.713, ΣY_i^2 = 814.847, $\bar{X}$ = -2.518 (10^X =0.003041 cm), and $\bar{Y}$ = -3.688 (10^Y = 0.000205 cm). Therefore, S_y^2 = 148.441, S_{xy} = 78.463, S_x^2 = 70.933, and S_{yx}^2 = 1.312. Using SAS, the appropriate program is listed below. This program was used to generate Table 3.

SAS PC Program

```
data flow;
 title 'Total Flow (cm)';
 infile 'fname.dat';
 input flow1 flow2;
logflow1=log10(flow1);
logflow2=log10(flow2);
Proc reg;
 Model logflow2=logflow1
       / P CLM;
run;
```

The resulting F statistic for this example would indicate that the regression relationship adequately explains a significant amount ($p<0.001$) of the variation in paired flow data.

Calibration duration. The ratio between the residual variance (mean squares) (S_{yx}^2) for the regression and the smallest worthwhile difference (d) is used to determine if a sufficient sample has been taken to detect that difference, from:

Table 3. Analysis of variance for regression of treatment watershed runoff on control watershed runoff.

Source	df	MS	F	p
model	1	86.79	66.17	0.0001
error	47	1.31		
total	48			

$$\frac{S_{yx}^2}{d^2} = \frac{n_1 n_2}{n_1+n_2}\left\{\frac{1}{F(1+\frac{F}{n_1+n_2-2})}\right\} \qquad (9)$$

where S_{yx}^2 is the estimated residual variance about the regression, d^2 is the square of the smallest worthwhile difference, n_1 and n_2 are the numbers of observations in the calibration and treatment periods ($n_1 = n_2$ for this calculation because n_2 is not known yet), and F is the table value ($p=0.05$) for the variance ratio at 1 and $n_1 + n_2 - 3$ df. The difference (d) is selected based on experience and would vary with project expectations. If the left side of the equation is greater than the right side of the equation, then there are an insufficient number of samples taken to detect the difference. For the example, S_{yx}^2 was 1.312 (from Table 3), $n_1 = n_2$ was 49, and F was 3.94. A ten percent change from the mean was considered a worthwhile difference; therefore, d = 0.10 * $\bar{X}$ = 0.10 * log 0.003041 cm and S_{yx}^2/d^2 = 20.7. The right side of Equation (9) = 6.0; since 20.7 is greater than 6.0, there

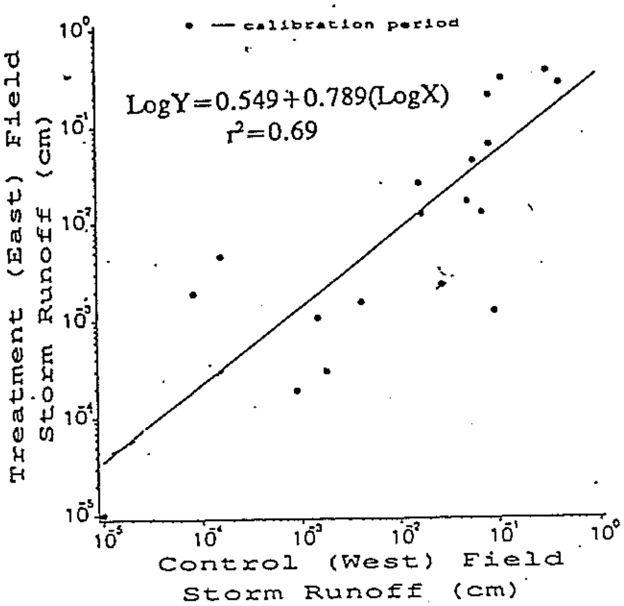


Figure 1. Calibration period regression.

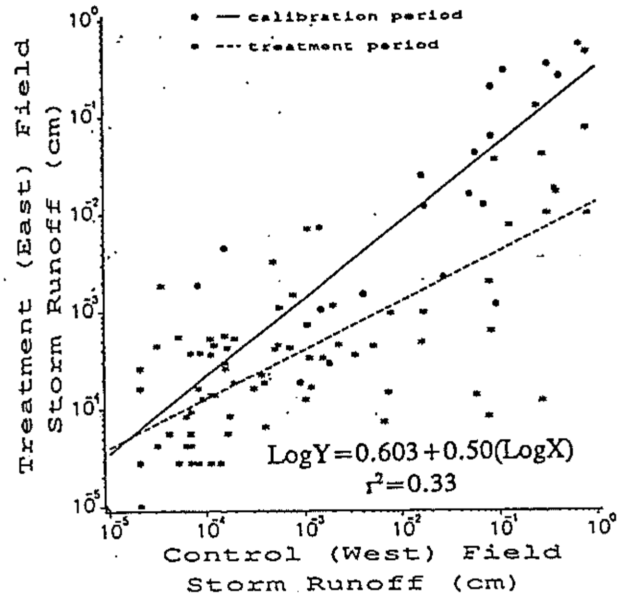


Figure 2. Treatment and calibration period regressions.

was an insufficient number of observations to detect a 10% change in discharge. There were enough samples to detect a 20% change in discharge ($S^2/d^2 = 5.2$).

Residual errors. The confidence bands for the regression equation allow determining the level of change needed to have a significant treatment effect. Thus, how far away from the calibration regression must the treatment data be to be significantly different? Confidence bands for the regression are determined from:

$$CI = \pm(t)(S_{yx})\sqrt{\frac{1}{n}+\frac{(X_i-\overline{X})^2}{S_x^2}} \qquad (10)$$

where CI is the confidence interval, S_{yx} is the square root of S_{yx}^2, n and S_x^2 have been previously defined, t is Student's 't', and X_i is the value at the point of comparison to compare to the mean on the regression line. Confidence limits can be generated in SAS by adding / P CLM to the MODEL statement (see page 4).

TREATMENT

At the end of the treatment period the significance of the effect of the BMP is determined using analysis of covariance (ANCOVA). The analysis is actually a series of steps determining a) the significance of the treatment regression equation, b) the significance of the overall regression which combines the calibration and treatment period data, c) the difference between the slopes of the calibration and treatment regressions, and d) the difference between the intercepts of the calibration and treatment regressions. The

Table 4. Analysis of covariance for comparing regression lines.

Source	df	S_x^2	S_{xy}	S_y^2	b_1	df	SS	MS	F
Within									
Calibration	n_1-1	Eq.(3)	Eq.(4)	Eq.(2)	Eq.(6)	n_1-2	$S_y^2-(S_{xy})^2/S_x^2$	Eq.(5)	--
Treatment	n_2-1	Eq.(3)	Eq.(4)	Eq.(2)	Eq.(6)	n_2-2	" "	Eq.(5)	--
				Pooled	Error	Σ	Σ	SS/df	
Slopes	n_1+n_2-2	Σ	Σ	Σ	Eq.(6)	n_1+n_2-3	$S_y^2-(S_{xy})^2/S_x^2$	Eq.(5)	
				Slope difference		1	Slope SS - Error SS		MS/Error MS
						1	Combined SS - Slope SS		MS/Slope MS
Intercepts	n_1+n_2-1	combined data				n_1+n_2-2	$S_y^2-(S_{xy})^2/S_x^2$		

analysis can be computed by hand as shown in Table 4 (Snedecor and Cochran, 1980, p. 386). In order to perform the calculations by hand, the following are determined for the example treatment data: ΣX_i = -358.14, ΣY_i = -416.05, $\Sigma X_i Y_i$ = 1408.37, ΣX_i^2 = 1352.54, ΣY_i^2 = 1653.43, $\overline{X}$ = -3.1416, $\overline{Y}$ = -3.650, and n = 114. Therefore, S_y^2 = 135.00, S_{xy} = 101.32, and S_x^2 = 227.43. The ANCOVA is completed for the example in Table 5. The summations symbol(Σ) in Table 4 is used to signify the addition of the column entries above it.

Since the slopes were found to be different, the differences in intercepts do not have any real meaning and do not need to be calculated. That is, if slopes are different, intercepts will usually be different. However, the calculation for the test of intercepts is presented to show the method. The combined data are determined by summing the ΣX_i, ΣY_i, $\Sigma X_i Y_i$, ΣX_i^2, and ΣY_i^2 values for both the calibration and treatment periods and calculating new values for S_y^2, S_{xy}, and S_x^2. The calculation of F for the intercept uses the slope MS in the denominator. The F for the slope test uses the error MS in the denominator. A significant difference in intercepts but not slopes indicates an overall parallel shift in the regression equation.

Using SAS, an example program is listed below. This program contains both a test of the treatment regression in the PROC REG statement and a test comparing the regression lines in the PROC GLM statement.

SAS PC Program

```
Proc reg;
  model logflow2=logflow1;
run;
Proc glm;
  class period;
  model logflow2=logflow1 period
        logflow1*period;
run;
```

The treatment period regression was found to be significant based on the analysis of variance for regression (Table 7).

Table 5. Example analysis of covariance for comparing regression lines.

Source	df	S_x^2	S_{xy}	S_y^2	b_1	df	SS	MS	F
Within									
Calibration	48	70.933	78.463	148.441	1.106	47	61.650	1.3117	
Treatment	113	227.430	101.315	135.000	0.445	112	89.866	0.8024	
				Error		159	151.516	0.9529	
Slopes	161	298.363	179.778	283.441	0.603	160	175.116	1.0945	
				Slope difference		1	23.600	23.600	24.77***
						1	5.8453	5.8453	5.34*
Intercepts	162	311.671	178.762	283.492		161	180.961		

*** indicates significance at p=0.001
* indicates significance at p=0.05

Table 7. ANOVA for regression of treatment watershed runoff on control watershed runoff for the treatment period.

Source	df	MS	F	p
model	1	45.13	56.25	0.0001
error	112	0.80		
total	113			

Table 8. ANCOVA for comparing calibration and treatment regressions.

Source	df	MS	F	p
model	3	43.99	46.17	0.001
error	159	0.95		
overall	1	103.09	108.18	0.0001
intercept	1	5.47	5.74	0.0178
slope	1	23.42	24.58	0.0001

The analysis of covariance obtained in SAS output summarizes the significance of the overall model, compares the two regression equations, the regression intercepts, and slopes (Table 8). The ANCOVA indicates that the overall treatment and calibration regressions were significantly different, and that the slopes and intercepts of the equations also were different. The difference in slopes is evident in Figure 2. The slight differences in F values between the hand calculation method and the SAS output are due to rounding errors.

DISPLAYING AND INTERPRETING RESULTS

The most common methods for displaying the results include a bivariate plot of paired observations together with the calibration and treatment regression equations (Figure 2). Another useful graph is a plot of deviations ($y_{observed}$ - $y_{predicted}$) as a function of time during the treatment. The predicted values are obtained from the calibration regression equation. For the example, the plot of deviations indicates that for most paired observations, the observed value was less than that predicted by the calibration regression equation. Results should be provided of mean values for each period and each watershed. The overall results due to the treatment can be expressed as the % change based on the mean predicted and observed values. For the example, there was a 64 % reduction in mean runoff due to the treatment (Table 9).

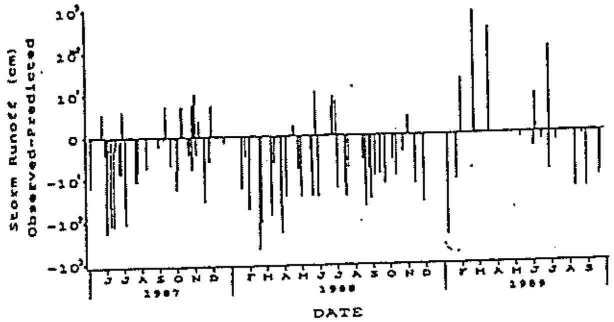


Figure 3. Observed deviations from predicted discharge.

Table 9. Mean values by period and watershed.

	Runoff (cm) x 10^{-2}	
Calibration		
Control	0.30	
Treatment	1.63	
Treatment		
Control	0.08	
Treatment	0.04	
Predicted	0.11	-64%

FURTHER READING

Bernstein, B.B. 1983. An optimum sampling design and power tests for environmental biologists. J. Environ. Mgmt. 16:35-43.

Hewlett, J.D. and L. Pienaar. 1973. Design and analysis of the catchment experiment. In Proc. Symp. Use of Small Watersheds. E.H. White (Ed.). Univ. Kentucky.

Green, R. H. 1979. Sampling design and statistical methods for environmental biologists. New York: John Wiley and Sons.

Kovner, J.L. and T.C. Evans. 1954. A method for determining the minimum duration of watershed experiments. Trans. AGU. 35(4):608-612.

Ponce, S.L. 1980. Statistical methods commonly used in water quality data analysis. WSDG Technical Paper WSDG-TP-00001. USDA Forest Service. Fort Collins, CO 80524.

Reinhart, K.G. 1967. Watershed calibration methods. In Proc. Intern. Symp. on Forest Hydrology. W.E. Sopper and H.W. Lull. (Eds.) Pergamon Press. Oxford. P.715-723.

SAS Institute, Inc. 1986. SAS system for linear models. Cary, NC 27511.

Snedecor, G.W. and W.G. Cochran. 1980. Statistical methods. 7th Ed. The Iowa State University Press. Ames, Iowa.

Wilm, H.G. 1949. How long should experimental watersheds be calibrated? Amer. Geophs. Union Trans. Part II. 618-622.

ACKNOWLEDGEMENT

This project was supported by U.S. EPA Office of Wetlands, Oceans, and Watersheds under EPA Contract No. 68-C9-0013. This fact sheet was prepared by Dr. John C. Clausen, University of Connecticut and Dr. Jean Spooner, North Carolina State University, and reviewed by Mr. Steve Dressing, U.S. EPA.

Appendix B - Appropriate Designs for Documenting Water Quality Improvements From Agricultural NPS Control Programs

APPROPRIATE DESIGNS FOR DOCUMENTING WATER QUALITY IMPROVEMENTS FROM AGRICULTURAL NPS CONTROL PROGRAMS

J. SPOONER
R. P. MAAS
S. A. DRESSING
M. D. SMOLEN
F. J. HUMENIK
National Water Quality Evaluation Project
North Carolina State University
Raleigh, North Carolina

ABSTRACT

Appropriate experimental designs are a function of the question to be answered. In the case of agricultural NPS control programs, the question is usually: How does BMP implementation affect the magnitude of pollutant concentrations or loads? This paper discusses the assumptions, analysis techniques, and advantages and disadvantages of three basic experimental designs that can be used in practical terms. Monitoring above and below an implementation site is generally more useful for documenting the severity of an NPS than for documenting BMP effectiveness. Time trend designs may be helpful; however, water quality trends are a result of complex interactions between land treatment, hydrology, and meteorologic factors. Accounting for these variables will therefore greatly increase the probability of documenting water quality improvements associated with BMP's. Paired watershed designs have the greatest potential for documenting improvements from BMP implementation because of the ability to control for meteorologic and hydrologic variability.

INTRODUCTION

A vast amount of information exists about best management practices (BMP's) for control of agricultural nonpoint sources (NPS). Most of this information, however, is from research efforts that considered only field plots or small watersheds. The investment of public funds to control nonpoint source pollution from agriculture requires that there be some assurance that nonpoint source pollution control programs be effective in protecting water quality. Hence, monitoring programs have been incorporated into many of these programs to verify that their application to the real world is, indeed, effective.

To evaluate the effectiveness of large-scale programs, such as the Rural Clean Water Program projects (12,000–40,000 ha), requires a great deal of money. Therefore, data analysis should be planned and executed carefully following a clearly specified experimental design. Lack of an experimental design often results in wasted data collection efforts, and inconclusive results.

In this paper, we present and discuss three alternative experimental designs that are applicable to most nonpoint source control projects. The methodologies are applicable to surface and ground water studies that deal with BMP effects on pollutant concentrations, loads, or the frequency of standard violations. Most of our examples are presented in terms of surface water concentration, but only for convenience. This treatment is not rigorous statistically, but we have attempted to present useful suggestions and lay out some of the advantages, disadvantages, and assumptions associated with each design.

MONITORING DESIGNS AND ANALYSES

Before and After (Time Trends or Time Series Analyses) Uncorrected for Meteorological Variables

Definition, Advantages, and Disadvantages: The before and after design is generally characterized by monitoring one or more sites in a watershed over time to determine whether a change in water quality conditions has occurred. Agricultural nonpoint source control programs generally involve water quality monitoring over a period of several years below the agricultural nonpoint source to assess the concentration or loading changes associated with BMP implementation.

This design is the easiest to conduct with limited funds and personnel. Little coordination between land treatment and water quality monitoring personnel is required. In nearly all cases the entire project area can be monitored. There are no physical limitations to applying this basic design to any watershed.

A disadvantage is that sensitivity is low unless meteorologically related variables are measured (stream flow, precipitation, lake levels, ground water levels). Thus, it is difficult to attribute water quality changes to land treatment measures. A long monitoring period is needed to assess whether significant changes in water quality have occurred. This is due to the extreme hydrological and meteorological variability in most systems.

Appropriate Hypothesis, Data Requirements, and Assumptions: For conceptual clarity, all the hypotheses will be stated in the alternative rather than the null form. When meteorologic variables are not measured, the appropriate hypothesis is:

> Ha: Mean annual (or seasonal) pollutant concentrations will decrease over time as BMP's are implemented.

The data needed to test this hypothesis are important. The sampling regimes should be similar for pre- and post-BMP implementation periods. Samples should be collected at equally spaced intervals or other predetermined schedules. It is important that sampling not be taken more frequently than scheduled. This allows pre- and post-BMP data to be compared with a minimum chance of sampling bias.

One assumption associated with this hypothesis is that every sample can be classified as belonging to either the pre- or post-BMP implementation period. If statistical tests are performed that divide the data into only these two groups, it is assumed that the level of BMP implementation is similar in each of the post-BMP years. Since this is often not the case, these tests may produce conservative estimates of effects.

Hypothesis Test, Conclusions, and Interpretations: The hypothesis can be tested using the Students t-test:

$$t_{sample} = \frac{(\bar{C}_{pre} - \bar{C}_{post})}{\sqrt{\left(\frac{1}{Y_{pre}} + \frac{1}{Y_{post}}\right)\frac{s_p^2}{n}}}$$

where n = the number of samples taken in each year or in each session if stratified, assumed constant

$$s_p^2 = \text{Pooled variance} = \frac{\sum_{i=1}^{Y} s_i^2}{Y}$$

y = the total number of years or seasons of monitoring

Y_{pre} = the number of years or seasons pre-BMP

Y_{post} = the number of years or seasons post-BMP

$\bar{C}_{pre}$ = the mean of the pre-BMP concentrations.

$\bar{C}_{post}$ = the mean of the post-BMP concentrations.

This t-sample statistic is compared to a t-table with (Y•n–Y) degrees of freedom. It should be noted that it may be advantageous to delete the interim time period if it can not be classified as pre- or post-BMP for this particular analysis.

An analysis that takes into account the cumulative nature of land treatment is the regression of concentration versus BMP application level. A significant negative slope suggests an improvement of water quality associated with BMP's. This approach does not require deleting data from intermediate years.

A third analysis that can be useful is generation of a Quantile–Quantile (Q–Q) plot. This analysis requires several steps. First, one generates a cumulative distribution of concentration for each site. This involves ranking by magnitude the concentration data and grouping it into percentiles. The mean for each percentile is calculated for both the pre- and post-BMP periods. These pairs are then plotted and the slope is tested to determine if it is significantly less than 1. An example of this plot is given in Figure 1. In this example a slope of less than 1 suggests a downward concentration trend.

Because uncontrolled variables such as flow have such a pronounced effect, often a downward concentration trend will not be observed. Even if a decrease in concentration is seen, no cause and effect relationship with BMP implementation level can be made. In a physical sense, there are four possible scenarios that may occur.

1. Mean flows increase; concentrations increase.
2. Mean flows increase; concentrations decrease.
3. Mean flows decrease; concentrations decrease.
4. Mean flows decrease; concentrations increase.

Of these four scenarios, there is generally only one (2) that provides strong evidence that BMP applications improved water quality. Also, without flow measurements, it is not possible to determine which of these four situations has occurred. Hence, without flow measurements, it is inevitable that a long-term monitoring program will be required to average out the fluctuations caused by stream flows, and to determine true effects of land treatment.

Before and After Time Trends Corrected for Stream Flows

Definition, Advantages, and Disadvantages: This design involves monitoring both concentration and flows over time at one or more sites in a watershed. Based upon

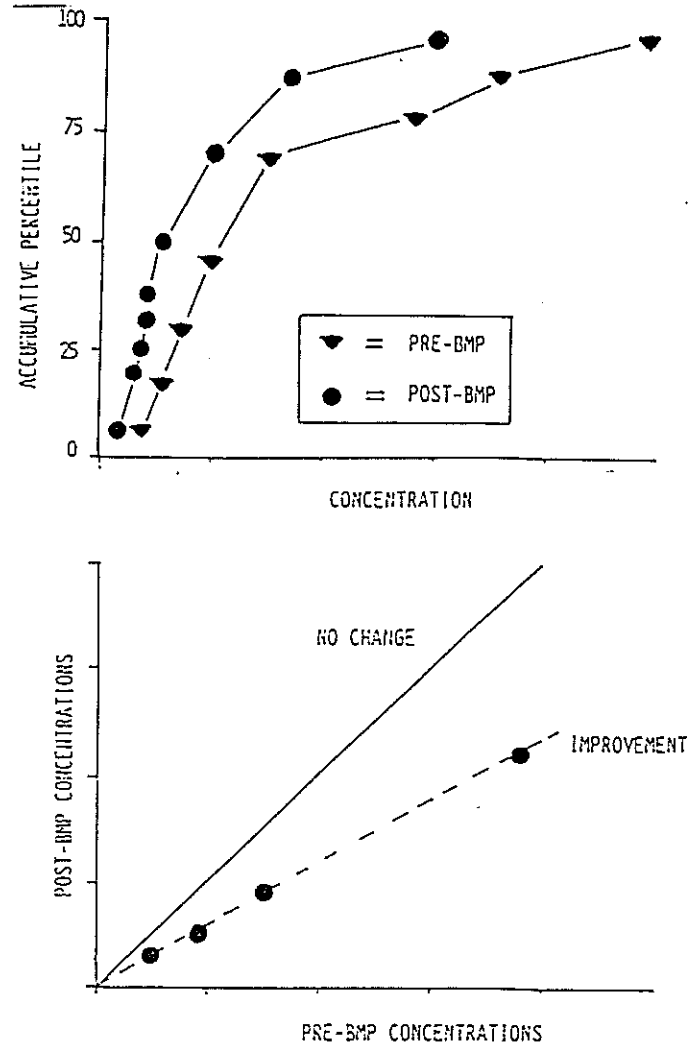


Figure 1.—An example of a Quantile–Quantile (Q–Q) plot derived from a plot of cumulative frequency distributions of concentration data from a pre- and post-BMP period.

previous studies, the variable with the greatest influence on surface water loads and concentrations is stream flow volume. (Froehlich, 1976; Johnson et al. 1974; McCool and Papendick, 1975). Thus, stream flows will be used in this and all subsequent examples that attempt to correct for meteorologic variations.

The basic advantages are the same as for the case just described. In addition, a stronger association with land treatment can be made. A long monitoring period is still needed to determine whether significant changes in water quality have occurred. Disadvantages are reduced, but unknown or unmeasured factors that occur during the project may still greatly reduce sensitivity.

Appropriate Hypothesis, Data Requirements and Assumptions: The hypothesis tested in this experimental design is:

Ha: Mean annual (or seasonal) pollutant concentrations will decrease over time when corrected for stream flows.

Flow-concentration pairs (concentration and flow measurments) need not be taken at equally spaced or predetermined time intervals. In fact, it can be seen from Figure 2 that the required data can be generated more efficiently if the monitoring is weighted toward periods of high flow. A wide range of flows is needed to establish a flow–concentration relationship, and the potential effects of BMP's are often greatest at high flows. Since the flow–concentration relationship often depends greatly upon whether the sample is taken during the rising or receding limb of the hydrograph (Baker, 1985), it may be advisable to partition the data on this basis.

All the assumptions stated for the uncorrected, before and after design still hold. In addition, this design assumes that the BMP's will decrease pollutant concentrations more than they will reduce stream flows. In general, the assumption will hold for sediment and sediment-adsorbed pollutants, but may be in error for pollutants lost primarily in the dissolved phase of runoff. The pre- and post-BMP flow-concentration sample pairs need to reflect similar ranges in flows. If not, only the post-BMP data taken in the flow ranges present in the pre-BMP data should be used in the analyses.

Hypothesis Tests, Conclusions and Interpretations: Separate linear regressions of concentrations versus flows for the pre- and post-BMP periods can be performed. The slopes are compared for equality for the two periods as shown in Figure 2. From this analysis we can determine whether concentrations have changed over time for a given flow rate. With the establishment of a good flow–concentration relationship, the effects of BMP's can be distinguished under all four of the scenarios described. There may be a significant seasonal influence on the concentration–flow relationship. This source of variability in the data can be eliminated by partitioning the data by seasons. The cost of this partitioning, however, is a loss in the number of degrees of freedom (effective sample number), which decreases the sensitivity of the subsequent statistical tests.

Above and Below (Upstream–Downstream)

Definition, Advantages and Disadvantages: This experimental design involves sampling a flowing system over time above and below a potential nonpoint source. This has classically been the design used to monitor the effects of nonpoint source discharges to flowing systems.

The primary advantage of this approach is that it can account for upstream inputs to the area of interest. For agricultural nonpoint source projects, this will often be important for watersheds where the upper portions are in nonagricultural land uses. In addition, some irrigation management projects receive irrigation water that varies greatly in quality on an annual or seasonal basis. Perhaps the most common use of this design, however, is to document the location and magnitude of sources. As with the before and after design there is also the advantage that little or no coordination is required between the land treatment and water quality monitoring components of the project.

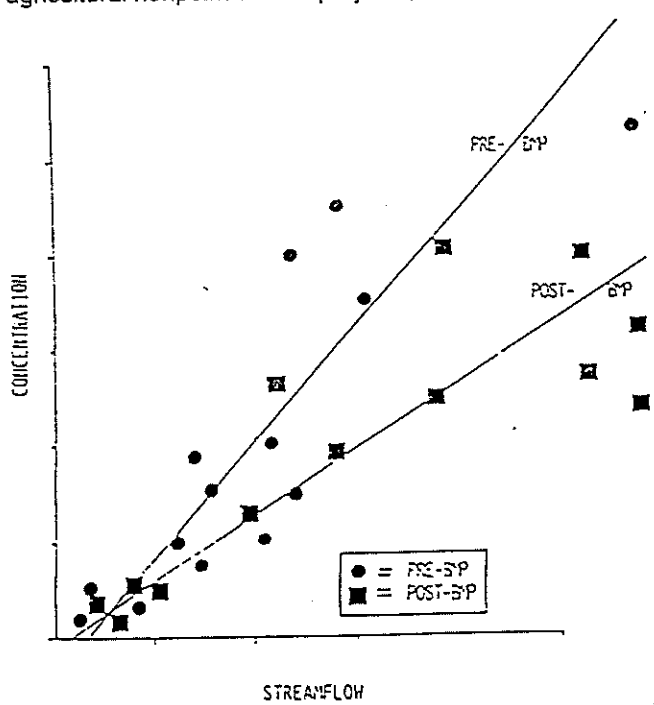


Figure 2.—An example of separate linear regression of concentration versus streamflows for a pre- and post-BMP period. Note that in this hypothetical example the data show a significant decrease in post-BMP concentrations when corrected for streamflow, even though the actual concentration mean is higher for the post-BMP period.

If the surface or ground water system originates within the nonpoint source area, there will be no suitable above sites. Also, the design provides only limited control for meteorologic variables, unless stream flow is monitored as described in the before and after design. In addition, it requires twice as many sampling sites as the before and after design to monitor an equivalent amount of the watershed area. The procedure may have low sensitivity because individual nonpoint source inputs are often small compared to background.

Appropriate Hypotheses, Data Requirements, and Assumptions: This design will generally provide information for testing two hypotheses: one concerning problem identification, and another concerning the effects of BMP's over time.

- Ha a. Agricultural pollutant concentrations will be higher downstream from a suspected agricultural nonpoint source as compared to upstream.
- Ha b. The difference between upstream and downstream pollutant concentrations will decrease over time as BMP's are applied.

Testing hypothesis a. requires paired concentration data above and below the potential nonpoint source over time during the pre-BMP period. For hypothesis b. the same paired data are needed for both the pre- and post-BMP periods.

The most important assumption for this design is that sampling is timed so that the same parcel of water is being sampled at the above and below sites. This requires some understanding of the hydrology system.

Hypotheses Tests, Conclusions, and Interpretations: For hypothesis a. to determine whether there is a significant concentration increase, a simple one-sided Student's t-test is used to determine whether the means of the paired differences between the upstream (C_{up}) and downstream (C_{down} concentrations are different from zero.

$$t_{calc} = \frac{\bar{D}}{s_D},$$

where $\bar{D}$ = the average of the paired differences,

$$= \frac{\sum_{i=1}^{n} (C_{up} - C_{down})}{n}$$

$$s_D = \frac{s_d}{\sqrt{n}}$$

In many cases, it is desirable to know what percentage of the pollutant concentration is attributable to the nonpoint source. The best estimate of this can be calculated from:

$$\text{NPS Percentage} = \sum^{n} [(C_{i\,down} - C_{i\,up}) / C_{i\,down}] \cdot 100/n$$

To test hypothesis b., paired differences (D_i) must first be calculated for pre- and post-BMP periods ($D_i = C_{i\,down} - C_{i\,up}$). Then, each of the four analyses described for the before and after design can be used to test for water quality improvements associated with BMP implementation. Briefly, these include: (a) Student's t-test for determining whether pre- and post-BMP mean concentrations are different, (b) Q–Q plots, (c) linear regression of D_i versus BMP implementation level, and (d) linear regressions of D_i versus flow for pre- and post-BMP periods to test for equality of flow-corrected D_i's.

From testing hypothesis a. we can conclude whether the suspected agricultural nonpoint source is actually a significant contributor to an identified water resource impairment. From this, we can estimate the upper limit of how such improvement can be accomplished using BMP's.

For hypothesis b. the interpretations are very similar to those that can be made for the before and after design. In the cases where not all the water originates within the project area this experimental design allows trends to be established with more certainty than the before and after design, because of the corrections for incoming concentrations.

Paired Watersheds Design (Controlled–Experimental Design or Treated–Untreated Design)

Definition, Advantages, and Disadvantages: The design consists of monitoring downstream from two or more agricultural drainages where at least one drainage has BMP implementation, and at least one does not. This design ideally possesses the following characteristics: (a) simultaneous monitoring below each drainage, (b) monitoring at all sites prior to any land treatment (calibration period) to establish the relative responses of the drainages, and (c) subsequent monitoring, where at least one drainage area continues to serve as a control through the land treatment period, i.e., receives significantly less land treatment than the other drainage areas.

This design controls for meteorologic (and to some extent hydrologic) variability, minimizing the need for monitoring meteorological parameters. In most cases, water quality improvements related to BMP implementation can be documented within a much shorter time frame. In addition, this design provides stronger statistical evidence of the cause–effect relationship between agricultural nonpoint source control efforts and water quality changes.

A disadvantage of this design is that land treatment and water quality personnel must coordinate closely to match implementation efforts with monitoring and data analysis needs. For some projects it may be difficult to find adequately similar drainages. Close physical proximity is essential. Another disadvantage is the fact that control basins cannot receive as much land treatment, thus reducing the potential water quality improvement for the overall project area. This design is not intended to determine the location or severity of the nonpoint source.

Appropriate Hypothesis, Data Requirements, and Assumptions:

> **Ha:** An agricultural drainage with BMP's applied will exhibit a decrease in pollutant concentrations over time, relative to an untreated agricultural drainage.

Site selection is crucial to this design. A similarity in hydrology and land use is desirable. Sampling from the watersheds should be conducted consistently (either simultaneously or separated by a constant time interval). Because concentration–flow relationships vary with rising or falling hydrograph limb, it is desirable to partition data on this basis.

It is assumed that paired watersheds have similar precipitation patterns, because of their geographic proximity. The hydrologic response of the paired watersheds should be consistent, even if actual concentrations are quite different because of differences in slope, soil type, cropping

	CONTROL BASINS	EXPERIMENTAL BASINS
CALIBRATION PERIOD	NO BMPs	NO BMPs
TREATMENT PERIOD	NO BMPs	BMPs APPLIED

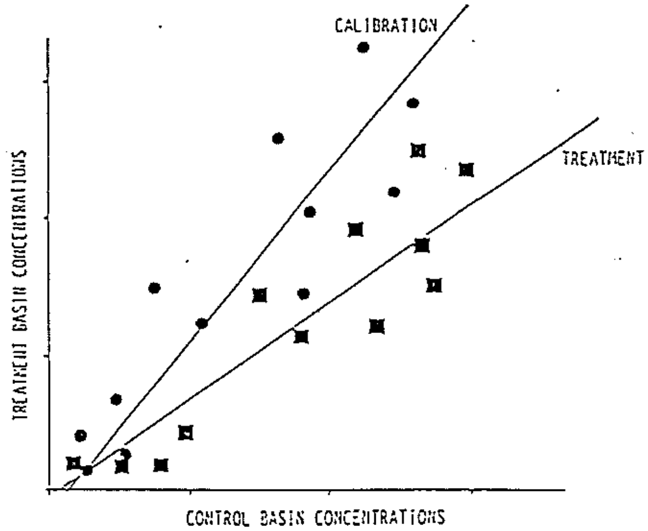


Figure 3.—An example of data analysis for the paired watersheds experimental design. If the predicted watershed value is significantly less during the treatment period as compared to the calibration period, a significant improvement in pollutant concentrations is indicated.

patterns, and other factors. It is assumed that BMP implementation levels can be measured accurately. Finally, the precipitation, stream flows, and cropping patterns should be at least somewhat similar for the calibration and treatment periods.

Hypothesis Tests, Conclusions, and Interpretations: Linear regressions of the concentrations (or log concentrations) for the treatment versus the control watersheds for the calibration and land treatment periods can be performed (Fig. 3). A Student's t-test is performed to determine if the predicted treatment watershed values at the mean control watershed concentration decrease over time.

A decrease in the predicted treatment watershed values suggests a positive effect of BMP's on the water quality. This is stronger evidence of a cause–effect relationship than that derived from any of the designs previously discussed because of greater control over the complex meteorologic, hydrologic, and temporal factors. Although this design compares only a treated drainage with an untreated drainage, the results can be interpreted to indicate that the BMP's have improved water quality in the treated subbasins relative to the condition that would have existed without treatment. It should be noted that this design documents water quality improvements only in the treated subbasins; the accuracy of extrapolating results from the test basins to other portions of the project areas will remain untested. This experimental design may develop from a project area by chance, as BMP implementation progresses in subbasins with varying levels of success.

SUMMARY

For documenting water quality improvements resulting from BMP's within the shortest possible time period we believe the paired watershed design is clearly superior, because of its control of meteorologically-related variables. To document the magnitude of nonpoint sources prior to implementing BMP's, the above and below design has advantages over the other designs. The before and after design is often the easiest design to follow, and can yield useful results provided that streamflows or some other surrogate measure of meteorologic variability is incorporated. Without correction for flow variability, it is unlikely that the before and after design can document BMP effects at the watershed level within any practical program time frame. It should be noted that for many of the experimental designs the time period required to observe BMP-related changes will depend upon how large a change is actually being made. For example, a 30 percent concentration reduction will take much longer to observe above the noise (variability) of the system than will a 90 percent reduction.

At least one of these experimental designs should be evident in any nonpoint source control project with water quality monitoring. The most appropriate monitoring strategies may include more than one of these experimental designs. The choice of the most appropriate design will depend upon the nature of the water resource impairment, the water quality objectives of the project, the anticipated level and timing of land treatment, the topography of the project-area, and the financial resources available for monitoring.

REFERENCES

Baker, D.B. 1985. Regional water quality impacts of intensive row crop agriculture: A Lake Erie basin case study. J. Soil Water Conserv. 40(1): 125-32.

Froehlich, H.A. 1976. Inorganic Pollution from Forests and Rangelands. Water Resour. Res. Inst. Publ. No. Seminar-WR021-76. Oregon State Univ., Corvallis.

Johnson, C.W., et al. 1974. Sediment yield from Southwest Idaho rangeland watersheds. Am. Soc. Civil Eng. No. 74-2505.

McCool, D.K., and R.I. Papendick. 1975. Variation of suspended sediment load in the Palouse Region of the Northwest. Am. Soc. Civil Eng. Pap. No. 75-2510.

TASK 2.1 Determine Baseline Conditions

The TSSWCB will obtain and develop data and other technical information pertaining to agricultural activities as necessary to assist TNRCC in identifying and quantifying NPS pollutant loads. Also, TSSWCB will provide concurrence to TNRCC on baseline condition determinations relating to agricultural activities.

TASK 2.2 Prioritize NPS Pollution

Data and other technical information assimilated in Task 2.1 will be utilized and evaluated by TNRCC Region 5 project staff to determine a subwatershed with relative impacts from agricultural activities. TSSWCB will provide concurrence to TNRCC on the selected subwatershed.

- Through meetings, written correspondence and phone calls these two tasks were completed. TNRCC completed the interim technical report.

TASK 3.1 NPS Management Activities

In the Running Creek subwatershed, the TSSWCB will develop and implement dairy water quality management plans on a voluntary basis. BMPs standards established by the NRCS Technical Guide and adopted by the Hopkins-Rains SWCD will be used in the design of the water quality management plans. The TSSWCB and NRCS will work with the local SWCD to include in the water quality management plans appropriate BMPs and practice standards to address identified NPS impacts. Through the SWCD, dairy producers will be encouraged to develop and implement water quality management plans, utilizing technical assistance provided by the NRCS and the TSSWCB. Water quality management plans will be approved by the district and certified by the TSSWCB as meeting appropriate practice standards and being consistent with State water law. Once plans are approved and certified, dairy producers will be provided technical and financial assistance to implement the water quality management plans. Water quality management plans will be implemented on dairies within the Running Creek subwatershed. On two of the dairies with water quality management plans, water quality monitoring will be conducted to determine the effectiveness of BMPs implemented.

- A total of 12 waste management systems (water quality management plans) were implemented in the watershed during the course of the project. Two of these systems were paid for out of project funds. These two systems were also utilized to collect pre-BMP data to assess the effects of small dairies on the water quality in the watershed. A report completed by the NRCS that describes the NPS pollution activities in the watershed during the project period is attached. A copy of a water quality management plan developed and implemented in the watershed was not included in this report. This can be obtained upon request.

NRCS/Hopkins-Rains SWCD Final Report
Lake Fork Watershed Project

The Natural Resources Conservation Service (NRCS) and the Hopkins-Rains Soil and Water Conservation District (SWCD) provided technical assistance to landowners within the Running Creek Watershed. During the course of the project a total of 12 Water Quality Management Plans (WQMPs) were installed in the watershed. These WQMPs are also referred to as Waste Management Systems. A WQMP is a site specific, whole-farm plan (consisting of numerous BMPs) designed and implemented to insure farming or ranching operations are carried out in a manner consistent with state water quality goals. To remain in compliance with state water quality rules and regulations, a producer must implement the certified plan as specified and agreed to in its implementation schedule.

The WQMPs installed on the Danny Coke and John Beezley dairies were paid for out of project funds. The other 10 WQMPs were funded through other land owner financial assistance programs. Attached is a list of the BMPs installed in the watershed and a compilation of NRCS quarterly reports detailing their NPS Management activities during the project.

BMP'S INSTALLED IN THE LAKE FORK CREEK RESERVOIR IMPLEMENTATION PROJECT*

Total Practices	Amount Installed	Unit
Waste Management Systems	12	no.
Waste Storage Ponds	12	no.
Pasture and Hayland Management	2200	ac.
Pasture Planting	200	ac.
Pond Sealing and Lining	4	no.
Nutrient Management	2200	ac.
Irrigation Pump	10	no.
Pipelines	24,000	ft.
Fencing	10,800	ft.
Sprinklers	10	no.
Heavy Use Protection	22	ac.
Irrigation Systems	10	no.
Cover and Green Manure Crops	500	ac.
Walkways	2	no.
Soil Testing	8	no.
Waste utilization	1800	ac.
Pest Management	2200	ac.

Danny Coke Dairy :

Practices	Amount Installed	Unit
Waste Management System	1	no.
Waste Storage Pond	1	no.
Pasture and Hayland Management	140	ac.
Pond Sealing and Lining	1	no.
Nutrient Management	140	ac.
Irrigation Pump	1	no.
Pipelines	4,000	ft.
Sprinkler	1	no.
Heavy Use Protection	3	ac.
Irrigation System	1	no.
Cover and Green Manure Crops	75	ac.
Soil Testing	1	no.
Waste utilization	100	ac.
Pest Management	140	ac.

John Beezley Dairy :

Practices	Amount Installed	Unit
Waste Management System	1	no.
Repair to Waste Storage Pond	1	no.
Pasture and Hayland Management	92	ac.
Nutrient Management	92	ac.
Irrigation Pump	1	no.
Pipeline	2,000	ft.
Sprinkler	1	no.
Heavy Use Protection	2	ac.
Irrigation System	1	no.
Cover and Green Manure Crops	50	ac.
Soil Testing	1	no.
Waste utilization	59	ac.
Pest Management	92	ac.

* When the project began there were 33 dairies in the project area, during the project 14 diaries closed.

Report of Activities in the Lake Fork Creek CWA 319 (h) Project

2nd Quarter - March 1, to May 31, 1996

* Board meet to discuss the project and agreed to sign an agreement with TSSWCB to provide a technician to do water quality planing in the Running Creek Watershed.

* Field activity in the project was not began until April.

* Board reviewed and signed the MOU with the TSSWCB regarding the Running Creek Project.

* A fields inventory was conducted to identify each dairy in the Project.

* A map was developed identifying the location, owner and operator of each dairy in the project area.

* Met with the Brian DeBose of TIAR to discuss the project how he planned to collect samples.

* Developed a spreadsheet identifying each dairy, the status of BMPs installed on each farm.

* Met with Lenny Winkleman, Bo Spoonth and Brian Debose to discuss the plans for implementing the project plan.

* Met with Danny Coke to obtain his permission to install water sampling equipment on his farm. He agreed to cooperate fully with insulation of this equipment.

* Went to the Danny Coke Dairy with Brian Debose, and Larry Haulk of TIAR to determine the locations for the water sampling equipment. Site were located. Brian plans to install the equipment in the next two months.

* Began an inventory to find another dairy who will be willing to let us install a second set of water quality collecting equipment.

* Non-reimbursable hours for the project:

1. 3/19/96 - Board discussed entering into agreement with the TSSWCB to do implement a water study in the Running Creek Watershed.

George T. Dicken	1 hour	Rodney Lennon	1 hour
R. E. Johnson	1 hour	Paul Lawrence	1 hour
Weldon Glossup	1 hour		

2. 4/16/96 - The board discussed the Running Creek project. The requested more information about what was to be the focus of the project, what type of equipment would be used. If there would be cost-sharing on farms involved in the project.

George T. Dicken	1 hour	Rodney Lennon	1 hour
R. E. Johnson	1 hour	Paul Lawrence	1 hour
Weldon Glossup	1 hour		

3. 5/14/96 - Board reviewed a letter form Lennie Winkleman answering the questions they had expressed concerning the Running Creek Project. They also reviewed the progress of 503 planing and the location of the water monitoring equipment to be installed.

George T. Dicken	1 hour	Rodney Lennon	1 hour
R. E. Johnson	1 hour	Paul Lawrence	1 hour
Weldon Glossup	1 hour		

Total Hours - 15

ACTION FOR NEXT QUARTER

* Work with TIAR to install water monitoring equipment on the Danny Coke Dairy

* Locate a dairy without BMPs, to install another set of water monitoring equipment.

* Developing Water Quality Management Plans on Jr. Hinton Dairy Roger Wright Dairy and Wayne Reeves Dairy.

Report of Activities in the Lake Fork Creek CWA 319 (h) Project

3rd Quarter - June 1, to August 31, 1996

* 6/1/96 - Contacted John Beezley to determine his interest in letting us do water sampling project his dairy. He said it would be fine with him. Went with Bryan Debose to look at John Beezely Dairy to determine if it would work as a sampling site, Bryan thinks it will work.

* 6/18/96 - Held a dairy management mnagement field day at the Yantis school.

* 6/18/96 - Board discussed the activities of the Lake Fork Creek CWA 319 (h) Project t the monthly meeting..

* 6/28/96 - Met with Dave Koran, Corey Anderson and Paul Reynolds of the TRNCC and went to the Danny Coke Dairy to determine location of water quality sampling equipment, they plan to be used inconjuction with the water monitoring equipment of the TAIR. They plans to install the equipment in the next few months.

* 7/1/96 - Met with the Brian DeBose and Larry Hauck of TIAER to discuss the Running Creek Project and collect economic data for the cost of installing BMPs.

* 7/11/96 - Worked with Tommy Hurley to construct a pond on his farm. This will improve water quality in the project area by collecting soil sediment and fertilizer nutrients.

* 8/1/96 - Met with Larry Hauck, Bryan Debose and John O,Conner to discuss the Running Creek Project and make plans to sample on Coke and Beezley dairies.

* 8/18/96 - Met with Paul Reynolds of the TRNCC to do a field study on Danny Coke Dairy and Don Gammill Dairy to determine sites for water monitoring.

* 8/20/96 - Discussed the activities of the Lake Fork Creek CWA 319 (h) Project at the SWCD board meeting.

* Completed SB-503 plan on J&K Hinton Dairy.

* Revived SB-503 plan on Roger Wright.

* Reviewed SB-503 plan on Wayne Reeves.

* Reviewed SB-503 plan on Randy Garrett.

* Up dated the spreadsheet identifying each dairy and the status of BMPs installed on each farm.

* Non-reimbursable hours for the project:

1. 6/18/96 - Board discussed the Running Creek Watershed project.

George T. Dicken	1 hour	Rodney Lennon	1 hour
R. E. Johnson	1 hour	Weldon Glossup	1 hour

1. 8/20/96 - Board discussed the Running Creek Watershed project.

George T. Dicken	1 hour	Rodney Lennon	1 hour
R. E. Johnson	1 hour	Weldon Glossup	1 hour
Paul Lawrence	1 hour		

Total Hours - 9

ACTION FOR NEXT QUARTER

* Work with TIAER to install water monitoring equipment on the Danny Coke Dairy

* Work with TIAER to install water monitoring equipment on the John Beezly Dairy

* Developing Water Quality Management Plans on Tommy Hurley Dairy.

Report of Activities on Task 3.1 management activities of the Lake Fork Reservoir Implementation Project.

4rd Quarter - September 1, to November 30, 1996.

* 9/5/96 - Went with Brian DeBose to look at John Beezley Dairy to determine if it would work as a sampling site. Brian thinks it will work. Some of the problems are two separate drains behind the barn and the creek will need to be fenced so cattle can be excluded.

* 9/17/96 - Discussed the activities of the Lake Fork Reservoir Implementation Project at the SWCD board meeting.

* 9/19,20,21/96 - Setup an information booth at the Hopkins County Fall Festival, to provide information about TEX-A-Syst and other information on water quality and animal water management.

* 10/3/96 - Assisted with the Hopkins County hay show. About 75 entries were received.

* 10/8/96 - Worked with James Emirine to construct a pond on his farm. This will improve water quality in the project area by collecting soil sediment and fertilizer nutrients. pond.

* 11/4/96 - Discussed developing a Water Quality Management Plan with Vera Herrington. She is undecided what she wants to do t this time.

* 10/10/96 - Sponsored the Annual Conservation Awards Banquet. The program featured a slide program showing the conservation and animal waste management programs being carried out on the 5 award winner's farms. Sponsored poster contest for grade school age children to draw posters about conservation and water quality. Also sponsored a essay for high school age student to write an essay on conservation of natural resources. Awards were presented to all winner at the banquet.

* 10/10/96 - J. D. Shear discussed the activities of the Lake Fork Lake Fork Reservoir Implementation Project at the SWCD board meeting.

* 10/16/96 - Met with Larry Hauk, Brian Debose and a team of economist from TIAER, to develop assumptions for use in a computer model to be used in the project area.

* 10/17/96 - Met with the TSSWCB, TIAER, TRNCC to discussed the progress of the Lake Fork Reservoir Implementation Project.

* 10/29/96 - Reviewed SB-503 plan with Tommy Hurley

* 11/17/96 - Met with Justin Hester, Bo Spoonths, Dave Koran, Brian Debose, Paul Reynolds David Powell, and John O'Conner to discuss activities of the project.

* 11/18/96 - Met with the team from TIAER to follow up on economic data needed for the computer model being developed for the Lake Fork HUA.

*11/19/96 - Held a public meeting to determine the 5 major resource concerns of Hopkins and Rains County about 15 people attended the meeting. The major concern determined at the meeting was non-point pollution on pasture and cropland.

* Updated the spreadsheet identifying each dairy and the status of BMPs installed on each farm.

* Non-reimbursable hours for the project:

1. 9/17/96 - Board discussed the Lake Fork Reservoir Implementation Project.

George T. Dicken	1 hour	Rodney Lennon	1 hour
R. E. Johnson	1 hour	Weldon Glossup	1 hour
Pul Lawrence	1 hour		

2. 10/10/96 - Board discussed the Lake Fork Reservoir Implementation Project.

George T. Dicken	1 hour	Rodney Lennon	1 hour
R. E. Johnson	1 hour	Weldon Glossup	1 hour
Paul Lawrence	1 hour		

3. 10/10/96 - Farm Bill meeting and Board discussion of the Lake Fork Reservoir Implementation Project.

George T. Dicken	2 hour	Rodney Lennon	2 hour
R. E. Johnson	2 hour	Weldon Glossup	2 hour

Total Hours - 18

ACTION FOR NEXT QUARTER

* Develop a Water Quality Management Plans on the John Beezley Dairy.

* Work with TIAER to install water monitoring equipment on the Danny Coke Dairy

* Work with TIAER to install water monitoring equipment on the John Beezley Dairy

Report of Activities on Task 3.1 management activities of the
Lake Fork Reservoir Implementation Project.

1st Quarter - December 1, to February 28, 1997.

* 12/17/96 - Discussed the activities of the Lake Fork Reservoir Implementation Project at the SWCD board meeting.

* 1/13/97 - Went to the John Beezley dairy to collect data to develop a animal waste management plan.

* 1/15/97 - Met with the TRNCC Outreach Team to discuss the Lake Fork Reservoir Implementation Project. Discussed the plan for monitoring program on Coke and Beezley Dairies as well as other aspects of the project.

* 1/21/97 - Discussed the activities of the Lake Fork Lake Fork Reservoir Implementation Project at the SWCD board meeting.

* 1/22/97 - Attented the Steering Committee meeting on the NET GLIC. This a private grazing lands Conservation Program. Helped to develop a plan of action for 1997 to implement conservation practices in the project area.

* 1/29/97 - Began developing the Waste Management Plan on John Beezley.

* 2/3/97 - Completed plan on C&J Dairy operated by Trey Hinton. The plan was sent to TSSWCB for review and certification.

* 2/4/97 - Went with Brian DeBose and a team from TIAER to look at the other John Beezley Dairy to determine if it would be better suited for a sampling site. After field investigation the team determined this diary would be a better site to collect samples.

* 2/6/97 - Reviewed the National Pilot Project: Livestock and the Environment report developed by the team of economist from TIAER.

* 2/10/97 - Worked with Billy Brown and Roxanne Rich (new employee for the Lakefork Creek HUA) to implement the TEX*A*SYST program Demonstrate Project Quality Assurance Program Plan in the project area.

* 2/11/97 - Went with Brian DeBose and a team from TIAER to install water monitoring equipment on the Danny Coke and John Beezley Dairies.

* 2/12/97 - Received training for the team from TIAER on using GPS equipment. Plans were developed to us GPS to determine the location of each dairy in the project area

* 2/18/97 - Discussed the activities of the Lake Fork Lake Fork Reservoir Implementation Project at the SWCD board meeting.

* 2/19/97 - Worked with Ronnie Lyles to install a poultry incinerator to dispose of dead birds.

* 2/23/97 - Completed waste management plan on John Beezley.

* 2/26/97 - Met with Extension, FSA, Texas A&M and TSSWCB personnel to discuss plans for the Southwest Dairy Field Day.

* Non-reimbursable hours for the project:

1. 12/17/96 - Board discussed the Lake Fork Reservoir Implementation Project.

George T. Dicken	1 hour	Rodney Lennon	1 hour
R. E. Johnson	1 hour	Weldon Glossup	1 hour

2. 1/21/97 - Board discussed the Lake Fork Reservoir Implementation Project.

George T. Dicken	1 hour	Rodney Lennon	1 hour
Weldon Glossup	1 hour	Paul Lawrence	1 hour

3. 2/18/97 - Board renewed the activities of the Lake Fork Reservoir Implementation Project.

George T. Dicken	1 hour	Rodney Lennon	1 hour
Weldon Glossup	1 hour	Paul Lawrence	1 hour

Total Hours - 12

ACTION FOR NEXT QUARTER

* Submit Water Quality Management Plans on the John Beezley Dairy to TSSWCB for certification..

* Work with TIAER to collect water samples from monitoring equipment on the Danny Coke Dairy

* Work with TIAER to collect water samples from water monitoring equipment on the John Beezley Dairy

* Collect GPS data for each dairy in the project, and work with TIAER to develop a digitized map.

Report of Activities on Task 3.1 management activities of the Lake Fork Reservoir Implementation Project.

2nd Quarter - March 1, to May 31, 1997.

* 3/10/97 - Attended a 319(h) information meeting in Longview.

* 3/13/97 - Reviewed the SB-503 plan with Phil and Bennie Gamblin on their dairy.

* 3/18/97 - Discussed the activities of the Lake Fork Reservoir Implementation Project at the SWCD board meeting.

* 3/19/97 - Held a land judging contest, with about 50 students participating in the contest.

* 3/31/97 - Met with TIAER to look at the sampling equipment on Coke Dairy. The sampling system was not working properly. We determined the area around the barn needs to be shaped so it will drain to the sampling equipment.

* 4/4/97 - Met with Brian DeBose and Larry Haulk to evaluate the sampling program ion Coke and Beezley. The drainage on Coke is still not working properly.

* 4/7/97 - Went with TIAER employees to raise the culvert on Danny Coke Dairy to improve the operation of the sampling Machine.

* 4/9/97 - Met with the Lakefork HUA committee to discus plans for the Southwest field day.

* 4/15/97 - Discussed the activities of the Lake Fork Reservoir Implementation Project at the SWCD board meeting.

* 4/16/97 - Met with the Hocking County Chamber of Commerce Agriculture Committee to discuss plans to promote intensive pasture grazing as a alternate for dairies in the county to off set the high cost of feed.

* 4/17/97 Met with Trey Hint J&K Dairy to determine the 503 cost-sharing needs on the dairy.

* 4/21/97 - The water sampler is still not working properly, Work with three dirt contractors to get bids on shaping the drainage on Coke Dairy.

*4/22/97 - Attended an Environmental conference at Texas A&M - Commerce.

* 4/23/97 Supervised dirt contractor to shaped the drain by the water sampling equipment, the equipment is now working.

* 4/2/97 Gathered information to design the waste water pipeline on J&K Dairy.

* 5/1/97 Worked with Don Smith to develop a pasture grazing system on his dairy.

* 5/6/97 Attended a training conference on conservation planning.

* 5/7/97 - Worked Extension, FSA, Texas A&M and TSSWCB personnel to discuss plans for the Southwest Dairy Field Day.

* 5/8/97 - Sponsored the Southwest Field day. It was attended by about 440 people.

* 5/14/97 - Attended a training conference on RUSLE, the erosion perditions model used in conservation planning.

* 5/15/97 - Developed design for irrigation system on J&K Dairy.

* 5/19/97 - Met with David Polk, GLCI Program Manger and two grazing specialist from New York State to work with dairies to improve their intensive grazing dairy management.

* 5/20/97 - Discussed the activities of the Lake Fork Reservoir Implementation Project at the SWCD board meeting.

* 5/21-22/97 - Attended a two day training workshop on intensive grazing for dairies.

* 5/23/97 - Worked with TIAER to install flumes on the water sampling equipment on Danny Coke.

* Non-reimbursable hours for the project:

1. 3/18/97 - Board discussed the Lake Fork Reservoir Implementation Project.

George T. Dicken	1 hour	Rodney Lennon	1 hour
Weldon Glossup	1 hour	Paul Lawrence	1 hour

2. 1/21/97 - Board discussed the Lake Fork Reservoir Implementation Project.

George T. Dicken	1 hour	Rodney Lennon	1 hour
Weldon Glossup	1 hour	Paul Lawrence	1 hour

3. 2/18/97 - Board renewed the activities of the Lake Fork Reservoir Implementation Project.

George T. Dicken	1 hour	Rodney Lennon	1 hour
Weldon Glossup	1 hour	Paul Lawrence	1 hour

Total Hours - 12

ACTION FOR NEXT QUARTER

* Install practices on J&K Dairy.

* Work with TIAER to collect water samples from monitoring equipment on the Danny Coke Dairy.

* Work with TIAER to collect water samples from water monitoring equipment on the John Beezley Dairy

* Work with TIAER to collect GPS data for each dairy in the project.

Report of Activities on Task 3.1 management activities of the Lake Fork Reservoir Implementation Project.

3rd. Quarter - June 1 to August 31, 1997.

* 6/4-6/97 - Worked with a crew from TIAER to collected GPS data for on all dairies in the project area.

* 6/17/97 - Discussed the activities of the Lake Fork Reservoir Implementation Project at the SWCD board meeting.

* 6/25/97 - Met with Brian DuBose and Larry Hauck, TIAER, to evaluate the sampling program on Coke and Beezley. We also discussed how to use the GPS data in project.

* 6/26/97 - Worked with John O'Conner, TSSWCB, to plan development of 503 planning activities in the project area.

* 7/3/97 - Met with Brian Dubose, TIAER, to discuss sampling progress on John Beezley. We also discussed the plans for BMPs to be installed on his place.

* 7/10/97 - Attended a TRNCC meeting on Subchapter K. The purpose of the meeting was to explain the Subchapter K program and how if differs form the TRNCC permitted dairy program.

* 7/15/97 - Discussed the activities of the Lake Fork Reservoir Implementation Project at the SWCD board meeting.

* 8/3/97 - Met with Barbara Parmley, TNRCC, to discuss the project and her plans to visit all the dairies in the project area without a 503 plan.

* 8/4/97 - Worked with Don Smith to install 503 cost-shared irrigation pipeline and big gun sprinkler.

* 8/6/97 - Assisted Barbara Parmley to updated the Running Creek dairy location map and spreadsheet of the project area.

* 8/18/97 - Randy Rushing, TRNCC, came by and we discussed his progress in collecting water samples in the project area.

* 8/19/97 - Discussed the activities of the Lake Fork Reservoir Implementation Project at the SWCD board meeting.

* 8/20/97 - Discussed progress on the sampling program with John Beezley. We also reviewed the planned BMPs to be installed on his dairy.

* 8/29/97 - Met with Larry Hauck, TIAER, to discuss a time table to install the BMPs. We discussed the problems of waiting too long to install the BMPs, because of the need to collect samples after the BMPs are installed.

* Non-reimbursable hours for the project:

1. 6/17/97 - Board discussed the Lake Fork Reservoir Implementation Project.

George T. Dicken	1 hour	Rodney Lennon	1 hour
Weldon Glossup	1 hour	Paul Lawrence	1 hour

2. 7/15/97 - Board discussed the Lake Fork Reservoir Implementation Project.

George T. Dicken	1 hour	Rodney Lennon	1 hour
Weldon Glossup	1 hour	Paul Lawrence	1 hour

3. 8/19/97 - Board renewed the activities of the Lake Fork Reservoir Implementation Project.

George T. Dicken	1 hour	Rodney Lennon	1 hour
Weldon Glossup	1 hour	Paul Lawrence	1 hour

Total Hours - 12

ACTION FOR NEXT QUARTER

* Work with TIAER to collect water samples from monitoring equipment on the [redacted] and [redacted].

* Install BMPs on the [redacted] and [redacted].

* Work with TIAER to put GPS data in a form that will be useful to the project.
* Install practices on [redacted].

Report of Activities on Task 3.1 management activities of the Lake Fork Reservoir Implementation Project.

4rd Quarter - September 1, to November 30, 1997.

* 9/2-30/97 - Setup an information display at the Hopkins County Historical Museum, to provide information about TEX-A-Syst and information on water quality.

* 9/9/97 - Discussed the 319(h) program with Randy Rushing. He is leaving the project. We reviewed what had been accomplished and what was needed to finish the work. We looked at sites on Beezley Dairy and Coke Dairy

* 9/10/97 - Met with the Larry Haulk, TIAER, to discussed the progress of the Lake Fork Reservoir Implementation Project.

* 9/13/97 - Assisted with the Hopkins County hay show. About 100 entries were received.

* 9/16/97 - Discussed the activities of the Lake Fork Reservoir Implementation Project at the SWCD board meeting.

* 9/17/97 - Met with the TRNCC Outreach Team to discuss the project. Discussed the plans for installing BMPs as soon as possible. They plan to inspect all dairies in the project area without SB-503 plans.

* 9/20/97 - Met with [redacted]. Discussed developing a Water Quality Management Plan and participating in the EQIP program. She agreed to sign up for the program.

* 9/27/97 - Discussed the activities of the Lake Fork Lake Fork Reservoir Implementation Project at the SWCD board meeting.

* 10/7/97 - Met with [redacted] to complete final draft of his the Waste Management Plan. Sent to TSSWCB for review and certification.

* 10/9/97 - Sponsored the Annual Conservation Awards Banquet. The program featured a slide program showing the conservation and animal waste management programs being carried out on the 5 award winner's farms. Sponsored poster contest for grade school age children to draw posters about conservation and water quality. Also sponsored a essay for high school age student to write an essay on conservation of natural resources. Awards were presented to all winner at the banquet.

* 10/9/97 - J. D. Shear discussed the activities of the Lake Fork Lake Fork Reservoir Implementation Project at the SWCD board meeting.

* 10/23/97 - Worked with Billy Brown and Roxanne Rich to do some work on TEX*A*SYST program in the project area.

* 11/3/97 - Waste management plan on [redacted] has been reviewed and certified by the TSSWCB.

* 11/10/97 - Met with the team from TIAER to follow up on economic data needed for the computer model being developed for the Lake Fork HUA.

* 11/13/97 Worked with John O'Conner to do a status review on [redacted]. All BMPs are installed and are being operated as planned.

* 11/18/97 - Discussed the activities of the Lake Fork Lake Fork Reservoir Implementation Project at the SWCD board meeting.

* Non-reimbursable hours for the project:

1. 9/16/97 - Board discussed the Lake Fork Reservoir Implementation Project.

George T. Dicken	1 hour	Rodney Lennon	1 hour
Weldon Glossup	1 hour		
Paul Lawrence	1 hour		

2. 10/9/97 - Board discussed the Lake Fork Reservoir Implementation Project.

George T. Dicken	1 hour	Rodney Lennon	1 hour
Weldon Glossup	1 hour		
Paul Lawrence	1 hour		

3. 11/18/97 - Board discussed the Lake Fork Reservoir Implementation Project.

George T. Dicken	1 hour
Weldon Glossup	1 hour
Paul Lawrence	1 hour

Total Hours - 11

ACTION FOR NEXT QUARTER

* Work with dirt contractor to install BMPs on the Danny Coke Dairy.

* Work with dirt contractor to install BMPs on the John Beezley Dairy.

TASK 4.1 NPS Management Evaluation

TSSWCB will assess best management practice implementation to determine the effectiveness with respect to: (1) Water Quality monitoring on two dairies with water quality management plans; (2) Capitol and operating costs; (3) Methods/alternatives for financing BMPs; (4) Problems/constraints associated with the use of various BMPs.

- Although TIAER was not able to collect post-BMP data, they did complete a report summarizing their project accomplishments. In addition, a report was also completed by TIAER on the costs and environmental benefits of BMPs that are applicable to the Lake Fork watershed. Both of these reports completed by TIAER are attached.

TIAER
PR 98-05

Pre-BMP Water Quality Monitoring on Demonstration Dairy Sites in the Lake Fork Reservoir Watershed

Final Report to the Texas State Soil and Water Conservation Board on Pre-BMP Water Quality Monitoring for the Section 319(h) Project: Lake Fork Reservoir Watershed NPS Project

Nancy Easterling, Scott Ewer, and Anne McFarland

October 1998

Texas Institute for Applied Environmental Research
Tarleton State University • Box T0410 • Tarleton Station • Stephenville, Texas • 76402
(254) 968-9567 • FAX (254) 968-9568

TABLE OF CONTENTS

List of Tables

List of Figures

INTRODUCTION

Lake Fork Reservoir (LFR) in northeast Texas (Figure 1) has become known nationally as a premier fishery for trophy-sized largemouth bass. Originally constructed to meet increasing municipal water supply demands, Lake Fork is an important resource to the economy of the surrounding area. The watershed that feeds the reservoir is populated with numerous agricultural operations, notably dairies, that may contribute nutrient runoff to the reservoir. Some fishing specialists have attributed the size of largemouth bass caught in the Lake Fork Reservoir to the increased nutrient levels, although the effects of elevated nutrient levels on fish populations within Lake Fork Reservoir are not completely understood. The revenue generated by trophy bass fishing in the Lake Fork Reservoir may be seen by many in the local population as more important than the reservoir's potential as a water supply.

The predominant land use of the 575 square mile watershed is agriculture. Over two hundred dairies were located in the LFR watershed in 1997; 44 percent of the land use in the watershed was categorized as improved pasture and less than one percent was cropland (Ewer and Easterling, 1998). Sulfur mining and oil production represent other economically important sectors of the area that may threaten the health of the reservoir system. No industrial discharges have been permitted in the watershed; however, seven domestic discharges totaling 350,000 gallons per day have been permitted (TNRCC, 1996). These permitted domestic facilities include three marinas that are permitted to discharge directly into the reservoir plus the wastewater treatment facilities of four communities, Yantis, Point, Cumby and Como (Rushin, 1994). In addition, many homes in the watershed have on-site septic treatment systems.

The *State of Texas Water Quality Inventory* (TNRCC, 1996) classified segment 0512, the segment encompassing Lake Fork Reservoir, as water quality limited and lists the designated water uses as contact recreation, high aquatic life and public water supply. The inventory states that elevated levels of orthophosphate are a concern in the main body of the reservoir and in the Caney Creek arm. Depressed dissolved oxygen levels in the body of the reservoir result in only partial support of the high aquatic life use. According to the inventory, "Municipal point sources, as well as nonpoint source pollution from agricultural activities and on-site septic systems likely contribute to the problem. Elevated levels of barium in sediment and elevated levels of manganese in sediment are a concern in the entire reservoir." (TNRCC, 1996). Of the water samples reported in the 1996 inventory which were collected in segment 0512, over 19 percent had nitrite-plus-nitrate concentrations that exceeded the TNRCC screening level of 1.0 milligrams per liter, while over 30 percent of the samples had chloride and sulfate concentrations that exceeded TNRCC criteria. Segment 0512 was not, however, included in the State of Texas 1998 303(d) List for targeting priority watersheds.

A summary report prepared for the Texas Clean Rivers Act (TWC, 1992) identified and confirmed that parts of Sabine River Basin stream segment 0512 had experienced depressed dissolved oxygen values and elevated fecal coliform and nutrient values. From 1990 through mid-1994, six oil and/or hazardous waste spills were reported and investigated in the Lake Fork Reservoir watershed. Also, eleven fish kills in the watershed were reported and investigated from 1989 through late 1994. Of these incidents, dairy wastewater was responsible for three and oil production activities for four, while the causes of the remaining four are unknown (Rushin, 1994).

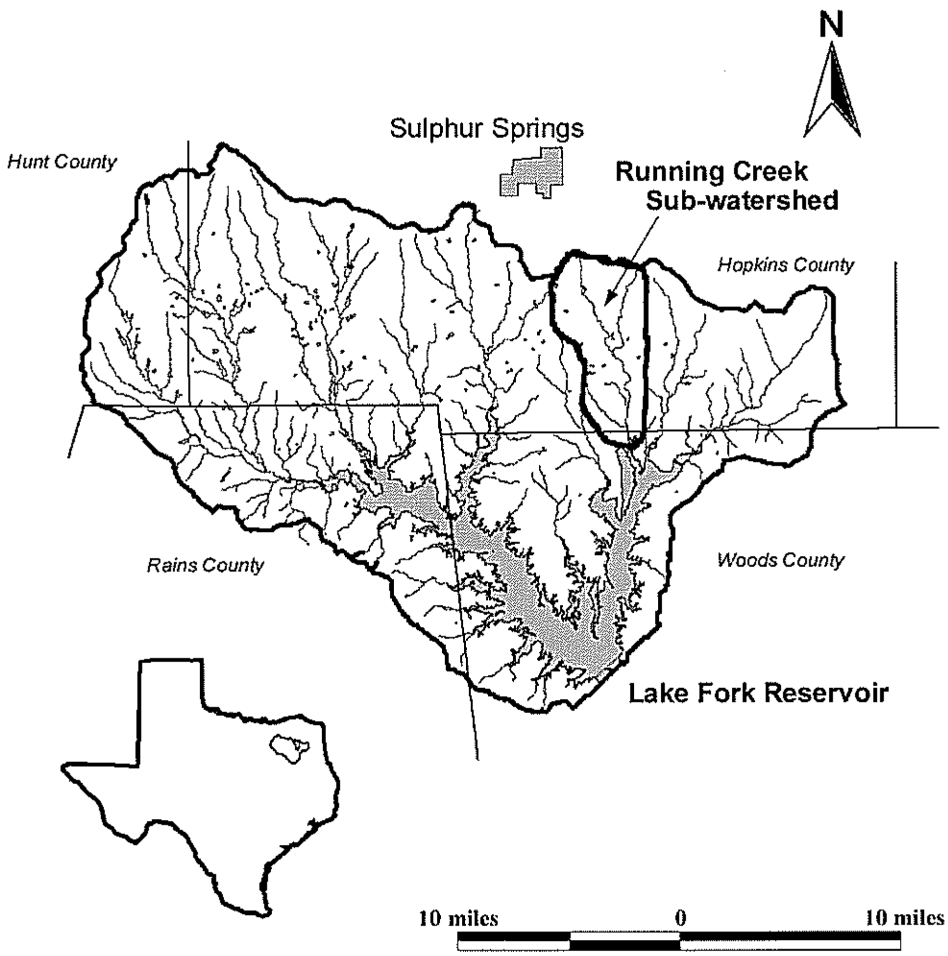


Figure 1. Lake Fork Reservoir Watershed and Running Creek Subwatershed

The Texas State Soil and Water Conservation Board (TSSWCB), with a grant funded through the Texas Natural Resource Conservation Commission (TNRCC) from the U.S. Environmental Protection Agency's 319(h) nonpoint source water pollution program, conducted a demonstration and education project in the Lake Fork Reservoir watershed. The Lake Fork Reservoir Watershed NPS Project is a multidisciplinary effort to evaluate the effectiveness of selected best management practices (BMPs) in controlling nonpoint source (NPS) water pollution in the Lake Fork Reservoir watershed. As part of this project, Texas Institute of Applied Environmental Research (TIAER) monitored surface water runoff on two dairy demonstration sites in the Lake Fork Reservoir watershed from April 1997 until June 1998 to collect data on nutrient concentrations at those sites. TIAER was responsible for the water quality monitoring on these sites prior to BMP implementation, laboratory analysis of collected samples and statistical analysis of collected data.

DEMONSTRATION DAIRY SITES

In order to demonstrate the efficacy of BMPs for confined animal feeding operations, two dairies requiring additional BMPs were selected as demonstration sites. Both selected dairies are located in the Running Creek subwatershed of the Lake Fork Reservoir watershed and have filed 503 water quality management plans with the TSSWCB. Approximately 44 dairies are located in this subwatershed, few of which have either a waste disposal permit or an approved waste management plan. The Lake Fork Reservoir watershed, with Running Creek subwatershed outlined, is shown in Figure 1.

The average dairy herd size for the LFR watershed is approximately 130 head, with 95 percent of the dairies classified as pasture operations (Bailey and Riggs, 1996). The selected dairies are considered representative of typical dairies in the watershed. Neither dairy is large enough to require a waste disposal permit, but they are required to implement waste management practices to meet the TNRCC no-discharge criteria. Both dairy operators need financial assistance to install waste management practices on their land, which is the primary reason for the current lack of BMPs. Both dairies have water courses running directly through the properties, which is common for the watershed. Figure 2 shows the locations of the two dairies on a topographic map.

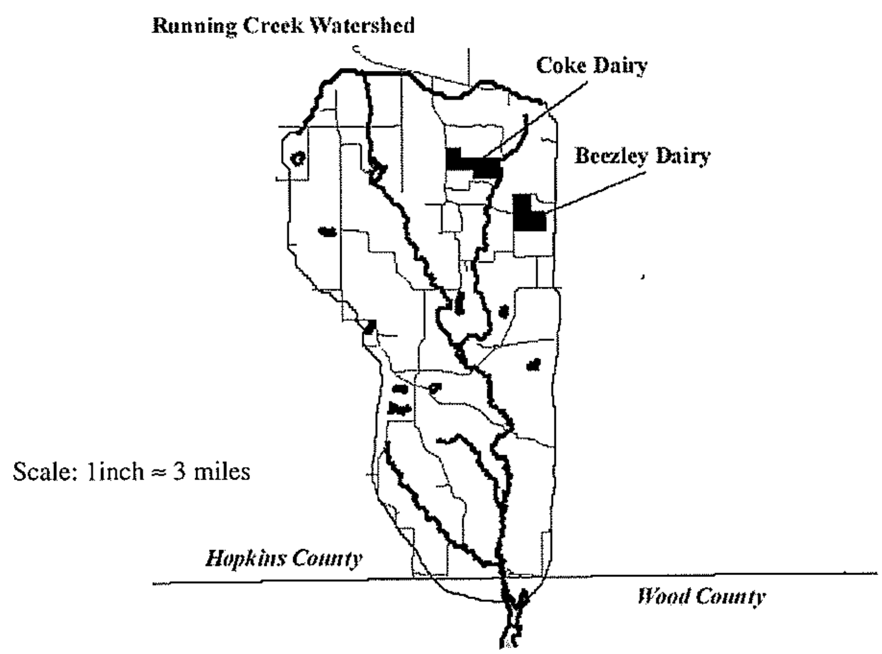


Figure 2. Location of Demonstration Dairies for Lake Fork Reservoir 319(h) NPS Project

Beezley Dairy

The Beezley Dairy, one of the demonstration sites, is located at the intersection of County Roads 2321 and 2325, approximately 8 miles southeast of Sulphur Springs (Figure 3). This dairy comprises 96 acres and has a total of 150 cattle, which are milked twice daily. There are no dairies upgradient from the Beezley Dairy. The Beezley Dairy has an under-sized waste storage pond located just down-gradient from the milking barn. The milking barn and waste storage pond are located on a somewhat steep slope leading to a small stream that runs through the property. The soil around the barn and storage pond has almost no crop cover.

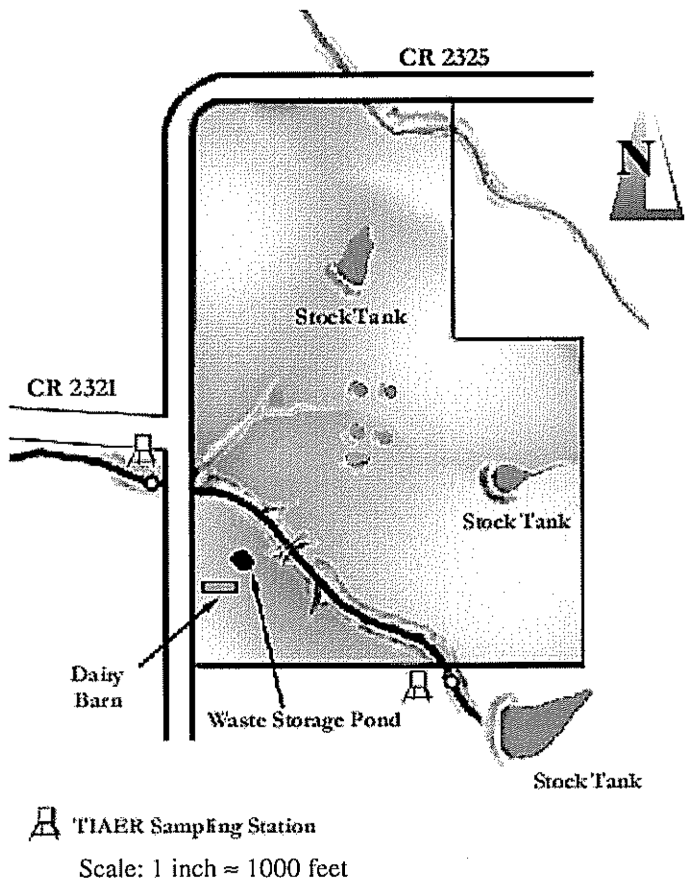


Figure 3. Layout of Beezley Demonstration Dairy

The cows are confined to the milking barn approximately four hours per day. When not being milked, the cattle spend the majority of time in a 53 acre field, which includes the barn, waste storage pond, stream, and several closely located feed stations. The ground in much of this field undergoes a large amount of trampling and consequently many acres are almost bare, although coastal Bermuda has been planted. Cows have been observed standing in the stream, which is not fenced. Approximately one mile down-gradient, this stream enters Dry Creek. All of the land associated with this dairy is characterized as either pasture or hayland.

The waste storage pond berm located on the Beezley Dairy is partially breached. According to a TNRCC inspection dated December 28, 1995, wastewater from the Beezley Dairy barn was discharging through an open ditch to the streambed. In addition, the pond on the Beezley Dairy has been determined by USDA Natural Resources Conservation Service (NRCS) staff to be too small for the size of the current operation.

Coke Dairy

The Coke Dairy, the other demonstration site, is located approximately one mile south of Highway 11 on County Road 2321, about 5 miles southeast of Sulphur Springs (Figure 4). This dairy has a total of 150 head and milks approximately 118 head twice daily. Most of the 117 acres of the dairy is used as pasture and hay. No other dairy operations are located up-gradient from the Coke Dairy. One large permitted dairy operation is located directly across County Road 2321 from the Coke Dairy, but it drains into a different subwatershed.

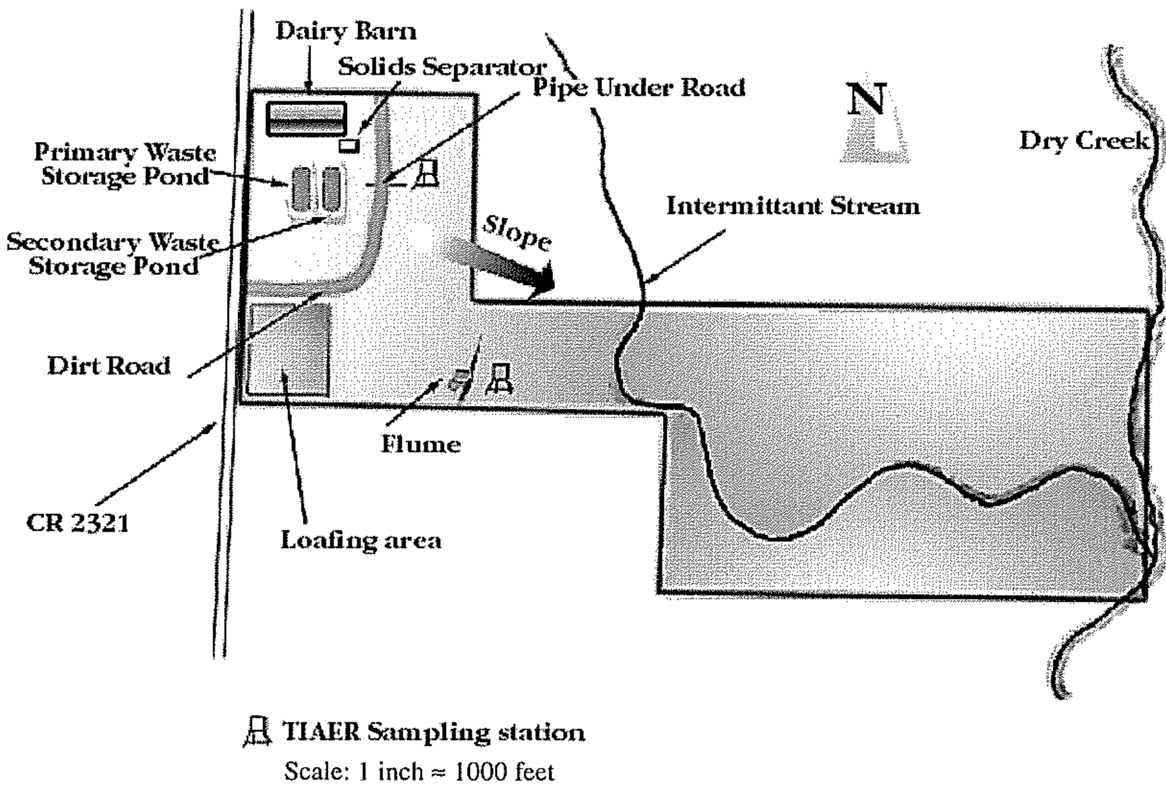


Figure 4. Layout of Coke Demonstration Dairy

The general slope of the land is from west to east toward Dry Creek, which flows directly through the eastern end of the property. The milking shed is located upgradient from a drainage swale on adjacent property. Liquid waste overflow for the storage pond has been observed flowing into this drainage swale. Well-drained soil types underlie the majority of this dairy.

A flush system was used in the milking shed to direct wastes out of the parlor and through a solid/liquid separator before the liquids enter the storage ponds. The solid waste from the separator was stacked near the milking shed. The solid waste is applied to the grass whenever weather permits. The storage pond leaked due to a sandy layer approximately four to five feet below the surface, and consequently does not meet TNRCC criteria for storage pond lining. The required holding capacity for a 24-hour, 25-year rainfall was determined to be inadequate. The waste storage pond has primary and secondary cells, but it is probable that full benefits from a two-stage system are not realized due to insufficient capacity. Waste management plans were previously drawn up for the Coke Dairy, but were never implemented due to lack of funds.

The milking cows were kept in the shed and immediately adjacent areas approximately four hours per day; otherwise, the cattle spent the majority of the time on either the pasture surrounding the milking shed or in a pasture just uphill from the creek bed. Both of these fields are planted in coastal Bermuda. A cool season crop of wheat and Rye grass is also grown on this dairy. Nitrate fertilizer is applied during the summer, when necessary.

EXPERIMENTAL DESIGN

The focus of this portion of the section 319(h) demonstration project was to gather water quality data before the installation of best management practices on the two dairies. Two automated samplers were installed on each dairy to collect water samples to characterize water quality and provide background data for comparison after BMPs are implemented. The experimental design and placement of sampling equipment reflected the drainage patterns unique to each dairy.

An upstream-downstream experimental design was implemented on the Beezley Dairy with automated monitoring equipment located upstream and downstream of the dairy operation (Figure 3). This approach compares analyte concentrations in stream water sampled up-gradient of a specific land area to concentrations in stream water sampled down-gradient of that area and is discussed in more detail by Spooner *et al.* (1985). In this case, one sampling site was located on a small unnamed stream immediately before it enters the dairy property. The other was located within a drainage pipe that lies underneath County Road 2325 immediately after the stream exits the property. This drainage pipe, and therefore the sampling site, also receives runoff from a ditch that runs beside the road. The headwaters of the stream is a large stock pond located on the pasture south of the Beezley Dairy, which receives enough surface runoff and/or groundwater seepage to remain typically full. Drainage from this pond provides an almost constant base flow to the stream.

A paired watershed approach was implemented on the Coke Dairy. The paired watershed approach involves placing two samplers downstream of areas used for agricultural practices. One area undergoes some change in land management practices (such as implementation of best management practices) during the sampling period, while the other area is used as the control. This design is more fully explained in the U.S. Environmental Protection Agency Office of Water document Paired Watershed Study Design (EPA, 1993). The treatment sampler for this dairy was installed below the undersized waste storage pond system and manure storage area. The control sampler was installed on a low-lying area of the dairy that receives intermittent flow during rainfall events from a pasture and a dry cow loafing area (Figure 4). An earthen berm was constructed upgradient of the control sampler to channel runoff through a flume housing the sampler's intake tube. The soil types near the control sampler have rapid infiltration rates (SCS, 1977), which may explain why the control site rarely received runoff.

BMP Plans

The Sulphur Springs District Office of the NRCS designed the specific BMPs for the two demonstration sites. The waste management plan for the Beezley Dairy includes an underground high pressure irrigation pump plus irrigation lines and sprinklers. The current waste storage pond will be relined and enlarged. Additionally, some of the bare pasture areas will be seeded with grass, and a fence will be installed along the creek bed to exclude cattle. A total of 30 acres is planned for application of liquid waste.

The waste management plan for the dairy of Danny Coke includes construction of a new waste storage pond with the bottom liner designed to TNRCC specifications. An underground, high-pressure irrigation pump with irrigation lines and sprinklers for lagoon effluent represents another planned BMP. Cattle exclusion fences will surround the creek bed and 56 acres will be set aside for liquid waste disposal.

METHODS OF DATA COLLECTION AND ANALYSIS

All data represent water quality samples collected from the Beezley and Coke dairies between April 1997 and June 1998. Monitoring efforts were conducted under the approved quality assurance project plan (QAPP) for the research project. Data collected for this project will be archived by TIAER for at least five years.

Data Collection Methods

Each automated stormwater sampling site consisted of an ISCO 3230 or 4230 bubbler-type flow meter and an ISCO 3700 automatic sampler.[1] The flow meter and sampler were enclosed in a weatherproof, lockable sheet metal shelter. The flow meters recorded water level data at five-minute intervals by measuring the pressure required to force an air bubble through a one-eighth inch polypropylene tube (bubbler line). Electrical power was provided by marine, deep-cycle batteries with recharge provided by solar cells. The sampler intake lines at sites KO010 and KO020 on the Coke Dairy were located in H-flumes. On the Beezley Dairy, the intake lines were located in a v-notch weir (site DC010) and in a road culvert (site DC020).

ISCO 3230 meters initiated pre-set sampling programs for the ISCO 3700 automatic samplers when threshold actuation water levels were exceeded. Actuation levels selected for each site were as low as possible, but avoided actuation resulting from causes other than rainfall events. Actuation levels for the sites were adjusted as necessary during the course of the project to accommodate variances in precipitation, base flow level, releases from waste storage ponds and other disturbances.

Once activated, samplers were programmed to retrieve samples in the following time sequence: an initial sample, 4 samples taken at 15-minute intervals, 4 samples taken at 30-minute intervals, 4 samples at 1-hour intervals, 4 samples at 2-hour intervals and all remaining samples at 6-hour intervals. These sampling sequences were selected to allow more samples to be taken during the typical rapid rise and peak periods of a storm hydrograph and fewer samples during the slower, receding portion of a storm hydrograph. In October 1997, the sampling sequence at sites KO020, DC010 and DC020 was modified to accommodate the extended hydrograph duration associated with those sites. The following modified

[1] Mention of trade names or equipment manufacturers does not represent endorsement of these products or manufacturers by TIAER.

time sequence was implemented at those sites: an initial sample, 6 samples taken at 30-minute intervals, 4 samples at 1-hour intervals, 4 samples at 2-hour intervals, 4 samples at 3-hour intervals and all remaining samples at 6-hour intervals.

Laboratory Analysis Methods

A general outline of the water quality constituents measured, the abbreviations used in this report and the units of measurements are provided in Table 1. The EPA-approved methods of analysis used by TIAER are listed in Table 2.

Table 1. Descriptions, abbreviations and units of water quality constituents measured at stream sites in the Lake Fork Reservoir watershed.

Constituent	Abbreviation	Units	Description
Chemical Oxygen Demand	COD	mg/L	Indication of oxygen demanding properties of the water in terms of complete chemical oxidation.
Ammonia-Nitrogen	NH_3-N	mg/L	Inorganic form of nitrogen that is readily soluble and available for plant uptake. Elevated levels are toxic to many fish species.
Nitrite-Nitrogen	NO_2-N	mg/L	Inorganic form of nitrogen. Generally a transitory phase in the nitrification of NH_3 to NO_3.
Nitrate-Nitrogen	NO_3-N	mg/L	Inorganic form of nitrogen that is readily soluble and available for plant uptake. Considered the end product in the conversion of N from ammonia to nitrite then to nitrate under aerobic conditions.
Nitrite-plus-nitrate nitrogen	NO_{2+3}-N	mg/L	Total of two inorganic forms of nitrogen. Allows the comparison of the total amount of inorganic nitrogen regardless of the phase.
Total Nitrogen	Total N	mg/L	Total of inorganic and organic forms of nitrogen. It is calculated by adding NO_2-N, NO_3-N and TKN, rather than being a measured parameter.
Orthophosphate-Phosphorus[2]	PO_4-P	mg/L	Inorganic form of phosphorus that is readily soluble and available for plant uptake.
Total Kjeldahl Nitrogen	TKN	mg/L	Organic and ammonia forms of nitrogen are included in TKN.
Total Phosphorus	Total P	mg/L	Represents both organic and inorganic forms of phosphorus.
Total Suspended Solids	TSS	mg/L	Measures the solid materials, i.e., clay, silts, sand and organic matter, suspended in the water.

[2] Dissolved reactive phosphorus (DRP) is another term for this constituent.

Table 2. Analysis methods and method detection limits for water quality constituents.

CONSTITUENT	METHOD*	ESTIMATED MDL**
Chemical Oxygen Demand	EPA 410.4	4 - 6 mg/L
Ammonia-Nitrogen	EPA 350.1	0.022 - 0.037 mg/L
Nitrite- and Nitrate-Nitrogen	EPA 353.2	0.003 - 0.016 mg/L
Orthophosphate-Phosphorus	EPA 365.2	0.008 - 0.011 mg/L
Total Kjeldahl Nitrogen	EPA 351.2	0.173 - 0.195 mg/L
Total Phosphorus	EPA 365.4	0.024 - 0.153 mg/L
Total Suspended Solids	EPA 160.2	3 - 10 mg/L

* EPA – Methods for Chemical Analysis of Water and Wastes, March 1983.

** Estimated method detection limits are periodically updated; therefore, a range of estimated MDLs is presented.

Data Management Procedures

Outliers

Screening was used to highlight questionable data points. Questionable data were then tracked through the Chain of Custody sheets and field and laboratory notebooks, as necessary, to verify if these points represented transcription errors in the database. If a transcription error was found, the error was corrected prior to statistical analysis of the data. No statistical methods were used to identify or remove outliers from the water quality database for stream water quality data.

Censored Data

Left censored data (values measured below the laboratory method detection limit) were entered as one-half the method detection limit (MDL) as recommended by Gilliom and Helsel (1986) and Ward *et al.* (1988).

Statistical Analysis Methods

Data were statistically analyzed only if water samples were collected from both sites at a dairy as a result of the same stormwater runoff event. Data for each set of sites were summarized and compared by individual storm event. Comparison of individual observations within storm events was not possible due to the differences in the response timing of the sites to rainfall-runoff events. Basic statistics for storm events (mean, median, volume-weighted mean, standard deviation, minimum, maximum and the number of observations in each event) are presented by site in Appendix A. Hydrographs of these storm events are presented in Appendix B for all storms. Hydrographs could not be developed directly for the first four events at DC010 due to problems in generating the rating curve for this site. Storm volumes were therefore estimated for these four events using a modified equation for a triangular weir with the DC010 water level data. A v-notched weir was installed at this site in December 1997 to resolve the problem. Plots of the rating curve equations used to convert stage data to flow for each site are presented in Appendix C.

Storm event mean, median and volume-weighted mean values for water quality constituents were evaluated across storm events to compare water quality between paired sites. Generally, a volume-weighted mean value is more meaningful for comparisons between sites as it takes into account the flow associated with each storm event. The mean and median storm values were also used in these comparisons to provide as much information as possible for later evaluation of post-BMP water quality, particularly if obtaining flow measurements proves problematic.

Volume-weighted means were calculated by combining the storm hydrograph with the water quality data for each storm event. The flow hydrograph was divided into intervals based on the date and time when water quality samples were taken using a midpoint rectangular method between water quality samples (Stein, 1977). Constant flow was assumed between each five-minute water level measurement to estimate the water volume associated with each water quality sample. The beginning of each storm event was set an hour before the first water quality sample was taken to include any rise in the hydrograph that occurred before the sampler was initiated. The end of each storm event was set one hour after the last water quality sample was taken. A new storm event was defined if more than 12 hours occurred between water quality samples or if an obvious new pulse of flow was indicated in the storm hydrograph.

Two statistical approaches were taken to maximize future utility of the pre-BMP data. Regression analysis was used on a constituent-by-constituent basis to compare water quality responses of the paired sites on each dairy. Comparison of pre-BMP regressions to post-BMP regressions represents the typically recommended approach with either the paired or upstream-downstream experimental designs (Spooner *et al.*, 1985). Paired Student's *t*-tests and unpaired Student's *t*-tests provide additional information indicating differences between the paired sites on each dairy.

Regression analysis was the initial test used to compare water quality responses between paired sites by storm event. As a log-log relationship is often indicated in these types of analyses (Spooner *et al.*, 1985), regressions were evaluated using both non-transformed and $\log_{(e)}$-transformed data to evaluate the pre-BMP relationships between each pair of sites.

A paired *t*-test by storm event was then conducted between paired sites for each constituent. The paired *t*-test was used to remove extraneous variance existing from storm to storm for these paired observations (Ott, 1984). For comparison, a normal or unpaired *t*-test was also performed. The data were evaluated to determine whether data transformations were needed using a Shapiro-Wilks test on the difference between storm values for the paired *t*-test and the summarized storm event values for the unpaired t-tests (Ott, 1984). Overall, a natural-log transformation was indicated to better fit the assumptions of normality than the non-transformed data (see Appendix D). The standard deviations across storm events for mean, median, and volume-weighted mean were also tested for equal variances using Hartley's F-test (Ott, 1984). The Hartley's F-test generally confirmed the need for using a natural-log transformation of the water quality data in that the assumption of equal variances was generally indicated for the transformed values but not the non-transformed values. Results for the Shapiro-Wilks and Hartley's tests are presented in Appendix D.

Because of stormwater sampling and transportation logistics, the 48-hour holding times for nitrite-nitrogen, nitrate-nitrogen, and orthophosphate-phosphorus were exceeded by several hours for samples in some storm events. In addition, some TKN and COD samples slightly exceeded holding times because of analytical instrument malfunctions. Many of the samples whose holding times were exceeded were taken during major hydrograph peaks. Samples that could not be analyzed prior to holding time expiration were typically held on ice throughout the time between collection and analysis. The laboratory completed the analysis of those samples but coded the results on the chain-of-custody data sheets that holding times had been exceeded.

Because of the importance of these data in subsequent analyses, the decision was made to review each analysis that occurred after holding time had been exceeded. In the majority of cases, the holding time was exceeded by fewer than six hours. If the holding time was exceeded by more than six hours, the data were not used. If these data conformed to the general pattern and concentrations of other data for which holding times were not exceeded, the data were included in the statistical analysis. The storm events with data from samples that exceeded holding times are indicated in Appendix A.

While not conducted specifically on samples from the Lake Fork Reservoir watershed, TIAER performed a series of tests in the North Bosque River watershed to determine whether violations of holding times result in significant changes in nutrient concentrations (TIAER, 1995). Results from long-term testing showed no significant differences in mean values until hour 72 of the test. For that reason, results of samples whose holding time violations were less than six hours were included in the statistical analysis. As previously mentioned, a review of the data prior to its inclusion revealed no extreme differences in concentrations when compared to other data analyzed within accepted holding times. Inclusion of these data allowed a more complete examination of available stormwater data.

RESULTS

Regression Analysis

In comparing storm event values between sites using regression analysis, significant relationships were indicated for the Coke Dairy and Beezley Dairy sites for various constituents (Table 3).

Table 3. Regression Model P-Values for Constituents at Paired Demonstration Sites

	Volume-Weighted Mean		MEAN		MEDIAN	
	Non-transformed	Log-transformed	Non-transformed	Log-transformed	Non-transformed	Log-transformed
BEEZLEY DAIRY SITES						
COD	0.6528	0.2573	0.0657	0.0501	**0.0350***	**0.0195***
NH3	0.2672	0.8673	0.7720	0.8016	0.5840	0.5594
NO_2-N	**0.0433***	**0.0026****	**0.0003****	**0.0006****	**0.0001****	**0.0009****
NO_{2+3}-N	0.4214	0.4770	0.4387	0.4892	0.2701	0.3441
NO_3-N	0.4185	0.4616	0.4369	0.4723	0.2757	0.4286
PO4-P	0.5596	0.3329	0.7813	0.9707	0.9840	0.8788
TKN	0.3709	0.2017	0.3574	0.3483	0.3373	0.2228
Total N	0.3503	0.1780	0.2972	0.2582	0.2584	0.1182
Total P	0.2393	0.1910	0.3576	0.2575	0.4639	0.5193
TSS	0.6154	0.8792	0.1043	0.1094	**0.0227***	**0.0074****
COKE DAIRY SITES						
COD	0.3583	0.4141	**0.0288***	0.0502	**0.0474***	0.0732
NH3	0.1269	0.0772	0.1482	**0.0188***	0.3615	0.1895
NO_2-N	0.0601	0.0517	**0.0286***	**0.0395***	0.5301	0.1739
NO_{2+3}-N	0.0681	0.1997	0.1477	0.2619	0.2839	0.4777
NO_3-N	0.0779	0.2309	0.1557	0.2794	0.3308	0.5546
PO4-P	0.0528	0.0675	0.2332	0.2227	0.3950	0.2624
TKN	0.0669	0.1062	**0.0472***	**0.0283***	0.1778	**0.0374***
Total N	0.1472	0.0932	0.0611	0.0513	0.2081	0.0673
Total P	0.5520	0.6113	0.2665	0.1903	0.3472	0.2648
TSS	0.3609	0.0717	0.6093	0.1178	**0.0210***	**0.0096****

* Significant at $\alpha = 0.05$
** Significant at $\alpha = 0.01$

The significant COD relationships at both sites were negative, i.e., higher storm COD values at one site corresponded with lower COD values at the other site on the dairy. The significant NH_3-N and TKN relationships between sites KO010 and KO020 were also negative. The other significant relationships between sites at each demonstration dairy were positive. Significant positive regression relationships indicate a relative increase in constituent concentration at one site as values increase at the other site on the demonstration dairy. The direction of the slope can be ascertained from the sign in the regression equation. Regression equations for the Beezley Dairy sites and Coke Dairy sites for all constituents are presented in Appendix E. The R-square values and standard deviations of the slopes are also provided in Appendix E. Table 4 provides the linear regression relationships with $\alpha = 0.05$ or less for the Beezley Dairy and Table 5 provides the linear regressions with $\alpha = 0.05$ or less for the Coke Dairy.

Table 4. Significant Regression Relationships between Beezley Dairy Sites

Measure of Central Tendency	Constituent	Equation	R^2	p-value	n*
Volume Weighted Mean	NO_2-N	ln(DC010) = -5.760+1.3591*ln(DC020)	0.32	0.0433	13
Mean	NO_2-N	DC010 = 0.0011+0.6622*(DC020)	0.71	0.0003	13
Median	COD	ln(DC010) = 6.9602-0.5460* ln(DC020)	0.40	0.0195	13
	NO_2-N	DC010 = -0.0011+0.986*(DC020)	0.94	0.0001	13
	TSS	ln(DC010) = -5.77+1.36*ln(DC020)	0.49	0.0074	13

*'n' represents the number of storm events used as observations in the regression analysis

Table 5. Significant Regression Relationships between Coke Dairy Sites

Measure of Central Tendency	Constituent	Equation	R^2	p-value	n*
Mean	COD	KO010 = 1426.6 – 4.2921*(KO020)	0.47	0.0288	10
	NH_3	ln(KO010) = 4.5944-0.5443*ln(KO020)	0.57	0.0188	9
	NO_2-N	ln(KO010) = 0.7851+0.6461*ln(KO020)	0.48	0.0395	9
	TKN	ln(KO010) = 6.7621 - 0.8184*ln(KO020)	0.47	0.0283	10
Median	COD	KO010 = 1221.03 – 3.3481*(KO020)	0.41	0.0474	10
	TKN	ln(KO010) = 6.3336-0.7408*ln(KO020)	0.44	0.0374	10
	TSS	ln(KO010) = 0.2387+ 1.2860*ln(KO020)	0.59	0.0096	10

*'n' represents the number of storm events used as observations in the regression analysis

T-Test Results

The unpaired *t*-test compares the means of all storm events for both sites while the paired *t*-test evaluates the difference between the storm means of the two sites for all of the paired storm events. The null hypothesis for the unpaired *t*-tests is that the cumulative storm means of the two sites are not different. The null hypothesis for the paired *t*-test is that the difference between the storm means at the two sites is zero. Differences were considered to be significant at $\alpha = 0.05$ and to be highly significant at $\alpha = 0.01$.

The probabilities calculated by the paired and unpaired t-tests for the two demonstration sites are summarized in Table 6. Both the transformed and non-transformed results are presented for comparison purposes. Fairly similar results were indicated for the paired and unpaired data regardless of whether the data were non-transformed or $\log_{(e)}$ transformed prior to analysis. For the Coke Dairy, significant differences at α=0.01 were indicated for COD, PO4, and TP by all analyses. Some significant differences were shown for NH_3, NO_2-N, and TSS. Nitrate-nitrogen and nitrite-plus-nitrate nitrogen showed no significant differences for any analysis. For the Beezley Dairy, significant differences were consistently indicated at the $\alpha = 0.05$ for all constituents except NO_2-N. NO_2-N is considered a fairly transitory constituent as an intermediary in the oxidation of NH_3-N to NO_3-N, so lack of significant differences in NO_2-N concentrations between the Beezley Dairy sites is not considered unusual.

Table 6. T-Test Results for Demonstration Dairy Sites

	Volume Wt Mean Paired *t*-test		MEAN Paired *t*-test		MEDIAN Paired *t*-test		Unpaired *t*-test
	Non-transformed	Log-transformed	Non-transformed	Log-transformed	Non-transformed	Log-transformed	Log-transformed Volume Wt Mean
BEEZLEY DAIRY SITES							
COD	**0.0005***	**0.0001***	**0.0001***	**0.0001***	**0.0008***	**0.0001***	**0.0001***
NH3	0.0518	**0.0001***	**0.0482**	**0.0001***	0.0629	**0.0001***	**0.0001***
NO_2-N	0.2445	0.2028	0.1422	0.0878	0.1964	0.2336	0.4900
NO_{2+3} -N	**0.0129**	**0.0012***	**0.0019***	**0.0006***	**0.0020***	**0.0015***	**0.0001***
NO_3-N	**0.0127**	**0.0013***	**0.0019***	**0.0007***	**0.0020***	**0.0051***	**0.0001***
PO4-P	**0.0027***	**0.0001***	**0.0051***	**0.0001***	**0.0002***	**0.0001***	**0.0001***
TKN	**0.0008***	**0.0001***	**0.0032***	**0.0001***	**0.0136**	**0.0001***	**0.0001***
Total N	**0.0006***	**0.0001***	**0.0022***	**0.0001***	**0.0088***	**0.0001***	**0.0001***
Total P	**0.0001***	**0.0001***	**0.0001***	**0.0001***	**0.0001***	**0.0001***	**0.0001***
TSS	**0.0014***	**0.0001***	**0.0001***	**0.0001***	**0.0001***	**0.0001***	**0.0001***
COKE DAIRY SITES							
COD	**0.0040***	**0.0022***	**0.0014***	**0.0006***	**0.0019***	**0.0009***	**0.0002***
NH3	0.0536	**0.0183**	**0.0465***	**0.0083***	0.0628	**0.0043***	**0.0025***
NO_2-N	**0.0087***	**0.0001***	**0.0058***	**0.0001***	**0.0228***	**0.0001***	**0.0001***
NO_{2+3} -N	0.1177	0.1003	0.0682	0.0783	0.1818	0.5463	0.1919
NO_3-N	0.1397	0.1514	0.0752	0.1077	0.2391	0.7398	0.2498
PO_4-P	**0.0001***	**0.0010***	**0.0001***	**0.0002***	**0.0002***	**0.0001***	**0.0034***
TKN	**0.0383**	**0.0112**	**0.0242**	**0.0032***	**0.0323**	**0.0020***	**0.0009***
Total N	**0.0474**	**0.0162**	**0.0294**	**0.0056***	**0.0412**	**0.0039***	**0.0018***
Total P	**0.0009***	**0.0016***	**0.0003***	**0.0004***	**0.0006***	**0.0008***	**0.0004***
TSS	0.0558	**0.0003***	0.0609	**0.0004***	**0.0173**	**0.0001***	**0.0010***

Results in bold indicate significant difference at α=0.05.
*Asterisks indicate significant difference at α=0.01.

Graphs representing the geometric means of the $\log_{(e)}$ transformed values for each constituent by storm value and the results of the unpaired t-test are presented in Figures 5 and 6 to emphasize the differences in constituent values between the two sites. When significant differences were indicated for the Beezley Dairy sites, higher constituent values were consistently indicated at downstream site DC020 than at upstream site DC010. When significant differences were indicated for the Coke Dairy sites, higher constituent values were consistently indicated at site KO010, which was downgradient from the waste storage pond and manure storage area than at site KO020, which is downstream from a pasture and a loafing area. Basic statistics for each site across storms for $\log_{(e)}$ transformed values and non-transformed values are presented in Appendix F.

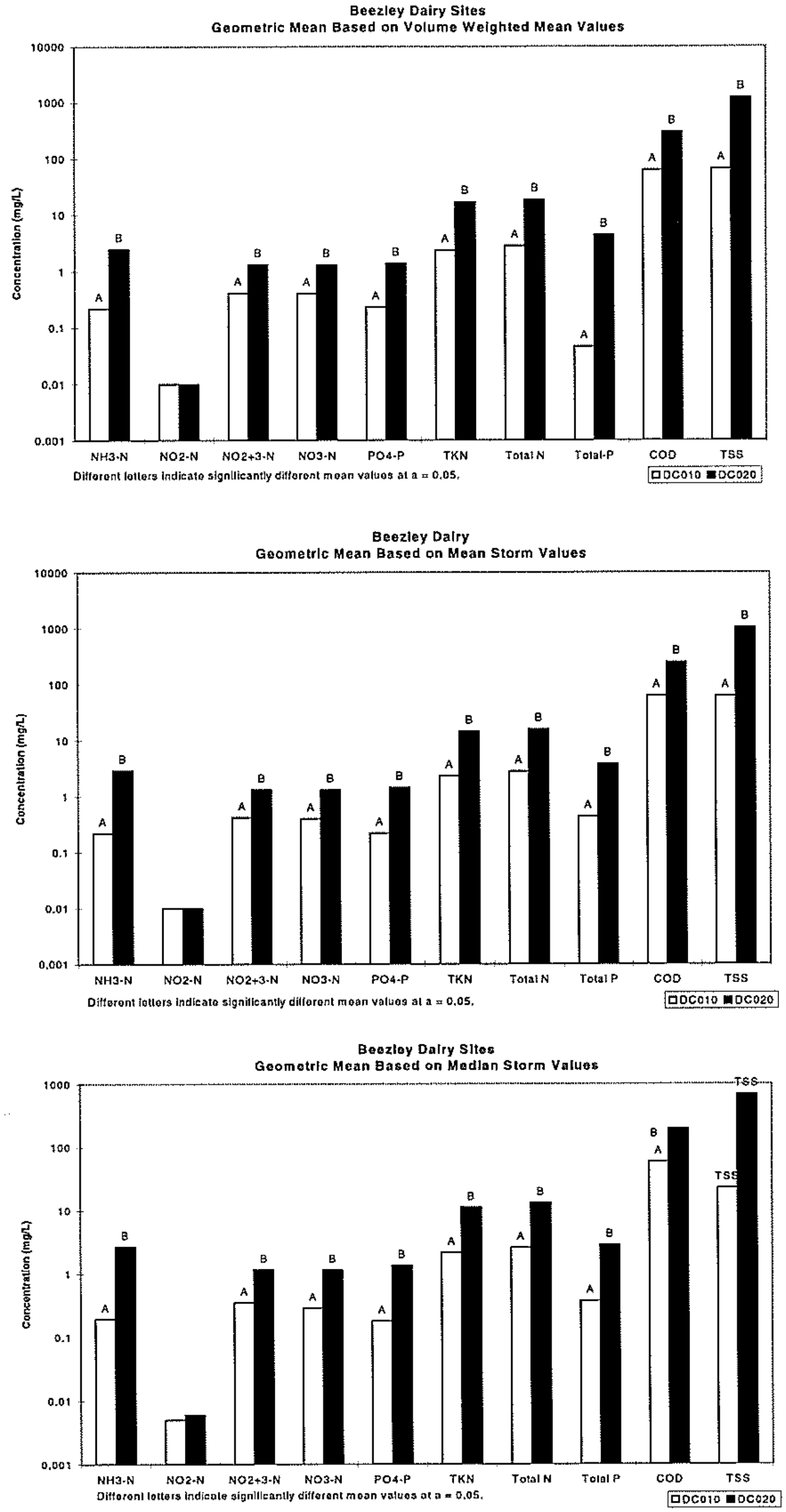


Figure 5. Mean Storm Values for Coke Dairy Sites
$Log_{(e)}$ Transformed Geometric Means of All Storms

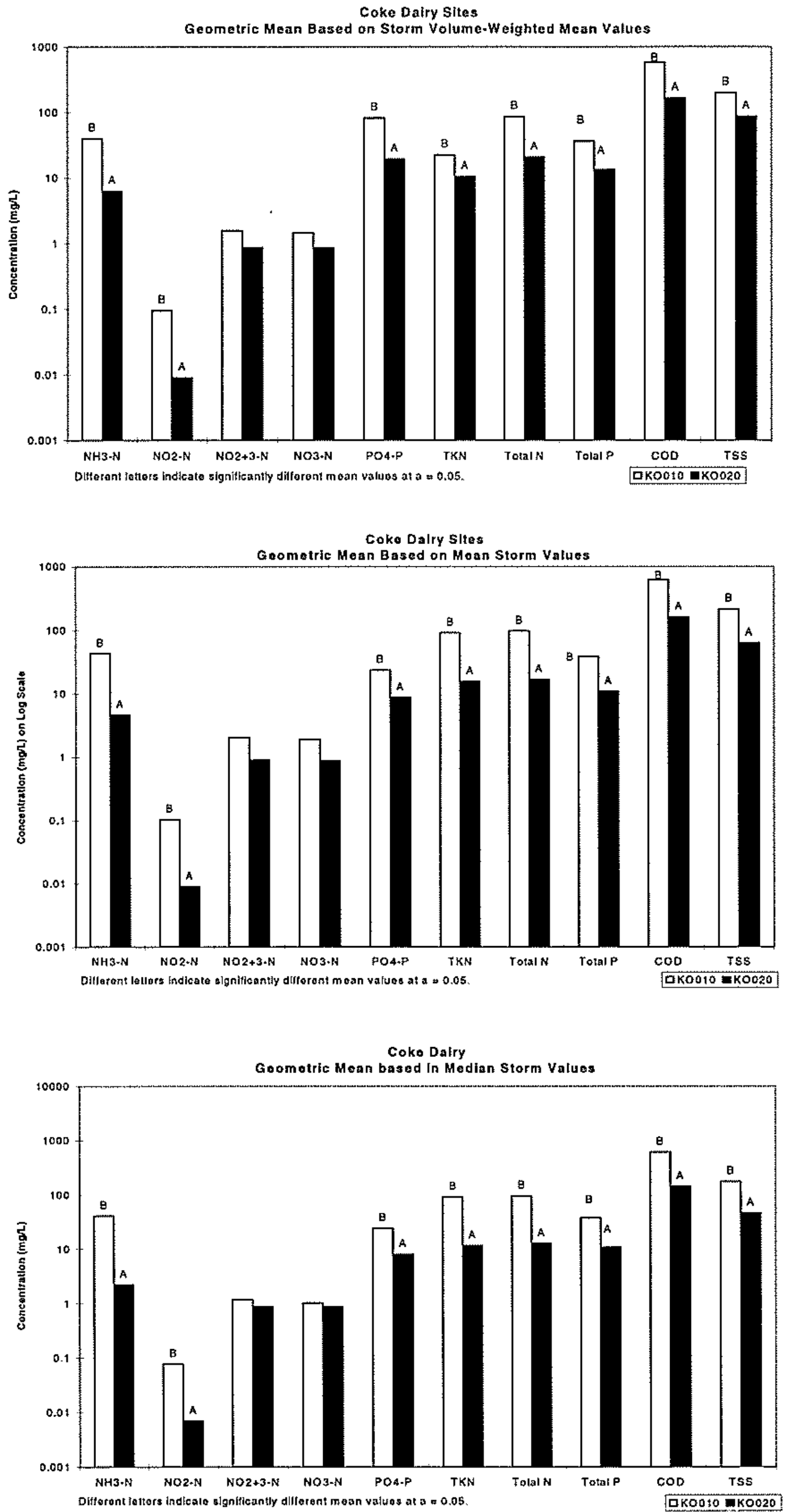


Figure 6. Mean Storm Values for Beezley Dairy Sites
$Log_{(e)}$ Transformed Geometric Means of All Storms

SUMMARY AND CONCLUSIONS

Nutrient data were obtained during stormwater runoff events from two sites on the Coke Dairy as a paired watershed study and two sites on the Beezley Dairy as an upstream/downstream study. Water level and flow data were also obtained for all storm events. The water quality and flow data provided characterization of conditions prior to implementation of best management practices (pre-BMP). At each dairy, one monitoring site had a drainage area that will receive treatment or BMPs and the other site had a drainage area that will not receive treatment and will serve as a control.

The pre-BMP data from both dairies were statistically analyzed to determine linear regressions between the paired sites at each dairy. The linear regression analyses indicated only a few significant regression equations at each dairy. The lack of significant regression equations will make it more difficult to show statistically significant improvement in water quality from BMP installation after post-BMP monitoring has occurred. Nonetheless, water quality improvements from BMP implementation are expected to be considerable, which means that comparison of pre-BMP and post-BMP regressions may still be successful in demonstrating water quality improvement.

As an alternative, should the regression approach fail to demonstrate water quality improvement, *t*-test analyses (paired and unpaired) are also provided in this report. The comparison of means by *t*-test from the two monitoring sites at each dairy may provide an alternative manner to statistically demonstrate water quality improvement through the monitoring data. Most water quality constituents for the two monitoring sites at each dairy were shown by the *t*-test to be different at a very high level of significance.

This data report includes the results of the statistical analyses, i.e., linear regression and *t*-test, for the pre-BMP monitoring program. Appropriate graphs and tables are provided to allow subsequent analyses and comparisons of post-BMP data with the intent of showing water quality improvement through BMP implementation on the Beezley and Coke Dairies.

LITERATURE CITED

APHA, American Public Health Association, American Water Works Association, and Water Environment Federation. 1995. Standard Methods for the Examination of Water and Wastewater. 19th edition. APHA, Washington, D.C.

Bailey, K.L. and Riggs, D.W. 1996. A Nutrient Budget Analysis for the Lake Fork Reservoir Watershed. Texas Institute for Applied Environmental Research.

EPA, United States Environmental Protection Agency. 1993. Paired Watershed Study Design. Office of Water, US-EPA, Washington, D.C. 841-F-93-009.

EPA, United States Environmental Protection Agency. 1983. Methods for Chemical Analysis of Water and Wastes. Environmental Monitoring and Support Laboratory, Office of Research and Development, US-EPA, Cincinnati, Ohio. EPA-600/4-79-020, Revised March 1983.

Ewer, S. and N. Easterling. 1998. Lake Fork Reservoir Watershed and Running Creek Subwatershed Geographic Information System Data Report for TSSWCB's Lake Fork Reservoir NPS 319(h) Project. Texas Institute for Applied Environmental Research WP 98-05.

Gilliom, R.J. and D.R. Helsel. 1986. Estimation of distributional parameters for censored trace level water quality data. 1. Estimation techniques. Water Resources Research 22:135-126.

Ott, L. 1984. An Introduction to Statistical Methods and Data Analysis, second edition. Duxbury Press, Boston.

Rushin, Randy. Lake Fork Reservoir Watershed Comprehensive Nonpoint Source Water Quality Management Project, Interim Report, Evaluation of Available Information. Tyler, TX: Texas Natural Resource Conservation Commission, November 1994.

SCS, United States Department of Agriculture Soil Conservation Service. Nov 1977. Soil Survey of Hopkins and Rains Counties, Texas.

Spooner, J., R.P. Maas, S.A. Dressing, M.D. Smolen, and F.J. Humenik. 1985. Appropriate Designs for Documenting Water Quality Improvements from Agricultural NPS Control Programs, pp. 30-34. In: Perspectives on Nonpoint Source Pollution. EPA 440/5-85-001.

Stein, S.K. 1977. Calculus and Analytic Geometry, second edition. McGraw-Hill Book Company, New York, New York.

TIAER, Texas Institute for Applied Environmental Research. 1996. Quality Assurance Project Plan for the Environmental Measurement Activities Relating to Lake Fork Reservoir Watershed NPS Project.

TIAER, Texas Institute for Applied Environmental Research. 1995. Livestock and the Environment: Scientific Underpinnings for Policy Analysis. Stephenville, Texas

TNRCC, Texas Natural Resources Conservation Committee. 1996. The State of Texas Water Quality Inventory, 13th Edition 1996, Volume 2, Dec. 1996.

Texas Water Commission. 1992. Regional Assessments of Water Quality Pursuant to The Texas Clean Rivers Act. Austin, Texas. Summary Report GP 92-01.

Ward, R.C., J.C. Loftis, H.P. DeLong, and H.F. Bell. 1988. Groundwater quality: A data analysis protocol. Journal of the Water Pollution Control Federation 60:1938-1945.

APPENDIX A: Basic Statistics For Demonstration Sites By Storm Event

APPENDIX B: Hydrographs of Storm Events at Demonstration Sites

APPENDIX C: Plots of Rating Curve Equations for Each Sampling Site

APPENDIX D: Results for the Shapiro-Wilks and Hartley's F Tests

APPENDIX E: Regression Relationships Between Sites for All Constituents

APPENDIX F: Basic Statistics Across Storms for Each Site Using Non-Transformed and Natural-Log Transformed Values

APPENDIX A: Basic Statistics For Demonstration Sites By Storm Event

Table A-1 Basic Statistics for Samples Collected during Storm Events at Beezley Dairy Site DC010

Site DC010 Storm 1*			Storm Volume 234cu.ft.		First Sample Last Sample		4/4/97 10:50 4/5/97 13:45	
Variable	Units	#	Vol. Wtd. Mean	Mean	Median	Std Dev	Min.	Max.
COD	mg/L	9	56	54.33	56	14.40	24	81
NH_3-N	mg/L	9	0.17	0.21	0.18	0.12	0.06	0.37
NO_2-N	mg/L	9	0.020	0.020	0.020	0.001	0.019	0.020
NO_{2+3}-N	mg/L	9	0.132	0.12	0.09	0.06	0.079	0.269
NO_3-N	mg/L	9	0.11	0.10	0.07	0.06	0.06	0.25
PO_4-P	mg/L	9	0.27	0.28	0.29	0.05	0.19	0.34
TKN	mg/L	9	2.86	2.50	2.01	0.83	1.73	3.9
Total N	mg/L	9	2.989	2.620	2.09	0.869	1.810	4.049
Total P	mg/L	9	1.13	0.86	0.6	0.64	0.43	2.12
TSS	mg/L	9	291	212.89	124	203.88	35	617

Site DC010 Storm 2			Storm Volume 24cu.ft.		First Sample Last Sample		6/16/97 16:15 6/17/97 9:15	
Variable	Units	#	Vol. Wtd. Mean	Mean	Median	Std Dev	Min.	Max.
COD	mg/L	15	43	37.33	24	25.49	20	97
NH_3-N	mg/L	17	0.25	0.22	0.21	0.05	0.15	0.32
NO_2-N	mg/L	17	0.047	0.046	0.050	0.005	0.040	0.050
NO_{2+3}-N	mg/L	17	0.271	0.20	0.058	0.31	0.048	1.17
NO_3-N	mg/L	17	0.22	0.16	0.008	0.31	0.008	1.12
PO_4-P	mg/L	13	0.16	0.15	0.15	0.02	0.13	0.19
TKN	mg/L	17	1.9	1.65	1.3	0.73	1.12	3.59
Total N	mg/L	17	2.17	1.855	1.348	1.025	1.168	4.760
Total P	mg/L	17	0.19	0.16	0.12	0.11	0.039	0.42
TSS	mg/L	17	33	20.24	5	45.03	5	184

Site DC010 Storm 3*			Storm Volume 671cu.ft.		First Sample Last Sample		7/7/97 8:45 7/8/97 7:45	
Variable	Units	#	Vol. Wtd. Mean	Mean	Median	Std Dev	Min.	Max.
COD	mg/L	18	52	56.11	52.5	22.01	32	110
NH_3-N	mg/L	18	0.81	0.60	0.47	0.33	0.27	1.32
NO_2-N	mg/L	18	0.011	0.01	0.0045	0.01	0.003	0.05
NO_{2+3}-N	mg/L	18	0.541	0.68	0.4785	0.71	0.04	2.683
NO_3-N	mg/L	18	0.53	0.67	0.46	0.72	0.017	2.68
PO_4-P	mg/L	18	0.2	0.22	0.075	0.27	0.03	1.07
TKN	mg/L	18	3.12	2.98	2.79	1.76	1.67	9.48
Total N	mg/L	18	3.666	3.657	3.135	2.414	1.808	12.163
Total P	mg/L	18	0.6	0.55	0.35	0.64	0.1	2.88
TSS	mg/L	18	126	100.28	31.5	209.64	14	859

* As explained in the text, some of the samples analyzed for this storm had exceeded holding times but are considered to be representative of the water quality for the site.

Site DC010 Storm 4			Storm Volume 1131cu.ft.			First Sample Last Sample	12/20/97 20:15 12/21/97 23:55	
Variable	Units	#	Vol. Wtd. Mean	Mean	Median	Std Dev	Min.	Max.
COD	mg/L	14	61	64	57	17.03	46	101
NH_3-N	mg/L	14	0.060	0.079	0.070	0.03	0.03	0.13
NO_2-N	mg/L	14	0.004	0.005	0.003	0.00	0.003	0.014
NO_{2+3}-N	mg/L	14	0.601	0.645	0.6085	0.19	0.423	1.123
NO_3-N	mg/L	14	0.6	0.640	0.6	0.19	0.42	1.12
PO_4-P	mg/L	14	0.55	0.431	0.42	0.18	0.19	0.92
TKN	mg/L	14	2.41	2.25	1.995	0.73	1.39	3.72
Total N	mg/L	14	3.009	2.897	2.5335	0.828	1.913	4.553
Total P	mg/L	14	0.75	0.65	0.685	0.17	0.36	0.88
TSS	mg/L	14	108	73.93	13.5	157.05	4	606

Site DC010 Storm 5*			Storm Volume 3411cu.ft.			First Sample Last Sample	12/23/97 11:35 12/24/97 7:35	
Variable	Units	#	Vol. Wtd. Mean	Mean	Median	Std Dev	Min.	Max.
COD	mg/L	16	65	66.06	60	24.54	50	156
NH_3-N	mg/L	16	0.28	0.29	0.245	0.15	0.14	0.74
NO_2-N	mg/L	16	0.003	0.00	0.003	0.00	0.003	0.003
NO_{2+3}-N	mg/L	16	0.568	0.66	0.543	0.34	0.233	1.393
NO_3-N	mg/L	16	0.56	0.66	0.54	0.34	0.23	1.39
PO_4-P	mg/L	16	0.68	0.84	0.465	0.63	0.19	1.99
TKN	mg/L	16	1.79	1.85	1.785	0.19	1.6	2.25
Total N	mg/L	16	2.356	2.511	2.323	0.362	2.063	3.213
Total P	mg/L	16	0.62	0.62	0.63	0.09	0.43	0.82
TSS	mg/L	16	42	36.88	11	44.62	4	155

Site DC010 Storm 6			Storm Volume 1419cu.ft.			First Sample Last Sample	1/5/98 0:10 1/5/98 9:10	
Variable	Units	#	Vol. Wtd. Mean	Mean	Median	Std Dev	Min.	Max.
COD	mg/L	11	88	86.27	84	15.43	69	120
NH_3-N	mg/L	11	0.17	0.14	0.15	0.07	0.011	0.23
NO_2-N	mg/L	11	0.004	0.00	0.003	0.00	0.003	0.007
NO_{2+3}-N	mg/L	11	0.834	0.84	0.933	0.28	0.053	1.095
NO_3-N	mg/L	11	0.83	0.84	0.93	0.28	0.05	1.09
PO_4-P	mg/L	11	0.19	0.17	0.17	0.06	0.04	0.27
TKN	mg/L	11	3.5	3.47	3.37	0.34	3.17	4.17
Total N	mg/L	11	4.330	4.315	4.153	0.473	3.343	5.133
Total P	mg/L	11	0.48	0.47	0.49	0.10	0.34	0.71
TSS	mg/L	11	80	89.27	18	177.49	3	610

* As explained in the text, some of the samples analyzed for this storm had exceeded holding times but are considered to be representative of the water quality for the site.

Site DC010			Storm Volume		First Sample		1/6/98 0:25	
Storm 7*			2543cu.ft.		Last Sample		1/6/98 9:25	
Variable	Units	#	Vol. Wtd. Mean	Mean	Median	Std Dev	Min.	Max.
COD	mg/L	11	93	93.91	83	28.33	64	138
NH_3-N	mg/L	11	0.58	0.60	0.28	0.58	0.12	1.5
NO_2-N	mg/L	11	0.006	0.01	0.003	0.00	0.003	0.013
NO_{2+3}-N	mg/L	11	0.791	0.79	0.793	0.13	0.643	1.043
NO_3-N	mg/L	11	0.78	0.78	0.78	0.13	0.64	1.04
PO_4-P	mg/L	11	0.45	0.47	0.28	0.33	0.2	1.09
TKN	mg/L	11	4.59	5.32	6.32	3.27	1.85	10.1
Total N	mg/L	11	5.376	6.106	7.283	3.235	2.643	10.747
Total P	mg/L	11	0.85	0.85	0.32	0.79	0.25	2.22
TSS	mg/L	11	169	165.73	88	174.73	13	460

Site DC010			Storm Volume		First Sample		1/6/98 21:40	
Storm 8			5961cu.ft.		Last Sample		1/7/98 8:40	
Variable	Units	#	Vol. Wtd. Mean	Mean	Median	Std Dev	Min.	Max.
COD	mg/L	12	66	68.00	68	6.32	56	76
NH_3-N	mg/L	12	0.12	0.10	0.105	0.07	0.011	0.24
NO_2-N	mg/L	12	0.007	0.01	0.003	0.01	0.003	0.019
NO_{2+3}-N	mg/L	12	0.678	0.69	0.6705	0.07	0.557	0.783
NO_3-N	mg/L	12	0.67	0.68	0.66	0.08	0.54	0.78
PO_4-P	mg/L	12	0.2	0.19	0.195	0.01	0.16	0.22
TKN	mg/L	12	1.72	1.73	1.725	0.12	1.59	2
Total N	mg/L	12	2.394	2.421	2.436	0.096	2.263	2.557
Total P	mg/L	12	0.51	0.52	0.52	0.05	0.43	0.65
TSS	mg/L	12	30	33.92	10.5	45.31	5	154

Site DC010			Storm Volume		First Sample		1/11/98 17:30	
Storm 9			9804cu.ft.		Last Sample		1/12/98 8:30	
Variable	Units	#	Vol. Wtd. Mean	Mean	Median	Std Dev	Min.	Max.
COD	mg/L	14	48	50.50	47.5	11.25	36	75
NH_3-N	mg/L	14	0.29	0.28	0.27	0.05	0.19	0.35
NO_2-N	mg/L	14	0.007	0.01	0.008	0.00	0.003	0.011
NO_{2+3}-N	mg/L	14	0.291	0.32	0.2975	0.11	0.159	0.491
NO_3-N	mg/L	14	0.28	0.31	0.29	0.12	0.15	0.48
PO_4-P	mg/L	14	0.12	0.12	0.12	0.01	0.11	0.14
TKN	mg/L	14	1.57	1.62	1.6	0.20	1.36	1.99
Total N	mg/L	14	16.56	12.625	8.673	7.173	2.603	27.553
Total P	mg/L	13	0.21	0.23	0.25	0.04	0.17	0.29
TSS	mg/L	14	11	12.93	7.5	14.04	4	53

* As explained in the text, some of the samples analyzed for this storm had exceeded holding times but are considered to be representative of the water quality for the site.

Site DC010 Storm10			Storm Volume 3805cu.ft.			First Sample Last Sample	1/26/98 1:20 1/26/98 9:20	
Variable	Units	#	Vol. Wtd. Mean	Mean	Median	Std Dev	Min.	Max.
COD	mg/L	10	52	54.10	55.5	8.56	42	69
NH_3-N	mg/L	10	0.12	0.12	0.11	0.04	0.09	0.23
NO_2-N	mg/L	10	0.008	0.01	0.008	0.00	0.005	0.016
NO_{2+3}-N	mg/L	10	0.467	0.50	0.5365	0.12	0.297	0.675
NO_3-N	mg/L	10	0.46	0.49	0.525	0.12	0.29	0.67
PO_4-P	mg/L	10	0.1	0.10	0.1	0.01	0.09	0.12
TKN	mg/L	10	1.79	1.80	1.74	0.26	1.59	2.45
Total N	mg/L	10	2.258	2.296	2.2135	0.338	1.949	3.022
Total P	mg/L	10	0.36	0.38	0.39	0.10	0.2	0.6
TSS	mg/L	10	41	44.95	12	73.30	1.5	225

Site DC010 Storm 11			Storm Volume 16508cu.ft.			First Sample Last Sample	2/10/98 7:30 2/10/98 20:35	
Variable	Units	#	Vol. Wtd. Mean	Mean	Median	Std Dev	Min.	Max.
COD	mg/L	17	82	80.41	87	16.96	47	100
NH_3-N	mg/L	17	0.38	0.42	0.41	0.11	0.3	0.7
NO_2-N	mg/L	17	0.004	0.00	0.003	0.00	0.003	0.016
NO_{2+3}-N	mg/L	17	0.48	0.59	0.495	0.33	0.213	1.223
NO_3-N	mg/L	17	0.48	0.59	0.48	0.33	0.21	1.22
PO_4-P	mg/L	17	0.13	0.12	0.12	0.04	0.03	0.19
TKN	mg/L	17	2.87	2.95	3.02	0.71	1.97	4.7
Total N	mg/L	17	3.351	3.546	3.643	0.947	2.195	5.413
Total P	mg/L	17	0.41	0.38	0.37	0.13	0.21	0.7
TSS	mg/L	17	336	257.53	226	216.54	30	744

Site DC010 Storm 12			Storm Volume 3823cu.ft.			First Sample Last Sample	2/25/98 18:50 2/26/98 8:50	
Variable	Units	#	Vol. Wtd. Mean	Mean	Median	Std Dev	Min.	Max.
COD	mg/L	6	80	73.50	71	14.24	61	99
NH_3-N	mg/L	6	0.32	0.28	0.29	0.11	0.14	0.43
NO_2-N	mg/L	6	0.006	0.01	0.0045	0.00	0.003	0.01
NO_{2+3}-N	mg/L	6	0.31	0.21	0.218	0.15	0.043	0.439
NO_3-N	mg/L	6	0.3	0.20	0.21	0.15	0.04	0.43
PO_4-P	mg/L	6	0.34	0.25	0.185	0.28	0.05	0.8
TKN	mg/L	6	2.29	2.03	1.84	0.71	1.34	2.97
Total N	mg/L	6	2.598	2.241	2.0995	0.835	1.383	3.409
Total P	mg/L	6	0.36	0.33	0.34	0.15	0.13	0.55
TSS	mg/L	6	50	46.83	19	59.04	1.5	143

| Site DC010 | Storm Volume | | | | First Sample | 3/16/98 7:50 | | |
| Storm 13 | 26073cu.ft. | | | | Last Sample | 3/17/98 9:50 | | |

Variable	Units	#	Vol. Wtd. Mean	Mean	Median	Std Dev	Min.	Max.
COD	mg/L	10	54	57.10	55	11.70	35	76
NH_3-N	mg/L	10	0.13	0.14	0.135	0.03	0.11	0.22
NO_2-N	mg/L	10	0.004	0.00	0.003	0.00	0.003	0.006
NO_{2+3}-N	mg/L	10	0.178	0.20	0.179	0.06	0.146	0.273
NO_3-N	mg/L	10	0.17	0.20	0.175	0.06	0.14	0.27
PO_4-P	mg/L	10	0.15	0.14	0.14	0.02	0.09	0.16
TKN	mg/L	10	1.85	2.06	1.82	0.58	1.57	3.13
Total N	mg/L	10	2.026	2.264	1.9895	0.630	1.735	3.403
Total P	mg/L	10	0.31	0.34	0.31	0.11	0.23	0.54
TSS	mg/L	10	28	45.90	23	53.66	5	177

Table A-2 Basic Statistics for Samples Collected during Storm Events at Beezley Dairy Site DC020

Site DC020 Storm 1*			Storm Volume 1,033,016 cu.ft.			First Sample Last Sample	4/4/97 11:00 4/4/97 23:55	
Variable	Units	#	Vol. Wtd. Mean	Mean	Median	Std Dev	Min.	Max.
COD	mg/L	9	224	220.22	192	98.10	148	472
NH_3-N	mg/L	9	2.36	2.23	2.07	0.37	1.88	2.96
NO_2-N	mg/L	9	0.019	0.02	0.02	0.00	0.016	0.02
NO_{2+3}-N	mg/L	9	3.55	2.99	2.98	0.96	1.93	5.13
NO_3-N	mg/L	9	3.53	2.97	2.96	0.96	1.91	5.11
PO_4-P	mg/L	9	1.1	1.02	1.05	0.17	0.77	1.24
TKN	mg/L	9	18.02	15.81	13.6	5.65	8.9	26.2
Total N	mg/L	9	21.57	18.801	17.076	6.126	11.140	28.640
Total P	mg/L	9	5.63	4.96	4.55	1.75	2.21	7.62
TSS	mg/L	9	4574	3174.44	1980	2100.80	1370	7310

Site DC020 Storm 2			Storm Volume 41,750cu.ft.			First Sample Last Sample	6/17/97 5:30 6/17/97 9:30	
Variable	Units	#	Vol. Wtd. Mean	Mean	Median	Std Dev	Min.	Max.
COD	mg/L	3	559	564.00	564	16.00	548	580
NH_3-N	mg/L	3	29.45	30.73	32.3	3.80	26.4	33.5
NO_2-N	mg/L	3	0.047	0.05	0.05	0.01	0.04	0.06
NO_{2+3}-N	mg/L	3	1.322	1.31	1.34	0.05	1.26	1.34
NO_3-N	mg/L	3	1.27	1.26	1.28	0.05	1.21	1.3
PO_4-P	mg/L	3	5.77	6.54	4.19	4.12	4.14	11.3
TKN	mg/L	3	62.36	62.50	61.9	2.75	60.1	65.5
Total N	mg/L	3	63.69	63.81	63.24	2.785	61.36	66.84
Total P	mg/L	3	8.08	7.97	8.3	0.57	7.32	8.3
TSS	mg/L	3	229	213.33	208	52.20	164	268

Site DC020 Storm 3*			Storm Volume 41750cu.ft.			First Sample Last Sample	7/7/97 6:30 7/8/97 7:10	
Variable	Units	#	Vol. Wtd. Mean	Mean	Median	Std Dev	Min.	Max.
COD	mg/L	20	224	246.45	187	164.75	167	902
NH_3-N	mg/L	20	18.92	13.13	13.75	7.44	3.65	26.2
NO_2-N	mg/L	20	0.073	0.04	0.0085	0.06	0.003	0.2
NO_{2+3}-N	mg/L	20	5.406	3.07	1.935	2.33	0.383	7.37
NO_3-N	mg/L	20	5.33	3.03	1.89	2.30	0.38	7.26
PO_4-P	mg/L	20	2.42	1.99	1.775	0.64	1.12	3.19
TKN	mg/L	20	29.98	15.71	2.88	16.33	0.93	42.7
Total N	mg/L	20	35.39	18.785	8.46	17.165	2.353	50.070
Total P	mg/L	20	4.61	2.59	0.72	2.99	0.039	8.32
TSS	mg/L	20	581	1891.90	943	1967.89	224	6450

* As explained in the text, some of the samples analyzed for this storm had exceeded holding times but are considered to be representative of the water quality for the site.

Site DC020 Storm 4				Storm Volume 28679 cu.ft.		First Sample Last Sample	12/20/97 19:20 12/21/97 12:20	
Variable	Units	#	Vol. Wtd. Mean	Mean	Median	Std Dev	Min.	Max.
COD	mg/L	15	293	299.20	268	184.55	109	627
NH_3-N	mg/L	15	2.38	4.15	3.58	2.25	1.93	9.46
NO_2-N	mg/L	15	0.003	0.01	0.003	0.01	0.003	0.03
NO_{2+3}-N	mg/L	15	0.887	1.27	1.102	0.65	0.163	2.873
NO_3-N	mg/L	15	0.88	1.26	1.09	0.65	0.16	2.87
PO_4-P	mg/L	15	1.81	2.17	1.75	0.94	1.22	3.65
TKN	mg/L	15	19.81	21.94	23.7	11.75	9.2	43.4
Total N	mg/L	15	20.70	23.211	24.693	11.582	10.363	43.563
Total P	mg/L	15	5.05	4.97	3.65	3.53	1.14	11.6
TSS	mg/L	15	2843	1402.33	1320	1163.79	46	3940

Site DC020 Storm 5*				Storm Volume 5376cu.ft.		First Sample Last Sample	12/23/97 11:50 12/24/97 7:50	
Variable	Units	#	Vol. Wtd. Mean	Mean	Median	Std Dev	Min.	Max.
COD	mg/L	16	326	265.75	147	364.13	78	1560
NH_3-N	mg/L	16	1.78	1.81	1.605	0.46	1.3	2.86
NO_2-N	mg/L	16	0.004	0.00	0.003	0.00	0.003	0.012
NO_{2+3}-N	mg/L	16	0.86	1.07	0.868	0.44	0.793	2.293
NO_3-N	mg/L	16	0.86	1.07	0.865	0.44	0.79	2.29
PO_4-P	mg/L	16	1.85	1.59	1.62	0.63	0.81	2.96
TKN	mg/L	16	16.32	13.52	9.67	10.08	5.69	44.1
Total N	mg/L	16	17.18	14.594	10.613	9.898	7.503	44.893
Total P	mg/L	16	5.63	4.54	3.075	5.41	1.4	23.5
TSS	mg/L	16	1478	1122.31	597.5	1887.72	96	8000

Site DC020 Storm 6				Storm Volume 2575cu.ft.		First Sample Last Sample	1/5/98 0:25 1/5/98 9:25	
Variable	Units	#	Vol. Wtd. Mean	Mean	Median	Std Dev	Min.	Max.
COD	mg/L	11	784	326.18	208	274.05	130	1010
NH_3-N	mg/L	11	3.29	3.78	2.16	5.42	1.81	20.1
NO_2-N	mg/L	11	0.004	0.00	0.003	0.00	0.003	0.007
NO_{2+3}-N	mg/L	11	1.045	1.04	1.236	0.47	0.133	1.495
NO_3-N	mg/L	11	1.04	1.03	1.23	0.47	0.13	1.49
PO_4-P	mg/L	11	0.86	1.09	1.08	0.38	0.36	1.6
TKN	mg/L	11	25.63	17.27	10.9	14.74	7.57	56.7
Total N	mg/L	11	26.67	18.310	11.033	14.460	8.857	56.843
Total P	mg/L	11	7.7	5.03	2.84	4.97	1.56	18.5
TSS	mg/L	11	5613	1993.09	878	2067.16	345	5990

* As explained in the text, some of the samples analyzed for this storm had exceeded holding times but are considered to be representative of the water quality for the site.

Site DC020 Storm 7			Storm Volume 3587cu.ft.			First Sample Last Sample	1/6/98 2:10 1/6/98 9:10	
Variable	Units	#	Vol. Wtd. Mean	Mean	Median	Std Dev	Min.	Max.
COD	mg/L	9	74	130.33	144	64.18	67	224
NH_3-N	mg/L	9	0.15	0.81	1.14	0.67	0.11	1.55
NO_2-N	mg/L	9	0.004	0.00	0.003	0.00	0.003	0.01
NO_{2+3}-N	mg/L	9	0.897	0.83	0.813	0.10	0.643	0.963
NO_3-N	mg/L	9	0.89	0.82	0.81	0.10	0.64	0.96
PO_4-P	mg/L	9	0.24	0.95	1.28	0.76	0.17	2.03
TKN	mg/L	9	2.37	6.67	8.11	4.70	1.88	13.9
Total N	mg/L	9	3.26	7.494	8.923	4.619	2.663	14.543
Total P	mg/L	9	0.37	1.93	2.58	1.74	0.19	4.73
TSS	mg/L	9	49	470.33	580	475.33	5	1200

Site DC020 Storm 8			Storm Volume 15756cu.ft.			First Sample Last Sample	1/6/98 22:10 1/7/98 9:10	
Variable	Units	#	Vol. Wtd. Mean	Mean	Median	Std Dev	Min.	Max.
COD	mg/L	12	147	131.00	116	61.56	98	324
NH_3-N	mg/L	12	1	1.00	1.04	0.12	0.78	1.18
NO_2-N	mg/L	12	0.006	0.01	0.006	0.00	0.003	0.012
NO_{2+3}-N	mg/L	12	0.776	0.83	0.8235	0.12	0.603	1.011
NO_3-N	mg/L	12	0.77	0.82	0.815	0.11	0.6	1
PO_4-P	mg/L	12	1.64	1.44	1.31	0.38	1.04	2.33
TKN	mg/L	12	7.95	6.84	5.91	1.87	4.98	10.2
Total N	mg/L	12	8.72	7.673	6.702	1.812	5.886	11.043
Total P	mg/L	12	3.39	2.82	2.395	1.05	1.8	5.31
TSS	mg/L	12	864	610.00	415	490.24	239	1680

Site DC020 Storm 9*			Storm Volume 19452cu.ft.			First Sample Last Sample	1/11/98 16:05 1/12/98 9:05	
Variable	Units	#	Vol. Wtd. Mean	Mean	Median	Std Dev	Min.	Max.
COD	mg/L	15	307	225.93	152	173.13	77	671
NH_3-N	mg/L	15	2.38	2.24	2.06	0.35	1.88	2.96
NO_2-N	mg/L	15	0.004	0.00	0.003	0.00	0.003	0.012
NO_{2+3}-N	mg/L	15	2.921	2.40	1.313	2.51	0.853	8.273
NO_3-N	mg/L	15	2.92	2.39	1.31	2.51	0.85	8.27
PO_4-P	mg/L	15	1.63	1.32	1.09	0.69	0.6	3.16
TKN	mg/L	15	13.64	10.23	7.79	6.39	1.52	26.7
Total N	mg/L	15	16.56	12.625	8.673	7.173	2.603	27.553
Total P	mg/L	15	4.61	3.14	2.16	2.54	0.73	9.02
TSS	mg/L	15	1777	1094.87	483	1273.84	64	4090

* As explained in the text, some of the samples analyzed for this storm had exceeded holding times but are considered to be representative of the water quality for the site.

Site DC020 Storm10			Storm Volume 3829cu.ft.			First Sample Last Sample	1/26/98 1:40 1/26/98 9:40	
Variable	Units	#	Vol. Wtd. Mean	Mean	Median	Std Dev	Min.	Max.
COD	mg/L	10	741	336.40	165	359.35	60	1200
NH_3-N	mg/L	10	2.63	2.58	2.585	0.34	1.99	3.02
NO_2-N	mg/L	10	0.017	0.01	0.008	0.01	0.005	0.02
NO_{2+3}-N	mg/L	10	1.353	1.47	1.5135	0.14	1.145	1.585
NO_3-N	mg/L	10	1.34	1.46	1.505	0.14	1.13	1.58
PO_4-P	mg/L	10	1.62	1.17	1.21	0.50	0.38	2.33
TKN	mg/L	10	35.03	17.70	12.3	14.09	6.8	48.2
Total N	mg/L	10	36.38	19.164	13.877	14.081	8.196	49.742
Total P	mg/L	10	10.05	4.81	3.305	3.95	1.44	12.3
TSS	mg/L	10	3574	1570.40	629	2126.19	243	7100

Site DC020 Storm 11			Storm Volume 83245cu.ft.			First Sample Last Sample	2/11/98 7:50 2/10/98 20:55	
Variable	Units	#	Vol. Wtd. Mean	Mean	Median	Std Dev	Min.	Max.
COD	mg/L	17	210	243.59	216	129.03	100	592
NH_3-N	mg/L	17	1.72	2.80	1.56	2.17	1.05	6.76
NO_2-N	mg/L	17	0.005	0.01	0.003	0.01	0.003	0.03
NO_{2+3}-N	mg/L	17	1.188	1.44	1.267	0.67	0.703	2.423
NO_3-N	mg/L	17	1.18	1.43	1.26	0.67	0.7	2.42
PO_4-P	mg/L	17	1.10	1.111	0.98	0.56	0.36	2.25
TKN	mg/L	17	13.03	14.83	14.1	7.99	5.23	28.8
Total N	mg/L	17	14.22	16.272	15.543	8.604	5.933	30.980
Total P	mg/L	17	3.74	3.88	3.89	1.87	1.35	7.66
TSS	mg/L	17	1436	1296.88	1350	702.94	400	2990

Site DC020 Storm 12			Storm Volume 2833cu.ft.			First Sample Last Sample	2/25/98 23:55 2/26/98 8:55	
Variable	Units	#	Vol. Wtd. Mean	Mean	Median	Std Dev	Min.	Max.
COD	mg/L	11	371	255.45	230	114.97	138	476
NH_3-N	mg/L	11	2.35	1.98	2.17	0.42	1.3	2.47
NO_2-N	mg/L	11	0.011	0.01	0.012	0.01	0.003	0.02
NO_{2+3}-N	mg/L	11	1.232	0.98	0.915	0.19	0.743	1.44
NO_3-N	mg/L	11	1.22	0.97	0.9	0.19	0.73	1.43
PO_4-P	mg/L	11	0.8	0.90	0.9	0.12	0.7	1.14
TKN	mg/L	11	16.92	11.29	10.6	4.38	6.03	18.5
Total N	mg/L	11	18.15	12.269	11.515	4.540	6.900	19.672
Total P	mg/L	11	5.41	3.06	2.32	1.91	1.09	6.13
TSS	mg/L	11	1578	757.64	486	659.66	108	1920

Site DC020 Storm 13			Storm Volume 3882cu.ft.			First Sample Last Sample	3/16/98 8:20 3/17/98 10:20	
Variable	Units	#	Vol. Wtd. Mean	Mean	Median	Std Dev	Min.	Max.
COD	mg/L	10	337	205.30	194	122.08	62	460
NH_3-N	mg/L	10	1.99	1.65	1.715	0.73	0.7	2.88
NO_2-N	mg/L	10	0.01	0.01	0.01	0.00	0.008	0.013
NO_{2+3}-N	mg/L	10	0.423	0.65	0.552	0.27	0.393	1.229
NO_3-N	mg/L	10	0.41	0.64	0.54	0.27	0.38	1.22
PO_4-P	mg/L	10	1.45	1.07	1.15	0.44	0.37	1.58
TKN	mg/L	10	16.3	10.64	10.555	5.50	3.98	18.8
Total N	mg/L	10	16.72	11.284	11.032	5.310	5.209	19.193
Total P	mg/L	10	4.4	2.74	2.52	1.63	0.7	5.28
TSS	mg/L	10	1631	811.60	671.5	741.41	59	2240

Table A-3 Basic Statistics for Samples Collected during Storm Events at Coke Dairy Site KO010

Site KO010			Storm Volume			First Sample		4/5/97 3:20	
Storm 1*			56,149cu.ft.			Last Sample		4/5/97 9:55	
Variable	Units	#	Vol. Wtd. Mean	Mean	Median	Std Dev		Min.	Max.
COD	mg/L	19	908	1045.000	1030	443.67		550	2320
NH_3-N	mg/L	19	44.16	43.645	36.9	25.60		4.96	108
NO_2-N	mg/L	19	0.099	0.225	0.21	0.19		0.02	0.61
NO_{2+3}-N	mg/L	19	1.163	5.708	2.06	6.13		0.11	16.85
NO_3-N	mg/L	19	1.06	5.483	1.45	6.03		0.08	16.6
PO_4-P	mg/L	19	19.18	16.232	15.6	4.29		8.4	24.6
TKN	mg/L	19	112.4	128.453	111	80.29		57	383
Total N	mg/L	19	134.161	118.11	80.776	57.14		385.06	113.60
Total P	mg/L	19	33.82	32.474	27.6	10.07		25.1	58.2
TSS	mg/L	19	1276	1118.421	763	1073.20		160	4140

Site KO010			Storm Volume			First Sample		4/25/97 13:55	
Storm 2			282cu.ft.			Last Sample		4/25/97 21:40	
Variable	Units	#	Vol. Wtd. Mean	Mean	Median	Std Dev		Min.	Max.
COD	mg/L	9	472	487.556	512	97.27		340	624
NH_3-N	mg/L	10	23.52	26.540	22.15	9.84		17.4	45.8
NO_2-N	mg/L	10	0.372	0.368	0.38	0.11		0.09	0.46
NO_{2+3}-N	mg/L	10	8.532	12.030	7.375	8.67		2.54	22.46
NO_3-N	mg/L	10	8.16	11.662	7.005	8.70		2.08	22.1
PO_4-P	mg/L	10	17.43	18.560	19.6	3.37		13.1	22.2
TKN	mg/L	10	62.11	68.480	67.3	20.33		42.6	105
Total N	mg/L	10	80.510	70.625	27.453	49.39		126.62	70.64
Total P	mg/L	10	26	28.780	26.75	6.29		21.4	37.7
TSS	mg/L	10	164	211.400	187.5	122.13		70	390

Site KO010			Storm Volume			First Sample		7/7/97 4:40	
Storm 3*			11050cu.ft.			Last Sample		7/8/97 7:45	
Variable	Units	#	Vol. Wtd. Mean	Mean	Median	Std Dev		Min.	Max.
COD	mg/L	16	1236	1291.875	1410	256.68		670	1500
NH_3-N	mg/L	16	196.3	222.556	255	76.25		37.7	293
NO_2-N	mg/L	16	0.14	0.080	0.06	0.13		0.012	0.54
NO_{2+3}-N	mg/L	16	0.854	0.500	0.27	0.77		0.058	3.14
NO_3-N	mg/L	16	0.71	0.420	0.21	0.66		0.008	2.6
PO_4-P	mg/L	16	14.43	14.066	14.65	4.86		4.52	22.7
TKN	mg/L	16	384.8	436.131	511	153.97		69.1	583
Total N	mg/L	16	49.444	55.4	14.440	18.9		64.8	44.59
Total P	mg/L	16	44.59	49.444	55.4	14.44		18.9	64.8
TSS	mg/L	16	318	325.688	315	102.85		154	534

* As explained in the text, some of the samples analyzed for this storm had exceeded holding times but are considered to be representative of the water quality for the site.

Site KO010			Storm Volume			First Sample		8/7/97 4:40
Storm 4			21296cu.ft.			Last Sample		8/8/97 7:45
Variable	Units	#	Vol. Wtd. Mean	Mean	Median	Std Dev	Min.	Max.
COD	mg/L	22	371	629.773	687.5	208.58	94	880
NH_3-N	mg/L	22	38.42	66.835	60.85	35.59	7.36	136
NO_2-N	mg/L	22	0.073	0.080	0.04	0.11	0.003	0.4
NO_{2+3}-N	mg/L	22	6.423	11.439	7.243	12.38	2.506	55.15
NO_3-N	mg/L	22	6.35	11.359	7.21	12.30	2.49	54.9
PO_4-P	mg/L	22	21.54	30.036	30.4	11.65	9.49	56.9
TKN	mg/L	22	80.9	150.091	163	75.14	15.5	257
Total N	mg/L	22	161.530	168.808	70.455	18.62	264.35	87.32
Total P	mg/L	22	29.7	47.145	48.55	14.30	11.1	71.8
TSS	mg/L	22	59	112.091	113.5	53.86	5	192

Site KO010			Storm Volume			First Sample		12/20/97 20:10
Storm 5			29357cu.ft.			Last Sample		12/21/97 11:20
Variable	Units	#	Vol. Wtd. Mean	Mean	Median	Std Dev	Min.	Max.
COD	mg/L	14	777	748.929	698.5	409.74	164	1360
NH_3-N	mg/L	14	54.23	50.866	51.65	34.78	2.58	95.8
NO_2-N	mg/L	14	0.048	0.049	0.025	0.05	0.01	0.14
NO_{2+3}-N	mg/L	14	0.757	0.751	0.172	0.96	0.09	2.51
NO_3-N	mg/L	14	0.71	0.702	0.155	0.92	0.08	2.44
PO_4-P	mg/L	14	22.75	21.641	22.75	8.03	9.18	32.1
TKN	mg/L	9	71.38	79.420	80	65.78	4.28	184
Total N	mg/L	9	80.510	80.57	64.827	6.79	184.15	72.36
Total P	mg/L	14	34.88	32.636	34.15	14.74	11.2	52.6
TSS	mg/L	14	176	191.786	169	121.02	72	443

Site KO010			Storm Volume			First Sample		12/23/97 11:50
Storm 6			26770cu.ft.			Last Sample		12/24/97 7:50
Variable	Units	#	Vol. Wtd. Mean	Mean	Median	Std Dev	Min.	Max.
COD	mg/L	16	767	751.750	704	221.13	495	1470
NH_3-N	mg/L	16	54.87	57.450	58.3	16.66	33	83.3
NO_2-N	mg/L	16	0.027	0.025	0.0225	0.02	0.003	0.07
NO_{2+3}-N	mg/L	16	0.405	0.405	0.29	0.30	0.193	1.203
NO_3-N	mg/L	16	0.38	0.380	0.255	0.30	0.19	1.2
PO_4-P	mg/L	16	24.76	26.450	27.35	5.21	16.6	34.8
TKN	mg/L	15	102.2	120.820	121	31.87	44.9	170
Total N	mg/L	15	121.235	121.316	31.650	46.103	170.25	102.58
Total P	mg/L	16	40.87	40.794	39.7	5.06	31.7	50.4
TSS	mg/L	16	302	266.438	233.5	135.23	143	630

Site KO010 Storm 7	Storm Volume 13008cu.ft.	First Sample 1/6/98 22:20	Last Sample 1/7/98 9:20

Variable	Units	#	Vol. Wtd. Mean	Mean	Median	Std Dev	Min.	Max.
COD	mg/L	12	209	223.083	220	43.88	139	304
NH_3-N	mg/L	12	11.09	11.370	10.8	2.05	7.64	16
NO_2-N	mg/L	12	0.071	0.080	0.05	0.07	0.02	0.21
NO_{2+3}-N	mg/L	12	1.034	0.944	0.96	0.33	0.38	1.44
NO_3-N	mg/L	12	0.96	0.864	0.925	0.37	0.25	1.38
PO_4-P	mg/L	12	20.56	20.650	19.9	3.02	17.2	28.5
TKN	mg/L	12	21.17	22.017	21.9	3.35	16.9	29.9
Total N	mg/L	12	22.961	22.845	3.254	18.18	30.76	22.21
Total P	mg/L	12	23.21	23.700	22.7	3.62	18.8	32.5
TSS	mg/L	12	60	70.000	64.5	39.65	19	150

Site KO010 Storm 8*	Storm Volume 9605cu.ft.	First Sample 1/11/98 16:20	Last Sample 1/12/98 9:20

Variable	Units	#	Vol. Wtd. Mean	Mean	Median	Std Dev	Min.	Max.
COD	mg/L	15	295	311.933	266	84.51	220	484
NH_3-N	mg/L	15	18.79	18.040	15.5	6.60	11.1	31.8
NO_2-N	mg/L	15	0.142	0.154	0.17	0.08	0.02	0.25
NO_{2+3}-N	mg/L	15	1.218	1.254	1.18	0.49	0.67	2.32
NO_3-N	mg/L	15	1.08	1.100	0.99	0.45	0.58	2.07
PO_4-P	mg/L	15	33.5	32.733	29.6	7.60	22.5	47
TKN	mg/L	14	31.95	32.929	30.4	10.02	22.2	59.5
Total N	mg/L	14	34.224	31.43	10.313	23.38	61.82	33.23
Total P	mg/L	12	36.12	35.717	32.85	7.49	29.6	50.9
TSS	mg/L	15	204	238.400	116	198.56	74	748

Site KO010 Storm 9	Storm Volume 84113cu.ft.	First Sample 2/10/98 12:30	Last Sample 2/11/98 12:30

Variable	Units	#	Vol. Wtd. Mean	Mean	Median	Std Dev	Min.	Max.
COD	mg/L	10	532	550.100	615	162.28	294	735
NH_3-N	mg/L	0	. .		.	..	.	
NO_2-N	mg/L	0	. .		.	..	.	
NO_{2+3}-N	mg/L	0	. .		.	..	.	
NO_3-N	mg/L	0	. .		.	..	.	
PO_4-P	mg/L	10	33.5	35.320	38.55	9.86	18.6	48.6
TKN	mg/L	10	74.46	76.480	79.05	21.63	43.4	110
Total N	mg/L	0	. .		.	..	.	
Total P	mg/L	10	41.82	44.410	47.55	13.74	23.3	63.8
TSS	mg/L	10	126	125.200	116	46.12	84	245

* As explained in the text, some of the samples analyzed for this storm had exceeded holding times but are considered to be representative of the water quality for the site.

Site KO010 Storm 10			Storm Volume 137044cu.ft.			First Sample 3/16/97 8:35 Last Sample 3/17/98 10:35		
Variable	Units	#	Vol. Wtd. Mean	Mean	Median	Std Dev	Min.	Max.
COD	mg/L	10	1137	915.600	784	613.26	288	1970
NH_3-N	mg/L	10	54.83	45.520	49.65	28.55	12.2	91.8
NO_2-N	mg/L	10	0.132	0.184	0.11	0.18	0.03	0.48
NO_{2+3}-N	mg/L	10	2.845	4.572	2.365	4.92	0.2	11.88
NO_3-N	mg/L	10	2.71	4.388	2.11	4.80	0.17	11.7
PO_4-P	mg/L	10	23.75	29.379	35.8	16.03	8.59	45.8
TKN	mg/L	10	161.9	129.100	129.5	83.81	30.3	251
Total N	mg/L	10	133.672	131.86	79.349	40	251.25	164.97
Total P	mg/L	10	58.33	57.140	57.7	10.45	42.5	72
TSS	mg/L	10	308	242.000	153.5	170.42	78	500

Table A-4 Basic Statistics for Samples Collected during Storm Events at Coke Dairy Site KO020

Site KO020 Storm 1*			Storm Volume 14560 cu.ft.			First Sample Last Sample	4/4/97 5:35 4/5/97 5:15	
Variable	Units	#	Mean	Median	Vol. Wtd. Mean	Std Dev	Min.	Max.
COD	mg/L	17	189.471	152	322	98.12	100	436
NH_3-N	mg/L	18	3.592	0.355	12.49	6.42	0.28	19.7
NO_2-N	mg/L	18	0.028	0.03	0.03	0.01	0.02	0.04
NO_{2+3}-N	mg/L	18	2.004	2.08	1.297	0.81	0.73	3.8
NO_3-N	mg/L	18	1.976	2.055	1.27	0.81	0.7	3.77
PO_4-P	mg/L	18	9.514	8.02	13.91	3.53	5.45	17.2
TKN	mg/L	18	16.403	9.815	37.06	15.04	6.14	55.7
Total N	mg/L	18	18.407	12.37	14.707	7.14	56.43	38.35
Total P	mg/L	18	11.213	8.925	17.49	4.54	7.35	20
TSS	mg/L	18	92.667	83	67	62.78	41	312

Site KO020 Storm 2*			Storm Volume 8522cu.ft.			First Sample Last Sample	4/25/97 13:50 4/26/97 6:50	
Variable	Units	#	Mean	Median	Vol. Wtd. Mean	Std Dev	Min.	Max.
COD	mg/L	17	196.471	166	238	92.97	82	320
NH_3-N	mg/L	17	5.275	0.71	7.77	6.01	0.21	14.1
NO_2-N	mg/L	17	0.025	0.006	0.029	0.04	0.002	0.13
NO_{2+3}-N	mg/L	17	3.421	2.952	3.967	1.33	1.812	5.989
NO_3-N	mg/L	17	3.396	2.95	3.94	1.32	1.81	5.98
PO_4-P	mg/L	17	10.330	5.93	13.39	5.83	4.1	18.2
TKN	mg/L	17	20.070	10.8	26.27	13.83	5.68	42.8
Total N	mg/L	17	23.491	13.206	14.941	8.412	46.8	30.23
Total P	mg/L	17	13.983	14.4	18.26	7.79	5.03	23.6
TSS	mg/L	17	82.824	65	53	69.97	5	262

Site KO020 Storm 3			Storm Volume 1499cu.ft.			First Sample Last Sample	7/6/97 10:15 7/6/97 14:15	
Variable	Units	#	Mean	Median	Vol. Wtd. Mean	Std Dev	Min.	Max.
COD	mg/L	7	73.429	76	81	32.33	8	113
NH_3-N	mg/L	7	0.801	0.71	0.79	0.23	0.58	1.23
NO_2-N	mg/L	7	0.018	0.014	0.016	0.01	0.006	0.05
NO_{2+3}-N	mg/L	7	2.167	2.08	2.301	0.89	0.803	3.6
NO_3-N	mg/L	7	2.149	2.07	2.29	0.88	0.79	3.55
PO_4-P	mg/L	7	3.044	3.41	3.35	1.22	0.7	4.32
TKN	mg/L	7	6.889	5.27	5.77	3.08	4.83	13.2
Total N	mg/L	7	9.055	7.134	2.915	6.895	14.003	8.08
Total P	mg/L	7	4.730	4.57	5.05	2.21	1.43	8.36
TSS	mg/L	7	369.714	48	106	802.13	16	2180

* As explained in the text, some of the samples analyzed for this storm had exceeded holding times but are considered to be representative of the water quality for the site.

Site KO020 Storm 4			Storm Volume 4564cu.ft.			First Sample Last Sample	8/8/97 4:00 8/8/97 10:00	
Variable	Units	#	Mean	Median	Vol. Wtd. Mean	Std Dev	Min.	Max.
COD	mg/L	10	100.300	54	97	155.43	29	541
NH_3-N	mg/L	10	0.828	0.555	0.84	0.65	0.21	2.4
NO_2-N	mg/L	10	0.003	0.003	0.003	0.00	0.003	0.003
NO_{2+3}-N	mg/L	10	0.777	0.673	0.808	0.50	0.203	1.683
NO_3-N	mg/L	10	0.774	0.67	0.8	0.50	0.2	1.68
PO_4-P	mg/L	10	4.086	4.125	4.36	2.21	1.09	8.72
TKN	mg/L	10	3.619	2.94	3.73	2.54	0.86	9.82
Total N	mg/L	10	4.396	3.593	3.008	1.063	11.503	4.54
Total P	mg/L	10	4.577	4.585	4.87	2.24	1.33	9.59
TSS	mg/L	10	34.100	27	27	26.62	13	102

Site KO020 Storm 5			Storm Volume 5227 cu.ft.			First Sample Last Sample	12/20/97 22:25 12/21/97 6:25	
Variable	Units	#	Mean	Median	Vol. Wtd. Mean	Std Dev	Min.	Max.
COD	mg/L	12	157.417	99.5	192	111.85	41	308
NH_3-N	mg/L	12	7.861	0.955	10.87	9.39	0.34	24.3
NO_2-N	mg/L	12	0.003	0.003	0.004	0.00	0.003	0.007
NO_{2+3}-N	mg/L	12	0.579	0.623	0.637	0.14	0.243	0.747
NO_3-N	mg/L	12	0.576	0.62	0.63	0.14	0.24	0.74
PO_4-P	mg/L	12	6.277	5.17	7.66	3.98	1.21	11.3
TKN	mg/L	12	22.453	6.775	29.74	22.17	2.44	49.7
Total N	mg/L	12	23.033	7.428	22.239	2.783	50.323	30.38
Total P	mg/L	12	7.315	6.09	9.47	4.58	1.52	13.3
TSS	mg/L	12	57.500	53.5	59	11.93	39	74

Site KO020 Storm 6			Storm Volume 848 cu.ft.			First Sample Last Sample	12/23/97 18:30 12/24/97 4:30	
Variable	Units	#	Mean	Median	Vol. Wtd. Mean	Std Dev	Min.	Max.
COD	mg/L	13	211.077	236	241	115.22	61	376
NH_3-N	mg/L	13	14.187	17	17.7	10.58	1.5	26.1
NO_2-N	mg/L	13	0.004	0.003	0.004	0.00	0.003	0.02
NO_{2+3}-N	mg/L	13	0.450	0.453	0.44	0.05	0.383	0.56
NO_3-N	mg/L	13	0.445	0.45	0.44	0.05	0.38	0.54
PO_4-P	mg/L	13	8.219	8.86	9.68	4.17	3.03	13.3
TKN	mg/L	13	28.663	31.9	34.37	18.85	4.9	51.7
Total N	mg/L	13	29.113	32.293	18.813	5.393	52.093	34.82
Total P	mg/L	13	10.443	10.9	12.17	5.85	3.23	17.7
TSS	mg/L	13	78.077	81	83	12.04	49	91

Site KO020	Storm Volume	First Sample	1/7/98 2:55
Storm 7	1143cu.ft.	Last Sample	1/7/98 8:55

Variable	Units	#	Mean	Median	Vol. Wtd. Mean	Std Dev	Min.	Max.
COD	mg/L	10	222.300	226	249	42.91	133	272
NH_3-N	mg/L	10	14.319	14.55	17.34	4.66	4.19	20
NO_2-N	mg/L	10	0.014	0.0125	0.012	0.01	0.003	0.03
NO_{2+3}-N	mg/L	10	0.386	0.394	0.356	0.06	0.303	0.51
NO_3-N	mg/L	10	0.372	0.38	0.34	0.05	0.3	0.48
PO_4-P	mg/L	10	14.517	14.2	17.31	3.58	7.87	19.8
TKN	mg/L	10	25.420	25.65	30.71	7.08	12.1	35.4
Total N	mg/L	10	25.806	26.0445	7.026	12.61	35.743	31.07
Total P	mg/L	10	17.809	17.55	21.65	4.90	8.99	25.3
TSS	mg/L	10	36.200	35.5	40	5.65	27	46

Site KO020	Storm Volume	First Sample	1/12/98 2:05
Storm 8*	365cu.ft.	Last Sample	1/12/98 9:05

Variable	Units	#	Mean	Median	Vol. Wtd. Mean	Std Dev	Min.	Max.
COD	mg/L	11	234.364	240	241	18.06	194	256
NH_3-N	mg/L	11	18.645	19.1	19.47	2.42	12.8	21.2
NO_2-N	mg/L	11	0.006	0.005	0.005	0.00	0.003	0.012
NO_{2+3}-N	mg/L	11	0.652	0.603	0.579	0.18	0.443	1.077
NO_3-N	mg/L	11	0.646	0.6	0.57	0.18	0.44	1.07
PO_4-P	mg/L	11	22.518	23.1	23.42	2.31	18.1	25.2
TKN	mg/L	11	33.309	30.5	36.26	10.44	21.8	62.7
Total N	mg/L	11	33.961	31.143	10.340	22.877	63.213	36.84
Total P	mg/L	11	28.109	26.8	29.62	6.63	23.7	47.6
TSS	mg/L	11	32.545	30	31	10.17	15	55

Site KO020	Storm Volume	First Sample	2/10/98 12:40
Storm 9	10399cu.ft.	Last Sample	2/11/98 5:40

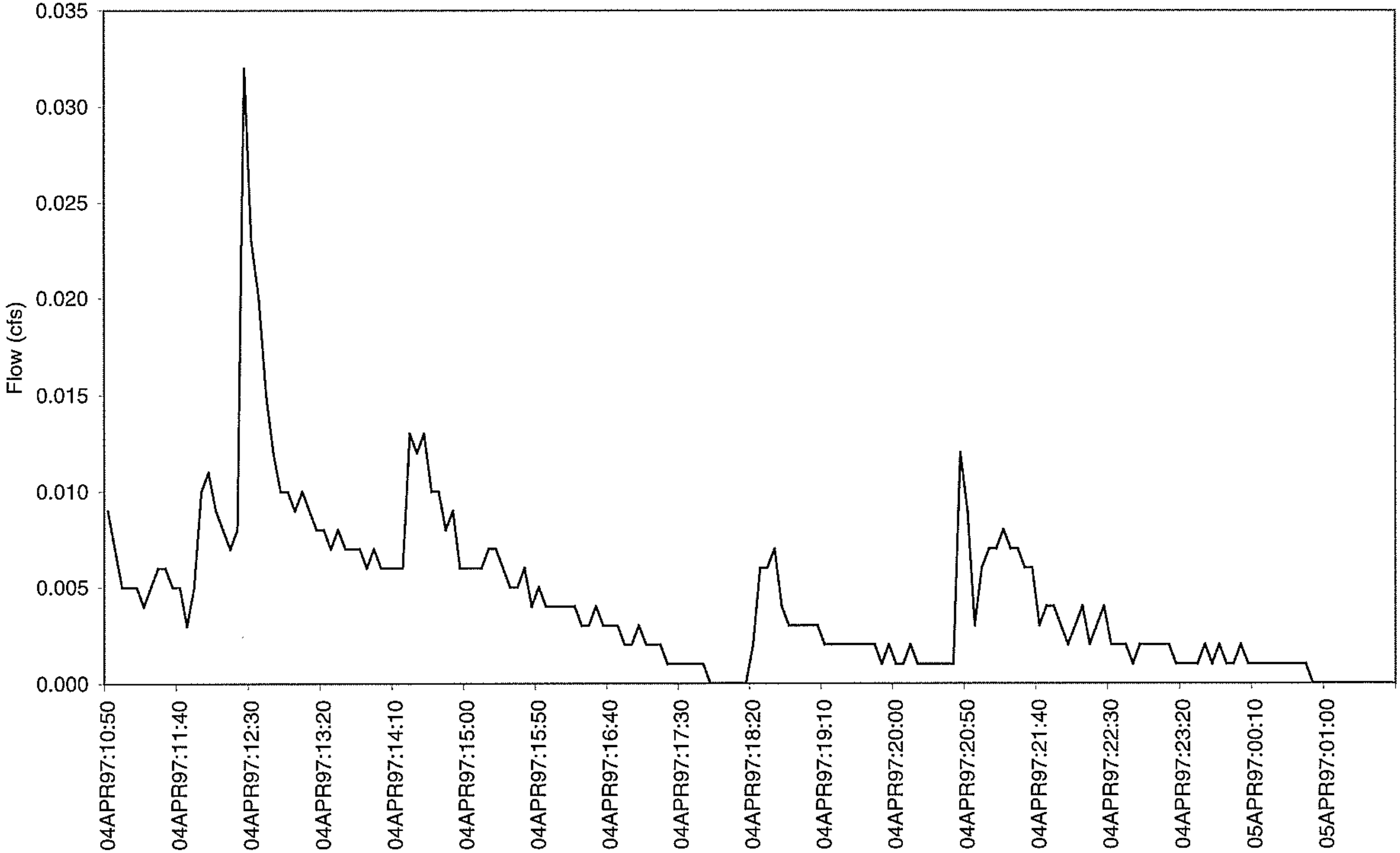
Variable	Units	#	Mean	Median	Vol. Wtd. Mean	Std Dev	Min.	Max.
COD	mg/L	17	175.471	182	235	103.50	50	308
NH_3-N	mg/L	0	.	. .	.	.	.	
NO_2-N	mg/L	0	.	. .	.	.	.	
NO_{2+3}-N	mg/L	0	.	. .	.	.	.	
NO_3-N	mg/L	0	.	. .	.	.	.	
PO_4-P	mg/L	16	11.497	9.645	15.99	8.64	2.65	21.9
TKN	mg/L	17	18.392	15.5	25.54	14.28	2.54	35.2
Total N	mg/L	0	.	. .	.	.	.	
Total P	mg/L	17	14.656	19	19.98	10.50	2.97	26.6
TSS	mg/L	17	42.412	33	56	24.80	12	98

* As explained in the text, some of the samples analyzed for this storm had exceeded holding times but are considered to be representative of the water quality for the site.

Site KO020			Storm Volume			First Sample	3/16/98 17:30	
Storm 10			148cu.ft.			Last Sample	3/16/98 23:30	
Variable	Units	#	Mean	Median	Vol. Wtd. Mean	Std Dev	Min.	Max.
COD	mg/L	10	143.100	146.5	152	26.27	103	176
NH_3-N	mg/L	10	2.910	2.945	3.49	1.78	0.62	5.94
NO_2-N	mg/L	10	0.010	0.01	0.011	0.00	0.006	0.015
NO_{2+3}-N	mg/L	10	0.482	0.5005	0.533	0.15	0.266	0.673
NO_3-N	mg/L	10	0.472	0.49	0.52	0.15	0.26	0.66
PO_4-P	mg/L	10	10.199	10.865	11.5	3.78	5.08	15.1
TKN	mg/L	10	10.543	10.49	11.97	4.55	4.93	18.4
Total N	mg/L	10	11.025	11.015	4.686	5.216	18.951	12.50
Total P	mg/L	10	12.026	12.9	13.73	4.77	5.86	19.2
TSS	mg/L	10	47.800	40.5	47	15.07	36	84

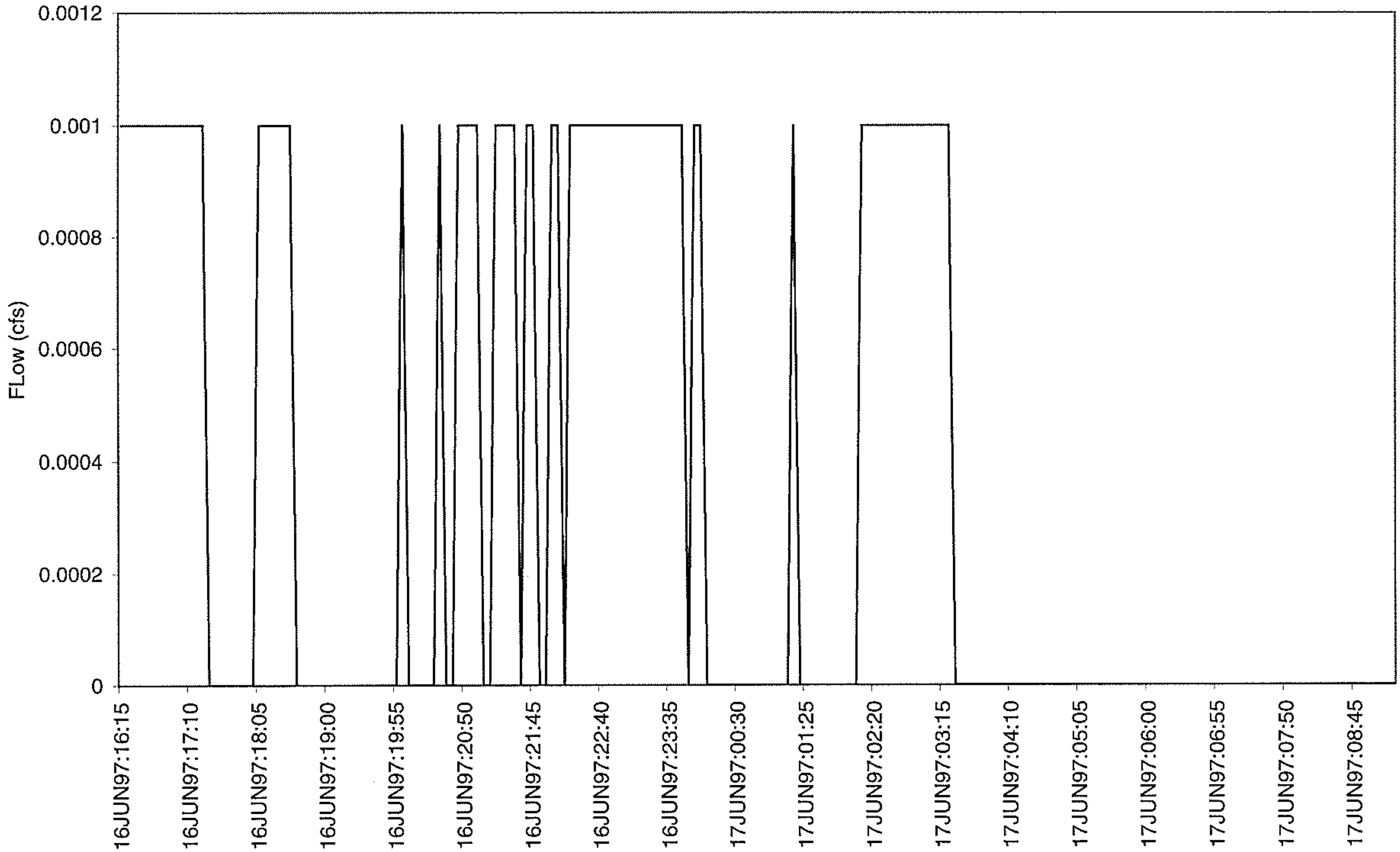
APPENDIX B: Hydrographs of Storm Events at Demonstration Sites

Storm 1 - Site DC010*



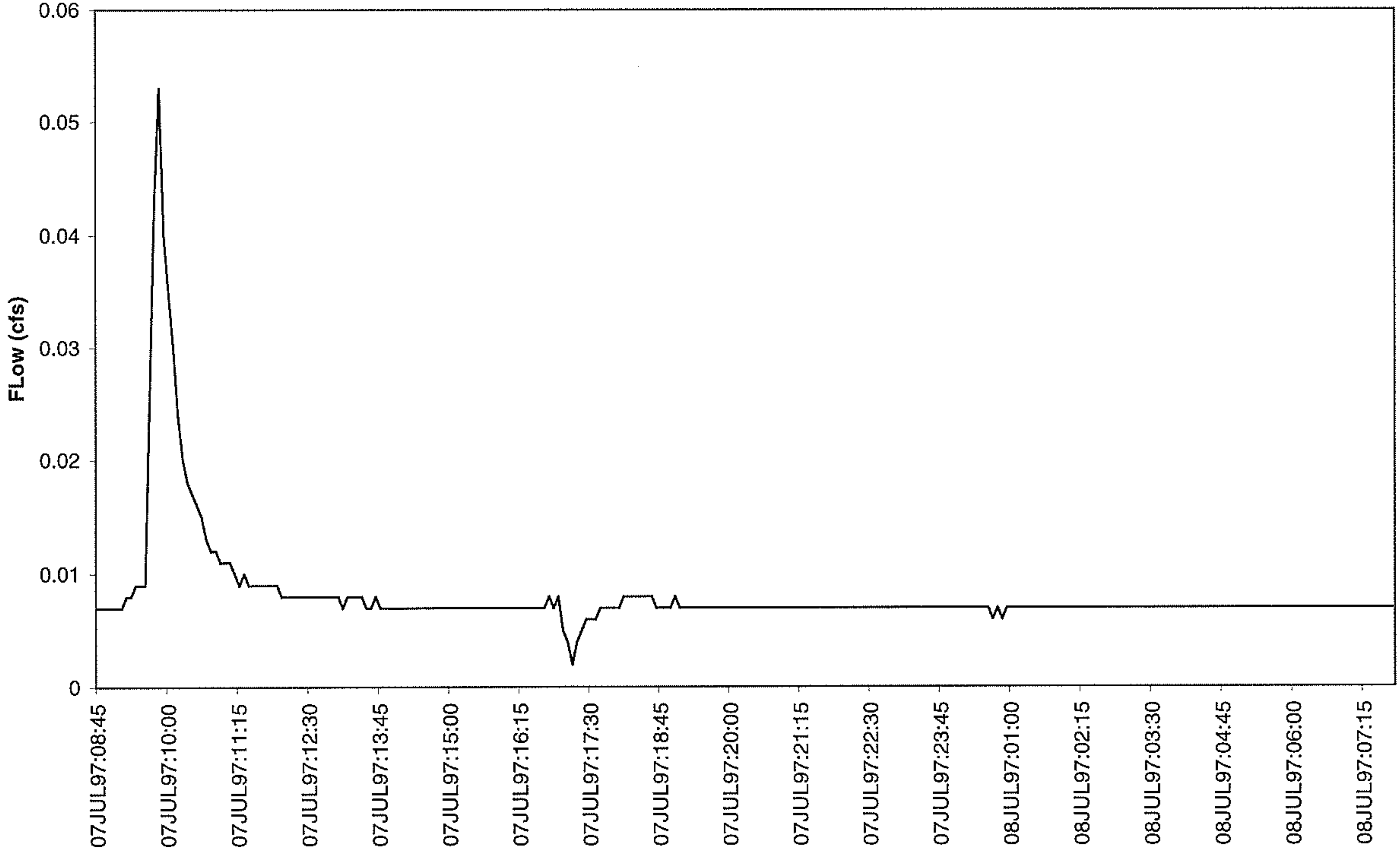
* Noise in flow values suspected to be caused by clogging due to sedimentation.

Storm 2 - Site DC010*



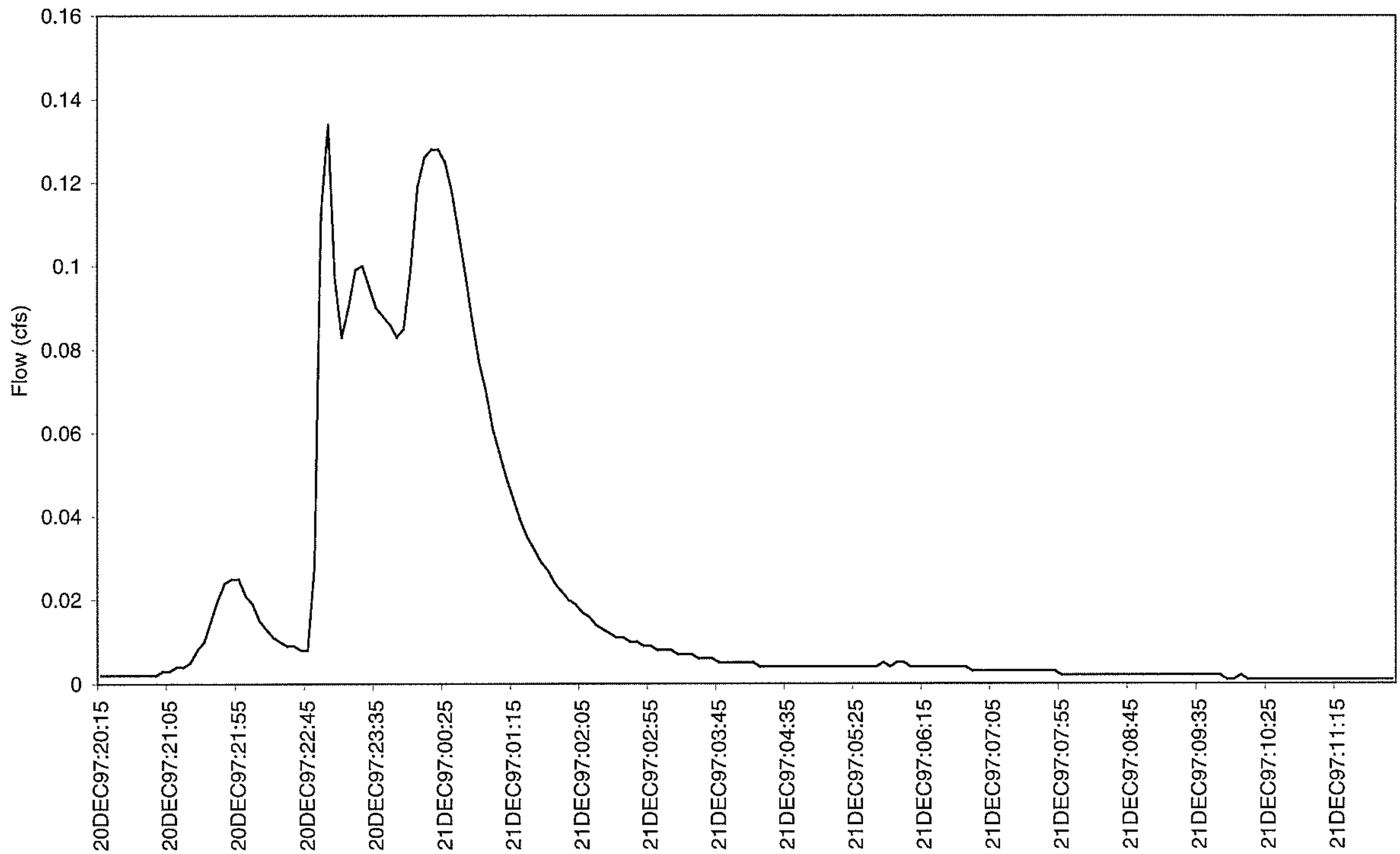
* Noise in flow values suspected to be caused by clogging due to sedimentation.

Storm 3 - Site DC010*



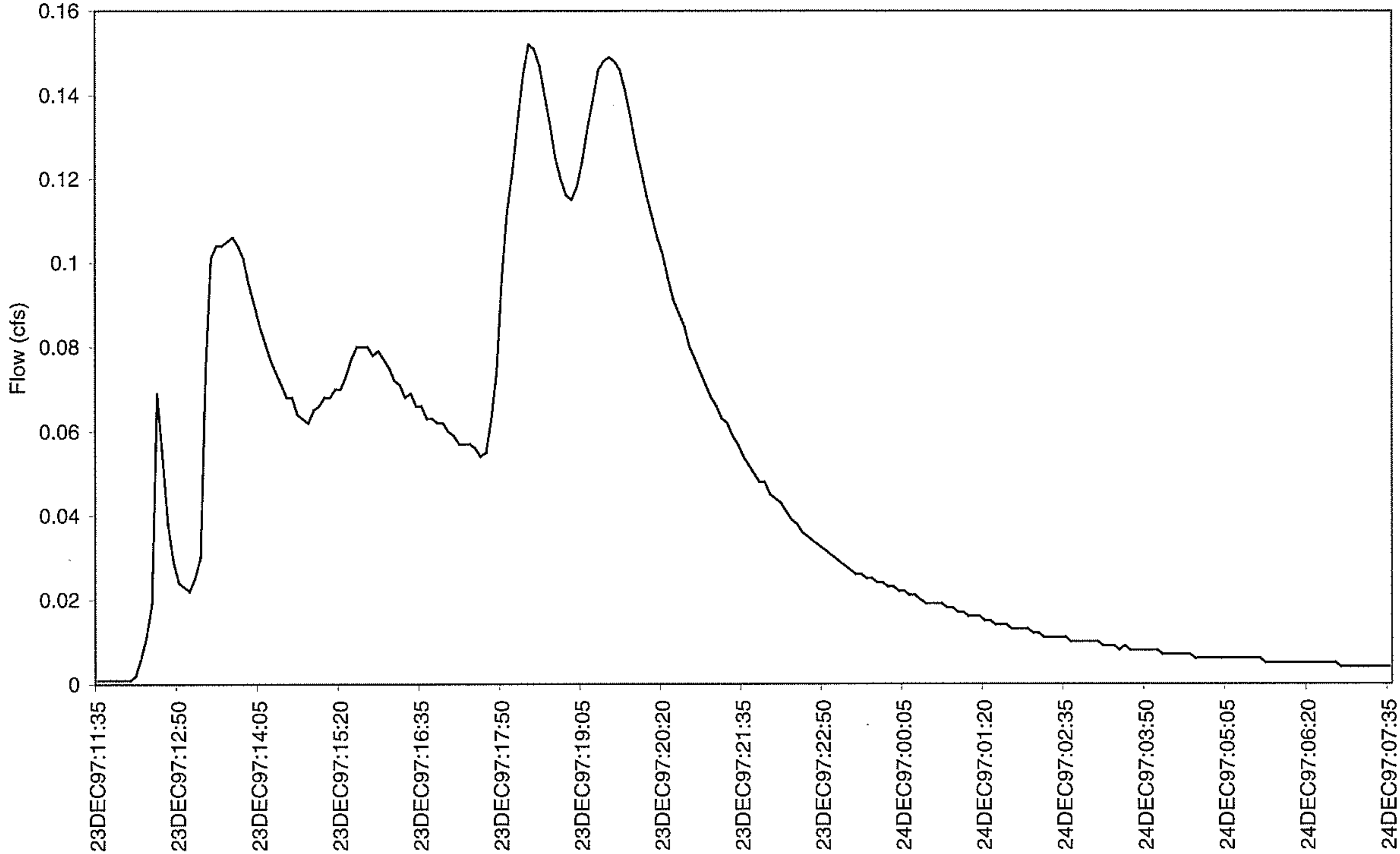
* Noise in flow values suspected to be caused by clogging due to sedimentation.

Storm 4 - Site DC010*



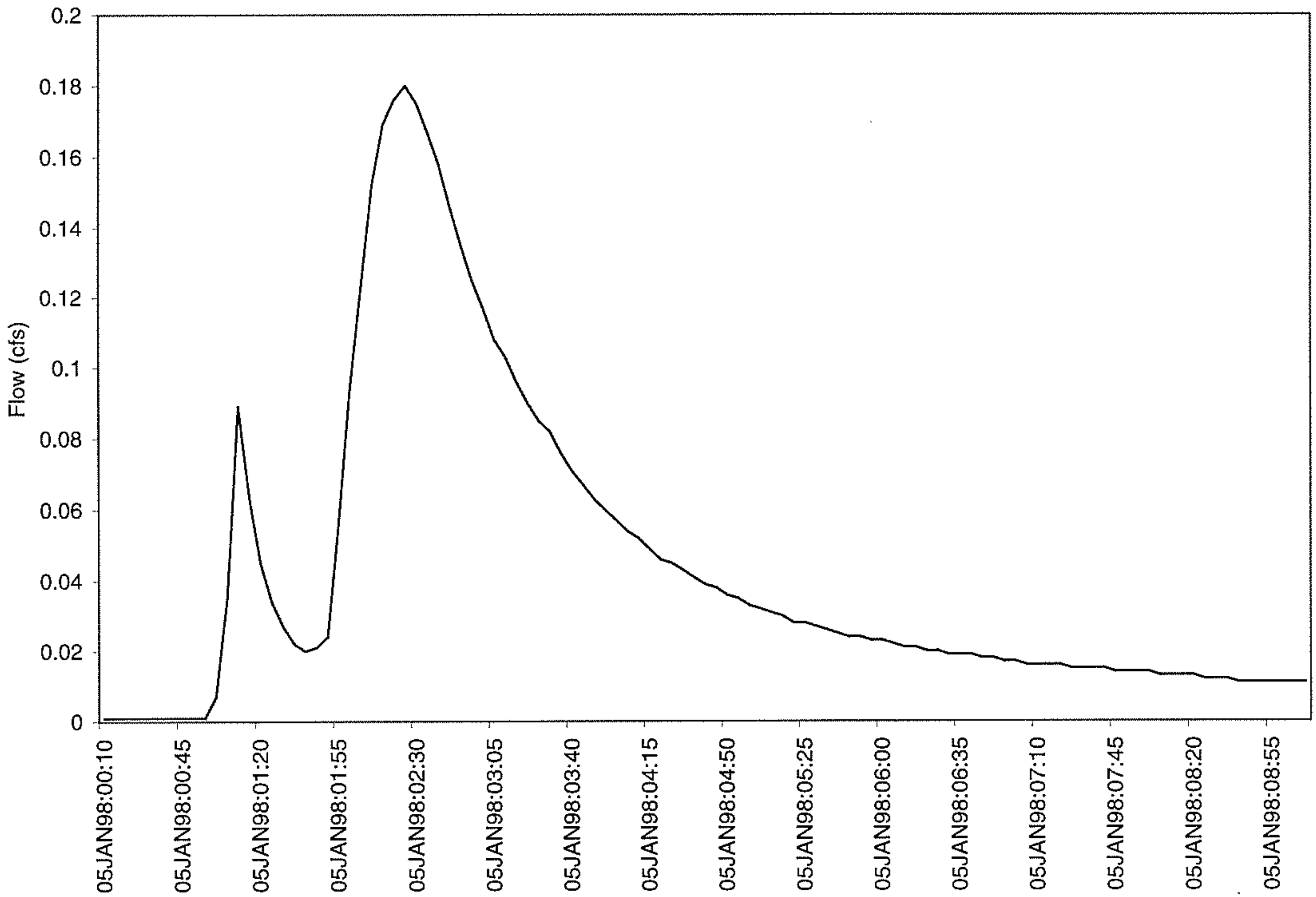
* Noise in flow values suspected to be caused by clogging due to sedimentation.

Storm 5 - Site DC010*



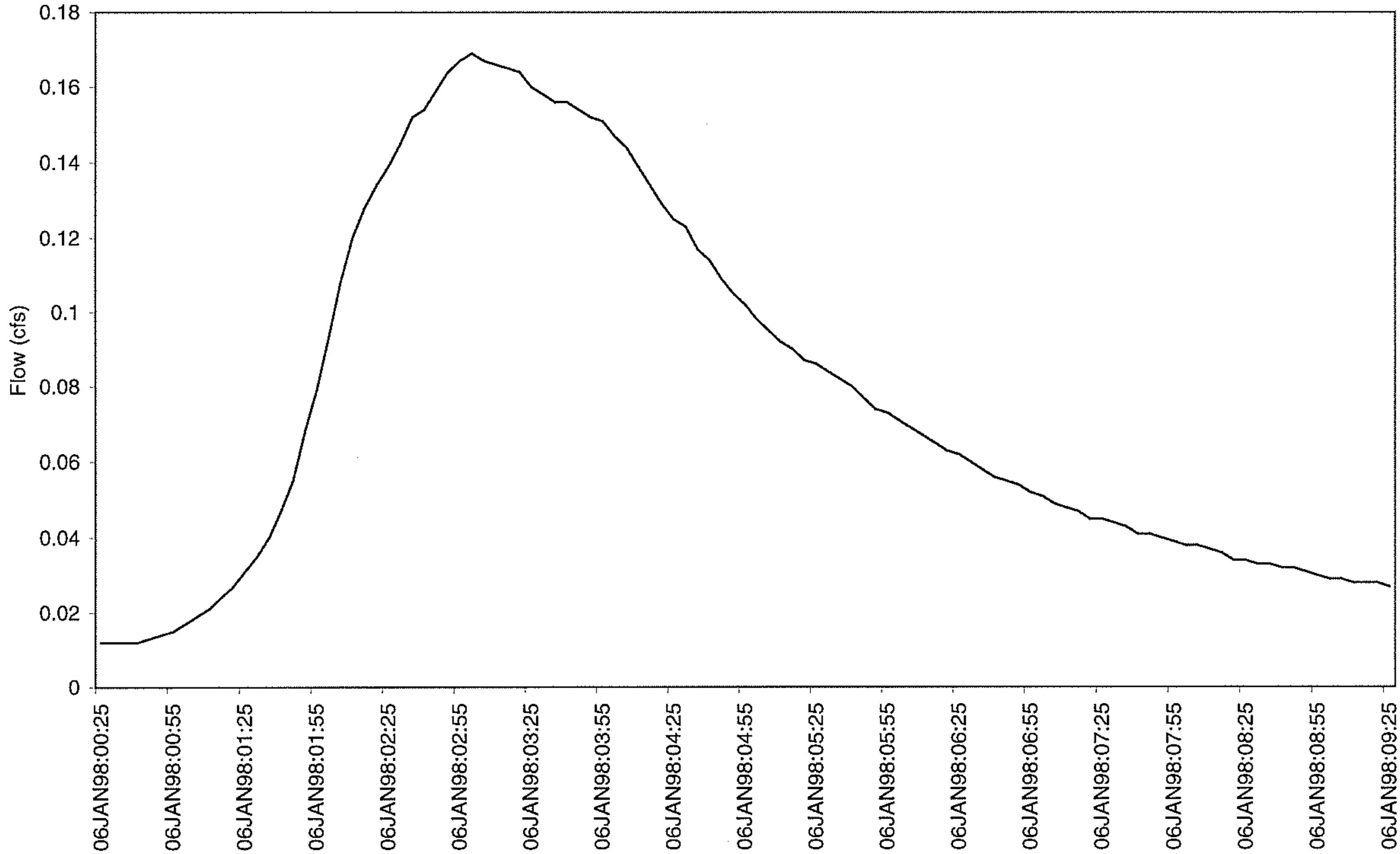
* Noise in flow values suspected to be caused by clogging due to sedimentation.

Storm 6 - Site DC010*



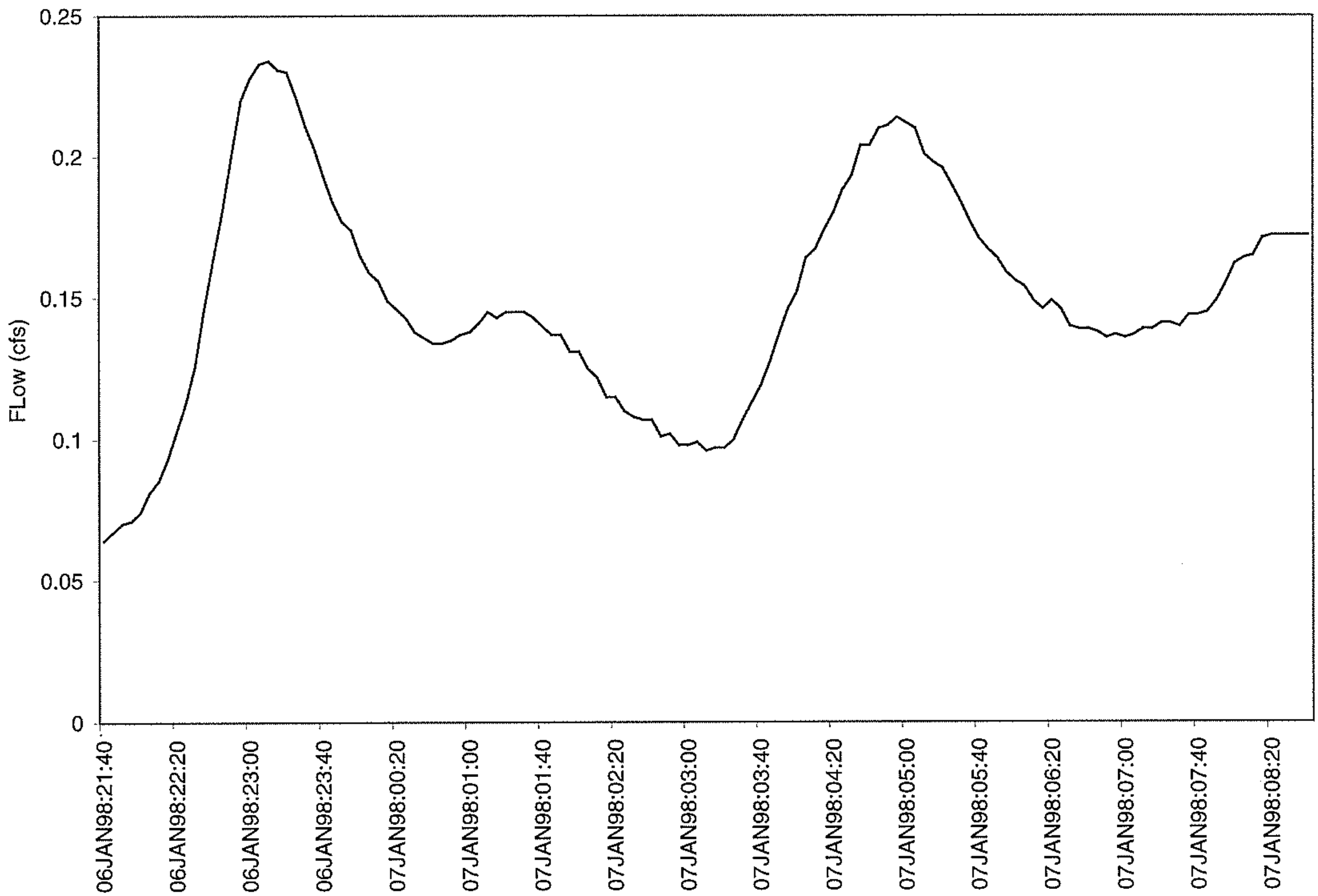
* Noise in flow values suspected to be caused by clogging due to sedimentation.

Storm 7 - Site DC010*



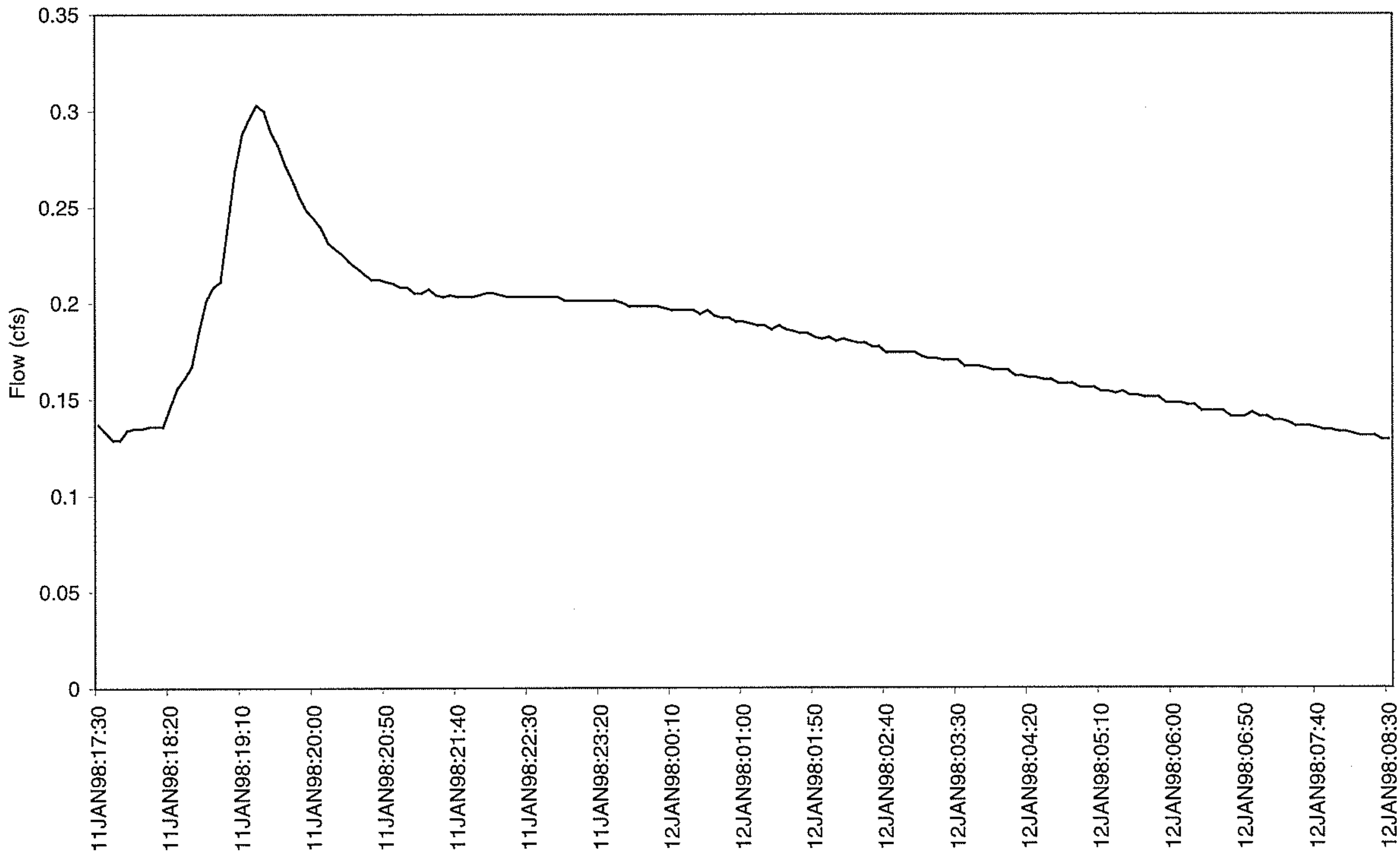
* Noise in flow values suspected to be caused by clogging due to sedimentation.

Storm 8 - Site DC010*



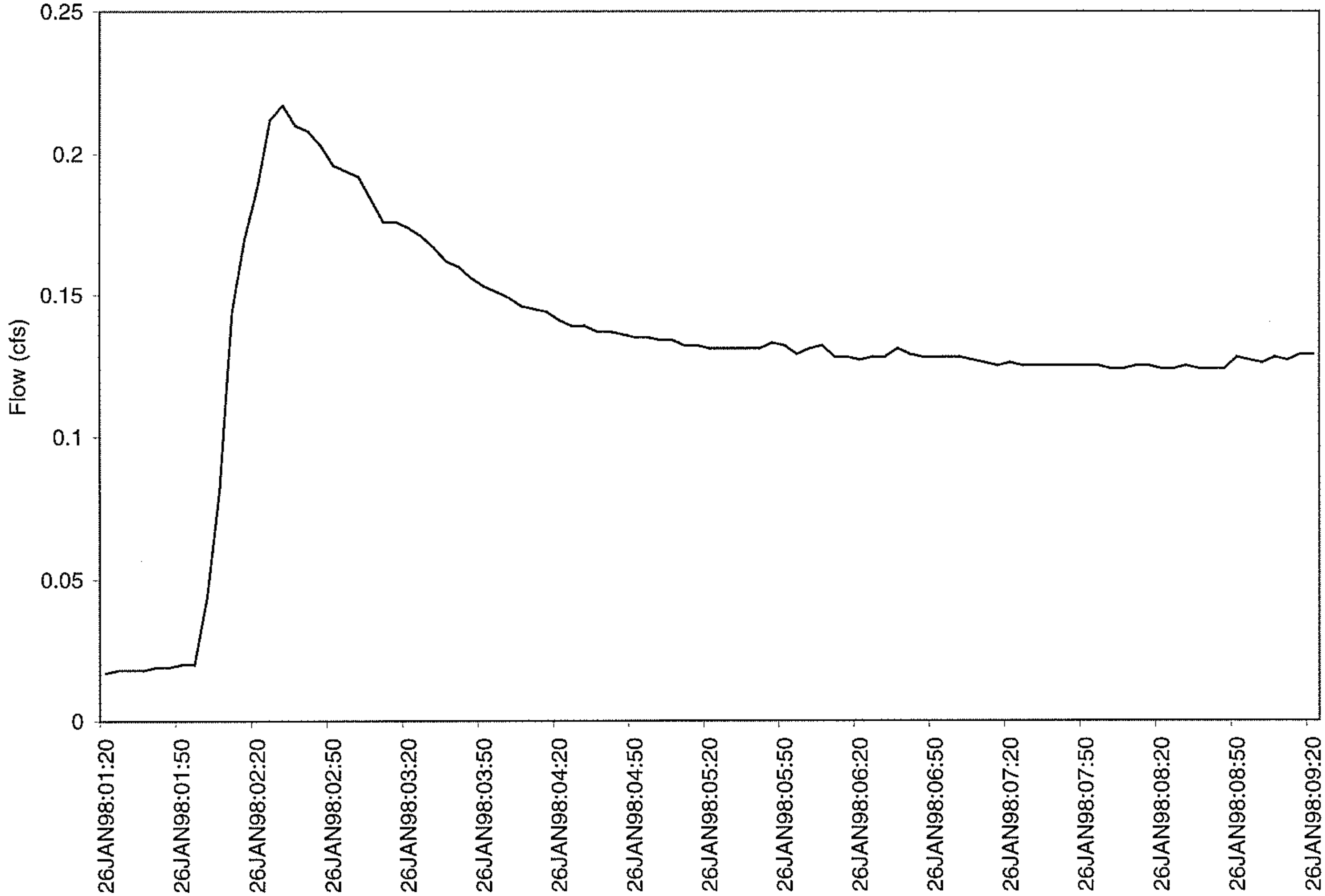
* Noise in flow values suspected to be caused by clogging due to sedimentation.

Storm 9 - Site DC010*



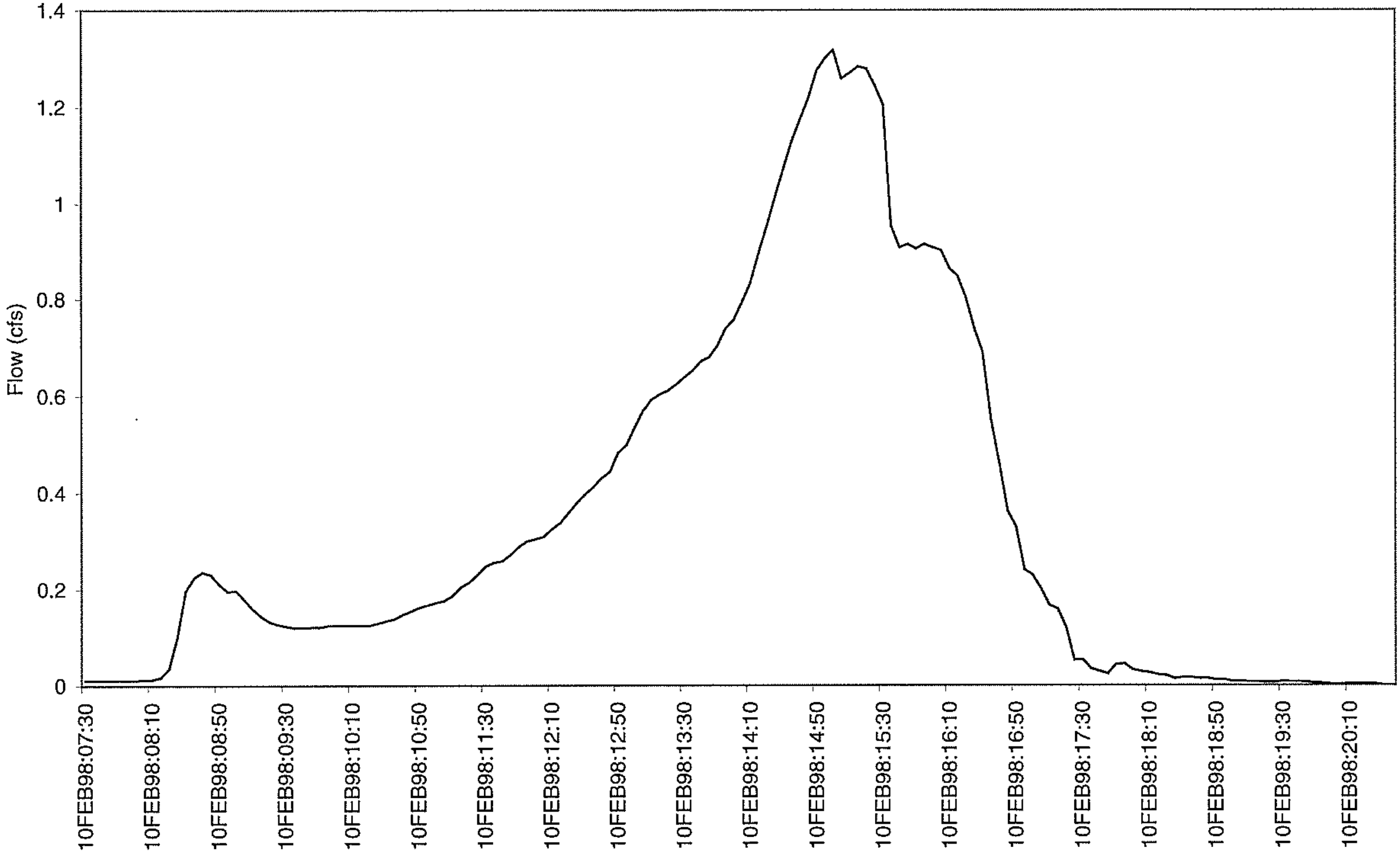
* Noise in flow values suspected to be caused by clogging due to sedimentation.

Storm 10 - Site DC010*



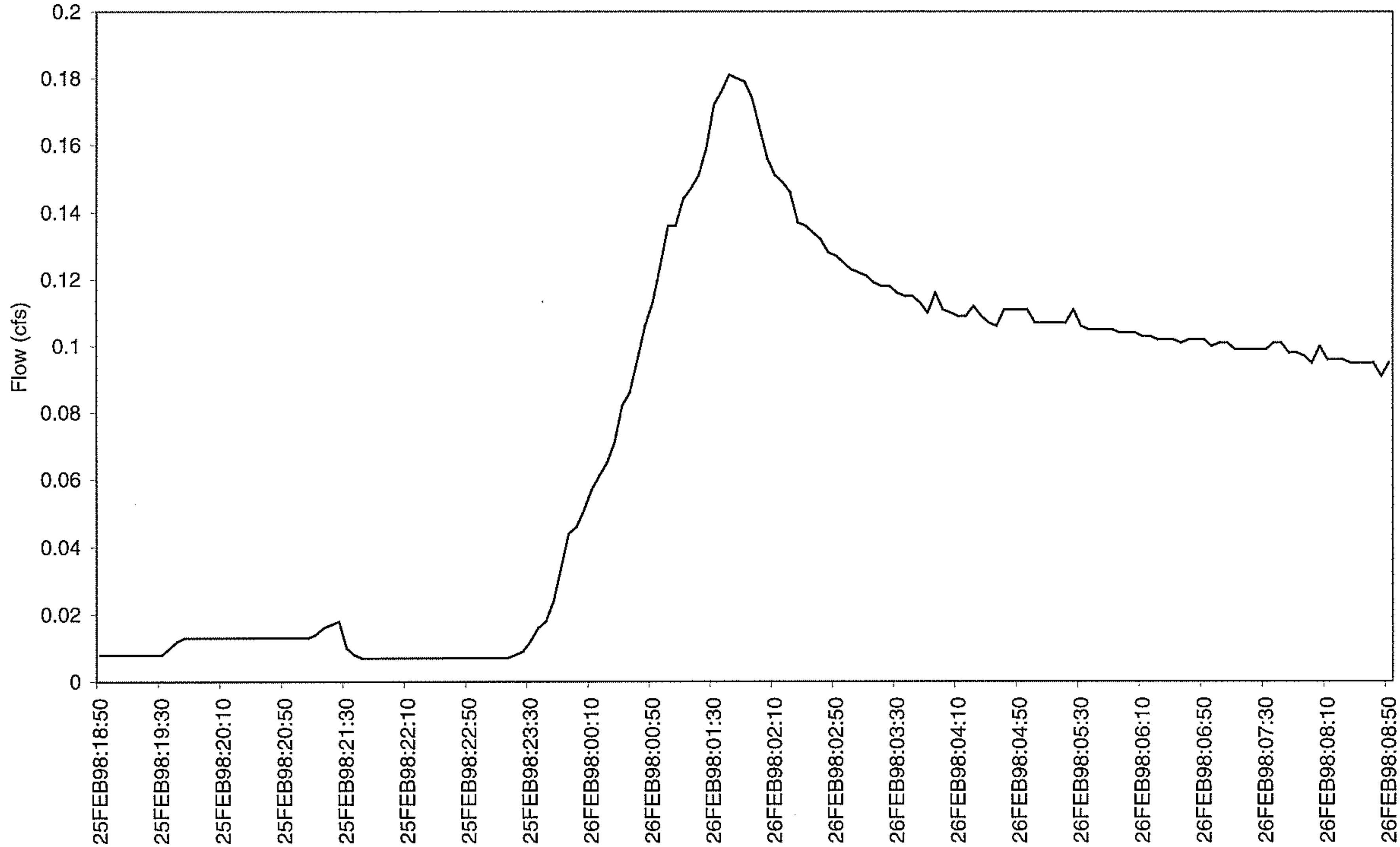
* Noise in flow values suspected to be caused by clogging due to sedimentation.

Storm 11 - Site DC010*



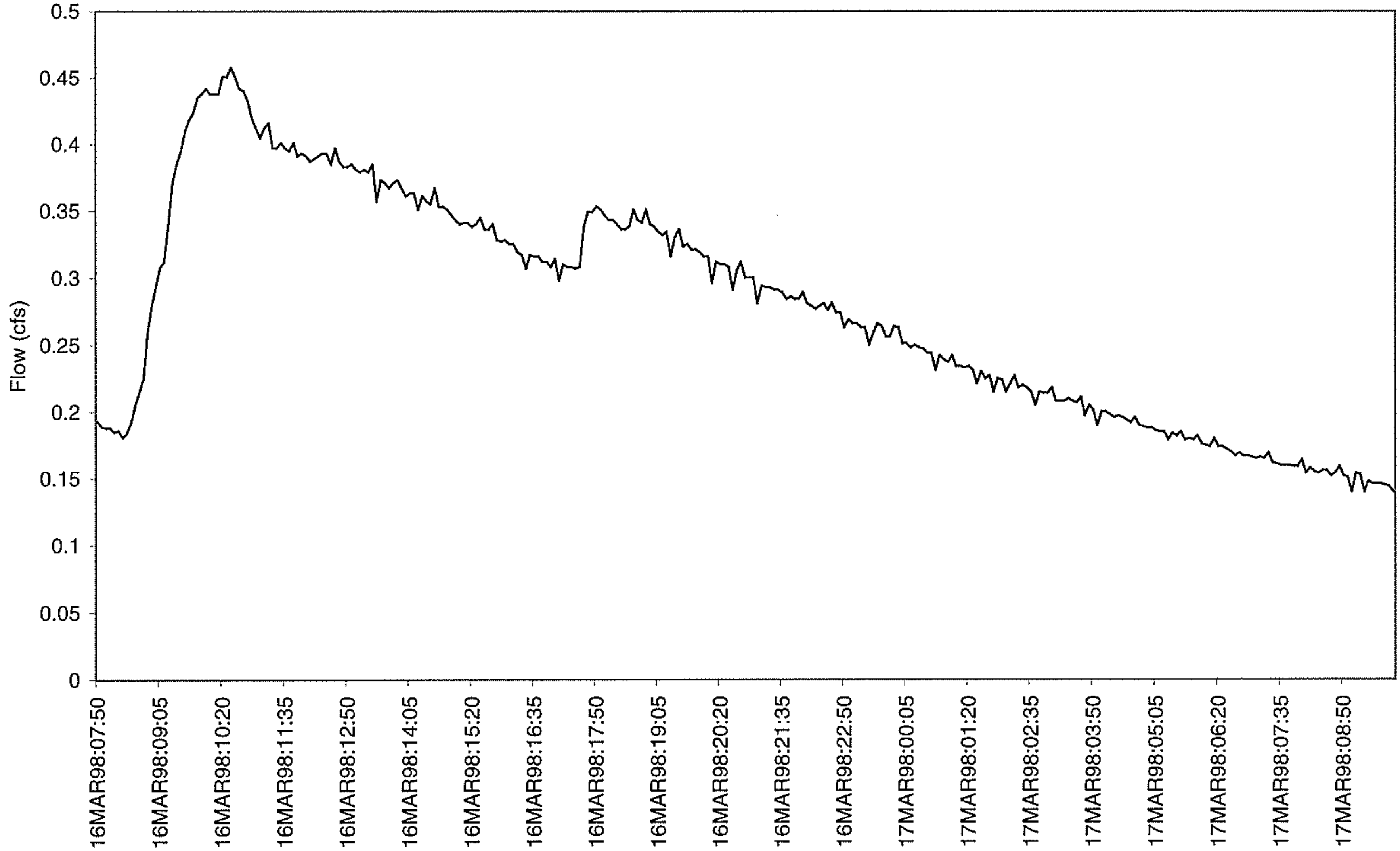
* Noise in flow values suspected to be caused by clogging due to sedimentation.

Storm 12 - Site DC010*



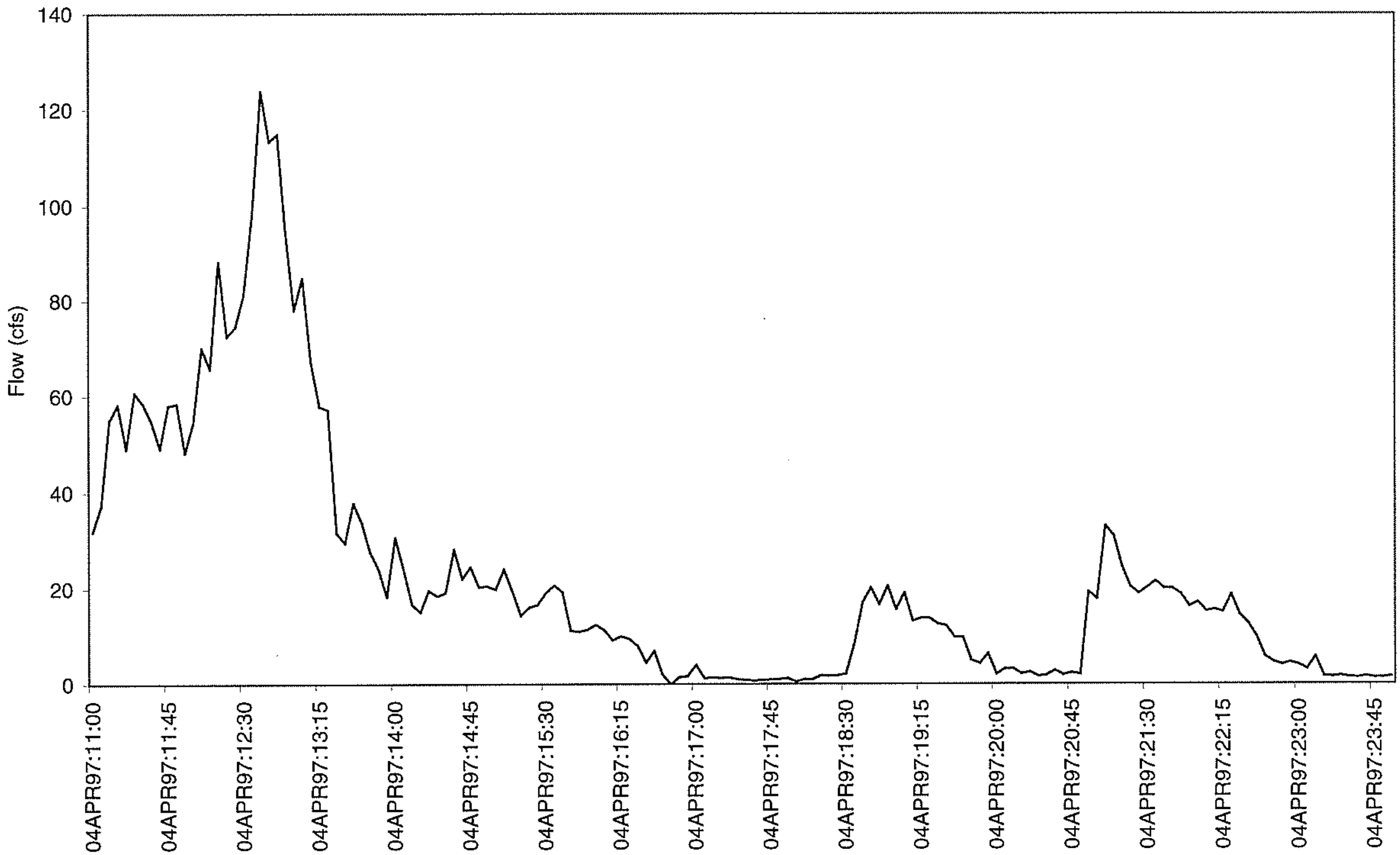
* Noise in flow values suspected to be caused by clogging due to sedimentation.

Storm 13 - Site DC010*



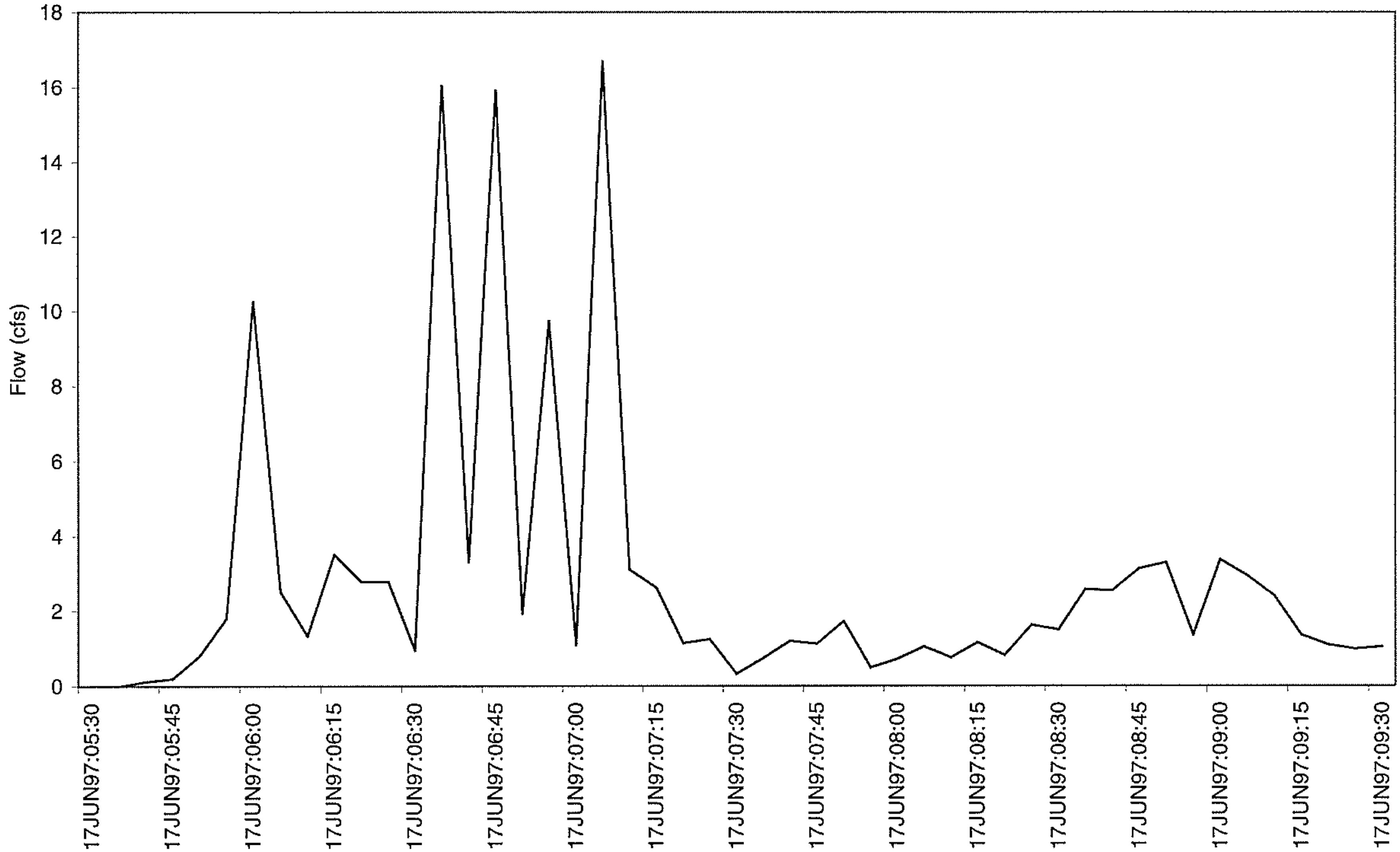
* Noise in flow values suspected to be caused by clogging due to sedimentation.

Storm 1 - Site DC020*



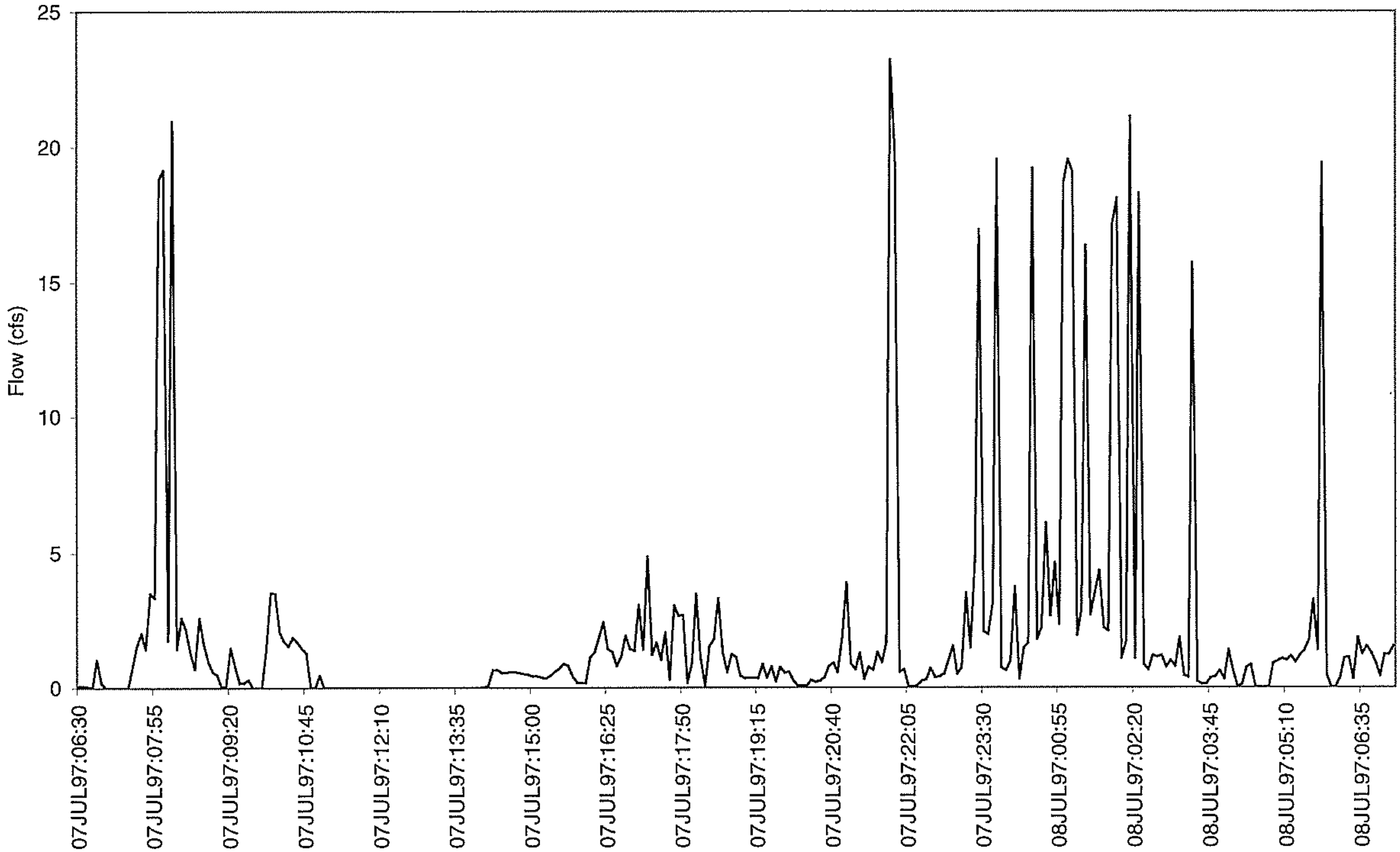
*Noise in flow values suspected to be caused by clogging due to sedimentation

Storm 2 - Site DC020*



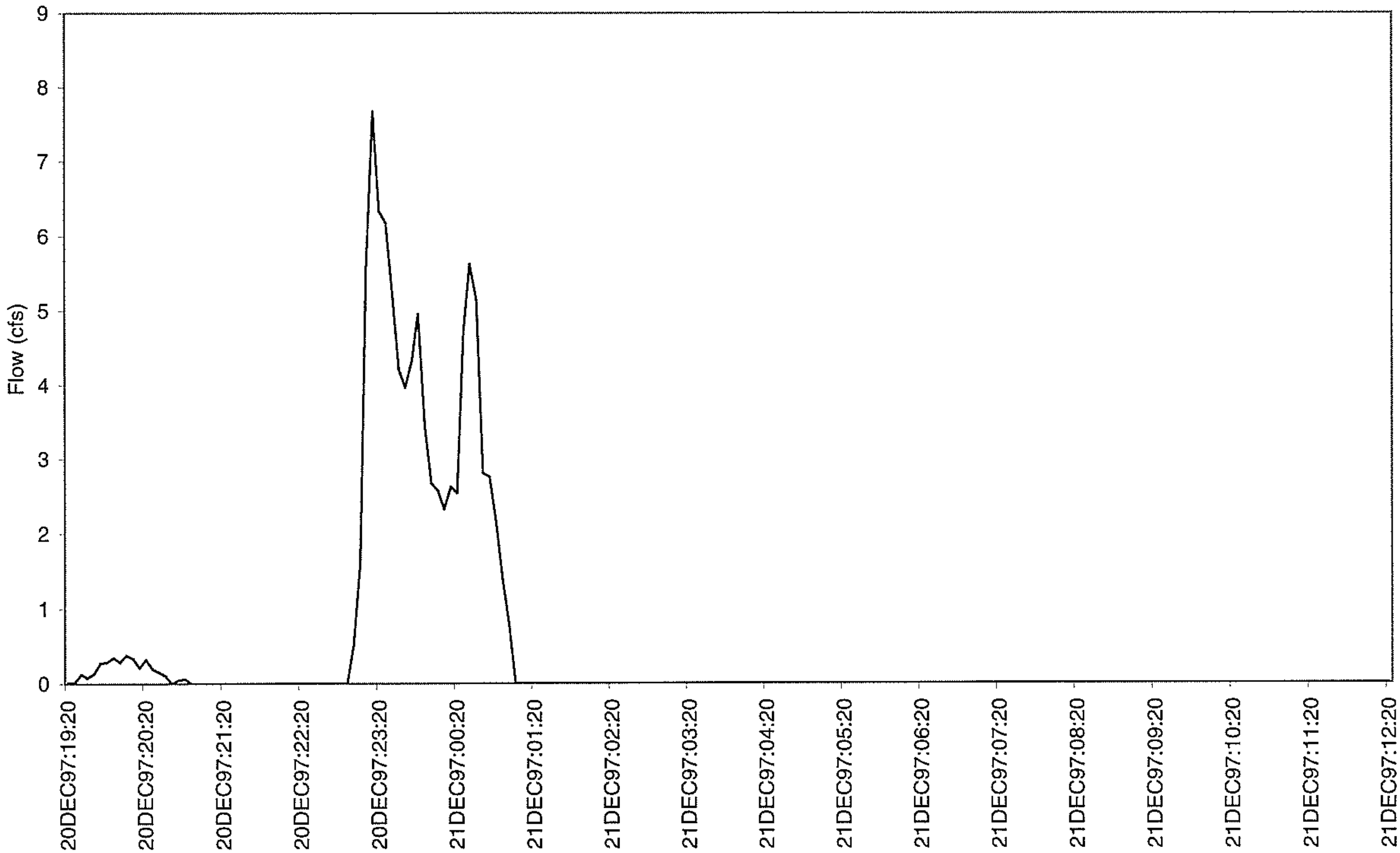
*Noise in flow values suspected to be caused by clogging due to sedimentation

Storm 3 - Site DC020*



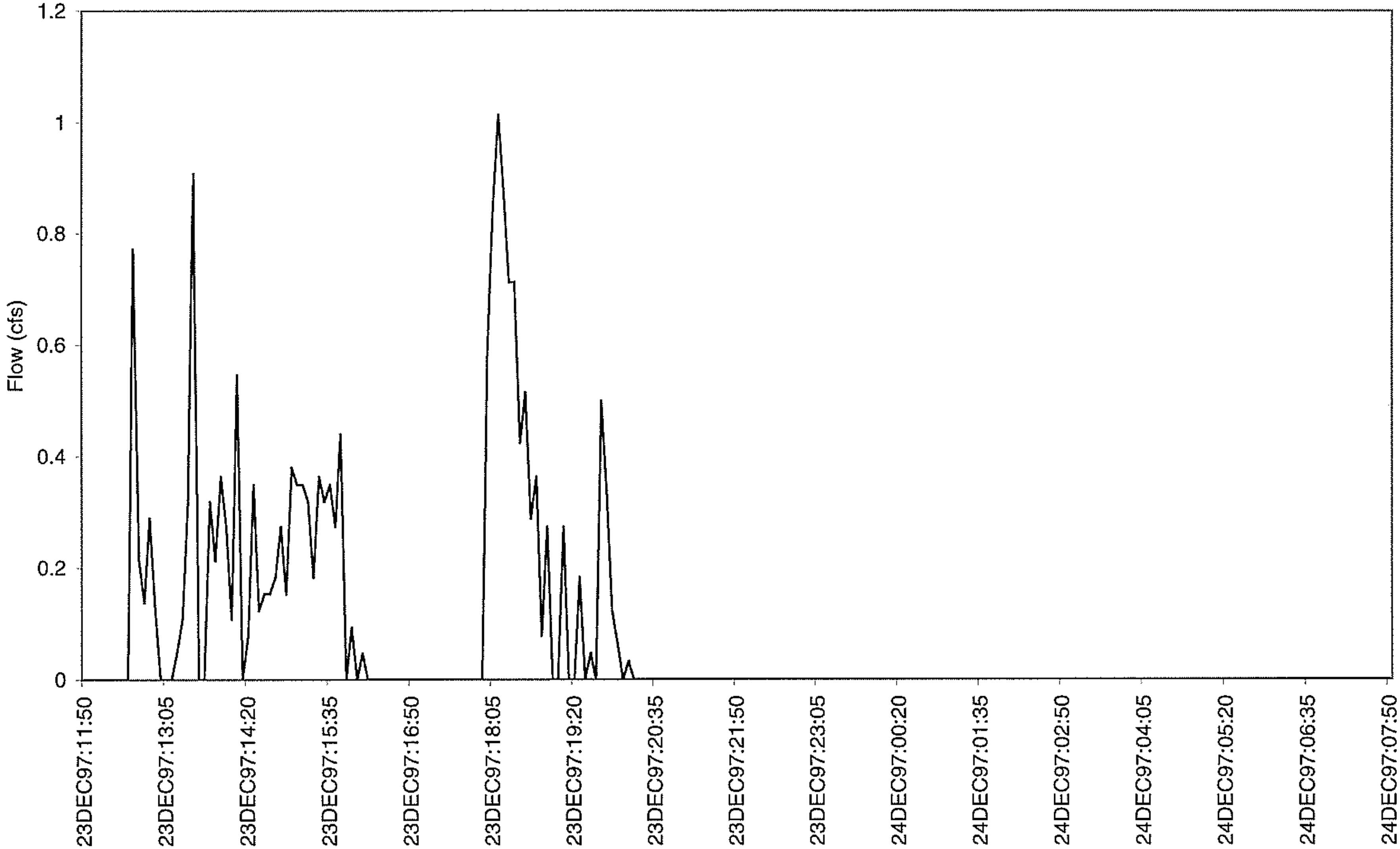
*Noise in flow values suspected to be caused by clogging due to sedimentation

Storm 4 - Site DC020*



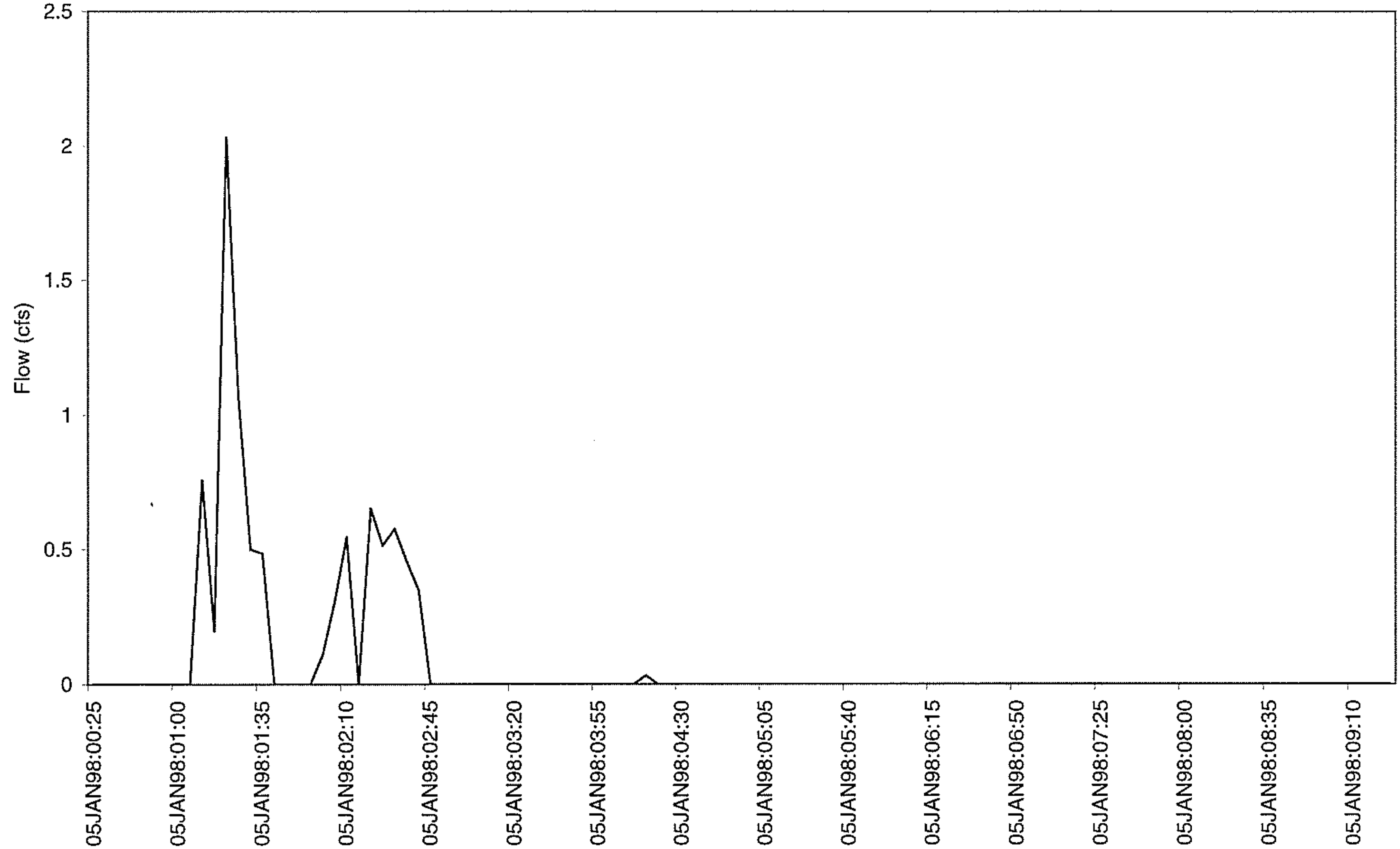
*Noise in flow values suspected to be caused by clogging due to sedimentation

Storm 5 - Site DC020*



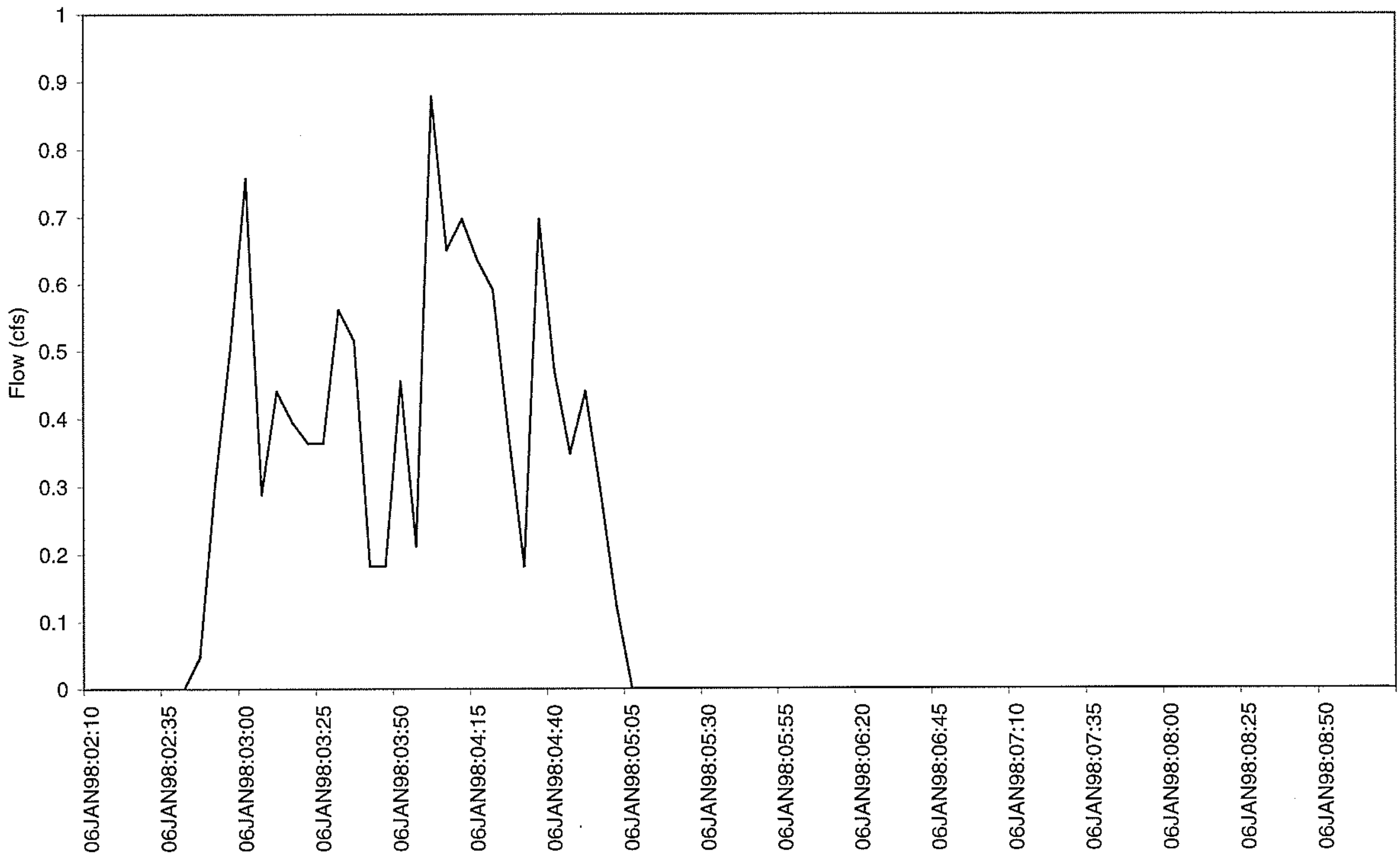
*Noise in flow values suspected to be caused by clogging due to sedimentation

Storm 6 - Site DC020*

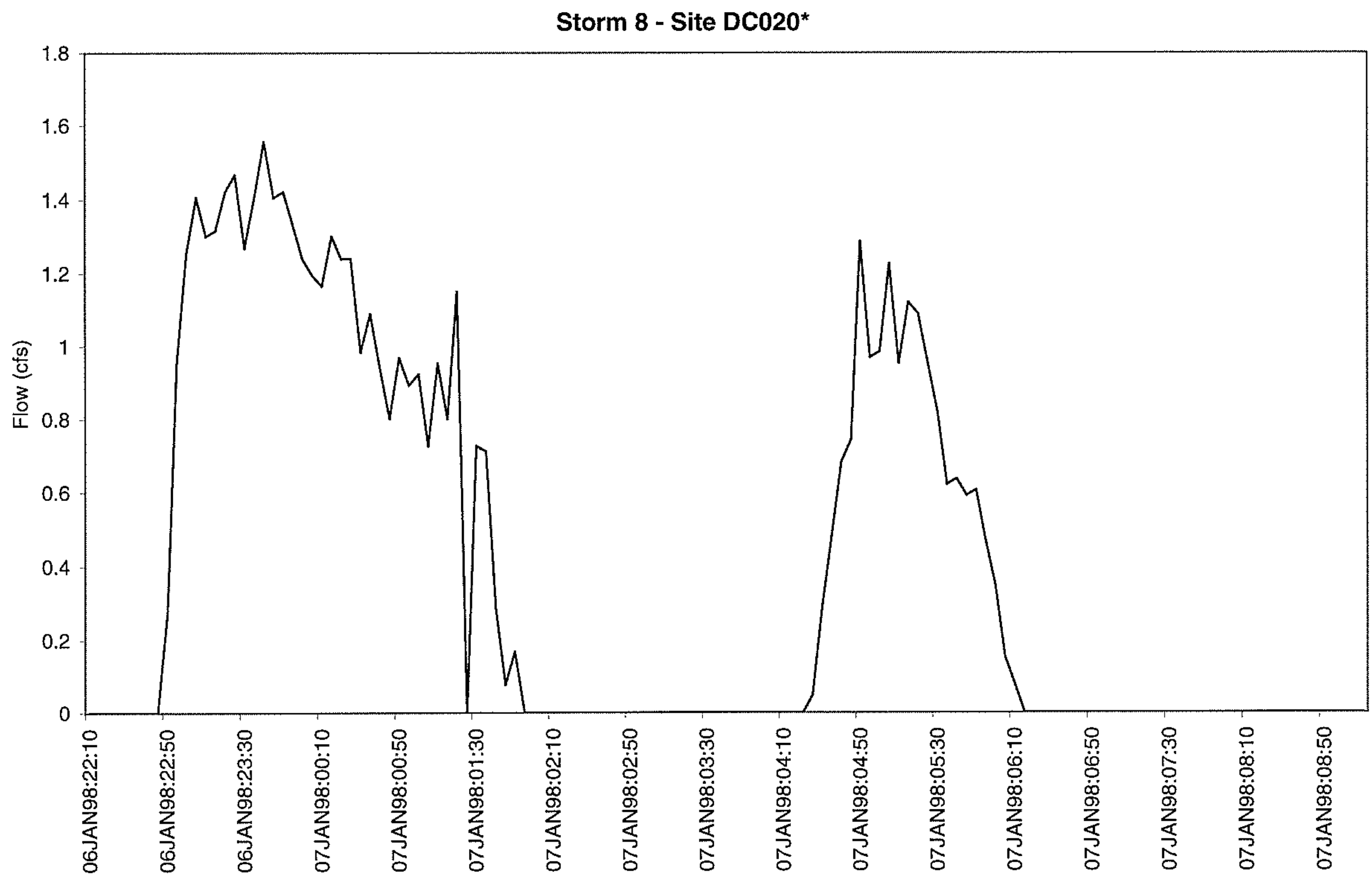


*Noise in flow values suspected to be caused by clogging due to sedimentation

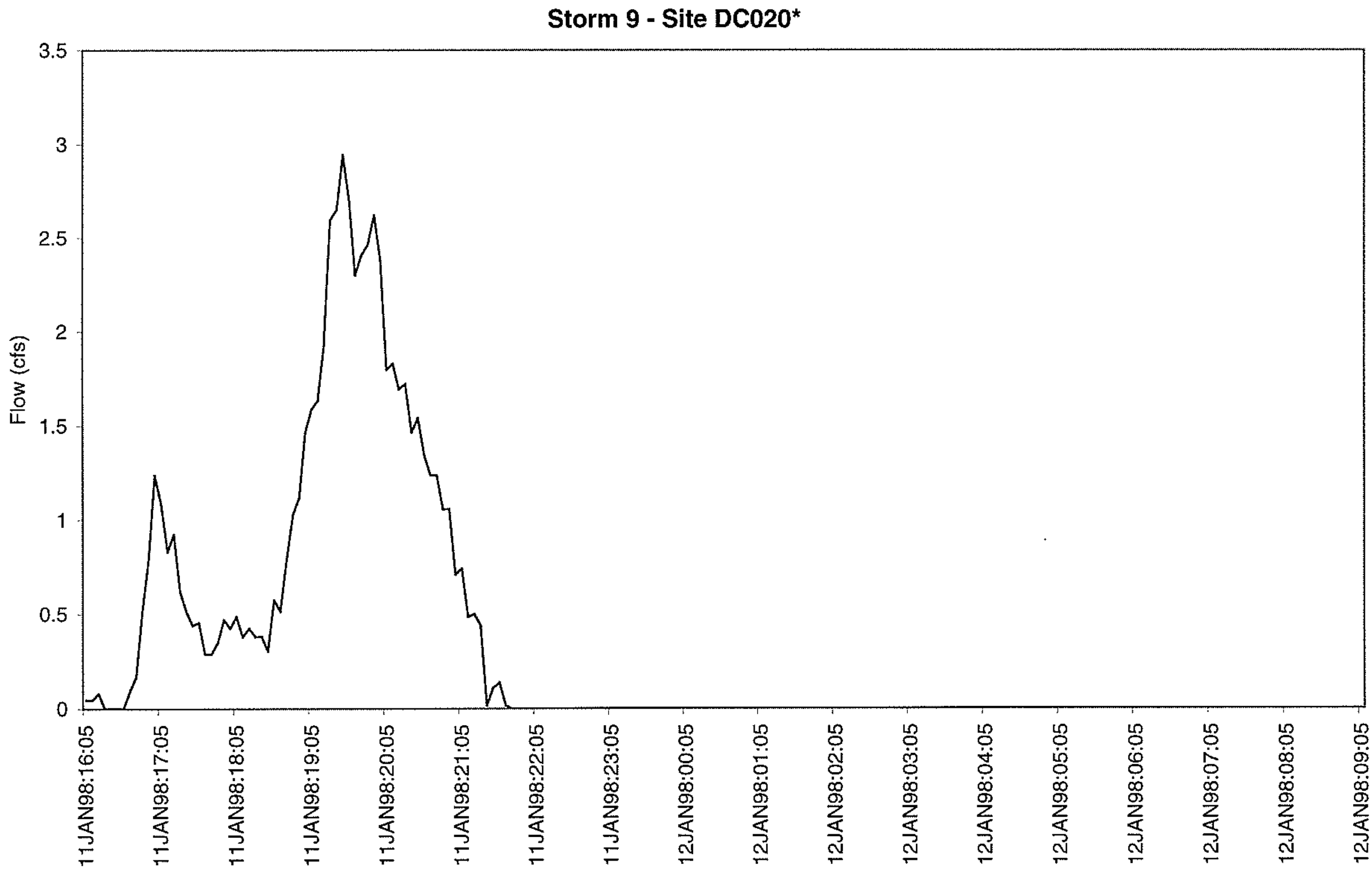
Storm 7 - Site DC020*



*Noise in flow values suspected to be caused by clogging due to sedimentation

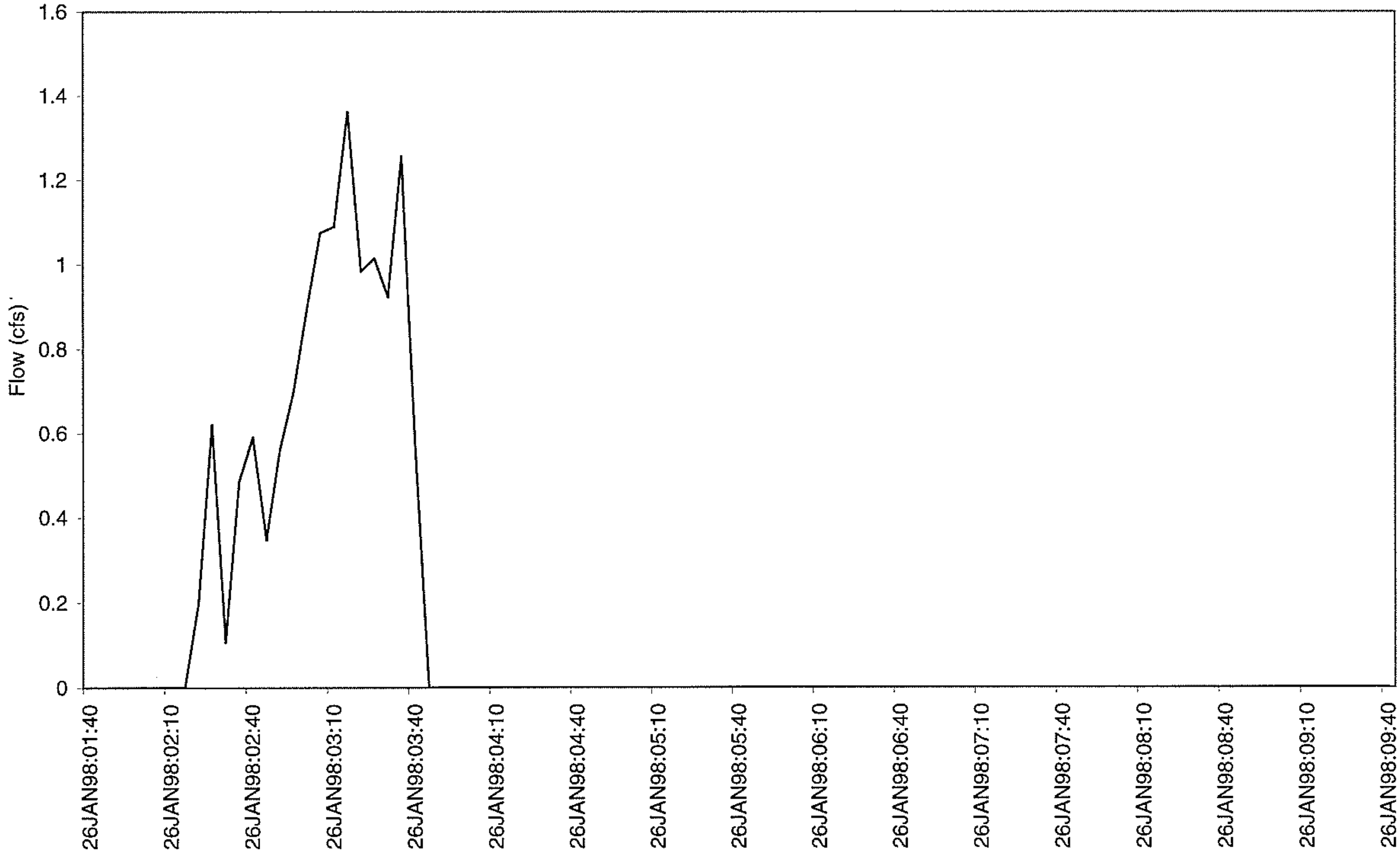


*Noise in flow values suspected to be caused by clogging due to sedimentation



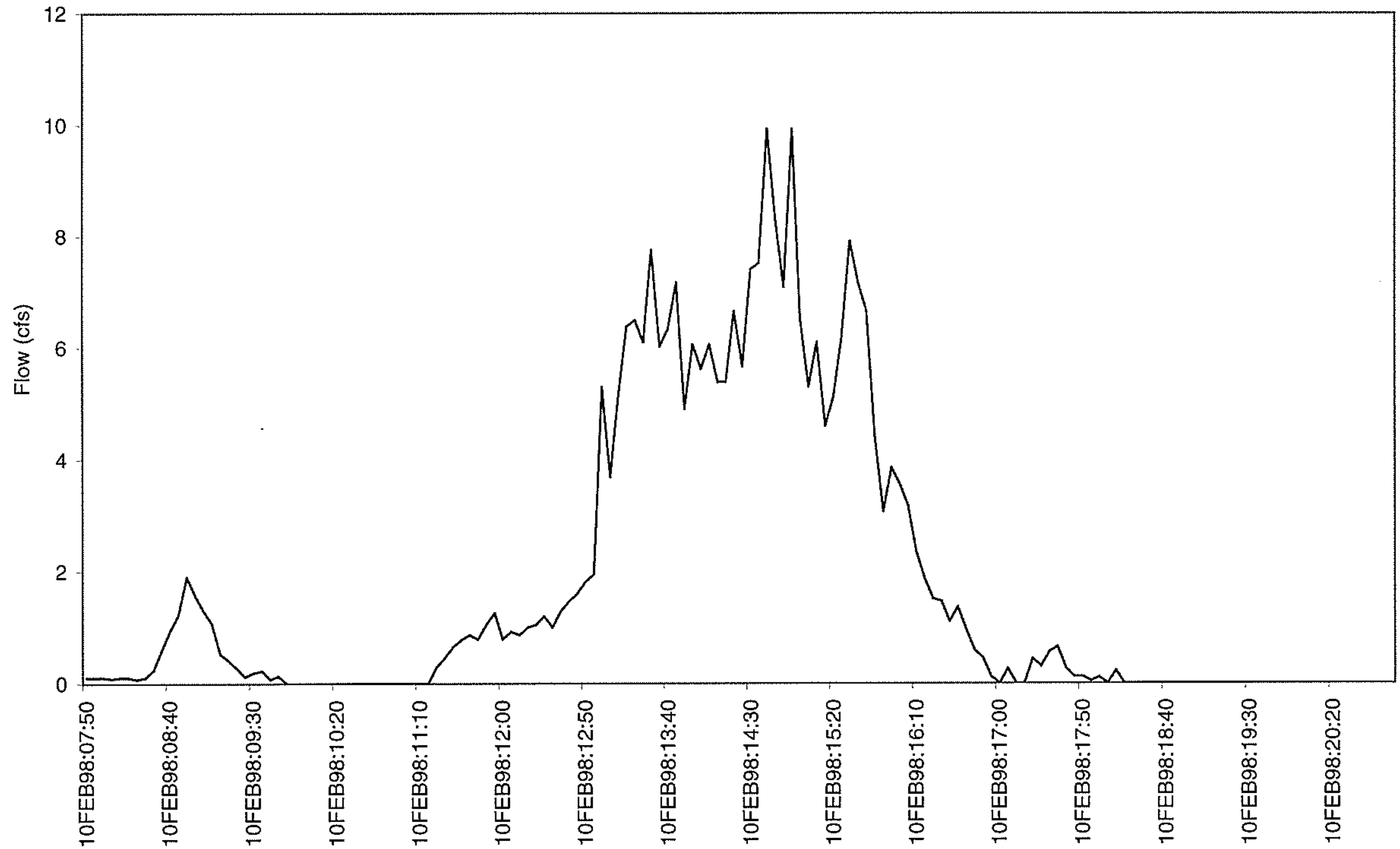
*Noise in flow values suspected to be caused by clogging due to sedimentation

Storm 10 - Site DC020*

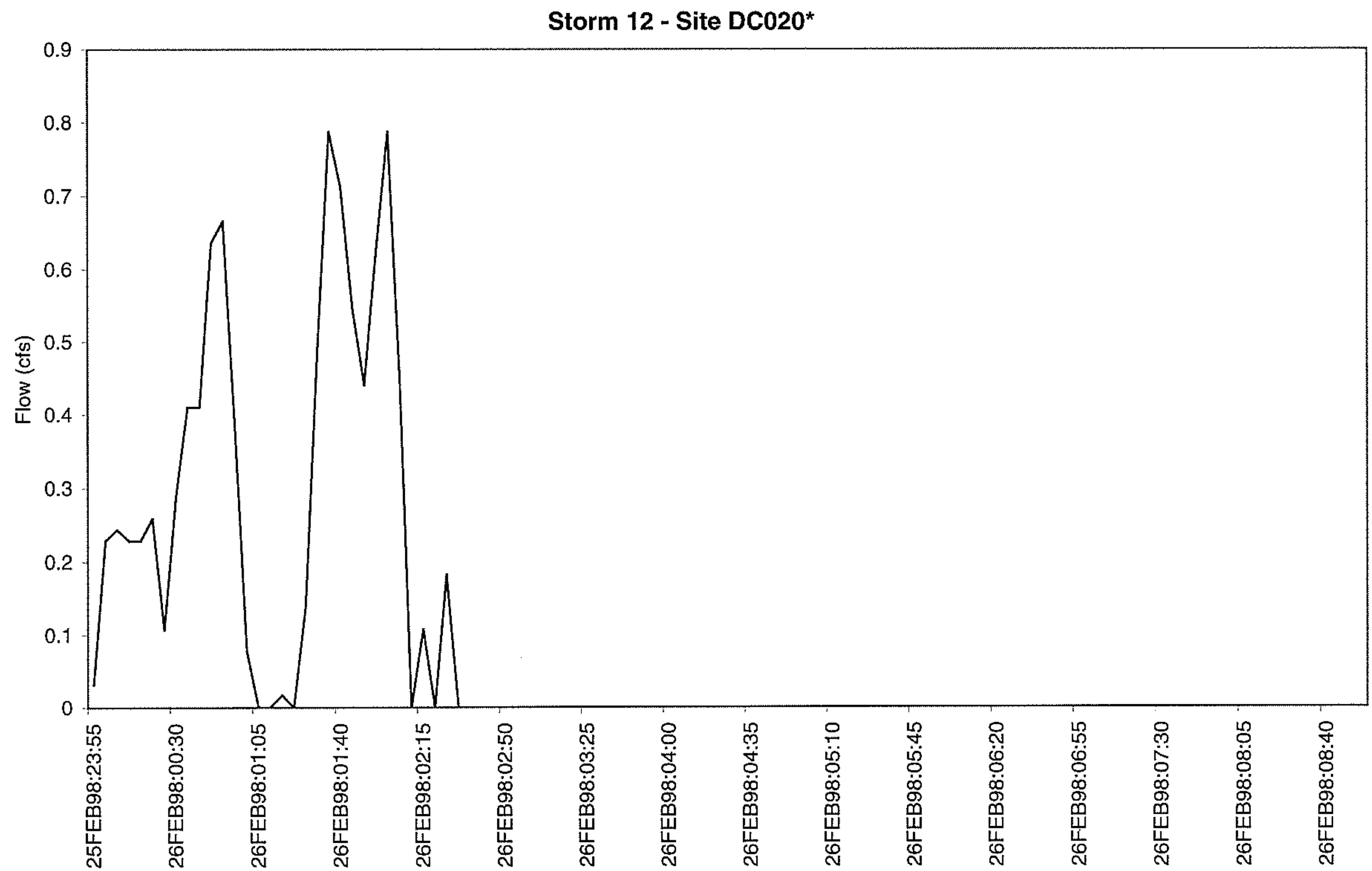


*Noise in flow values suspected to be caused by clogging due to sedimentation

Storm 11 - Site DC020*

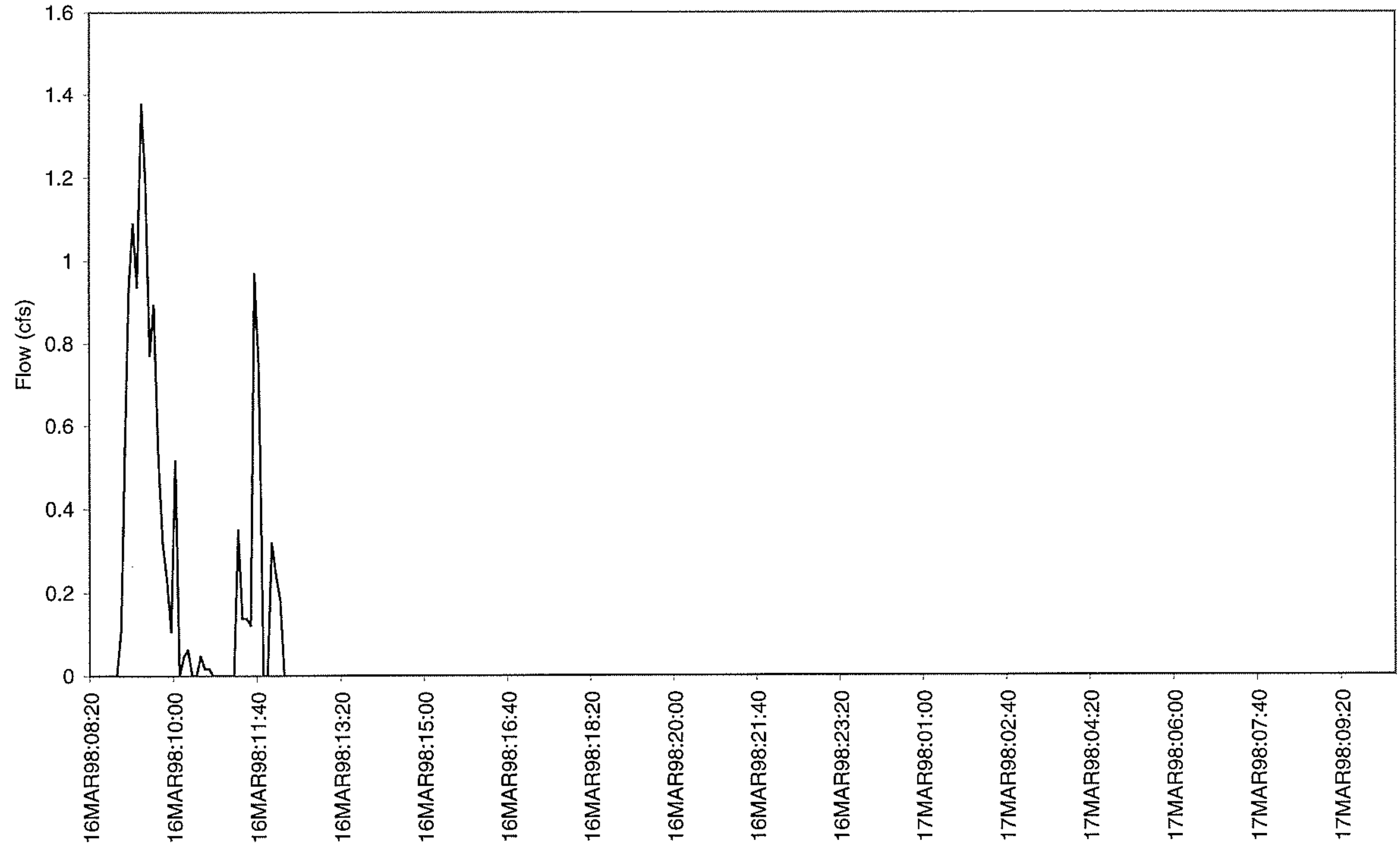


*Noise in flow values suspected to be caused by clogging due to sedimentation



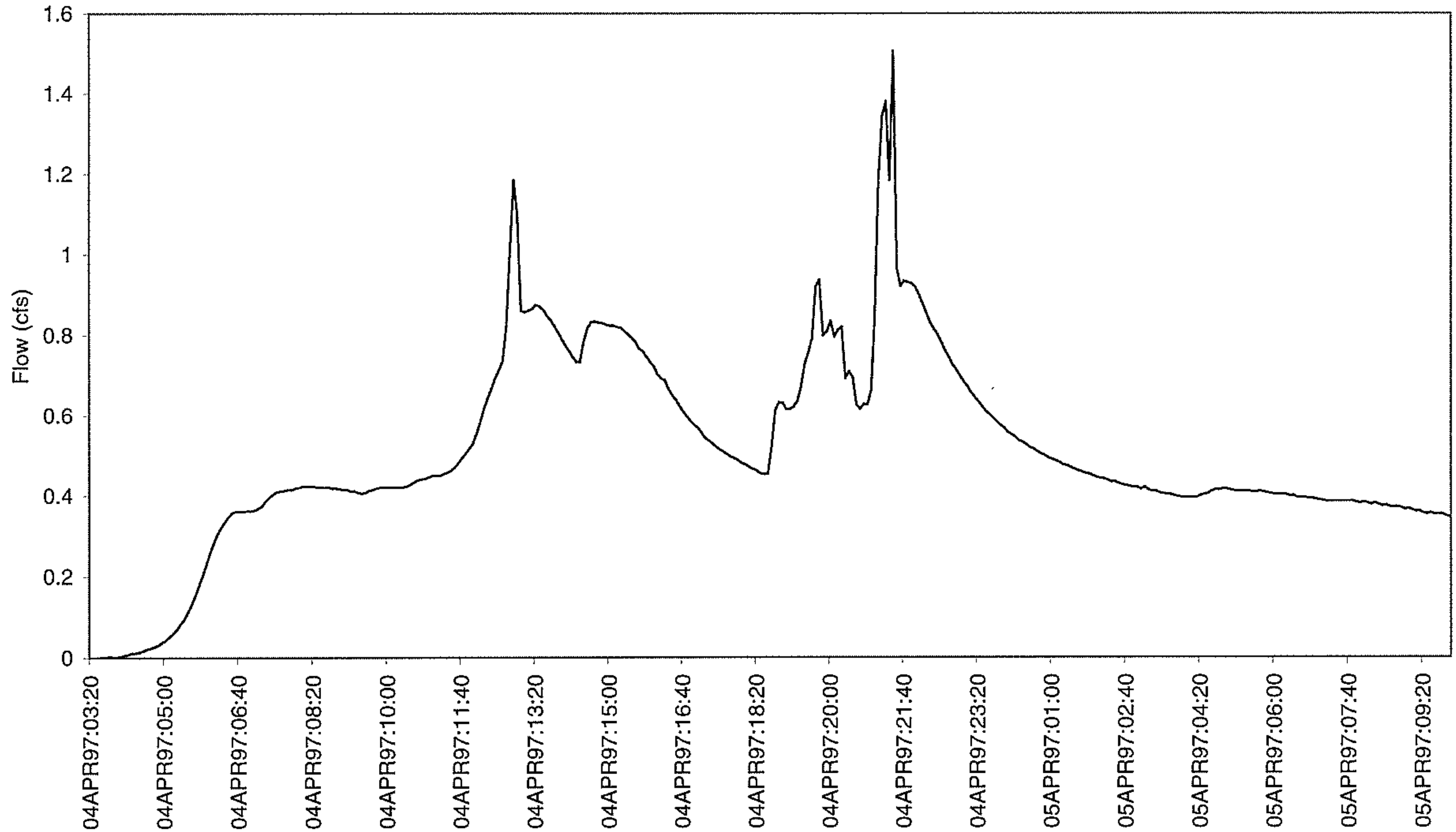
*Noise in flow values suspected to be caused by clogging due to sedimentation

Storm 13 - Site DC020*



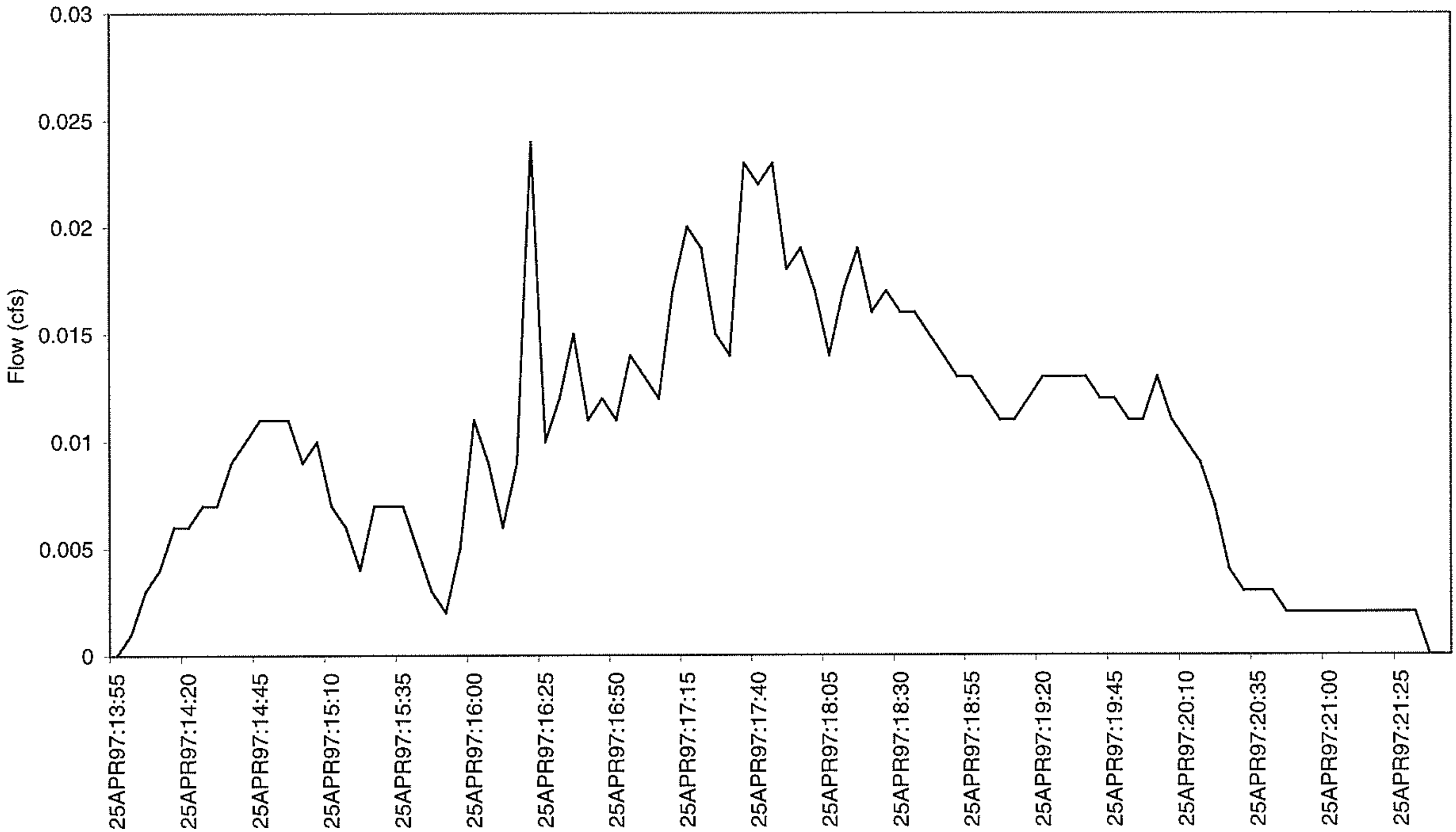
*Noise in flow values suspected to be caused by clogging due to sedimentation

Storm 1 - Site KO010*



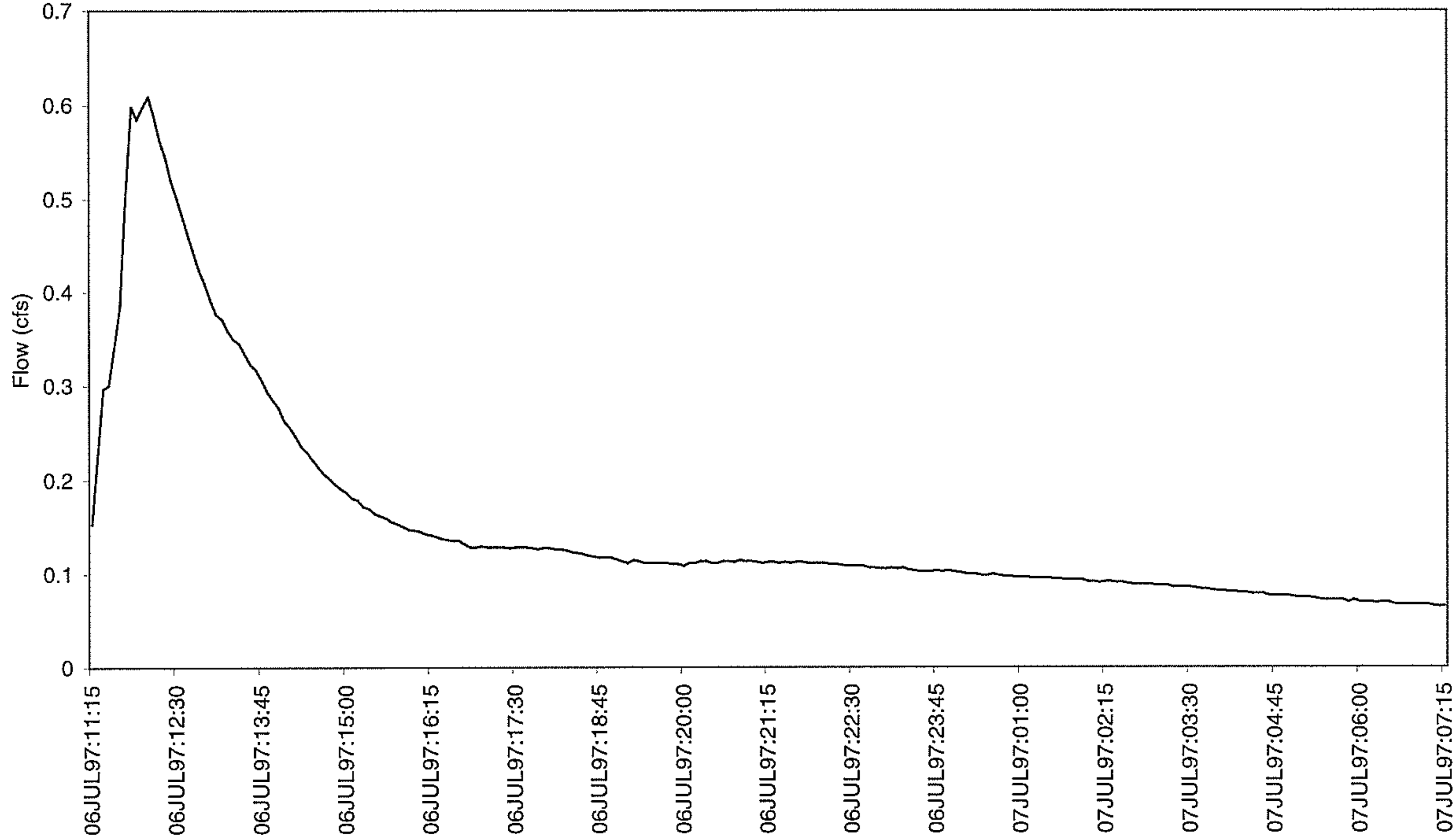
*Noise in flow values suspected to be caused by clogging due to sedimentation.

Storm 2 - Site KO010*



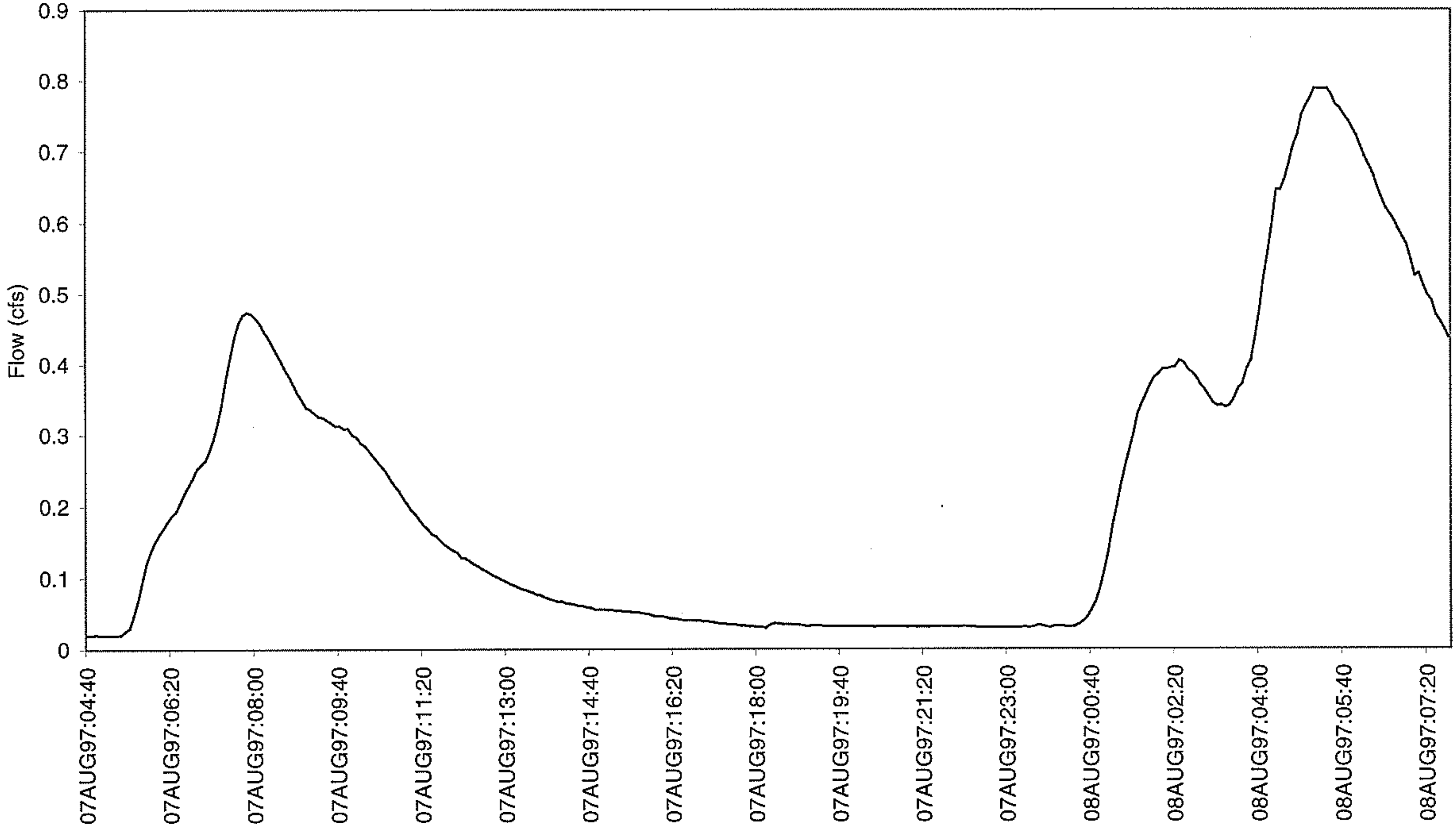
*Noise in flow values suspected to be caused by clogging due to sedimentation.

Storm 3 - Site KO010*



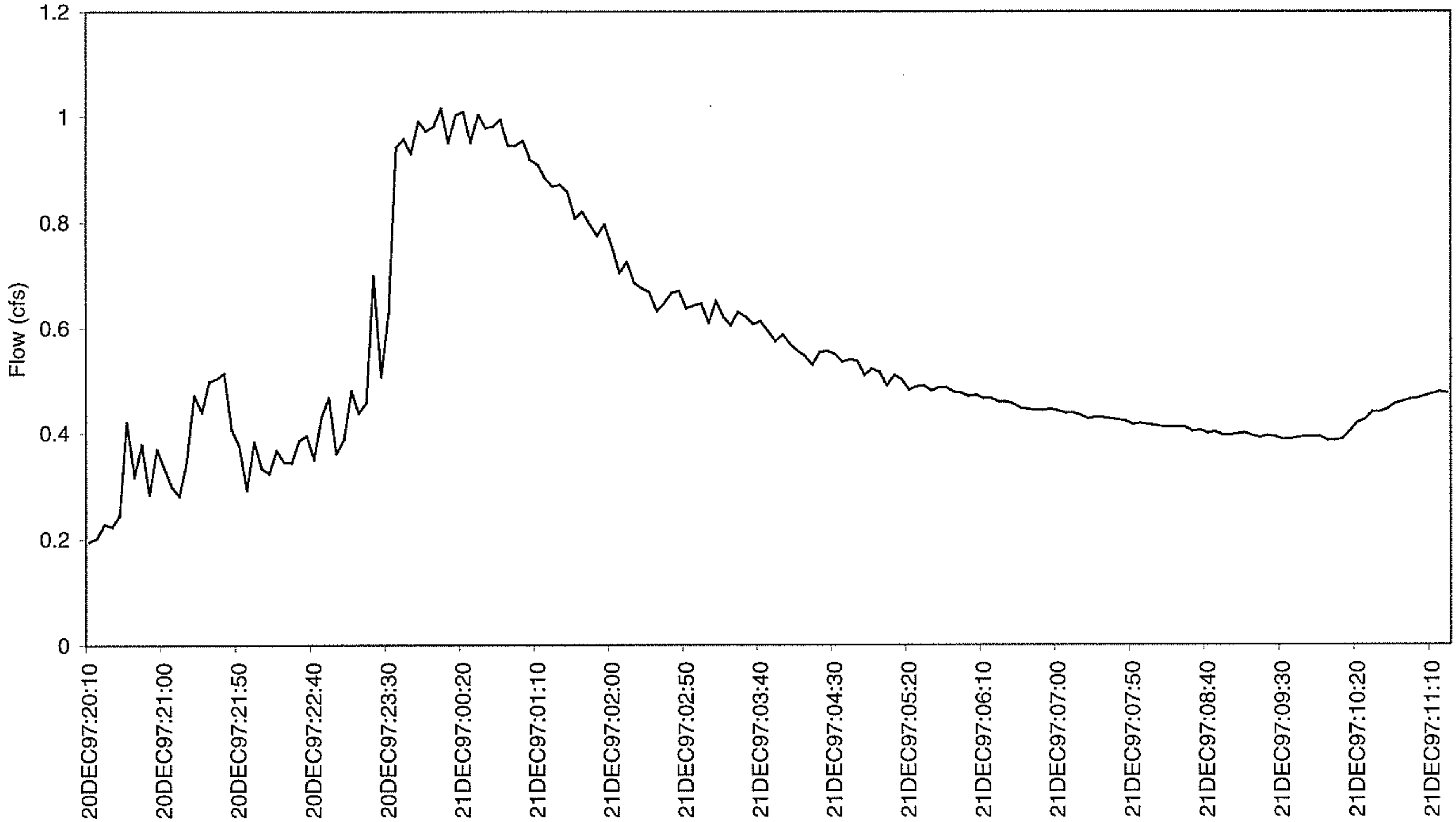
*Noise in flow valus susupected to be caused by clogging due to sedimentation.

Storm 4 - Site KO010*



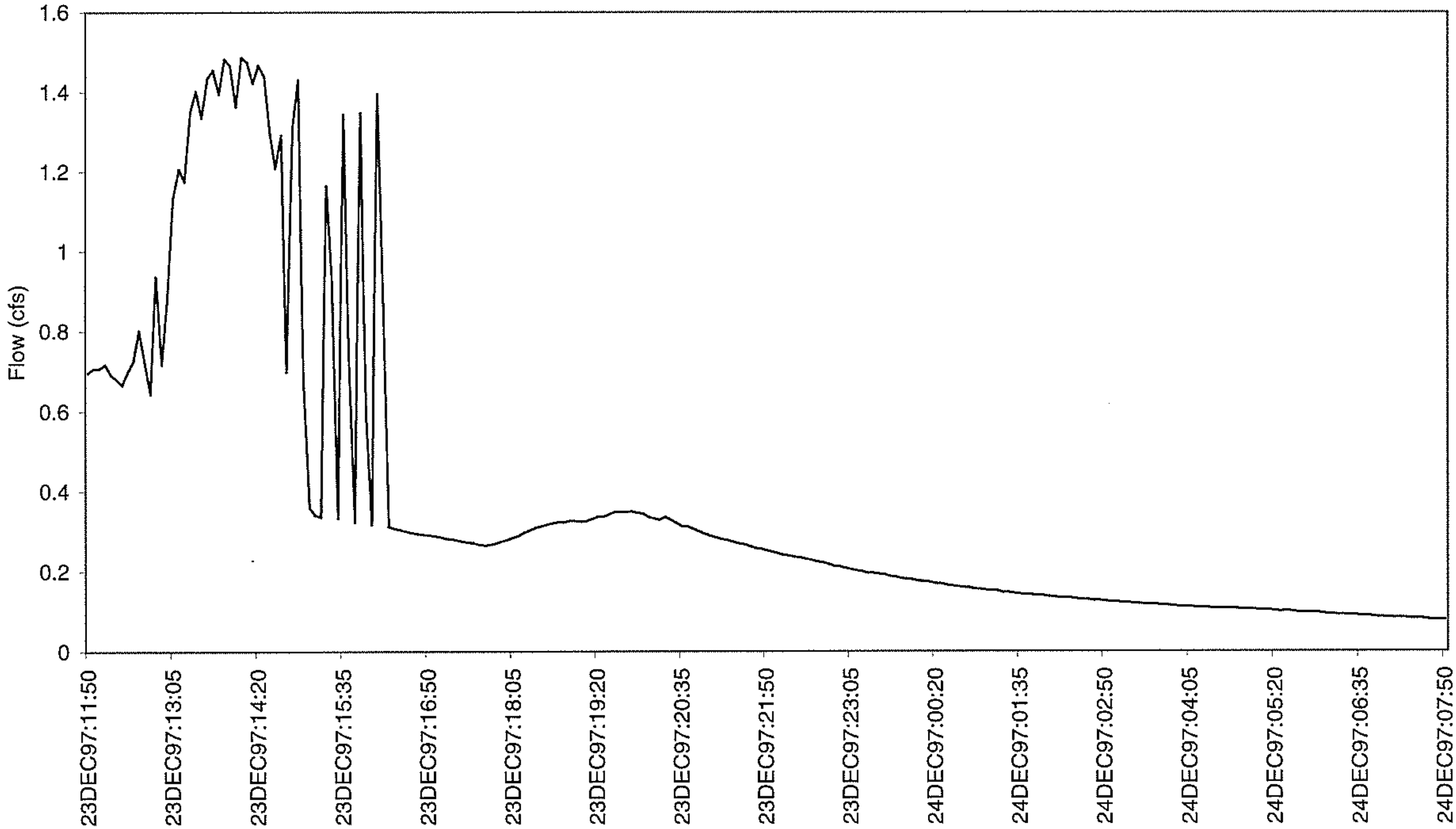
*Noise in flow values suspected to be caused by clogging due to sedimentation.

Storm 5 - Site KO010*



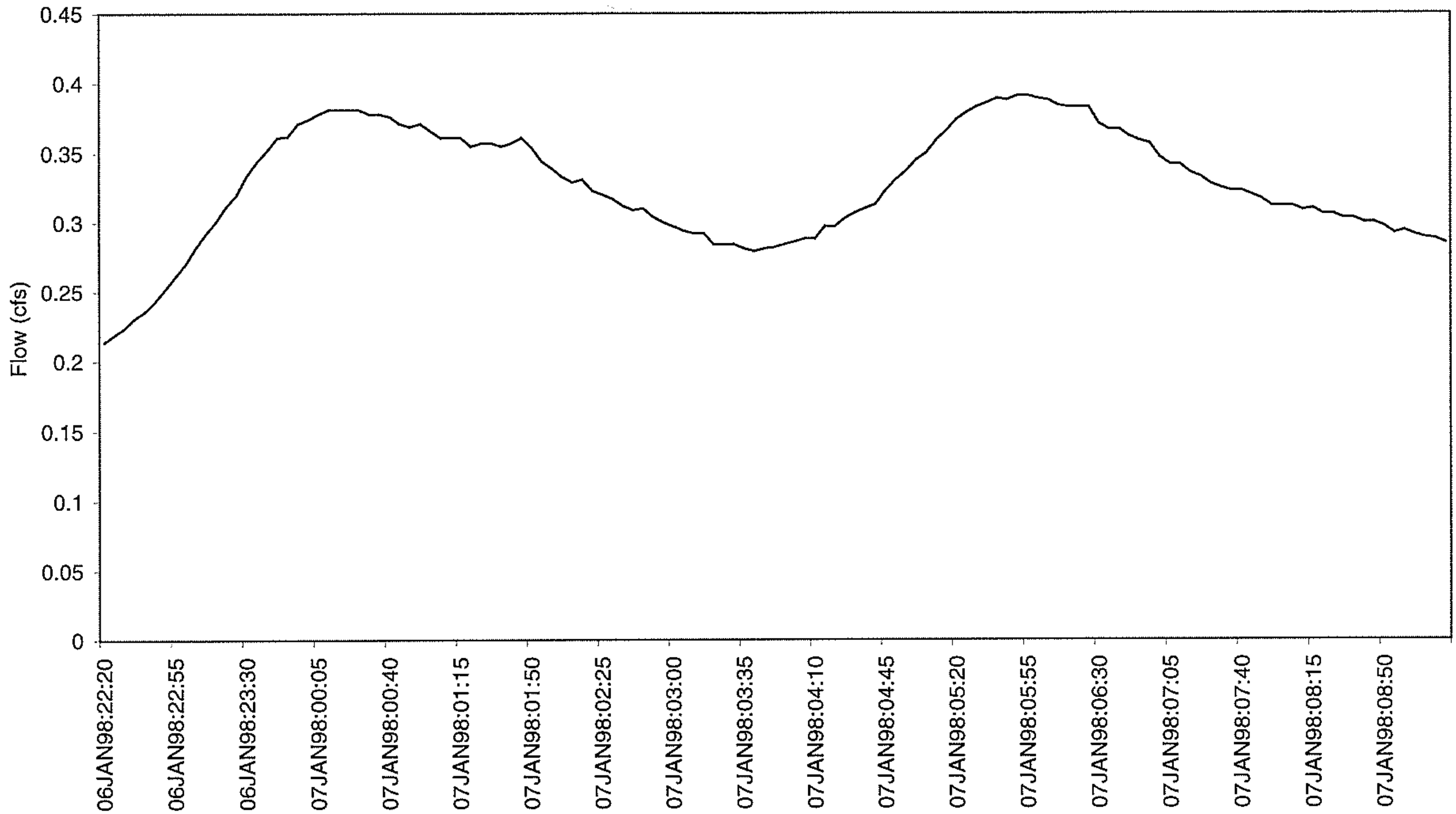
*Noise in flow values suspected to be caused by clogging due to sedimentation.

Storm 6 - Site KO010*



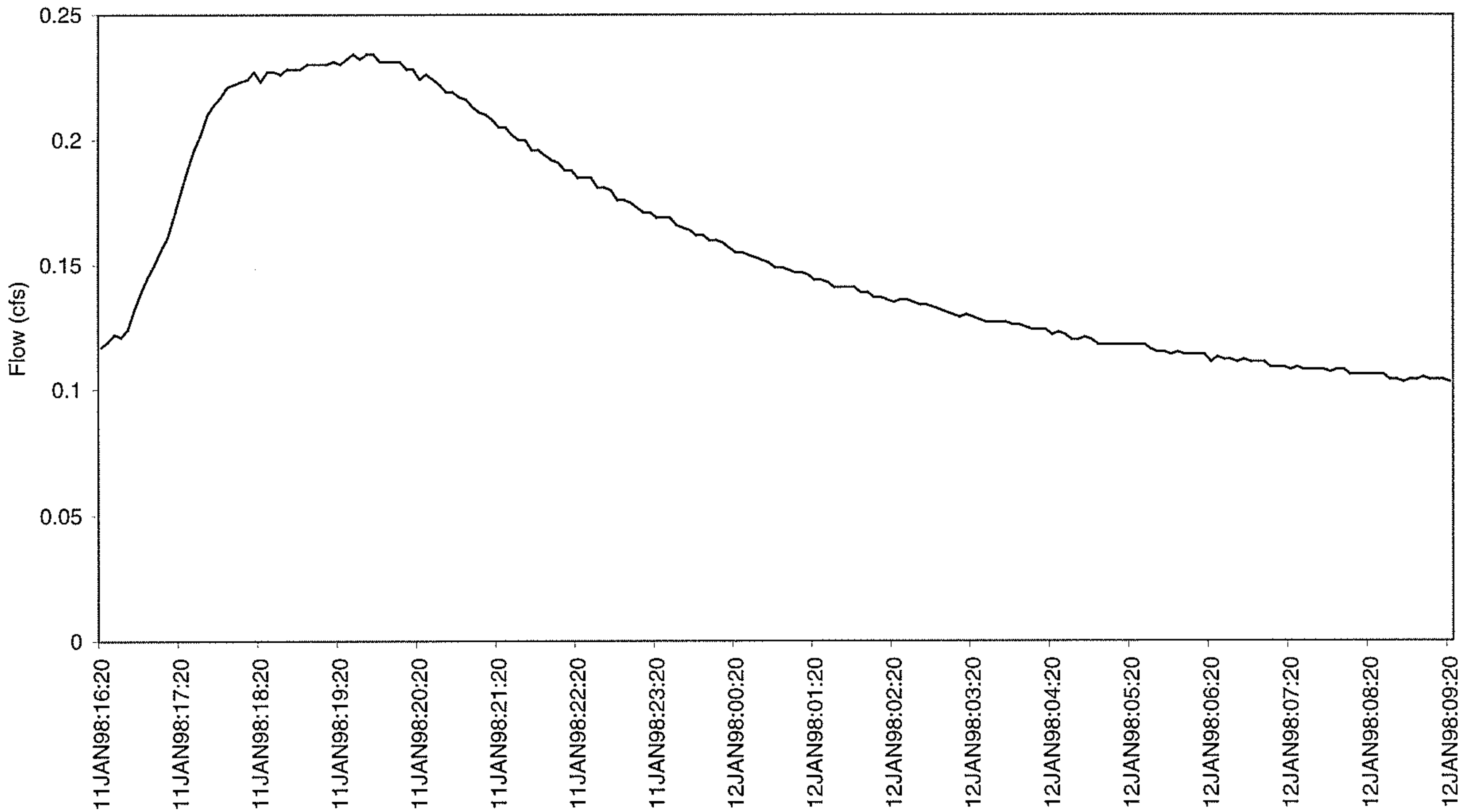
*Noise in flow values suspected to be caused by clogging due to sedimentation.

Storm 7 - Site KO010*



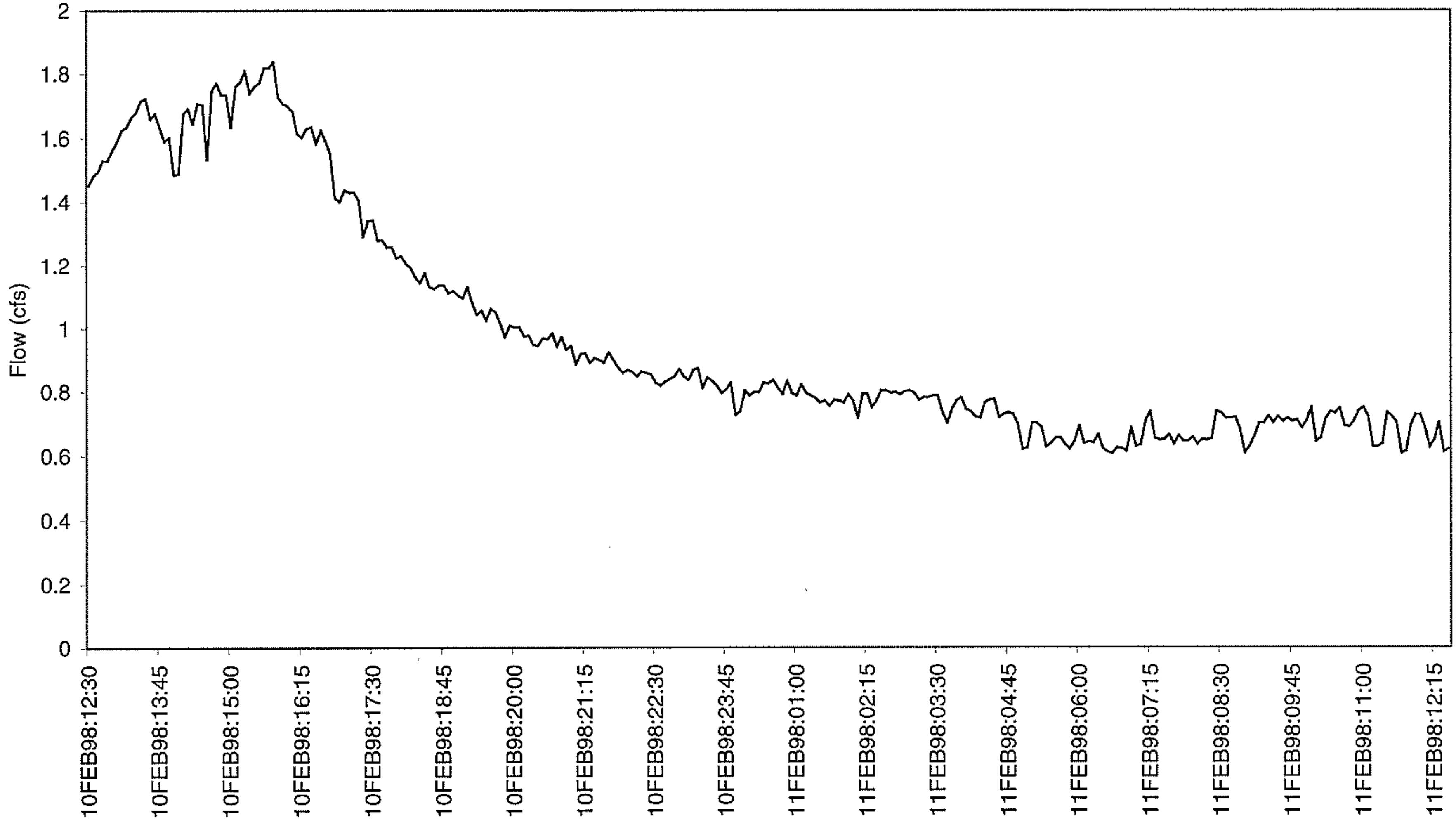
*Noise in flow values suspected to be caused by clogging due to sedimentation.

Storm 8 - Site KO010*



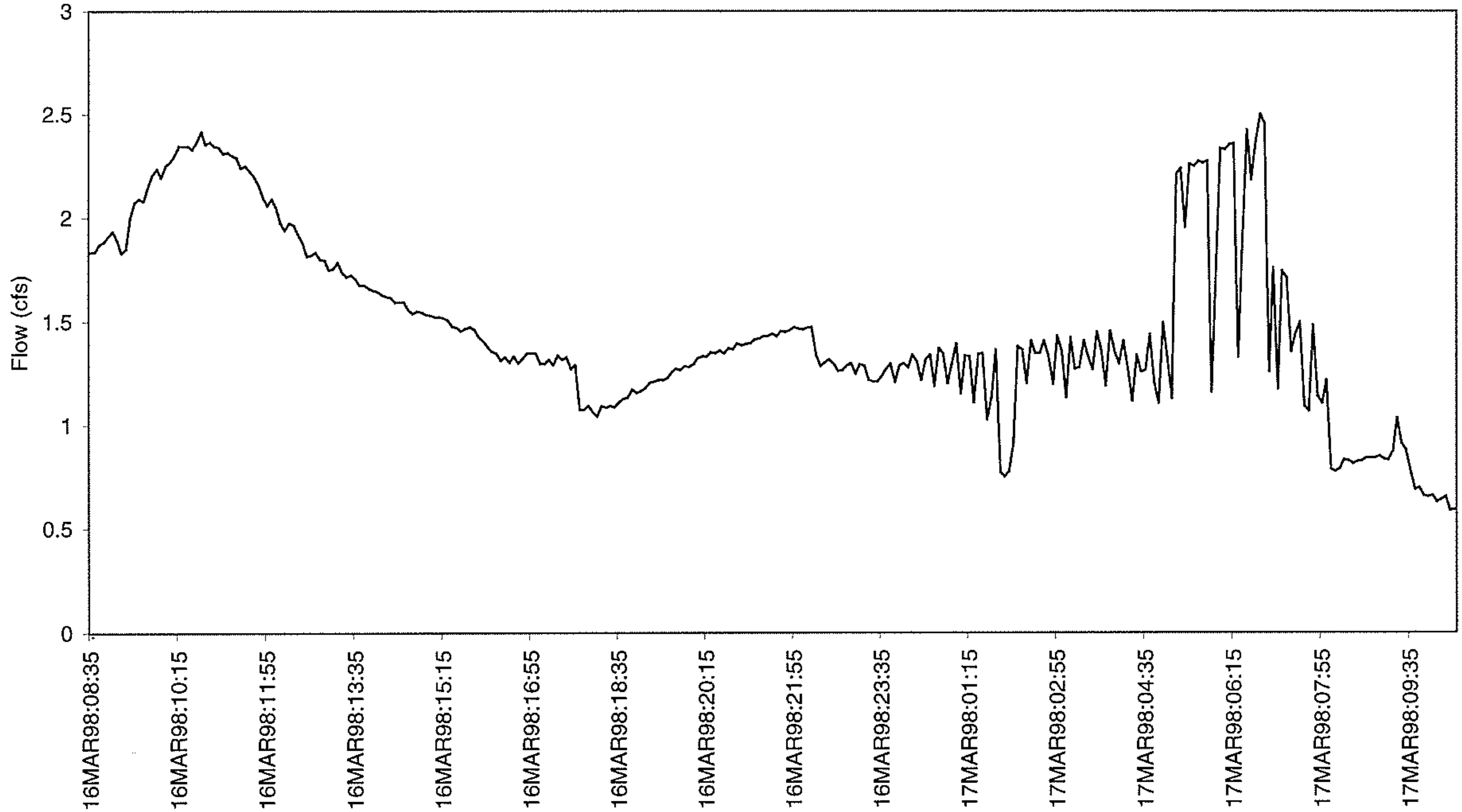
*Noise in flow values suspected to be caused by clogging due to sedimentation.

Storm 9 - Site KO010*



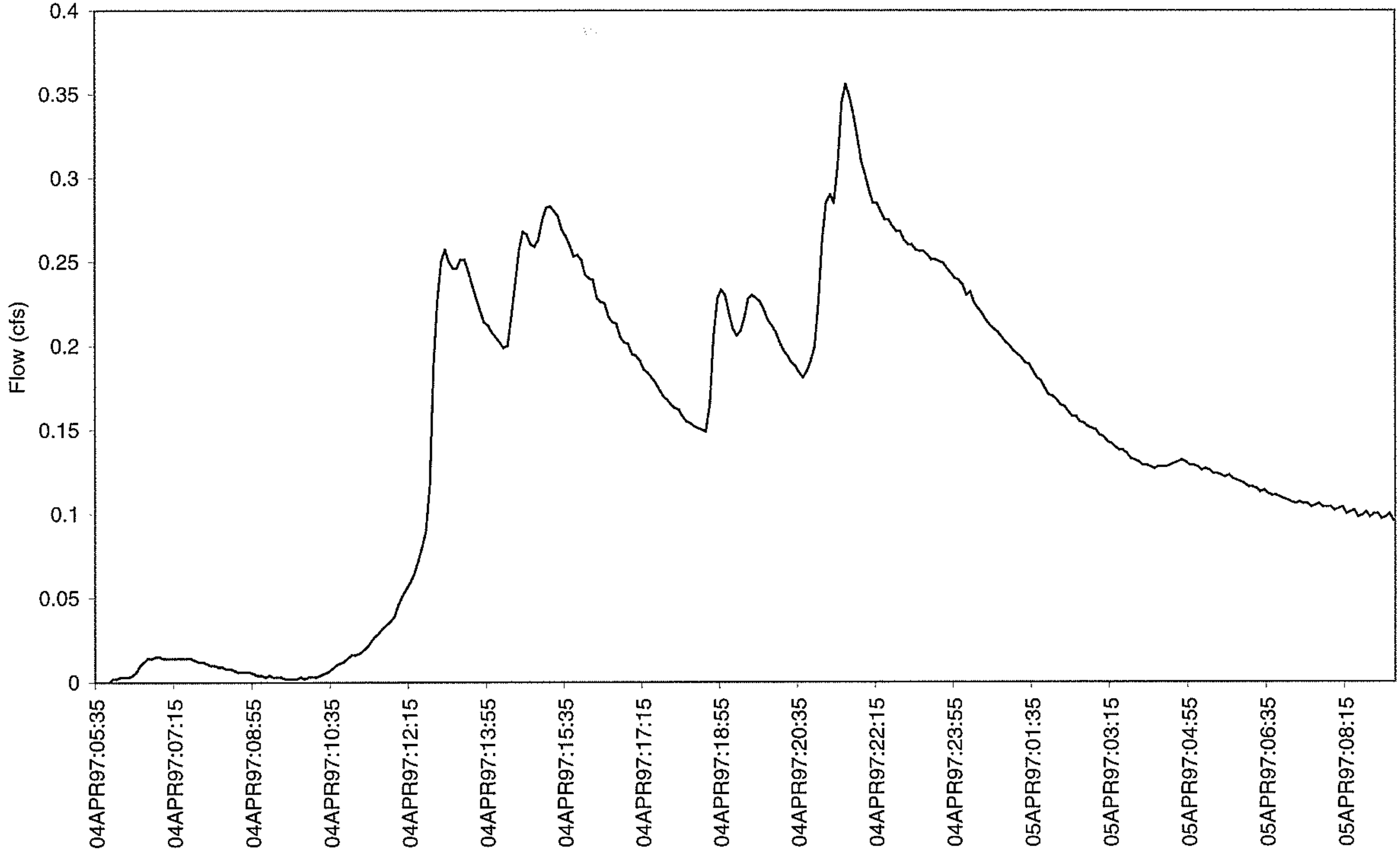
*Noise in flow values suspected to be caused by clogging due to sedimentation.

Storm 10 - Site KO010*



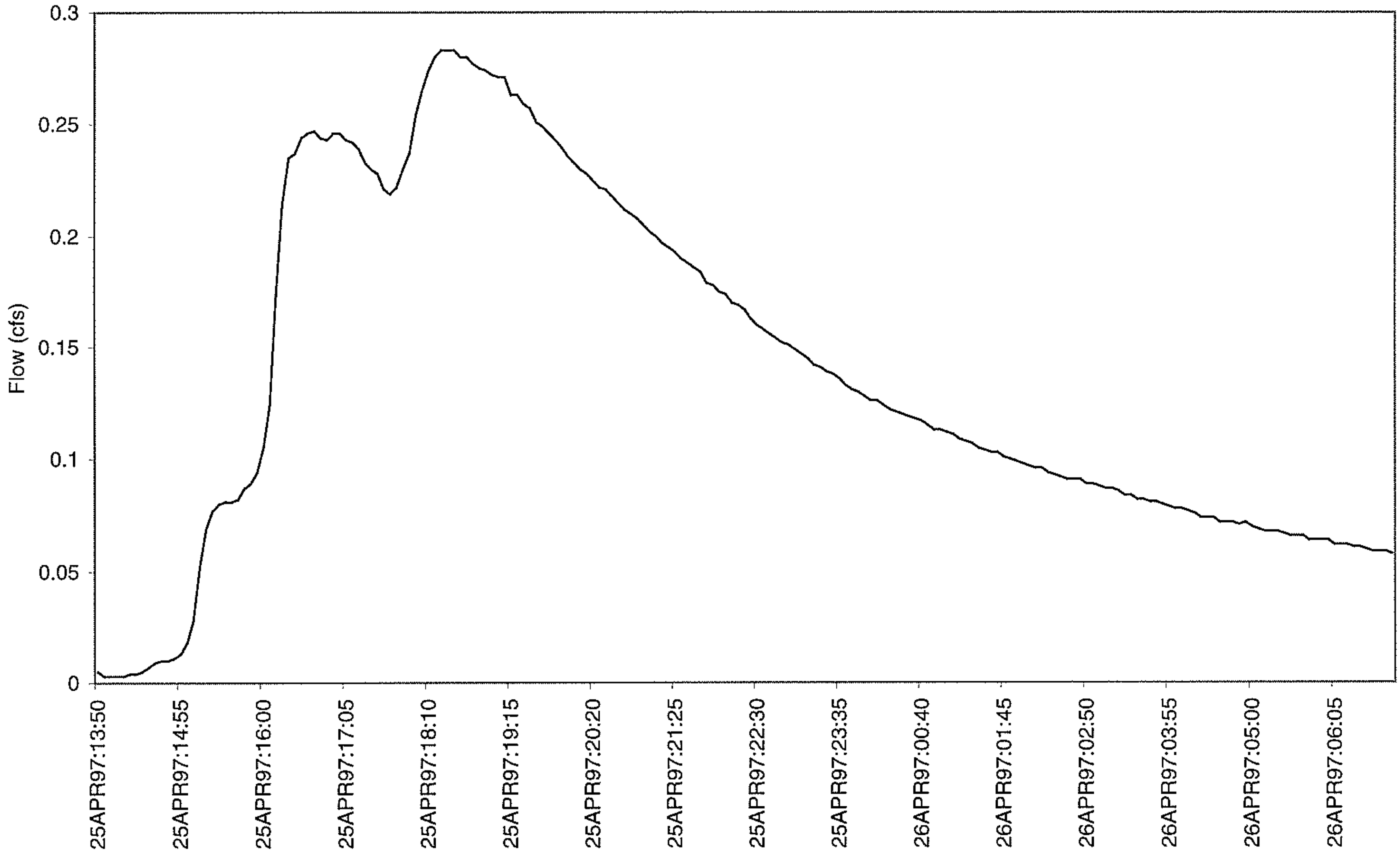
*Noise in flow values suspected to be caused by clogging due to sedimentation.

Storm 1 - Site KO020*

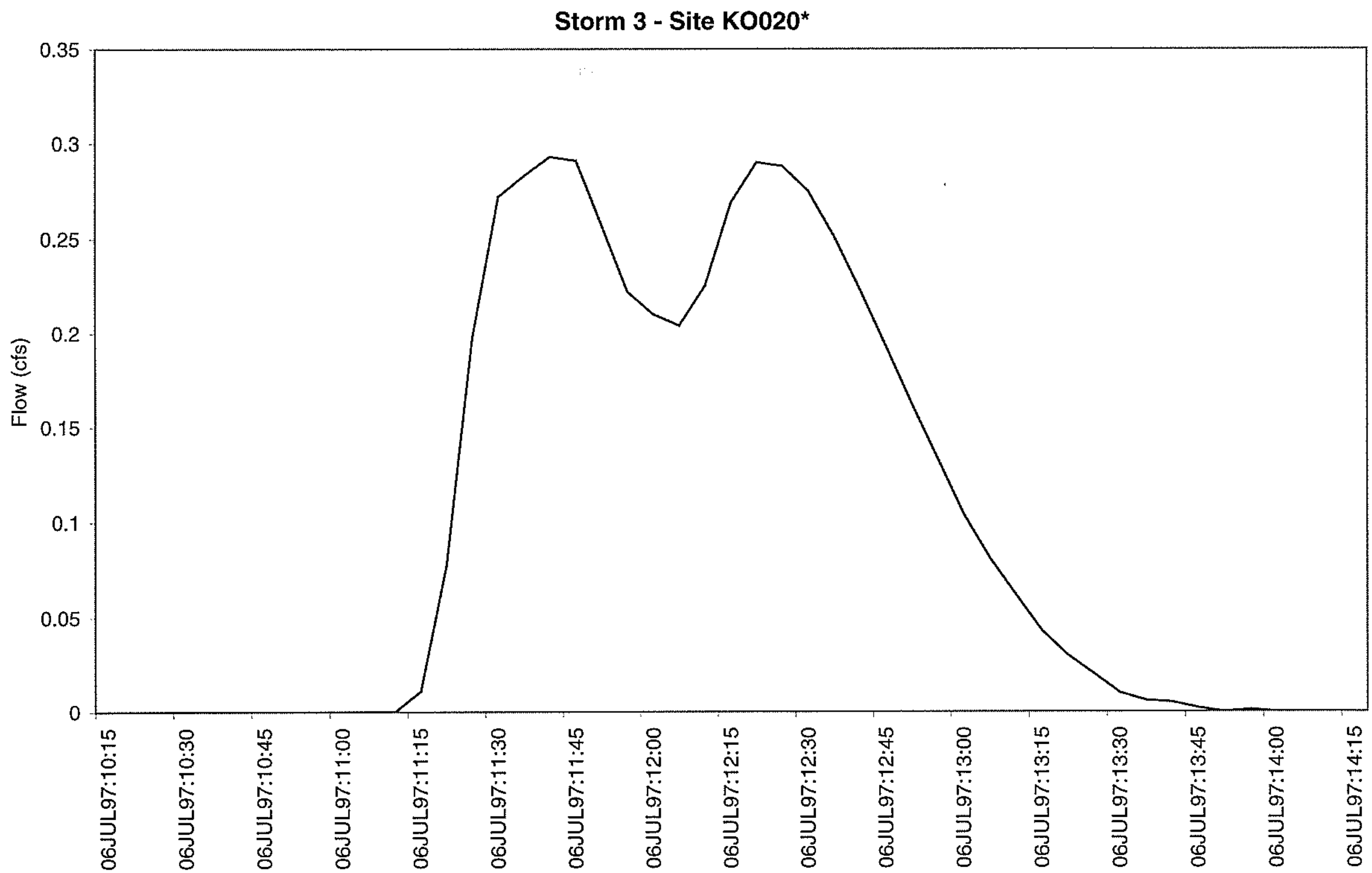


*Noise in flow values suspected to be caused by clogging due to sedimentation

Storm 2 - Site KO020*

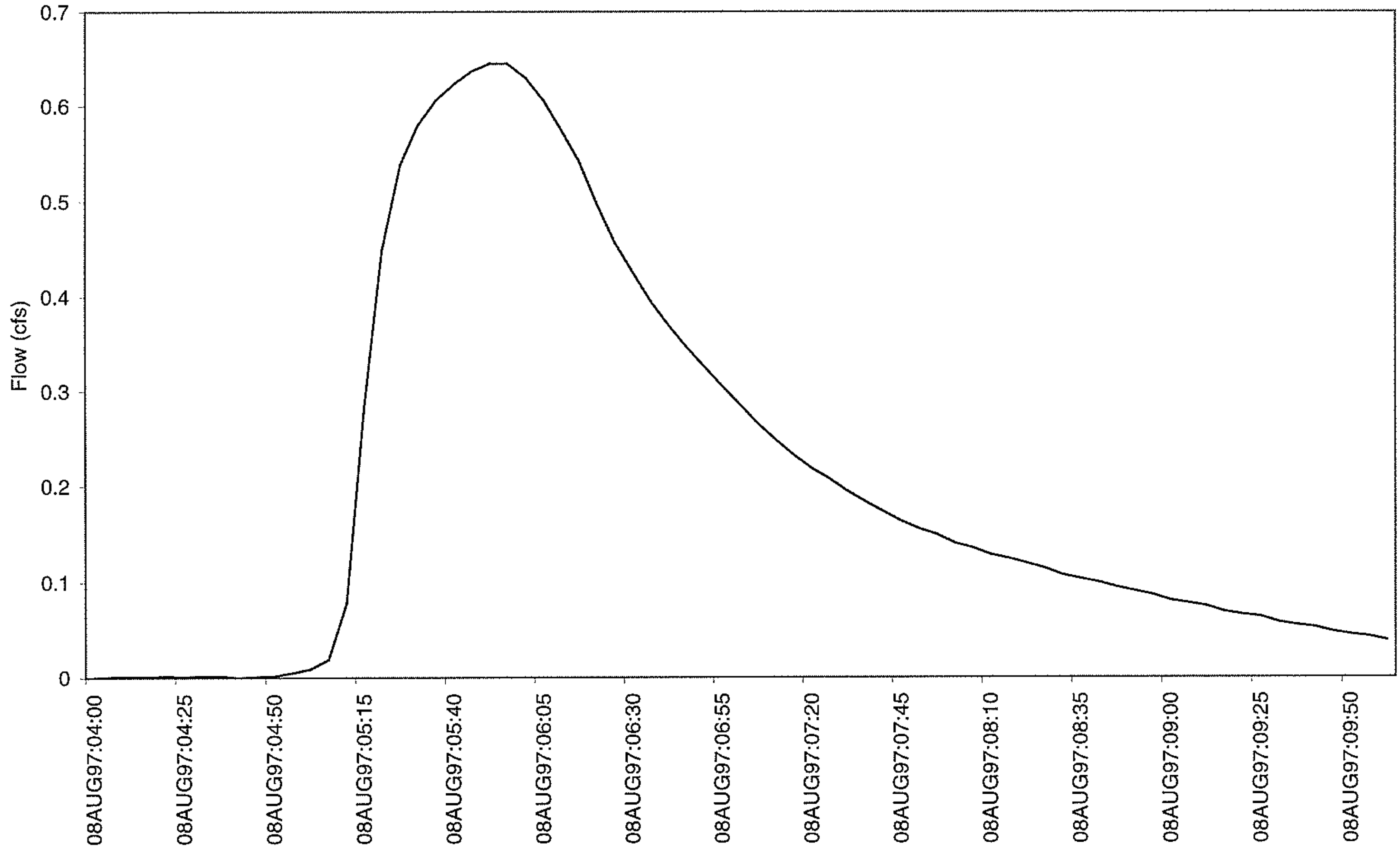


*Noise in flow values suspected to be caused by clogging due to sedimentation



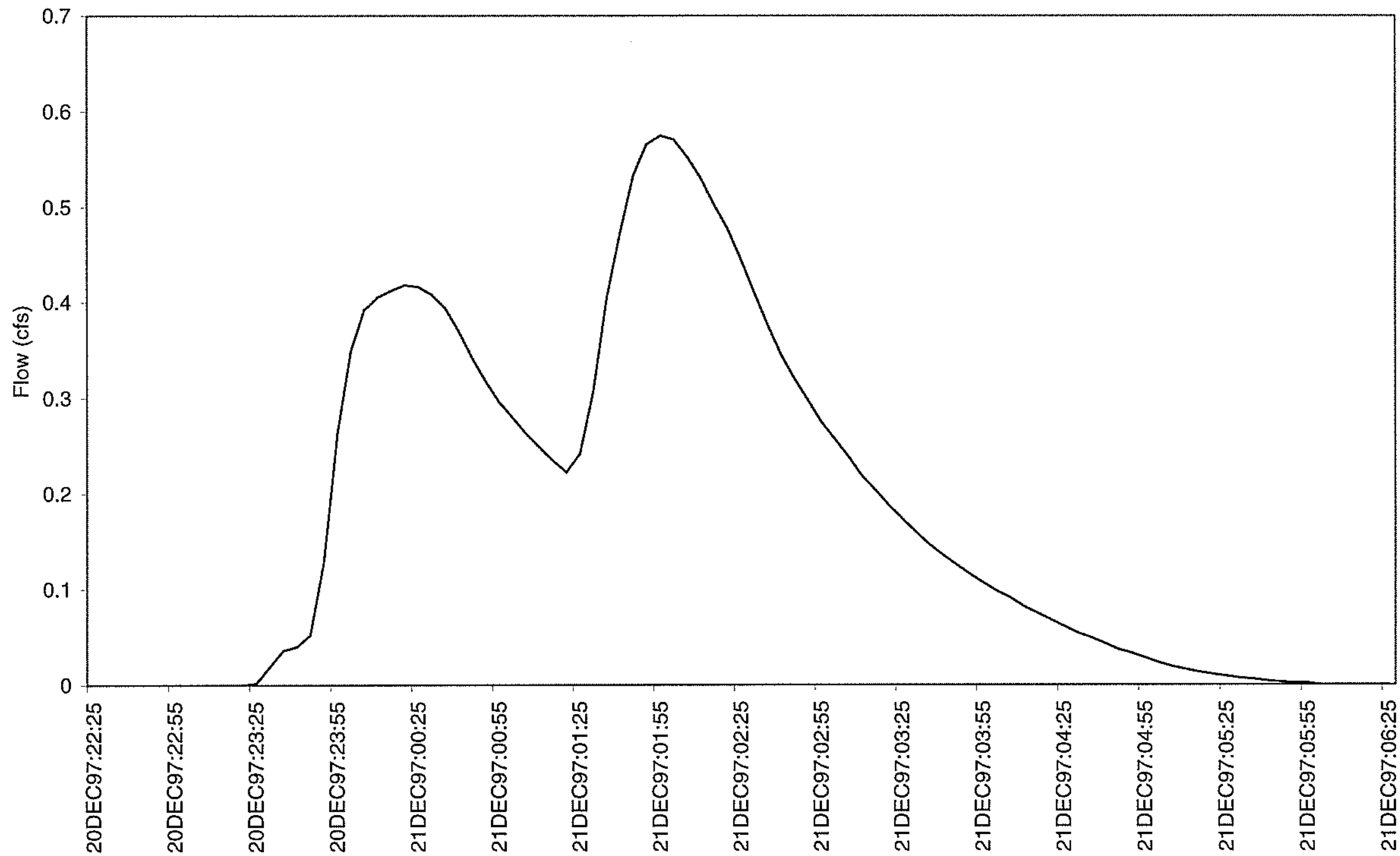
*Noise in flow values suspected to be caused by clogging due to sedimentation

Storm 4 - Site KO020*



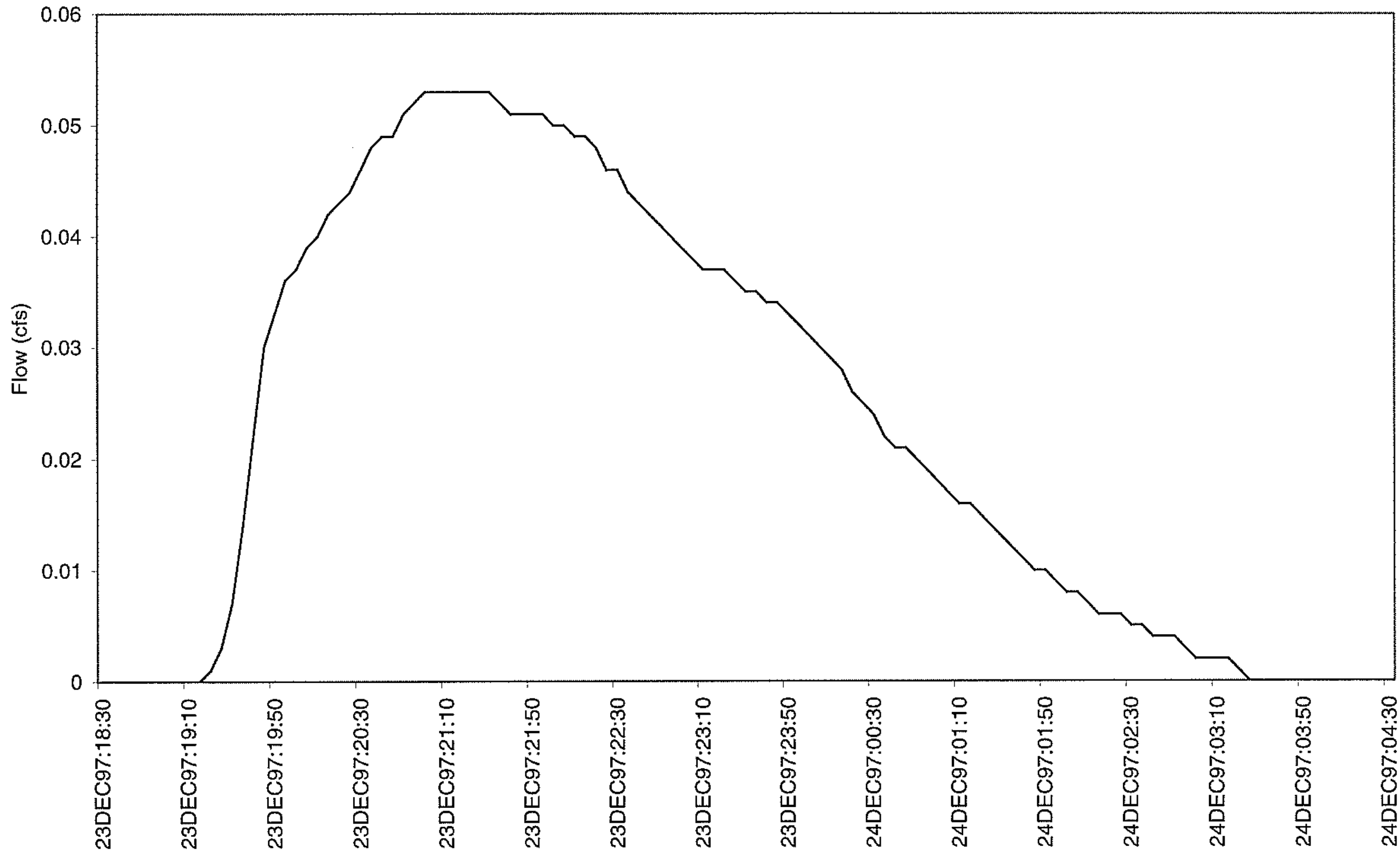
*Noise in flow values suspected to be caused by clogging due to sedimentation

Storm 5 - Site KO020*



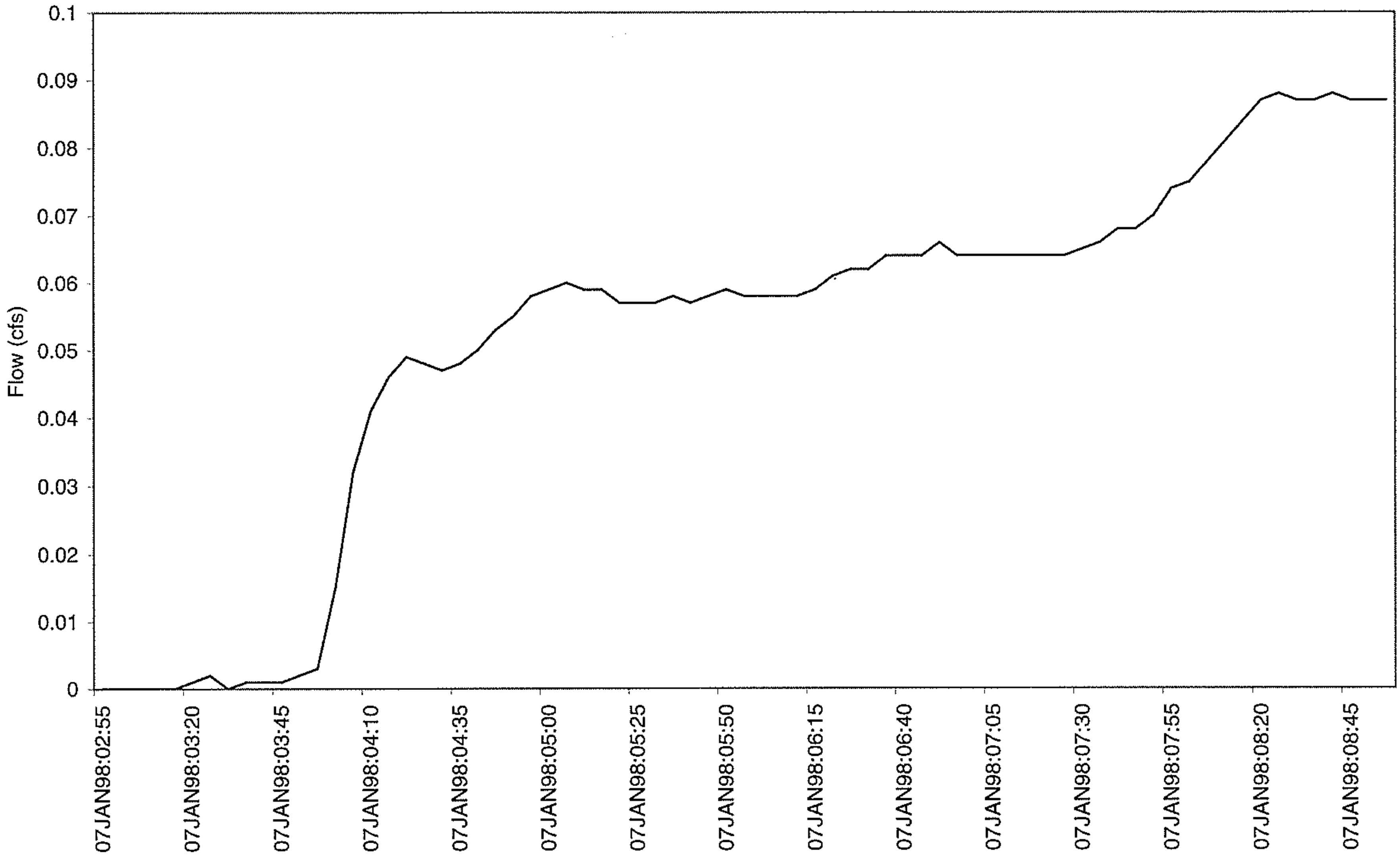
*Noise in flow values suspected to be caused by clogging due to sedimentation

Storm 6 - Site KO020*

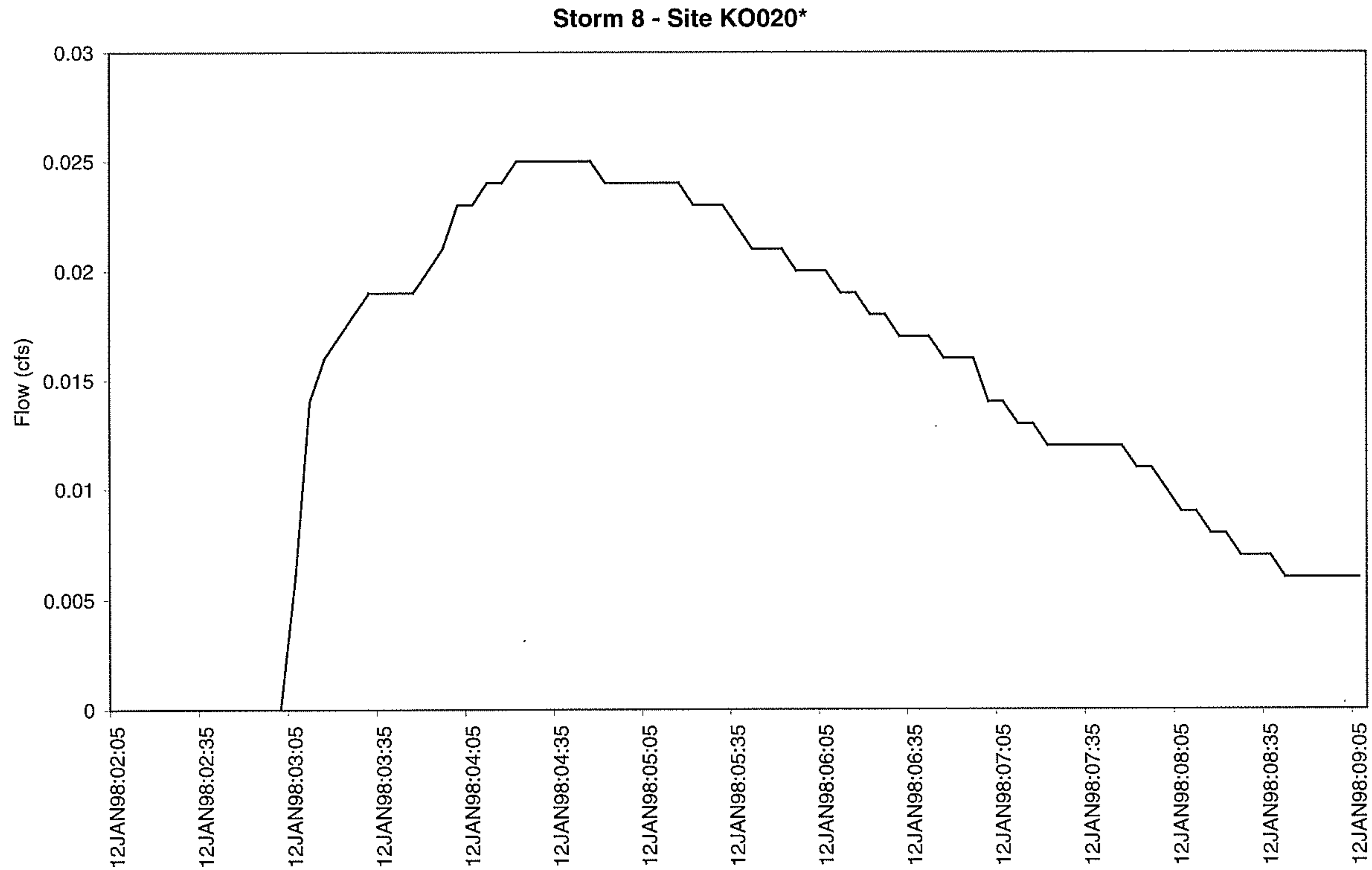


*Noise in flow values suspected to be caused by clogging due to sedimentation

Storm 7 - Site KO020*

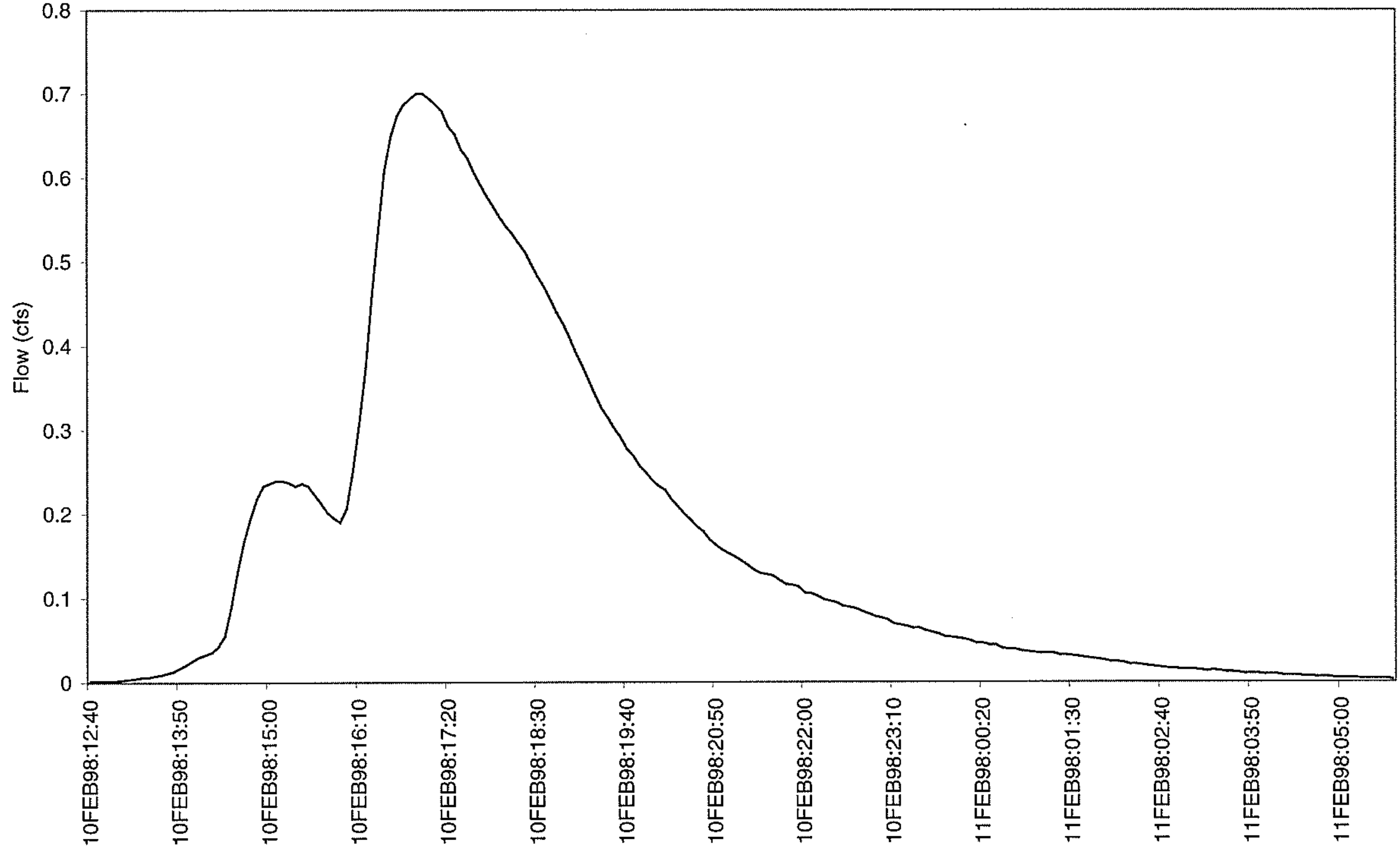


*Noise in flow values suspected to be caused by clogging due to sedimentation



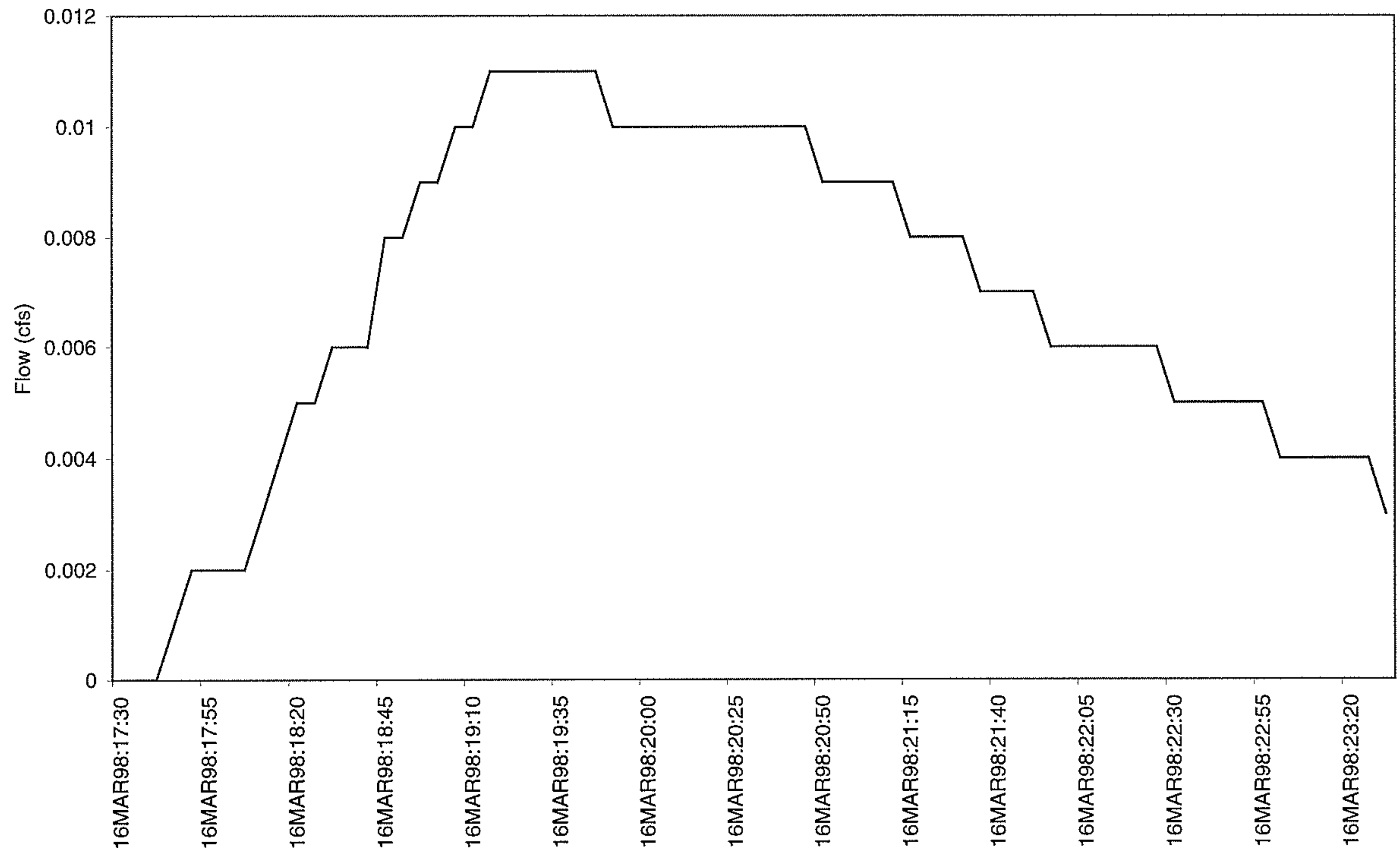
*Noise in flow values suspected to be caused by clogging due to sedimentation

Storm 9 - Site KO020*



*Noise in flow values suspected to be caused by clogging due to sedimentation

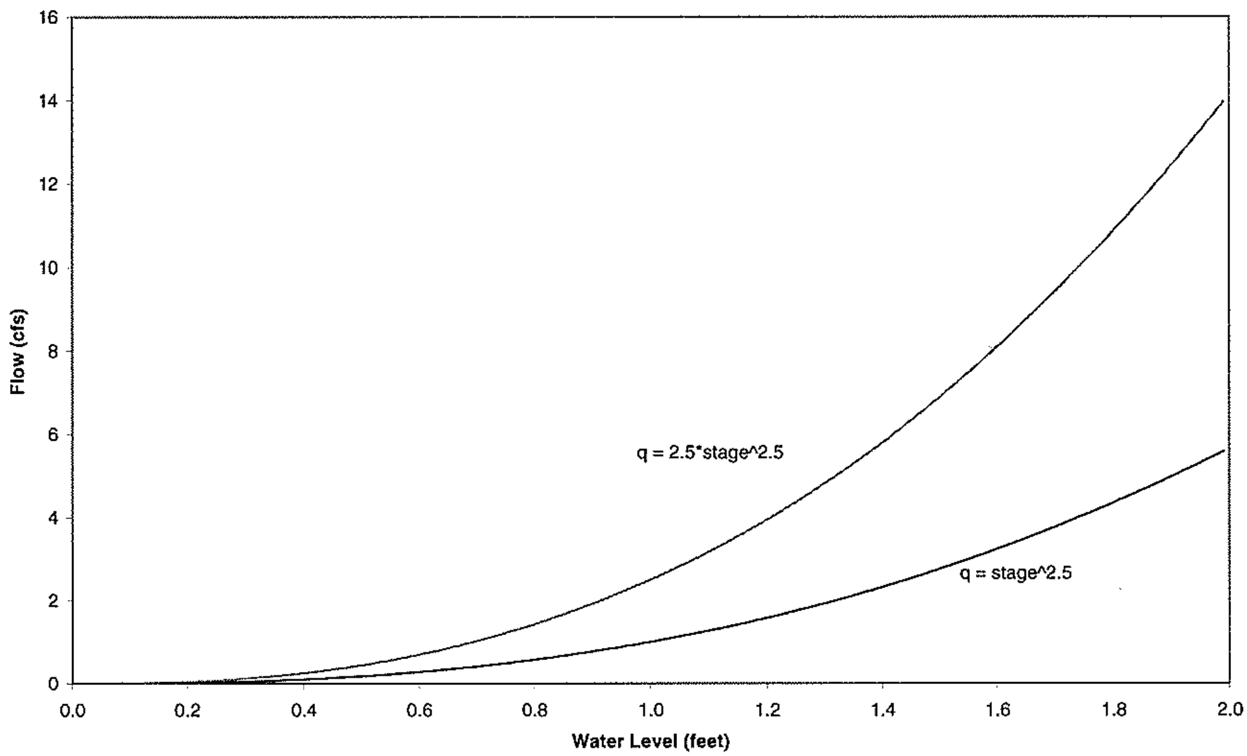
Storm 10 - Site KO020*



*Noise in flow values suspected to be caused by clogging due to sedimentation

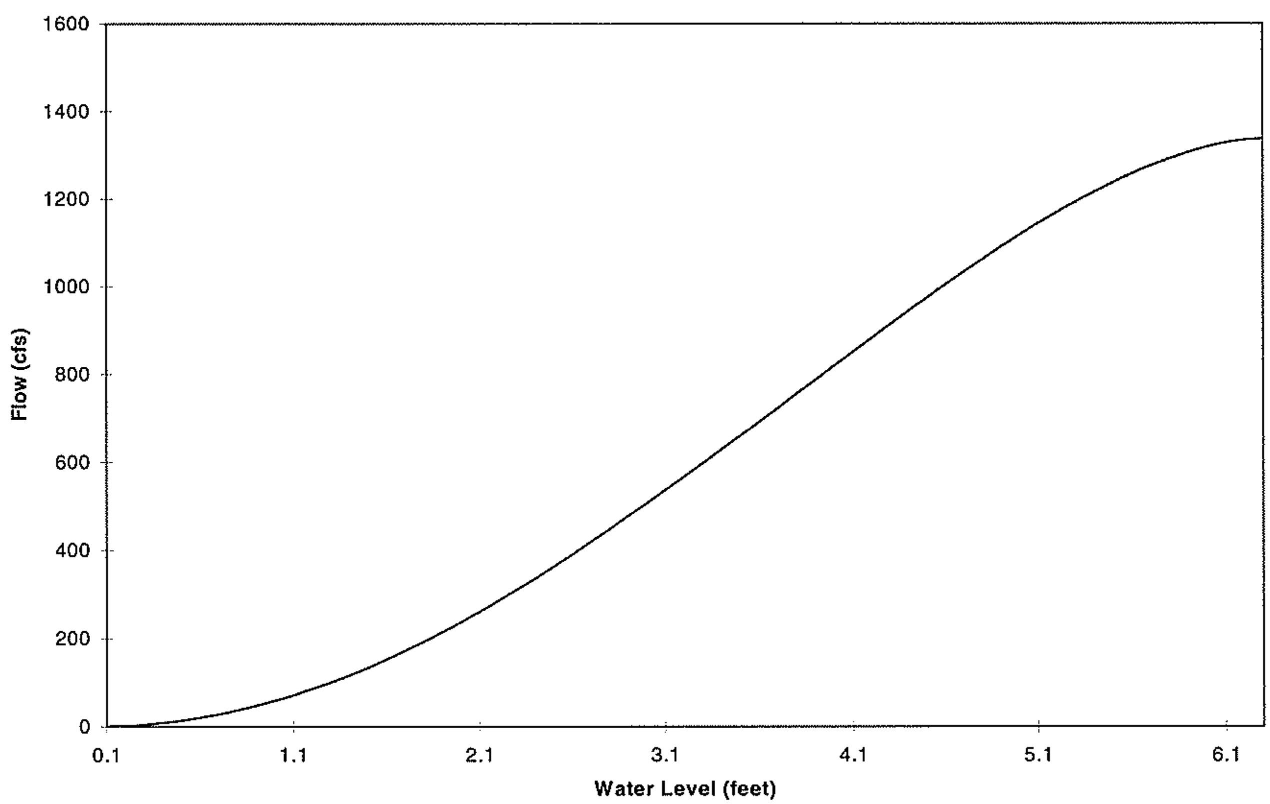
APPENDIX C: Plots of Rating Curve Equations for Each Sampling Site

DC010



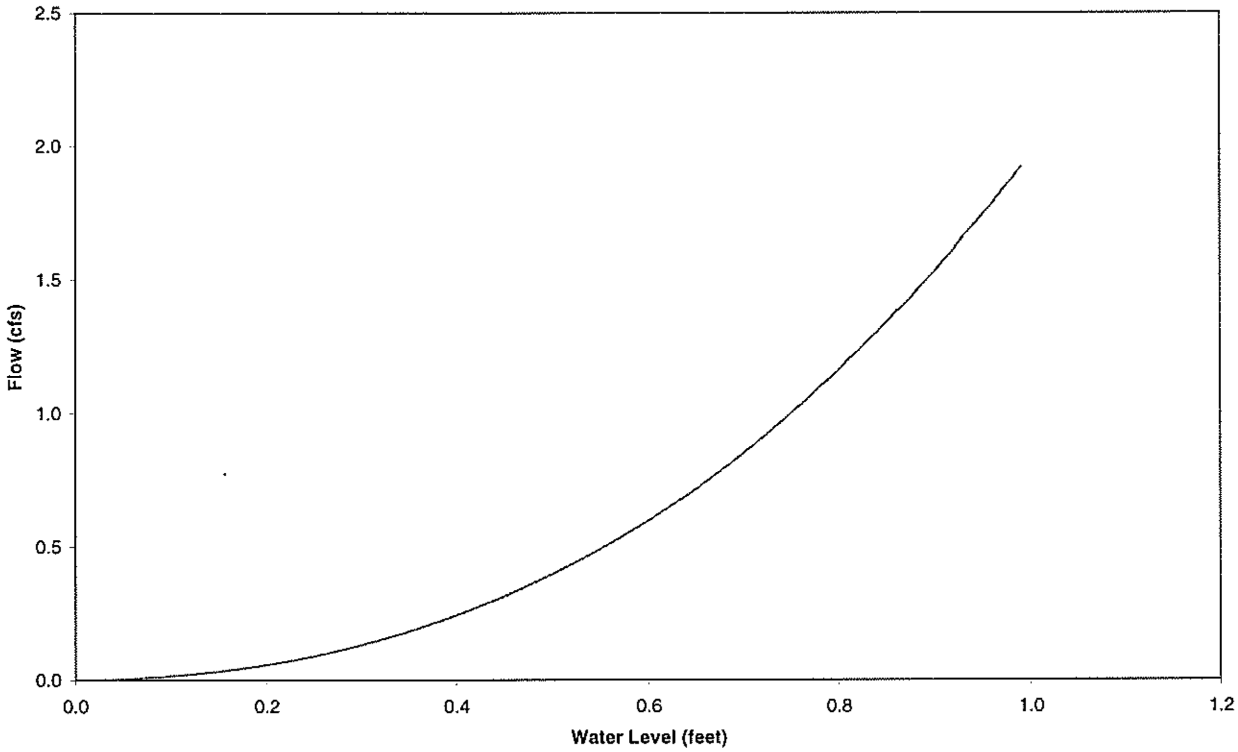
16
14
12
10
8
6
4
2
0
Flow (cfs)
q = 2.5*stage^2.5
q = stage^2.5
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
Water Level (feet)

DC020



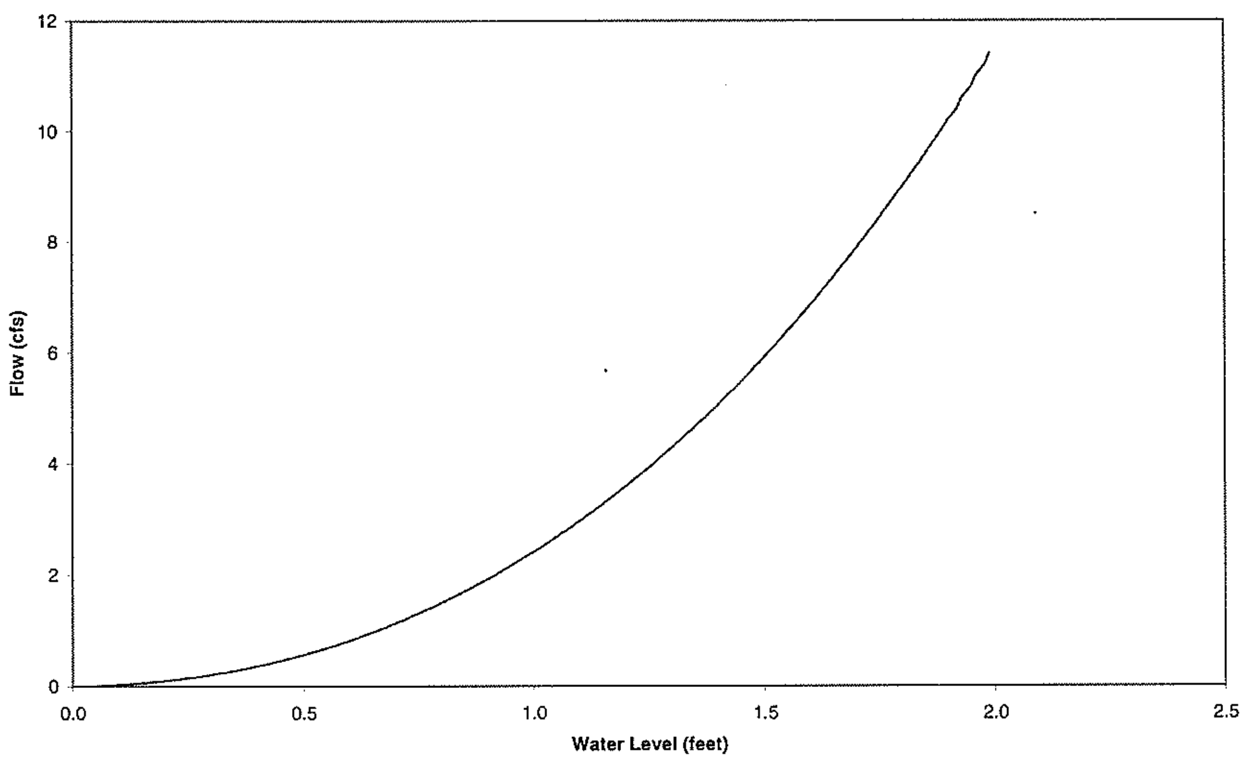
1600
1400
1200
1000
800
600
400
200
0
Flow (cfs)
0.1
1.1
2.1
3.1
4.1
5.1
6.1
Water Level (feet)

KO010



2.5
2.0
1.5
1.0
0.5
0.0
Flow (cfs)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
Water Level (feet)

KO020



12
10
8
6
4
2
0
Flow (cfs)
0.0
0.5
1.0
1.5
2.0
2.5
Water Level (feet)

APPENDIX D: Results for the Shapiro-Wilks and Hartley's F Tests

Table D-1. Shapiro-Wilks and Hartley's F-test P-Values for Storms at Sites DC010 and DC020.

The Shapiro-Wilks test evaluates normalcy of data distribution and indicates the need for $\log_{(e)}$ transformation. Hartley's F-test evaluates equality of variance between sites and indicates the need for $\log_{(e)}$ transformation.

Constitutent	Site	Volume Weighted Mean Non-Transformed	Volume Weighted Mean $\log_{(e)}$ Transformed	Mean Non-Transformed	Mean $\log_{(e)}$ Transformed	Median Non-Transformed	Median $\log_{(e)}$ Transformed
COD	Shapiro-Wilks Test (p-value)						
	DC010	0.27197	0.54909	0.87571	0.86985	0.31706	0.02164
	DC020	0.06788	0.95442	0.02149	0.71216	0.00011	0.03997
	D-Values	0.08633	0.40535	0.01485	0.11530	0.00005	0.00068
	Hartley's F-Test	0.00000	0.00220	0.00000	0.14700	0.00000	0.60540
NH_3-N	Shapiro-Wilks Test (p-value)						
	DC010	0.02267	0.03139	0.03731	0.10199	0.38777	0.91382
	DC020	0.00001	0.31453	0.00001	0.03510	0.00000	0.00218
	D-Values[1]	0.00001	0.06670	0.00001	0.56669	0.00000	0.26622
	Hartley's F-Test	0.00000	0.05500	0.00000	0.15420	0.00000	0.05810
NO_2-N	Shapiro-Wilks Test (p-value)						
	DC010	0.00002	0.27401	0.00003	0.03773	0.00000	0.00087
	DC020	0.00011	0.46234	0.00021	0.27741	0.00003	0.01858
	D-Values	0.00000	0.14147	0.00002	0.35165	0.00911	0.01705
	Hartley's F-Test	0.06430	0.32640	0.40530	0.65900	0.95410	0.95440
NO_{2+3}-N	Shapiro-Wilks Test (p-value)						
	DC010	0.73918	0.28625	0.11942	0.10078	0.73031	0.07810
	DC020	0.00086	0.54430	0.00995	0.18351	0.01561	0.77141
	D-Values	0.00133	0.12887	0.04395	0.36316	0.01893	0.03322
	Hartley's F-Test	0.00000	0.51590	0.0.0003	0.32360	0.00670	0.02650
NO_3-N	Shapiro-Wilks Test (p-value)						
	DC010	0.74831	0.96769	0.13589	0.66863	0.89347	0.00228
	DC020	0.00085	0.76806	0.00927	0.86398	0.01299	0.71567
	D-Values	0.00137	0.11961	0.04396	0.28973	0.01702	0.00266
	Hartley's F-Test	0.00000	0.70390	0.00040	0.21110	0.00930	0.00060
PO_4-P	Shapiro-Wilks Test (p-value)						
	DC010	0.01747	0.61342	0.00151	0.33582	0.04095	0.78717
	DC020	0.00049	0.02235	0.00001	0.06263	0.00003	0.00535
	D-Values	0.00061	0.71976	0.00001	0.34170	0.00001	0.16855
	Hartley's F-Test	0.00000	0.54430	0.00000	0.61340	0.00000	0.29440
TKN	Shapiro-Wilks Test (p-value)						
	DC010	0.05633	0.06001	0.00378	0.05567	0.00026	0.02668
	DC020	0.01831	0.19301	0.00003	0.27711	0.00003	0.19020
	D-Values	0.01949	0.00766	0.00004	0.02963	0.00004	0.16461
	Hartley's F-Test	0.00000	0.00510	0.00000	0.10600	0.00000	0.07340
Total N	Shapiro-Wilks Test (p-value)						
	DC010	0.07063	0.17788	0.00855	0.26388	0.00104	0.16468
	DC020	0.03060	0.15225	0.00005	0.00206	0.00002	0.01959
	D-Values	0.03357	0.02443	0.00008	0.05155	0.00004	0.11230
	Hartley's F-Test	0.00000	0.00700	0.00000	0.12330	0.00000	0.28990
Total P	Shapiro-Wilks Test (p-value)						
	DC010	0.37326	0.16294	0.66758	0.08049	0.73858	0.16899
	DC020	0.52612	0.26663	0.09964	0.08891	0.00728	0.08160
	D-Values	0.30644	0.03664	0.03528	0.16953	0.00168	0.00419
	Hartley's F-Test	0.00000	0.14920	0.00000	0.39080	0.00000	0.56380
TSS	Shapiro-Wilks Test (p-value)						
	DC010	0.00464	0.00020	0.01495	0.63697	0.00009	0.18467
	DC020	0.12617	0.06654	0.31778	0.78444	0.06969	0.86275
	D-Values	0.20469	0.68586	0.36803	0.31253	0.09173	0.13413
	Hartley's F-Test	0.00000	0.38290	0.00000	0.42300	0.00000	0.03030

[1] D-Values refer to the difference between values for the DC010 and DC020 sites. The D-Values are used in evaluation of the paired t-test. The p-values shown indicate the probability of the D-Values.being normally distributed.

Table D-2. Shapiro-Wilks and Hartley's F-test P-Values for Storms at Sites KO010 and KO020.

The Shapiro-Wilks test evaluates normalcy of data distribution and indicates the need for $\log_{(e)}$ transformation. Hartley's F-test evaluates equality of variance between sites and indicates the need for $\log_{(e)}$ transformation.

Constituent		Volume Weighted Mean Non-Transformed	Volume Weighted Mean $\log_{(e)}$ Transformed	Mean Non-Transformed	Mean $\log_{(e)}$ Transformed	Median Non-Transformed	Median $\log_{(e)}$ Transformed
COD	Shapiro-Wilks Test (p-value)						
	KO010	0.64939	0.74604	0.96687	0.75463	0.43656	0.33541
	KO020	0.25343	0.04850	0.54332	0.09579	0.51868	0.20836
	D-Values[1]	0.55196	0.92801	0.92036	0.83934	0.54857	0.74652
	Hartley's F-Test	0.00000	0.41460	0.00000	0.28250	0.00000	0.75030
NH_3-N	Shapiro-Wilks Test (p-value)						
	KO010	0.00076	0.56105	0.00072	0.67993	0.00026	0.52454
	KO020	0.32406	0.03135	0.19529	0.29226	0.00318	0.05838
	D-Values	0.00166	0.43914	0.00139	0.66276	0.00066	0.41434
	Hartley's F-Test	0.00000	0.23320	0.00000	0.37460	0.00000	0.13290
NO_2-N	Shapiro-Wilks Test (p-value)						
	KO010	0.00834	0.88084	0.14415	0.88925	0.03120	0.71137
	KO020	0.04507	0.29722	0.17994	0.31828	0.01291	0.31154
	D-Values	0.00771	0.86543	0.13420	0.34594	0.01337	0.26652
	Hartley's F-Test	0.00000	0.66720	0.00000	0.85560	0.00000	0.61090
NO_{2+3}-N	Shapiro-Wilks Test (p-value)						
	KO010	0.00377	0.30915	0.01459	0.22198	0.00592	0.46407
	KO020	0.00389	0.27691	0.01225	0.12291	0.00844	0.04901
	D-Values	0.14184	0.95042	0.12505	0.89917	0.13605	0.94096
	Hartley's F-Test	0.02150	0.52320	0.00040	0.16770	0.00530	0.11330
NO_3-N	Shapiro-Wilks Test (p-value)						
	KO010	0.00304	0.22090	0.01137	0.17659	0.00290	0.42469
	KO020	0.00392	0.30593	0.01314	0.14356	0.00925	0.05905
	D-Values	0.18421	0.96675	0.12298	0.89697	0.12581	0.96615
	Hartley's F-Test	0.02440	0.49040	0.00040	0.15020	0.00590	0.10270
PO_4-P	Shapiro-Wilks Test (p-value)						
	KO010	0.26607	0.69120	0.72246	0.67966	0.67022	0.68554
	KO020	0.94056	0.43563	0.28982	0.80615	0.07605	0.97395
	D-Values	0.26852	0.37157	0.41375	0.45706	0.39823	0.49660
	Hartley's F-Test	0.95470	0.01910	0.43710	0.07510	0.32480	0.11600
TKN	Shapiro-Wilks Test (p-value)						
	KO010	0.00172	0.81100	0.00129	0.63384	0.00043	0.63598
	KO020	0.08226	0.00756	0.96472	0.17036	0.10471	0.68311
	D-Values	0.00197	0.23298	0.00286	0.46696	0.00082	0.63395
	Hartley's F-Test	0.00000	0.94350	0.00000	0.60910	0.00000	0.73980
Total N	Shapiro-Wilks Test (p-value)						
	KO010	0.00558	0.86740	0.00534	0.63870	0.00151	0.71760
	KO020	0.04984	0.01381	0.79257	0.17298	0.10731	0.55967
	D-Values	0.00681	0.39296	0.01144	0.56907	0.00301	0.64443
	Hartley's F-Test	0.00000	0.85220	0.00000	0.47470	0.00000	0.56510
Total P	Shapiro-Wilks Test (p-value)						
	KO010	0.67866	0.98015	0.95648	0.96503	0.51472	0.62677
	KO020	0.81295	0.31227	0.23437	0.70081	0.51369	0.63643
	D-Values	0.80111	0.76540	0.40450	0.51916	0.45664	0.68882
	Hartley's F-Test	0.43210	0.02490	0.24840	0.03830	0.11370	0.07560
TSS	Shapiro-Wilks Test (p-value)						
	KO010	0.00013	0.38302	0.00012	0.32577	0.00062	0.43765
	KO020	0.58196	0.98261	0.00003	0.02797	0.18740	0.53022
	D-Values	0.00006	0.18754	0.00014	0.78300	0.00023	0.49498
	Hartley's F-Test	0.00000	0.03410	0.00340	0.95470	0.00000	0.13950

[1] D-Values refer to the difference between values for the KO010 and KO020 sites. The D-Values are used in evaluation of the paired t-test. The p-values shown indicate the probability of the D-Values being normally distributed.

Appendix E: Regression Relationships Between Sites for All Constituents

Table E-1 Beezley Dairy Sites

Measure of Central Tendency	Transformation	Constituent	Regression equation	R Square	Standard Deviation of the Slope
VWM	None	COD	DC010 = 68.28 - 0.01 *DC020	-0.0191	-0.010367
VWM	None	NH_3-N	DC010 = 0.24 + 0.01 *DC020	0.1105	0.008084
VWM	None	NO_2-N	DC010 = 0.005 + 0.32 *DC020	0.3216	0.324395
VWM	None	NO_{2+3}-N	DC010 = 0.54 - 0.04 *DC020	0.0596	-0.038598
VWM	None	NO_3-N	DC010 = 0.53 - 0.04 *DC020	0.0604	-0.040293
VWM	None	PO_4-P	DC010 = 0.31 - 0.02 *DC020	0.0319	-0.024237
VWM	None	TKN	DC010 = 2.82 - 0.02 *DC020	0.0733	-0.015877
VWM	None	Total N	DC010 = 3.38 - 0.02 *DC020	0.0796	-0.018708
VWM	None	Total P	DC010 = 0.73 - 0.04 *DC020	0.1234	-0.039457
VWM	None	TSS	DC010 = 84.28 + 0.01 *DC020	0.0237	0.009506
VWM	$Log_{(e)}$	COD	ln(DC010) = 4.88 - 0.13 *ln(DC020)	0.1148	-0.129594
VWM	$Log_{(e)}$	NH_3-N	ln(DC010) = -1.52 + 0.03 *ln(DC020)	0.0027	0.028823
VWM	$Log_{(e)}$	NO_2-N	ln(DC010) = -2.28 + 0.57 *ln(DC020)	0.5770	0.567693
VWM	$Log_{(e)}$	NO_{2+3}-N	ln(DC010) = -0.83 - 0.2 *ln(DC020)	0.0470	-0.178822
VWM	$Log_{(e)}$	NO_3-N	ln(DC010) = -0.87 - 0.20 *ln(DC020)	0.0503	-0.200397
VWM	$Log_{(e)}$	PO_4-P	ln(DC010) = -1.40 - 0.24 *ln(DC020)	0.0853	-0.244141
VWM	$Log_{(e)}$	TKN	ln(DC010) = 1.30 - 0.16 *ln(DC020)	0.1436	-0.158404
VWM	$Log_{(e)}$	Total N	ln(DC010) = 1.54 - 0.17 *ln(DC020)	0.1584	-0.172484
VWM	$Log_{(e)}$	Total P	ln(DC010) = -0.39 - 0.25 *ln(DC020)	0.1501	-0.251638
VWM	$Log_{(e)}$	TSS	ln(DC010) = 4.45 - 0.04 *ln(DC020)	0.0022	-0.036183
Mean	None	COD	DC010 = 84.73 - 0.07 *DC020	0.2752	-0.075321
Mean	None	NH_3-N	DC010 = 0.26 + 0.001 *DC020	0.0079	0.001887
Mean	None	NO_2-N	DC010 = 0.001 + 0.66 *DC020	0.7066	0.656941
Mean	None	NO_{2+3}-N	DC010 = 0.61 - 0.07 *DC020	0.0557	-0.073668
Mean	None	NO_3-N	DC010 = 0.59 - 0.07 *DC020	0.0559	-0.076080
Mean	None	PO_4-P	DC010 = 0.29 - 0.01 *DC020	0.0074	-0.011803
Mean	None	TKN	DC010 = 2.83 - 0.02 *DC020	0.0774	-0.020120
Mean	None	Total N	DC010 = 3.46 - 0.03 *DC020	0.0982	-0.025964
Mean	None	Total P	DC010 = 0.64 - 0.04 *DC020	0.0771	-0.037575
Mean	None	TSS	DC010 = 29.08 + 0.05 *DC020	0.2217	0.046511

* VWM = volume-weighted mean

Measure of Central Tendency	Transformation	Constituent	Regression equation			R Square	Standard Deviation of the Slope
Mean	$Log_{(e)}$	COD	ln(DC010) =	6.12 -	0.36 *ln(DC020)	0.3056	-0.358229
Mean	$Log_{(e)}$	NH_3-N	ln(DC010) =	-1.56 +	0.05 *ln(DC020)	0.0061	0.050986
Mean	$Log_{(e)}$	NO_2-N	ln(DC010) =	-1.47 +	0.73 *ln(DC020)	0.6942	0.731432
Mean	$Log_{(e)}$	NO_{2+3}-N	ln(DC010) =	-0.79 -	0.28 *ln(DC020)	0.0448	-0.283765
Mean	$Log_{(e)}$	NO_3-N	ln(DC010) =	-0.83 -	0.32 *ln(DC020)	0.0479	-0.317558
Mean	$Log_{(e)}$	PO_4-P	ln(DC010) =	-1.51 -	0.01 *ln(DC020)	0.0002	-0.014904
Mean	$Log_{(e)}$	TKN	ln(DC010) =	1.31 -	0.17 *ln(DC020)	0.0802	-0.174311
Mean	$Log_{(e)}$	Total N	ln(DC010) =	1.62 -	0.21 *ln(DC020)	0.1145	-0.213187
Mean	$Log_{(e)}$	Total P	ln(DC010) =	-0.24 -	0.44 *ln(DC020)	0.1145	-0.436308
Mean	$Log_{(e)}$	TSS	ln(DC010) =	-0.03 +	0.59 *ln(DC020)	0.2161	0.589368
Median	None	COD	DC010 =	80.78 -	0.09 *DC020	0.3443	-0.089704
Median	None	NH_3-N	DC010 =	0.21 +	0.002 *DC020	0.0269	0.002220
Median	None	NO_2-N	DC010 =	-0.001 +	0.99 *DC020	0.9388	0.985479
Median	None	NO_{2+3}-N	DC010 =	0.64 -	0.14 *DC020	0.1090	-0.142301
Median	None	NO_3-N	DC010 =	0.63 -	0.15 *DC020	0.1068	-0.146269
Median	None	PO_4-P	DC010 =	0.21 +	0.001 *DC020	0.0000	0.000875
Median	None	TKN	DC010 =	2.79 -	0.03 *DC020	0.0838	-0.025503
Median	None	Total N	DC010 =	3.42 -	0.03 *DC020	0.1144	-0.034738
Median	None	Total P	DC010 =	0.48 -	0.02 *DC020	0.0497	-0.020329
Median	None	TSS	DC010 =	-22.25 +	0.08 *DC020	0.3892	0.083315
Median	$Log_{(e)}$	COD	ln(DC010) =	6.96 -	0.55 *ln(DC020)	0.4045	-0.546033
Median	$Log_{(e)}$	NH_3-N	ln(DC010) =	-1.72 +	0.09 *ln(DC020)	0.0286	0.095420
Median	$Log_{(e)}$	NO_2-N	ln(DC010) =	-1.19 +	0.80 *ln(DC020)	0.6620	0.800035
Median	$Log_{(e)}$	NO_{2+3}-N	ln(DC010) =	-0.95 -	0.56 *ln(DC020)	0.0820	-0.563622
Median	$Log_{(e)}$	NO_3-N	ln(DC010) =	-1.13 -	0.72 *ln(DC020)	0.0579	-0.723847
Median	$Log_{(e)}$	PO_4-P	ln(DC010) =	-1.73 +	0.06 *ln(DC020)	0.0022	0.064196
Median	$Log_{(e)}$	TKN	ln(DC010) =	1.29 -	0.21 *ln(DC020)	0.1318	-0.211610
Median	$Log_{(e)}$	Total N	ln(DC010) =	1.81 -	0.33 *ln(DC020)	0.2071	-0.332309
Median	$Log_{(e)}$	Total P	ln(DC010) =	-0.79 -	0.17 *ln(DC020)	0.0387	-0.165955
Median	$Log_{(e)}$	TSS	ln(DC010) =	-5.77 +	1.36 *ln(DC020)	0.4938	1.359130

Table E-2 Coke Dairy Sites

Measure of Central Tendency	Transformation	Const	Regression Equation	R Square	Standard Deviation of the Slope
VWM*	None	COD	KO010 = 985.64 - 1.54 *KO020	0.1062	-1.538297
VWM	None	NH_3-N	KO010 = 97.12 - 4.17 *KO020	0.3001	-4.162527
VWM	None	NO_2-N	KO010 = 0.04 + 6.28 *KO020	0.4179	6.276772
VWM	None	NO_{2+3}-N	KO010 = 0.72 + 1.53 *KO020	0.3991	1.533278
VWM	None	NO_3-N	KO010 = 0.70 + 1.46 *KO020	0.3786	1.463140
VWM	None	PO_4-P	KO010 = 15.44 + 0.64 *KO020	0.3922	0.638534
VWM	None	TKN	KO010 = 231.51 - 5.02 *KO020	0.3596	-5.018879
VWM	None	Total N	KO010 = 241.67 - 4.95 *KO020	0.3503	-4.949098
VWM	None	Total P	KO010 = 41.21 - 0.28 *KO020	0.0460	-0.281112
VWM	None	TSS	KO010 = 24.99 + 4.82 *KO020	0.1051	4.820798
VWM	$Log_{(e)}$	COD	ln(KO010) = 8.39 - 0.39 *ln(KO020)	0.0849	-0.386110
VWM	$Log_{(e)}$	NH_3-N	ln(KO010) = 4.42 - 0.39 *ln(KO020)	0.3798	-0.396361
VWM	$Log_{(e)}$	NO_2-N	ln(KO010) = 0.31 + 0.57 *ln(KO020)	0.4394	0.566465
VWM	$Log_{(e)}$	NO_{2+3}-N	ln(KO010) = 0.54 + 0.59 *ln(KO020)	0.2229	0.596554
VWM	$Log_{(e)}$	NO_3-N	ln(KO010) = 0.46 + 0.57 *ln(KO020)	0.1974	0.572029
VWM	$Log_{(e)}$	PO_4-P	ln(KO010) = 2.51 + 0.26 *ln(KO020)	0.3582	0.256980
VWM	$Log_{(e)}$	TKN	ln(KO010) = 5.96 - 0.53 *ln(KO020)	0.2929	-0.528254
VWM	$Log_{(e)}$	Total N	ln(KO010) = 6.14 - 0.56 *ln(KO020)	0.2751	-0.561400
VWM	$Log_{(e)}$	Total P	ln(KO010) = 3.79 - 0.08 *ln(KO020)	0.0338	-0.082131
VWM	$Log_{(e)}$	TSS	ln(KO010) = 0.29 + 1.26 *ln(KO020)	0.3497	1.261067
Mean	None	COD	KO010 = 1426.66 - 4.29 *KO020	0.4692	-4.292014
Mean	None	NH_3-N	KO010 = 98.74 - 5.05 *KO020	0.2739	-5.054598
Mean	None	NO_2-N	KO010 = 0.04 + 8.16 *KO020	0.5190	8.158904
Mean	None	NO_{2+3}-N	KO010 = 1.39 + 2.29 *KO020	0.2745	2.297713
Mean	None	NO_3-N	KO010 = 1.35 + 2.24 *KO020	0.2655	2.242382
Mean	None	PO_4-P	KO010 = 19.07 + 0.54 *KO020	0.1721	0.542289
Mean	None	TKN	KO010 = 270.89 - 7.89 *KO020	0.4069	-7.886325
Mean	None	Total N	KO010 = 292.66 - 8.01 *KO020	0.4150	-8.012232
Mean	None	Total P	KO010 = 46.47 - 0.58 *KO020	0.1513	-0.580725
Mean	None	TSS	KO010 = 242.26 + 0.55 *KO020	0.0341	0.547947

* VWM = volume-weighted mean

Measure of Central Tendency	Transformation	Const	Regression Equation	R Square	Standard Deviation of the Slope
Mean	$Log_{(e)}$	COD	ln(KO010) = 11.09 - 0.92 *ln(KO020)	0.3989	-0.916508
Mean	$Log_{(e)}$	NH_3-N	ln(KO010) = 4.59 - 0.54 *ln(KO020)	0.5693	-0.544310
Mean	$Log_{(e)}$	NO_2-N	ln(KO010) = 0.78 + 0.65 *ln(KO020)	0.4767	0.646111
Mean	$Log_{(e)}$	NO_{2+3}-N	ln(KO010) = 0.79 + 0.69 *ln(KO020)	0.1754	0.699886
Mean	$Log_{(e)}$	NO_3-N	ln(KO010) = 0.73 + 0.69 *ln(KO020)	0.1641	0.692837
Mean	$Log_{(e)}$	PO_4-P	ln(KO010) = 2.67 + 0.23 *ln(KO020)	0.1793	0.225866
Mean	$Log_{(e)}$	TKN	ln(KO010) = 6.76 - 0.82 *ln(KO020)	0.4713	-0.818399
Mean	$Log_{(e)}$	Total N	ln(KO010) = 7.02 - 0.86 *ln(KO020)	0.4404	-0.862493
Mean	$Log_{(e)}$	Total P	ln(KO010) = 4.15 - 0.22 *ln(KO020)	0.2038	-0.215568
Mean	$Log_{(e)}$	TSS	ln(KO010) = 3.15 + 0.54 *ln(KO020)	0.2774	0.537024
Median	None	COD	KO010 = 1221.03 - 3.35 *KO020	0.4065	-3.348108
Median	None	NH_3-N	KO010 = 82.61 - 3.21 *KO020	0.1198	-3.211966
Median	None	NO_2-N	KO010 = 0.09 + 3.28 *KO020	0.0587	3.280794
Median	None	NO_{2+3}-N	KO010 = 1.04 + 1.21 *KO020	0.1613	1.209392
Median	None	NO_3-N	KO010 = 1.01 + 1.09 *KO020	0.1349	1.090238
Median	None	PO_4-P	KO010 = 21.45 + 0.43 *KO020	0.0917	0.425734
Median	None	TKN	KO010 = 223.11 - 6.13 *KO020	0.2143	-6.127426
Median	None	Total N	KO010 = 240.29 - 6.28 *KO020	0.2155	-6.280637
Median	None	Total P	KO010 = 46.59 - 0.58 *KO020	0.1109	-0.580032
Median	None	TSS	KO010 = -124.62 + 7.00 *KO020	0.5061	7.004424
Median	$Log_{(e)}$	COD	ln(KO010) = 9.67 - 0.66 *ln(KO020)	0.3469	-0.656882
Median	$Log_{(e)}$	NH_3-N	ln(KO010) = 3.93 - 0.27 *ln(KO020)	0.2317	-0.274571
Median	$Log_{(e)}$	NO_2-N	ln(KO010) = 0.41 + 0.59 *ln(KO020)	0.2466	0.598198
Median	$Log_{(e)}$	NO_{2+3}-N	ln(KO010) = 0.22 + 0.49 *ln(KO020)	0.0744	0.493561
Median	$Log_{(e)}$	NO_3-N	ln(KO010) = 0.08 + 0.42 *ln(KO020)	0.0521	0.421141
Median	$Log_{(e)}$	PO_4-P	ln(KO010) = 2.72 + 0.23 *ln(KO020)	0.1538	0.225965
Median	$Log_{(e)}$	TKN	ln(KO010) = 6.33 - 0.74 *ln(KO020)	0.4370	-0.740823
Median	$Log_{(e)}$	Total N	ln(KO010) = 6.55 - 0.78 *ln(KO020)	0.4007	-0.781352
Median	$Log_{(e)}$	Total P	ln(KO010) = 4.12 - 0.21 *ln(KO020)	0.1523	-0.208444
Median	$Log_{(e)}$	TSS	ln(KO010) = 0.24 + 1.29 *ln(KO020)	0.5881	1.286049

Appendix F: Basic Statistics Across Storms for Each Site Using Non-Transformed and Natural-Log Transformed Values

Table F-1. Non-$log_{(e)}$ transformed values using the storm volume-weighted mean across storm events for sites DC010 and DC020.

Site	Constituent*	Mean	Median	Std Dev	Minimum	Maximum	n
DC010	COD	64.615	61	16.215	43	93	13
DC020	COD	353.615	307	215.980	74	784	13
DC010	NH_3-N	0.283	0.25	0.210	0.06	0.81	13
DC020	NH_3-N	5.415	2.36	8.638	0.15	29.45	13
DC010	NO_2-N	0.010	0.006	0.012	0.003	0.047	13
DC020	NO_2-N	0.016	0.006	0.021	0.003	0.073	13
DC010	NO_{2+3}	0.472	0.48	0.225	0.132	0.834	13
DC020	NO_{2+3}	1.682	1.188	1.423	0.423	5.406	13
DC010	NO_3-N	0.461	0.48	0.231	0.11	0.83	13
DC020	NO_3-N	1.665	1.18	1.409	0.41	5.33	13
DC010	PO_4-P	0.272	0.2	0.182	0.1	0.68	13
DC020	PO_4-P	1.715	1.62	1.340	0.24	5.77	13
DC010	TKN	2.482	2.29	0.882	1.57	4.59	13
DC020	TKN	21.335	16.92	15.039	2.37	62.36	13
DC010	Total N	2.952	2.598	1.016	1.857	5.376	13
DC020	Total N	23.016	18.15	15.324	3.26	63.69	13
DC010	Total P	0.522	0.48	0.268	0.19	1.13	13
DC020	Total P	5.282	5.05	2.389	0.37	10.05	13
DC010	TSS	103.462	50	103.988	11	336	13
DC020	TSS	2017.462	1578	1684.856	49	5613	13

Table F-2. Geometric mean and standard deviation for natural-log$_{(e)}$ transformed storm volume-weighted mean values for sites DC010 and DC020.

Site	Constituent*	Geometric Mean	Lower Std Dev	Upper std Dev	n
DC010	COD	62.816	49.127	80.321	13
DC020	COD	296.433	155.867	563.763	13
DC010	NH_3-N	0.225	0.111	0.458	13
DC020	NH_3-N	2.486	0.699	8.845	13
DC010	NO_2-N	0.007	0.003	0.015	13
DC020	NO_2-N	0.009	0.003	0.025	13
DC010	NO_{2+3}	0.414	0.234	0.733	13
DC020	NO_{2+3}	1.313	0.658	2.621	13
DC010	NO_3-N	0.396	0.213	0.737	13
DC020	NO_3-N	1.298	0.649	2.599	13
DC010	PO_4-P	0.228	0.124	0.417	13
DC020	PO_4-P	1.368	0.663	2.821	13
DC010	TKN	2.356	1.700	3.266	13
DC020	TKN	16.880	7.734	36.843	13
DC010	Total N	2.810	2.058	3.850	13
DC020	Total N	18.700	9.083	38.480	13
DC010	Total P	0.462	0.274	0.779	13
DC020	Total P	4.408	1.971	9.860	13
DC010	TSS	66.236	24.380	179.951	13
DC020	TSS	1226.835	336.241	4476.324	13

Table F-3. Non-$\log_{(e)}$ transformed values using the storm mean across storm events for sites DC010 and DC020.

Site	Constituent*	Mean	Median	Std Dev	Minimum	Maximum	n
DC010	COD	64.740	64	15.701	37.33	93.91	13
DC020	COD	265.369	246.45	109.351	130.33	564	13
DC010	NH_3-N	0.269	0.221	0.175	0.079	0.603	13
DC020	NH_3-N	5.300	2.238	8.263	0.808	30.733	13
DC010	NO_2-N	0.010	0.006	0.012	0.003	0.046	13
DC020	NO_2-N	0.014	0.007	0.015	0.004	0.05	13
DC010	NO_{2+3}-N	0.496	0.592	0.253	0.117	0.844	13
DC020	NO_{2+3}-N	1.488	1.267	0.811	0.648	3.072	13
DC010	NO_3-N	0.485	0.587	0.259	0.098	0.841	13
DC020	NO_3-N	1.474	1.26	0.804	0.638	3.032	13
DC010	PO_4-P	0.268	0.193	0.206	0.104	0.836	13
DC020	PO_4-P	1.721	1.173	1.501	0.901	6.543	13
DC010	TKN	2.478	2.064	1.032	1.616	5.315	13
DC020	TKN	17.304	14.832	14.268	6.666	62.5	13
DC010	Total N	2.974	2.511	1.186	1.855	6.106	13
DC020	Total N	18.792	16.272	14.315	7.494	63.813	13
DC010	Total P	0.488	0.474	0.216	0.155	0.861	13
DC020	Total P	4.033	3.884	1.595	1.933	7.973	13
DC010	TSS	87.791	46.83	77.360	12.93	257.53	13
DC020	TSS	1262.240	1122.31	783.207	213.33	3174.44	13

Table F-4. Geometric mean and standard deviation for natural-log$_{(e)}$ transformed storm mean values for sites DC010 and DC020.

Site	Constituent*	Geometric Mean	Lower Std Dev	Upper Std Dev	n
DC010	COD	62.964	49.112	80.721	13
DC020	COD	247.623	168.763	363.332	13
DC010	NH_3-N	0.222	0.117	0.424	13
DC020	NH_3-N	2.915	1.088	7.808	13
DC010	NO_2-N	0.007	0.003	0.016	13
DC020	NO_2-N	0.009	0.004	0.022	13
DC010	NO_{2+3}-N	0.419	0.217	0.809	13
DC020	NO_{2+3}-N	1.322	0.809	2.159	13
DC010	NO_3-N	0.401	0.196	0.818	13
DC020	NO_3-N	1.309	0.801	2.140	13
DC010	PO_4-P	0.220	0.119	0.407	13
DC020	PO_4-P	1.439	0.847	2.445	13
DC010	TKN	2.328	1.643	3.298	13
DC020	TKN	14.424	8.190	25.404	13
DC010	Total N	2.800	1.992	3.940	13
DC020	Total N	15.970	9.284	27.460	13
DC010	Total P	0.440	0.269	0.720	13
DC020	Total P	3.769	2.575	5.518	13
DC010	TSS	61.758	25.333	150.556	13
DC020	TSS	1035.862	512.925	2091.947	13

Table F-5. Non-$log_{(e)}$ transformed values using the storm median across storm events for sites DC010 andDC020.

Site	Constituent*	Mean	Median	Std Dev	Minimum	Maximum	n
DC010	COD	61.577	57	17.237	24	87	13
DC020	COD	214.077	192	112.754	116	564	13
DC010	NH_3-N	0.226	0.21	0.119	0.07	0.47	13
DC020	NH_3-N	5.212	2.07	8.789	1.04	32.3	13
DC010	NO_2-N	0.009	0.003	0.013	0.003	0.05	13
DC020	NO_2-N	0.010	0.006	0.013	0.003	0.05	13
DC010	NO_{2+3}-N	0.455	0.5	0.269	0.06	0.93	13
DC020	NO_{2+3}-N	1.282	1.24	0.625	0.55	2.98	13
DC010	NO_3-N	0.441	0.48	0.277	0.008	0.93	13
DC020	NO_3-N	1.266	1.23	0.618	0.54	2.96	13
DC010	PO_4-P	0.208	0.17	0.122	0.075	0.465	13
DC020	PO_4-P	1.491	1.21	0.859	0.9	4.19	13
DC010	TKN	2.409	1.84	1.321	1.3	6.32	13
DC020	TKN	14.770	10.6	14.994	2.88	61.9	13
DC010	Total N	2.858	2.323	1.529	1.348	7.283	13
DC020	Total N	16.260	11.033	14.882	6.702	63.24	13
DC010	Total P	0.413	0.37	0.162	0.12	0.685	13
DC020	Total P	3.254	2.84	1.783	0.72	8.3	13
DC010	TSS	45.308	18	64.778	5	226	13
DC020	TSS	810.846	629	485.046	208	1980	13

Table F-6. Geometric mean and standard deviation for natural-log$_{(e)}$ transformed storm median values for sites DC010 and DC020.

Site	Constituent*	Geometric Mean	Lower Std Dev	Upper Std Dev	n
DC010	COD	58.890	42.219	82.144	13
DC020	COD	196.930	133.647	290.179	13
DC010	NH_3-N	0.196	0.112	0.343	13
DC020	NH_3-N	2.707	1.014	7.223	13
DC010	NO_2-N	0.005	0.002	0.013	13
DC020	NO_2-N	0.006	0.003	0.016	13
DC010	NO_{2+3}-N	0.352	0.150	0.825	13
DC020	NO_{2+3}-N	1.171	0.763	1.798	13
DC010	NO_3-N	0.291	0.080	1.059	13
DC020	NO_3-N	1.156	0.753	1.776	13
DC010	PO_4-P	0.181	0.105	0.312	13
DC020	PO_4-P	1.358	0.910	2.028	13
DC010	TKN	2.191	1.446	3.321	13
DC020	TKN	11.205	5.492	22.861	13
DC010	Total N	2.598	1.699	3.970	13
DC020	Total N	13.216	7.388	23.640	13
DC010	Total P	0.379	0.239	0.603	13
DC020	Total P	2.863	1.654	4.957	13
DC010	TSS	22.716	7.289	70.791	13
DC020	TSS	694.008	385.601	1249.081	13

Table F-7. Non-log transformed values using the storm volume-weighted mean across storm events for sites KO010 and KO020.

Site	Constituent*	Mean	Median	Std Dev	Minimum	Maximum	n
KO010	COD	670.600	649.5	352.548	209	1236	10
KO020	COD	204.800	236.5	74.702	81	322	10
KO010	NH_3-N	55.140	44.16	55.440	11.09	196.3	9
KO020	NH_3-N	10.084	10.87	7.296	0.79	19.47	9
KO010	NO_2-N	0.123	0.099	0.102	0.027	0.372	9
KO020	NO_2-N	0.013	0.011	0.011	0.003	0.03	9
KO010	NO_{2+3}-N	2.580	1.163	2.906	0.405	8.532	9
KO020	NO_{2+3}-N	1.213	0.637	1.197	0.356	3.967	9
KO010	NO_3-N	2.458	1.06	2.834	0.38	8.16	9
KO020	NO_3-N	1.200	0.63	1.192	0.34	3.94	9
KO010	PO_4-P	23.137	22.145	6.246	14.43	33.5	10
KO020	PO_4-P	12.057	12.445	6.126	3.35	23.42	10
KO010	TKN	110.347	77.68	104.442	21.17	384.8	10
KO020	TKN	24.142	28.005	12.479	3.73	37.06	10
KO010	Total N	116.948	87.32	109.375	22.21	385.62	9
KO020	Total N	25.201	30.38	13.080	4.54	38.35	9
KO010	Total P	36.932	35.5	10.164	23.21	58.31	10
KO020	Total P	15.229	15.61	7.752	4.87	29.62	10
KO010	TSS	299.300	190	356.216	59	1276	10
KO020	TSS	56.900	54.5	23.951	27	106	10

Table F-8. Geometric mean and standard deviation for natural-log transformed storm volume weighted mean values for sites KO010 and KO020.

Site	Constituent*	Geometric Mean	Lower Std Dev	Upper Std Dev	n
KO010	COD	580.801	321.786	1048.308	10
KO020	COD	189.502	121.333	295.971	10
KO010	NH_3-N	40.070	17.711	90.655	9
KO020	NH_3-N	6.252	1.757	22.254	9
KO010	NO_2-N	0.095	0.045	0.202	9
KO020	NO_2-N	0.009	0.004	0.022	9
KO010	NO_{2+3}-N	1.575	0.570	4.355	9
KO020	NO_{2+3}-N	0.873	0.390	1.952	9
KO010	NO_3-N	1.457	0.513	4.140	9
KO020	NO_3-N	0.860	0.382	1.934	9
KO010	PO_4-P	22.419	17.218	29.191	10
KO020	PO_4-P	10.416	5.634	19.259	10
KO010	TKN	81.499	36.447	182.240	10
KO020	TKN	19.332	8.475	44.098	10
KO010	Total N	85.501	37.063	197.240	9
KO020	Total N	20.515	9.395	44.800	9
KO010	Total P	35.734	27.273	46.821	10
KO020	Total P	13.189	7.205	24.143	10
KO010	TSS	199.352	81.428	488.052	10
KO020	TSS	52.610	34.571	80.061	10

Table F-9. Non-log transformed values using the storm mean across storm events for sites KO010 and KO020.

Site	Constituent*	Mean	Median	Std Dev	Minimum	Maximum	n
KO010	COD	695.560	689.351	328.512	223.083	1291.875	10
KO020	COD	170.340	182.471	52.430	73.429	234.364	10
KO010	NH_3-N	60.314	45.52	63.524	11.37	222.556	9
KO020	NH_3-N	7.602	5.275	6.578	0.801	18.645	9
KO010	NO_2-N	0.138	0.08	0.108	0.025	0.368	9
KO020	NO_2-N	0.012	0.01	0.010	0.003	0.028	9
KO010	NO_{2+3}-N	4.178	1.254	4.682	0.405	12.03	9
KO020	NO_{2+3}-N	1.213	0.652	1.068	0.386	3.421	9
KO010	NO_3-N	4.040	1.1	4.613	0.38	11.662	9
KO020	NO_3-N	1.201	0.646	1.060	0.372	3.396	9
KO010	PO_4-P	24.507	24.0455	7.292	14.066	35.32	10
KO020	PO_4-P	10.020	9.8565	5.579	3.044	22.518	10
KO010	TKN	124.392	100.12	117.466	22.017	436.131	10
KO020	TKN	18.576	19.231	9.501	3.619	33.309	10
KO010	Total N	133.937	121.235	122.737	22.961	436.632	9
KO020	Total N	19.810	23.033	9.868	4.396	33.961	9
KO010	Total P	39.224	38.2555	10.376	23.7	57.14	10
KO020	Total P	12.486	11.6195	6.951	4.577	28.109	10
KO010	TSS	290.142	224.9	301.130	70	1118.421	10
KO020	TSS	87.384	52.65	101.541	32.545	369.714	10

Table F-10. Geometric mean and standard deviation for natural-log transformed storm mean values for sites KO010 and KO020.

Site	Constituent*	Geometric Mean	Lower Std Dev	Upper Std Dev	n
KO010	COD	618.406	360.343	1061.281	10
KO020	COD	161.294	111.169	234.020	10
KO010	NH_3-N	42.682	18.257	99.781	9
KO020	NH_3-N	4.686	1.444	15.206	9
KO010	NO_2-N	0.104	0.046	0.239	9
KO020	NO_2-N	0.009	0.004	0.022	9
KO010	NO_{2+3}-N	2.053	0.540	7.797	9
KO020	NO_{2+3}-N	0.894	0.402	1.987	9
KO010	NO_3-N	1.911	0.484	7.546	9
KO020	NO_3-N	0.882	0.395	1.970	9
KO010	PO_4-P	23.488	17.183	32.107	10
KO020	PO_4-P	8.676	4.829	15.590	10
KO010	TKN	91.141	39.731	209.073	10
KO020	TKN	15.625	7.786	31.354	10
KO010	Total N	97.292	40.888	231.504	9
KO020	Total N	16.884	8.666	32.896	9
KO010	Total P	37.971	28.943	49.815	10
KO020	Total P	10.863	6.152	19.181	10
KO010	TSS	216.188	102.969	453.896	10
KO020	TSS	63.329	30.598	131.073	10

Table F-11. Non-log transformed values using the storm median across storm events for sites KO010 and KO020.

Site	Constituent*	Mean	Median	Std Dev	Minimum	Maximum	n
KO010	COD	692.700	693	346.574	220	1410	10
KO020	COD	157.800	159	65.998	54	240	10
KO010	NH_3-N	62.311	49.65	74.603	10.8	255	9
KO020	NH_3-N	6.320	0.955	8.039	0.355	19.1	9
KO010	NO_2-N	0.119	0.06	0.118	0.0225	0.38	9
KO020	NO_2-N	0.010	0.006	0.009	0.003	0.03	9
KO010	NO_{2+3}-N	2.435	1.18	2.868	0.172	7.375	9
KO020	NO_{2+3}-N	1.151	0.623	0.953	0.394	2.952	9
KO010	NO_3-N	2.257	0.99	2.823	0.155	7.21	9
KO020	NO_3-N	1.143	0.62	0.951	0.38	2.95	9
KO010	PO_4-P	25.420	25.05	8.233	14.65	38.55	10
KO020	PO_4-P	9.333	8.44	5.857	3.41	23.1	10
KO010	TKN	131.415	95.5	140.359	21.9	511	10
KO020	TKN	14.964	10.645	10.605	2.94	31.9	10
KO010	Total N	139.648	118.11	147.234	22.845	511.27	9
KO020	Total N	16.025	12.37	10.883	3.593	32.293	9
KO010	Total P	39.295	36.925	12.426	22.7	57.7	10
KO020	Total P	12.572	11.9	7.133	4.57	26.8	10
KO010	TSS	223.150	161.25	202.537	64.5	763	10
KO020	TSS	49.650	44.25	20.571	27	83	10

Table F-12. Geometric mean and standard deviation for natural-log transformed storm median values for sites KO010 and KO020.

Site	Constituent*	Geometric Mean	Lower Std Dev	Upper Std Dev	n
KO010	COD	609.654	347.212	1070.465	10
KO020	COD	142.762	86.181	236.491	10
KO010	NH_3-N	40.859	16.223	102.911	9
KO020	NH_3-N	2.222	0.440	11.222	9
KO010	NO_2-N	0.077	0.029	0.208	9
KO020	NO_2-N	0.007	0.003	0.016	9
KO010	NO_{2+3}-N	1.166	0.292	4.655	9
KO020	NO_{2+3}-N	0.871	0.405	1.872	9
KO010	NO_3-N	1.018	0.246	4.219	9
KO020	NO_3-N	0.862	0.399	1.862	9
KO010	PO_4-P	24.200	17.314	33.824	10
KO020	PO_4-P	7.985	4.466	14.276	10
KO010	TKN	91.481	38.063	219.867	10
KO020	TKN	11.627	5.317	25.427	10
KO010	Total N	95.588	38.156	239.453	9
KO020	Total N	12.761	6.064	26.853	9
KO010	Total P	37.506	27.099	51.909	10
KO020	Total P	10.750	5.849	19.756	10
KO010	TSS	174.968	88.785	344.809	10
KO020	TSS	46.076	30.746	69.050	10

TIAER
WP 98-07

COSTS AND ENVIRONMENTAL EFFECTIVENESS OF NUTRIENT BMPS

For Dairy Farms in the Lake Fork Reservoir Watershed

October 1998

by Keith O. Keplinger and Bryan DuBose

Texas Institute for Applied Environmental Research
Tarleton State University • Box T0410 • Tarleton Station • Stephenville, Texas • 76402
(254) 968-9567 • FAX (254) 968-9568

ACKNOWLEDGEMENTS

A number of people, mainly from state and federal agencies, were instrumental in providing information, clarifying legislation, and verifying facts for this document. For the most part, this information was not available in published form so their input was indispensable. Without exception, these contributors were helpful, courteous, and informative in answering my questions. They include Jim Wyrick, Jim Griffin, David Byer, and Randy Wells of the Natural Resources Conservation Service (NRCS); Beade Northcutt, John O'Conner, and Justin Hester of the Texas State Soil and Water Conservation Board (TSSWCB); Darrell Williams, Hari Krishna, David Fowler, and Barbara Parmley of the Texas Natural Resource Conservation Commission (TNRCC); Tom Pegues, Miles Hall, and Rick Masters of the Sabine River Authority (SRA), John Grant of Town and Country Bank, Stephenville, Texas, and Seth Terry of Tractor Supply Company, Sulphur Springs, Texas.

Thanks are also due several colleagues at the Texas Institute for Applied Environmental Research (TIAER). These include Erinn Neyrey and Anne McFarland for addressing legislative and biological questions, respectively; Edward Osei for supplying economic and dairy structure information; Charles Maguire, Larry Hauck, Jan McNitt, Heather Jones, and Ron Jones for reviewing drafts of this document and making insightful comments; Kendall Gaither for formatting; Tommie Nielsen for checking references and proofing; and Stuart Norvell for proofing.

TABLE OF CONTENTS

INTRODUCTION

Background

The effect of agricultural practices on environmental quality has surfaced as one of the nation's preeminent environmental concerns during the last two decades. Environmental impacts associated with livestock operations have received particular attention as increasing concentration in the livestock industry has produced ever larger operations and attendant environmental concerns.

State and federal natural resource agencies have responded by designing programs to encourage adoption of best management practices (BMPs). Section 319 of the Clean Water Act (CWA),[1] for instance, requires states to develop "state management programs" that include identification and implementation of BMPs to control nonpoint source (NPS) pollution (*Clean Water Act*, 1972). As part of a Section 319 funded project, this report seeks to assist the State in identifying and implementing nutrient BMPs for dairies in the Lake Fork Reservoir watershed. Specifically, this report identifies and assesses BMPs for dairy farms in the Lake Fork Reservoir Watershed in northeast Texas in terms of (1) impact on water quality, (2) capital and operating costs, (3) acceptability from a political/social standpoint, (4) methods of financing, and (5) problems associated with the use of particular BMPs.

Waste accumulated on traditional dairy pasture operations is both point source and NPS in nature. Dairy waste discharged from animal confinement and process areas may represent a point source. However, pollution caused by animal waste after it has been applied to land is currently considered NPS pollution, which is less amenable to traditional command and control methods of pollution control (Frarey and Jones, 1994, & Pratt, 1996).

Concern over point source and NPS pollution entering the nation's waterways arises from the harm they can pose to beneficial uses of water.[2] These uses include (1) domestic, industrial, and agricultural water supplies; and (2) swimming, fishing, boating, and other forms of recreational use (USDA, 1992).

Water quality problems associated with dairy operations stem primarily from high levels of nutrients entering surface and groundwater. "Important nutrients from a water quality standpoint are nitrogen and phosphorus" (USDA ERS, 1997). Without management practices specifically designed to contain and control waste from livestock operations, nutrients enter water resources by any

[1] Officially the "Federal Water Pollution Control Act," in 1977 Congress adopted its common designation as the "Clean Water Act."

[2] "The value of water lies in its usefulness for a wide variety of purposes, and the quality determines its acceptability for a particular use. Therefore, a quality problem occurs when water is contaminated to a level where it is no longer acceptable for a particular use" (USDA, 1992).

of three ways: runoff over the soil surface, run-in directly to groundwater, and leaching through the soil by percolating rain or irrigation water (USDA ERS, 1997).

Although nutrients play an essential role in agriculture as well as in aquatic ecosystems, unnaturally high nutrient concentrations in water bodies can accelerate algal production resulting in a variety of water-quality problems including increased rates of eutrophication (Sharpley, 1995). Algal blooms may develop, which decrease available oxygen and often lead to fish kills (Sharpley, 1995). Decaying algae may also produce odor and taste problems that make municipal water supplies more costly to treat. Pathogens contained in animal waste may also pose a threat to human health. "Up to 150 diseases from the microorganisms in livestock waste can be contracted through direct contact with contaminated water, consumption of contaminated drinking water, or consumption of contaminated shellfish" (USDA ERS, 1997). The more far-reaching effects of nutrient pollution can include outbreaks of *Pfiesteria*[3] and *Cryptosporidium*[4] (USEPA & USDA, 1998). Results of economic studies indicate that the annual benefits of improving water quality could total tens of billions of dollars (USDA ERS, 1997).

The CWA, major provisions of which were enacted in 1972, is the nation's most extensive legislation pertaining to water quality. While the CWA is credited with many successes in cleaning up the Nation's waters, many waterways still do not support beneficial uses such as fishing and swimming, nor do they meet applicable water quality standards. In part, this is due to the CWA's initial focus on point-source pollution and relative neglect of NPS pollution, which is more difficult to monitor and control. NPS pollution caused by agricultural runoff, however, is currently considered the most extensive source of pollution in the Nation's waters (USEPA, 1994). In 1995, EPA reported that nutrient pollution was the leading cause of water quality impairment in lakes and estuaries and was the third leading cause of impairment in rivers. EPA also reported that agriculture was the primary source of nutrients in impaired surface waters (USDA ERS, 1997).

Description and Uses of Lake Fork Reservoir

Lake Fork Reservoir is located in the Sabine River Basin in northeast Texas, not far from the town of Quitman. Construction on the reservoir began in the fall of 1975 and was completed in February 1980; its conservation pool level was reached in December 1985 (Sabine River Authority, 1998a). The reservoir has an estimated surface area of 27,690 acres at its conservation pool elevation of 403.0 feet above mean sea level (Sabine River Authority, 1998a). The reservoir

[3] *Pfiesteria* is a protozoan that generally is a herbivore but can also attack fish causing potentially lethal open sores. Fish kills resulting from outbreaks of *Pfiesteria* have been prevalent in Chesapeake Bay and North Carolina and are thought to be related to nutrient over-enrichment (USEPA, & USDA, 1998).

[4] *Cryptosporidium* is a waterborne pathogen that has been identified in both surface and groundwater. The protozoan is highly resistant to conventional disinfection systems and can cause the disease crypotosporidiosis, the symptoms of which often include diarrhea. The disease is usually not serious for immunologically healthy persons, but can be fatal among the young, the elderly, and those with weakened immune systems. Potential sources of *Cryptosporidium* include agricultural runoff from livestock operations and human wastewater (Safe Water Solutions L.L.C., 1998).

was constructed to provide water for municipal and industrial uses. Several small communities in the Lake Fork Reservoir region currently utilize the reservoir for water supply. The City of Dallas has contracted for 79 percent of the reservoir's surface water rights but has not yet utilized the reservoir as a water source, pending construction of a pipeline between Lake Fork Reservoir and Lake Tawakoni (Pegues, 1998).

Pursuant to Section 305b of the CWA, the Texas Natural Resource Conservation Commission (TNRCC) has designated Lake Fork Reservoir for contact recreation, high aquatic life, and public water supply.

Lake Fork Reservoir is highly utilized for sport fishing and has distinguished itself as "the premier trophy Largemouth Black Bass lake in Texas" (Rushin, 1994). The Texas Parks and Wildlife Department began stocking the reservoir with Florida largemouth bass in 1978 (Sabine River Authority, 1998a). A large percentage of the state's top trophy fish are now caught in the reservoir,[5] which has lead to the development of a sizable and economically important sport fishing industry around the lake. Thirty-eight marinas currently service the sport fishing industry (Pegues, 1998).

Water Quality in the Lake Fork Reservoir Watershed

CWA Amendments in 1987 strengthened control of NPS pollution. Section 319 required states to prepare "state assessment reports" to identify waters that could not reasonably be expected to meet water quality standards because of NPS pollution (Percival, 1992). Many states including Texas conducted studies to identify potentially sensitive areas. In a 1988 state water quality study, the Texas Water Commission (predecessor to the TNRCC) and the Texas State Soil and Water Conservation Board (TSSWCB) identified Lake Fork Reservoir as a potential nonpoint source pollution problem due to dairy waste (TNRCC, 1996). A 1990 update to the nonpoint source water pollution assessment report also listed Lake Fork Reservoir as a potential nonpoint source pollution problem (Texas Water Commission and TSSWCB, 1991). In both cases, however, "degree of use support" was listed as full. A 1996 TIAER study estimates that approximately 50 percent of potential nitrogen and phosphorus contribution to the Lake Fork Reservoir watershed originated with dairies (Bailey and Riggs, 1996). Other sources, such as beef operations and urban runoff, account for the remaining nutrient contribution.

The Sabine River Authority (SRA) maintains an extensive water quality monitoring program (Sabine River Authority, 1998b). A 1996 assessment of water quality by the SRA for reach 6, which includes numerous streams that discharge into Lake Fork Reservoir, "showed mostly no concerns, some possible

[5] The following excerpt from a TPWD news release is indicative of Lake Fork's reputation as a sport fishery:

"A late night catch on Lake Fork by Allen Fopay of Harleton has netted the largest Budweiser ShareLunker of the year thus far, a 14.62-pounder that was received here at the Texas Freshwater Fisheries Center April 2 [1998]. The huge bass marked the sixth of the year from Lake Fork and 14th overall. ... the fish is the largest entry thus far this year" (News Releases from Texas Parks and Wildlife, April 6, 1998).

concerns, and a few concerns."[6] A total of ten sites were monitored by SRA in the Lake Fork Reservoir subwatershed. Data analysis showed a possible concern for pH at one site, but high pH values are thought to be due to natural conditions (Sabine River Authority, 1996). "No other water quality concerns were indicated" (Sabine River Authority, 1996).

According to Rushin, "Although nutrient concentrations in the tributary streams are elevated, most sampling locations in [Lake Fork Reservoir] have low nutrient levels. This disparity is likely due to nutrient uptake by aquatic macrophytes" (Rushin, 1994). Overall, water quality in the lake is considered to be swimmable and fishable (Pegues, 1998).

By contrast, numerous water quality impairments have been identified in Lake Fork Reservoir tributaries. In fiscal year 1993, a comprehensive nonpoint source water quality management project for the Lake Fork Reservoir watershed, funded by section 319 of the CWA, was awarded to and carried out by the TNRCC. Comprehensive baseline monitoring of the watershed was conducted between May 2 and June 8, 1995 on eight major tributary streams that comprise most of the 575 square mile drainage basin (Rushin, 1995). "Twenty stations, located mainly on these tributaries, were monitored using sediment, physicochemical, benthic macroinvertebrate, and fecal coliform samples" (Rushin, 1995). A number of water quality impairments indicative of nutrient enrichment were documented in a 1995 report, including elevated levels of nitrates + nitrite-nitrogen, orthophosphates, total phosphorus, and fecal coliform (Rushin, 1995).

In TNRCC's State of Texas Water Quality Inventory for 1996, the agency determined that the high aquatic life use of Lake Fork was only partially supported due to depressed oxygen concentrations in parts of the reservoir, which may have been caused by elevated phosphorus levels.[7]

Dairy Operations in the Lake Fork Reservoir Region

The Lake Fork Reservoir watershed surrounds the reservoir and encompasses portions of Hopkins, Hunt, Rains, and Wood counties. The watershed is located in the second largest dairy-producing region of the state.[8] As of October 1996,

[6] "... concern or possible concern was determined on a parameter-by-parameter and site-by-site basis. In general, a possible concern was defined as 10 – 25% of the values exceeding the criteria and a concern was defined as more than 25 – 50% of the values exceeding the criteria" (Sabine River Authority, 1996).

[7] The segment summary for Segment 0512 of the Sabine River Basin reads:

"Elevated levels of orthophosphorus are a concern in the main body of the reservoir and the Caney Creek arm. This factor may contribute to depressed dissolved oxygen concentration, and associated partial support of the high aquatic life use, in the main body of the reservoir near the dam. Municipal point sources, as well as nonpoint source pollution from agricultural activities and on-site septic systems likely contribute to the problem" (TNRCC, 1996).

[8] The geographic region, as defined by the Milk Marketing Administrator, encompassing the Lake Fork Reservoir watershed contains 572 dairies with a total of 83,878 cows and produces 29% of the milk in Texas (USDA, 1998).

there were 216 dairies in the Lake Fork Reservoir watershed with an average of 129 cows per dairy, yielding an estimated total of 27,864 cows in the watershed.[9] Currently, about 95 percent of dairies in the Lake Fork Reservoir watershed are pasture operations, while the remaining five percent (about 10 dairies) are freestall operations.[10] Pasture operations are well suited to the Lake Fork Reservoir region because of adequate rainfall which supports coastal bermudagrass and other grasses for grazing. Because of the preponderance of pasture operations, discussion is limited to BMPs appropriate for this type of dairy.

Dairy size in the Lake Fork Reservoir region has remained relatively small due to a slow rate of consolidation relative to other dairy regions (Bailey and Riggs, 1996). There is, however, a slow trend toward somewhat larger dairies (Bailey and Riggs, 1996).[11] A move to more concentrated (denser) forms of dairy operations, freestalls, or more intensive grazing, for example, could have negative consequences for Lake Fork Reservoir water quality.[12] On the other hand, if industry consolidation results in larger numbers of animals grazing on correspondingly larger land areas, then increasing industry concentration may have little effect on water quality. In addition to animal concentration, a number of factors, particularly management style and BMP implementation, are important factors impacting water quality.

Cows in typical Lake Fork Reservoir region pasture operations spend six hours each day (two three-hour sessions) either in a holding pen or a milking parlor. Supplemental feeding may also occur either before or after milking, (Wyrick, 1998) or in a feed lane or trough located in or next to a pasture (Parmley, 1998). Cows spend the rest of the day grazing on improved pastureland, where supplemental feed and hay may also be provided (Wyrick, 1998). Waste generated in confined areas is generally flushed and piped to a waste storage pond, where it is then held until land applied.

Environmental Regulation

Handling of livestock wastes is specifically addressed in federal and state legislation designed to reduce the risk of water pollution. At the state level,

Hopkins County, which constitutes the largest percentage of the land area of the four counties in the Lake Fork Reservoir Watershed, ranks number two in the State (after Erath County) in terms of number of cows and milk production, but contains the largest number of dairies of any county in Texas at 272 (USDA, 1998).

[9] Compiled by TIAER based on information provided by TNRCC inspection sheets and a TNRCC data list. An analysis of the structure of the dairy industry in Hopkins County using somewhat less recent data can be found in Bailey and Riggs (1996).

[10] Soil and weather conditions (high rainfall) virtually preclude the operation of open lot dairies in the Lake Fork Reservoir area (Wyrick, 1998).

[11] Occasionally, a small dairy will be purchased and the new owner will increase the size of the herd, often through intensive rotational techniques (Wyrick, 1998).

[12] In a study that quantified the effects of land use patterns on water quality, McFarland and Hauck found that "The percent land area in waste application fields and dairy cow density associated with each site consistently showed the highest positive correlations with water quality constituents of any land characteristics for both reservoir and stream sites" (McFarland and Hauck, 1995).

Texas Administrative Code vol. 30 section 321.31 - 321.46 (Subchapter B)[13] specifies that CAFOs[14] with over 700 cows require TNRCC permitting. Subchapter B also requires TNRCC permitting for CAFOs with between 200 and 700 cows that are located in designated Dairy Outreach Program Areas (DOPA).[15] The TNRCC designated two regions of the state, one of which includes Hopkins and surrounding counties; as DOPAs. Under certain circumstances the TNRCC can also designate a dairy of any size as a CAFO, (30 TAC § 321.33 (b)) thereby requiring TNRCC permitting.

Dairies with 200 cows or less are considered nonpoint pollution sources. The Texas legislature gave the TSSWCB responsibility for overseeing activity related to abating agricultural and silvicultural nonpoint source pollution (State of Texas, 1993). As of October 1996, an estimated 80 percent of dairies in the Lake Fork Reservoir watershed had 200 cows or less.[16] Under Subchapter B rules, (30 TAC § 321.33 (d)) facilities which obtain an operate under a certified water quality management plan from the TSSWCB are not considered CAFOs and are exempted from obtaining a TNRCC permit. The TSSWCB does not have enforcement powers; it can, however, refer non-complying dairies to the TNRCC for enforcement of violations of water quality rules and regulations.

All dairies, regardless of size and permitting authority, are required to meet TNRCC regulations. In addition, NRCS waste management plans may require dairies to comply with provisions not explicitly included in State regulations. Provisions in Subchapter B read, "Where the provisions in a NRCS plan are equivalent or more protective the permittee may refer to the NRCS plan as documentation of compliance with the BMPs required by this subchapter" (30 TAC § 321.40).

---

[13] Revised Subchapter B rules (30 TAC § 321.30 et seq.) went into effect on September 18, 1998. Reference to Subchapter B rules in this report refers to these revised rules.

[14] With regard to dairies, confined animal feeding operations (CAFOs) are defined in Subchapter B as: 1) "Any animal feeding operation which the executive director designates as a significant contributor of pollution...," 2) "Any new and existing operations which stable and confine and feed or maintain for a total of 45 days or more in any 12-month period more than ... 700 mature dairy cattle (whether milkers or dry cows), and 3) "Any new and existing operations covered under this subchapter which discharge pollutants into waters in the state... which stable or confine and feed or maintain for a total of 45 days or more in any 12-month period more than ... 200 mature dairy cattle (whether milkers or dry cows)" (30 TAC § 321.32 (3)).

[15] "The Texas Natural Resource Conservation Commission (TNRCC) initiated the Dairy Outreach Program in Erath County in December 1992 and expanded the project in 1993 to include a total of eight counties [in the two major dairy producing regions of the state]. The Dairy Outreach Program is designed to provide assistance to dairy owners/operators to ensure compliance with Agency rules and regulations. TNRCC personnel provide referrals to agencies which provide information on the implementation of Best Management Practices (BMPs). In addition, educational programs are provided to the general public and regulated community to increase awareness of nonpoint source pollution and protection of water quality" (TNRCC, 1995).

Regulations applying to DOPAs also specify "that the dairy is designed to stable or confine and feed or maintain for a total of 45 days or more in any 12-month period more than [200 dairy cows]." If the cumulative time dairy cows are in confinement for milking operations is translated in terms of days, then all dairy operations in the Lake Fork Reservoir region would be considered CAFOs, and thus require TNRCC permitting.

[16] Compiled by TIAER based on information provided by TNRCC inspection sheets and a TNRCC data list.

BMP Implementation

Dairy waste management plans can be developed by the Natural Resources Conservation Service (NRCS), private consultants, or, for smaller dairies, the TSSWCB. The TSSWCB has developed water quality management plans for about eighty percent of the dairies in the Lake Fork Reservoir region falling under its purview as of July 1998 (Wyrick, 1998).

Waste management plans and permits to dispose of waste issued by the TNRCC specify detailed BMPs designed to control waste by reducing potential runoff. A BMP is defined by EPA as

> A practice or combination of practices found to be the most effective, practicable (including economic and institutional considerations) means of preventing or reducing the amount of pollution generated by non-point sources to a level compatible with water quality goals (USDA, 1996).
>
> Best management practices also include operating procedures and practices to control site runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage (USEPA, 1995a).

Implementation of many BMPs requires structural controls involving significant capital and operating costs. Other BMPs are primarily managerial rather than structural. An integrated system of BMPs designed to manage wastes constitutes a waste management system.

The NRCS maintains a national list of BMPs, referred to as conservation practice standards. The TSSWCB selects a subset of BMPs from the NRCS list that may be eligible for Senate Bill 503b (SB503b) funding. Local Conservation Districts (LCDs) in each TSSWCB region then develop a list of individual components of TSSWCB approved BMPs that are eligible for SB503b funding. Certain managerial BMPs, (e.g., nutrient management), are not funded *per se* but may be required in order to receive cost-share funding for other BMPs (Wyrick, 1998).

In 1990, in response to water quality concerns, USDA and the Texas State Legislator created the Lake Fork Creek Hydrologic Unit Area Project. The Agricultural Extension service offices in Hopkins, Wood, and Rains counties along with the local NRCS office were charged with developing an educational program designed to reduce nonpoint source pollution to Lake Fork. An objective of the program was to provide educational programs on BMPs for handling dairy waste and pesticides, and to encourage their adoption. Through the cooperative efforts of numerous federal, state, and local agencies involved in the project, dairy operators in the area implemented 115 waste management systems as of fiscal year 1997 (Brown and Rich, 1997). Approximately 645 acres were converted from open access to intensive grazing management systems and nutrient management practices were implemented on 11,180 acres (Brown and Rich, 1997). Thus, a concerted effort to implement BMPs in the Lake Fork Reservoir watershed has already taken place.

The remainder of this report is organized as follows. First, BMPs that are appropriate for the Lake Fork Reservoir region are identified, defined, and described. In addition, BMP implementation costs for equipment and improvements are estimated. Second, costs (both capital and operational) associated with owning and operating a total waste management system for three representative Hopkins County dairies are calculated. Third, a literature review of studies on the environmental effectiveness of selected waste management practices is provided. Fourth, alternative financing methods are discussed. Fifth, social/political acceptability, and problems/constraints associated with implementing selected BMPs are discussed. Finally, a summary and conclusions are presented.

SELECTED BMPs

A number of BMPs, from the NRCS's list of practice standards that were considered appropriate for the Lake Fork Reservoir watershed were identified. These BMPs include but are not confined to those selected as eligible for funding by the TSSWCB and the Hopkins and Rains Soil and Water Conservation District. Some of the major structural components of BMPs, (e.g., pipe, pumps) are also specified as separate BMPs. Several BMPs listed herein involve considerable overlap at the managerial and component level (e.g. waste utilization, nutrient management, sprinkler irrigation system, and manure transfer).

NRCS distributes information on practice standards in a variety of publications. General information on waste management is found in the *Agricultural Waste Management Field Handbook* (USDA, 1996). A list of nationally recognized BMPs is provided in the *National Handbook of Conservation Practices* (NHCP), (USDA, NRCS, 1998b) where a definition, purpose, and design criteria is provided for each BMP.[17] Practice standards are periodically updated by the NRCS and are also included in *Field Office Technical Guides* (FOTGs). FOTGs are the documents used for technical guidance and outreach in NRCS field offices and by the TSSWCB in developing water quality management plans (TNRCC, 1994). In addition to NHCP material, each state can also incorporate state addenda into their FOTGs that amplify NHCP standards.[18]

The following sections provide definitions, statements of purpose, descriptive information, and estimates of cost components for each of the identified BMPs. Terminology and descriptive information is largely drawn from NHCP standards and their Texas addenda. In most cases, cost estimates are drawn from the list of BMP components approved for state cost-share funds by the Hopkins – Rains Soil and Water Conservation District (TSSWCB, 1998). Otherwise, costs were obtained by interviewing a local supplier.

---

[17] "The National Handbook of Conservation Practices (NHCP) establishes national standards for conservation practices commonly used to treat natural resource problems (soil, water, air, plants, and animals). National practice standards include the following components: name; unit of measurement; code number; definition; purposes; conditions where practice applies; criteria; considerations; plans and specification; and operation and maintenance" (USDA, NRCS, Preface).

[18] The following quote, stated at the beginning of many Texas addenda, describes the function of the state addenda. "This addendum serves as an integral part to the companion Standard of the National Handbook of Conservation Practices. The contents of this addendum magnify national guidance and implement experience factors important to the installation of this practice under the range of conditions found within Texas. Criteria or guidance contained herein addresses items to be conformed to in addition to satisfying the items of the Standard in the National Handbook of Conservation Practices" (USDA, SCS-TX, 1991).

Waste Storage Pond [19]

Definition:

"A waste impoundment made by constructing an embankment and/or excavating a pit or dugout..." (USDA, NRCS, 1995b).

Purpose:

"To temporarily store wastes such as manure, wastewater, and contaminated runoff as a function of an agricultural waste management system" (USDA, NRCS, 1995b).

"This practice reduces the direct delivery of polluted water, which is the runoff from manure stacking areas, feedlots, and barnyards, to the surface waters. This practice may reduce the organic, pathogen, and nutrient loading to surface waters" (USDA, SCS-TX, 1991).

Description:

As applied to dairies in the Lake Fork Reservoir area, the most practicable type of waste storage facility is a pond (incorporating embankments and excavation) as opposed to a structure or tank. It is designed for temporary storage of waste accumulated from dairy milking operations, including the milking parlor, the wash down area, and any cemented supplemental feeding areas associated with the milking routine.[20] Accumulated dairy waste is flushed down drains and piped to the waste storage pond. The structure temporarily stores the waste (both liquid and solid) along with flush water, direct rainfall into the pond, and any runoff from unroofed areas, until it can be land applied.

In addition, a waste storage pond must be "located in soils with acceptable permeabilities, or the pond shall be lined" (USDA, NRCS, 1995b). The Texas Addendum for Waste Storage Pond further specifies "that seepage losses from waste storage ponds be within prescribed limits" (USDA, SCS-TX, 1991). In the Lake Fork Reservoir region, if the in-situ material does not meet these standards, soil with a high clay content can typically be found on the dairy's premises, and used as an earthen blanket (Wyrick, 1998).

Further criteria applying to Waste Storage Ponds include a minimum elevation for the top of the embankment at one foot above the required storage volume, and a minimum top width of eight feet (USDA, NRCS, 1995b). In addition, an emptying facility such as a pump and provisions for periodic removal of accumulated solids are required (USDA, NRCS, 1995b). The Texas Addendum further specifies that "Waste storage ponds shall be located a minimum horizontal distance of 150 feet from any well..." (USDA, SCS-TX, 1991).

---

[19] The practice standard for Waste Storage Pond (425) was deleted by NHCP Notice 115. "Standards for this practice are now contained in practice standard Waste Storage Facility (313)" (USDA, SCS, not dated). In the current standard for Waste Storage Facility, however, separate criteria are broken out for "pond" and "fabricated structure" (USDA, NRCS, 1995b).

[20] Dairies in the Lake Fork Reservoir region often provide supplemental feed to milking herds before, during, or after milking. Feeding areas may be cemented and located adjacent to the milking parlor (Wyrick, 1998). Dairies may also provide cemented feed lanes in areas not adjacent to the milking parlor. Supplemental feeding areas for smaller dairies are often not cemented but are on dirt (Parmley, 1998).

Costs of Implementation:

Cost estimates of individual services and materials typically needed to construct a waste storage pond are itemized in Table 1 and are representative of the Lake Fork Reservoir region. All items in the list may not be required at every site. For example, some sites may not require a sealed pond because it is constructed on naturally occurring clay soil. Other miscellaneous costs not included on the list may also be required.

Table 1: Waste Storage Pond Costs

Expense Item	Cost
Moving Earth	$1.00 per cubic yard
Sealing Pond	up to $10,000
Sealing Pond – Bentonite	$0.20 per pound
Testing Soil	
with liner	$2,000* (2 tests)
without liner	$1,000 (1 test)
Sodding Structure	$1.00 per cubic yard
Constructing Fences	$1.25 per linear foot
Pipe Support	$250 each

* Testing soil with a liner is $2,000 because the soil must be tested twice. First, it is tested without a liner. If it requires a liner, then it must be tested again after the liner is installed.

Source: TSSWCB, Mt. Pleasant Regional Office.

Actual costs of constructing waste storage ponds on three dairy operations in the Lake Fork Reservoir watershed were $3,600, $3,370, and $3,378 respectively for a 160-cow, 225-cow, and a 230-cow dairy (see Table 6). Cost as well as size of the pond is not directly proportional to number of cows due to a variety of factors discussed in the "Waste Management Systems" section of this paper.

Manure Transfer

Definition:

"A manure conveyance system using structures, conduits, or equipment" (USDA, NRCS, 1997b).

Purpose:

To transfer animal manure (bedding material, spilled feed, process and wash water, and other residues associated with animal production may be included) through a hopper or reception pit, a pump (if applicable), and a conduit to:

- A manure storage/treatment facility,
- A loading area, and
- To agricultural land for final utilization. This includes application of manure to the utilization area (USDA, NRCS, 1997b).

Description:

Manure and wastewater transfer systems typically incorporate pipeline, pumps, and sprinkler systems, which are broken out as separate BMPs in succeeding sections of this report. Most dairies in the Lake Fork Reservoir area have a pit adjacent to the milking parlor, where wash down manure and water is initially collected.[21] Effluent is then either piped (by gravity flow) or pumped to a waste storage pond. From the waste storage pond, water is conveyed (by gravity flow or pump) through pipe and flexible hose to a "big gun" irrigation sprinkler system. A tank wagon (commonly referred to as a honey wagon) may also be used to land apply liquid effluent (Wyrick, 1998).

Alternatively, manure may be scraped from the milking parlor and surrounding areas and land applied with a manure spreader. Both systems of manure transfer (by pipe or vehicle) and variants of each are acceptable provided that NHCP guidelines are met.

Minimum pipeline capacity from collection facilities to the waste storage pond should be the maximum flow anticipated on a daily basis. Pumps should be sized to transfer manure at required system head and volume (USDA, NRCS, 1997b).

> Manure shall be applied to the utilization area in amounts and at a time consistent with the manure management plan and Practice Standard 633, Waste Utilization. Sprinklers or sprinkler systems shall be designed in accordance with Practice Standard 442, Irrigation System, Sprinkler.
>
> ...
>
> Manure spreaders and/or tank wagons shall have adequate capacity to insure the emptying of storage/treatment facilities within appropriate time periods as stated in the system operation and maintenance plan (USDA, NRCS, 1997b).

Costs of Implementation:

Costs associated with installing a manure transfer system can vary greatly depending on the number and type of components required for each particular situation. Individual components required for manure transfer (waste transfer pipeline; pumps; irrigation system, sprinkler, and waste utilization) and their associated costs are described in succeeding sections.

Waste Transfer Pipeline

Definition:

A pipeline and appurtenances installed to transfer dairy waste.

[21] Waste storage pits are artifacts of older waste storage systems. Before waste storage ponds where required by the TNRCC, manure was land applied directly from these pits (Wyrick, 1998).

Purpose:

"To prevent erosion or loss of water quality or damage to the land, to make possible proper management of irrigation water, and to reduce water conveyance losses" (USDS, SCS, 1988).

As practiced by dairies in the Lake Fork Reservoir region in Texas, dairy waste conveyance systems are typically Polyvinyl chloride (PVC) pipeline (but may be aluminum) used to carry wastewater from the milking parlor and surrounding areas to the waste storage pond, and from the waste storage pond to application fields. Eight or 10 inch PVC pipeline typically connects the washdown area or pit to the waste storage pond, whereas 6 inch PVC is usually used for the sprinkler system (Wyrick, 1998).

Costs of Implementation:

Table 2 presents the average costs for pipeline components used to convey dairy waste for dairies in the Lake Fork Reservoir region. Component costs include pipeline installation.

Table 2: Pipe to Pond Costs

Expense Item	Cost
6 inch PVC pipe – SDR* 26	$6.75 per linear foot
8 inch PVC pipe - SDR 26	$8.00 per linear foot
10 inch PVC pipe - SDR 26	$10.75 per linear foot
6 inch PVC pipe - SDR 21	$7.75 per linear foot
8 inch PVC pipe - SDR 21	$9.00 per linear foot
10 inch PVC pipe - SDR 21	$11.75 per linear foot
Portable Pipe Alum. – 4 inch	$3.50 per linear foot
Portable Pipe Alum. – 6 inch	$3.85 per linear foot
Riser 4x4	$106 each
Riser 4x6	$120 each
Riser and Air Vent 4x4	$201 each
Riser and Air Vent 4x6	$215 each
End Riser 4x4	$201 each
End Riser 4x6	$215 each
Z Pipe	$225 each
Air Vent	$30 each
Pressure Relief Valve	$175 each

* Standard Dimension Ratio (SDR) is a measure of pipe thickness. Small SDR numbers indicate thicker pipe. An engineer determines appropriate pipe thickness.

Source: TSSWCB, Mt. Pleasant Regional Office.

Pumps

Definition:

A pumping facility installed to transfer wastewater (USDA, SCS, 1977).

Purpose:

Pumps are used to transport manure and wastewater from the milking and wash down areas to the waste storage pond and from the waste storage pond to application fields.

Description:

Pumps used to convey waste from the wash down areas to the waste storage pond are typically small 2 or 3 horsepower units, whereas larger pumps are required for irrigation systems. Important requirements for pumping plants (which may consist of one or more pumps) include the ability to generate adequate total head under critical operating conditions (USDA, SCS, 1977). Additional specifications are outlined in Practice Standard 533, Pumping Plant for Water Control (USDS, SCS, 1977).

Costs of Implementation:

Table 3 presents average costs of several irrigation pumps that are of the specifications generally required for typical Lake Fork Reservoir watershed region dairies.

Table 3: Irrigation Pump Costs

Expense Item	Cost
Pump – Electric (3 HP)	$2,900 each
Pump – Electric (10 HP)	$6,600 each
Pump – Electric (40 HP)	$8,300 each
Diesel Pump	$7,100 each
Diesel Engine	$10,000 each

Source: TSSWCB, Mt. Pleasant Regional Office.

Irrigation System, Sprinkler

Definition:

"A planned irrigation system in which all necessary facilities are installed for efficiently applying water by means of perforated pipes or nozzles operated under pressure" (USDA, NRCS, 1987).

Purpose:

When utilized as part of a waste management system, irrigation systems serve a dual purpose of disposing of dairy wastes in an environmentally acceptable manner while supplying water and nutrients to crops in an optimal manner.[22]

Description:

For dairies in the Lake Fork Reservoir region, irrigation systems are designed to apply nutrient rich dairy wastewater from waste storage ponds to application fields. From a water quality standpoint, the rate and timing of wastewater

[22] The purpose listed in the NHCP, which focuses only on the plant watering function of an irrigation system states: "To efficiently and uniformly apply irrigation water to maintain adequate soil moisture for optimum plant growth without causing excessive water loss, erosion, or reduced water quality" (USDA, NRCS, 1987).

application is important and the application area should be of adequate size to accommodate the amounts of wastewater produced while applying at an agronomic rate. (See Nutrient Management.)

In the Lake Fork Reservoir region, three irrigation methods are employed:

1. Water is pumped through an underground 6 or 8 inch PVC pipeline to an above ground riser, where it is attached to a flexible hose, which leads to a "big gun" sprinkler. Strategic placement of risers and the flexible hose allow sprinklers to be moved to various locations on application fields allowing an even application of wastewater.

2. The flexible hose may be attached directly to the pump.

3. Water is pumped through an above ground aluminum pipeline, where it is attached to a flexible hose leading to a "big gun" sprinkler (Wyrick, 1998).

Method 3 has gone out of favor because above ground aluminum pipe can be easily damaged by farm equipment (Wyrick, 1998). Thus, methods 1 and 2 are currently considered the most practicable wastewater irrigation system for dairies in the Lake Fork Reservoir region of Texas.

Nozzle size is an important consideration when applying dairy wastewater. Large diameter "big gun" sprinklers are designed to accommodate high levels of total solids typically found in waste-storage-pond effluent. Sprinkler irrigation systems also require pipeline and pumps, described in previous sections of this report.

Costs of Implementation:

Table 4 presents estimated costs of irrigation system components exclusive of pumps and pipeline, which are presented in previous sections.

Table 4: Irrigation System Costs

Expense Item	Cost
Portable Sprinkler - small	$1,800 each
Portable Sprinkler – large	$2,200 each
Sprinkler Appurtenances	$289 each
Hose Reel Sprinkler	$18,000 each
3 Inch Plastic Hose –SDR* 17	$1.75 per linear foot
4 Inch Plastic Hose – SDR 17	$2.12 per linear foot
3 Inch Plastic Hose – SDR 11	$2.12 per linear foot
4 Inch Plastic Hose – SDR 11	$2.75 per linear foot
Plastic Hose Appurtenances	$219 each

* Standard Dimension Ratio (SDR) is a measure of pipe thickness. Smaller SDR numbers indicate thicker pipe. An engineer determines appropriate pipe thickness.

Source: TSSWCB, Mt. Pleasant Regional Office.

Waste Utilization

Definition:

"Using agricultural waste or other waste on land in an environmentally acceptable manner while maintaining or improving soil and plant resources" (USDA, NRCS, 1978).

Purpose:

"To safely use wastes to provide fertility for crop, forage, or fiber production; to improve or maintain soil structure; to prevent erosion; and to safeguard water resources" (USDA, NRCS, 1978).

Description:

Dairy waste can be land applied using a variety of techniques.

> The kind of equipment used depends on the [total solids] concentration of the waste. If the manure handles as a solid, a box spreader or flail spreader is used. Solids spreaders are used for manure from solid manure structures and for the settled solids in sediment basins.
>
> Slurry wastes are applied using tank wagons or flail spreaders. Some tank wagons can be used to inject the waste directly into the soil. ...
>
> Waste that has a [total solids] concentration of less than 5 percent can be applied using tank wagons, or it can be irrigated using large diameter nozzles (USDA, NRCS, 1996).

Dairies in the Lake Fork Reservoir region employ a variety of techniques for waste utilization and may combine several techniques (Wyrick, 1998). Irrigation systems are most commonly used, followed by use of a tank wagon (honey wagon). Little or no solid manure can be efficiently collected from most pasture operations, thus, application of solid manure does not occur to a great extent in the Lake Fork Reservoir region. Dairy producers using tank wagons most often pump waste directly from the cement pit adjacent to the milking operation into the tank wagon and apply it to application fields (Griffin, 1998). Wastewater from waste storage ponds may also be utilized. The trend over the last several years has been for dairy producers in the Lake Fork Reservoir region to adopt irrigation systems for waste utilization because it is less labor intensive (Griffin, 1998).

The Texas Addendum for Waste Utilization includes several additional specifications including:

a) Waste application to land must comply with these specifications, state laws, regulations or technical guides or local ordinances, whichever are most restrictive.
b) Wastes will not be applied to frozen or snow-covered soil ...
c) Wastes will not be applied to and within 200 feet of ponds, lakes, streams, wells, sinkholes, and land subject to frequent flooding or other areas where there is a probability of water pollution from runoff. ...
d) Highly permeable soils that have low absorptive capacity shall be investigated onsite (USDA, SCS-TX, 1990).

Costs of Implementation:

The costs associated with waste utilization depend on the particular method employed. Costs of an irrigation system are presented in the previous section. Tank wagons used for manure spreading cost about $10,000 new and range in price from $4,500 - $6,500 used (Griffin, 1998).

Nutrient Management

Definition:

Managing the amount, form, placement, and timing of applications of plant nutrients (USDA, NRCS, 1990).

Purpose:

To supply plant nutrients for optimum forage and crop yields, minimize entry of nutrients to surface and groundwater, and to maintain or improve chemical and biological condition of the soil (USDA, NRCS, 1990).

Description:

Nutrient management is an important element in a waste management system because it specifically addresses potential nonpoint source pollution. Nutrient management minimizes the amount of nutrients reaching surface and groundwater from crop fertilization while attempting to achieve "optimum" crop yields. In theory, both objectives can be achieved by applying nutrients at an agronomic rate – a rate at which almost all applied nutrients are taken up by the crop. Achieving this rate requires a delicate balance. Under-application may result in sub-optimal crop yields, whereas over-application can contribute to excessive nutrient loadings in surface and groundwater.

Applying manure or fertilizer at an agronomic rate requires developing a nutrient management plan incorporating a nutrient budget as outlined below:

1) Select a realistic yield goal.

2) Determine the amount of nutrients (nitrogen and phosphorus) required to produce the targeted yield (crop fertility needs).

3) Estimate an amount of residual nutrients in the soil and crop residue.

4) Calculate additional fertility required. Subtract 3) from 2) to determine additional fertility required, which can be supplied by either organic waste or chemical fertilizer applications.

5) Estimate nutrients to be supplied by organic wastes and determine the amount of organic waste to be applied. Nutrients from organic waste (manure wastewater) can be applied up to, but not over, the rate that additional fertility is required.

6) Calculate amount of additional fertilizer (if any) needed to meet nutrient requirements. Subtract 5) "estimated nutrients from organic wastes," from 4) "additional fertility required," to determine the amount of nutrients that can be supplied by chemical fertilizer.

The application rate and total amount of chemical fertilizer required is determined by the nutrient content of the fertilizer used (USDA, NRCS, 1990 & USDA, SCS-TX-Area 7, 1990).

Subchapter B (30 TAC 321.30 et seq.) regulations specify that applications of manure, wastewater, and pond solids shall not exceed nutrient uptake by crops. Meeting this limitation while still applying at a rate consistent with optimal crop yields may be difficult to achieve in practice. Appropriate nutrient management for wastewater and manure applications is also complicated by the fact that both nitrogen (N) and phosphorus (P) have important implications for crop requirements and water quality. The P:N ratio in fresh manure is higher than the P:N ratio required for plant material (Gilliam, 1995). Moreover, more N than P is lost to surface and subsurface drainage water in most soils (Gilliam, 1995). Consequently, manure or wastewater applications designed to provide sufficient N for crops will lead to P accumulation in soil. TNRCC Subchapter B regulations and dairy permits require that standards for both nitrogen and phosphorus be met.[23] Specifically, the TNRCC requires waste application at a phosphorus rate (versus nitrogen rate) when extractable phosphorus at an application field reaches 200 ppm, based on Texas Agricultural Extension Service – TAMU extractant or Mahlich III (30 TAC § 321.39 (f) (28) (F) (ii)).

The Texas Addendum for nutrient management provides several tables to assist dairy operators in managing nutrients including: 1) nutrient recommendations (N, P, and K) for specific crop yield goals, 2) approximate percent of plant nutrients in crop residues, and 3) fertilizer establishment rates for grasses and legumes (USDA, SCS-TX-Area 7, 1990). More precise guidance is included in TNRCC dairy permits where tables for nutrient requirements for various crops, the nutrient content for various types of manure, and maximum wastewater application rates are provided. TNRCC dairy permits also require that representative samples of wastewater and waste application sites be analyzed on a number of measures including nitrate nitrogen and extractable phosphorus.

Costs of Implementation:

Nutrient management is a conservation practice requiring management, oversight, and measurement. Soil testing, however, is the only out-of-pocket expense required by the producer. The NRCS supplies forms and bags for soil samples to dairy producers. After collection, producers may send samples to either Texas A&M University or Stephen F. Austin State University for analysis for a fee of $10 per sample.

[23] A section of a typical Texas dairy permit reads:

> When the annual soil analysis for extractable phosphorus ... has a test result of greater than 200 ppm (reported as phosphorus measured on a dry-weight basis) for a particular site, then the permittee shall limit the waste application rate on that site. The solid waste application rate shall be the lower value of either the value found in Section ... above, or the application rate as determined by using the phosphorus value in the manure ... and the phosphorus requirement of the desired crop.... The waste application rate shall be calculated in this manner until the soil analysis for extractable phosphorus on that site is below 200 ppm.

Fence

Definition:

"A constructed barrier to livestock, wildlife or people" (USDA, NRCS, 1995a).

Purpose:

"This practice may be applied as part of a conservation management system to facilitate the application of conservation practices that treat the soil, water, air, plant animal, and human resource concerns" (USDA, NRCS, 1995a).

Description:

Fencing involves enclosing or dividing an area of land with a suitable permanent or moveable structure that acts as a barrier to dairy cows. Fencing excludes livestock from areas that should be protected from grazing. TNRCC dairy permits, for example, forbid the entry of livestock into retention structures, such as waste storage ponds. Fencing also prevents direct nutrient contribution to surface water. Fencing can be placed along creeks, for instance, to prevent direct nutrient contribution.

Costs of Implementation:

Costs of typical fence construction in the Lake Fork Reservoir region are estimated at $1.25 per linear ft. (TSSWCB, 1998).

Filter Strips

Definition:

"A strip or area of vegetation for removing sediment, organic matter, and other pollutants from runoff and waste water" (USDA, NRCS, 1997a).

Purpose:

"To remove sediment and other pollutants from runoff or waste water by filtration, deposition, infiltration, absorption, adsorption, decomposition, and volatilization, thereby reducing pollution and protecting the environment" (USDA, NRCS, 1997a).

Description:

In the Lake Fork Reservoir region, filter strips can be employed in pastures and manure spreading areas adjacent to streams, ponds, and lakes. Filter strips should be positioned between a water body needing protection and pasture or application fields.

Filter strips require a gentle slope in order to prevent water from running off. The filter area should be seeded with a stable crop suitable to the region in which the operation is located. Vegetative cover should be maintained to keep the cover thick. Impairments to the strip (e.g. channels) should be fixed immediately. A filter strip should be fenced to control grazing if it is used for livestock grazing (USDA, NRCS, 1997a).

A properly maintained filter strip should reduce the amount of nutrients entering the waterways. As wastewater runs off, it should flow uniformly over the filter strip, which slows the flow of water allowing the nutrients to be deposited before the runoff reaches a stream or other water body (USDA, NRCS, 1997a).

Costs of Implementation:

Costs associated with a filter strip system depend on the size of the filter strip, the site's slope, existing crops or grass, and the amount of fencing needed. Table 5 lists the costs of components that may be required for installation of a filter strip in the Lake Fork Reservoir region.

Table 5: Filter Strip Costs

Expense Item	Cost
Constructing Fences	$1.25 per linear foot
Seedbed Preparation	$30.00 per acre
Bermudagrass sprigs	$24.00 per acre
Bermudagrass seed - Giant	$6.00 per pound
Bermudagrass Sprigging	$20.00 per acre
Bermudagrass Seeding	$20.00 per acre
Applying Fertilizer	$48.00 per acre annually

Source: TSSWCB, Mt. Pleasant Regional Office.

Prescribed Grazing

Definition:

"The controlled harvest of vegetation with grazing or browsing animals, managed with the intent to achieve a specified objective" (USDA, NRCS, 1994).

Purposes:

Prescribed grazing may be applied as part of a conservation management system to accomplish one or more of the following purposes:

- Improve or maintain the health and vigor of selected plant(s) and to maintain a stable and desired plant community.
- Provide or maintain food, cover and shelter for animals of concern.
- Improve or maintain animal health and productivity.
- Maintain or improve water quality and quantity.
- Reduce accelerated soil erosion and maintain or improve soil condition for sustainability of the resource (USDA, NRCS, 1994).

Description:

Prescribed grazing is a practice in which two or more grazing units are alternately grazed and rested in a planned sequence. Prescribed grazing maintains existing plant cover or hastens its improvement while properly maintaining the forage intake of dairy cows. In the Lake Fork Reservoir region, "Coastal bermudagrass is used during the summer months and then overseeded with small grains (wheat, elbon rye, and/or annual ryegrass) in the winter months" (Brown and Rich, 1997). Although prescribed grazing is employed primarily to improve the economic efficiency of pasture dairy operations,[24] environmental benefits also accrue.

Grazing systems can be set up on rangeland, pastureland, and hay fields. The land is sectioned so that dairy cows spend a determined amount of time on each section. Livestock are relocated in cycles of days or months depending on the size of the sections and number of cows. The season of the year may also influence the time that cows are on each section. Rotation allows the grasses in each section to recover from grazing in an optimal manner.

Prescribed grazing can be employed in any degree of intensity. A highly managed form of prescribed grazing is referred to as intensive rotational grazing. This grazing method is defined as rotation of grazing cows among several small pasture subunits called paddocks versus continuous stocking on a large pasture field. "Each paddock is grazed quickly and then allowed to regrow for several days, ungrazed, until ready for another grazing" (USDA, NRCS, not dated).

As dairies have become larger in the Lake Fork Reservoir region, the extent and intensity of prescribed grazing techniques are increasing, thereby allowing more cows to graze on the same area (Griffin, 1998).

Costs of Implementation:

Capital expenditures required to implement prescribed grazing generally include costs associated with additional fencing and supplying water, if water is not available on all grazing sections. Inexpensive water troughs, to put water in every paddock, and inexpensive fences using electrified poly-wire or poly–tape are recommended (USDA, NRCS, not dated). A charger is also required if electric fencing is used. There is a considerable range in the costs for chargers depending on whether they are powered by standard residential electric current, battery, diesel-powered generator, or solar energy. Cost components are presented in Table 6.[25] Additional costs may be incurred if bare areas need to be reseeded or if pipe is required to supply water to paddock sections.

Table 6: Prescribed Grazing Costs

Expense Item	Cost
Poly-Wire, high visibility	$17.99 per 400 meters
Poly-Tape high visibility	$29.00 per 400 meters
Charger	$26.99 - $299 each
Post – round steel	$0.69 each
Post – fiberglass	$0.99 each
Post – step-in poly	$1.69 each
Insulators	$5 - $8 per pkg. of 25
Insulated handles	$0.99 - $1.99 each
Water Trough – metal	$44.99 - $199 each
Water Trough – plastic	$59.99 - $189 each
Block Feeder	$4.99 each

Source: Tractor Supply Company, Sulphur Springs, TX.

24 For example, "The $129 per acre profit with intensive rotational stocking method far exceeded the $75 profit from continuous stocking" (USDA, NRCS, not dated).

25 Since most components needed for prescribed grazing are not included on the TSSWCB list of approved BMPs for cost-share funding, costs for Table 6 were determined by interviewing an employee at Tractor Supply Company, Sulphur Springs, Texas.

WASTE MANAGEMENT SYSTEMS

Definition:

"A planned system in which all necessary components are installed for managing liquid and solid waste, including runoff from concentrated waste areas, in a manner that does not degrade air, soil, or water resources" (USDA, NRCS, 1979).

Purpose:

To manage waste in rural areas in a manner that prevents or minimizes degradation of air, soil, and water resources and protects public health and safety. Such systems are planned to preclude discharge of pollutants to surface or ground water and to recycle waste through soil and plants to the fullest extent practicable (USDA, NRCS, 1979).

Description:

A waste management system incorporates an integrated system of BMPs employed to utilize and manage dairy wastes in an environmentally sound manner. In the Lake Fork Reservoir region, as elsewhere, the particular set of BMPs integrated into a waste management system is dependent on a variety of farm characteristics, such as soil type, location, and size of herd. Waste management plans developed in the Lake Fork Reservoir region may include several of the BMPs identified in this report.

Costs of Implementation:

Due to a variety of factors, costs of dairy waste management systems vary considerably. Actual waste management system costs for three pasture operations located in the Running Creek area of the Lake Fork Reservoir watershed are portrayed in Table 7. Cost-share programs (discussed later in this report) typically finance a portion of implementation costs.

Table 7: Waste Management System Installation Costs for Three Dairies in the Running Creek Area of the Lake Fork Reservoir Watershed

BMP	160 Cow Dairy	225 Cow Dairy	230 Cow Dairy
Fencing	$700	$700	$600
Irrigation Pump	$6,500	$6,000	$6,500
Pipeline	$1,500	$6,823	$1,825
Plastic Hose	$2,635	$2,500	-
Slurry Pump	$6,000	$3,460	-
Sprinkler	$2,700	$2,700	$3,378
Vegetation	$150	$100	$100
Waste Storage Pond	$3,600	$3,370	$4,226
Total	$23,785	$25,653	$16,629

Source: NRCS Office, Sulphur Springs, TX

Table 7 itemizes costs of waste management systems for a 160-cow dairy, a 225-cow dairy, and a 230-cow dairy. Because of dairy location and topography, the 160 and 225 head dairies required a system with both a slurry pump and a plastic hose.

Location and topography also required the 160-cow dairy to pump waste uphill to a waste storage pond. Although constructing a waste storage pond uphill from the dairy barn is not the ideal situation, it was the only option for this operation given the dairy location. The 160-cow dairy also had to use a plastic hose to allow for more mobility in using the sprinkler system, which added costs to the plan.

The 225-cow dairy also required a slurry pump, used to pump waste to an area with clay soils, thus eliminating the need to bring in a clay liner and reducing the cost of the waste storage pond. The cost of the slurry pump on the 225-head dairy was less than the one on the 160-cow dairy because the pump was smaller. However, the 225-cow dairy had to transport the waste almost four times as far because the waste application field was much farther from the barn. This increased pipeline costs by about four thousand dollars.

The 230-cow dairy had higher waste storage pond construction costs than the other two dairies, but did not require a slurry pump or plastic hose for its operation. This resulted in the lowest total cost of the three dairies, despite the fact that it was the largest of the three dairies in terms of herd size.

Financing Costs:

Cost-share funds available in the Lake Fork Reservoir region typically finance up to 75 percent of waste management system costs up to a maximum of $10,000. Dairy owners must finance the remainder of system costs. For this analysis, we assume that each of the dairies in Table 6 can access $10,000 of cost share funds. This leaves $13,785, $15,653, and $6,629 to be financed by the owners of the 160-, 225-, and 230-cow dairies respectively. Amortized over a 15-year period at 8.5 percent annual interest, total annual financing costs (principal and interest) would be $1,660, $1,885, and $801 for the 160-, 225-, and 230-cow dairies respectively.

Costs of Operation:

In addition to capital costs, waste management systems require ongoing operational costs, such as annual repairs, maintenance, fuel, and labor costs. Like capital costs, operational costs are unique to each dairy. Using the set of assumptions described below, operational costs of a waste management system using the 160-cow dairy were estimated.

Annual repairs and maintenance costs were estimated at 3.5 percent of initial investment (Outlaw, 1995), resulting in an annual cost of $833.[26] Labor costs associated with operating the waste management system were estimated using an annual full time salary of $18,500 resulting in an estimated hourly labor rate of $8.89 per hour (Outlaw, 1995).[27] Labor costs accrue when waste ponds are dewatered. Typically a dairy farmer in this region will irrigate twice a year. Preparation for irrigation may require half a day. Once irrigating commences, however, very little labor is required. Thus, if a farmer irrigates twice a year, an estimated $71 per year for labor is required.[28]

Fuel costs are estimated assuming that 2 gallons of fuel are used per hour at current diesel costs. Irrigation time depends on herd size, size of pump, and waste storage pond capacity. Given the 160-cow dairy used in this example, irrigation may take five days, pumping twelve hours a day, twice a year (Wyrick, 1996). Assuming two gallons of diesel per hour at $1.00 per gallon, total fuel cost is estimated at $240 annually.[29] Total estimated waste management system operating costs sum to $1,144 annually. Operating costs for the 160-cow dairy are summarized in Table 8.

Table 8: Annual Waste Management System Operating Costs for a 160 Cow Dairy

Item	Cost
Repairs and Maintenance	$833
Labor (Irrigation)	$71
Fuel	$240
Total	$1,144

[26] $23,785 * 0.035 ≈ $833 annually.

[27] $18,500 annually / 52 weeks / 40 hours per week ≈ $8.89 per hour.

[28] $8.89* 4 hours * 2 times per year ≈ $71 annually. Washing the milking parlor and flushing the holding pens are not included as an operating cost for a waste management system because these tasks would need to occur because of health considerations, regardless of nutrient management BMPs. Thus, only additional costs required for the operation of a waste management system are included.

[29] 5 days * 12 hours * 2 gallons per hour = 120 gallons of fuel * $1.00 per gallon = $120 per irrigation process * 2 irrigations a year = $240 annually.

ENVIRONMENTAL EFFECTIVENESS

Dairy waste includes both the liquid and solid manure from livestock, process water from the milking parlor, and the feed, bedding, litter, and soil with which they become intermixed (USEPA, 1993). Pollutants contained in the waste, such as nutrients, pathogens, and salts can leach into groundwater or run off into surface water. Waste management systems are designed to reduce or prevent pollutants from reaching water sources.

"The effectiveness of BMPs can be measured in terms of their impact on pollutant loads, acceptability by farmers, cost-effectiveness, and ease of implementation and maintenance" (Logan, 1990). For purposes of this section, BMP effectiveness is rated in terms of the adequacy of the BMP to prevent target nutrients from reaching either surface or ground water supplies.

Feedlot runoff and land applied manure have the highest concentration of nitrogen and phosphorus of all nonpoint sources (Ritter, 1988). As a result, a number of studies have investigated the effects of dairy waste management practices on the reduction of nitrogen and phosphorus.

A review of the literature reveals a wide range of effectiveness measures. For particular cases, effectiveness values of a practice can vary considerable depending on site-specific variables such as soil type, animal housing and feed, methods of waste handling and storage, and seasonal variations. The studies reviewed here examine the effectiveness of either specific practices or systems of practices on the reduction of nitrogen and/or phosphorus. Osei and others (1995) summarize effectiveness results from a number of studies. This report extends the work of Osei and others by incorporating additional study results, including effectiveness results from vegetative filter strips and from systems of practices that reduce nitrogen and phosphorus.

Table 9 summarizes the results of several individual studies. In many cases, multiple sites were tested by the same researcher resulting in varying percent reductions. While study results depend on site-specific circumstances and baseline conditions, they can provide policy makers with a general range of values for gauging the potential effectiveness of various management practices.

Table 9: Environmental Effectiveness of Selected Waste Management Practices

Source	Practice Category	% Reduction in Total P	% Reduction in Total N
Lyman et al. 1970	Waste storage pond	83.30	-
Lyman et al. 1970	Waste storage pond	58.80	-
Lyman et al. 1970	Waste storage pond	51.00	-
Sweeten & Wolfe 1993	Single Stage Lagoon	38.10	33.90
Sweeten & Wolfe 1993	Single Stage Lagoon	9.60	27.80
Sweeten & Wolfe 1993	Single Stage Lagoon	4.28	7.34
Sweeten & Wolfe 1993	Single Stage Lagoon	-18.30	-4.00
Moore & Gamroth 1994	Single Stage Lagoon	60.00	70.00
Dillaha et al. 1989	9.1m Vegetative Filter Strip	79.00	-
Dillaha et al. 1989	4.6m Vegetative Filter Strip	61.00	-
USDA-EPA 1993	Vegetative Filter Strip	70.00	45.00
USDA-EPA 1993	Animal Waste Systems	90.00	80.00
Dawson, Smith, and Dial, 1996	Vegetative Filter Strip	85.00	-
Gunsalus 1992	Waste Management System	50.00-70.00	-

Note: Negative values indicate that test results showed an increase of the pollutant (P or N). This could be due to uncontrolled factors.

Phosphorus Effects

The most widespread method used to prevent phosphorus (P) from reaching surface and groundwater is the utilization of waste storage ponds or lagoons. Reported values for P reduction by waste storage ponds and lagoons vary considerably. Gilliam (1995) reports that studies show up to 90 percent of the P entering either aerobic lagoons[30] or anaerobic lagoon systems may remain in the sludge. Lyman, Gray and Bailey (1970) found that P levels declined by 58.8 percent, 83.3 percent and 51.0 percent, in three case studies examining waste storage ponds used to collect human waste. A 1993 research project that evaluated dairy waste management systems in North Central Texas reported that P levels of effluent, for dairies with single stage lagoons, declined by 38.1 percent, 9.5 percent, and 4.28 percent on three dairies and increased by 18.3 percent on one of the dairies (Sweeten and Wolfe, 1993). Moore and Gamroth (1994) reported that P levels declined by 60 percent due to the use of a single stage lagoon. A point of caution regarding reported removal efficiencies is that the lost P has gone to the sludge, which must be dredged from the storage pond in most instances. Sludge is typically surface applied to agricultural lands and therefore re-enters the environment with the potential to reach receiving waters.

[30] A waste storage pond is technically distinct from an aerobic lagoon or an anaerobic lagoon system in that a waste storage pond stores but is not designed to treat effluent. In practice, however, there may be little difference between single stage lagoons, aerobic lagoons and waste storage ponds.

Although the use of vegetated filter strips (VFS) is less common, studies have indicated that they can effectively control nonpoint source pollutants in some situations. A 1989 study by Dillaha and others (1989) found that 9.1 meter and 4.6 meter wide VFS removed an average of 79 percent and 61 percent, respectively, of the incoming P. However, "Surface runoff in fields with greater slope lengths will tend to concentrate in natural drainageways within the field and cross the [vegetative filter strip] in a few localized areas as concentrated flow. Filter strips are not expected to be effective under these concentrated flow conditions" (Dillaha, et al., 1989). Another study estimates the relative gross effectiveness of P control attributed to VFS at 75 percent reduction (USEPA, 1993). A study by Dawson, Smith, and Dial (1996) in Vermont reported that when VFS were implemented around barn houses, P loadings in streams decreased by 85 percent.

Lake Okeechobee, Florida is one of the most noteworthy case studies of efforts to control agricultural nonpoint source pollution. Questions concerning the health of the lake where raised in the late 1960s and early 1970s when fisherman started seeing excessive weed growth (Bottcher, 1995). Research investigations found that the lake was in danger of becoming hypereutrophic primarily because of nutrient inputs from agricultural activities (Frederico, Dickson, and Davis, 1981). Consequently, three phases of BMPs were implemented during the past 20 years. The most recent phase included intensive animal waste collection and the installation of nutrient recycling systems to reduce phosphorus loads from dairy and beef pasture operations (Gunsalus, Flaig, and Ritter, 1992). Even though some of the sample sites demonstrated an increase in total P levels, overall, the data reveal that total P concentrations decreased by an estimated 50 percent to 70 percent on dairies in the basin (Gunsalus, Flaig, and Ritter, 1992).

Nitrogen Effects

Data on nitrogen (N) transport to surface waters also exhibit considerable variability, depending on site specific characteristics, application techniques, and management practices. Research results suggest that negative effects can be greatly reduced by employing appropriate N reducing BMPs.

As in the case of P, one of the most widespread BMPs for reducing N is the utilization of a waste storage pond. Sweeten and Wolfe (1993) estimate N levels of effluent, for three dairies which used a single stage lagoon, declined by 33.9 percent, 27.8 percent and 7.34 percent and increased by 4.0 percent on one dairy. A study by Moore and Gamroth (1994) reported that N level declined by 70 percent due to the use of a single stage lagoon.

Studies also show that VFS can be effective in reducing N loading in streams. A 1989 study by Dillaha and others (1989) which examined the effectiveness of VFS in reducing nutrient losses from cropland found that 9.1 meter and 4.6 meter wide VFS removed an average of 73 percent and 61 percent, respectively, of the incoming N. Another study estimates the relative gross effectiveness of N control attributed to VFS at 70 percent reduction (USEPA, 1993).

FINANCING OF BMPs

Costs associated with BMPs or systems of BMPs can be substantial. To alleviate much of the financial burden, both state and federal cost-share programs have emerged and have been and are being employed.

State Cost-Share Funds

At the state level, state cost-share funds are available for areas of the state that the TSSWCB has "identified as having water quality problems or the potential for such problems caused by agricultural and/or silvicultural activities" (TNRCC, 1994). This cost-share program was authorized by Senate Bill 503 in 1993, the same legislation that authorized the TSSWCB to develop site-specific water quality plans (TNRCC, 1994). Under the program, dairies were assigned top priority for cost-share funds followed by poultry operations (O'Conner, 1998). To qualify for cost-share funds, a dairy farmer must have a water quality management plan certified by the TSSWCB or the NRCS. Once the water quality plan has been approved, 75 percent of the BMP's costs, up to a maximum of $10,000 per individual, can be covered by state funds. The farmer is responsible for the remaining 25 percent, or amounts over $10,000. In some cases, dairy farmers may qualify for federal cost-share funds in addition to state funds.

For Hopkins County, $217,000 was allocated for the cost-share program in 1996, 1997, and 1998 (O'Conner, 1998). Approximately 20 dairies a year have received funding under the program (Wyrick, 1998). Because funds are limited, some dairies are on a waiting list to receive state funds or have qualified for federal funding.

Federal Cost-Share Funds

In many cases, federal funds are also available to assist livestock producers with environmental compliance. The Environmental Quality Incentive Program (EQIP) was established under the Federal Agriculture Improvement and Reform Act of 1996 (commonly referred to as the 1996 Farm Bill) "to assist crop and livestock producers deal with environmental and conservation improvements on the farm" (USDA, 1996). Half of the available funds are designated for addressing conservation problems associated with livestock operations where assistance includes a focus on high priority areas (USDA, 1996). In 1998, the Nutrient Management – Lake Fork Reservoir priority area ranked fourth on the Texas priority list (Wells, 1998).

Nationally, EQIP provides funding of $200 million annually until 2002 (except for fiscal year 1996, which was funded at $130 million) (USDA, 1996). Funds are divided among the 50 states; the states then divide their share of funding among priority areas and the rest of the state.[31] In 1998, Texas received $13 million in EQIP funding. Of this, $450,000 was channeled to the Nutrient Management – Lake Fork priority area (Wells, 1998). Within a priority area, bids are offered by producers who enumerate environmental benefits and can request up to 75 percent of project funding (Wells, 1998). Bids are then ranked and funds are distributed with the goal of maximizing environmental benefits per dollar spent (USDA, NRCS, 1998a).

Limited federal funding for waste management systems in the Lake Fork Reservoir watershed has been and may possibly again become available through Section 319 funding. Section 319 of the CWA provides a grant program provision that funds implementation of demonstration projects designed to control serious nonpoint source pollution. The Lake Fork Creek Reservoir Implementation (319) Project helped fund two water quality management plans in the Running Creek watershed, a sub-basin of the Lake Fork Reservoir watershed. This project is due to end on August 31, 1998. However, another 319 demonstration project is being considered for the Running Creek watershed. If implemented, this program could provide up to $10,000 per dairy for up to 20 dairies in the watershed (Hester, 1998). Although Section 319 funds are federal, projects are administered through the TSSWCB and their terms and conditions are the same as those of the State cost-share program (SB503 funds) (Hester, 1998).

Dairy producers may utilize more than one source of state or federal assistance provided that each individual project is funded by only one source of government assistance. An individual item or project, a pump for instance, cannot receive cost-share funds from more than one source of government assistance (Wyrick, 1998).

After cost-share funds have been distributed, the balance of waste management system costs is typically financed either by private financial institutions or by the producer (Wyrick, 1998). Private banks that make loans to agricultural producers offer a variety of loan products, the terms of which are unique to each lending institution (Grant, 1998). Loans to dairies for waste management systems would most likely be classified as either real estate or equipment loans, depending on the source of collateral. Interest rates on these loans are typically tied to the prime rate (8.5 percent in July 1998) (Grant, 1998).

[31] Priority areas are given preferential funding. Remaining funds not assigned to priority areas are distributed to the rest of the State.

SOCIAL AND POLITICAL ACCEPTABILITY

Most of the nutrient BMPs described in this report are already in widespread use in the Lake Fork Reservoir watershed region, and are generally accepted by area dairy producers as a cost of doing business. Flexible schedules of BMP implementation by state and federal regulators along with considerable cost sharing contribute to the social/political acceptability of waste management plans.

Problems and Constraints

Implementation of waste management plans can be costly to dairy operators, even with cost-share programs. For dairy producers with nonexistent or low profit margins, any additional costs could contribute to the operation becoming unprofitable. Thus, many dairy owners may be reluctant to implement BMPs. According to a report for the Lake Fork Creek Hydrologic Unit Area Project, "Although many producers have participated in FSA cost-share programs to install waste management systems, many others have been unable to install systems because of their inability to provide their share of the costs" (Brown and Rich, 1997).

Another potential problem regarding environmental compliance for dairies in the Lake Fork Reservoir region, as elsewhere, involves the application of wastewater at the proper rate (nutrient management). Also, manure applications designed to provide sufficient N to crops lead to P accumulation in soil. The TNRCC requires waste application at a phosphorus rate (versus nitrogen rate) once extractable phosphorus at an application field reaches 200 ppm, based on Texas Agricultural Extension Service – TAMU extractant or Mahlich III. If an application field were found to be at or above 200 ppm, and the phosphorus application rate enforced, then application fields would need to be much larger, which could pose economic as well as logistical challenges to dairy operators.

SUMMARY AND CONCLUSIONS

The *National Water Quality Inventory: 1994 Report to Congress,* identifies agriculture as the leading source of water quality impairments in the rivers and lakes of the United States (USEPA, 1995b). Much of this impairment can be traced to concentrated livestock operations, which have, as a result, come under greater levels of scrutiny by state and federal agencies.

This study presents the costs and environmental effectiveness of selected BMPs for dairies in the Lake Fork Reservoir watershed in Texas. In addition, costs of operating a total waste management system for a representative Hopkins County dairy are estimated; alternative methods of financing BMPs are identified; and social and political acceptability and problems and constraints of implementing BMPs are described.

Cost estimates for each BMP were stated in the respective BMP section. In addition, costs of waste management systems actually implemented on three dairies in the Running Creek area of the Lake Fork Reservoir watershed were also provided. These dairies housed 160, 225, and 230 cows. Total installation costs of waste management systems for these dairies were $23,785, $25,653 and $16,629, respectively. Annual financing costs for the amounts over $10,000 (the portion often not picked up by state and federal cost-share programs) would be $1,660, $1,885, and $801 respectively, assuming an 8 ½ percent interest rate on a 15-year loan.

Operational costs were estimated for the 160-cow dairy. Repairs and maintenance associated with the capital investment were estimated at $833 annually. Labor costs associated with operating the waste management system were estimated at $71 per year. Fuel costs were estimated at $240 annually. Thus, total annual operating expense for the waste management system at the 160-cow dairy was estimated at $1,144.

Waste management systems represent a substantial cost to dairy farmers. In order to alleviate some of the financial burden and to encourage implementation, state and federal cost-share programs have been initiated to provide assistance for environmental and conservation improvements (USDA, 1996). These programs include a state cost-share program authorized by Senate Bill 503 in 1993, and two federal programs: the EQIP program, authorized in the 1996 Farm Bill, and grants made for demonstration projects under Section 319 of the CWA. Even with assistance programs, government funds are limited and the amount of cost-share funds distributed for a single project or items is generally capped at $10,000 or 75 percent of project cost. Thus, dairy operators typically must finance a significant portion of waste management improvements, either through private lending institutions, or from personal resources.

A review of the literature indicates that BMPs are generally effective at reducing target nutrients. The environmental effectiveness of implementing nutrient BMPs, however, is highly dependent on variables such as dairy operational style, location, and soil type and hence is unique to each dairy. The information presented in this report, however, can provide policy makers with a general range of values for assessing the potential cost and effectiveness of proposed waste management practices.

While implementing nutrient BMPs can impose substantial costs on dairy farmers, improvements in water quality lower costs and produce benefits to other sectors of society. Cost-share programs, which often pay a major portion of water quality management plans, are typically utilized, making them more economically feasible and therefore more acceptable to area dairy producers.

The BMPs identified in this report are all technically feasible and most if not all are already being utilized in the Lake Fork Reservoir watershed. A potential problem in the Lake Fork Reservoir watershed, as in other areas of high dairy concentration, is phosphorus buildup in soil. Manure application at the N rate for crops leads to P accumulation in soil. Application at the phosphorus agronomic rate may be required if wastewater application fields are found to have 200 ppm or more extractable phosphorus, based on Texas Agricultural Extension Service – TAMU extractant or Mahlich III. In some cases, a dairy operator could simply irrigate more acres of land, or shift application to an area that has not reached the 200 ppm phosphorus trigger. In other cases, additional land might need to be purchased for wastewater application. In either case, application at the P rate could pose economic and logistical challenges to dairy operators as well as monitoring and enforcement challenges to regulators.

REFERENCES

Bailey, Kameran L. and David W. Riggs, 1996. *A Nutrient Budget Analysis for the Lake Fork Reservoir Watershed,* Texas Institute for Applied Environmental Research, Stephenville, TX, August 1996.

Bottcher, A.B., Terry K. Tremwel, and Kenneth L. Campbell. 1995. "Best Management Practices for Water Quality Improvement in the Lake Okeechobee Watershed" *Ecological Engineering*, Vol. 5, pp. 341-356.

Brown, Billy and Roxanne Rich. 1997. *Lake Fork Creek Hydrologic Unit Area Project, Annual Project Report, Fiscal Year 1997,* USDA, NRCS, Texas Agricultural Extension Service, Farm Service Agency in cooperation with Texas Agricultural Experiment Station, TSSWCB, U.S. Geological Service, EPA, TNRCC, and local soil and water conservation districts, December 1, 1997.

Clean Water Act, U.S. Code, vol. 33, § 1251-1387 (1972).

Dawson, Deena K., Matt C. Smith, and Jim J. Dial. 1996. "Evaluation of Best Management Practices on a Dairy Farm in the Piedmont Region of Georgia" Annual International Meeting, Paper No. 962007, ASEA, 2950 Niles Rd., St. Joseph, MI 49805-9659 USA, July 17, 1996.

Dillaha, T.A., R.B. Reneau, S Mostaghimi, and D. Lee. 1989. "Vegetative Filter Strips for Agricultural Nonpoint Source Pollution Control" *American Society of Agricultural Engineers*, Vol. 32 (2): March-April 1989.

Frarey, Larry C. and Ron Jones. 1994. "'Planned Intervention': Merging Voluntary CAFO Pollution Abatement with Command and Control Regulation" Environmentally Sound Agriculture: Proceedings of the Second Conference, Orlando, Florida, American Society of Agricultural Engineers, April 1994.

Frederico, A.C., K.G. Dickson, and F.E. Davis. 1981. *Lake Okeechobee Water Quality Studies and Eutrophication*, West Palm Beach, Florida: South Florida Water Manager District, Assess. Tech. Pub. 8-12.

Gilliam, J.W. 1995. "Phosphorus Control Strategies" *Ecological Engineering*, Vol. 5, pp. 405-414.

Grant, John. 1998. Personal Communication, Vice President and Loan Officer, Town and Country Bank, Stephenville, TX, July 15, 1998.

Griffin, Jim. 1998. Personal Communications, Civil Engineering Technician, NRCS, Sulphur Springs, TX, May 21, 1998.

Gunsalus, Boyd, Eric G. Flaig, and Gary Ritter. 1992. "Effectiveness of Agricultural Best Management Practices Implemented in Taylor Creek/Nubbin Slough Watershed and the Lower Kissimmee River Basin" Proceedings of National RCWP Symposium, West Palm Beach, Florida: South Florida Water Manager District.

Haven, Karl, E., Eric G. Flaig, R. Thomas James, Sergio Lostal, and Dera Muszick. (no year) "Environmental Auditing Results of a Program to Control Phosphorus Discharges from Dairy Operations in South Central Florida" *Environmental Management*, Vol. 21, No. 4, pp.585-593.

Hester, Justin. 1998. Personal Communication, Project Manager, TSSWCB, Temple, TX, July 15, 1998.

Logan, Terry. 1990. "Agricultural Best Management Practices and Groundwater Protection" *Journal of Soil and Water Conservation*, March-April 1990, pp. 201-206.

Lyman, Edwin D., Melville W. Gray, and John H. Bailey. 1970. "A Field Study of the Performance of Waste Stabilization Ponds Serving Small Towns" International Symposium for Waste Treatment Lagoons, Kansas City, Missouri. June 1970, pp. 387-404.

McFarland, Ann and Larry Hauck. 1995. *Livestock and the Environment: Scientific Underpinnings for Public Policy Analysis,* Texas Institute for Applied Environmental Research, Stephenville, TX, September 1995.

Moore, James A. and Michael J. Gamroth. 1994. "Pathways of Nitrogen Movement from Land Spread Manures" Dairy Systems for the 21st Century: Proceedings of the Third International Dairy Housing Conference, American Society for Agricultural Engineers, Orlando FL, February 1994, pp. 760-768.

O'Conner John. 1998. Personal Communication, TSSWCB, Mt. Pleasant, TX: July 8, 1998.

Osei, Edward, P.G. Lakshminarayan, Shannon Neibergs, Aziz Bouzaher, and S.R. Johnson. 1995. *Livestock and the Environment: A National Pilot Project, The Policy Space, Economic Model, and Environmental Linkages*, Livestock Series Report 4, Ames, IA: Center for Agricultural and Rural Development, December 1995.

Outlaw, Joe, Amy Purvis, and John W. Miller. 1995. *An Evaluation of Dairy Manure Management Economics*, Agricultural and Food Policy Center, Texas A&M, College Station, TX, November 1995.

Parmley, Barbara. 1998. Personal Communication, Environmental Investigator, TNRCC, Tyler, TX, August 6, 1998.

Pegues, Tom. 1998. Personal Communication, Division Manager, Lake Fork Division - Lake Fork Reservoir, Sabine River Authority, Quitman, TX, August 4, 1998.

Percival, Robert V, et al. 1992. *Environmental Regulation: Law, Science, and Policy*, Little, Brown and Company, Boston, Toronto, London, 1992.

Pratt, Staci. 1996. "Facilitating Natural Resource Dialogues on a Watershed Basis" Proceedings: Watershed '96 MOVING AHEAD TOGETHER, Technical Conference and Exposition, June 8 - 12, 1996, Baltimore, Maryland, http://www.epa.gov/owowwtr1/watershed/Proceed/pratt.html .

Ritter, William F. 1988. "Reducing Impacts of Nonpoint Source Pollution From Agriculture: A Review" *Journal of Environmental Science and Health*, Vol. 7, pp.645-667.

Rushin, Randy. 1995. *Lake Fork Reservoir Watershed Comprehensive Nonpoint Source Water Quality Management Project, Interim Report, Assessment of Baseline Conditions*, TNRCC, Tyler, TX, September 1995.

Rushin, Randy. 1994. *Lake Fork Reservoir Watershed Comprehensive Nonpoint Source Water Quality Management Project, Interim Report, Evaluation of Available Information*, TNRCC, Tyler, TX, November 1994.

Sabine River Authority. 1998a. "Lake Fork Project," http://www.sra.dst.tx.us/projects/lfp.htm.

Sabine River Authority, 1998b. *Sabine River Basin Highlights*, March 1998.

Sabine River Authority. 1996. *1996 Assessment of Water Quality*, October 1, 1996.

Safe Water Solutions L.L.C. 1998. Brown Deer, WI, http://www.safewater.com/ croypto.html, 1998.

Sharpley, Andrew N.1995. "Soil Phosphorus Dynamics: Agronomic and Environmental Impacts" *Ecological Engineering*, Vol. 5, pp. 261-79.

State of Texas. 1993. Senate Bill. No 503, 73rd Legislature, Regular Session., 1993.

Sweeten, John and Mary Leigh Wolfe. 1993. *The Expanding Dairy Industry: Impact on Ground Water Quality and Quantity with Emphasis on Waste Management System Evaluation for Open Lot Dairies,* Texas Water Resources Institute, Texas A&M, College Station, TX, August 1993.

Texas Agricultural Statistics Service. 1996. *Texas Agricultural Statistics 1996.*

Texas Water Commission and TSSWCB. 1991. *1990 Update to the Nonpoint Source Water Pollution Assessment Report for the State of Texas*, March 1991.

TNRCC. 1996. *The State of Texas Water Quality Inventory, 13th Edition 1996, Volume 2* Dec. 1996.

TNRCC. 1995. "Quarterly NPS Report to EPA" 4th quarter, 1995.

TNRCC. 1994. "Texas Groundwater Protection Committee, Record of Meeting, Third Quarter Meeting, FY 94" http:www.tnrcc.state.tx.us/water...gw/tgpc/ meetings/Fy94-3rd_min.html. Meeting date: May 3, 1994.

TSSWCB. 1998a. "Hopkins – Rains Soil and Water Conservation District, List of Practices Eligible for Cost-share for Soil and Water Conservation Land Improvement," Mt. Pleasant Regional Office, June 16, 1998.

TSSWCB. 1998b. "List of Practices Eligible for Cost-Share For Soil and Water Conservation Land Improvement," Mt. Pleasant Regional Office, June 16, 1998.

USDA. 1996. *The Federal Agriculture Improvement and Reform Act of 1996 Title-by-Title Summary of Major Provisions of the Bill,* Office of Communications, Washington, D.C. www.usda.gov/farmbill/title0.htm.

USDA. 1998. *The Market Administrator's Report, Texas Marketing Area, New Mexico—West Texas Marketing Area,* http://members.aol.com/fmmo1126.

USDA, ERS. 1997. *Agricultural Resources and Environmental Indicators 1996-97,* July 1997.

USDA, NRCS. Not dated. *Farmer Profitability with Intensive Rotational Stocking.*

USDA, NRCS. 1998a. "Fact Sheet, Environmental Quality Incentives Program" http://www.nhq.nrcs.usda.gov/OPA/FB96OPA/eqipfact.html.

USDA, NRCS. 1998b. *National Handbook of Conservation Practices* http://www.ncg.nrcs.usda.gov/nhcp_2.html.

USDA, NRCS. 1997a. *National Handbook of Conservation Practices*, Filter Strip, Code 393A, July, 1997.

USDA, NRCS. 1997b. *National Handbook of Conservation Practices*, Manure Transfer, Code 634, July, 1997.

USDA, NRCS. 1996. *Agricultural Waste Management Field Handbook*, July 1996.

USDA, NRCS. 1995a. *National Handbook of Conservation Practices*, Fence, Code 382, April, 1995.

USDA, NRCS. 1995b. *National Handbook of Conservation Practices*, Waste Storage Facility, Code 313, April 1995.

USDA, NRCS. 1994. *National Handbook of Conservation Practices*, Prescribed Grazing, Code 528A, June, 1994.

USDA, NRCS. 1990. *National Handbook of Conservation Practices*, Nutrient Management, Code 590, August, 1990.

USDA, NRCS, *National Handbook of Conservation Practices*, Irrigation System, Sprinkler, Code 442, October 1987.

USDA, NRCS. 1979. *National Handbook of Conservation Practices*, Waste Management System, Code 312, April 1979.

USDA, NRCS. 1978. *National Handbook of Conservation Practices*, Waste Utilization, Code 633, October 1978.

USDA, SCS. Not dated. *National Handbook of Conservation Practices*, Notice 116, 450-VI.

USDA, SCS. 1992. *National Engineering Handbook: Agricultural Waste Management Field Handbook*, April 1992.

USDA, SCS –Texas. 1991. Texas Addendum to the *National Handbook of Conservation Practices*, Waste Storage Pond 425, March 1991.

USDA, SCS – Texas – Area 7. 1990. Texas Addendum to the *National Handbook of Conservation Practices*, Nutrient Management, Code 590, January 1990.

USDA, SCS –Texas. 1990. Texas Addendum to the *National Handbook of Conservation Practices*, Waste Utilization 633, December 1990.

USDA, SCS. 1988. *National Handbook of Conservation Practices*, Irrigation Water Conveyance, High-Pressure, Underground, Plastic Pipeline, Code 430-DD, May, 1988.

USDA, SCS. 1977. *National Handbook of Conservation Practices*, Pumping Plant for Water Control, Code 533, October, 1977.

USEPA & USDA. 1998. *Clean Water Action Plan: Restoring and Protecting America's Waters*, February 14, 1998

USEPA. 1995a. *Guide Manual On NPDES Regulations For Concentrated Animal Feeding Operation,* EPA-833-B-95-001, December 1995.

USEPA. 1995b. *National Water Quality Inventory: 1994 Report to Congress*, Washington D.C., December 1995.

USEPA. 1994. *EPA Fact Sheet, National Water Quality Inventory 1992 Report to Congress*, EPA841-F-94-002, April 1994.

USEPA. 1993. *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Water,* Washington D.C, January 1993.

University of Waterloo. 1998. Waterloo, Ontario, Canada, http://INWEH1.uwaterloo.ca/crypto/introduc.htm.

Wells, Randy. 1998. Personal Communication, Management Analyst, NRSC, Temple, TX, July 15 1998.

Wyrick, Jim. 1996 and 1998 Personal Communication, District Conservationist, NRCS, Sulphur Springs, TX, various dates, 1996 and 1998.

TASK 5.1 Information Transfer Activities

TSSWCB educational activities will be geared toward dairy owners in the Running Creek subwatershed. Educational activities will consist of the following:

(1) TSSWCB will work with TAEX in establishing and operating a dairy training program that includes appropriate curriculum/manuals on dairy waste management for small dairy owners in the targeted subwatershed, distributing manuals to dairy owners, conducting one workshop that makes dairy owners aware of how activities could contribute to NPS pollution.

*(2) TSSWCB will work with TAES to complete a TEX*A*Syst program in the Running Creek subwatershed. Activities in this program will include: conducting an inventory of water wells in the subwatershed and determine the potential for contamination (improper storage of dairy manure, pesticides, etc.) for these well owners, distributing TEX*A*Syst materials to dairy owners, conducting two workshops that make dairy owners aware of how activities could contaminate groundwater resources.*

- Both TAEX and TAES completed educational activities in the watershed. These activities are detailed in the attached reports.

FINAL REPORT

Non-Permitted Dairy Producer Training Program for Nonpoint Source Water Quality Protection: Lake Fork Creek Reservoir, Hopkins County, Texas

Prepared by:
Dr. John M. Sweeten
Professor and Resident Director
Texas A&M University Agricultural Research and Extension Center
6500 Amarillo Blvd. West
Amarillo, Texas 79106

Dr. Ellen Jordan, Professor and Extension Dairy Specialist, Dallas, Texas
Dr. Sam Feagley, Professor and Environmental Soils Scientist, College Station, Texas
Dr. Sandra Stokes, Assistant Professor and Extension Dairy Specialist, Stephenville, Texas

Submitted to:
Texas State Soil and Water Conservation Board
P. O. Box 658
Temple, Texas 76503-0658

Texas Agricultural Extension Service (TAEX), Texas A&M University System
and
Texas State Soil and Water Conservation Board (TSSWCB)

Lake Fork Creek Water Quality Project
Section 319(h) Grant Project
Interagency Contract No. 994-592-555-4200000040
(TAEX Account #450670)

October, 1998

Final Report
Texas Agricultural Extension Service (TAEX)
Texas A&M University System
October 31, 1998

Lake Fork Reservoir Watershed
Comprehensive NPS Water Quality Management Project

Project Personnel (Faculty): John Sweeten, Ellen Jordan, Sam Feagley, Sandra Stokes, Max Sudweeks, Brent Auvermann, Roy Childers, and Larry Spradlin.

TASK 3: Implement NPS Activities to Reduce NPS Pollution

In each area of the program targeted for agricultural NPS management activities, best management practices will be identified by Texas State Soil and Water Conservation Board (TSSWCB) for agricultural activities believed to be contributing to NPS loadings. Levels of BMP implementation for each activity needed to meet water quality objectives will be determined. Best Management Practice standards will be established based on the County USDA Technical Guide adopted by the local soil and water conservation district and consideration of water quality objectives.

TAEX will assist the TSSWCB in conducting education activities targeted to subwatersheds where management activities are planned. Educational activities will consist of the following:

1. Establish and operate agricultural producer training programs including appropriate curriculum development and production to make producers aware of nonpoint source problems, activities contributing to NPS loadings, best management practices, needed treatment levels, sources of assistance and legal requirements.

2. Establish on a pilot basis, in conjunction with TSSWCB and Texas Natural Resources Conservation Commission (TNRCC), an agricultural producer water quality management certification program based on continuing education credits and evidence of water quality management plan implementation and management.

Project Management

The project was initially funded in FY1994 and planned as a companion project to other TSSWCB and TNRCC funded activities in the Lake Fork Reservoir Project area. The initial plan was also to link this project closely with the ongoing USDA Hydrologic Unit Area (HUA) project for the Lake Fork Creek Watershed. The TAEX project staff was realigned since the project began due primarily to faculty promotions and reassignments or staff attrition. Therefore, this project was refocused during the last 2 years and needed clarifications were made by TSSWCB/NPS staff that allowed for completion of the project.

Most of the work on this project occurred in 1996-98, and that is the period this report focuses on. Planning meetings were held in Temple on September 20, 1996 and July 7, 1997. The meeting on September 20, 1996 involved the TAEX project team. Attending were Dr. Sam

Feagley, Extension Environmental Soil Scientist; Mr. Roy Childers, Extension Agricultural Engineer; Dr. Ellen Jordan, Extension Dairy Specialist, Dallas; Dr. Sandra Stokes, Extension Dairy Specialist, Stephenville; and Dr. John Sweeten, Resident Director and Extension Agricultural Engineer, Amarillo. This TAEX group also met with NPS staff at TSSWCB headquarters in Temple. Key decisions were made that lead to the successful conclusion of this project by the target date. This group analyzed the original scope of work and had several questions and a few reservations about the commitments made originally in light of subsequent experiences and ever-changing regulatory/policy climate. They set specific goals and outlined the actions that would be needed to achieve the purposes of the grant.

They noted progress to that point had consisted primarily of:

1. Development of the TNRCC/TAEX Dairy Outreach Program Area (DOPA), Phase I, training materials in July 1996, pursuant to the 1995 TNRCC Subchapter K regulations.
2. Producer dairy tour stop (1996) on composting and compost utilization, July 1996.
3. CEA and agency staff training on composting was held on April 10, 1997 in Sulphur Springs and toured the Vallergo Dairy with solids separation and composting operation.
4. Numerous Lake Fork HUA activities as were documented in annual reports of that project by Billy Brown, TAEX Project Manager, Sulphur Springs.

Generally it was agreed that the two-volume DOPA Training Manual developed for permitted dairies was too lengthy and complex, and a one-volume set of training guides was needed for the small dairy producers in Hopkins County. Dr. Sam Feagley and Mr. Roy Childers determined what to modify, add, or delete, e.g., add pasture systems; whole farm nutrient management; soils and nutrient management, P management, etc. The materials developed would be flexible enough to be incorporated into other subsequent TAEX programs such as:

a. Soil Fertility/Nutrient Management
b. Pasture Management
c. Nonpoint Source Water Quality Management
d. Dairy Ration Modification
e. Composting
f. Water/Soil Conservation
g. Tex-A-Syst Well Head Protection Program
h. Lake Fork Creek HUA Tours

A copy of all the DOPA Phase I training materials that Dr. Sweeten, Eric Chasteen (TNRCC), and others had produced in Summer, 1996 was furnished on diskette. Dr. Feagley and Mr. Childers proceeded with condensation of the DOPA Phase I and Phase II training materials into a shorter, more encompassing and less technically complex set of training materials for small dairies (below TNRCC permit threshold) in the Running Creek watershed of the Lake Fork Creek watershed, as a pilot project.

Ideas were developed for a producer certification program that is workable and acceptable, with minimal agency record keeping. It was agreed that the responsibility for participation and record-keeping should be placed on the participants with Water Quality Management Plans developed by Soil and Water Conservation Districts under the Senate Bill 503 program rather than one the agencies.

The training was originally scheduled for April 11, 1997 but was postponed to May 22, 1997 and subsequently until April 1998. The postponements were at the request of the TSSWCB's NPS staff to allow greater coordination with other NPS projects in the target area. The training program was coordinated with the USDA Lake Fork Hydrologic Unit Area Program (Billy Brown) and TSSWCB, Temple and Mt Pleasant offices (John O'Connor and Jim Wyrick).

A second meeting was held with TSSWCB staff on July 7, 1997, with Dr. Stokes and Dr. Sweeten participating. Materials and plans available at that time were provided for review by TSSWCB project staff, and comments received.

The training and implementation program targeted small dairies (below TNRCC permit threshold levels of 250 hd per Subchapter B and Subchapter K regulations) in the Running Creek watershed of the Lake Fork Creek watershed of Hopkins County. There were about 30-35 small dairies in the watershed at the time of this study. A map of the watershed is shown in Figure 1.

Training Materials Development:
In 1996-97, a draft of the training manual was prepared, using the previously developed (1996) manual prepared for TNRCC Dairy Outreach Program Area (DOPA) Producer Training Program as a point of departure. Roy Childers and Sam Feagley condensed the DOPA Phase I and Phase II training materials into a shorter and less technically complex set of training materials that would be appropriate for small dairies (below TNRCC permit threshold) in the Running Creek watershed of the Lake Fork Creek watershed, as a pilot project. Some DOPA training guides were deleted or combined in preparation of the final training manual with a focus on simplification and brevity.

Dr. Ellen Jordan and Dr. Sandy Stokes planned and wrote three new training guides and fact sheets for a Northeast Texas program in spring of 1997. These training units included sample calculations and involved specific dairy information on farm nutrient balances, ration balancing, effects on P excretion by the animal, and BMPs for grazing operations. The farm balance information included tracking all incoming and outgoing nutrients and identifying the cycle within the farm as tools to enhance environmental stewardship. Drafts of the fact sheets were circulated to other team members for comments and refinements. Slide sets were developed of all three sections. In addition, Dr. Jordan and Dr. Stokes prepared three slide sets for the Lake Fork Creek Demonstration Educational Program. These materials were on: 1. Management of Intensive Grazing to Protect Water Quality; 2. Manure and Crop Nutrient Balances; and 3. Ration Management. A student technician at Stephenville assisted in developing these written training materials and slide sets to accompany the educational units. These new materials were incorporated into a draft training manual. A training guide on introductory soil science was developed by Dr. Feagley.

Comments on the training manual were provided by TSSWCB staff to TAEX project faculty team representatives. Technical comments were incorporated into the training guides.

During the quarter December 1, 1997 - February 28, 1998, Dr. Sam Feagley assumed leadership for consolidation and revision of training materials for the manual. The final manual was submitted to TSSWCB staff for review and approval by TSSWCB Board Members. No further comments were received, and approval to proceed with reproducing the manual was forthcoming in February. The training materials were reproduced (50 copies) in preparation for the non-permitted dairy producer training in Hopkins County on April 14, 1998. County Extension Agents in the Northeast Texas region were apprised of the status of the Lake Fork Creek Hydrologic Unit project and the training opportunity.

Guidelines for Producer Training and Certification Program:
Guidelines for a small/non-permitted producer certification program were developed by the TAEX team and revised based on comments from TSSWCB staff, including Justin Hester, NPS Coordinator. The program required a minimum of agency record keeping by the TSSWCB and by the participating dairy farmers.

Guidelines for the training were as follows:

A. Training criteria -- Non-permitted dairy producers in selected portions of the Lake Fork Creek Reservoir watershed received voluntary training and testing to demonstrate knowledge of proper manure and wastewater management practices. The training was provided by professional staff, jointly by TAEX faculty and TSSWCB, with assistance from USDA-NRCS personnel. The voluntary training involved dairy producer's participation in the following:

B. Review of Training Manual
   - Training guides
   - Supporting fact sheets
   - Supporting slide sets

C. Participation in direct instruction activities provided by qualified instructors was as follows:

   - 5.5 hours classroom instruction involving training on: policies, alternative BMP's, and exemplary management practices for Animal Waste Management Systems (AWMS)

D. Knowledge Testing
   - Development of test materials -- TSSWCB and TAEX
   - Pre-test (prior to training) and Post Test (after training) -- 24 questions (multiple choice, true/false, etc.)
   - Passing score (70 or more) on post test
   - Participation in sign-up as a cooperator for development of Water Quality Management Plan (if not already done)

E. Record-keeping Responsibilities
   - Records of training kept by dairy farmer

- Record of participants kept by TSSWCB
- TSSWCB and TAEX instructors provided signed certificate upon completion of training as evidenced in items C and D above.
- Certificate to be kept by producer on-site as part of Water Quality Management Plan.

Producer Training:
An outline of speakers and topics for the producer training for the 32 identified non-permit sized dairy producers in the Running Creek Watershed of Southern Hopkins County was developed and revised to incorporate suggestions by TSSWCB. The program was originally scheduled for April 1997. However, it was postponed at TSSWCB's request to April 1998 to allow the TSSWCB's NPS staff to develop and implement a $200,000 cost sharing program for dairies in the target area during Fiscal Year 1997-98.

The voluntary in-depth training program for non-permitted diary producers was rescheduled and was conducted in Hopkins County on April 14, 1998 at the Western Sizzlin' Restaurant at Sulphur Springs. All dairy producers in the watershed were notified by letter by Larry Spradlin, CEA-Ag, Hopkins County; Dr. Ellen Jordan; and by TSSWCB personnel about the training.

Pre-test and post-test questions for the dairy producer training program were developed by Drs. Stokes, Jordan, and Sweeten (attached) to measure improved knowledge of manure and wastewater management BMP's as a result of the training. The 24 questions were reviewed by TSSWCB and revised per comments received. The pre and post test were provided at the training.

The approved training manual was printed (50 copies), distributed, and utilized at the April 14, 1998 producer training. A copy is attached. Attendance at the training included 4 of the targeted producers of those invited and 10 agency personnel.

An attendance sheet is attached along with the training manual. The following TAEX faculty provided the training:

Mr. Larry Spradlin, Sulphur Springs
Dr. Ellen Jordan, Dallas
Dr. E. Max Sudweeks, Overton
Dr. Brent Auvermann, Amarillo
Dr. Sam Feagley, College Station

The following TSSWCB personnel also served as speakers at the training:

Mr. Justin Hester, Temple
Mr. Jim Wyrick, Mt. Pleasant
Mr. John O'Connor, Mt. Pleasant

In addition, the following USDA-NRS State Conservation Engineer served as speaker:

Mr. Jerry D. Walker, Temple.

The Certificate of Completion was awarded each participating dairyman. It will become a part of each dairy's Water Quality Management Plan developed by the Soil and Water Conservation District under the Senate Bill 503 program. A copy of the certificate is attached.

Pasture Production Demonstration

Dr. Sudweeks evaluated alfagraze plots for dairy cattle grazing as a BMP pertaining to pasture operations in lieu of open lots or free stall barns. The first plot, which is in its' third year, has thinned greatly. The second plot, which is in its' second year, withstood the hot dry summers and maintained its strand. It looks good with late summer rain received.

Percent Complete:

The two tasks are both 100% complete.

Deliverables:

1. The Training Manual was developed (attached).
2. The Training Program was conducted and successfully concluded (attached).

Personnel:

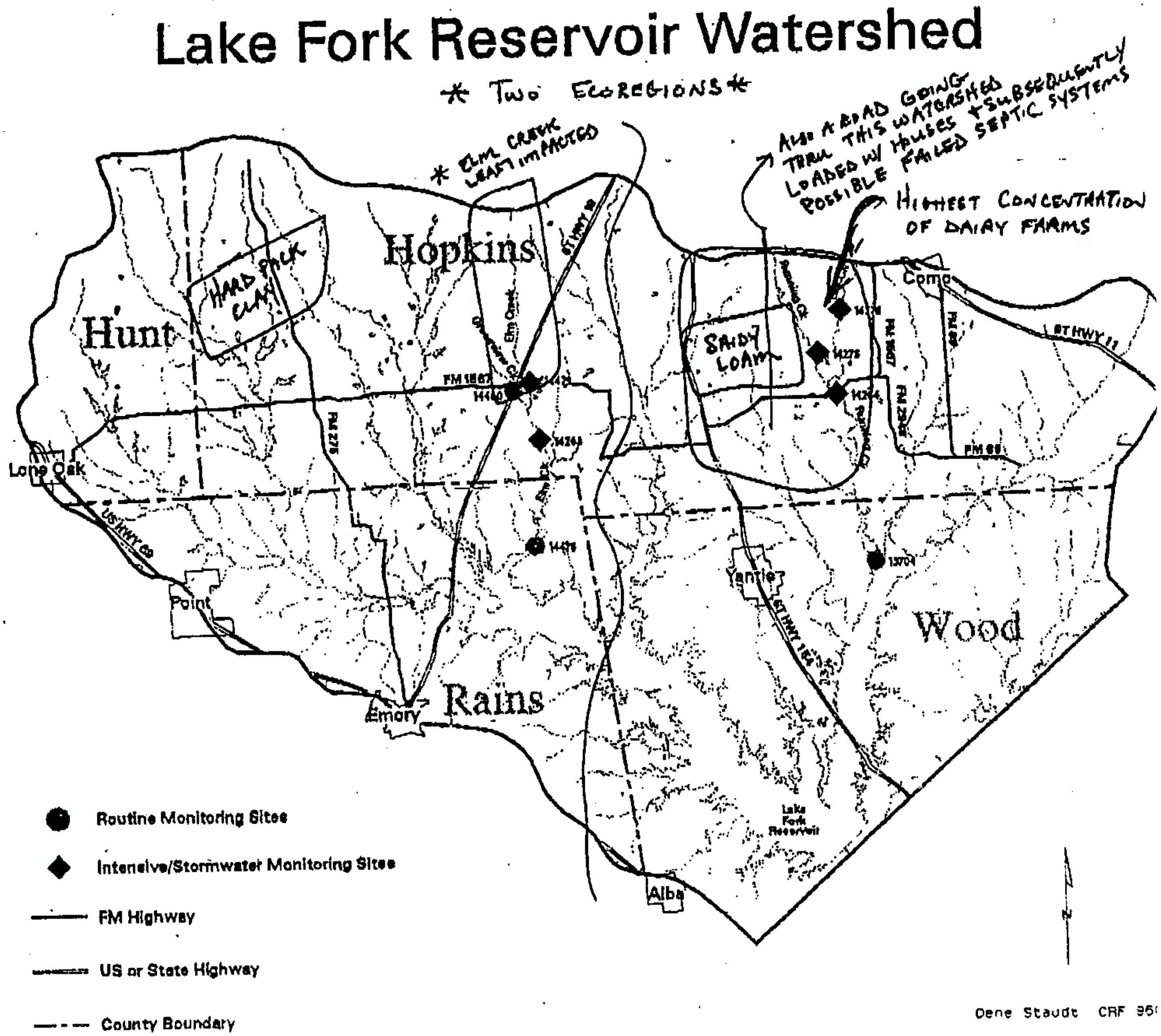
Staff supported on the project included an Extension Associate/Agricultural Engineering in College Station and two student workers in Stephenville and Dallas. These personnel assisted TAEX faculty with development and finalization of training materials.

Budgetary Report:

The grant was funded in FY1994 as a cost-reimbursable contract with matching requirement. The completion date was extended twice through the final date of August 31, 1998. The main budgetary requirement was for salaries, travel, and publishing materials. The budget was revised as needed several times with the concurrence of Bobbie Stephens, TSSWCB, to balance remaining funds among categories where they were effectively used.

The account balance remaining as of the ending date of August 31, 1998, after project completion was $3,965.82 direct costs plus applicable indirect costs. The TAEX Fiscal Office is tabulating the final bill, balances, and cost sharing provided. In summary, the project was conducted 9% under budget despite the turnover in project leadership, personnel, delays, and time extensions.

Figure 1


Lake Fork Reservoir Watershed
* TWO ECOREGIONS *
* ELM CREEK LEAST IMPACTED
ALSO A ROAD GOING THRU THIS WATERSHED LOADED W/ HOUSES + SUBSEQUENTLY POSSIBLE FAILED SEPTIC SYSTEMS
HIGHEST CONCENTRATION OF DAIRY FARMS
HARD PACK CLAY
SANDY LOAM
Hunt
Hopkins
Rains
Wood
Lone Oak
Point
Emory
Alba
Yantis
Como
FM 1567
FM 275
STHWY 11
Lake Fork Reservoir
Routine Monitoring Sites
Intensive/Stormwater Monitoring Sites
FM Highway
US or State Highway
County Boundary
Dene Staudt CRF 95

Texas Agricultural Extension Service
The Texas A&M University System

Texas State Soil and Water Conservation Board

Lake Fork Creek Reservoir
Running Creek Watershed

Training for
Non-Permitted Dairy Producer

April 14, 1998
Western Sizzlin
Sulphur Springs

Sponsored by:
Texas Agricultural Extension Service
Texas State Soil and Water Conservation Board

Lake Fork Creek Reservoir
Running Creek Watershed

Training for
Non-Permitted Dairy Producer
April 14, 1998

9:00 a.m.	Welcome and Introductions *Ellen Jordan, TAEX, Dallas*
9:10 a.m.	Pre-Test *Justin Hester, TSSWCB, Temple*
9:30 a.m.	Overview of Materials *Sam Feagley, TAEX, College Station*
9:50 a.m.	Planning for Water Quality Management *Jim Wyrick, TSSWCB, Mt. Pleasant and John O'Conner, TSSWCB*
10:30 a.m.	Manure and Nutrient Production *Brent Auvermann, TAES/TAEX, Amarillo*
11:00 a.m.	Nutrient Management Planning: Soils, Forages and Cropping Systems *Sam Feagley, TAEX, College Station*
11:45 p.m.	Buffet Lunch
12:30 p.m.	Ration Modification Options for Water Quality Protection *Ellen Jordan, TAEX, Dallas*
1:00 p.m.	Pasture Management Systems *E. Max Sudweeks, TAEX, Overton*
1:30 p.m	Nitrogen and Phosphorus Balances for Non-Permitted Dairies *Sam Feagley, TAEX, College Station*
2:00 p.m.	Composting *Brent Auvermann, TAEX/TAES, Amarillo*
2:15 p.m.	Lagoon Management *Brent Auvermann, TAES/TAEX, Amarillo*
2:30 p.m.	Effluent Irrigation Systems *Jerry D. Walker, USDA-NRCS*
2:45 p.m.	Filter Strips *Jerry D. Walker, USDA-NRCS*
3:00 p.m.	Question and Answer Session *All Speakers*
3:10 p.m.	Post-Test and Certificates Awarded *Justin Hester, TSSWCB, Temple*
3:30 p.m.	Adjourn

Lake Fork Creek Rd
Running Creek Watershed Meeting
April 14th

Attendees:

Don Smith - Dairyman
Vera Harrington - Dairyman
Bryant Fisher - Dairyman
Billy Mac Chaman - Dairyman
Larry Spradlin - TAEX - Hopkins Co.
Max Dukowski - TAEX - Overton
Billy Brown - TAEX - Hopkins Co.
Jerry Jackson - TAEX - Wood Co.
Ellen Jordan - TAEX - Dallas
Joe Price TAEX Dallas
Jim Wyrick - Water & Soil Dept Hop. Co
Roanna Rich - Water & Soil Dept Hop. Co

RUNNING CREEK WATERSHED/LAKE FORK RESERVIOR
WATER QUALITY TRAINING PROGRAM FOR NON-PERMITTED DAIRY FARMERS
Hopkins County, Texas

Sponsored by
Texas Soil and Water Conservation Board, and
Texas Agricultural Extension Service, Texas A & M University System

PRE-TEST AND POST-TEST

1. **Water quality protection is the responsibility of every dairy producer.**
(Circle the correct answer)

True False

2. **Manure is a source of valuable plant nutrients if properly utilized and applied.**
(Circle the correct answer)

True False

3. **Regular soil testing is important when using manure, effluent, compost or commercial fertilizer on pastures or crops.** (Circle the correct answer)

True False

4. **The most limiting factor to consider for land application of dairy manure and effluent is:**
(Check the correct answer)
__Nitrogen
__Phosphorus
__Salt/soil salinity
__May be any of the above.

5. **The purpose of a filter strip is to remove the following from effluent or runoff:**
(Check the correct answer)
__Sediment
__Nutrients (Nitrogen and Phosphorus)
__Bacteria
__Oxygen-demanding organic matter
__All of the above.

6. **Calibrating application equipment before applying manure or effluent on pastures or cropland is important.** (Circle the correct answer)

True False

7. **Which of the following are necessary to estimate nutrient loading of pasture animals?**
(Check the correct answer)
__Forage species
__Number of animals on pasture
__Length of time animals are on pasture
__Size of pasture
__Time of year
__All of the above.

8. Nutrients applied to pastures should follow similar agronomic rate criteria as those applied to crop land. (Circle the correct answer)

True False

9. Pasture management can be included as a best management practice to reduce environmental impact of dairies. (Circle the correct answer)

True False

10. Manipulating dairy cattle rations to increase efficiency of nitrogen and phosphorus utilization should enhance the producer's bottom line. (Circle the correct answer)

True False

11. A nutrient mass balance is calculated as the amount of nutrients brought onto the dairy farm minus the amount of nutrients exported from the farm. (Circle the correct answer)

True False

12. Animals sold from the dairy farm will affect the mass nutrient balance.
(Circle the correct answer)

True False

13. Purchased animals do not affect a mass nutrient balance on a dairy farm.
(Circle the correct answer)

True False

14. Which of the following are potential fates for nutrients remaining on the dairy farm?
(Check the correct answer)

__Crop or forage uptake and production
__Runoff
__Leaching
__Volatilization
__Erosion
__All of the above.

15. The total amount of phosphorus (P) excreted from all the dairy cows on a farm can be reduced by changing the ration P to meet the needs of different groups of cows.
(Circle the correct answer)

True False

16. Purchased animals do not affect a mass nutrient balance on a dairy farm.
(Circle the correct answer)

True False

17. Drinking water sources are not a sensitive water resource.
(Circle the correct answer)

True False

18. Alternative dairy water-supply sources may include:
(Check the correct answer)
__Wells
__Ponds
__Streams
__Springs
__All of the above.

19. Dairy farmers which (due to small herd size or other factors) are not required to obtain a state permit from TNRCC should strongly consider obtaining and following a voluntary Water Quality Management Plan.
(Circle the correct answer)

True False

20. A Water Quality Management Plan typically will address the following:
(Check all that apply)
__Appropriate Best Management Practices
__Manure and effluent management systems
__Runoff control
__Nutrient mass balance
__Sampling of soils, forage, crop, manure, and effluent
__Ground water protection
__Soil erosion control

21.To obtain a Water Quality Management Plan, a non-permitted dairy producer should contact the local Soil and Water Conservation District. (Circle the correct answer)

True False

22. Main functions of a lagoon system are:
(Check all that apply)
__Digestion of organic matter in manure
__Storage of effluent
__Transformation of nutrients
__ All the above.

23. Composting is defined as the controlled, biological decomposition of organic materials (such as manure) through microbial activity in the presence of free oxygen.
(Circle the correct answer)

True False

24. **The following materials can be composted using proper equipment:**

(Check all that apply)

__Solid manure
__Semi-solid manure
__Crop residues
__Hay and wasted feed
__Calf mortality

Texas Agricultural Extension Service
The Texas A&M University System

Texas State Soil and Water
Conservation Board

Certificate of Completion

Training for
Non-Permitted Dairy Producer

April 14, 1998

____

Training Program on Water Quality Management
In the Running Creek Watershed
Hopkins County, Texas

____
Larry Spradlin
County Extension Agent-Agriculture
Texas Agricultural Extension Service

____
Justin Hester
Texas State Soil and Water
Conservation Board

Dairy Outreach Training Guides

Lake Fork Creek Reservoir
Running Creek Watershed
Non-Permitted Dairy Producer

CONTRIBUTING AUTHORS

Dr. Sam Feagley, Professor
State Soil Environmental Specialist
Soil and Crop Sciences Department
Texas A&M University
College Station, TX 77843-2474
Training Guide #9, Co-editor, and Corresponding Editor

Dr. John Sweeten, Director
Amarillo Research and Extension Center
6500 Amarillo Blvd., West
Amarillo, TX 79106
Training Guides #1, #3, #8, and Co-editor

Mr. Roy Childers, Associate Professor (Former)
Animal Waste Management
Agricultural Engineering Department
Texas A&M University
College Station, TX 77843-8203
Training Guide #4

Mr. Jerry Don Walker , P.E.
Water Management Engineer
Natural Resources Conservation Service
101 South Main
Temple, TX 76501-7682
Training Guide #5

Dr. Ellen Jordon, Professor
Dairy Specialist
Dallas Research and Extension Center
17360 Coit Road
Dallas, TX 75252-6599
Training Guides #7, #10, and #11

Mr. Ted Kantor, Extension Assistant (Former)
Agricultural Engineering Department
Texas A&M University
College Station, TX 77843-8201
Training Guide #3

Dr. Bruce Lesikar, Associate Department Head
Agricultural Engineering Department
Texas A&M University
College Station, TX 77843-8201
Training Guide #6

Mr. Beade Northcut, Engineer IV
Nonpoint Source Abatement
Texas State Soil and Water Conservation Board
P.O. Box 658
Temple, TX 76503
Training Guide #2

Dr. Sandy Stokes, Assistant Professor
Dairy Specialist
Stephenville Research and Extension Center
Route 2, Box1
Stephenville, TX 76401
Training Guides $7, #10, and #11

TABLE OF CONTENTS

TRAINING GUIDE # 1

SITE SELECTION FOR DAIRIES

OBJECTIVES:

The objectives of this training guide are for the dairy producer to:

1. Learn important site selection factors that contribute to a successful dairy operation.

2. Recognize the major factors that should influence his/her decisions regarding environmentally-sound site selection for dairy facilities.

TEACHING POINTS:

A. Introduction

Major factors to evaluate in selecting a site for dairy operation include topography (land shape), drainage features, soil (fertility and ability to support dairy facilities), aquifers, recharge features, quantity and quality of water, separation distances to neighbors, atmospheric variables affecting air quality, availability of land for beneficial animal waste management, accessibility, and availability of utilities.

B. Topographic features that are desirable for all dairy facilities should include:

1. Good slope for drainage -- 3-5 percent for open lots, or 2-3 percent for free stall barns
2. Slope direction -- away from buildings or working corrals
3. Elevation -- above the 100-year flood plain
4. Near top of ridge or hill -- avoid subsurface water flow and facilitate runoff collection
5. Slope aspect -- west or south facing slopes
6. Avoid pen-to-pen drainage

C. Soils are critical to a successful dairy operation. Soils information is available from the USDA-NRCS, County Soil Survey Report, and County Extension offices.

1. Different types of soils are optimum for different aspects of dairy site selection, development and operation. The ideal site will have soils that are suitable for all three aspects:

    a. Building sites and corrals

b. Holding pond and lagoon lining materials
c. Land application of manure and wastewater based on crop nutrient requirements

2. For the building sites and corrals, soils should have these properties:

   a. Firm, stable subsoil
   b. High coefficient of uniformity (clay through small pebbles)
   c. Medium textured topsoil - 0-2 feet
   d. Low shrink-swell potential
   e. Moderately well-drained
   f. Restrictive layer -- below 2-3 feet to retard any leachate

3. For the holding ponds and lagoons, soils should have these properties:

   a. Clay subsoil -- permeability of 1 x 10^{-7} cm/sec to meet TNRCC requirements
   b. Compacted soil is able to form stable embankments
   c. See the training guide in this manual on "Lagoon Seepage Prevention and Ground Water Protection" (Training Guide #5) for further details.

4. For land application of manure/wastewater, the following soil properties are desirable:

   a. Good soil depth (3 ft)
   b. Medium texture
   c. Good nutrient holding capacity
   d. Moderate permeability and drainage
   e. Absence of restricting layer in root zone
   f. Slopes 5% or less

D. Appropriate geological features of the dairy site to protect against groundwater contamination

1. Deep fresh water aquifer -- 100 ft or greater depth is highly desirable; less than 25 feet may require special design considerations.
2. Moderate textured or well-graded soil material underlain by a restrictive clay layer above the water table.

E. Adequate water supply in both quality and quantity is critical to a successful dairy operation for cattle performance, comfort, excellent milk sanitation, and manure handling.

1. Good ground water quality -- less than 1,000 ppm total dissolved solids
2. Absence of recharge features
3. Adequate water supply -- capable of at least 50-100 gallons per cow per day for cattle watering and minimum sanitation
4. facilities located 150 ft or more from wells
5. facilities located ¼ mile or more from surface water or significant drainage features (creeks or reservoirs)

F. Avoiding nuisance odor and gaining and maintaining the respect of neighbors will require significant efforts in site selection to locate facilities in a manner that will not create moderate or strong odor at off-site residences or businesses, and occurrences of low odor intensity will be kept to a minimum (e.g., less than 10% at off-site locations).

1. Separation distance down wind from neighbors--0.25 to 2 miles from rural neighbors or towns, depending on size of dairy facility
2. Optimum wind direction and topography (gradual slopes, avoidance of valley drainage to residences, etc.).
3. Aesthetic features such as visual barriers and compatible land uses can be very helpful in successful, nuisance-free operation of a dairy.

G. Adequate land areas for beneficial application of effluent and solid waste is crucial for surface and ground water pollution prevention.

1. Sufficient to achieve nutrient balance for nitrogen and phosphorus (Training Guide #9)
2. Reasonable haul distance (Training Guide #10)
3. Neighboring farmer demand for manure/wastewater
4. Appropriate distances from application sites to waterways or other drainage features (approximately 100 ft) with vegetated filter strips.

H. Utilities:

1. Availability of 3-phase electricity for milking center and pumps for wastewater treatment lagoons or retention structures.
2. Location of major oil, gas, or electric transmission lines will not interfere with construction.

I. Accessibility:

1. Good roads for hauling milk and feedstuffs
2. Feedstuffs supply--grain and roughage
3. Labor and market access

REFERENCES:

1. Sweeten, J.M., C. Baird, and L. Manning. 1991. Animal Waste Management. L-5043, Texas Agricultural Extension Service and Texas State Soil and Water Conservation Board.

2. Sweeten, J.M. and M.L. Wolfe. 1993. The Expanding Dairy Industry: Impact on Groundwater Quality with Emphasis on Waste Management System Evaluation for Open Lot Dairies. TR-155. Texas Water Resources Institute. Texas A&M University, College Station, Texas. 142 p. August 31.

BON
1/8/98
SEF
1/13/98

TRAINING GUIDE #2

THE WATER QUALITY MANAGEMENT PLAN PROGRAM of the TEXAS STATE SOIL AND WATER CONSERVATION BOARD

OBJECTIVES:

The objective of this training guide is for operators of animal feeding operations to:

1. Become familiar with Texas State Soil and Water Conservation Board's water quality management plan program, and

2. To learn how agricultural operations can voluntarily comply with the State's water quality goals through the Texas State Soil and Water Conservation Board's water quality management plan program.

TEACHING POINTS:

A. The Water Quality Management Plan (WQMP) program created by Senate Bill 503 provides agricultural and silvicultural producers the opportunity to comply with state water quality laws through traditional voluntary incentive based programs.

B. Animal feeding operations may be considered as point or non-point sources depending on size, location and other considerations. For the purposes of this program, all confined animal feeding operations not required to obtain a permit from the Texas Natural Resource Conservation Commission (TNRCC) will be non-point sources.

C. S.B. 503 provided for the development and certification of water quality management plans. These plans are site specific plans for agricultural or silvicultural lands, which include appropriate land treatment practices, production practices, management measures, technologies or combinations thereof. When implemented they are to achieve a level of pollution prevention or abatement determined by the Texas State Soil and Water Conservation Board (TSSWCB) in consultation with the local soil and water conservation district and TNRCC to be consistent with state water quality standards. To be certified, a water quality management plan must cover all lands whether contiguous or noncontiguous that constitutes an operating unit for agricultural or silvicultural purposes.

1. A WQMP must contain an implementation schedule. The Legislature gave responsibility for this program to the TSSWCB and districts, as far as is practicable to balance the state's need for protecting water quality with the needs of agricultural and silvicultural producers to have sufficient time to implement practices in an economically feasible manner. No other entity is more qualified to make this determination than a soil and water conservation district. This places tremendous responsibility on districts, because these types of decisions are not cut and dried. Consideration must be given to local conditions and economy and must place appropriate importance on protecting the State's water resources.

2. TSSWCB policy requires that a water quality management plan cover an operating unit before it is eligible for certification. The terms "operating unit" and "management unit" have been used in federal programs for many years, and are confusing in many instances. The intent of the TSSWCB is, when a water quality management plan is certified, it will protect water quality to a degree consistent with the state's water quality standards. Certification by the TSSWCB affords the producer certain protections under state law in that it holds the same status as a discharge permit. It is important that certified water quality management plans do what they are intended to do and protect water quality consistent with state standards. To do that, all activities on a farm or ranch should be covered. Therefore, the TSSWCB's policy includes a requirement that the entire operating unit be included. There is an element of judgement involved in making determinations as to whether or not a plan covers an operating unit. Again, no other entity is better equipped to make such decisions than a soil and water conservation district.

D. The TSSWCB adopted the Natural Resources Conservation Service (NRCS) Field Office Technical Guide (FOTG) as the criteria applicable for water quality management plans. The FOTG contains technical information, important conservation considerations for natural resources, quality criteria and treatment levels, conservation management system guide sheets by land use, information on the effects of applied conservation treatments, and practice standards and specifications. The guide is specifically tailored for the geographic area of each district and is the basis for the water quality planning process.

1. The water quality planning process will begin when a producer requests assistance from the district to obtain a water quality management plan. The producer should fill out a "Request for Water Management Planning Assistance", form TSSWCB001. If the producer is not already a cooperator with the district, a district cooperative agreement should be executed at this time. The producer may also indicate interest in cost-

share. Operations that include an animal feeding operation (dairy, poultry, feedlot) that is required to obtain a permit are not eligible to operate under a water quality management plan.

2. The district, within its priority system, may then cause plan development to begin. Depending on technical needs and workload, the plan development may be accomplished by either local NRCS or TSSWCB Regional Office personnel.

3. In the same fashion as a conservation plan, district approval of a water quality management plan should be based on conformity with the technical guide and adherence to its priorities and policies. Certification of conformity with the technical guide will normally be made by the District Conservationist (DC).

   Certification form TSSWCB004 should be signed by the applicant, DC, and district. After district approval, two originally signed copies of the form are to be sent to the TSSWCB Regional Office, along with two copies of the plan. Plans are sent to the TSSWCB Regional Office to be reviewed and submitted to the TSSWCB Headquarters for final certification. Once certified, the producer has a plan that meets the state's goals for water quality as per Section 26.121 of Texas Water Code.

4. Criteria to consider in planning a WQMP:

   a. Cover the entire operating unit.

   b. Include required practices applicable to the land use planned:

      Cropland: Conservation Crop Rotation and Residue Management (No-Till and Strip Till, Mulch Till, Ridge Till or Seasonal).

      Hayland: Pasture and Hayland Management.

      Rangeland/Pastureland: Prescribed Grazing and the first water facility.

      Wildlife Land: Wildlife Upland Habitat Management if upland and Wildlife Wetland Habitat Management if wetland.

      Forest Land: Forest Management.

   c. Include nutrient management when nutrients are applied.
   d. Include pest management when pesticides are applied.
   e. Include animal waste management System when animal feeding operations are involved.
   f. Include waste utilization when agricultural wastes are

applied.

g. Include irrigation water management when irrigated land is involved.

h. Include erosion control measures to bring soil loss to T.

I. Include erosion control to treat other forms of erosion according to quality criteria in the FOTG.

j. Include other practices to meet site concerns for a Resource Management System.

5. The sequence of events in the planning process is as follows:

a. The participant requests planning assistance.
b. The Soil and Water Conservation District (SWBD) approves this request and sets a planning priority.
c. The plan is developed.
d. The producer's signature is to be entered after he has reviewed the completed WQMP document and agrees that it is what he intends to do.
e. The DC will certify the WQMP meets the FOTG requirements for a Resource Management System.
f. The (SWBD) then approves the WQMP as meeting their program, plan and priorities.
g. The (SWBD) routes the plan through the TSSWCB Region Office for review.
h. Then the WQMP is submitted to the TSSWCB for certification.

6. A WQMP is subject to a yearly status review with the producer to review the application of scheduled practices and for follow-up of any technical assistance needs. During this status review, the producer may be required to produce documentation for the implementation of some practices such as fertilizer application dates and application rates, or a copy of the most recent soil test.

E. Complaint resolution once a complaint is referred to the TSSWCB, the following steps will be taken:

TSSWCB and (SWBD) will investigate complaint.
TSSWCB and (SWBD) will determine if corrective action is required.
(SWBD) will establish priority for plan development if needed.
Corrective action plan to be developed.
(SWBD) approves corrective action plan.
TSSWCB certifies the corrective action plan.

F. The purpose of the cost-share program is to provide the needed incentive to landowners or operators for the installation of soil and water conservation land improvement measures consistent with the purpose of controlling erosion, conserving water, and/or protecting water quality.

1. Responsibilities of the TSSWCB:
   a. Establish a procedure to allocate funds to designated (SWBD)'s for their use in cost-share assistance.
   b. Establish conservation land treatment measures eligible for cost-share and their standards, specifications, maintenance and expected life.
   c. Establish the maximum cost-share for each conservation land treatment measure approved for cost-share.
   d. Establish the minimum cost-share assistance prior to September 1st each year that may be made under the program and the maximum cost-share assistance that an eligible person may receive under the program in any one year.
   e. Perform clerical, administrative and record keeping responsibilities required for carrying out the cost-share program.
   f. Receive and maintain monthly reports from (SWBD)'s showing the unobligated balance of allocated funds as shown on each ledger at the close of the last day of each month.
   g. Receive requests for reallocated funds and funds reverted from participating (SWBD)'s.
   h. Act on appeals filed by applicants.
   I. Process vouchers and issue warrants for cost-share to eligible recipients.

2. Responsibilities of the local (SWBD):
   a. Designate, from TSSWCB approved list, those conservation treatment measures that will be eligible for cost-share in their (SWBD).
   b. Establish the district's average cost of practices and practice components for each program year.
   c. Establish annually the maximum amount of cost-share available to each applicant.
   d. Administer the cost-share program within the funds allocated by the TSSWCB.
   e. Establish, under guidelines of the TSSWCB, the priority system to be used for evaluation of applications.
   f. Establish the period(s) of time for accepting applications and announce the cost-share program locally.
   g. Accept and process cost-share applications.
   h. Determine eligibility of lands and persons for cost-share assistance under guidelines established by the TSSWCB.
   I. Notify applicants of the district's decisions on approval of applications.
   j. Approved applications will be filed the district's copy of the

applicant's Resource Management Plan

k. Obligate allocated funds for applications receiving final approval.

l. Provide or arrange for technical assistance to applicants, or approve applicant and provide for an alternate source of technical assistance.

m. Certify completed conservation land treatment measures to the TSSWCB prior to payment.

n. Submit required reports on the unobligated balance of allocated funds and on accomplishments to the TSSWCB.

3. Cost-share assistance processing procedures:

a. Responsibilities of applicants:

- Complete and submit an application to the (SWBD).
- If the applicant fills out the "**Federal Tax ID (Corp, Partner, etc.)**"blank of the cost-share application form TSSWCB02, they must complete and attach the addendum form TSSWCB02Ad.
- If the applicant is a district director they must complete and attach the **"Addendum to TSSWCB02 (to be completed by District Directors)** form.
- Where an applicant does not have a certified water quality management plan and has not determined the anticipated total cost of the requested measure(s), he/she, as part of the application, may request assistance form the (SWBD) in developing such plan and determining costs.
- After being notified of approval and obligation of funds by the district, request technical assistance through the district to design and layout the approved practices or request approval of alternated sources of technical assistance.
- Secure any approved contractor(s) needed and all-contractual or other agreements necessary to construct or perform the approved practice(s). Cost-share will not be allowed for work begun before the application approved.
- Complete and sign performance and maintenance agreements and any amendments to those agreements.
- Supply the documents necessary to verify completion of the approved practice(s) along with a completed and signed certification of cost.

b. Responsibilities of (SWBD)'s:

- Establish the period(s) of time for accepting applications and announce the cost-share program locally.
- Accept cost-share applications at the (SWBD)'s office.
- Determine eligibility of lands and persons for cost-share

assistance. If and applicant's land is in more than one (SWBD), the respective (SWBD) board of directors will review the application and agree to oversee all works, administrate all contracts and obligate all funds from one (SWBD) or prorate the funding between SWCDs

- Give initial approval to those applications that meet the eligibility requirements.
- Evaluate the initially approved applications under the (SWBD)'s priority system and given final approval to the high priority applications that can be funded by the (SWBD)'s allocated funds.
- Obligate funds for the approved conservation land treatment measures that can be funded and notify the applicants that his/her conservation land treatment measure(s) has/have been approved for cost-share and to proceed with installation.
- Determine compliance with standards and specifications and certify the amount of cost-share for completed conservation land treatment measure(s) that meet standards.

c. Performance Agreement: As a condition for receipt of cost-share assistance for conservation land treatment measures, the eligible person receiving the benefit of such assistance shall agree to perform those measures in accordance with standards established by the TSSWCB. Completion of the performance agreement and the signature of the eligible person is required prior to payment.

d. Maintenance Agreement: As a condition of the receipt of state cost-share funds, the person receiving the funds shall agree to implement and maintain all measures in his or her WQMP consistent with its implementation schedule. This agreement shall remain in effect for a minimum period of two years after the WQMP is completely implemented for all practices except those cost-shared. This maintenance agreement shall remain in effect on cost-share practice(s) for the expected life of the cost-shared practice(s) as established by the TSSWCB or, a period of two years after the WQMP is completely implemented, whichever period of time is longer.

TEACHING MATERIALS AND REFERENCES:

1. Senate Bill 503 as passed by the 73rd Texas Legislature

2. Reference Guide, Non-point Source Pollution/Agriculture & Silviculture, published and maintained by Texas State Soil and Water Conservation Board.

TRAINING GUIDE # 3

MANURE AND WASTEWATER PRODUCTION

OBJECTIVE:

To develop an understanding of wastewater production calculations and assumptions.

TEACHING POINTS:

1. An adequate estimate of the manure load for a dairy farm is important for proper design and management of manure and wastewater facilities.

2. Key parameters that describe the manure load from a dairy farm include: total solids, volatile solids, nitrogen, phosphorus and potassium. These and other parameters are defined in Appendix I.

3. Manure production for dairy cattle can be calculated in several ways. One of the most convenient ways is to estimate the manure production based on total liveweight and hours per day in confinement of the animals contributing to the manure load that is to be managed.

4. A convenient method of calculating the manure load is to use standard tables prepared by the American Society of Agricultural Engineers (ASAE). This is illustrated in Attachment 3.1.

5. Sample manure production calculations are illustrated in Attachment 3.1 and 3.2.

6. Wastewater production volume estimates are important for properly sizing the structures such as lagoons for storage and treatment of the land application system.

7. The volume of wastewater to be handled is the sum of: wet manure; water used for manure removal; water used for rinsing milking equipment and milk storage tanks; rinse water used for cow washing; spilled drinking water; and other uses that enter the wastewater system.

8. Sample calculations for wastewater production are shown in Attachments 3.3 and 3.4.

TEACHING MATERIALS AND REFERENCES:

1. Attachment 3.1 - Illustration of method for estimating manure production for dairy cattle based on ASAE data

2. Attachment 3.2 - Sample manure production calculation for 200 head dairy.

3. Attachment 3.3 - Wastewater production estimates.

4. Attachment 3.4 - Sample wastewater production calculation for 200 head dairy.

5. REFERENCES:

a. ASAE D384.1 Manure production and characteristics. American Society of Agricultural Engineers, 1997 Yearbook of Standards, St. Joseph, Michigan. 4p.

b. Sweeten, J.M. and M.L. Wolfe. 1993. The expanding dairy industry impact on groundwater quality with emphasis on waste management system evaluation for open lot dairies. TR-155, Texas Water Resource Center, TAMU, College Station. 142p.

ATTACHMENT 3.1

Illustration of Method for Estimating Manure Production for Dairy Cattle

- To illustrate the use of ASAE DATA (D384.1) Manure Production and Characteristics.
  - Mean total solids for dairy cattle = 12 lb per 1,000 lb liveweight per day
  - Standard deviation = 2.7 lb per 1,000 lb liveweight per day
- Standard design practice in Texas uses the mean value + one standard deviation, or 12 + 2.7 = 14.7 per 1,000 lbs liveweight per day
- Therefore, the standard design value for total solids (dry manure) produced each day from dairy cattle is 14.7 lb solids per 1,000 lb cattle liveweight per day.
- The value of 14.7 lbs total solids per day per 1,000 lbs liveweight will give a good estimate if all manure is produced on a concrete surface, a corral, or alley and will need to be collected.
- However, cattle on pasture will excrete manure that does not need to be collected and handled in most cases. For example, if dairy cattle spend only 6 hours per day (i.e. 25% of the time) on average in feeding lots or lanes, alleys, holding shed, or milking parlor, and the rest (75%) on pasture then only 25%, or 3.7 lbs, total solids per 1,000 lbs per day needs to be collected and "managed."

ATTACHMENT 3.2

Sample Manure Production Calculations for 200 Head Dairy

1. Assumptions: 200 head dairy
   1,400 lb Holstein milking cow
   6 hours/day confinement period for concrete, and
   18 hours/day on open lots

2. Total Liveweight:

   200 head x 1,400 lb/head = 280,000 lb liveweight

3. Total Manure Solids Production:

   a. Based on 24 hour confinement (all manure collected into waste stream)

   280,000 lb liveweight x 14.7 solids/1,000 head/day

   = 4,116 lb solids/day
   = 751 tons/year

   b. Based on 6 hour/day confinement period on concrete (remaining 18 hours/day in open lots):

   Total solids load on concrete entering liquid manure system =

   $$\frac{(6 \text{ hours/day})}{(24 \text{ hours/day})} \times 4{,}116 \text{ lb solids/day}$$

   = 1,029 lbs solids/day
   = 188 tons/year

WORKSHEET I. MANURE PRODUCTION DATE FOR COLLECTABLE MANURE

TYPE OF ANIMAL (Dairy=0, Swine=1, Laying Hens=2, Beef Feed Lot=3
Sheep FeedLot=4, Horses=5, Turkeys=6, Broilers=7) -> 0

Manure Production Criteria for Dairy Feeding Facilities

	Parameters	Buildings, Concrete Pens & Alleys	Open Lots	Total
#1.	Number of Animals	200	200	
#2.	Average Liveweight per Head, Lbs./hd	1400	1400	
#3.	Total Liveweight, Lbs (#1 x #2)	280000	280000	
#4.	Confinement Period, hours/day	6	18	24
#5.	Confinement Period, fraction (#4/24)	.25	.75	1.00
#6.	Adjusted Total Liveweight, Lbs (#3 x #5)	70000	210000	280000
#7.	Wet Manure Production, Lbs/day	7140	21420	28560
#8.	Dry Manure Production, Lbs/day	1029	3087	4116
#9.	Dry Manure Production, tons/year	188	563	751
#10.	Volatile Solids (VS) Production, Lbs/day	755	2266	3021
#11.	Total Nitrogen Production, Lbs/day	38	115	153
#12.	Total Phosphorus (P205), Lbs/day	19	57	76
#13.	Total Potassium (K20), Lbs/day	32	97	130
#14.	Sodium Production, Lbs/day	5	16	22
#15.	COD Production, Lbs/day	938	2814	3752
#16.	BOD5 Production, Lbs/day	146	437	582

ATTACHMENT 3.3

Average Daily Wastewater Production Estimates, (gallons/day)

- Wet manure volume is the weight of wet manure per day divided by 8.34 lbs/gallon (see Attachment 3.2, Worksheet I).
- Most of the wastewater will be water used for manure removal.
- Based on flush systems and/or manual scrape/wash systems used at the dairy.
- Flush systems typically use 8 - 12 gallons per lb of total solids removed from a concrete floor.
- Manual scrape/wash systems typically use 3 - 6 gallons per lb of solids removed from a concrete floor.
- Water used for milk sanitation (lines, equipment, tanks, etc.) plus the cow-rinse water will be 5 - 10 gallons per cow per day.
- Estimates must include spilled drinking water, and other clean-up water.
- Estimates should also take into account the amount of recycled flush water (if any) that may be used on concrete feeding alleys or free stall barns. Recycling of water will reduce the fresh water use.
- If sprinkler cow-washes are used in holding shed ahead of the milking parlor, they will add about 30-40 gallons per cow per day to the wastewater stream in most cases.
- The total daily wastewater load is the sum of the above components.
- Rainfall runoff from exposed feeding lanes or lots must be taken into account as well by the designer. It will add to the total daily wastewater load unless the runoff is handled separately.

ATTACHMENT 3.4

Sample Wastewater Production Calculation for 200 Head Dairy

1. Assumptions: 200 head dairy
   1,400 lb Holsteins

2. From previous example: Manure Production (total solids) = 4,116 lb/day (24 hr/day basis)

   Manure Production on concrete entering liquid manure stream (6 hrs/day) = 1,029 lbs solid/day

3. Wastewater for manure removal on concrete entering liquid manure stream

   a. Flush System

   1,029 lb/day x 10 gallons/lb = 10,290 gallons/day*
   = 1376 ft^3 /day
   = 0.032 acre feet/day

   * not including spilled drinking water, other clean-up water, or recycled flush water

   b. Manual Scrape/Wash System:

   1,029 lb/day x 5 gallons/lb = 5,145 gallons/day*
   = 689 ft^3 /day
   = 0.014 acre feet/day

   * not including spilled drinking water, or other clean-up water

4. Wet manure volume:

   Wet manure production = 7,140 lbs/day(from Attachment 3.2, Worksheet I)
   Wet manure volume = (7,140 lbs/day) / (8.34 lbs/gallon)
   Wet manure volume = 856 gallons/day

5. Other wastewater (spilled drinking water and clean-up water):

   Assume: 8 gallons/cow/day

   Other wastewater volume = 8 gallons/cow/day X 200 cows
   = 1,600 gallons/day

6. Total wastewater volume (not including runoff):

   a. With Flush System, Total = 10,290 + 856 + 1,600 = 12,746 gallons/day

   b. With Manual Scrape/Wash System, Total = 5,145 + 856 + 1,600
   = 7,601 gallons/day

WORKSHEET II - VOLUME OF MANURE & WASTEWATER FROM CONFINEMENT BUILDINGS

Parameter		Quantity
#1 Wet Manure Production (#7 from Worksheet I)	=	7140 lbs/day
#2 Wet Manure Production (#1 / 8.34)	=	856 gal/day
#3 Spilled Drinking Water, Estimated Volume	=>	0 gal/day
#4 Water Used for Manure Removal		

a. Dry Manure Production (#8 from Worksheet
I) = 1029 lbs/day

b. Water Volume Required for Manure Removal

1. Flush Systems:
(Enter gallons water per pound of dry manure =>
10.00
production, range 8 - 12 gal/lb)
Total flush water (#4

REC
4/97
SEF
12/97

TRAINING GUIDE # 4

SOLIDS SEPARATION SYSTEMS FOR TREATMENT

OBJECTIVES:

1. To learn the purpose of solids separation systems in facilitating liquid dairy manure management and runoff control.

2. To learn the basic types of pretreatment/solids separation systems.

3. To learn the amount of organic solids and nutrients that can be reliably removed from the liquid manure and runoff streams in most types of CAFO's.

4. To learn the proper management of separated solids for utilization and prevention of odor or fly breeding.

TEACHING POINTS:

A. The main purpose of the solids separation systems is to remove coarse organic and inorganic particles entrained in manure, wastewater and runoff, in order to:

   1. Reduce organic matter/volatile solids loading into lagoons or holding ponds, which will have the effect of either--

      a. lowering odor potential through reduced volatile solids loading rates; or
      b. allowing a reduction in lagoon volume where continual operation of the pretreatment system can be reliably predicted.

   2. Preserve essential design capacity of lagoons or holding ponds for treatment and storage of effluent and runoff;

   3. Maximize the number of years before settled solids/sludge removal becomes necessary.

B. There are several alternative types of pretreatment systems, including settling basins and several types of mechanical separators.

   1. Settling Basins

      a. Settling basins, earthen or concrete lined, should be used primarily for removal of settleable solids from--

- rainfall runoff from the open lots and other manure-covered surfaces that drain into the lagoon/holding pond system.
- liquid manure/process generated wastewater.

b. Settling basins are designed to slow the speed of runoff from open lot portions of the CAFO facilities in order to deposit readily settleable solids for mechanical removal, allowing liquids to freely drain by gravity into the lagoon/retention system. Settling basins should be shallow (2-3 ft.) with a long flow path (e.g. 100 ft.) to maximize solids capture. Minimum average settling time should be 10 to 30 minutes. Settling basins should be designed for complete drainage of liquids and should not be allowed to store runoff for longer than five days following runoff, to minimize odor. They should have a concrete bottom and ramp with 12:1 slope on each end.

c. Wet settled solids should be removed completely as soon as practical following each runoff producing storm, with a recommended interval of 7 to 14 days or more frequently if conditions for high potential for fly breeding develop.

2. Mechanical Separators

a. Mechanical separators, for process generated wastewater from confinement buildings, including flushed liquid manure or rinse water from dry-scraped/concrete floors, and/or manual wash water.

b. Types of mechanical separators include:

- Static screens
- In-channel screens (auger/porous sleeve or flighted conveyor/tilted screen)
- Vibrating screen
- Screw press
- Other

C. Mechanical separators are generally not economically feasible for small operations.

E. Typical removal efficiencies of solids separation systems from the wastewater stream are as follows:

Constituent	Settling Basin	Mechanical Screens
Total Solids	30%	20%
Volatile Solids	30%	20%
Total Nitrogen	20%	15%
Total Phosphorus	20%	15%

F. Typical physical and chemical properties of separated solids are as follows:

Constituent	Settling Basin	Static Screen Separators	Other Mechanical Separators*
Moisture Content, % wet basis	82.7	76	83.0
Ash, % dry basis	36.0	8	12.0
Total nitrogen, % dry basis	2.1	1.7	1.6

Total phosphorus, % dry basis	--	0.2	0.2
Potassium, % dry basis	--	0.4	0.4
Bulk Density, lbs/ft^3	--	21	--

* Data from Hydrocyclones (2), flighted conveyor, auger/perforated sleeve, and static screens (2).

G. Separated solids should be stored such that drainage will be caught in the lagoon, holding pond, or other wastewater storage.

H. Separated solids may be composted or spread directly on land.

TEACHING RESOURCES:

1. Auvermann, B.W. and J.M. Sweeten. 1992. Solids Separation Systems for Livestock Manure and Wastewater. Technical Report, Texas Agricultural Extension Service, Texas A&M University, College Station, Texas.

2. MWPS. 1985. Livestock Waste Facilities Handbook. Midwest Plan Service, Iowa State University, Ames, Iowa.

3. ASAE. 1995. Manure Production and Characteristics. D384.1, ASAE: The Society for Engineering in Agricultural, Food, and Biological Systems, St. Joseph, Michigan.

4. Pope, J.N. 1995. Evaluation of Physical and Chemical Characteristics of Separated Dairy Manure Solids. In: 1994 Result Demonstration Handbook for Erath County, Texas Agricultural Extension Service, Texas A&M University System, Stephenville, Texas.

JDW
5/96
SEF
12/97

TRAINING GUIDE # 5

LAGOON SEEPAGE PREVENTION AND GROUND WATER PROTECTION

OBJECTIVES:

1. To learn the benefits of lagoons and holding ponds in protecting ground water quality when designed, constructed and maintained properly, in accordance with engineering standards.

2. To learn the minimum soil testing specifications for soil materials that can be used for controlling seepage from lagoons and holding ponds, in accordance with TNRCC Subchapter K regulations, equivalent federal (USEPA Region 6) requirements, and USDA-NRCS Field Office Technical Guides (FOTG).

3. To learn the proper methods of placement of soil materials used for lagoon and holding pond liners.

4. To learn how to inspect, monitor, and maintain the structural integrity of the embankments used for lagoons and holding ponds.

TEACHING POINTS:

A. Lagoons and holding ponds offer a means of protection of surface and ground water through:

   1. containment of manure and wastewater;
   2. treatment to reduced levels of organic solids, oxygen demand, and nutrients such as nitrogen
   3. storage to achieve timely application to better insure nutrient uptake at designed rates and control of direct runoff or deep percolation; and
   4. reduction of land areas needed for manure and wastewater application.

B. The basic legal requirement and responsibility of the CAFO operator regarding lagoon/holding pond seepage protection and embankment construction is to insure:

   1. there is no hydrologic connection to waters of the state or U. S.
   2. ground water quality is not degraded below quality standards for a legitimate purpose, e.g. below safe drinking water standards; and
   3. the embankment has structural integrity at all times.

C. "No hydrologic connection" can include construction of lagoons or holding ponds using present in-situ soil materials or soil material liners that meet specified requirements of both TNRCC and USEPA, as follows:

   1. minimum thickness = 1.5 ft.
   2. maximum hydraulic conductivity = 1.0×10^{-7} cm/sec.

3. in lieu of (a) and (b), compliance with criteria in USDA-NRCS Technical Note 716 and 717.

D. The degree of compaction achieved will depend on the type of equipment utilized and the moisture content of the soil material.

E. It is difficult to achieve good compaction by operating earth moving or compaction equipment on steep slopes. Therefore, it is recommended that for slopes steeper than 3:1 (horizontal:vertical) a "stairstep" construction technique be utilized. The conventional "bathtub" construction technique generally can be utilized when the side- and end-slopes are less than 3:1.

F. Seepage losses are more likely to occur horizontally (between compacted lifts) rather than vertically. However, lateral seepage can be controlled by proper bonding of joints between adjacent lifts, using scarification, moistening, mixing, and removal of clods, roots or rocks prior to placement and compaction of the succeeding lift. The maximum thickness of each compacted lift should not exceed 6 inches.

G. Livestock should be fenced out of wastewater retention structures to prevent puncturing the soil liners.

H. Trees and brush should be removed from embankments before roots penetrate the liner.

I. Caution should be exercised and steps planned to prevent mechanical damage during agitation, pumping and/or removal of settled solids/sludge from lagoons and holding ponds.

J. Wildlife or aquatic life that may damage the liner or embankment should be removed; these include rodents, nutria, and crayfish.

K. When a wastewater retention structure or lagoon is empty, desiccation cracks can compromise the liner's ability to reduce or prevent seepage.

1. Desiccation cracks can be prevented by a blanket of silty sand, lagoon sludge or other material that remains moist, or by periodically sprinkling the liner during empty periods.
2. The bottom of the wastewater retention structure must be kept moist to prevent the cracks.

L. Inlets of lagoons receiving daily loading of wastewater should extend at least 10-20 feet into the lagoon beyond the water line to prevent erosion and embankment undercutting from turbulence.

M. Rip-rap may be needed in some cases to protect the liner from wave erosion.

N. Lagoons or holding ponds must be located at least 150 ft from private water supply wells and 500 ft from public water wells. Greater distances may be recommended in specific cases.

TEACHING MATERIALS:

1. ASAE. 1993. Design of Anaerobic Lagoons for Animal Waste Management. EPA 403.2, ASAE Standards 1993, ASAE: The Society for Engineering in Agricultural, Food, and Biological Systems, St. Joseph, MI.

2. NRCS. 1991. Technical Note 717, USDA-Natural Resource Conservation Service, Washington, DC.

3. NRCS. 1993. Technical Note 716, USDA-Natural Resource Conservation Service, Washington, DC.

4. TNRCC. 1995. Subchapter K Regulations, Texas Register, July, 13.

5. USEPA. 1993. National Pollutant Discharge Elimination System General Permit and Reporting Requirements for Discharges From Concentrated Animal Feeding Operations. Environmental Protection Agency, Region 6. Federal Register, Vol. 58, No. 24. pp. 7610-7644.

6. Walker, J. D. 1995. Seepage Control from Waste Storage Ponds and Treatment Lagoons. In: Volume 1--Proceedings, Conference on Innovations and New Horizons in Livestock and Poultry Manure Management, Austin, Texas. Texas Agricultural Extension Service and Texas Agricultural Experiment Station, pp.70-78.

BL
6/96
SEF
12/97

TRAINING GUIDE # 6

CONSTRUCTED WETLANDS SYSTEMS FOR EFFLUENT AND WASTEWATER TREATMENT

OBJECTIVES :

The objectives of this training guide are for the CAFO owner/operator to learn:

1. The major purpose and uses of a constructed wetland system for wastewater treatment.
2. The mechanisms by which the wetland system treats effluent.
3. The components and operating principles and design criteria of a wetland system.
4. The expected treatment efficiency and resulting water quality.
5. Alternative uses of the effluent from wetland system.

TEACHING POINTS:

A. Constructed wetland systems can serve the following purposes:

   1. Further treatment of lagoon effluent, especially in terms of nitrogen and phosphorus removal; and removal of oxygen - demanding organic solids.
   2. Enhance evapotranspiration of wastewater;
   3. Add protection from non-point source pollution through treatment of rainfall runoff from land application areas for manure and wastewater.

B. Constructed wetland systems consist of four main components including: water management, waterway berms, storage basin for flow alternation, and wetlands for treatment.

C. Where a wetland is used to treat runoff from fields receiving manure, compost or effluent, a waterway berm system collects runoff from the land application field and diverts the water into a storage basin or to natural drainage. In these cases waterway berms are located downslope of the land application area for collection of the runoff. Some of the management aspects include:

   1. The integrity of berms associated with the system must be examined for erosion and leakage.

   2. The grassed waterway should be managed by mowing regularly to maintain thick, vigorous turf and repairing any double channeling due to erosion and waterway

sedimentation. Similar mowing and repairs will also be necessary to maintain uniform slope and the outlet channel.

3. Gates and instrumentation directing flow into the storage basin or the outlet channel must be inspected and repaired as necessary for proper performance.

4. Stage recorders and effluent sampling equipment should be maintained to obtain the information regarding the volume and quality of runoff leaving the application field.

D. The storage basin retains the runoff until it can enter the wetland cells. The water is metered from the storage basin into the wetland cells through a trash trap and overflow weir that can be used to monitor the flow rate into the wetland cells when desired.

1. The storage basin outlet structure (wetland inlet structure) needs to be inspected periodically and cleaned in order to remove any accumulating debris around the outlet/trash trap.

2. A sliding valve can be adjusted to change the flow of water leaving the storage basin. The flow rate will normally not need to be adjusted. However, if the lines become clogged, the valve may need to be adjusted to remove debris in the line.

3. The side walls of the storage basin will need to be inspected to insure their integrity and repair any erosion occurring on the slopes.

E. Where a constructed wetland is used to treat effluent from a primary lagoon, second stage lagoon, or runoff retention pond, a storage basin may not be necessary as that function is served by the treatment lagoons. The effluent can be discharged by gravity into the constructed wetland cells.

F. Wetland cells can be designed to provide treatment of runoff from the land application areas. The wetland should be sized to remove organic matter from the runoff. If nitrogen, phosphorus, and pathogens are in the runoff, the wetland will also reduce the concentration of these contaminants (or at least equilibrate them with background levels).

1. The water level in the wetland is controlled by adjusting the height of the "stop-logs" in the outlet structure. The water level can be changed to assist in propagation of plants or for maintenance of the system. Under normal operating conditions, the water level will remain constant.

2. Water inflow to the wetland should be intermittent. No supplemental water will be added to the wetland system during periods without rainfall events. Some water should remain in the deeper regions even during dry periods.

3. The vegetation in the wetland may need occasional harvesting (annually if necessary). Excessive vegetation can be removed during dry periods, and, if necessary, a cool burn can be used during the winter months prior to birds nesting within the wetland.

G. Wetland cells along with storage basins need to built in in-situ soil materials or sufficient clay liner material needs to be placed to control seepage in accordance with the applicable state (TNRCC) and federal (USEPA) regulations that require no hydrologic connection to waters of the U.S. and prevention of groundwater contamination. (Specifications for materials and methods of placement are covered in detail in "Lagoon Seepage Prevention and Ground Water Protection," Training Guide # 5, in this manual.)

H. Effluent from a concentrated wetland system used for further treatment of lagoon or holding pond effluent will be of improved quality but still may not be suitable for direct discharge to a stream. The Water Quality Management plan will provide guidance to the ---?--- on this question.

TEACHING MATERIALS:

1. Stall, ... .1983.

2. Du Bowy, Paul. (ed.) 1996. Second National Work Shop on Constructed Wetlands for Animal Waste Management, Fort Worth, Texas, May 15-18. Department of Wildlife and Fisheries, TAMU, College Station, TX.

SS/EJ
3/97
SEF
12/97

TRAINING GUIDE # 7

RATION MANAGEMENT AND MANURE NUTRIENT CONTENT

OBJECTIVE:

The objective of this training guide is to manipulate ration management to increase efficiency of nutrient utilization, especially nitrogen and phosphorus.

TEACHING POINTS:

A. Potential methods:

1. Modify ration formulation according to carbohydrate models
2. Modify ration formulation in response to cow performance (manure phosphorus, milk urea nitrogen)
3. Modify cow grouping strategies (see example on next page)
4. Modify feeding management

B. Environmental benefits:

1. Lowered manure phosphorus and nitrogen content
2. Decreased non-point source pollution to surface and groundwater from nitrogen and phosphorus runoff and leaching

C. Producer benefits:

1. Improved ration efficiency
2. Lowered feed cost without reduction in milk production

D. Example of grouping strategies on manure phosphorus

1. Example of potential manipulation in manure phosphorus content. Calculations use estimates of requirements and digestive efficiencies from current National Research Council recommendations of [Phosphorus requirement = 1.1 *(.0143*BW) + (.99*FCM) + (.0047*(1.23*BW)) / 0.5, where BW is body weight and FCM is fat-corrected milk]. Typically, when one feeding group strategy is used, supplementation is targeted toward the nutritional needs of the early lactation animal and allowing overfeeding of the later lactation animal. Estimates of the efficience of phosphorus absorption is averaged at 55%.

a. Group 1 feeding strategy

300 cow herd, milk average	75 lbs of milk
Phosphorus (P) requirement	0.42% of ration
Dry matter intake	50 lbs

Total Phosphorus (P) excreted = [50*0.0042*0.45*300] = 28.3 lbs per day

b. Group 2 feeding strategy

300 cow herd, milk average	75 lbs of milk
High group (150 cows)	85 lbs of milk
Phosphorus requirement:	0.42% of ration
Dry matter intake:	54 lbs
Low group(150 cows)	65 lbs of milk
Phosphorus requirement:	0.39% of ration
Dry matter intake:	47 lbs

Phosphorus (P) excreted:

High group: [54*0.0042*0.45*150] = 15.7 lbs per day

Low group: [47*0.0039*0.45*150] = 12.4 lbs per day

Total (P) excreted = 28.1 lbs per day

c. Group 3 feeding strategy

300 cow herd, milk average	75 lbs of milk
High group (100 cows)	90 lbs of milk
Phosphorus requirement:	0.44% of ration
Dry matter intake:	54 lbs
Middle group (100 cows)	70 lbs of milk
Phosphorus requirement:	0.40% of ration
Dry matter intake:	48 lbs
Low group (100 cows)	50 lbs of milk
Phosphorus requirement:	0.38% of ration
Dry matter intake:	41 lbs

Phosphorus (P) excreted:

High group: [54*0.0044*0.45*100] = 10.7 lbs per day

Middle group: [48*0.0040*0.45*100] = 8.6 lbs per day

Low group: [41*0.0038*0.45*100] = 7.0 lbs per day

Total P excreted = 26.3 lbs per day

d. Compare: The daily amount of total phosphorus excreted by a 300 cow herd can be reduced by group feeding as follows:

	lbs P/day	lbs P/year
Group 1	28.3	10,329
Group 2	28.1	10,256
Group 3	26.3	9,599

JMS
4/96
SEF
12/97

TRAINING GUIDE # 8

COMPOSTING

OBJECTIVES:

1. To learn the fundamental principles of composting manure and other organic materials.
2. To learn the principal methods of composting.
3. To learn the major parameters that control proper composting.
4. To learn the nutrient composition of composted manure in relation to manure prior to composting.

TEACHING POINTS:

A. Composting is the controlled degradation of organic matter to simpler compounds of (carbon dioxide, water, etc.) under high temperature conditions.

B. Composting requires the presence of oxygen, adequate but not excessive moisture, and suitable energy for nutrient balances (carbon : nitrogen : phosphorus).

C. Materials suitable for composting on a typical dairy:

   1. Manure
   2. Screened fiber from mechanical separators
   3. Debris basin settled solids
   4. Waste feedstuffs
   5. Spoiled hay or other feedstuffs
   6. Dead calves or whey, mixed with other materials

D. Favorable conditions for composting include oxygen (3-5% by volume), moisture (40-60 % wet basis), C : N : P ratio (20-25: 1: 0.2), pH (7.0-8.0), ash content in manure (45 % or less), and temperature (135-165 F).

E. C : N ratio

   1. Manures normally have a C : N ratio of around 10 : 1.
   2. Composting can benefit from addition/blending of bulking agents in various types of crop residues as a carbon energy source, since the C : N ratio of crop residues is normally about 50 : 1 (30-100 : 1).

F. Aeration can be provided by:

1. Crop residues serve as a bulking agent that absorbs excess moisture and adds porosity which facilitates aeration.
2. Frequent turning or mixing
3. Forced aeration--positive or negative pressure
4. Natural ventilation--chimney effect

G. Major methods of composting include:

1. Static pile/windrow (unmixed)
2. Windrow method
3. Aerated static pile/windrow (e.g. Beltsville aerated static pile method)
4. In-bin mechanically mixed
5. In-vessel (e.g. rotation cylinder)

H. Composting benefits:

1. Manure stabilization
2. Particle size reduction and uniformity
3. Improved spreading uniformity
4. Major reduction of viable weed seeds
5. Pathogen reduction, several orders of magnitude
6. Reduced odor potential for land spreading
7. Retention of phosphorus and other minerals

I. Nutrient content of compost as compared to manure is:

1. N--similar or slightly lower concentration in compost. The major nutrient loss occurs through volatilization of ammonia-nitrogen
2. N availability -- probably lower
3. P and K -- higher in compost
4. Salt ions and other minerals -- higher in compost

J. Odor considerations:

1. Intense or offensive odor may be produced for first week of composting.
2. Odor reduced during composting
3. Odor of <u>finished</u> compost is less than uncomposted manure
4. Odor dissipates rapidly with distance downwind

K. Composting of manure is covered under TNRCC and USEPA Region 6 permits for dairies and other CAFO's. Runoff from composting manure and stored compost must be collected as for corrals and other manure-covered surfaces.

L. Composting of manure and other agricultural residues does not require notification, registration, or a permit from TNRCC, provided it is not mixed with municipal or mixed wastes.

TEACHING MATERIALS:

1. Sweeten, J.M. 1990. "Composting Manure and Sludge," L-2289, Texas Agricultural Extension Service, Texas A&M University System, College Station 77843. 4 p.

2. Rynck, R. 1992. "On-Farm Composting Handbook," NRAES-54, Northeast Region Agricultural Engineering Service, Cornell University, Ithaca, N.Y. 14853. 186 p.

3. TNRCC. 1995. Composting Rules of the State of Texas. 30 Texas Administrative Code, Chapter 332. Texas Natural Resource Conservation Service, Austin, Texas. November 1.

4. "Farm Scale Composting." The JG Press, Inc., Emmaus, PA. 80 p.

5. Biocyle: Journal of Composting and Recycling, the JG Press, Inc., January-December, 1995-1996. (Issues since 1959).

SEF
1/98

TRAINING GUIDE # 9

SOIL FERTILITY AND NUTRIENT MANAGEMENT

OBJECTIVES

The objectives of this training guide are for the dairy producer to:

1. Learn how to collect soil, manure, and lagoon samples.

2. Learn how to interpret and use soil, manure, and lagoon sample analyses.

3. Learn how to manage nutrients for plant growth through manure and fertilizer applications.

4. Become familiar with nitrogen and phosphorus based land application of animal wastes.

5. Learn how to calibrate a manure spreader.

TEACHING POINTS:

A. The first essential step in fertilizer recommendations is the collection of a representative soil sample.
   1. Tools
      a. Shovel or other sampling type of sampling equipment
      b. Plastic bucket and knife or metal spatula
      c. Soil sample bag for shipping sample. A zip-lock sandwich bag or a soil sample bag obtained from your local county agent.
      d. Water to clean tools between sample location
   2. Collection of sample - See Attachment 9.1
      a. Divide the area in 40 acre or less areas
      b. Collect 10 to 15 subsamples within each divided area and combine to represent that area. Be sure to avoid areas were animals collect for watering or feeding. Also avoid drainage areas and areas where vegetation is different. These type areas are usually not representative of the rest of the soil.
      c. At each subsample location dig a hole about 8 inches deep. Take a one inch slice from a cleaned side of the hole to a 6 inch depth. Using the knife or metal spatula take a 1 inch slice out of the middle of the sample in the shovel.

d. Place the subsample in the plastic bucket and move on to the next site within the 40 acres to be subsampled
e. After all 10 to 15 subsamples have been collected, mix the soil and remove enough to fill the soil sample bag 2/3 full. Samples can be air-dried on a paper towel if it is wet to reduce the weight and cost of mailing. DO NOT OVEN DRY the samples or dry them on newspaper. Both of these can change the chemical analyses of the sample.
f. Clean all tools before starting to sample and between each area to be sampled
g. Label the sample and make a map of the areas sampled. Keep the map for your records so you know where the samples were collected and how you labeled each sample.
h. Send the sample with your requested analyses, crop to be grown, and estimated yield to the TAEX Soil, Water, and Forage Testing Laboratory, Soil and Crop Sciences, Texas A&M University, College Station, TX 77843-2474 or other laboratory of your choice.
i. Request routine analyses for fertilizer recommendations

B. The first step in managing nutrients from animal wastes is to know the amount of nutrients in the animal wastes.

1. Collection and analyses of manure sample
    a. Clean a sampling tool such as a shovel thoroughly before collecting any samples
    b. Collect about 10 subsamples from the manure to be tested and place each subsample in a clean plastic bucket. Mix thoroughly and remove enough manure to fill a zip-lock sandwich bag 2/3 full.
    c. Label and send the sample to the TAEX Testing Laboratory or laboratory of your choice
    d. Request nitrogen and minerals, at least phosphorus and potassium, be analyzed
2. Collection and analyses of lagoon sample
    a. Attach a cleaned plastic bottle to a long pole
    b. Using the pole with the plastic bottle, collect 5 to 10 subsamples from various locations around the pond
    c. Mix the samples in a clean plastic bucket
    d. Remove and submit at least 8 oz of sample in a tightly sealed plastic bottle (a new plastic baby bottle works well)
    e. Submit the sample to the TAEX Testing Laboratory or other laboratory of your choice
    f. Request routine lagoon water analyses (pH, EC (salinity), ammonia-nitrogen, nitrate-nitrogen, and total nitrogen, phosphorus, and potassium, at least)

B. The interpretation of the soil test information is very important. The main information to find on the report form is the recommended nitrogen, phosphorus, and potassium. This is usually written as 100-30-60 referring to pounds per acre (lb/A) of N-P_2O_5-K_2O. This would mean that you should apply 100 lb/A nitrogen, 30 lb/A P_2O_5, and 60 lb/A K_2O. Be sure to read all of the report for any details on fertilizer application management practices, such a split applications, etc.

C. Interpretation of the manure and lagoon analyses in conjunction with the soil test nutrient recommendations will enable the producer to determine how much manure or lagoon effluent needs to be applied to reach the suggested nutrient recommendations. The producer should be aware that most nutrient management plans are based upon the nitrogen recommendations. Due to the phosphorus content in the manure and effluent compared to nitrogen, phosphorus will be over applied. Attachment 9.2 illustrates this fact by showing the amount of land required if manure is applied on a nitrogen basis compared to a phosphorus basis. The producer needs about 3.4 times more land to apply manure on a phosphorus basis compared to nitrogen.

D. It is recommended that the producer manage for both nitrogen and phosphorus. This involves applying animal wastes in sufficient quantities to meet the first application of nitrogen and commercial nitrogen for additional applications. For example, we normally recommend 60 to 100 lb/A nitrogen in the spring for the hybrid bermudagrasses and 60 to 100 lb/A nitrogen after each grazedown or cutting. The additional nitrogen would be applied through commercial fertilizer and not manure. This type of management or variation is suggested so the phosphorus does not build-up in the soil.

E. Phosphorus build-up in soil can be detrimental to surface water and shallow ground water quality. Nitrogen runoff or leaching can be detrimental to surface water and ground water quality. Thus, it is extremely important that the manure and effluent be applied at the appropriate rates to meet the crop requirement.

F. Apply manure and effluent during times when crops are growing so the nutrients will be utilized efficiently. Be sure to avoid drainage areas and maintain approximately 100 ft buffer strips from waterways.

G. Manure spreader calibration can be accomplished in a number of ways. One simple procedure requires four sheets of material cut in 4'8" squares and a scale that is accurate to 0.5 lb. The material can be plastic, an old bed sheet, etc. Make one pass in the field with the manure spreader running. Measure the width of the spread manure. On the next application pass, lay the four squares of material equally spaced across the width the manure will be spread. After the manure has been applied, carefully pick the material squares up and pour each one separately into a clean bucket and weigh. Each pound of manure is equivalent to one ton of manure/A. The reason for the four sheets of material is to show the producer the variability of the manure spreader and get a better average.

H. To calculate the amount of nutrients being applied through the effluent, multiply the nutrient concentration in % times 2264 to obtain the total pounds of nutrient per acre-inch.

I. Conversion of phosphorus (P) to P_2O_5 is done by multiplying the P by 2.29. Conversion of potassium (K) to K_2O is done by multiplying the K by 1.2.

TEACHING MATERIALS

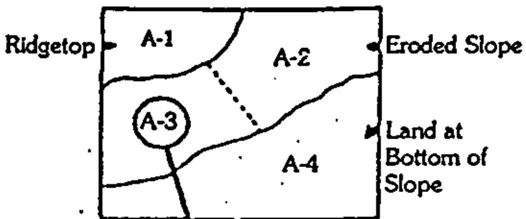
1. McFarland, M.L., T.L. Provin, and S.E. Feagley. 1997. Managing crop nutrients through soil, manure and effluent testing. Tx. Agric. Ext. Ser. Pub. # L-5175.

ATTACHMENT 9.1

Procedure for Taking Soil Samples

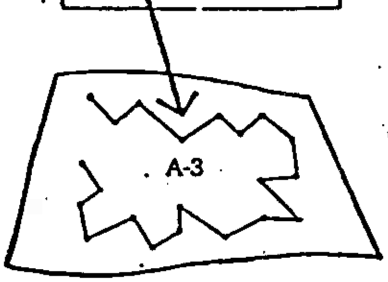
Soil tests can be as accurate as the samples on which they are made. Proper collection of soil samples is extremely important. Chemical tests of poorly taken samples may actually be misleading because they do not represent the area to be croppped.

Step 1.



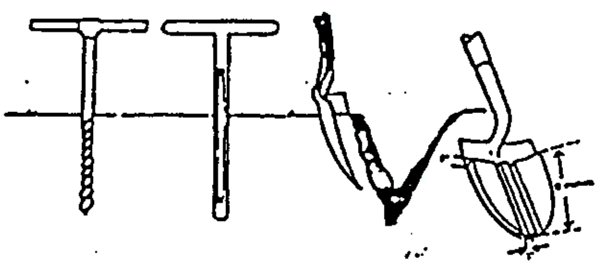
Take one composite soil sample from each uniform area of 10 to 40 acres in a field. In areas such as East Texas, one sample should represent only 10 to 20 acres: whereas, in areas where soils are more uniform, one sample can represent up to 40 acres.

Step 2.



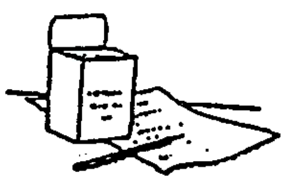
The composite sample should be taken from each area. This can be done by taking small cores or slices from 10 to 15 different places. Please these in a clean container (plastic bucket, paper sack, etc.), mix thoroughly and take out approximately 1 pint for the composite sample.

Step 3.



When taking soil samples, use a spade, soil auger or soil sampling tube as illustrated. Scrape the litter from the surface. make the core or boring 6 inches deep in the soil. (For permanent sod, sample to a depth of 3 to 4 inches). To use a spade, dig a V-shaped hole and take a 1 inch slice of soil from the smooth side of the hole. Then take a 1 X 1 inch core from the center of the shovel slice as illustrated. Repeat in 10 to 15 different splaces, put in a clean plastic bucket, thoroughly mix and remove a pint as a composite sample representing the field or area..

Step 4.



Complete the information form on the opposite side. Enclose the completed form and payment inside the package containing samples. Make check payable to Soil Testing. DO NOT SEND CASH. Address the letter and package to the following address:

Extension Soil, Water and Forage Testing Laboratory
Texas A&M University — Soil and Crop Sciences
College Station, Texas 77843-2474
Phone (409) 845-4816

PRECAUTIONS

1. Avoid sampling spots in the field such as small gullies, slight field depressions, terrace waterways and unusual spots.
2. When sampling fertilized fields, avoid sampling directly in fertilized band.
3. Do not use old vegetable cans, tobacco cans, match boxes, etc., to submit samples.
4. Do not use heat to dry samples.
5. Be sure to keep a record for yourself as to the area represented by each sample.
6. Be sure sample numbers on the boxes correspond with sample numbers on the information sheet.

For Further Details Consult Your County Extension Agent

ATTACHMENT 9.2

NUTRIENT BALANCE FOR SOLID DAIRY MANURE APPLICATION OPEN LOT EXAMPLE 200 COWS @ 1400 POUND COW

Manure Production: 75% of manure produced in open lots and
25% in confinement building or concrete lanes.
(Adapted from John Sweeten 7/12/96 handout)

		(1) Nitrogen (N)	(2) Phosphorus P_2O_5
Total solid manure available, dry basis =	0.75 x dry tons / hd-yr	562 dry tons/yr	562 dry tons/y
Total solid manure available, wet basis, as collected	35% moisture	1,606 tons/yr	1,606 tons/y
Crop - Coastal Bermudagrass, 3 cuttings			
Nutrient Balance:			
Nutrient requirement of crop	(A1)	300 #/ac/yr	10
Nutrients from soil test (assumed)	(B1)	(-) 50 #/ac/yr	(-) 5
Nutrients from wastewater application (none)	(B2)	0 #/ac/yr	
Total nutrients available to crop (B1 + B2)	(B3)	(-) 50 #/ac/yr	(-) 50 lb/a
Additional nutrient to meet crop needs (A1 - B3)	(C1)	250 #/ac/yr	5
Solid Manure Application (wet basis @ 35% moisture)			
% Total N/P_2O_5 in solid manure (dry basis)	(C2)	2.0%	1.6%
% Total N/P_2O_5 in solid manure (wet basis) = (C2) x	(1.00-0.35)	1.3%	1.04%
% Total N/P_2O_5 in solid manure (dry basis)	(D1)	0.0130	0.010
% Total Nutrients available in first year	(D2)	50%	75%
Solid manure application rate to meet plant requirements [(C1/D1)/(D2)] =		250 lbs/ac/yr / 0.013 x 0.50	50 lbs P_2O_5/ac/y / 0.0104 x 0.7
-pounds, #/ac/yr	(E1)	83,460	6,41
-tons (E1/2,000), wet basis, tons/ac/yr	(F1)	19.2	3.
-tons, dry basis (F1 x (1-0.35)), dry tons/ac/yr		12.5	12.
Total solid manure applied, wet basis (on hand), tons/yr	(G1)	1,606	1,60
Total acres needed (G1/F1), first year, acre	(H1)	84ac	502a
…jected acres needed, per residual, fifth year (H1/60%)		140 ac	502a

Notes:

Nitrogen bases:

Total acres in 1st year = $\frac{1,606 \text{ tons w.b./yr}}{19.2 \text{ tons w.b./ac/yr}}$

= 84 acres 1st year

Total acres in 5th year = $\frac{1,606 \text{ tons w.b./yr}}{60 \% \times 19.2 \text{ tons/ac/yr}}$

= 188 acres 5th year

Phosphorus bases:

Total acres in 1st year = $\frac{1,606 \text{ tons w.b./yr}}{3.2 \text{ tons w.b./ac/yr}}$

= 502 acres 1st year

Total acres in 5th year = $\frac{1,606 \text{ tons w.b./yr}}{3.2 \text{ tons w.b./ac/yr}}$

= 502 acres 5th year

TRAINING GUIDE # 10

HOW FAR CAN YOU HAUL?

OBJECTIVES:

The objectives of this training guide are for the dairy producer to learn:

1. The amount of nutrients in manure and wastewater and their equivalent fertilizer value.
2. How to estimate nitrogen available for crop production.
3. The cost of handling manure in order to recover nutrient value.
4. The net benefits of utilizing manure nutrient value.

TEACHING POINTS:

A. Manure distance worksheet

1. Factors needed to complete worksheet

a. Average manure analysis:

	Solid/Semi Solid Manure lbs per Ton	Liquid Manure lbs per 1,000 Gals.
$Nitrogen_I$	4	12
$Nitrogen_D$	2.5	6
Phosphorus	5	14
Potassium	9	30

$Nitrogen_I$ - amount of nitrogen in manure incorporated at 48 hrs of application.
$Nitrogen_D$ - amount of nitrogen in manure not immediately incorporated or daily spread.

b. Input Costs

Nitrogen Cost per lb__________

Phosphorus Cost per lb__________

Potassium Cost per lb__________

c. Size of Tractor (in horsepower) that hauls manure spreader: __________

d. Average road speed traveling to and from field (in miles per hr): __________

e. Capacity of manure spreader in tons or gallons: __________

f. Fuel Cost per Gallon: ______________

g. Labor Cost per Hour: ______________

h. If a truck - mounted manure spreader is used, guide for expense is $30 per hour.

2. Calculate amount of N, P, and K in a spreader load of manure

   a. Tons/gallon Manure per Load = _______ (same as 1.e.)

   b. Formula to Use:
   Tons or Gallons in Spreader x lbs. Nutrient per Ton or 1,000 gal. = lbs nutrient per load

      Nitrogen per load = __________x__________=________ lbs

      Phosphorus per load = __________x__________=________ lbs

      Potassium per load = __________x__________=________ lbs

3. Calculate projected fertilizer savings from applying manure

   a. Formula to Use:
   Nutrient Savings per Load = Commercial Nutrient Cost x lbs Nutrient

   N Savings per Load = N cost _______ x lbs N _______ = $_______

   P Savings per Load = P cost _______ x lbs P _______ = $_______

   K Savings per Load = K cost _______ x lbs K _______ = $_______

   $_______Total Savings/Load

4. Calculate operating costs:

   a. Table 1: Cost of Operating Tractor for 1 hr.

   Add shaded columns, 2, 5, and 6, together to determine total cost.

Tractor Size (Hp)	Op. & Dep. Cost/hr	Fuel & Lubricant Cost/hr.			Labor cost/hr	Total cost/hr
		Amt. used	x Cost/gal.	= **Total**		
60	$6.75	3.02				
80	$10.00	4.03				
90	$11.30	4.54				
110	$13.95	5.54				
150	$18.44	7.56				

5. Calculating breakeven distance for hauling manure

   a. Cost of tractor or truck operation per hour: _______ (Total from table above)

b. Cost of tractor operation per mile = $\frac{\text{Cost of tractor operation, \$/hr (5.a.)}}{\text{miles per hr (1.d.)}}$ = ________ $/mile

c. Breakeven miles manure can be hauled = $\frac{\text{Total Fertilizer Value (3.a.)}}{\text{Cost per mile (5.b.)}}$ = ________ miles

d. Breakeven Travel Distance, one way = $\frac{\text{Breakeven miles}}{2}$ = ________ miles, one way

B. Estimating nitrogen available for crop production

1. Example: A dairy manure sample was taken from a nonliquid storage facility and analyzed. The following calculations show how to estimate the amount of nitrogen that will be available during the growing season from the current manure application and from previous applications. Assume that 2: tons/acre having an organic N content of 6 lb/ton, were applied each of the past 3 years.

a. Insert the percentage of dry matter and the nitrogen value of the manure from the analysis in lb per ton for a nonliquid system of lb/per 1000 gal for a liquid system. Organic N = Total N - Ammonium N.

	Example	**Your Farm**
Dry Matter	15%	________
Total N*	10 lb/ton	________
Ammonium N	4 lb/ton	________
Organic N*	6 lb/ton	________

b. Determine the availability of nitrogen during the first year. Available N = lb. of ammonium N or organic N in item A x the percentage of availability.

		Time of Application	*Quantity available from* Ammonium N (lb x %)		Organic N (lb x %)		Available N
		Spr. 1 wk. delay	4 x 0	+	6 x .35	=	2.1 lb/ton
Example:		Spr. 2 day delay	4 x .41	+	6 x .35	=	3.7 lb/ton
		Spr. Immed.	4 x .65	+	6 x .35	=	4.7 lb/ton
Your Farm:							
Field #	________	________	________	+	________	=	________
Field #	________	________	________	+	________	=	________
Field #	________	________	________	+	________	=	________
Field #	________	________	________	+	________	=	________
Field #	________	________	________	+	________	=	________

c. Determine the availability of nitrogen from previous applications. Omit those years when manure was not applied. Available N per acre = application rate from previous records in tons or 1000s of gal. x percentage of availability.

	Quantity available from residual organic N from:					Residual N availability
	1 year ago (rate x N x %)	2 years ago (rate x N x %)		3 years ago (rate x N x %)		
Example:	25 x 6 x .12	25 x 6 x .05		25 x 6 x .02		28.5 lb/A
Your Farm:						
Field # ________	________	________	+	________	=	________
Field # ________	________	________	+	________	=	________
Field # ________	________	________	+	________	=	________
Field # ________	________	________	+	________	=	________
Field # ________	________	________	+	________	=	________

* Some laboratories may report their nitrogen results under the heading "nitrogen" and "ammonium or ammonia N". The larger of the two numbers is total N. Many laboratories do not report organic N simply because it is the difference between total N and inorganic N (ammonium N and nitrate N).

SS/EJ
3/97
SEF
12/97

TRAINING GUIDE #11

MANAGEMENT OF INTENSIVE GRAZING AND THE ENVIRONMENT

OBJECTIVES:

1. Encourage high quality management of pastures to protect farm resources and the environment.
2. Understand that most of the environmental expectations for pastures are modest, often easily achieved, and benefit the farm.
3. Encourage livestock producers to exclude their animals from the waters of the State of Texas, regardless of hydrologic sensitivity. Enhance public perception of agriculture and the marketing of livestock products by achieving this goal.
4. To protect water and on-farm resources from degradation.

TEACHING POINTS:

A. Benefits to agriculture for environmental protection in non-sensitive areas

   1. For marketing and public perception, it is *recommended* that all livestock be excluded from the water of the State of Texas, regardless of hydrologic sensitivity.
   2. When exclusion is not feasible, access into water should be limited and access sites designed for environmental protection.

B. Switching from confined feeding to pasture and the potential environmental improvements

   1. Reduced row crop production -- potentially reduces:
      a. Runoff
      b. Erosion
      c. Pesticide use
      d. Fuel use

   2. Increased pasture acreage -- potentially results in:
      a. Increasing soil organic matter
      b. Decreasing atmospheric carbon dioxide
      c. Decreasing soil nitrogen losses

3. Use of properly managed pasture:
   a. Reduces manure management needs

C. Grazing management for environmental protection

1. Sensitive water resources include:
   a. Streams and stream banks
   b. Ponds
   c. Lake shores
   d. Wetlands
   e. Riparian zones
   f. Reservoirs
   g. Drinking water supplies

2. One of more of the following BMP's may be implemented:
   a. Exclusion of livestock from water
   b. Provide stream crossings or hardened watering access
   c. Provide alternative drinking water locations
   d. Locate salt and shade away from sensitive areas
   e. Use improved grazing management

3. Producers are encouraged to implement applicable practices from the Field Office Technical Guide of the USDA - Natural Resources Conservation Service (former SCS) and their farm's Water Quality Management Plan.

D. Improved pasture management practices addressing environmental concerns

1. Exclusion from sensitive water resource areas
   a. Cost: fencing
   b. Farm benefits: keeps animals on feed
      improves udder health

2. Water system development
   a. Cost: installation and piping
   b. Farm benefit: better water quality
      higher production
      less laneway use

3. Laneway development to limit or reduce runoff and erosion
   a. Cost: gravel, fencing
   b. Farm benefit: animal health
      adequate access to all paddocks

4. Drainage, diversions, grassed waterways
   a. Cost: Installation
   b. Farm benefit: improved forage quality, grazing season
      system reliability

5. Stand establishment and improvement
   a. Cost: tillage and seeding
   b. Farm benefit: improved forage quality
      improved animal production

E. Manure management guidelines for pasture situations

1. Cows grazing and loafing in a pasture deposit manure nutrients. To estimate pasture loading, consider the following:
   a. Number of animals on pasture
   b. Length of time they are there
   c. Size of pasture
   d. Forage species present
   e. Time of year

2. Nutrients applied to pastures must follow the same agronomic rate criteria as nutrients applied to a crop field.

3. Pasture forage production and nutrient uptake can be calculated and the total nutrient needs determined. Nutrient needs can then be met with commercial fertilizer or manure applications.

4. Key factors to consider when developing pastoral nutrient budgets
   a. Crediting the field for only that portion of the day when cows are grazing
   b. Balance nutrients produced from cows with amount needed for forage production
   c. Adopt a grazing management system that does not result in nutrient over-loading

5. Controlled stream access for cows
   a. Reduces risks of broken legs or drowned cows

   b. Provides substantial benefits to water quality
      *Reduces fecal coliform contamination
      *Reduces erosion of streambanks
      *Reduces sedimentation of streambeds
      *Minimizes potential for negative impact on fish and wildlife habitat
   c. Does not mean NO in-stream access, but CONTROLLED stream access

F. Livestock exclusion from water & controlled stream crossings

1. Environmental benefits:
   a. No direct deposition of manure, pathogens, and bacteria in water
   b. Stabilizes stream banks, reducing sedimentation of waterways
   c. Protects riparian zones which aids in filtering farmland runoff
   d. Increased vegetation may decrease surface water temperature.

2. Producer benefits:
   a. Improved water sources for livestock
   b. Protects herd from water-borne disease
   c. Improved wildlife and aquatic habitat
   d. Improved public perception of agriculture

3. Alternative water sources to streams, creeks, and open waterways:
   a. Diversion or pumping - protects stream but questionable water quality
   b. Ponds - not recommended, water quality for cattle questionable
   c. Spring development - better, water quality likely higher
   d. Wells - recommended, water quality for cattle likely highest

Appendix # I

SELECTED TERMS, DEFINITIONS AND USEFUL CONVERSIONS FOR ANIMAL WASTE MANAGEMENT ACTIVITIES

OBJECTIVES: To become familiar with technical terms, their definitions and useful conversions that are commonly used to describe animal management system activities.

TEACHING POINTS:

Terms and Definitions

Ammonia (NH_3) - An irritating, non-toxic (in normal concentrations), gas resulting from manure degradation.

Ammonification - The biochemical process whereby ammoniacal nitrogen is released from nitrogen-containing organic compounds.

Aerobic decomposition - Reduction of the net energy level of organic matter by aerobic microorganisms that require free elemental oxygen for their growth.

Aeration - A process causing intimate contact between air and a liquid by one or more of the following methods: (a) spraying the liquid in the air, (b) bubbling air through the liquid, and (c) agitating the liquid to promote absorption of oxygen through the air liquid interface.

Anaerobic digestion - Conversion of organic matter in the absence of oxygen under controlled conditions to gases such as methane and carbon dioxide.

Alkaline soil - Any soil that has pH >7.

Biochemical oxygen demand (BOD) - The quantity of oxygen used in the biochemical oxidation of organic matter in a specified time, at a specified temperature, and under specified conditions. A standard test used in assessing the biodegradable organic matter in wastewater.

Biological wastewater treatment - Forms of wastewater treatment in which bacterial or biochemical action is intensified to stabilize or oxidize the unstable organic matter present. Oxidation ditches, aerated lagoons, anaerobic lagoons and anaerobic digesters are examples.

Bulk density (soil) - The mass of dry soil per unit of bulk volume, including air space.

Carbon-nitrogen ratio (C/N) - The weight ratio of carbon to nitrogen in organic matter.

Cation exchange capacity (CEC) - The sum total of exchangeable cations that a soil can adsorb expressed in centimoles per kilogram (cmol/kg) of soil.

Chemical oxygen demand (COD) - A measure of the oxygen-consuming capacity of inorganic and organic matter present in water or wastewater. It is expressed as the amount of oxygen consumed from a chemical oxidant in a specified test. It does not differentiate between stable and unstable organic matter and thus does not necessarily correlate with BOD.

Composting- Biological degradation of organic matter under aerobic conditions to a relatively stable humus-like material called compost.

Denitrification - The reduction of oxidized nitrogen compounds (such as nitrates) to nitrogen gas or nitrous oxide gas.

Digestion - Usually refers to the breakdown of organic matter in water solution or suspension into simpler or more biologically stable compounds, or both. In anaerobic digestion organic matter may be decomposed to soluble organic acids or alcohols and subsequently converted to such gases as methane and carbon dioxide. Complete decomposition of organic solid materials to gases and water by bacterial action alone is never accomplished.

Effluent - The discharge of wastewater or other liquid, treated or untreated.

Electrical conductivity - A measure of a solution's ability to carry an electrical current; varies both with the number and type of ions contained by the solution.

Facultative bacteria - Bacteria which can use either free oxygen or reduced carbon compounds as electron acceptors (as in organic substrates like sugars, starches, etc.) in their metabolism.

Fertilizer value - An estimate of the value of commercial fertilizer elements (N, P, K) that can be replaced by manure or organic waste material. Usually expressed as dollars per ton of manure or quantity of nutrients per ton of manure.

Fixed solids - The portion of the total solids remaining as an ash or residue when heated at a specific temperature and time.

Holding pond - An earthen structure constructed to store runoff water and other wastewater until such time as the liquid may be recycled onto land. Sometimes called runoff control structure, holding ponds or waste storage ponds.

Horizon, soil - A layer of soil, approximately parallel to the soil surface, differing in properties and characteristics from adjacent layers below or above it.

Lagoon- An earthen structure for the biological treatment of liquid organic wastes. Lagoons can be aerobic, anaerobic, or facultative depending on their design and can be used in series to produce a higher quality effluent.

Leaching- The removal of materials in solution from the soil by percolating waters.

Liner - Any barrier in the form of a layer, membrane, or blanket, naturally existing, constructed, or installed to prevent a significant hydrologic connection between liquids contained in rentention structures and waters in the state.

Liquid manure - Livestock manure with liquid content high enough that the mixture will flow and pump relatively easily. Solid content is usually less than about 13%.

Manure- The fecal and urinary excretions of livestock. Manure may be described in different categories as related to solids and moisture content.

Manure gas - Mixture of gases (primarily H_2S, NH_3, CH_4 and CO_2) formed during decomposition of waste.

Mechanical solids separation - The process of separating suspended solids from a liquid-carrying medium by trapping the particles on a mechanical screen or sieve, or by centrifugation.

Milking center wastes - The wastewater containing milk residues, detergents and manure which is generated in a milking center.
Mineralization - The conversion of an element from an organic form to an inorganic state as a result of microbial decomposition.
Nitrification - The biochemical oxidation of ammoniacal nitrogen to nitrate.
Odor threshold - The lowest concentration of an odorant in air which can be detected by the human olfactory sense.
Percolation, soil water - The downward movement of water through soil. Especially, the downward flow of water in saturated or nearly saturated soil at hydraulic gradients of the order of 1,0 or less.
Profile, soil - A vertical section of the soil through all its horizons and extending into the parent material.
Saline soil - A nonsodic soil containing sufficient soluble salts to impair its productivity.
Semi-solid manure - Thick, slurry manure, usually 13-18% solids content. Material is too viscous to handle as a liquid and too fluid to handle as a solid, requiring specially designed equipment such as positive displacement pumps or with a front-end loader.
Settleable solids - That matter in wastewater which will not stay in suspension during a preselected settling period.
Settling basin - Structure used to slow the flow of liquids, allowing suspended solids to settle.
Solid manure - Livestock manure with liquid content low enough that the mixture will pile or stack. Solids content is usually greater than about 15%.
Slurry manure - Manure in which the percent solids content could vary by a few percent depending on whether water is added or a slight drying occurs. Slurry manure can be handled with conventional, centrifugal manure pumps and equipment.
Sludge - the precipitate or settled solids from treatment, coagulation, or sedimentation of water or wastewater.
Solids content - The sum of the dissolved and suspended constituents in water and wastewater; usually stated in percent solids.
Supernatant - The liquid standing above a sediment or precipitate after settling or centrifuging.
Suspended solids - Solids that are in water and wastewater which are largely removable by filtering or centrifuging.
Topography - Slope of the land surface.
Volatile solids - That portion of the total solids driven off as volatile (combustible) gases at a specified temperature and time.
Waste/Wastewater- Manure, plus feed, waterer wastage, washwater and other by-products of livestock production.

Useful Conversion Factors

1 part per million (ppm) = 1 milligram per liter (mg/l) <u>or</u> 1 milligram per kilogram (mg/kg)

ppm	x	0.002	=	lbs./ton
ppm	x	0.0083	=	lbs/1,000 gal.
ppm	x	0.2266	=	lbs/acre-inch
		10,000 ppm	=	1%
		27,154 gal.	=	1 acre-inch
		1 gal. water	=	8.345 lbs
		1 gal. lagoon effluent	=	approx. 8.34 lbs
		1 cu. ft. manure	=	7.5 gal.
		50 lbs. manure (wet basis)	=	approx. 1 cu. ft.
		1,355 lbs. manure (wet basis)	=	approx. 1 cu. yd.
Elemental P	x	2.29	=	P_2O_5 (phosphate)
Elemental K	x	1.2	=	K_2O (potash)

TEACHING MATERIALS AND REFERENCES:

American Society of Agricultural Engineers. 1990. ASAE Standard: ASAE S501 "Uniform Terminology For Livestock Production Facilities". ASAE, St. Joseph, MI.

American Society of Agricultural Engineers. 1990. ASAE Standards 1990 37th Edition Standards, Engineering Practices and Data: ASAE S292.4 "Uniform Terminology For Rural Waste Management". ASAE, St. Joseph, MI. pp 440-443.

Brady, N.C. 1984. The Nature and Properties of Soils. 9th Edition. Macmillan Publishing Company, New York, NY. pp. 1-737.

FINAL REPORT
Texas Agricultural Experiment Station

Task 5.1 TEX*A*Syst documents (attached) and information was disseminated (at meetings, seminars, workshops and at cooperators homesteads) to implement an effective ground water protection program in the Lake Fork Creek area.

Pollution prevention is recognized as the most cost-effective approach to protecting water quality. TEX*A*Syst provides a mechanism for identifying pollution risks and motivating voluntary actions to prevent pollution. It provides rural residents with an effective, voluntary system to promote pollution prevention on farms, ranches and rural residences. It strengthens cooperation and builds partnerships among public officials, environmentalists and farmers. It provides citizens with an acceptable approach for identifying and addressing pollution risks on their property. These comprehensive and voluntary pollution prevention programs can play a major role in watershed management efforts and source water protection projects. The goals of these activities were to provide training, educational materials and assistance to facilitate implementation of ground water protection Best Management Practices (BMPs).

The purpose of TEX*A*Syst is to assist rural residents in assessing their own well water pollution risks by identifying management practices and structures that present pollution risks and to recommend actions to reduce or eliminate identified risks. The TEX*A*Syst Groundwater Protection Program was developed to assist rural residents implement the most effective BMPs. This program has increased Lake Fork area ground water knowledge and understanding of the environment, existing policies, regulations, and recommendations that relate to their activities and aided them in taking voluntary actions to reduce and prevent ground water pollution risks. Ground water protection information was presented at 8 meetings, 5 tours and in numerous radio and news articles during 1995-96.

1995-96 TEX*A*Syst Well Head Protection Activities at Lake Fork Creek

	Meeting /attendance	**Tours /attendance**	**Display /attendance**	**BMPs Adopted**	**News articles /distribution**	**Media Articles**
1995	3 / 224	3 / 250			2 / 850	3 Radio 22 News P.
1996	4 / 260	2 / 200	1 / 9700	21	2 / 882	3 Radio 14 News P.