West Tule Creek Sediment Trap Pond and Habitat Enhancement
Quality Assurance Project Plan for Modeling
Revision0.0
QUALHYMO

Segment(s) # West Tule Creek

Date submitted to TCEQ: 06/11/2012

Funding source: CWA 319(h) Nonpoint Source Grant Program

Federal Grant #99614614

Aransas County

David J. Reid, P.E., Project Manager
Assistant County Engineer
1931 FM 2165
Rockport, Texas 78382
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Nonpoint Source Management Program
Office of Water, Planning & Implementation Section
Texas Commission on Environmental Quality
P.O. Box 13087, MC - 203
Austin, Texas78711-3087

This QAPP is effective for a period of one year from approval date.

Questions concerning this QAPP should be directed to:

David J. Reid, P.E.
(361)790-0152

SECTION A: PROJECT MANAGEMENT

A1 Approval Page

Texas Commission on Environmental Quality

Field Operations Support Division

____
Stephen Stubbs, TCEQ QA Manager Date

____
Kyle Girten, Lead NPS QA Specialist Date
Quality Assurance Team

Water Quality Planning Division

____
Kerry Niemann, Team Leader Date
Nonpoint Source Program

____
Anju Chalise, NPS QA Specialist Date
Nonpoint Source Program

Jeff Foster 8/3/12
Jeff Foster, TCEQ NPS PM Date
Project Manager, Nonpoint Source Program

Contractor

8-3-12
David J. Reid, P.E. Date
Aransas County Project Manager and QAO

Aransas County will secure written documentation from additional project participants (e.g., subcontractors, laboratories) stating the organization's awareness of and commitment to requirements contained in this quality assurance project plan and any amendments or revisions of this plan. Aransas County will maintain this documentation as part of the project's quality assurance records. This documentation will be available for review. Copies of this documentation will also be submitted as deliverables to the TCEQ NPS Project Manager within 30 days of final TCEQ approval of the QAPP.

Subcontractors

8/2/12
Craig B. Thompson, P.E. Date
NEI, Project Manager

8-2-12
David E. Sullivan, CEP Date
NEI Monitoring QAO
(361) 814-9900

Modeling Subcontractors

8/1/12
Linda D. Pechacek, P.E. Date
LDP
Project Manager, Modeler and QAO

2012/07/30
A. Charles Rowney, PhD, D.WRE Date
ACR
Modeling Data Manager and Lead Modeler

Bryan W. Shaw, Ph.D., *Chairman*
Carlos Rubinstein, *Commissioner*
Toby Baker, *Commissioner*
Zak Covar, *Executive Director*

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

Protecting Texas by Reducing and Preventing Pollution

August 8, 2012

David Reid
Project Manager
Aransas County
1931 FM 2165
Rockport, TX 78382

Re: West Tule Creek Sediment Trap Pond and Habitat Enhancement Quality Assurance Project Plan (QAPP) for Modeling
Approval Date: August 8, 2012 (Expiration Date: August 8, 2013)

Dear Mr. Reid:

The above named QAPP has been approved. The original document and signature pages are enclosed as documentation of approval.

In accordance with the terms of the QAPP, **please ensure that copies of this document and any subsequent amendments are distributed to each sub-tier participant as noted in Section A3 of the QAPP.** This approval letter must be available for review during a monitoring systems audit.

Should you have questions, please contact me at (512) 239-0425.

Sincerely,

Kyle Girten
Quality Assurance Specialist

enclosure

cc: Sharon Coleman, Senior Quality Assurance Specialist, MC 165
Anju Chalise, Project Manager, MC 203

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(361)790-0152

SECTION A: PROJECT MANAGEMENT

A1 Approval Page

Texas Commission on Environmental Quality

Field Operations Support Division

Stephen Stubbs, TCEQ QA Manager Date

Kyle Girten, Lead NPS QA Specialist Date
Quality Assurance Team

Water Quality Planning Division

Kerry Niemann, Team Leader Date
Nonpoint Source Program

for Anju Chalise, NPS QA Specialist Date
Nonpoint Source Program

Jeff Foster, TCEQ NPS PM Date
Project Manager, Nonpoint Source Program

Contractor

8-3-12
David J. Reid, P.E. Date
Aransas County Project Manager and QAO

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Subcontractors

8/2/12
Craig B. Thompson, P.E. Date
NEI, Project Manager

8-2-12
David E. Sullivan, CEP Date
NEI Monitoring QAO
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Modeling Subcontractors

8/1/12
Linda D. Pechacek, P.E. Date
LDP
Project Manager, Modeler and QAO

2012/07/30
A. Charles Rowney, PhD, D.WRE Date
ACR
Modeling Data Manager and Lead Modeler

A2 Table of Contents

A3 Distribution List

The Lead NPS QA Specialist will provide original versions of this project plan and any amendments or revisions of this plan to the TCEQ NPS Project Manager and the Aransas County Project Manager. The TCEQ NPS Project Manager will provide copies to the TCEQ Data Management and Analysis Team Leader and EPA Project Officer within two weeks of approval. The TCEQ NPS Project Manager will document receipt of the plan and maintain this documentation as part of the project's quality assurance records. This documentation will be available for review.

Texas Commission on Environmental Quality
PO Box 13087
MC - 234
Austin, TX 78711-3087

U.S. Environmental Protection Agency Region 6
State/Tribal Section
1445 Ross Avenue
Suite # 1200
Dallas, TX75202-2733
Leslie Rauscher, Project Officer
(214) 665-2773

The Aransas County Project Manager will provide copies of this project plan and any amendments or revisions of this plan to each project participant defined in the list below. The Aransas County Project Manager will document receipt of the plan by each participant and maintain this documentation as part of the project's quality assurance records. This documentation will be available for review.

Aransas County
1931 FM 2165
Rockport, Texas 78382

David J. Reid, P.E.
Project Manager and QAO
(361)790-0152

Subcontractors

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4501Golihar
Corpus Christi, TX 78411

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NEI Project Manager
(361)814-9900

David E. Sullivan, CEP
NEI Monitoring QAO
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Sandi Hart
NEI Field Supervisor
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Linda D. Pechacek, P.E.
Project Manager and Modeler
LDP QAO
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ACR
184 Tollgate Branch
Longwood, FL 32750

A. Charles Rowney, Ph.D., D. WRE
ACR
Modeling Data Manager
Lead Modeler
(407)970-8744

List of Acronyms

ACR	ACR, LLC
API	Antecedent precipitation index
APIk	Antecedent precipitation index recovery rate
Ia	Initial abstraction
BST	Bacteria Source Tracking
CAR	Corrective Action Report
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
ICPR	Interconnected Pipe Routing
LDP	LDP Consultants Inc.
MA-NERR	Mission Aransas National Estuarine Research Reserve
NCDC	National Climatic Data Center
NEI	Naismith Engineering Inc.
NOAA	National Oceanic and Atmospheric Administration
NRCS	National Resource Conservation Service
NURP	National Urban Runoff Program
NWS	National Weather Service
PM	Project Manager
QA	Quality Assurance
QA/QC	Quality Assurance/Quality Control
QAO	Quality Assurance Officer
QAM	Quality Assurance Manual (or Manager)
QAPP	Quality Assurance Project Plan
QAS	Quality Assurance Specialist
QMP	Quality Management Plan
QUALHYMO	Quality Hydrologic Model
RE	Relative Error
SCS	Soil Conservation Service
SOP	Standard Operating Procedure
SOW	Scope of Work
SSURGO	Soil Survey Geographic
TMDL	Total Maximum Daily Load
TCEQ	Texas Commission on Environmental Quality
TSS	Total Suspended Solids
USEPA	United States Environmental Protection Agency
WERF	Water Environment Research Foundation
WPP	Watershed Protection Plan
WWTP	Wastewater Treatment Plant

A4 PROJECT/TASK ORGANIZATION

TCEQ

Field Operations Support Division

Kyle Girten
Lead NPS QA Specialist
Assists the TCEQ Project Manager in QA related issues. Serves on planning team for NPS projects. Participates in the planning, development, approval, implementation, and maintenance of the QAPP. Determines conformance with program quality system requirements. Coordinates or performs audits, as deemed necessary and using a wide variety of assessment guidelines and tools. Provides a point of contact at the TCEQ to resolve QA issues. Recommends to TCEQ management that work be stopped in order to safe guard project and programmatic objectives, worker safety, public health, or environmental protection.

Water Quality Planning Division

Kerry Niemann, Team Leader
NPS Program
Responsible for management and oversight of the TCEQ NPS Program. Oversees the development of QA guidance for the NPS program to be sure it is within pertinent frameworks of the TCEQ. Monitors the effectiveness of the program quality system. Reviews and approves all NPS projects, internal QA audits, corrective actions, reports, work plans, and contracts. Ensures NPS personnel are fully trained and adequately staffed.

Jeff Foster
TCEQ NPS Project Manager
Maintains a thorough knowledge of work activities, commitments, deliverables, and time frames associated with projects. Develops lines of communication and working relationships between the contractor, the TCEQ, and the EPA. Tracks deliverables to ensure that tasks are completed as specified in the contract. Responsible for ensuring that the project deliverables are submitted on time and are of acceptable quality and quantity to achieve project objectives. Serves on planning team for NPS projects. Participates in the development, approval, implementation, and maintenance of the QAPP. Assists the TCEQ QAS in technical review of the QAPP. Responsible for verifying that the QAPP is followed by the contractor.

Anju Chalise
NPS Quality Assurance Specialist
Assists Lead QAS with NPS QA management. Serves as liaison between NPS management and Agency QA management. Responsible for NPS guidance development related to program quality assurance. Serves on planning team for NPS projects. Participates in the development, approval, implementation, and maintenance of the QAPP.

Aransas County

David J. Reid, P.E.
Aransas County Project Manager and QAO
Responsible for ensuring tasks and other requirements in the contract are executed on time and are of acceptable quality. Monitors and assesses the quality of work. Coordinates attendance for conference calls, training, meetings, and related project activities with the TCEQ. Meets with NEI staff throughout project as needed to oversee project.

NEI

NEI Project Manager
Craig B. Thompson, P.E.
Responsible for ensuring tasks and other requirements on the contractor side are executed on time and are of acceptable quality. Monitors and assesses the quality of work. Provides input on model selection and implementation. Notifies Aransas County Project Manager of circumstances that may adversely affect quality of data derived from modeling efforts. Meets with TCEQ, Aransas County, LDP and ACR, staff as needed. Coordinates development and implementation of QA Program.

NEI QAO
Dave E. Sullivan, NEI Monitoring QAO
Responsible for writing and maintaining the monitoring QAPP. Responsible for maintaining written records of sub-tier commitment to requirements specified in the QAPP. Responsible for maintaining records of monitoring QAPP distribution, including appendices and amendments. Responsible for identifying, receiving and maintaining project quality assurance records. Responsible for coordinating with Aransas County QAO and TCEQ QAS to resolve QA related issues. Notifies the NEI Project Manager and TCEQ Project Manager of particular circumstances which may adversely affect the quality of monitoring data.

LDP

LDP Project Manager, QAO, and modeler
Linda D. Pechacek, P.E.
Ensures project oversight on contractor side is consistent with QAPP requirements as related to modeling QAPP and communicates project status to NEI Project Manager and NEI Monitoring QAO. Provides input on model selection and implementation. Notifies the NEI Project Manager and/or the NEI QAO of circumstances that may adversely affect the quality of data derived from the modeling efforts. Helps coordinate planning activities and works with other project team members. Responsible for ensuring that proper methods and protocols are followed for all LDP and ACR activities related to this effort. Manages production of final modeling results, meets with NEI, Aransas County, TCEQ and ACR staff as needed. Responsible for the transfer of quality assured modeling data to NEI Project Manager for submittal to TCEQ.

ACR

Modeling Data Manager and Lead Modeler
A. Charles Rowney, Ph.D., D.WRE (LDP Associate / ACR)
Responsible for ensuring that processes are in place to enable proper entry of data into spreadsheets or alternative electronic storage systems, and that the selected model is employed in a manner that is technically valid and consistent with its intended purpose and capabilities. Coordinates and maintains records of data verification and validation. Oversees interpolation of flow data, preparation and operation of model, calibration and validation procedures.

The Grant Connection

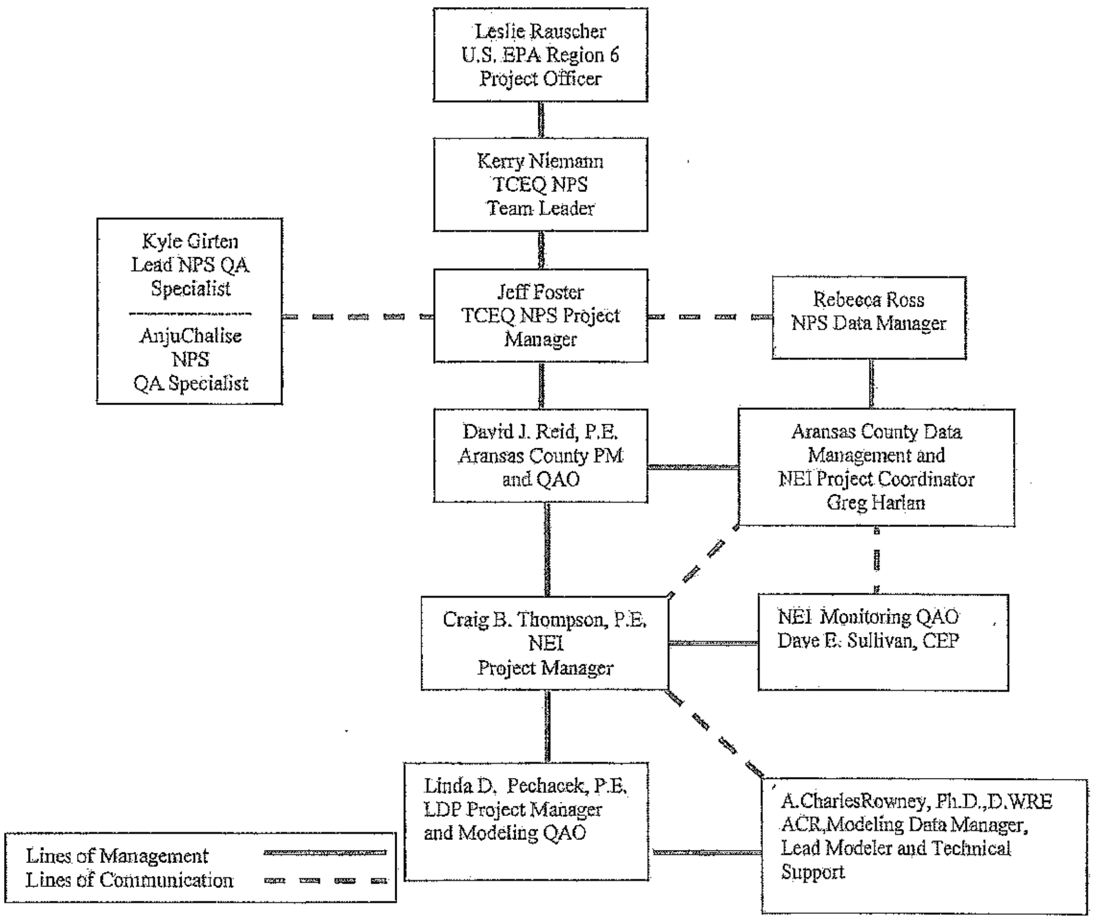
Aransas County Data Manager
Greg Harlan

Responsible for acquiring all laboratory data from project team members (monitoring data covered under separate QAPP) and modeling data results and ensures data are submitted according to TCEQ with Quarterly Reports. Provides the point of contact for the TCEQ Data Manager to resolve issues related to the data.

U.S. EPA Region 6

Leslie Rauscher
EPA Project Officer
Responsible for managing the CWA Section 319 funded grant on the behalf on EPA. Assists the TCEQ in approving projects that are consistent with the management goals designated under the State's NPS management plan and meet federal guidance. Coordinates the review of project work plans, draft deliverables, and works with the State in making these items approvable. Meets with the State at least semi-annually to evaluate the progress of each project and when conditions permit, participate in a site visit on the project. Fosters communication within EPA by updating management and others, both verbally and in writing, on the progress of the State's program and on other issues as they arise. Assists the regional NPS coordinator in tracking a State's annual progress in its management of the NPS program. Assists in grant close-out procedures ensuring all deliverables have been satisfied prior to closing a grant.

Figure A4.1. Organization Chart - Lines of Communication



A5 PROBLEM DEFINITION/BACKGROUND

PROBLEM STATEMENT

Sediments and pollutants associated with sediment are primary pollutants of concern in Tule Creek and, its receiving waterway, Little Bay. The goal of this project is to better characterize solids present in Tule Creek's runoff. Two objectives of this goal –stormwater monitoring and the sediment trap pond monitoring – are addressed in a separate QAPP. The objective of this QAPP is to provide QA of modeling data and results.

The modeling effort is part of a larger NPS project and is not related to a TMDL or WPP modeling effort. While this modeling effort is at a very small scale and has a small scope, there is a need for a limited effort applied to assessment of sediments to gain a better understanding of facility performance as an aid to confirming sizing and operation, in particular, the likely cycle of sediment build up and removal. Therefore, a simplified continuous simulation model will be constructed, based on available local data, to evaluate these factors. The paragraphs below describe the physical context of the project, and the chosen model.

BACKGROUNDINFORMATION

Aransas County is located in the Coastal Bend area of South Texas, situated northeast of Corpus Christi. The County is typified by flat slopes and sandy soils in the urban areas. The population of Aransas County has increased significantly over the past 50 years and will continue to increase. This increase is threatening the pristine environment and rich quality of life. The County is situated along a flat coastal plain surrounded by seven bays. The three inland bays, Copano, Port and Mission Bays, located in western Aransas County, currently have a bacteria TMDL study in progress. The other bay systems located generally east of Aransas County meet the state's water quality standards. Aransas County and the City of Rockport are not included in an urbanized area as defined by the US Census and do not have regulated municipal separate storm sewer (MS4) systems. As a result, these local governments are not required to have a TCEQ municipal storm water permit.

The growth in population of both permanent and part-time residents is fueling development pressures which pose a serious threat to the quality of the wetlands, wildlife habitats, and water resources that make the region attractive. As more and more land is converted to residential or commercial uses, the potential for water quality degradation is increased.

This threat is most obvious in Little Bay, a shallow bay within the corporate boundaries of the City of Rockport that historically has supported a productive fishery, large flocks of wintering waterfowl, and large populations of nesting water birds. It is used year round with a variety of water-based recreation, including kayaking, boat pier and wade fishing, swimming, windsurfing, and birding. Water quality studies conducted by MA-NERR in Little Bay have documented high levels of nitrogen loading and reduced salinity attributed to stormwater outflows. These conditions are further exacerbated by poor water exchange between Little Bay and Aransas Bay.

At present in Little Bay, a substantial delta is growing immediately downstream of Tule Creek's outfall. Erosion and construction activity are the primary activities that have contributed to this sediment accumulation in Little Bay. Sediments and pollutants associated with sediment are primary pollutants of concern found in Tule Creek and Little Bay.

Tule Creek is a 2,100 acre watershed that discharges both stormwater drainage and WWTP effluent into Little Bay. The stream drains areas of the City of Rockport, the Town of Fulton, and areas of Aransas County outside the jurisdiction of either municipality. The Tule Creek watershed is urbanizing, and all governmental entities in Aransas County are involved in a cooperative effort to protect Little Bay. There is consensus among these entities that the Tule Creek drainage and pollution of Little Bay are top-priority concerns.

In Aransas County, the Tule Creek watershed exhibits some of the changes to the hydrologic cycle components described above as a result of development. It was reconfigured and enlarged to better drain the urbanizing part of the watershed and discharge excess runoff downstream. The growing delta fan directly downstream of the Tule Creek discharge point into Little Bay is indicative of active erosion and sediment transport processes. Less obvious is the notion that as the flow line of a creek is deepened in a sandy bank system like Tule Creek, dewatering of creek banks, shallow water bearing sands and surface water depressions may occur and alter the various natural habitats and ecosystems that existed prior to development, affecting infiltration and shallow aquifer recharge.

Aransas County, along with the City of Rockport, Aransas County Navigation District, and the Town of Fulton, are cooperatively developing a regional storm water master plan, the Aransas County Regional Stormwater Management Plan (Plan). The Plan includes implementing storm water controls within the priority Tule Creek watershed. The program's approach is to integrate stormwater quantity and quality concerns with ecological habitat considerations to help guide land development, construction, and stormwater runoff requirements. The proposed project will help accomplish a decrease in the discharge of sediment and pollutant-clad sediments transported into Little Bay while helping to preserve the ecological integrity of the creek system through the removal of selected invasive species. It also introduces a regional and low maintenance approach toward water quality enhancement.

However, detailed local water quality information for Tule Creek is very limited. Data from other part of the country must be used to broadly assess water quality constituents, pollutant removal rates and long-term performance of stormwater quality control facilities. The County is very unique when compared to the rest of the country, and using data derived from other areas of the country does not adequately assess local characteristics.

This portion of the coastal plain is generally devoid of riverine or creek systems because of the flat topography. Runoff is captures in pothole depression storage areas. Potholes are water-holding depressions that collect direct rainfall and stormwater runoff from shallow basin drainage areas and provide storage and infiltration opportunities. If enough runoff has been

captured, the water level within the depression area will rise and cascade over the edge and flow away towards a lower elevation, such as another depression area, swale or other flow path to the receiving salt flat, marsh, or bay.
Since it is the long term behavior of sediments that is of primary interest, a continuous simulation model will be used to track the system response continuously over time. The selected model must have the ability to represent the contributing watershed, the BMP, and potentially the channel linking the two. It must also be able to represent flow and sediments carried by that flow, on a continuous basis. Finally, it must be a model that can be deployed and applied in the context of this project, namely a rapid and low level of effort, and one with only basic information on runoff relationships and on sediment generation. A model which is suitable for this condition is QUALHYMO.[1]

QUALHYMO's capability to simulate many processes with the added capability to use the rainfall record differentiates it from spreadsheet calculator models that operate by inputting the average annual rainfall value as the initial step to calculate generated pollutant loads of various selected parameters for 2 scenarios - with and without a BMP in place.

QUALHYMO Model

QUALHYMO uses a derivative of the SCS method that enables finer/denser spatial resolution and temporal variability than the SCS method. The SCS method is effective in many situations, but is limited in that it is generally applied with a limited choice of antecedent moisture conditions (three cases, representing dry, wet and average conditions).[2]The basic approach to watershed hydrology that has been used in QUALHYMO is to view the rainfall runoff process as a series of multiple events that influence each other in succession, with antecedent moisture varying continuously from event to event as a result. This provides a more realistic response to varying dryness in the watershed over time.

The volumetric calculation is based on the following relation:

$$Qv = \frac{(P - Ia)^2}{(P - Ia + S)}$$

where

P = rain volume (mm or ins)

Ia = initial abstraction (mm or ins)

Qv = runoff volume (mm or ins)

S = loss parameter (mm or ins)

This is the original SCS relation

In the SCS method, the initial abstraction was taken as a constant fraction of the S parameter:

[1] QUALHYMO USER Manual and Documentation, Version QUALHYMO0777v1c, March, 2009 (Appendix D).

[2]NRCS.Part630 Hydrology, Chapter 10 Estimation of Direct Runoff from Storm Runoff, July 2004.

$$Ia = 0.2S$$

and the S parameter was related to a curve number:

$$S = \frac{1000}{CN} - 10$$

QUALHYMO builds on this approach by letting the initial abstraction and S parameter vary continuously. In wet weather, the initial abstraction is reduced by moisture, and in dry weather it recovers due to evaporation. The S parameter varies between a maximum and minimum value, as a function of an antecedent precipitation index.

$$S = S_{\min} + \left(S_{\max} - S_{\min}\right)\exp(-kS \times API)$$

where

$S_{\min}$ = the minimum value of S

$S_{\max}$ = the maximum value of S

sK = a parameter

The antecedent precipitation index itself varies according to precipitation, and a reduction factor representing recovery:

$$API_{i+1} = kAPI \times API_i + P_i^{i+1}$$

where

API_j=the antecedent precipitation index at some time j

P_i^{i+1}=the precipitation falling between time i and $i+1$

$kAPI$ = a reduction factor $(0 \le kAPI \le 1)$

In short, both of the key parameters (initial abstraction and the loss parameter S) are much more variable in QUALHYMO, in response to prevailing moisture conditions. This makes the model an effective choice for long term simulations (for which the model was designed) when such variations can be important in determining rainfall/runoff relationships.

The model itself will be used in this study by applying three commands, namely the GENERATE, REACH and POND commands, as follows:

<u>Watershed Areas</u>

The object of this project is not to assess flows in the watershed, but to address conditions that may arise in the sediment trap. However, the amount of measured flow data that will be available is anticipated to be inadequate as a basis for evaluating conditions in the trap itself. Therefore, a simulated flow record will be needed to drive the simulation in the trap. To do this, the watershed above and below the confluence west of Highway 35 will be simulated with the GENERATE command. The command will be applied in two major sub-watershed areas, one north and one south of the confluence. A third small area, between the confluence and the sediment trap, will also be simulated. TSS data, infiltrometer data and piezometer data (all parameters collected under a separate monitoring QAPP) will be used to estimate the infiltration rate which may be possible in this area. The piezometer data will be used to verify the prevailing depth of water below the watershed surface. The infiltrometer data will be used to estimate the maximum infiltration rate. Land surface characteristics (slope, length and area, etc.) will be obtained from the subcatchment delineation done in the course of hydrologic and hydraulic modeling by the County for the Tule Creek Watershed.[3]

This will provide an estimate of flow that will drive the simulation of the sediment trap just upstream of Highway 35.

Channel Sections

As with the watershed area simulation, the objective of this project is not to evaluate in-stream conditions. However, there will need to be some mechanism for routing flows from the watershed to the sediment trap. This will be done using the REACH command. A single channel section will likely be all that is needed for present purposes, extending from the confluence to the sediment trap. The two major sub-watershed areas will be applied to the upstream end of that reach, and the smaller area between the confluence and the sediment trap will be applied along its length.

The Sediment Trap

This is the focus of the analysis. The watershed and channel sections discussed above will provide an estimated flow series that will need to be routed through the sediment trap. The trap itself will be simulated with the POND command. Basic characteristics of the POND command application will be as follows:

- Sediment approaching the trap will be simulated by applying concentrations measured in the monitoring program, and flows simulated as noted above.
- Sediment will be simulated as removed by discrete settling.
- The trap will be simulated as completely mixed.
- The depth/area relationship for the trap will be based on the design pond geometry which will be obtained from the design drawings during the course of the project.
- The depth/outflow relationship for the trap will be based on the constricted geometry at the trap outlet, using a standard broad crested weir relationship which will be developed during the course of the analysis.
- No operated gates, overflows or bypasses will be simulated. They are all within the capabilities of the model, but will not be physically present in this case.

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[3] Naismith Engineering Inc., Tule Creek Watershed Project Report, Aransas Count Stormwater Management Plan, August 2, 2010.

- No exfiltration losses from the trap will be simulated. This is within the capabilities of the model, but the low elevation and perennially saturated conditions mean that substantial losses will be associated with this term.

Results to be delivered will include estimates of inlet and outlet flow rate behavior (i.e. controlled and uncontrolled) and estimates of volumetric sediment build-up (as an aid to estimating disposal requirements), consistent with the sediment data obtained from field observations made for this purpose in the study area. To provide an indication of potential long term volumetric behavior, volume utilization will also be assessed and a percent utilization curve will be generated.

Literature Review

The US Geological Survey has identified sediment as one of the most prevalent urban runoff pollutants in its National Water Quality Assessment Program.[4] Transport and deposition of sediment into the receiving creek or bay during storm events can result in the depletion of

- dissolved oxygen,
- increased turbidity
- aquatic habitat degradation
- nutrients.

It can also transport and down-slope distribution of sediment clad pollutants, including

- phosphorus
- metals
- pathogen
- organic substances

National studies have shown that urban areas have been closely associated with the degradation of aquatic habitats and ecosystems.[5] Urban areas are likely to increase imperviousness which affect the natural flow regime of stormwater in predictable ways.[6] Development in Aransas County impacts the drainage systems, aquatic habitats, and ecosystems.

Rates of runoff change as the natural landscape is developed. Developed land has steeper slopes and smoother surfaces that are less pervious, resulting in excess runoff that arrives sooner with an increased volume. Opportunities for flow to infiltrate into the ground are decreased, as fill dirt is brought in and impervious surfaces such as streets, driveways, roof tops, etc., of the development are constructed. As more flow is discharged at a faster rate, more pollutants may become entrained and carried by the runoff. The potential for erosion is also increased, particularly along sandy creek banks or roadside drainage swales. Downstream ponding of

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[4]US Geological Survey National Water Quality Assessment Program Inventory, 1991 to 2001.

[5]Center for Watershed Protection , 2003, Impacts of Impervious Cover on Aquatic Systems.

[6]Struck, S. D., Rowney, A. C., and L.D. Pechacek, Innovative Approaches for Urban Watershed Wet-Weather Management and Control: State-of-the-Technology, for United States Environmental Protection Agency, Office of Research and Development, Washington DC 20460, (August 2009), EPA/600/R-09/128.

excess runoff can increase and require that small receiving waterways or creeks be enlarged, or channelized to safely convey the increased runoff volume. These changes to the hydrologic cycle by human actions can also have impacts on a wide range of other factors, including water quality, drainage needs, natural habitats, water supply and flood protection.

Non-point or distributed source pollutants are entrained and transported by stormwater in drainage ways. Particles or sediment can transport occluded or adhered bacteria in a waterway. The Great Lakes beaches research program conducted by USGS over the past 15 years has found E. Coli in highly variable counts in beach sands, forest soils, sediments surrounding stream margins and shallow ground water.[7] Researchers have recommended that increased settling rates be incorporated into models involving bacteria sedimentation.

Local Studies

Scientists have identified stormwater runoff as a principal cause of declining water quality and loss of wildlife habitat within Little Bay. Studies documented high levels of nitrogen loading from land-based activities, reduced salinity due to stormwater outflows (exacerbated by poor water exchange with Aransas Bay), and persistent eutrophication problems surrounding algal blooms during the summer months.[8] Over the past 15 years, a water quality study by MA-NERR reported that Little Bay has experienced a steady decline in the once extensive beds of submerged seagrasses, especially during the last five years.[9] Fishing is less productive, and winter flocks of waterfowl have declined in numbers and diversity in some recent years.

Other local efforts include the City of Rockport. The City of Rockport's Water Quality Committee has been collecting nutrient data at several designated sampling locations over the past several years.

A6 PROJECT/TASK DESCRIPTION AND SCHEDULE

Aransas County and its subconsultants will conduct a modeling effort to characterize sediment removal associated with a pre-determined sediment trap design in Tule Creek.

This QAPP will only address modeling activities. Water quality samples will be collected from Tule Creek under a separate monitoring QAPP - the monitoring QAPP should be consulted for details related to field data gathering and analysis.

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[7] http://greatlakesbeaches.usgs.gov/publications.html. Numerous studies cited including: Whitman, R. L and M.B Nevers. 2008. Summer E. coli patterns and responses along 23 Chicago beaches. Environmental Science & Technology 42:9217-9224. Webpage accessed November 20, 2011.

[8] Dunton, K. and C Wilson. 2010. An assessment of Little Bay Sediment and Water Quality in Relation to Indices of Seagrass Condition. University of Texas Marine Science Institute, Technical Report Number TR/10-001.

[9] Buskey, E.J, and B. Dean. 3/31/2011. Little Bay Water Quality Characterization. University of Texas Marine Science Institute, CBBEP Contract Number: 0922, Project No. 0922, Final Report.

Appendix A provides a project plan, tasks and schedule associated with this QAPP. Appendix B contains a map of the sampling station locations used to provide data inputs into the model. The tasks listed in Appendix A and the following descriptions are those relevant to the scope of this QAPP.

The modeling tasks are as follows:

1. Confirm approach

Develop and obtain approval for the modeling QAPP prior to undertaking model development or application tasks.

2. Obtain precipitation data

Obtain local rainfall data or design precipitation series and prepare them for input into the model.

3. Obtain monitoring data from the NEI project team

This will be required as a part of the data input into the QUALHYMO model. As noted, details of monitoring are contained in a separate QAPP, and are not addressed in this document. However, the following basic information is provided for convenient reference in relation to the modeling effort.

   a. It is noted that four storm water monitoring locations (shown in Appendix B) have been defined in the monitoring QAPP, and that parameters to be measured are identified there as well. For modeling purposes, data from these locations will be evaluated, and the parameter to be monitored is TSS.
   b. Flow data will be obtained from available physical measurements and mathematical estimates also identified in the monitoring QAPP. For modeling purposes, infiltration and runoff estimates will be based on soil type with supplementary information on infiltration from infiltrometer measurements per the monitoring QAPP.
   c. Hydraulic information will be obtained from the ICPR modeling of the Tule Creek watershed undertaken as a part of the prior Aransas County Stormwater Management Plan, supplemented if necessary for present purposes by outflow structure conveyance calculations.

4. Develop model input data set

The available data will be put into a form suitable for modeling. This will include:

   a. definition of contributing areas, and definition of land use types, based on available data from the earlier ICPR modeling of the Tule Creek watershed.
   b. definition of the volume/depth and area/depth characteristics of the sediment trap, based on available design information and GIS based landform information,

c. definition of initial estimates of hydrologic parameters, sediment characteristics (production rating curve based on observations from the monitoring program, and settling velocities based on information from the monitoring program), and
d. definition of connectivity between the contributing areas, sediment trap and channel between these features based on geophysical information contained in available GIS data sets.

All model features will be oriented towards surface flow capture and management. The model will then be adjusted to represent the available observations, with values adjusted based on monitoring results and well as typical hydrologic and hydraulic behavior if monitoring data are insufficient for a formal calibration. The monitored flow values will be the principal data used in the adjustment process.

The sequence of adjustment will be to 1) develop representative and reasonable estimates of rainfall/runoff relationships, 2) develop hydraulically reasonable estimates of volumetric estimates of the routing (and bypass) of flows around the BMP, and 3) develop physically reasonable estimates of sediment removal based on fall velocities consistent with observed sediment characteristics.

5. Assess BMP performance

BMP behavior will be estimated based on volumetric routing through the sediment trap itself, as determined by QUALHYMO modeling. Model outputs will include:

a. estimated flow mass balance accounting (inflow, outflow, bypass and evaporation),
b. estimated sediment load and removal, and
c. estimated volumetric detention time in the BMP.

6. Conduct internal QC

The modeling data results will be reviewed and checked. Details to be verified will include 1) data sources, 2) data reduction, 3) data storage, 4) model structure, 5) model parameter adjustment, and 6) predicted model results.

7. Complete reporting and submission

Documentation of the above development and activities, analysis and review processes will be completed and included in the Final Project Report, in addition to complete data sets (input and output) for the model in digital form, the metadata suitable for those data sets, a description of the input adjustments resulting from the calibration process, and a summary of the validation results.

QAPP Revision

Until the work described is completed, this QAPP shall be revised as necessary and reissued annually on the anniversary date, or revised and reissued within 120 days of significant changes, whichever is sooner. The last approved version of a QAPP shall remain in effect only for the approval period defined by the approving authorities. Upon expiration of the approval period for a QAPP, all the work covered by the expired QAPP shall cease until such time as revised QAPP has been fully approved by the approving authorities. If the entire QAPP is current, valid, and accurately reflects the project goals and organization's policy, the annual reissuance may be done by a certification that the plan is current *The reissuance must be signed by all approving authorities. This can be accomplished by submitting a cover letter stating the status of the QAPP and copies of new, signed approval pages for the QAPP.*

QAPP Amendments

Amendments to the QAPP may be necessary to reflect changes in project organization, tasks, schedules, objectives, and methods; address deficiencies and nonconformances; improve operational efficiency; and/or accommodate unique or unanticipated circumstances. Requests for amendments are directed from the contractor Project Manager to the TCEQ Project Manager electronically using the QAPP Amendment shell. The changes are effective upon review and signature by the TCEQ NPS Project Manager and Quality Assurance Specialist, or their designees, and additional parties affected by the amendment.

A7 QUALITY OBJECTIVES AND CRITERIA FOR MODEL INPUTS/OUTPUTS

Data requirements are as outlined in section A6. These include monitoring data that are fully documented in the monitoring QAPP, and alluded to here for completeness. They also include GIS and other data obtained from existing local sources. In all cases, the intent is to enable analysis of long term sediment removal and volumetric performance in the BMP. The intent is not to provide definitive hydraulic data for design; that information has been developed in ICPR modeling carried out as part of the prior Aransas County Stormwater Quality Plan. Consequently, the need in this project is for credible estimates of mass balance and sediment removal. Detailed temporal distribution is neither necessary nor possible in the context of this study.

Criteria that are reasonable in these circumstances include several factors that are important in assessing the numerical behavior of the model:

1. Watershed flow mass balance closure

   The model will be expected to resolve rainfall and simulated runoff components to within 95% (i.e. less than a 5% internal mass balance accounting error for flow) over an annual period.

2. BMP flow mass balance closure
   The model will be expected to resolve water quantity inflow, outflow and simulated losses to within 95% (i.e. less than a 5% internal mass balance accounting error for flow) on an event basis over an annual period.

3. BMP sediment mass balance closure

The model will be expected to resolve water born sediment inflow, outflow and simulated losses in and through the BMP to within 95% (i.e. less than a 5% internal mass balance accounting error for sediment).

Experience with the model shows that numerical mass balance accounting errors less than 5% are the norm for QUALHYMO in this type of project, so it is not likely there will be problems meeting these criteria. However, if problems are encountered, the numerical methods applied will be revisited, beginning with an adjusted time step. Other numerical solutions will also be pursued as necessary to bring results within the stated target. A fourth criterion is also appropriate in this situation, related to the credibility of the source data.

4. Verification of monitoring data

   Since the monitoring data to be used in this project will have been obtained in the context of a separate QAPP, technical assessment of those data will focus on verification that they were obtained in a manner consistent with the monitoring QAPP. This will be done by requesting confirmation from those responsible for the monitoring (including TCEA and Aransas County representatives) that the data were was collected as defined in the QAPP. Verification of laboratory, field or other procedures directly will not be included in this project as that level of scrutiny is a function of the project in which the data originated.

A8 SPECIAL TRAINING REQUIREMENTS/CERTIFICATION

All personnel involved in model calibration, validation, and development will have the appropriate education and training required to adequately perform their duties. No special certifications are required.

A9 DOCUMENTATION AND RECORDS

The project documentation will include a full record of the modeling process including data sources and the process of calibration and validation. This will include reasons for selecting particular coefficients and the results of sensitivity analysis, where appropriate. Electronic copies of the code, input and output files will be provided to Aransas County for archiving for a five year period. These files will document model testing, the specific data inputs and outputs of the model runs used for the final analysis, calibration, and evaluation, and will include documentation of the basis for model selection, record code validation (hand calculation checks) data sources (Section C1), documentation of adjustments to parameter values given calibration, and data validation. These data sets will be provided to TCEQ and maintained by Aransas County for the time period shown above.

Corrective Action Reports (CAR) will be used when necessary and the report format is attached as Appendix C. They will be maintained in an assessable location for reference at Aransas

County and will be disseminated to the individuals listed in Section A3. CARs resulting in any changes or variations from the QAPP will be made available to pertinent project personnel and documented in updates or amendments to the QAPP.[10]

See Section B10 for more details.

Table A9.1 Project Documents and Records

Document/Record	Location	Retention*a	Form*b
QAPPs, amendments, and appendices	Aransas County	5 years	Paper/Electronic
QAPP distribution documentation	Aransas County	5 years	Paper/Electronic
SOPs	Aransas County	5 years	Paper/Electronic
Model User's Manual or Guide (including application-specific versions)	Aransas County	5 years	Paper/Electronic
Assessment reports for acquired data	Aransas County	5 years	Paper/Electronic
Raw data files	Aransas County	5 years	Paper/Electronic
Model input files	Aransas County	5 years	Electronic
Model output files	Aransas County	5 years	Electronic
Code Verification Reports	Aransas County	5 years	Paper
Interim results from iterative calibration runs	Aransas County	5 years	Electronic
Calibration Report	Aransas County	5 years	Paper
Model Assessment Reports	Aransas County	5 years	Paper/Electronic
Progress report/CAR/final report/data	Aransas County/TCEQ	3 years	Paper/Electronic

*a – After the close of the project
*b – Electronic files should be ASCII (DOS) pipe delimited text files or MS Word/Excel; model input and output files can be archived in the format used by the modeling software, provided the capability of conversion to ASCII (DOS) pipe delimited text files or MS Word/Excel (TCEQ compatible version) is maintained over the time of retention.

The TCEQ may request records at any time and/or elect to take possession of records at the conclusion of the specified retention period.

[10] Naismith Engineering Inc., Tule Creek Watershed Project Report, Aransas Count Stormwater Management Plan, August 2, 2010

SECTION B: MEASUREMENT AND DATA ACQUISITION

B1 SAMPLING PROCESS DESIGN

Table B.1 below is from the Tule Creek Monitoring QAPP and is presented for informational purposes as requested by TCEQ.

TABLE B1.1 MONITORING SITES

TCEQ Station ID	Site Description	Latitude Longitude	Sample Matrix	Habitat and Physical Characteristics	Total Suspended Solids	Flow	Infiltration rate	Comments
21185	Below sediment trap above TX Bus. 35	28°03'02.03"N 97°02'33.4"W	Water	Water	Water	Water	NA	Wet and dry weather sampling
21189	Above sediment trap at confluence	28°03'05.88"N 97°02'36.74"W	Water	Water	Water	Water	NA	Wet and dry weather sampling
21190	Traylor Ave.	28°03'13.63"N 97°02'38.33"W	Water	Water	Water	Water	NA	Wet and dry weather sampling
21191	Below Upper Tule Creek West – Phase 1	28°03'02.11"N 97°02'47.58"W	Water	Water	Water	Water	NA	Wet and dry weather sampling
21192	Above Upper Tule Creek West – Phase 1	28°02'42.54"N 97°03'01.67"W	Water	Water	Water	Water	NA	Wet and dry weather sampling
21193	Tule Creek Drive	28°02'46.60"N 97°02'21.30"W	Water	Water	Water	Water	NA	Wet and dry weather sampling
GWP-1A	Rockport Country Club ROW	28°02'51.79"N 97°03'14.52"W	Water	NA	NA	NA	Soil	Groundwater level
GWP-1B	InverraryDr, ROW of Frost Property	28°02'50.32"N 97°03'03.64"W	Water	NA	NA	NA	Soil	Groundwater level
GWP-1C	InverraryDr, ROW of Frost Property	28°02'50.32"N 97°03'1.07"W	Water	NA	NA	NA	Soil	Groundwater level
GWP-2A	City of Rockport Aquatic Center Park	28°02'47.39"N 97°02'57.42"W	Water	NA	NA	NA	Soil	Groundwater level
GWP-2B	City of Rockport Aquatic Center Park	28°02'42.08"N 97°02'59.84"W	Water	NA	NA	NA	Soil	Groundwater level
GWP-2C	Rockport/Fulton High School	28°02'45.35"N 97°02'50.57"W	Water	NA	NA	NA	Soil	Groundwater level

B2 SAMPLING METHODS
Not Applicable

B3 SAMPLE HANDLING AND CUSTODY
Not Applicable

B4 ANALYTICAL METHODS
Not Applicable

B5 QUALITY CONTROL
Not Applicable

B6 INSTRUMENT/EQUIPMENT TESTING, INSPECTION AND MAINTENANCE
Not Applicable.

B7 MODEL CALIBRATION
The model will be adjusted to reflect the physical observations of surface recharge that will be measured in this project. (There is no existing BMP facility in place, so calibration to the BMP inflows and outflows will not be possible.) To do this, the main model parameters will be adjusted by successive approximation until a satisfactory fit is obtained. The table below provides a listing of the parameters that will be affected. These are all runoff relationship parameters, based on an extended continuous simulation version of the SCS method.

Model Calibration Parameters

Inputs	Units	Source	Calibration Criteria	Description
SCS 'S' Parameter	S in inches	S is based on local soil types (L)	See the two paragraphs that follow below	The "S" parameter represents the potential for moisture losses during the event that are over and above the initial abstraction. See A5, p.14-15
Antecedent Precipitation Index (API)	API is nondimens-ional	API is based on rainfall. Rainfall is acquired data (L)	See the two paragraphs that follow below	Number derived from accumulated rainfall depth prior to the event. Used to estimate soil moisture at the beginning of the event. See A5, p. 14-15
Initial Abstraction (Ia)	Ia in inches	Ia is based on land use (L)	See the two paragraphs that follow below	Ia is the amount of rain lost to initial wetting of the land surface at the start of an event. Runoff can only happen once this initial wetting is complete. See A5, p. 14-15

(L) Literature

It should be noted that as discussed below, the amount of calibration information which will be forthcoming from the monitoring effort is very limited, so the number of options for calibration parameters is also limited. With a wider data set, other model features and calibration options might be considered, but that will not be possible in this case.

Acceptance Criteria for Model Calibration
Due to the very limited size of this project, there will only be four wet weather data points (grab samples) for the three model calibration inputs, and these will not extend over the duration of any particular event but will be point estimates taken by crews at the time of sampling. A statistically significant metric for relative error beyond bulk or average error is therefore not advisable or possible. Consequently, all error will be expressed in terms of bulk average error. However, predictive variability will also be evaluated. The key model parameters will be varied, and a joint uncertainty in predicted error will be provided. The results will be expressed as an estimated performance plus or minus one standard deviation in variability, as a joint outcome of perturbing the key model parameters listed above.

Model Sensitivity
Sensitivity analysis determines the effect of a change in a model input parameter or variable on the model outcome.

Sensitivity will be evaluated and expressed as a curve of model results (exceedance curves) generated for independently perturbed values of key parameters (from the table above) plus and minus 20%. This will also be done for estimated discrete settling velocity in the pond, and for the pan evaporation coefficient applied to losses from the pond surface, as well as to exfiltration losses if found to be necessary to simulate losses from the pond bottom.

B8 INSPECTION/ACCEPTANCE OF SUPPLIES AND CONSUMABLES
Not Applicable

B9 NON-DIRECT MEASUREMENTS (DATA ACQUISITION REQUIREMENTS)
The ICPR Model was used for the hydrology and hydraulics modeling of the Tule Creek watershed component of the Aransas County Stormwater Management Plan. As discussed in greater detail in Section A6 (modeling tasks 3 and 4), appropriate ICPR watershed datawill be inputted into QUALHYMO as acquired data.In addition to the ICPR watershed data, other available data include precipitation data andevaporation data.

Precipitation: Precipitation records from the NWS/NOAA Aransas County Airport from 1959 to current will be used as acquired data for use in the QUALHYMO Model.

Evaporation Data: Evaporation Data from 1954 to 2010 for Aransas County and distributed by the Texas Water Development Board will be used as acquired data for the QUALHYMO Model.

Below is a summary of acquired data to be inputted into the QUALHYMO model.

Type of Measurement or Analysis	**Type of Data (time series, rate, constant, statistic, taxa, etc.)**	**Units**	**Source (weblink when available)**	**Quality Assurance Documentation**	**Use**	**Date Range**
Daily precipitation data	rainfall series	inches/hour	NCDC records - NWS/NOAA Aransas County Airport	per NCDC standards	model basis	Extracted from period of record 1959-present
Evaporation data	Monthly time series	inches/day	TWDB, NWS and NCDC records	per TWDB, NWS NCDC standards	model basis	Extracted from period of record 1954 -2010
ICPR watershed model inputs:	Tule Creek watershed parameters:	See watershed parameters below	Tule Creek Watershed Proj. Report, 8/2/2010	Tule Creek Watershed Proj. Report, 8/2/2010	Model input data	2010
-Sub-basin drainage area	"	acres	Tule Creek Watershed Proj. Report, 8/2/2010	Tule Creek Watershed Proj. Report, 8/2/2010	model input data	2010
-Land Use/ Impervious cover percent	"	non-dimensional	Tule Creek Watershed Proj. Report, 8/2/2010	Tule Creek Watershed Proj. Report, 8/2/2010	model input data	2010
-Soils Data: Soil Survey Geographic (SSURGO)	"	non-dimensional	Tule Creek Watershed Proj. Report, 8/2/2010	SSURGO - detailed soil maps by NRCS	model input data	2010
-Flow length	"	feet	Tule Creek Watershed Proj. Report, 8/2/2010	Tule Creek Watershed Proj. Report, 8/2/2010	model input data	2010
-Slope	"	non-dimensional	Tule Creek Watershed Proj. Report, 8/2/2010	Tule Creek Watershed Proj. Report, 8/2/2010	model input data	2010
-Channel length	"	feet	Tule Creek Watershed Proj. Report, 8/2/2010	Tule Creek Watershed Proj. Report, 8/2/2010	model input data	2010
-Channel velocity	"	feet/sec	Tule Creek Watershed Proj. Report, 8/2/2010	Tule Creek Watershed Proj. Report, 8/2/2010	model input data	2010
Particle Size Distribution	Statistics	non-dimensional	NURP Study[11]	EPA requirements	Model input data	1983

[11] U.S. Environmental Protection Agency, Results of the Nationwide Runoff Study (NURP), 1983.

SELECTED ACQUIRED DATA FROM TULE CREEK MONITORING QAPP
For informational purposes and as requested by TCEQ, selected acquired data from Table B9.1 from the **Tule Creek Monitoring** QAPPthat is not duplicative of data already included in the abovemodeling QAPP table is presented below.

Table B9.1 – Acquired Data (selected data from the Tule Creek Monitoring QAPP)

PARAMETER	UNITS	MATRIX (LAB)	SOURCE
TSS	mg/L	water	Sample collected 1/17/2012) (pre-construction

B10 DATA MANAGEMENT AND HARDWARE/SOFTWARE CONFIGURATION

B10 (A) Data Management

Data Dictionary
Data definitions will be consistent with industrial norms, but two are outlined below for convenience.

Data Unit - The basic granularity of information will consist of two major formal sets and ad hoc data sets as needed. The two formal data sets will be QUALHYMO input/output sets, and time series sets. The ad hoc data sets will be in the form of database files (MS ACCESS or SQLLite), spreadsheets (MS EXCEL or LibreOffice CALC), or document files (MS WORD or portable document format). Each data unit will be uniquely identified and will be described by project metadata.

Project Metadata – All data units will be uniquely identified, and will be associated with data sufficient to define their origin, reuse, and transformations between origin and disposal. The information which does this is referred to as project metadata. Project metadata will include initiating author, change authors, dates of initiation and change, and project context (project task and intent or relevance of each data unit version for that task). Metadata will also include unequivocal descriptions of support software needed to access and interact with the data unit (e.g. in the case of a spreadsheet, the name and specific version of the software), as well as the operating system necessary to use that software.

Migration/Transfer/Conversion
All data units will be managed in sets that are worked on locally, but contained in a central repository for backup and documentation purposes. To do this, a data server will be used to track each data unit and its associated metadata through the life of the project. The data server will be housed with a commercial ISP. Access will be password controlled and at an individual user level of granularity. All data units will be managed in two contexts, namely as working

copies (those data units on a project worker computer) and as record copies (those data units backed up on the server). Working copies will be managed by the individual professional responsible, who will document all modifications made to the data in the associated metadata set. Working copies will be posted by individuals onto the server to provide record copies on a schedule to be determined by the project manager, but not less than at the receipt and the handoff of data.

All formal transmissions between identified project participants (e.g. NEI, LDP, Aransas County) less than 100 mb in size will be via the server, with posted content limited to read access by the recipient, so that an unequivocal record of transmission will exist. In the event that data units exceed 100mb in size or are for other reasons not communicated via the server, they will be communicated by media determined by the project manager, but complete physical record copies with associated metadata will be provided by the sender for storage over the life of the project. Where physical copies are delivered, copies of metadata and pointers to the location of the physical repository will be maintained on the server as surrogate data sets.

Information Dissemination
Project updates will be provided to the Aransas County Project Manager to be included in progress reports for distribution to TCEQ.

B10 (B) Hardware/Software configuration
For record copies of data units, hardware will consist of Linux based servers as described elsewhere in this section. The underlying operating system will be CentOS or an equivalent. For working copies of data units, hardware will consist of Linux or Windows (XP SP3 or 7), on laptops or office servers as convenient. Data transfer media for physical record copy transmission will consist of DVD and/or portable hard drive (Western Digital or Seagate, formatted in keeping with the host PC, transfer by USB2, USB3 or ESATA cable interface). Data transfer media for physical working transfer copy transmission will be the same as for record copies but may in addition include USB or SD memory sticks as convenient.

No software development is anticipated as required in this project. Spreadsheets may be used from time to time for convenience, and if so will be internally documented and managed as data units (described above).

Archives/Data Retention
At the conclusion of the project, all record copies of data units and metadata will be recovered from the servers, and saved on physical media. Summary metadata will be provided in printed form to provide a ready index to the electronic images on the physical media.

Backup/Disaster Recovery
All record copies of data units will be backed up and recovered as necessary by the ISP in which the server is housed. At the end of the project, physical record copies of data units will be duplicated and maintained in a physical location separate from the originals; it is intended that

original and duplicate record copies will be housed at Aransas County and NEI offices in Corpus Christi.

SECTION C: ASSESSMENT AND OVERSIGHT

C1 ASSESSMENTS AND RESPONSE ACTIONS

The following assessment and response actions will be applied to modeling activities. As described in Section B9 (Non-direct Measurements), modeling staff will evaluate data to be used in calibration and as model input according to criteria discussed in Section A-7 (Quality Objectives and Criteria for Model Inputs/Outputs Data) and will follow up with the various data sources on any concerns that may arise. Reporting of assessments and response actions is described in Section A9. The TCEQ QAO may, as appropriate, perform an assessment of activities described and referenced in this QAPP.

Table C1.1 Assessments and Response Actions

Assessment Activity	Approximate Schedule	Responsible Party	Scope	Response Requirements
Status Monitoring Oversight, etc.	Continuous	Aransas County Project Manager	Monitoring of the project status and records to ensure requirements are being fulfilled. Monitoring and review of subcontractors performance and data quality	Report to TCEQ in Quarterly Status Report.
Technical Systems Audit	at the discretion of the TCEQ QA Specialist and Project Manager	TCEQ	Assessment tailored in accordance with objectives to assure QAPP compliance.	Per TCEQ request. 30 days to respond in writing to TCEQ to address corrective actions.

Model Calibration and Results Assessment and Response

The criteria for acceptable outcomes are provided in Section A7 (Quality Objectives and Criteria for Model Inputs/Outputs). The data employed as part of the modeling results will be evaluated during the validation process specifically for its utility as a standard of model performance evaluation.

The model calibration procedure is discussed in Section B7 (Validation and Verification Methods), and criteria for acceptable outcomes are provided in Section A7 (Quality Objectives and Criteria). Results will be reported to the Aransas County Project Manager or AC QAO in the format provided in Section A9. If agreement is not achieved between the calibration standards and the predictive values, corrective action will be taken by the Project Manager to assure that the correct files are read appropriately and the test is repeated to document compliance. 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. CARs (Appendix C) will be filled out to document the problems and the remedial action taken. Copies of CARs will be included with the annual QA report. The QA report will discuss any problems encountered and solutions made. These QA reports are the responsibility of the Aransas County QAO and the Project Manager and will be disseminated to individuals listed in section A3. If the predicted value cannot be brought within calibration standards, the Project Manager or Quality Assurance Officer will work with TCEQ to arrive at an agreeable compromise.

Evaluation of model calibration and predictive results will involve both quantitative and qualitative measures (Sections A7, B7). The Council on Regulatory Modeling (USEPA 2009) defines model reliability as "corroboration", which in other words, refers the degree to which a model corresponds to reality. In simple terms, this means comparing the model's predictions/results with observed data. Both quantitative and qualitative concepts (Section A7) will be used to corroborate model performance to the degree deemed appropriate by the stakeholder group. Areas where model performance is not appropriate will be documented after attempting to rectify problem areas.

Model Software Assessment and Response

Software requirements, software design, or code are examined to detect faults, programming errors, violations of development standards, or other problems. All errors found are at the time of inspection, with later verification that all errors found have been successfully corrected. Software used to compute model predictions are tested to assess its performance relative to specific response times, computer processing usage, run time, convergence to solution, stability of the solution algorithms, the absence of terminal failures, and other quantitative aspects of computer operation.

QUALHYMO Model

The QUALHYMO model that will be used in this project was originally developed as a research tool targeted at BMP evaluation and was designed for rapid simulation of long term quality/quantity behavior. It was originally funded by the Ontario Ministry of Environment, and has been developed by means of continued government funding from the US and Canada since that time, with recent implementations of BMP simulation capabilities undertaken in the context of Texas project activity. Although the model was first developed some thirty years ago, it has been the subject of development since that time. More broadly, advanced capabilities recently incorporated in the model include water reuse, distributed storage, and climate change. No checks or verifications will be conducted on the source code of the model. The QUALHYMO users manual is found in AppendixD.

Corrective Action for Deficiencies

Deficiencies are any deviation from the QAPP, SOPs, or data management procedures. Deficiencies may invalidate resulting data and may require corrective action.

The Aransas County Project Manager or QAO is responsible for implementing and tracking corrective action procedures as a result of audit findings. Records of audit findings and corrective actions are maintained by the Aransas County Project Manager or QAO. Corrective action documentation will be submitted to the TCEQ Project Manager with the next progress report.

C2 Reports to Management

Reports to Aransas County Project Management

All reports detailed in this section are contract deliverables and are transferred to Aransas County Project Manager in accordance with contract requirements.

Progress Report –Quarterly Progress Reports briefly summarizes the Subcontractors activities for each task. Quarterly Progress Reports should also include modeling status, issues, and corrective actions.

Final Project Report – Summarizes the Subcontractors activities for the entire project period including items included in the Progress Reports, a description and documentation of the major project activities, evaluation of project results and environmental benefits, and a conclusion. The final report will also include the input and output data for the initial and final model runs, a description of the input adjustments resulting from the calibration process and validation results.

Reports to TCEQ Project Management

All reports, including subcontractor reports, detailed in this section are contract deliverables and are transferred to TCEQ in accordance with contract requirements.

Progress Report–Quarterly Progress Reports summarizes Aransas County's and the Subcontractors activities for each task. Monthly Progress Reports should also include modeling status, issues, and corrective actions,

Final Report – Summarizes Aransas County's and Subcontractors activities for the project period including all information contained in the Aransas County Final Report.

Audit Report and Response- Following any audit performed by the Aransas County Project Manager, a report of findings, recommendations and responses are sent to the TCEQ project manager in the quarterly/monthly progress report. Such reports will include model performance assessments, calibration, and validation performance determination.

Reports by TCEQ Project Management

Contractor Evaluation - Aransas County is evaluated in a Contractor Evaluation by the TCEQ annually for compliance with administrative and programmatic standards. Results of the evaluation are submitted to the TCEQ Financial Administration Division, Procurements and Contracts Section.

SECTION D: DATA VALIDATION AND USABILITY

Validation - Validation is an extension of the calibration process that reduces uncertainty. The rates and settings developed during calibration are checked for adequacy using data set(s) that represent the modeled waterbody under different conditions than were observed during the calibration data set. The rates then, if necessary, are adjusted further so that they work adequately well for all data sets. Validation is the comparison of the modeled results with independently derived numerical observations from the simulated environment. Model validation is, in reality, an extension of the calibration process. Its purpose is to assure that the calibrated model properly assesses the range of variables and conditions that are expected within the simulation.

D1 DEPARTURES FROM VALIDATION CRITERIA

The principal activities in this project occur over at time scale and under physical circumstances in which a variation on the primary data set suitable for validation is not likely to emerge. However, the criteria that have been determined (high accuracy mass balance closure) can be verified under independent circumstances, and this will be done. If the model does not meet the specified closure limits, performance interpreted as a part of the BMP function could in reality be an artifact of the numerical methods applied in the model. Therefore, this is a fundamental and important criterion, and departures from this specification will not be accepted.

D2 VALIDATION METHODS

Model Validation
This will be done by applying an alternative precipitation data set to the watershed and BMP model data set, and verifying that under this condition the model behaves in a manner consistent with that which was predicted using the primary data set. The alternative precipitation set will be taken from a Texas based precipitation station, and will not necessarily be representative of predictive conditions in the project at hand. However, it will provide a basis for verifying that the model mass balance closure is achieved under both conditions. The acceptable result will be a mass balance closure as good as or better than that which was achieved with the primary precipitation set.

D3 RECONCILIATION WITH USER REQUIREMENTS

The requirements in this project are specific and limited. The need is to develop a generalized estimate of long term removal of sediments in the pre-determined sediment trap design which is being evaluated. Data will be limited to the monitoring which is available, and extensive calibration and predictive results will therefore not be necessary nor possible. Once constructed, the sediment trap will require observation and adaptation as data accumulates and performance becomes clearer. This does not mean that the modeling will be taken lightly. On the contrary, the available data will be used to best effect and the robust behavior of the model in this context will be verified as described in this QAPP. However, the specific and limited context of this project needs to be a realistic part of the program and project objectives.

APPENDIX A
WORK PLAN TASKS AND SCHEDULE
AND
SOW FOR 2009 and 2011 319(h) GRANTS

Tule Creek Grant Projects
Project/Task Reconciliation

GRANT:	TCEQ FY09 319(h) (amendment 1) August 2012 - August 2013	TCEQ FY11 319(h) August 2011 - August 2014
Goal/Objective: Mode of Coordination	To improve water quality in Tule Creek by 1) Restoring wetlands with non-point source run-off treatment capability and habitat value and 2) improving water quality from Tule Creek discharge to Little Bay and Aransas Bay.	To reduce erosion: sloughing of creek banks; and transportation of fine sand and other sediments through the West Tule Creek System into Little Bay (Phase 1).
Activity	TASK DESCRIPTION	TASK DESCRIPTION
Stakeholder facilitation	Task 1 Project Administration including oversight,QPRs, Reimbursements, contract communication, contractor evaluation, project fact sheet, and annual report. Task 2 Invasive Tree Removal includes tree removal, seedling regeneration, and removal report. Task 3 includes sediment pond construction and sediment pond report. Task 4 Data Collection and Analysis includes Data Quality Objectives and Monitoring Plan, QAPP planning meeting, Modeling QAPP, Monitoring QAPP, QAPP updates and amendments, modeling, monitoring, and data submittal. Task 5 Signage Task 6 Final Report	Task 1 Project Administration including oversight,QPRs, Reimbursements, contract communication, and annual report. Task 2 Engineering Analysis, Permitting, Design, and Construction Bid Selection Process includes preliminary engineering analysis of bank stabilization and slope protection strategies and permitting, final design plans and specifications, construction bid selection process, and Final Report. Task 3 Performance monitoring and QUALHYMO modeling includes QAPP updates and amendments, wq and streamflow monitoring groundwater monitoring, QUALHYMO modeling and assessment, and data submittal. Task 4 Construction includes upland vegetation clearing, excavation and widening/re-sloping of east side of ditch, bank stabilization and slope protection, and construction report. Task 5 Final Report
WQ Monitoring: Monitoring QAPPs will be coordinated as part of the development of the monitoring component. The study designs will be distinct, and the monitoring sites will be different	Subtask 4.1 Data Quality Objectives and Monitoring Plan have been identified to estimate load reductions of the bmp performance. Subtask 4.2 QAPP Planning Meeting. Subtask 4.3 Development and submittal of QAPP for Monitoring. Subtask 4.5 and 4.6 QAPP updates and amendments. Subtask 4.7 Monitoring at 4 locations for 8 sampling events (dry and wet) post-construction for TSS, pH, conductivity, salinity, do, temperature, and oil and grease.	Subtask 3.1 QAPP updates and amendments. Subtask 3.2 Monitoring at 6 locations for 6 sampling events (dry and wet) pre and post-construction for TSS, pH, conductivity, salinity, do, temperature, and oil and grease. Subtask 3.3 Groundwater and rainfall gauge monitoring.
WQ Modeling: All the modeling will be conducted under a single QAPP with TCEQ and EPA review will be with the 319 PM (Anju Chalise).	Subtask 4.1 Data Quality Objectives and Monitoring Plan have been identified to estimate load reductions of the bmp performance. Subtask 4.2 QAPP Planning Meeting. Subtask 4.3 Development and submittal of QAPP for Monitoring. Subtask 4.5 and 4.6 QAPP updates and amendments. Subtask 4.8 Modeling using the QUALHYMO model to evaluate bmp assessment evaluating data from flow, groundwater elevations, infiltrometer tests, stream flow rating curves, and meterological data.	Subtask 3.1 QAPP updates and amendments. Subtask 3.4 Modeling using the QUALHYMO model to evaluate bmp assessment evaluating data from flow, groundwater elevations, infiltrometer tests, stream flow rating curves, and meterological data.
DELIVERABLES	Post-Award Meeting Minutes	Post-Award Meeting Minutes
	Quarterly Progress Reports	Quarterly Progress Reports
	Quarterly Conference Call Meeting Minutes	Quarterly Conference Call Meeting Minutes
	Project Fact Sheet	Annual Report
	Annual Report	Project Designs and Specifications (Sept 2012)
	Invasive Tree Removal Report (June 2012)	USACE Permit
	Sediment Pond Report with Photos (Sept-Oct 2012)	Bid Packages (Feb 2012)
	Draft QAPP for Monitoring (January - April 2012)	Engineering Analysis, Permitting, Design Report (April 2012)
	Draft QAPP for Modeling (April 2012)	Draft and Final QAPP Updates
	Final QAPP for Monitoring (January - April 2012)	Draft and Final QAPP Amendments
	Final QAPP for Modeling (April 2012)	Data Submittals (quarterly)
	QAPP Updates and Amendments	Excavation and Widening Photos (April 2014)
	Data Submittals (every 6 months)	Construction Photos (April 2014)
	Photos of Signs (Feb 2012)	Construction Report (June 2014)
	Draft Final Report (June 2013)	Draft Final Report (August 2014)
	Final Report (July 2013)	Final Report (Sept 2014)

Agreement Amendment No.1

Nonpoint Source Water Quality Management Planning Implementation Grant

In accordance with Article 6, **Changes to the Agreement Documents**, of the General Terms and Conditions, Texas Commission on Environmental Quality (TCEQ) and Aransas County hereby agree to amend Agreement No. 582-10-90462.

Agreement Document	Expiration Date	TCEQ Funds Increase/ Decrease	Total TCEQ Obligation
Original Agreement	8/31/2012	-------	$142,800.00
Amendment No. 1	8/31/2013	$86,702.00	$229,502.00

1. The agreement term is extended to 8/31/2013. The **Agreement Expiration Date** and **Article 2, AGREEMENT TERM** are amended to read 8/31/2013.

2. In accordance with Article 3, Section 3.1, **Total Obligation Amount,** the parties agree that the total amount of this Agreement shall not exceed $382,503.00 (Federal and Local Match), and that TCEQ will reimburse up to $229,502.00.

3. In accordance with Article 1, Section 1.1, **Authorized Expense Budget**, the parties agree that the authorized expenses, acquisitions, or expenditures under this Agreement are as follows:

Budget Category	Original Budget	Budget Revision	Amended Budget
Personnel/ Salary	-	-	-
Fringe Benefits	-	-	-
Travel	-	-	-
Supplies	-	-	-
Equipment	-	-	-
Contractual	$72,000.00	$310,503.00	$382,503.00
Construction	$166,000.00	-$166,000.00	0
Other	-	-	-
Total Direct Costs	$238,000.00	$144,503.00	$382,503.00
Authorized Indirect Costs	-	-	-
Total Grantee Costs	$238,000.00	$144,503.00	$382,503.00
Other Third Party In-Kind	-	-	-
Total Project Costs	$238,000.00	$144,503.00	$382,503.00
Grantee Cost Share	$95,200.00	$57,801.00	$153,001.00
Total Reimbursable Costs	$142,800.00	$86,702.00	$229,502.00

1. The Scope of Work is amended to modify Tasks 2, 3, 4 and 5. The revised Scope of Work and Schedule of Deliverables are attached.

All conditions and requirements of Agreement No. 582-10-90462 that are not addressed in this Agreement Amendment No. 1 shall remain unchanged, and shall apply to all services specified herein just as if those services had been included in the original specifications of this Agreement.

TCEQ	ARANSAS COUNTY
(Signature)	(Signature)
L'Oreal W. Stepney, P.E.	C. H. "Burt" Mills, Jr.
(Printed Name)	(Printed Name)
Deputy Director	County Judge
(Date Signed)	(Date Signed)

CWA §319(h) Nonpoint Source Grant Program
FY 2009 Proposal 1.08

NONPOINT SOURCE SUMMARY PAGE
for the CWA §319(h) Urban Nonpoint Source Grant Program

Title of Project:	1.03 West Tule Creek Sediment Trap Pond and Habitat Enhancement
Project Goals:	To improve the water quality in Tule Creek by 1) Restoring wetlands with non-point source runoff treatment capability and habitat value and 2) Improving water quality from Tule Creek discharge to Little Bay and Aransas Bay.
Project Tasks:	(1) Project Administration; (2) Invasive Tree Removal; (3) West Tule Creek Sedimentation Pond and Habitat Enhancement; (4) Data Collection and Analysis; (5) Signage; (6) Final report
Measures of Success:	Success will be measured through completion of stormwater Best Management Practices (BMPs) that have non- point source runoff capability and habitat value.
Project Type:	Implementation (X); Education (X); Planning ( ); Assessment ( ); Groundwater ( )
Status of Water Body: 2008 Texas Water Quality Inventory and 303(d) List	Segment ID: Aransas Bay/Copano Bay Watershed; Parameter: Bacteria; Category: 5a
Project Location (Statewide or Watershed and County)	Tule Creek - Aransas County
Key Project Activities:	Hire Staff ( ); Surface Water Quality Monitoring ( ); Technical Assistance ( ); Education (X); Implementation (X); BMP Effectiveness Monitoring ( ); Demonstration ( ); Planning ( ); Modeling ( ); Bacterial Source Tracking ( ); Other ( )
Texas NPS Management Program Elements:	Element One (LTG Objectives 1 and 2; STG 2A, STG 2B, STG 3A, STG 3B, STG 3D) Element Two Element Four This project is also consistent with Texas Coastal Nonpoint Source Pollution Control Program Chapter 5 - 5.2.5.2 and 5.2.5.3.

Project Costs:	Federal: (TCEQ)	$229,502	Non-Federal: (Match)	$153,001	Total:	$382,503

Project Management:	Aransas County
Project Period:	January 1, 2010 – August 31, 2013

Part I – Applicant Information

Applicant

Project Lead:	David Reid, P.E.
Title:	Assistant County Engineer
Organization:	Aransas County
E-mail Address	dreid@aransascounty.org
Street Address	1931 FM 2165

City	Rockport	County	Aransas	State	Tx	Zip Code	78382

Telephone Number:	361-790-0152, extension 31	Fax Number:	361-790-0125

Project Partners:	
Names	Roles and Responsibilities
Texas Commission On Environmental Quality (TCEQ)	Provide state oversight and management of all project activities and ensure coordination of activities with related projects and Texas State Soil and Water Conservation Board (TSSWCB).
Aransas County	Project oversight and management of all project activities.
The Mission - Aransas The National Estuarine Research Reserve (MA-NEER)	Technical data and support.
Coastal Bend Bays and Estuaries Program (CBBEP)	Public outreach and education.
Aransas First, Stewardship Aransas and Chamber of Commerce Environmental Committee	Land Trust, public outreach and education.
Coastal Bends Bays Foundation (CBBF)	Public outreach and education.

Part II – Project Information

Project Type							
Surface Water	X	Groundwater					
Does the project implement recommendations made in a completed Watershed Protection Plan or an adopted TMDL or Implementation Plan?				Yes		No	X
If yes, identify the document. If yes, identify the agency/group that developed and/or approved the document.				Year Developed			

Watershed Information				
Watershed Name(s)	Hydrologic Unit Code (8 digit)	Segment ID	305(b) Category	Size (Acres)
Aransas Bay/Copano Bay Watershed	12100405	2472	5a	2,100

Water Quality Impairment
Describe all known causes (pollutants of concern) of water quality impairments from any of the following sources: 2008 Texas Water Quality Inventory and 303(d) List, Clean Rivers Program Basin Summary, Basin Highlights Reports or Other Documented Sources.
Aransas County is surrounded by seven bay systems including four (Copano Bay-Port Bay-Mission Bay, and Redfish Bay) that are listed as "water bodies that do not meet applicable water quality standards or is threatened for one or more designated uses" and are also listed as Category 5a. These bays are listed due to bacteria contamination (oyster waters) and stormwater runoff from land use practices upstream.

Project Narrative

Problem/Need Statement

Aransas County is experiencing growth in population of both permanent and part-time residents. Development pressure poses a serious threat to the quality of the wetlands, wildlife habitats, and water resources that make the region attractive. As more and more land is converted to residential or commercial uses, the potential for water quality degradation is increased. Pollutants that threaten the health of the area's six bays are nutrients and sediments from human activities such as shoreline development, and polluted runoff.

This threat is most obvious in Little Bay, a shallow bay within the corporate boundaries of the City of Rockport that historically has supported a productive fishery, large flocks of wintering waterfowl, and large populations of nesting water birds. Little Bay is bounded on the south and southeast by public lands (Rockport Beach Park, Festival Grounds) and on the west by a street with multiple parking areas. It is fully accessible to the public and usage levels are high, especially on weekends. It is utilized year round with a variety of water-based recreation, including kayaking, boat pier, wade fishing, swimming, windsurfing, skiing, and birding. Universities and public schools from throughout South Texas use Little Bay as a research and teaching resource, and it is common to see groups of students on Little Bay or along its shore, taking part in environmental studies and field trips. Apart from Little Bay there are very few locations in Aransas County that provide public access to wade fisherman, and the shore-based recreational opportunities afforded by Rockport Beach Park.

Scientists have identified polluted stormwater runoff, a product of urbanization, as a principal cause of declining water quality and loss of wildlife habitat within Little Bay. Studies documented high levels of nitrogen loading from land-based activities, reduced salinity due to stormwater outflows (exacerbated by poor water exchange with Aransas Bay), and persistent eutrophication problems surrounding algal blooms during the summer months. Little Bay has experienced a decline in the once extensive beds of submerged seagrasses. Fishing is less productive, and winter flocks of waterfowl have declined in numbers and diversity in recent years.

Water Quality studies have been conducted by MA-NERR to determine the extent of problems within the surrounding Aransas County, and the City of Rockport's Water Quality Committee has several years' data surrounding the decline in water quality in Little Bay. In addition, CBBEP has determined that the seagrasses in Little Bay have been declining since the 1960's as a direct result of the reduced water quality in Little Bay. Just four years ago flats of Little Bay were lush with marsh grasses. In recent years, the bay bottom that has historically supported the seagrasses and fringe marsh that line the perimeter of the bay have almost disappeared.

On the west side of the Live Oak Peninsula, sections of Copano Bay and Port Bay have been closed to oystering due to localized water pollution problems.

Tule Creek is a 2,100 acre watershed that carries both stormwater drainage and sewage effluents into Little Bay. The stream drains areas of the City of Rockport, the Town of Fulton, and areas of Aransas County outside the jurisdiction of either municipality. The Tule Creek watershed is urbanizing, and the population in the area is expected to increase in the next two decades. The Aransas County Navigation District (ACND) owns Little Bay by virtue of a land patent from the Texas Legislature, and the ACND cooperates with the City of Rockport in managing Little Bay. Thus, all governmental entities in Aransas County are involved in a cooperative effort to protect Little Bay, and there is consensus among these entities that the Tule Creek drainage and pollution of Little Bay are top-priority concerns within the framework of the regional program to protect water and improve wildlife habitat described above.

The project site, Upper Tule Ditch, is an improved earthen drainage ditch that has been modified over the years, including filling and ditch excavating of various areas as well as pipe-type culverts. The U.S. Fish and Wildlife Service National Wetland Inventory Maps (1970-1980) identify the wetlands in this floodway to be palustrine emergent, forested, persistent and temporarily flooded. There are also upland areas within and along the drainage way. The restoration of this area with storm water best management practices (BMPs) will provide improved storm water quality habitat along with a range of control benefits.

Brazilian pepper trees (*Schinus terebinthifolius*), which are native to Brazil, Argentina, and Paraguay, were introduced to the U.S. as an ornamental from the mid- to late 1800s, however, it did not establish outside of cultivation in Florida until the 1950s. According to unpublished surveys, Brazilian pepper has inhabited over 700,000 acres in Florida including over 91% of the preserves in southern Florida. This pepper tree has occurred in Texas since the 1950s, and has recently become extremely invasive within Texas wetlands and coastal prairies. Brazilian pepper trees are very aggressive in their growth as they form extremely dense, ten-meter high thickets. This pepper tree threatens the destruction of natural vegetative communities and ecosystems.

Brazilian pepper trees are so invasive that they will quickly change native vegetative communities to monotypic stands of pepper trees. Native vegetation plays an important role in stabilizing the banks of ditches and canals thereby reducing erosion and sediment loadings. The native vegetation occurring along the non-maintained sections of Tule Ditch West, Tule Lake West, and within the Tule Marsh East is comprised of wetland and aquatic plants such as Coastal bacopa (*Bacopa monnieri*), lesser duckweed (*Lemna minor*), sedges (*Cyperus* spp.), and spikerush (*Eleocharis* spp.). These areas also contain native forbs and grasses such as bushy broomsedge (*Andropogon glomeratus)*, panic grasses (*Panicum* spp.), horsemint (*Monarda punctata*), fleabane (*Erigeron myrionactis*), and little bluestem (*Schizachyrium scoparium*). The shrub and tree layers contain laurel and live oak (*Quercus* spp.), wax myrtle (*Myrica cerifera*), coral bean (*Erythrina herbacea*), and yaupon (*Ilex vomitoria*). These various vegetative types play an important role in stabilizing the banks of the Tule Ditch, Tule Lake, and Tule Marsh areas with their root systems. In addition, each vegetative type has important filtration and contaminant uptake functions which improve local and downstream water quality conditions.

Brazilian pepper trees damage areas by crowding out native vegetative assemblages. The pepper tree's shallow root systems allow for soil erosion to take place. These pepper trees are also known to clog wetlands and waterways. Their colonization coupled with their prodigious water uptake allows them to change soil moisture and water table levels to conditions that favor them at the expense of native riparian species. Furthermore, the Brazilian pepper trees have little to no wildlife values. They are salt tolerant and they have no natural known predators.

Aransas County and the City of Rockport are not regulated municipal separate storm sewer (MS4) systems. The ACND is also not a regulated MS4. As a result, these local governments are not required to have a storm water permit. Aransas County is voluntarily developing a Drainage Master Plan with an emphasis on stormwater management and implementing BMPs. Aransas County, along with the City of Rockport, ACND, and the Town of Fulton, are cooperatively developing a regional storm water master plan – the Aransas County Regional Storm Water Management Plan (ACRSMP) - that includes implementing storm water BMPs within the priority Tule Creek watershed. The proposed project will help accomplish the following objectives of the ACRSMP:

- Decrease flooding impact on infrastructure,
- Decrease siltation, pollutants, and nutrient loading in the surrounding bays,
- Preserve ecological integrity of Aransas County and the Live Oak Peninsula,
- Develop standards to accommodate sustainable quality growth,
- Introduce a regional, long term, and low maintenance approach toward the water volume and quality issues,
- Continue to identify local issues and concerns and potential water quality programs,

- Identify and implement immediate and continued storm water BMPs,
- Identify and assist in the acquisition of public grants for the implementation of projects as a result of the ACRSMP,
- Integrate an ACRSMP into the existing permitting process for Aransas County, the City of Rockport, and the Town of Fulton, including cohesive design criteria and accepted storm event frequencies,
- Create flexible and practical standards that can be used by County staff,
- Identify and cultivate collaborative efforts with all partners within the region,
- Use a planning process that is transparent with opportunities for public participation and education, and
- Identify alternative funding methods for the procurement of easements and infrastructure improvements.

Using an overall watershed management approach to this ACRSMP project will include implementing storm water BMPs that provide water quality and ecological enhancements with drainage control improvements.

The ACRSMP will be completed in three (3) phases. The First Phase will include the Project Planning and Needs Assessment. The Second Phase will include the Modeling, Evaluation and Alternative Analysis; and the Third Phase will include Preparation and Implementation of the Master Plan and BMP Implementation. Aransas County has developed a Stormwater Management Advisory Committee and Technical Advisory Committee composed of representatives from Aransas County, the Cities of Rockport, Aransas Pass and Fulton, and the ACND to assist in guiding the performance of the ACRSMP. The Naismith Engineering Project Team has been selected by Aransas County to prepare the ACRSMP.

The County executed a contract with Naismith Engineering, Inc. on March 23, 2009. The ACRSMP will be a 12-18 month process. The First Phase of work was authorized by the Aransas County Commissioners Court and included work through July, 2009. Coordination has also started with a wide range of local, state, federal authorities and institutions, conservation groups, and private individuals to collect and evaluate information on water quality as well as flooding/drainage problems and ecological issues, priorities, constraints, and opportunities to implement stormwater improvements. The Tule Creek and Little Bay watersheds have been identified as priority areas for implementing improvements.

Phase II of the ACRSMP is currently being authorized by the County in Work Authorization No. 2 to be funded by Aransas County. Aransas County plans to utilize Coastal Impact Assistance Program (CIAP) funds to reimburse portions of the Phase II work and will fund outstanding costs not reimbursed by CIAP. The work under this phase will conduct drainage analysis and water quality modeling. The task also outlines that a water quality sampling and monitoring program will be recommended. Load reductions expected from the modeling and specific water quality improvements are not available until the Phase II tasks are completed which will be at the end of 2009. Phase II includes two modeling activities, H& H Modeling and QUALHYMO. H&H modeling will use HEC-HMS and ICPR (Interconnected pond routing software), and QUALHYMO will be used for BMP design and water quality modeling. The QUALHYMO was originally developed for use at a watershed scale and it is therefore watershed oriented. This model is based on a continuous simulation methodology that includes rainfall/runoff and snowmelt processes. It can stimulate water and can add sediments and dissolved constituents to the analysis process.

The H&H modeling and drainage analysis is being finalized and initial findings on water quality and BMP design is expected by the end of October, 2009.

There is no adequate water quality monitoring data for Tule Creek or Little Bay. The researchers, CBBEP, and MA-NERR have all recognized a decline in seagrass in Little Bay and expected that stormwater input to Little Bay is a major contributing course. The CBBEP and MA-NERR are conducting water quality and seagrass/habitat monitoring in Little Bay and areas of Tule Creek.

This monitoring has just begun and will be completed in 2010. The purpose of the CBBEP study is to assess water quality in Little Bay and expand the existing monitoring effort by the City of Rockport in the Little Bay system located in Rockport, Texas, in order to characterize the bay's recent (last 5 years) environmental degradation. The purpose of MA-NERR sampling plan is to identify the cause of seagrass decline in Little Bay in Rockport, Texas.

The ACRSMP will recommend additional water quality sampling and monitoring which will compliment the results of the ongoing CBBEP and MA-NERR testing. This monitoring by CBBEP and MA-NERR includes stations on Tule Creek.

Aransas County is committed to providing all the modeling results- quality and quantity, as well as project designs and recommended projects. A range of stormwater quality mitigative improvement projects have been identified along the Tule watershed including areas surrounding Little Bay. The suite of improvement projects includes the best management practices included in this workplan. The water quality sampling and monitoring recommended in the ACRSMP will further substantiate and support implementation of continued projects.

Project Narrative

General Project Description (Include Project Location Map)

The proposed project includes the following components: Invasive Tree Removal; West Tule Creek Sediment Trap Pond and Habitat Enhancement; Water Quality Monitoring and Modeling; and Informational Signage.

Invasive Tree Removal

The eradication of Brazilian peppers, Chinese Tallow, and other invasive species is a part of wetland and riparian area restoration and enhancement that serve a significant NPS abatement function. Maintaining desirable vegetation along channelized streams also has Best Management Practice (BMP) functions. Native vegetation plays an important role in stabilizing the banks of ditches and canals, thereby reducing erosion and sediment loadings. The native vegetation occurring along and within the areas of Tule Creek and Upper Tule Creek is comprised of wetlands, aquatic plants, and black willow trees. The root systems of the various native vegetative types play an important role in stabilizing the banks along Tule Creek. In addition, each vegetative type has important filtration and contaminant uptake functions which improve local and downstream water quality conditions.

The proposed removal of invasive trees will involve selectively removing these trees from the West Tule Creek area. The goal of this project is to reduce these non-native invasive plants, which will allow for the natural colonization of nearby native trees, shrubs, and forbs. The restoration of riparian habitat and bottomlands will improve shoreline stabilization functions, will reduce erosion and sedimentation, and will help improve water quality conditions in the immediate wetland area and downstream through sediment trapping and maintaining enhanced wetland function. This habitat restoration effort will also provide significant improvements in the habitat quality for wildlife use.

West Tule Creek Sediment Trap Pond and Habitat Enhancement

This project is located in a site that will enable capture of sediment from the watershed before discharge to Little Bay. A sediment pond will be constructed immediately below the confluence where the Upper West Tule Creek connects with the North Tule Creek, to remove sediment transported from erosion occurring upstream. Due to forested wetlands at this site already functioning as a BMP and supporting a stable ecosystem, the emphasis is to maintain the majority of existing forested wetlands and live oaks, and minimize the loss of their stormwater quality functions and/or ecological values. As previously discussed an invasive removal plan will be implemented to reduce invasive species in areas along the proposed pond. Construction specifications will involve "least harm approaches" and use of mats or large track equipment to avoid rutting and damage to habitat. The relatively small pond (approximately 1.5-2 acres) emphasizing sediment control will be placed more or less on-line but so as to avoid changes to flood and drainage control.

Water Quality Monitoring

The subject stream is not an "impaired stream segment." The purpose of this monitoring task is to assess the water quality treatment performance of the proposed sediment pond and to determine the need and basis for improvements to the sediment pond. The Monitoring Program will involve post sediment pond construction sampling and analysis of Tule Creek surface water chemical/physical/biological characteristics, groundwater elevations, geotechnical characterization, and hydrologic and hydraulic characterization of Tule Creek watershed above the proposed sediment pond location. Surface water quality monitoring will be performed at four (4) locations to assess post-construction total suspended solids (TSS) loading and the performance of the West Tule Creek Sediment Trap Project. Approximately eight (8) sampling events will be attempted to represent baseline dry and wet weather stormwater conditions. Samples will be analyzed for TSS, pH, conductivity, salinity, dissolved oxygen (DO), temperature, and oil and grease. The TSS samples will be collected since that is the principle stream pollutant to be controlled in the subject BMP. DO will be used to identify the potential for anoxic or eutrophic conditions in the sediment trap pond caused by organic nutrient loading. Oil and grease will be monitored to assist in identification of stormwater contributors from urban development (roadways). The pH, temperature, and conductivity will be collected with minimal time and cost using a multi-parameter probe and will help further distinguish stormwater contribution/sources from Waste Water Treatment Plant effluent without incurring a substantial additional cost. Streamflow monitoring will include stream velocity, elevation, and development of rating curves. Flow rate will be determined by measuring depth with a gauge placed at a point where depth/flow functions are known, and depths can be recorded. The depth can then be converted to a flow rate and a rating curve. The rating curve will be obtained by measuring flow near a location where a relationship between flow and depth exists at various times to obtain a series of records of flow rates. The stream flow gauge will be installed near the Highway 35 bridge and monitored concurrently. Piezometers are useful in characterizing deeper flow patterns, how the recharge behaves long-term, and groundwater flow direction towards a creek or bay. Piezometers provide an indication of water pressure and soil properties. By placing paired sets of piezometers, the water pressure difference is known and can provide information related to the water flow. Three (3) paired sets of groundwater piezometers will be installed and monitored at three (3) locations, to be determined in the field, to assess groundwater elevation, and conductivity. Infiltration testing is important in the consideration of water balance and stream erosion estimates. The infiltometer will take a series of measurements of the behavior of the way water soaks into the dominant soil types of Aransas County. Infiltration testing provides good insight into the behavior of the surface of the ground. Infiltration testing will occur simultaneously at the three (3) locations at the same time the piezometers are installed. Rainfall gauges will be installed to assess rainfall estimates correlated with the sampling to assess stormwater representation. Vegetative habitat characterization and changes will be noted from each field sampling event.

Signage

Signage will be installed to acknowledge the source of grant funding for the project, and at the same time actively involve the public in educational efforts to expand both the appreciation for, and the sense of responsibility for, stewardship and proactive protection of our aquatic resources. The signage will be attractive, informative, easy to understand, and will educate people about the effects of their actions on the local and regional environment.

Tasks, Objectives and Schedules						
Task 1:	**Project Administration**					
Costs:	Federal (TCEQ):	$23,500	Non-Federal (Match):	$ 0	Total:	$ 23,500
Objective:	To effectively administer, coordinate and monitor all work performed under this project including technical and financial supervision and preparation of status reports					
Subtask 1.1	**Project Oversight** - Aransas County will provide technical and fiscal oversight of the project staff and/or subgrantee(s)/ subcontractor(s) to ensure Tasks and Deliverables are acceptable, and are completed as scheduled and within budget. With the TCEQ Project Manager's authorization, Aransas County may secure the services of subgrantee(s)/ subcontractor(s) as necessary for technical support, repairs, and training. Project oversight status will be provided to the TCEQ with the Quarterly Progress Reports (QPRs).					
Subtask 1.2:	**QPRs**- Aransas County will submit QPRs to the TCEQ by the 15th of the month following each state fiscal quarter for incorporation into the Grant Reporting and Tracking System (GRTS). Progress reports will contain a level of detail sufficient to document the activities that occurred under each task during the quarter, and will contain a comprehensive tracking of deliverable status under each task. Progress reports will be distributed to all project partners.					
Subtask 1.3:	**Reimbursement Forms**- Aransas County will submit Reimbursement Forms to the TCEQ by the last day of the month following each state fiscal quarter. For the last reporting period of the project, Reimbursement Forms are required on a monthly basis, specifically for the months of June, July, and August of 2013.					
Subtask 1.4:	**Contract Communication** – Aransas County will participate in a post award orientation meeting with TCEQ within 60 days of contract execution. Aransas County will maintain regular telephone and/or email communication with the TCEQ Project Manager regarding the status and progress of the project in regard to any matters that require attention between QPRs. This will include a call or meeting each January, April, July, and October. Minutes recording the important items discussed and decisions made during each call will be attached to each QPR. Matters that must be communicated to the TCEQ Project Manager in the interim between QPRs may include the following: • Requests for prior approval of activities or expenditures for which the contract requires advance approval or that are not specifically included in the scope of work. • Notification in advance when Aransas County has scheduled public meetings or events, initiation of construction, or other major task activities under this contract. • Information regarding events or circumstances that may require changes to the budget, scope of work, or schedule of deliverables; these events or circumstances must be reported within 48 hours of discovery.					
Subtask 1.5:	**Contractor Evaluation** - Aransas County will participate in an annual Contractor Evaluation.					
Subtask 1.6:	**Project Fact Sheet** - Aransas County will develop a one page fact sheet of the project using the TCEQ NPS Projects Template. The fact sheet will briefly describe what the project is going to accomplish, and will provide background information on why the project is being conducted, the current status of the project, and who is involved in the project. The project fact sheet will be submitted to the TCEQ within 60 days after contract initiation. The fact sheet will be updated annually, and submitted with the fourth quarter QPR. The fact sheet will be updated more often, as the project status changes. The fact sheet will be published on Aransas County website after approval from the TCEQ Project Manager.					

Subtask 1.7	**Annual Report Article** - Aransas County will provide an article for the NPS Annual Report upon request by the TCEQ. This report is produced annually in accordance with Section 319(h) of the Clean Water Act (CWA), and is used to report Texas' progress toward meeting the CWA § 319 goals and objectives, and toward implementing its strategies as defined in the Texas NPS Management Program. The article will include a brief summary of the project and describe the activities of the past fiscal year.
Deliverables	• Minutes of Post - Award Orientation Meeting • Quarterly Progress Reports • Reimbursement Forms • Minutes of Quarterly Contract Conference Calls • Contractor Evaluation • Project Fact Sheet • Annual Report Article

Tasks, Objectives and Schedules						
Task 2:	**Invasive Tree Removal**					
Costs:	Federal (TCEQ):	$22,000	Non-Federal (Match):	$ 0	Total:	$ 22,000
Objective:	Remove Brazilian peppertree, Chinese tallow, and other invasive trees from the West Tule Creek and Upper Tule Ditch area, in order to allow for the natural colonization of nearby native trees, shrubs, and forbs which will provide shoreline stabilization, improve wetland functions, reduce erosion and sedimentation, and help improve water quality conditions in the immediate area and downstream.					
Subtask 2.1:	**Invasive Tree Removal** – Aransas County will identify, cut, and treat invasive root systems, to prevent resprouting. This will be accomplished through physical removal with heavy equipment such as bulldozers, front-end loaders, and other specialized equipment, as well as hand tools such as chain saws, followed by herbicidal treatment.					
Subtask 2.2:	**Prevent Seedling Regeneration** – Aransas County will take steps to prevent seedling regeneration with "basal spot" applications of acceptable herbicides. Nearby desired vegetation will not be harmed.					
Subtask 2.3:	**Invasive Tree Removal Report** – Aransas County will prepare a report detailing the implementation of invasive tree removal along Tule Creek.					
Deliverables	• Invasive Tree Removal Report					

Tasks, Objectives and Schedules						
Task 3:	**West Tule Creek Sedimentation Pond and Habitat Enhancement**					
Costs:	Federal (TCEQ):	$127,802	Non-Federal (Match):	$ 124,201	Total:	$ 252,003
Objectives:	To remove sediment transported from erosion occurring upstream, reduce erosion, and protect/enhance habitat.					
Subtask 3.1:	**Sediment Pond Construction**- Aransas County will construct an elongated sediment pond immediately below the confluence where the Upper West Tule Creek connects with the North Tule Creek. Construction specifications will involve "least harm approaches" and use of mats or large track equipment to avoid rutting and damage to habitat. The relatively small pond (approximately 1.5 acres) emphasizing sediment control will be placed more or less on-line but so as to avoid changes to flood and drainage control.					
Subtask 3.2	**Sediment Pond and Habitat Enhancement Report** – Aransas County will prepare Sedimentation Pond and Habitat Enhancement Report.					
Deliverables	• Photographs documenting construction of pond • Sediment Pond Report					

Tasks, Objectives and Schedules	
Task 4:	**Data Collection and Analysis**
Costs:	Federal: $43,200 | Non-Federal: $28,800 | Total: $72,000
Objective:	To provide the baseline information for determination of amounts of existing TSS NPSs of pollution; to provide additional data for incorporation into a model, which will serve to determine pollutant load reductions needed to achieve the goals of the sediment trap pond. The information collected will also form the baseline for future monitoring to determine if pollutant load reduction goals of the sedimentation pond are being met.
Subtask 4.1:	**Data Quality Objectives and Monitoring Plan -** Estimated Load Reductions- A TSS concentration of 165 mg/L was used as the influent TSS concentration value for the Tule Creek sediment trap BMP. It is possible to estimate total loads discharged by Tule Creek now and also with the sediment trap in place based on this estimate and on an estimate of flows from the watershed. Taking 35 inches of rain a year, with an estimated volumetric runoff coefficient of about 0.75. Assumptions include 1/3 of all events will be captured (large events will flow through) and 100% of the coarse solids and 50% of fine sediment will be removed. All that is needed is an estimate of removal rate to enable this calculation. It is assumed that for this small trap, coarse materials will be removed essentially completely, but that finer materials will be reduced by about 50%. Again, all of these numbers will need to be verified or updated by actual numbers from the site, but the suggested estimate load from Tule Creek is about 2.1 million pounds of sediment with the trap in place, per year. The above numbers are indicative, but need to be updated with closer estimates. The field data associated with this monitoring program will be used along with the Quality Hydrologic Model (QUALHYMO) for that purpose. This model was originally built for BMP analysis on a continuous simulation basis, and is able to assess settling and decay removal processes in a BMP, as well as, watershed flow generation and receiving water transport. Recent funding by the Environmental Protection Agency (EPA) and the City of Austin, as well as other public entities has expanded the capabilities of the tool, in particular its ability to represent portioning of contaminants between fluid and solid phases. Sediments can be simulated in 5 size fractions, and are tracked independently. Each fraction is removed according to user specified velocities. BMP characteristics can include by-pass, overflow, through-flow, exfiltration and regular discharge. Losses to evapotranspiration are also calculated on a continuous basis. In addition, the model has an effective set of calculation modules that enable simulation of distributed BMPs (Low Impact Development methods) and instream characteristics. The instream computations include several sediment transport modules able to represent stream power, excess critical shear, and sediment transport, which will be useful in this project in the event that erosive potential and erosive loads from the Tule Creek stream bank or bottom are to be calculated. For the present, as a part of this monitoring program, it is intended that the tool will be used to estimate loads into the sediment trap based on monitored flow and suspended solids data, and to simulate removal in the trap as a function of grain size, particle density, trap volume, outlet characteristics, mixing, through flow rate, overflow rate and sediment concentration distribution.
Subtask 4.2:	**Quality Assurance Project Plan (QAPP) Planning Meeting** – The Aransas County will coordinate planning meetings with the TCEQ Project Manager to implement a systematic planning process. The information developed during the planning meetings will be incorporated into a QAPP. A planning meeting may also be conducted to determine if any changes need to be made to an existing QAPP.

Subtask 4.3:	**Develop a QAPP for Monitoring** – The Aransas County will develop and submit a **QAPP** with project specific data quality objectives using *EPA Requirements for Quality Assurance Project Plans for Modeling Plans (QA/R5)* format and the TCEQ NPS QAPP Shell as a general guideline prior to the initiation of any data collection to TCEQ. All of the monitoring procedures and methods prescribed in the QAPP will use the TCEQ Surface Water Quality Monitoring Procedures, Volume 1 and 2 as a guide. The QAPP will be developed by Aransas County with technical assistance from the TCEQ Project Manager, Quality Assurance staff, technical staff, management, and contractors. The QAPP must be approved by TCEQ before any data collection begins.
Subtask 4.4:	**Develop a QAPP for Modeling** – The Aransas County will develop and submit a QAPP with project specific data quality objectives consistent with the *EPA Requirements for Quality Assurance Project Plans for Modeling* QA/G-5M format 120 days prior to the initiation of any modeling activities to the TCEQ. The QAPP will be developed by Aransas County, with technical assistance from the TCEQ Project Manager, Quality Assurance staff, technical staff, management, and contractors. The QAPP must be approved by TCEQ before any data collection begins.
Subtask 4.5:	**QAPP Update** – Aransas County will provide input to TCEQ 60 days prior to the end of the effective period of the QAPP, and will develop annual QAPP revisions no less than 45 days prior to the end of the effective period of the QAPP.
Subtask 4.6	**QAPP Amendments** – Aransas County will document changes and reasons for amendments to the QAPP, and revised pages will be forwarded to all persons on the QAPP distribution list by the Contractor Quality Assurance Officer. Amendments shall be reviewed, approved, and incorporated into a revised QAPP during the annual revision process or within 120 days of the initial approval in cases of significant changes.
Subtask 4.7	**Monitoring** - Monitoring will include surface water quality monitoring performed at four (4) locations to assess post-construction TSS loading and the performance of the West Tule Creek Sediment Trap Project. Approximately eight (8) sampling events will be attempted to represent baseline dry and wet weather stormwater conditions. Samples will be analyzed for TSS, pH, conductivity, salinity, DO, temperature, and oil and grease.
Subtask 4.8	**Modeling** - QUALHYMO modeling and BMP assessment will be conducted to assess the performance of the West Tule Creek Sediment Trap Project. The model can track mass balance and concentration on a continuous basis at any watershed or BMP discharge point. As part of this monitoring plan, the model will be used to estimate loads into the sediment trap based on monitored flow and TSS data, and to simulate removal in the trap as a function of grain size, particle density, trap volume, outlet characteristics, mixing, overflow rate, through flow rate, and sediment concentration distribution. This task will include the evaluation of the data from the stream water quality sampling program, stream flow gauge station, piezometer groundwater well elevation data, infiltrometer soil testing, stream flow rating curve field measurements, biological and other field observations, and monitoring of rainfall gauges and rainfall meteorological data.
Subtask 4.9	Data Submittal - The Aransas County will review, verify, and validate water quality monitoring modeling data before it is submitted to TCEQ. Data will be submitted to TCEQ twice per year prior to use, or prior to presenting to stakeholders.
Deliverables	• Draft and Final Monitoring and Modeling QAPPs • Draft and Final Monitoring and Modeling QAPP Annual Updates • Draft and Final Monitoring and Modeling QAPP Amendments • Data Submittals • Water quality monitoring non-conformances, reported in quarterly progress reports

Tasks, Objectives and Schedules						
Task 5:	**Signage**					
Costs:	Federal (TCEQ):	$5,000	Non-Federal (Match):	$ 0	Total:	$5,000
Objective:	To acknowledge the source of grant funding for the project, and expand the public's appreciation and sense of responsibility for stewardship and proactive protection of the aquatic resources.					
Subtask 5.1:	Signage will be installed that blends into the environment and is not visually disruptive.					
Deliverables	• Photographs documenting installation of signs.					

Tasks, Objectives and Schedules						
Task 6:	**Final Report**					
Costs:	Federal (TCEQ):	$8,000	Non-Federal (Match):	$ 0	Total:	$8,000
Objective:	To provide the TCEQ and the EPA with a comprehensive report on the activities and success of the proposed project.					
Subtask 6.1:	**Draft Final Report** - Aransas County will provide a draft final report summarizing all project activities, findings, and the contents of all previous deliverables, referencing and/or attaching them as web links or appendices. This comprehensive, technical report will provide analysis of all activities and deliverables under this scope of work. The report will include the following information: • Title • Table of Contents • Executive Summary • Introduction • Project Significance and Background • Methods • Results and Observations • Discussion • Summary • References • Appendices					
Subtask 6.2:	**Final Report** - Aransas County will revise the Draft report to address comments provided by the TCEQ Project Manager. • Draft Final Report • Final Report					
Deliverables:	• Draft Final Report • Final Report					

Project Goals (Expand from NPS Summary Page)

To improve the water quality in Tule Creek by 1) trapping sediments and cleansing stormwater before it is discharged downstream; 2) monitoring water quality to assess the water quality treatment performance of the proposed sediment pond, to determine the need and basis for improvements to the sediment pond, and to identify the stormwater pollutant characterization of Tule Creek; and 3) providing for the natural colonization of native trees, shrubs, and forbs, which will provide shoreline stabilization, reduce erosion and sedimentation, and filter and uptake pollutants.

Measures of Success (Expand from NPS Summary Page)

Success will be measured by:

1) Construction of a sediment pond along West Tule Creek;
2) Reduction of sediment from erosion occurring upstream along West Tule Creek;
3) Water quality monitoring, to assess the water quality treatment performance of the proposed sediment pond, to determine the need and basis for improvements to the sediment pond, and to identify the stormwater pollutant characterization of Tule Creek; and
4) Reduction in the number of invasive trees.

2005 Texas Nonpoint Source Management Program Reference (Expand from NPS Summary Page)

Goals and/or Milestone(s)

Element one – Explicit short- and long- term goals, objectives and strat egies that protect surface water.

LTG Objectives

1 - Aransas County will focus NPS abatement efforts, implementation strategies, and available resources in watersheds identified by Regional Stormwater Master Plan as impacted by nonpoint source pollution.

2 - Aransas County will support the implementation of regional Stormwater Master Plan to prevent nonpoint source pollution through implementation and education.

STG Objectives

2A - Aransas County will work with regional and local entities to determine priority areas and develop and implement strategies to address NPS pollution in those areas

2B - Aransas County will develop and implement BMPs to address decline in water quality and loss of seagrass as identified by MA-NERR, City of Rockport's and CBBEP's water quality data.

3A - Aransas County will enhance existing outreach programs at the regional level to maximize the effectiveness of NPS education.

3B - Aransas County will administer programs to educate citizens about water quality and their potential role in causing NPS pollution.

3C - Where applicable Aransas County will expedite development of technology transfer activities to be conducted upon completion of BMP implementation.

Element Two - Aransas County will work with the regional Stormwater Master Plan partnerships to prioritize and implement the stormwater BMPs along Tule Creek.

Element Four - Aransas County will abate water quality impairments from nonpoint source pollution and prevention of significant threats to water quality from present and future nonpoint source activities.

Texas Coastal Nonpoint Source Pollution Control Program

Chapter 5 - Management Measures
- 5.2 - Urban Developing Areas
  - 5.2.5 - Urban and Developing Areas Management Measure
    - 5.2.5.2 - Urban Runoff: Watershed Protection from Urban Runoff - Aransas County

	is developing watershed protection program to: (1) Avoid conversion, to the extent practicable, of areas that are particularly susceptible to erosion and sediment loss; (2) Preserve areas that provide important water quality benefits and/or are necessary to maintain riparian and aquatic biota; and (3) Site development, to protect to the extent practicable the natural integrity of waterbodies and natural drainage systems. 5.2.5.3 - Urban Runoff: Site Development Management Measures Aransas County will plan, design, and develop sites to: (1) Protect areas that provide important water quality benefits and/or are particularly susceptible to erosion and sediment loss; (3) Limit land disturbance activities such as clearing and grading, and cut and fill to reduce erosion and sediment loss; and (4) Limit disturbance of natural drainage features and vegetation.
Milestone 1:	Completion of Stakeholder Involvement Plan
Milestone 2:	Conduct Public Outreach Workshop
Milestone 3:	Construct Preferred Stormwater BMPs
Milestone 4:	Eliminate Brazilian Peppertree and Stabilize the bank
Milestone 4:	Submit Final Report

Estimated Load Reductions Expected (Only applicable to implementation projects)

Estimated Load Reductions- A TSS concentration of 165 mg/L was used as the influent TSS concentration value for the Tule Creek sediment trap BMP. It is possible to estimate total loads discharged by Tule Creek now and with the sediment trap in place, based on this estimate and on an estimate of flows from the watershed. Taking 35 inches of rain a year, with an estimated volumetric runoff coefficient of about 0.75, and assuming the sediment trap captures 1/3 of the events, all that is needed is an estimate of removal rate to enable this calculation. It is assumed that for this small trap, coarse materials will be removed essentially completely, but that finer materials will be reduced by about 50%. Estimated load from Tule Creek is about 2.1 million pounds of sediment with the trap in place, per year.

Part III – Financial Information

35. Budget Summary			
Federal (TCEQ Reimbursable)	**$229,502**	**% of total project**	**60%**
Non-Federal (Match)	**$153,001**	**% of total project (at least 40%)**	**40%**
Total	**$382,503**	**Total**	**100%**

Category	Federal	Non-Federal	Total
a. Personnel	$	$	$
b. Fringe Benefits	$	$	$
c. Travel	$	$	$
d. Supplies	$	$	$
e. Equipment	$	$	$
f. Contractual	$229,502	$153,001	$382,503.00
g. Construction	$	$	0
h. Other	$	$	$
i. Total Direct Costs (sum a-h)	$229,502	$153,001	$382,503.00
j. Indirect Costs (≤15%)	$	$	$
k. Total Grantee Costs (sum I & j)	$	$	$
l. Other In-kind / Third Party		$	$
m. Total Project Costs (sum k & l)	$229,502	$153,001	$382,503.00

3c. Budget Justification (Federal)		
Category	**Total Amount**	**Justification**
Personnel	**$0.**	
Fringe Benefits	**$0.**	
Travel	**$0.**	
Equipment	**$0.**	
Supplies	**$0.**	
Contractual	**$229,502**	Grant Administration- $23,500 Aransas County contracted with The Grant Connection, a local grant services provider, to administer the grant requirements of this project. The Grant Administrator will work closely with the Project Manager (David Reid) to make certain that the project proceeds on time and within budget, and that all project deliverables are submitted on time. **The Grant Administrator will:** • Be in charge of the compliance with TCEQ program rules and regulations by monitoring project reports, invoices, deliverables, and providing resources needed for the success of the project; • Assist county personnel with preparation of performance and financial reports as required by the terms described in the grant Agreement; • Meet with the Aransas County Project Manager weekly, at a minimum, by phone or in person to receive oral reports regarding the progress of the project, and to discuss potential problems; and • Visit the project sites, along with the Project Manager, at least once per month. Invasive Tree Removal- $22,000 Physical removal of approximately 1.5 - 2 acres, with heavy equipment, as well as, hand tools- $15,000 Treat invasive root systems, to prevent resprouting - $7,000 Sedimentation Pond Construction- $127,802 Initial TSS Characterization, BMP Performance Monitoring and QUALHYMO Modeling- $43,200 Pygmy Meter $600 Multi – Parameter Meter $1,500 Flow Monitoring Equipment and Installation $12,000 Field Sampling/Flow Rating Curve $4,500 Analytical Lab Sample Analysis $300 Piezometer/Infiltration Monitoring $7,800 QUALHYMO Modeling/Data Evaluation $6,000 QAPP Plan Preparation $6,000 Reporting $4,500 Signage- $5,000 (2) 24 x 36 panels on lexan for UV protection Sign design - $2000 Sign fabrication - $2000 Materials, Mounting and Labor - $1000 Final Report- $8,000
Construction	**$0**	
Other	**$0.**	
Indirect	**$0.**	

Budget Justification (Non-Federal)		
Category	**Total Amount**	**Justification**
Personnel	**$0.**	
Fringe Benefits	**$0.**	
Travel	**$0.**	
Equipment	**$0.**	
Supplies	**$0.**	
Contractual	**$153,001**	Sedimentation Pond Construction- $124,201 Initial TSS Characterization, BMP Performance Monitoring and QUALHYMO Modeling- $28,800 Pygmy Meter $400 Multi – Parameter Meter $1,000 Flow Monitoring Equipment and Installation $8,000 Field Sampling/Flow Rating Curve $3,000 Analytical Lab Sample Analysis $200 Piezometer/Infiltration Monitoring $5,200 QUALHYMO Modeling/Data Evaluation $4,000 QAPP Plan Preparation $4,000 Reporting $3,000
Construction	**$0**	
Other	**$0.**	
Indirect	**$0.**	

2009 319(h)
Aransas County Deliverable Due Dates
REVISED July 25, 2011

Schedule of Deliverables Based on Anticipated Project Funding/Initiation Date

Task 1- Project Administration		
Task No.	**Subtasks and Deliverables**	**Due Date**
Subtask 1.1	Post Award Meeting	Within 60 days of contract execution
Subtask 1.2	Quarterly Progress Reports	the 15th of the month following each state fiscal quarter
Subtask 1.3	Quarterly Reimbursement Requests	The last day of the month following each state fiscal quarter
Subtask 1.4	Quarterly conference call with TCEQ	The last day of January, April, July, and October
Subtask 1.5	Contractor Evaluation	15 days following the end the state fiscal year
Subtask 1.6	Initial Project Fact Sheet	Within 60 days of contract execution
Subtask 1.6	Project Fact Sheet Update	15 days following the end the state fiscal year
Subtask 1.6	Final Project Fact Sheet Update	15 days following the end the state fiscal year
Subtask 1.7	Annual Report Article – upon request by TCEQ	15 days following the end of the state fiscal year
Task 2- Invasive Tree Removal		
Task No.	**Subtasks and Deliverables**	**Due Date**
Subtask 2.1	Invasive Tree Removal	June 15, 2012
Subtask 2.2	Prevent Seedling Regeneration	June 15, 2012
Subtask 2.3 Deliverable	Invasive Tree Removal Report	June 15, 2012
Task 3- Tule Creek West Sedimentation Pond and Habitat Enhancement		
Task No.	**Deliverable**	**Due Date**
Subtask 3.1	Sediment Pond Construction	September 30, 2012

Deliverable Subtask 3.2	Photo documenting construction of pond and Sediment Pond and Habitat Enhancement Report	October 30, 2012
	Task 4- Water Quality Monitoring	
Task No.	**Tasks and Deliverables**	**Due Date**
Subtask 4.1	Data Quality Objectives and Monitoring Plan	Included in QAPP
Subtask 4.2	Quality Assurance Project Plan (QAPP) Planning Meeting	October 30, 2011 and as needed basis
Deliverable Subtask 4.3	Develop a draft QAPP for Monitoring Develop a final QAPP for Monitoring	January 31, 2012 April 30, 2012
Deliverable Subtask 4.4	Develop a draft QAPP for Modeling Develop a final QAPP for Modeling	January 31, 2012 April 30, 2012
Deliverable Subtask 4.5	QAPP Update	Aransas County will provide input to TCEQ 60 days prior to the end of the effective period of the QAPP, and will develop annual QAPP revisions no less than 45 days prior to the end of the effective period of the QAPP
Deliverable Subtask 4.6	QAPP Amendments	Amendments shall be reviewed, approved, and incorporated into a revised QAPP during the annual revision process or within 120 days of the initial approval in cases of significant changes.
Subtask 4.7	Monitoring	Included in QAPP
Subtask 4.8	Modeling	Included in QAPP
Deliverable Subtask 4.9	Data Submittal	Available data will be submitted in 6 month intervals starting once the QAPP has final approval.
Deliverable	Water quality monitoring non-conformances	Reported in quarterly progress reports

Task 5- Signage		
Task No.	**Tasks and Deliverables**	**Due Date**
5.1	Install Signage	January 30, 2012
Deliverable	Photographs documenting installation of signs.	February 15, 2012

Task 6- Final Report		
Task No.	**Tasks and Deliverables**	**Due Date**
Deliverable	Draft Final Report	June 15, 2013
Deliverable	Final Report	July 30, 2013

Texas Commission on Environmental Quality

CWA §319(h) Nonpoint Source Grant Program

FY 2011 Proposal 1.05

NONPOINT SOURCE SUMMARY PAGE for the CWA §319(h) Nonpoint Source Grant Program						
1. Title of Project:	1.05 Upper Tule Creek West Widening and Slope Protection and Realignment Project					
2. Project Goals:	To reduce erosion; sloughing of creek banks; and transportation of fine sand and other sediments through the West Tule Creek System to Little Bay.					
3. Project Tasks:	(1) Project Administration; (2) Engineering Analysis, Modeling, Permitting, Design, Water Quality and Best Management Practice (BMP) Performance Monitoring, and Project Management; (3) Construction; (4) Final Project Report.					
4. Measures of Success:	Success will be measured through completion of stormwater BMPs that have non-point source runoff pollution control capability and habitat value and load reduction from the BMPs.					
5. Project Type:	**Implementation (X); Education ( ); Planning ( ); Assessment ( ); Groundwater ( )**					
6. Status of Water Body: **2008 Texas Water Quality Inventory and 303(d) List**	Segment ID: Aransas Bay/Copano Bay Watershed		Parameter: Bacteria		Category: 5a	
7. Project Location (Statewide or Watershed and County)	Tule Creek- Aransas County					
8. Key Project Activities:	Hire Staff ( ); Surface Water Quality Monitoring ( ); Technical Assistance ( ); Education ( ); Implementation (X); BMP Effectiveness Monitoring (X); Demonstration ( ); Planning ( ); Modeling (X); Bacterial Source Tracking ( ); Other ( )					
9. Texas NPS Management Program Elements:	Element One (LTG Objectives 1 and 2; STG 1B, STG 1C, STG 1E, STG 2A, STG 2B, STG 3C) Element Two Element Four This project is also consistent with the Texas Coastal Nonpoint Source Pollution Control Program Chapter 5 - 5.2.5.2 and 5.2.5.3.					
10. Project Costs:	**Federal:**	$206,156	**Non-Federal:**	$137,438	**Total:**	$343,594
11. Project Management:	Aransas County					
12. Project Period:	Upon signature of both parties – August 31, 2014					

Part I – Applicant Information

Applicant							
13. Project Lead	David Reid, P.E.						
14. Title	Assistant County Engineer						
15. Organization	Aransas County						
16. Federal ID No.	74-6001998-1						
17. E-mail Address	dreid@aransascounty.org						
18. Street Address	1931 FM 2165						
City	Rockport	**County**	Aransas	**State**	TX	**Zip Code**	78382
19. Telephone No.	361-790-0152, extension 23			**Fax Number**	361-790-0125		

20. Project Partners	
Names	**Roles & Responsibilities**
Texas Commission On Environmental Quality (TCEQ)	Provide state oversight and management of all project activities and ensure coordination of activities with related projects and Texas State Soil and Water Conservation Board (TSSWCB).
City of Rockport, Texas	Provide planning and design guidance and assistance.
Town of Fulton, Texas	Provide planning and design guidance and assistance.
Aransas County Navigation District	Provide planning and design guidance and assistance.

Part II – Project Information

Project Type					
21. Surface Water	X	**Groundwater**			
22. Does the project implement recommendations made in a completed Watershed Protection Plan or an adopted TMDL or Implementation Plan?		**Yes**	X	**No**	
23. If yes, identify the document.	This project is designed to address requirements of the Coastal Zone Reauthorization Amendments (CZARA) and implement the Texas Coastal Management Program (CMP)				
24. If yes, identify the agency/group that developed and/or approved the document.		**25. Year Developed**			

26. Watershed Information				
Watershed Name(s)	**Hydrologic Unit Code (8 Digit)**	**Segment ID**	**305 (b) Category**	**Size (Acres)**
Aransas Bay/Copano Bay Watershed	12100405	2472	5a	2,100

26. Water Quality Impairment

Describe all known causes (pollutants of concern) of water quality impairments from any of the following sources: 2008 Texas Water Quality Inventory and 303(d) List, Clean Rivers Program Basin Summary, Basin Highlights Reports or Other Documented Sources.

Aransas County is surrounded by seven bay systems including three (Copano Bay-Port and Bay-Mission Bay,) that are listed as "water bodies that do not meet applicable water quality standards or is threatened for one or more designated uses" and are also listed as Category 5a. These bays are listed due to bacteria contamination (oyster waters) and stormwater runoff from land use practices upstream.

Sediment has been identified as a pollutant issue in Little Bay, which discharges into Aransas Bay.

Project Narrative

28. Problem/Need Statement

Aransas County is experiencing growth in population of both permanent and part-time residents. Development pressure poses a serious threat to the quality of the wetlands, wildlife habitats, and water resources that make the region attractive. As more and more land is converted to residential or commercial uses, the potential for water quality degradation is increased. Pollutants that threaten the health of the area's six bays are nutrients and sediments from human activities such as shoreline development, and polluted runoff.

This threat is most obvious in Little Bay, a shallow bay within the corporate boundaries of the City of Rockport that historically has supported a productive fishery, large flocks of wintering waterfowl, and large populations of nesting water birds. Little Bay is bounded on the south and southeast by public lands (Rockport Beach Park, Festival Grounds) and on the west by a street with multiple parking areas. It is fully accessible to the public and usage levels are high, especially on weekends. It is utilized year round with a variety of water-based recreation, including kayaking, boat pier, wade fishing, swimming, windsurfing, skiing, and birding. Universities and public schools from throughout South Texas use Little Bay as a research and teaching resource, and it is common to see groups of students on Little Bay or along its shore, taking part in environmental studies and field trips. Apart from Little Bay there are very few locations in Aransas County that provide public access to wade fisherman, and the shore-based recreational opportunities afforded by Rockport Beach Park.

Water Quality studies have been conducted by Mission Aransas-NERR (MA-NERR) to determine the extent of problems within the surrounding Aransas County, and the City of Rockport's Water Quality Committee has several years' data surrounding the decline in water quality in Little Bay. In addition, Coastal Bend Bays and Estuaries Program (CBBEP) has determined that the seagrasses in Little Bay have been declining since the 1960's. Just four years ago flats of Little Bay were lush with marsh grasses. In recent years, the bay bottom that has historically supported the seagrasses and fringe marsh that line the perimeter of the bay have almost disappeared. Recent studies completed by the University of Texas Marine Science Institute, MA-NERR, and the CBBEP's, "Assessment of Little Bay Water and Sediment Quality in Relation to Indices of Seagrass Condition" have identified stormwater as a possible factor limiting seagrass growth in Little Bay. A comparison of historical aerial photography indicated that sediment to Little Bay near stormwater outfalls was displacing vegetated wetlands. On the west side of the Live Oak Peninsula, sections of Copano Bay and Port Bay have been closed from time to time to oystering due to localized water pollution problems.

Tule Creek is a 2340-acre watershed that carries both stormwater drainage and sewage effluents into Little Bay. The stream drains areas of the City of Rockport, the Town of Fulton, and areas of Aransas County outside the jurisdiction of either municipality. The Tule Creek watershed is urbanizing, and the population in the area is expected to increase in the next two decades. The Aransas County Navigation District (ACND) owns Little Bay by virtue of a land patent from the Texas Legislature, and the ACND cooperates with the City of Rockport in managing Little Bay. Thus, all governmental entities in Aransas County are involved in a cooperative effort to protect Little Bay, and there is consensus among these entities that the Tule Creek drainage and pollution of

Little Bay are top-priority concerns within the framework of the regional program to protect water and improve wildlife habitat described above.

The project site, Upper Tule Creek West, is an improved earthen drainage ditch with steep and barren slopes that has been modified over the years, including filling and ditch excavating of various areas as well as pipe-type culverts. The U.S. Fish and Wildlife Service National Wetland Inventory Maps (1970-1980) identify the wetlands in this floodway to be palustrine emergent, forested, persistent, and temporarily flooded. There are also upland areas within and along the drainage way. The restoration of this area with stormwater BMPs will provide improved stormwater quality habitat along with a range of control benefits.

Stormwater moving through Tule Creek eventually discharges into Little Bay, which is currently experiencing water quality degradation due to a number of factors, including sedimentation from Tule Creek. This is largely due to the steep banks of the creek, which is unable to maintain adequate vegetation, and is badly eroding. Upper Tule Creek West Ditch also takes a sharp turn that is causing severe erosion. The water rushing down the creek has to make an almost ninety degree turn; the energy of the water, particularly during time of major storm events, eats away at the sandy banks of the ditch.

Aransas County and the City of Rockport are not regulated municipal separate storm sewer (MS4) systems. The ACND is also not a regulated MS4. As a result, these local governments are not required to have a stormwater permit. Aransas County is voluntarily developing a Stormwater Master Plan with an emphasis on stormwater management and implementing BMPs. Aransas County, along with the City of Rockport, the ACND, and the Town of Fulton, are cooperatively developing a regional stormwater master plan – the Aransas County Stormwater Management Plan (ACSMP) - that includes implementing stormwater BMPs within the priority Tule Creek watershed. The City of Rockport owns the Tule Creek and right-of-way, which is the location of the proposed BMPs. The coordination between the City of Rockport and Aransas County is being done to help manage Tule Creek stormwater and BMP facilities to be constructed on City property through Interlocal Agreements.

The proposed project will help accomplish the following objectives of the ACSMP:

- Decrease flooding impact on infrastructure
- Decrease siltation, pollutants, and nutrient loading in the surrounding bays
- Preserve ecological integrity of Aransas County and the Live Oak Peninsula
- Introduce a regional, long term, and low maintenance approach toward the water volume and quality issues
- Identify and implement immediate and continued stormwater BMPs
- Integrate an ACSMP into the existing permitting process for Aransas County, the City of Rockport, and the Town of Fulton, including cohesive design criteria and accepted storm event frequencies; and
- Use a planning process that is transparent with opportunities for public participation and education

Using an overall watershed management approach to this ACSMP project will include implementing stormwater BMPs that provide water quality and ecological enhancements with drainage control improvements.

The ACSMP is being completed in three (3) phases, the first two of which are completed. The First Phase involved a Project Planning and Needs Assessment. The Second Phase focused on Modeling, and Evaluation and Alternative Analysis; and the Third Phase, currently underway and is ongoing, includes Preparation and Implementation of the Master Plan and BMP Implementation. Aransas County has developed a Stormwater Management Advisory Committee and Technical Advisory Committee composed of representatives from Aransas County, the Cities of Rockport, Aransas Pass and Fulton, and the ACND to assist in guiding the performance of the ACSMP. The Naismith Engineering Project Team has been selected by Aransas County to prepare the ACSMP.

In Phase II, a detailed hydrologic and hydraulic model (H&H) was created to closely simulate existing conditions and determine existing peak flows and water levels for three design storms, 5-yr, 25-yr and the 100-year 24-hour storms. H&H modeling used HEC-HMS and ICPR (Interconnected Pond Routing Software) and the modeling information along with site visits identified the alternatives to sites suited for BMPs. The set of the recommended projects and conceptual plans were developed based on a combination of flood and drainage control, stormwater quality, and ecological considerations. The H&H modeling and drainage analysis has been finalized and initial findings on water quality and BMP design is addressed in the Tule Creek Watershed Report, which recommends the county address 5 priority areas along the creek.

The Tule Creek Project and entire ACSMP is a voluntary effort by a non-regulated County to improve stormwater management and head-off the potential for Tule Creek or Little Bay-Aransas Bay to become impaired like their neighbor Copano Bay-Mission Bay. The Upper Tule Ditch is a source of sediment load to Little Bay and the proposed project will reduce the loss of sediment from unimproved ditch slopes. Providing improved ditch sloping and vegetated slop protection will reduce sediment load. This project when combined with the FY2009 West Tule Creek Sediment Trap Pond will reduce the sediment transport to Little Bay.

As part of the ACSMP, various local, state and federal grant opportunities have been evaluated and acquired through a competitive grant solicitation effort. These grant opportunities were pursued in order to obtain added funds that could be used to implement stormwater management devices. The grant opportunities that have been successfully accomplished are summarized as follows-

FY 2009 CWA Section 319(h) grant- Aransas County was awarded this grant for construction of a sediment pond and habitat enhancement project at the Tule Marsh East and Tule Ditch West area. This project will start construction in late summer or early fall, 2011. The purpose of the grant is to improve the stormwater quality of Tule Creek by constructing a sediment trap pond with non-point source treatment capability and forested wetlands habitat and habitat value and thereby improving water quality from Tule Creek discharging to Little Bay and Aransas Bay. There is little to no pollutant load data for Tule Creek. Only studies by MA-NERR and CBBEP, which identify problem and concerns with habitat changes in Little Bay. Some very limited water quality data has been collected by the City of Rockport Water Quality Committee for purposes of identifying baseline nutrient levels. This study by the Water Quality Committee only involves grab samples of certain nutrient levels, does not involve any measurements of streamflow or loading, and included no data on solids. There has never been a water quality study by any entity on Tule Creek that has established loading related to stormwater or any other source. There is coordination ongoing between the City and County to collaborate on continued water quality monitoring. The stream is currently under no regulatory controls such as a Total Maximum Daily Load (TMDL) or aquatic life use criteria. A proposed amendment to this project includes a monitoring plan to collect baseline and BMP effectiveness monitoring data for Tule Creek. If approved, the monitoring included will be the first opportunity to start quantifying pollutants, as well as data from piezometers and infiltrometers to help in better understanding stormwater influences on Tule Creek. The key pollutant in question is sediment although there is a history of septic tank use in the watershed whereby bacteria from such septic tank discharges can be expected to adhere to sediment particles. Sediment is the key pollutant expected to be reduced in the watershed by the recommended BMP project.

Tule Creek West Sediment Pond and Habitat Enhancement (FY 09 319(h) project) and Upper Tule Creek West Widening/Enhancement (proposed FY 11 319(h) project) are priority #1 and #2 according to the priority project recommendations. The total FY 09 project is $238,000 which includes $95,200 in local in-kind contribution of excavation work from Aransas County.

Texas General Land Office (TXGLO) Coastal Management Program (CMP) grant for Land Acquisition- Aransas County was awarded TXGLO CMP grant to purchase approximately ten acres areas within the City of Rockport property for a combined stormwater pond and riparian habitat and woodland habitat protection and enhancement project. The project called Tule Creek North Pond and Habitat Enhancement which is priority # 5 according to the priority project recommendations. The total project is $485,000 which includes local contribution of $194,040.

Coastal Impact Assistance Program (CIAP) Live Oak Peninsula Shoreline Enhancement Project- The County was awarded CIAP grant which will involve shoreline stabilization using living shorelines techniques along Fulton Road-Aransas Bay shoreline. In addition, the project will involve wetland protection and enhancement along little Bay. The County has thus far dedicated $1,124,418 of their FY07 and 08 allocations to this project.

The County has essentially used $1.496 million in County special use taxes for quality of life improvement (through stormwater improvements) to leverage almost another $1.5 million in grants related to stormwater management, habitat protection, and education. Aransas County has acquired a range of grants which do not overlap, do not violate any state/federal grant rule regarding use of match, and all target different aspects of stormwater management from construction BMP facilities, to land acquisition, to constructing education facilities, and performing stormwater management plans. Aransas County has utilized CIAP funds to reimburse portions of the Phase II work and will fund outstanding costs not reimbursed by CIAP.

The ACSMP recommendations include additional water quality sampling and monitoring which will compliment the results of the ongoing CBBEP and MA-NERR testing, including stations along Tule Creek.

The BMPs identified thus far are to construct the West Tule Creek Sediment Trap Pond using TCEQ FY2009 funds. In addition, we propose to use TCEQ FY2011 funds to correct a source of the sediment pollutants from an unimproved-eroding ditch (Upper Tule Creek Ditch) by improving the ditch slope with vegetated slope protection.

This project is designed to address requirements of the Coastal Zone Reauthorization Amendments (CZARA) and implement the Texas Coastal Management Program (CMP). The project will reduce the erosion of sediment from Upper Tule Creek to Little Bay. Consistent with the requirements of the CZARA the state's strategy for meeting one of the requirements for New and Existing Development; Site Development; and Watershed Protection was to fund projects in areas within the coastal boundary with future CWA Section 319(h) allocations. While the FY 2009 Tule Creek project was already listed under implementation activities which will support above conditions, the proposed 2011 project is also a TCEQ NPS initiative that will have tangible results by providing sediment load reductions in Tule creek and Little Bay which drain into Aransas Bay.

The project is also consistent with Texas Coastal Nonpoint Source Program by avoiding conversion, to the extent practicable, of areas that are particularly susceptible to erosion and sediment loss; preserving areas that provide important water quality benefits and/or are necessary to maintain riparian and aquatic biota; protecting to the extent practicable the natural integrity of water bodies and natural drainage systems and areas that provide important water quality benefits and/or are particularly susceptible to erosion and sediment loss; and limiting land disturbance activities such as clearing and grading, cut and fill to reduce erosion and sediment loss, and disturbance of natural drainage features and vegetation.

There has been outstanding coordination between City of Rockport, Aransas County, Aransas County Navigation District, and the Town of Fulton while developing a storm water master plan. This project is a good example of a voluntary effort by a non-regulated County to improve stormwater management and protect the water quality. The project when combined with the FY2009 Tule Creek Project will reduce sediment transport to waters surrounding the Live Oak Peninsula, which include Little Bay, Aransas Bay, and Copano Bay.

As a part of their stormwater management plan effort, various local, state and federal grant opportunities have been evaluated and acquired. One such example is the Coastal Impact Assistance Program (CIAP) through which grant Fulton Road-Aransas Bay shoreline will be stabilized using living shoreline techniques. In addition, this project will involve wetland protection and enhancement along Little Bay. Aransas County has utilized CIAP funds to reimburse portions of the Phase II stormater management plan work and will fund outstanding costs not reimbursed by CIAP. The County has thus far dedicated $1,124,418 of their County Management Plan FY 07 and FY 08 allocation to this project. The County has essentially used $1.496 million in County special use taxes to leverage almost another $1.5 million in grants related to stormwater management, habitat protection, and education.

Project Narrative

29. General Project Description (Include Project Location Map)

The Upper Tule Creek West extends from the City of Rockport Wastewater Treatment Plant to the Tule Lake West area. The western bank of the project section has not been cleared or maintained and it currently contains native riparian vegetation. The creek is experiencing significant erosion during rainfall events. This sediment is carried downstream and will ultimately reach the Little Bay ecosystem. The purpose of the Upper Tule Creek West project is to stop immediate, chronic erosion in specific areas.

The project will include final engineering, permitting, plans and specifications preparation, completion of a construction bidding process and the construction of BMPs. The proposed immediate action will utilize appropriate techniques to re-vegetate and stabilize these eroding banks. These techniques require that the creek banks be re-shaped to greater than a 5:1 slope to reduce water velocities and permit re-vegetation using a geogrid fabric and re-seeding. Various alternative vegetative-sloping and erosion control techniques will be evaluated and the selected approach will be permitted and designed. Sections of the ditch will be lined with a combination of rock ditch liner and appropriate erosion control blankets, followed by re-seeding the banks with native coastal prairie grasses. The ultimate goal of the project is to improve water quality in the immediate area, and downstream, by eliminating the source of sedimentation and turbidity.

The project will effectively improve water quality moving downstream into Little Bay by creating a shallow sloped, vegetated, meandering stream with small "riffle ponds" in place of the present straight ditch. Improvements to the creek farther downstream, with widening and sloping, have proven highly successful in preventing erosion.

This area of the Upper Tule Creek West channel is a principal source of erosion problems and sediment discharged to Little Bay. This project will provide slope protection, widening, and realignment, to reduce erosion runoff and downstream sedimentation occurring within the existing channel, along with invasive tree removal. Widening the bottom of the channel will establish an aesthetically pleasing, natural meander with pool areas and riffles. Possible slope protection techniques include a combination of vegetated or articulated block-type slope protection. Following engineering analysis and public input, the county will determine a solution for the erosion problems caused by the sharp bend in the creek, which is causing severe erosion on the north side of the bank near adjacent homes. Alternatives for correcting the problem will likely include the "softening" and realignment of the bend, with a settling pool or by structural means, such as construction of a concrete bank or installation of articulated block to absorb energy.

The proposed project involves the excavation of upland areas to establish a wider and more gradual bank slope conducive to re-vegetation and stabilization. The project site contains native trees such as live oak (*Quercus virginiana*), sweet bay (*Persea borbonia*) and black willow (*Salix Niger*), shrubs such as yaupon (*Ilex vomitoria*), coral bean (*Erythrina herbacea*), bayberry (*Morella cerifera*), and American beautyberry (*Callicarpa Americana*). All excavation and construction activities will be performed within upland areas and no existing natural wetlands will be filled as a result of this project. Approximately 1 acre of woodland will be cleared. Some of the excavated material will be placed in designated upland areas, and the cleared vegetation will be hauled to nearby disposal sites.

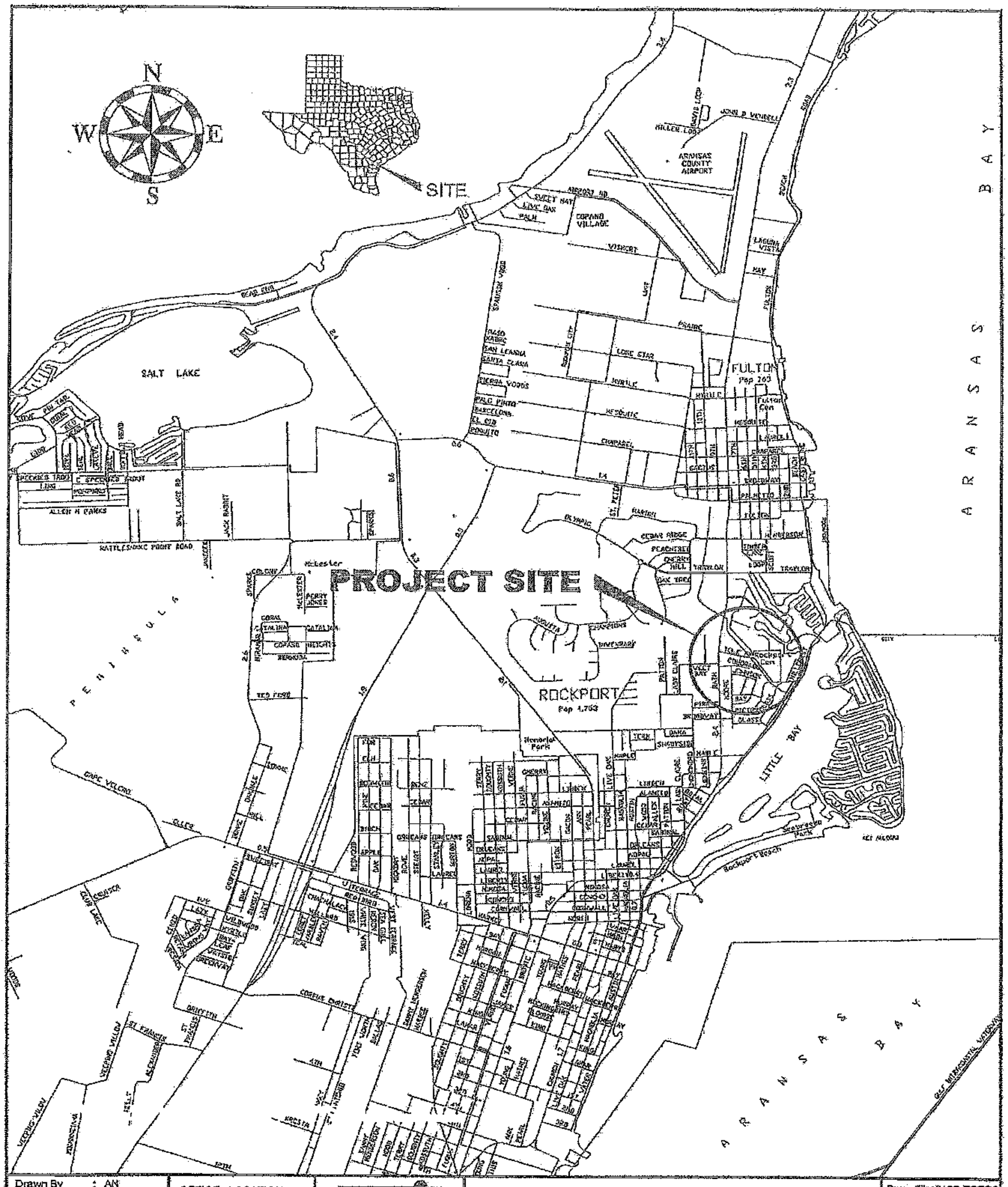
A water quality sampling and monitoring program and QUALHYMO modeling is being proposed as part of the Upper Tule Creek West Improvement Project and West Tule Creek Sediment Trap and Habitat Enhancement Project. The current FY 09 grant CWA Section 319 (h) grant project (West Tule Creek Sediment Trap Project) will be amended to begin the monitoring and modeling program by preparing a QAPP, purchasing testing equipment, installing stream gauges/groundwater elevation monitoring piezometers/soil hydraulic conductive infiltrometer testing, initial work involving the QUALHYMO model and BMP performance assessment and reporting.

This proposed project will involve the majority of actual field sampling and measurements, finalizing the QUALHYMO modeling and BMP performance assessment, and reporting/final report preparation. The QUALHYMO was originally developed for use at a watershed scale and it is therefore watershed oriented. This model is based on a continuous simulation methodology that includes rainfall/runoff and snowmelt processes. It can stimulate water and can add sediments and dissolved constituents to the analysis process. The data from the proposed monitoring task in FY 09 319(h) grant project will help simulate this model. The model will estimate the water quality pollutant loadings in the Tule Creek and load reductions from the Tule Creek West Sediment Pond and Habitat Enhancement BMP (FY 09 319(h) grant project). This model will also help in estimating pollutant reduction from Upper Tule Creek West Widening/Enhancement BMP (Proposed FY 11 319(h) grant project).

An initial and ongoing step in the construction process will involve selected clearing of various invasive trees, including the Chinese tallow, which thrives in river corridors and sandbars and is capable of rapidly replacing existing native vegetation, and Brazilian Peppertree, which threatens the destruction of natural vegetative communities and ecosystems. Eliminating the invasive trees will help provide for the natural colonization of native trees, shrubs, and forbs, which will provide shoreline stabilization, reduce erosion and sedimentation, and filter and uptake pollutants.

The project will require USACE permitting determination and possible permitting. It is possible that the Upper Tule Creek West project area is non-jurisdictional. A permit determination process has been indicated to determine the need for a permit. If a USACE permit is required, it is expected to be a Nationwide Permit, which will be obtained during preliminary engineering design.

It has been shown in numerous studies that river bottom sediments serve as a reservoir for *E Coli* and fecal bacteria. The sediment load reductions realized through this project will decrease the available bacteria reservoir and curtail re-suspension of sediments into the water column. Using literature values Aransas County will analyze bacteria reduction with sediments from the BMPs.



Drawn By : AN	OFFICE LOCATION :	NEI Naismith Engineering, Inc. TBPE - 355	VICINITY MAP	Dwg. File:8162-TCEQ2
Checked By : MV	4501 Gollihar Rd. Corpus Christi, Texas 78411		TULE WATERSHED ROCKPORT, TEXAS	1
Approved By : DES	P.O. Box 3099			Sheet 1 Of 6
Project No. : 8162	Corpus Christi, Texas 78463			
Scale : AS SHOWN	(361)-814-9900			
Date : 7/2009				
Revision : 0				

3.0 Tasks, Objectives and Schedules (Replicate or modify table as needed)	
Task 1:	**Project Administration**
Objective:	To effectively administer, coordinate, and monitor all work performed under this project including technical and financial supervision and preparation of status reports.
Subtask 1.1:	**Project Oversight** – The GRANTEE will provide technical and fiscal oversight of the staff and/or subgrantee(s)/ subcontractor(s) to ensure Tasks and Deliverables are acceptable and completed as scheduled and within budget. With the TCEQ Project Lead authorization, the GRANTEE may secure the services of subgrantee(s)/ subcontractor(s) as necessary for technical support, repairs and training. Project oversight status will be provided to the TCEQ with the Quarterly Progress Reports (QPRs).
Subtask 1.2:	**Quarterly Progress Reports (QPRs)** – Progress will be reported to the TCEQ by the 15th of the month following each state fiscal quarter for incorporation into the Grant Reporting and Tracking System (GRTS). The Reports are to include the following: • Status of deliverables for each task • Narrative description in Progress Report format
Subtask 1.3:	**Reimbursement Forms** - Reimbursement forms will be submitted to the TCEQ by the last day of the month following each state fiscal quarter. For the last reporting period of the project, Reimbursement Forms are required on a monthly basis.
Subtask 1.4:	**Contract Communication** – The GRANTEE will participate in a post-award orientation meeting with TCEQ within 30 days of contract execution. The GRANTEE will maintain regular telephone and/or email communication with the TCEQ Project Manager regarding the status and progress of the project in regard to any matters that require attention between QPRs. This will include a call or meeting each January, April, July, and October. Minutes recording the important items discussed and decisions made during each call will be attached to each QPR. Matters that must be communicated to the TCEQ Project Manager in the interim between QPRs may include: • Requests for prior approval of activities or expenditures for which the contract requires advance approval or that are not specifically included in the scope of work • Notification in advance when GRANTEE has scheduled public meetings or events, initiation of construction, or other major task activities under this contract Information regarding events or circumstances that may require changes to the budget, scope of work, or schedule of deliverables; these events or circumstances must be reported within 48 hours of discovery
Subtask 1.5:	**Annual Report Article** – The GRANTEE will provide an article for the Nonpoint Source Annual Report upon request by the TCEQ. This report is produced annually in accordance with Section 319(h) of the Clean Water Act (CWA), and it is used to report Texas' progress toward meeting the CWA § 319 goals and objectives and toward implementing its strategies as defined in the Texas Nonpoint Source Management Program. The article will include a brief summary of the project and describe the activities of the past fiscal year.
Deliverables	• QPRs • Reimbursement Forms • Annual Report Article (as requested by TCEQ) • Post-Award Orientation Meeting Minutes • Quarterly Conference Call Meeting Minutes

Tasks, Objectives and Schedules (Replicate or modify table as needed)	
Task 2:	**Engineering Analysis, Permitting, Design, and Construction Bid Selection Process**

Objective:	1) To evaluate the project site, along approximately 1,600 feet of creek, through engineering analyses, data collections, surveys, and environmental assessments; and 2) based on recommendations from the engineer as a result of the evaluation, to prepare project designs, obtain permits, and produce plans and specifications, and bid packages for techniques to stabilize the eroding banks. Due to budget constraints the extent of improvements may be limited to 1,000 feet or less of the creek.
Subtask 2.1:	**Preliminary engineering analysis of bank stabilization and slope protection strategies and permitting** - An engineering and environmental analysis will be performed and a preferred vegetated slope protection alternative will be selected based on cost, engineering (soils, slope, anchoring system, and erosion control) environmental and regulatory or USACE permitting considerations. There are various slope protection alternatives that will be evaluated including various types of concrete revetment block or articulated block, geogrid materials, or erosion control mats with various options involving earth retention and revegetation re-establishment. These options involve various degrees of vegetated slope protection as well as habitat establishment along the improved channel bank to provide a stormwater management control benefit by reducing bank erosion and downstream sedimentation. In addition, the application of the desired "vegetated" slope protection alternative involves alternative anchoring systems and appropriate slope and grade considering the channel bank soils and right-of-way considerations. A preliminary design of the preferred alternative will be prepared that will also serve as the proposed project addressed in a permit application to the U.S. Army Corps of Engineers (USACE). Since the project will involve greater than 500 ft. of drainage ditch, a pre-construction notification will be submitted to the USACE to obtain approval under Nationwide Permit No. 41, Reshaping Existing Drainage Ditches.
Subtask 2.2:	**Final design plans and specifications** - Once the USACE-NWP No. 41 approval is obtained, the final designs, plans and specifications will be prepared. The preliminary engineering drawings and construction plans, procedures, and methods outlined in the permit will be further detailed in plan sheets and specifications for purposes of obtaining construction bids.
Subtask 2.3:	**Construction Bid Selection Process** - Contract documents will be prepared to include all the construction plans and specifications including "bidding and contract" requirements, site work and ditch excavation and widening, clearing and grubbing, slope protection and revegetation materials and placement, TPDES Construction Site Permit requirements, and Stormwater Pollution Prevention Plans (SW3P). The Contract Documents will be advertized to receive Contractor Construction bids, and the bids will be reviewed and recommendations provided to the TCEQ and Commissioners Court for action. The recommended and approved construction contractor will be awarded the bid and will enter into a contract with Aransas County as per the Construction Contract Documents and Specifications.
Subtask 2.4:	**Engineering Analysis, Permitting, Design, and Construction Bid Selection Process Report** - The Aransas County will submit a report summarizing Tasks 2.2, 2.2 and 2.3.
Deliverables	• Project Designs and Specifications • USACE Permit • Bid Packages • Engineering Analysis, Permitting, Design, and Construction Bid Selection Process Report

Tasks, Objectives and Schedules - Replicate or modify table as needed	
Task 3:	**Performance Monitoring and QUALHYMO Modeling**
Objective:	To establish pre-construction and post-construction water quality TSS baseline loading data and BMP performance data on the Upper West Tule Project and 2009 West Tule Creek Sediment Trap Project by collecting stream water quality and flow data, groundwater elevation data, soils infiltrometer data, and performing QUALHYMO modeling and assessment of BMP performance for both BMPs.

Subtask 3.1:	**QAPP Updates and Amendments** – There will be two QAPPs, one for monitoring and one for modeling. The QAPP for Modeling and Monitoring will be prepared with FY 09 319 (h) grant project. The Aransas County will provide input to TCEQ 60 days prior to the end of the effective period of the QAPP and develop annual QAPP revisions no less than 45 days prior to the end of the effective period of the QAPP. Amendments to the QAPP and the reasons for the changes will be documented by the County and revised pages will be forwarded to all persons on the QAPP distribution list by the County Quality Assurance Officer. Amendments shall be reviewed, approved, and incorporated into a revised QAPP during the annual revision process or within 120 days of the initial approval in cases of significant changes. *Activities covered under this QAPP:* · Data collection · Evaluating BMP Effectiveness through modeling and monitoring *Tasks/Subtasks covered under this QAPP:* · Subtask 3.2 · Subtask 3.3 · Subtask 3.4 · Subtask 3.5
Subtask 3.2:	**Water Quality and Streamflow Monitoring** - Surface water quality monitoring will be performed at six (6) locations to assess pre-construction total suspended solids (TSS) loading, and post construction TSS loading to assess performance of the Upper West Tule Creek Improvement Project and post construction monitoring of the 2009 West Tule Creek Sediment Trap Project. Potential groundwater piezometer locations are illustrated in Exhibit 2, below. Approximately eight sampling events will be performed to represent baseline dry and wet weather stormwater conditions. The surface water samples will be analyzed for, pH, conductivity, dissolved oxygen, temperature, and oil and grease. Cost estimates reflect a total of 48 stream samples. The streamflow gauge installed with 2009 TCEQ grant funds will be monitored concurrent with monitoring of stream, groundwater piezometers, and rain gauges. The piezometers installation, infiltrometer testing, and testing equipment are to be purchased using the 2009 TCEQ grant funds. A limited amount of post construction West Tule Creek Sediment Trap BMP performance data will be collected with the 2009 TCEQ grant project but most monitoring will be performed concurrent with the pre-and post construction Upper Tule Creek West Widening BMP Project, and post-construction of the West Tule Creek Sediment Trap.
Subtask 3.3:	**Groundwater Piezometer** - The groundwater piezometers installed with 2009 TCEQ grant funds will be monitored and maintained along with rainfall gauges.
Subtask 3.4:	**QUALHYMO Modeling and Assessment** - The QUALHYMO modeling and BMP assessment of both the Upper Tule Creek West Widening Project BMP and Tule Creek West Sediment Trap Project BMP will be finalized to include performance assessment of both BMPs.
Subtask 3.5	**Data Submittals** – Aransas County will review, verify, and validate water quality monitoring data before it is submitted to the TCEQ. Aransas County will submit data to the TCEQ quarterly and at least one month prior to use, or prior to presenting to stakeholders. Aransas County will submit a semi-annual report of water quality data consistent with TCEQ formatting requirements for upload into the Surface Water Quality Monitoring Information System (SWQMIS).
Deliverables	• Draft and Final QAPP Annual Updates • Draft and Final QAPP Amendments • Data Submittals
Tasks, Objectives and Schedules (Replicate or modify table as needed)	
Task 4:	**Construction**

Objective:	To widen and re-slope the ditch, in order to reduce erosion; and to remove invasive trees, in order to allow for the natural colonization of nearby native trees, shrubs, and forbs which will provide shoreline stabilization functions, reduce erosion and sedimentation, and improve water quality conditions in the immediate area and downstream through the filtration and uptake of pollutants (an estimated 800-1,000 feet of creek is expected to be improved).
Subtask 4.1:	**Upland vegetation clearing**
Subtask 4.2:	**Excavation and widening/re-sloping of East side of ditch**
Subtask 4.3:	**Bank Stabilization and Slope Protection**
Subtask 4.4	**Construction Report** - Aransas County will prepare Construction Report summarizing Tasks 4.1, 4.2 and 4.3.
Deliverables	• Photographs documenting excavation and widening of creek • Photographs documenting construction of selected solution for the erosion problems caused by the sharp bend in the creek • Construction Report

*All projects must include a Final Project Report.

Tasks, Objectives and Schedules	
Task 5:	**Final Project Report**
Objective:	To produce a Final Report that summarizes project all activities completed and conclusions reached, and that contains all the reports completed under previous tasks either in the text or as appendices.
Subtask 5.1:	**Draft Report** – The GRANTEE will provide a draft report summarizing all project activities, findings, and the contents of all previous deliverables, referencing and/or attaching them as web links or appendices. This comprehensive, technical report will provide analysis of all activities and deliverables under this scope of work. The report will include the following information: • Title • Table of Contents • Executive Summary • Introduction • Project Significance and Background • Methods • Results and Observations • Discussion • Summary • References • Appendices
Subtask 5.2:	**Final Report** – To revise the Draft Report to address comments provided by the TCEQ Project Manager. The final report will be submitted to the TCEQ Project Manager and subsequently to EPA.
Deliverables	• Draft Report • Final Report

31. Project Goals (Expand from NPS Summary Page)
To improve the water quality in Tule Creek by 1) decreasing erosion of fine sand going from Upper Tule Ditch West to Little Bay by widening and re-sloping up to 1,000 l.f of creek bank; 2) correcting a sharp turn in the creek which is causing severe erosion; and 3) re-vegetating the creek banks, providing for the natural colonization of native trees, shrubs, and forbs, which will provide shoreline stabilization, reduce erosion and sedimentation, and filter and uptake pollutants.

32. Measures of Success (Expand from NPS Summary Page)

1) Tule Ditch re-sloped, widened, and realigned.

2) Effectiveness of re-sloping and widening the project area in reducing erosion.

3) Elimination of Chinese tallow, Brazilian Peppertrees, and other invasive species.

The data from the proposed monitoring task in both the FY 09 and FY 11 319(h) grant projects will be used to complete the simulate QUALHYMO modeling and BMP performance assessment. The model will estimate the water quality pollutant loadings in the Tule Creek and load reductions and performance from Upper Tule Creek West Widening/Enhancement BMP as well as the 2009 West Tule Creek Sediment Trap Project.

33. Estimated Load Reductions Expected (Only applicable if demonstration BMPs will be implemented)

A TSS concentration of 165 mg/L was used as the influent TSS concentration value for the Tule Creek sediment trap BMP. It is possible to estimate total loads discharged by Tule Creek now and with the sediment trap in place based on this estimate and on an estimate of flows from the watershed. Taking 35 inches of rain a year, with an estimated volumetric runoff coefficient of about 0.75, and assuming the sediment trap captures 1/3 of the events, all that is needed is an estimate of removal rate to enable this calculation. It is assumed that for this small trap, coarse materials will be removed essentially completely, but that finer materials will be reduced by about 50%. Again, all of these numbers will need to be verified or updated by actual numbers from the site, but the suggested estimate of load from Tule Creek that result is about 2.1 million pounds of sediment without the trap, and about 1.6 million pounds of sediment with the trap in place, per year.

The above numbers are indicative, but need to be updated with closer estimates. The field data associated with this monitoring program will be used along with the QUALHYMO model for that purpose. This model was originally built for BMP analysis on a continuous simulation basis, and is able to assess settling and decay removal processes in a BMP as well as watershed flow generation and receiving water transport. Recent funding by USEPA and the City of Austin as well as other public entities has expanded the capabilities of the tool, in particular in its ability to represent portioning of contaminants between fluid and solid phases. Sediments can be simulated in 5 size fractions, and are tracked independently. Each fraction is removed according to user specified settling velocities. BMP characteristics can include by-pass, overflow, through-flow, exfiltration and regular discharge. Losses to evapotranspiration are also calculated on a continuous basis. In addition, the model has an effective set of calculation modules that enable simulation of distributed BMPs (LID methods) and instream characteristics. The instream computations include several sediment transport modules able to represent stream power, excess critical shear, and sediment transport, which will be useful in this project in the event that erosive potential and erosive loads from the Tule creak stream bank or bottom are to be calculated. For the present, as a part of this monitoring program, it is intended that the tool will be used to estimate loads into the sediment trap based on monitored flow and suspended solids data, and to simulate removal in the trap as a function of grain size, particle density, trap volume, outlet characteristics, mixing, through flow rate, overflow rate and sediment concentration distribution.

Aransas County is committed to providing all the modeling results- quality and quantity, as well as project designs and recommended projects. A range of stormwater quality mitigative improvement projects have been identified along the Tule watershed including areas surrounding Little Bay. The suite of improvement projects includes the BMPs included in this scope of work. The water quality sampling and monitoring recommended in the ACRSMP will further substantiate and support implementation of continued projects.

It has been shown in numerous studies that river bottom sediments serve as a reservoir for *E Coli* and fecal bacteria. The sediment load reductions realized through this project will decrease the available bacteria reservoir and curtail resuspension of sediments into the water column. Using literature values Aransas County will analyze bacteria reduction with sediments from the BMPs.

APPENDIX B
MAP OF SAMPLING SITES

See last page of Appendices

APPENDIX C
CORRECTIVE ACTION STATUS REPORT

Corrective Action Status Table

Corrective Action #	Date Issued	Description of Deficiency	Action Taken	Date Closed

APPENDIX D
QUALHYMO USER MANUAL AND DOCUMENTATION
VERSION QUALHYMO0777V1C
December 2009

QUALHYMO USER MANUAL AND DOCUMENTATION

December, 2009

QUALHYMO User Documentation

Foreword

This is a concise manual that documents critical elements of a development version of the QUALHYMO model. It identifies a number of features that differ from earlier versions of the model, as well as some of the basic details of model input and operation. Users making reference to this document should verify that it corresponds with the model version they are using; after January 2009 users should refer to http://qualhymo.watertoolset.net for an updated manual (and corresponding model) if available.

License

A version of the license that users must agree to to use this manual and/or QUALHYMO is appended. Users are cautioned that there may be updated or different versions of the manual available, and that the license which appears when the model is installed may differ from the text appended to this manual, so they should verify the license and version they have in hand prior to using the model.

Table of Contents

1 Background

QUALHYMO was originally developed some 25 years ago as a research tool. It was intended to enable the rapid testing of various water quality algorithms related to BMP performance assessment. For that purpose it was decided to create a modular tool in which different sub-systems could be rapidly and easily coded, implemented, and tested on a common basis. The original QUALHYMO tool was developed with that in mind. The selected structure for this has proven to be robust and reliable, and lends itself well to use in assessing watershed level water quantity and quality problems.

Over the 20 years or so following the initial release of the model, the business activities of the original author tended to conflict with further development of the tool, and no substantive development was attempted by him during that period. Nevertheless, a number of descendant versions or variations of QUALHYMO seem to have emerged over that time. The code to the original model was available to developers and users, and it seems that an undetermined number of alternative versions of QUALHYMO have appeared as a result. No endorsement (or otherwise) of such alternatives will be attempted by the authors, and should not be interpreted from this manual. However it is noted that a casual survey suggests that these versions vary in their approaches to coding and simulation. It is not known to the authors of the present QUALHYMO effort how those multiple versions fared in practice, but discussions with individuals in the field suggested that the multiplicity of versions has led to a multiplicity of issues, not the least of which was a lack of confidence regarding which version of the tool was which.

As the practice of water resources has matured, the need for a tool like QUALHYMO for practical applications has been reinforced. A model targeted at BMP evaluation and designed for rapid simulation of long term quality/quantity behavior has emerged as a requirement in many situations. The decision was made, therefore, to update QUALHYMO into a single current version.

This re-development posed numerous challenges, not the least of which was the need to provide an upward migration path so that users accustomed to certain features could still have access to them when the new QUALHYMO was released. To the extent possible, upward compatibility has been preserved. As a part of this, variable names exposed to the user have for the most part been preserved (at least in the user manual). The underlying code is another matter. An immediate effort in developing current version was to retain no code that is not directly attributable to the identified authors. This means that the authors can release the model for general use under suitable license conditions. It also means, however, that the model may in some instances produce results that are somewhat different from those other variations of the earlier tool may generate. QA/QC procedures used in developing this tool have been substantial, and we believe that it can be relied on to produce reasonable results when applied by a knowledgeable user, but as noted in the license for the model and documentation, it is up to the user to ensure that the model is effective for the purpose for which they apply it and that the answers they generate are what they require.

2 Installing the Model

The model is provided in the form of a .zip file, 'installset.zip'. This can be downloaded from the http://qualhymo.watertoolset.com web site. To install QUALHYMO, place the zip file in any location that you prefer, and unzip the file. It is then ready to run. It is not necessary to install the software otherwise.

> Hint: Installed this way, the model can be run in its default configuration, and this is a good way to begin exploring the model and its use. However, it should be noted there are numerous other ways the model can be installed and run, at the discretion of the user. Appendix A provides details on how the model can be installed in ways that differ from the default case.

When the file is unzipped, you will see a folder 'InstallSet' appear in the directory you have selected as the unzip location. Depending on where you unzipped the model, that might look as follows:

Name	Size	Type	Date Modified
InstallSet		File Folder	10/14/2007 6:49 PM
InstallSet.zip	870 KB	WinZip File	10/14/2007 12:51 PM

If you look inside the InstallSet folder, you'll see the following:

Name	Size	Type	Date Modified
License		File Folder	10/14/2007 7:06 PM
Manual		File Folder	10/14/2007 11:34 AM
TestData		File Folder	10/14/2007 7:07 PM
QCONTROLFILE.TXT	1 KB	Text Document	10/14/2007 12:49 PM
QUALHYMO0777.exe	1,032 KB	Application	10/14/2007 11:27 AM

The three folders in the InstallSet folder are as follows:

- The folder 'License' contains the license under which QUALHYMO and this manual and associated documents must be accessed and used. Read it, and if you don't agree with it, don't use either the model or the manual further.
- The folder 'Manual', contains this manual or one like it.
- The folder 'TestData' contains a test data set that can be used to verify that the model is correctly installed and functioning.

Testing is described further below, and model use is described further in Chapter 2.

For now, you should test the model. There are two ways to do this:

- Double click on the QUALHYMO0777.exe file name in Windows Explorer, or else
- open a command window, navigate to the location of QUALHYMO0777.exe and

enter the command 'QUALHYMO0777' followed by the return key.

If you used Windows Explorer and double clicked to run the model, you should see a command line window pop up as follows and then after a few minutes disappear:

```
C:\Data\TestLocation\InstallSet\QUALHYMO0777.exe
Portions of this program include material copyrighted (c) by Absoft Corporation
1988-2001
THIS RUN WILL USE CONTROL AND LOG FILES: QCONTROLFILE.TXT AND QRUNLOG.TXT
POND    200   CALLED
```

If you ran the model from the command line, you should see something similar to the example below, but the window will remain in place after the run has completed:

```
Command Prompt
C:\Data\TestLocation\InstallSet>QUALHYMO0777
Portions of this program include material copyrighted (c) by Absoft Corporation
1988-2001
THIS RUN WILL USE CONTROL AND LOG FILES: QCONTROLFILE.TXT AND QRUNLOG.TXT
POND    200   CALLED
0

C:\Data\TestLocation\InstallSet>
```

Either way, if you look in the directory in which the model was installed, you'll see the following files:

Name	Size	Type	Date Modified
License		File Folder	10/14/2007 7:07 PM
Manual		File Folder	10/14/2007 7:07 PM
TestData		File Folder	10/14/2007 7:22 PM
COMMAND.TBL	1 KB	TBL File	10/14/2007 7:22 PM
PONDRESULTS.BIN	14,967 KB	BIN File	10/14/2007 7:22 PM
QCONTROLFILE.TXT	1 KB	Text Document	10/14/2007 12:49 PM
QRUNLOG.TXT	2 KB	Text Document	10/14/2007 7:22 PM
QUALHYMO0777.exe	1,032 KB	Application	10/14/2007 11:27 AM

The new files that have appeared indicate that the model has been correctly installed and correctly run. If you look further, in the file QRUNLOG.TXT, you'll see a series of diagnostics that will end with the following lines:

```
=== POND COMMAND
  - RETURN FROM COMMAND INTERPRETER, NER,NCODE:   0   22
=== TIME STAMP Sun Oct 14 19:22:35 2007===
=== POND STATS COMMAND
  - RETURN FROM COMMAND INTERPRETER, NER,NCODE:   0   23
=== TIME STAMP Sun Oct 14 19:22:35 2007===
=== IDENTIFY SERIES COMMAND
  - RETURN FROM COMMAND INTERPRETER, NER,NCODE:   0   23
=== TIME STAMP Sun Oct 14 19:22:35 2007===
=== IDENTIFY SERIES COMMAND
  - RETURN FROM COMMAND INTERPRETER, NER,NCODE:   0   21
=== TIME STAMP Sun Oct 14 19:22:35 2007===
=== RUN ENDED NORMALLY Sun Oct 14 19:22:35 2007===
```

The absence of messages indicating problems confirms that the model has indeed been correctly installed and run.

3 Running the Model

QUALHYMO is invoked from the command line of a Microsoft Windows operating system, by typing the command 'QUALHYMO0777' in a command line window or by double clicking on the 'QUALHYMO0777.exe' file from Windows Explorer or another suitable file manager. This version has been tested on Windows XP. Appendix A provides details on model control and ways that the model can be installed in other than the default configuration. The following discussion assumes you are operating in the default configuration. Section 3.2 below provides a discussion about alternative interfaces.

3.1 Input Files

If you look in the TestData folder, you'll see the following files if the model has not been run:

Name	Size	Type	Date Modified
TestEvap.evp	10 KB	EVP File	10/4/2007 1:20 AM
TestInput.inp	9 KB	INP File	10/14/2007 11:49 AM
TestPrecip.pre	1,560 KB	SQL Server Replicat...	10/4/2007 1:20 AM
TestTemp.tmp	908 KB	TMP File	10/4/2007 1:21 AM

or the following files if you did a test run with the model:

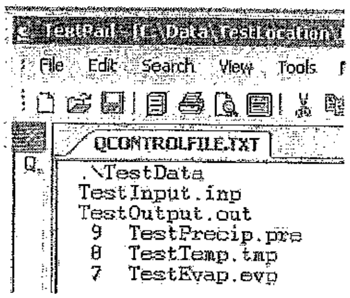
Name	Size	Type	Date Modified
QBIN1.BUF	15,619 KB	BUF File	10/14/2007 7:22 PM
QBIN2.BUF	15,619 KB	BUF File	10/14/2007 7:22 PM
TestEvap.evp	10 KB	EVP File	10/4/2007 1:20 AM
TestInput.inp	9 KB	INP File	10/14/2007 11:49 AM
TestOutput.out	77 KB	OUT File	10/14/2007 7:22 PM
TestPrecip.pre	1,560 KB	SQL Server Replicat...	10/4/2007 1:20 AM
TestTemp.tmp	908 KB	TMP File	10/4/2007 1:21 AM

You will not need to deal with the QBINx.BUF files unless you are an advanced user. The format of those files, however, is discussed in Chapter 4 of this manual if you are interested in their make-up and function. The file TestOutput.out is an output file generated by the model, and is where you'll find the results of a QUALHYMO run. The other files are:

- TestPrecip.pre – a rainfall record series,
- TestEvap.evp – an evaporation record series,
- TestTemp.tmp – a temperature record series, and
- TestInput.inp – an input deck that controls the model run.

The formats of the first three files is described elsewhere in this manual. They should be replaced with files appropriate for the model run you have decided to do. The fourth file is the file that controls what simulations are to be done, and is the way you control the model.

If you have renamed any of these four files, then you need to adjust a control file. That file is the QCONTROL.TXT file that is located in the directory where you unzipped the model. If you examine QCONTROLFILE.TXT created in the default install, you'll see the following:



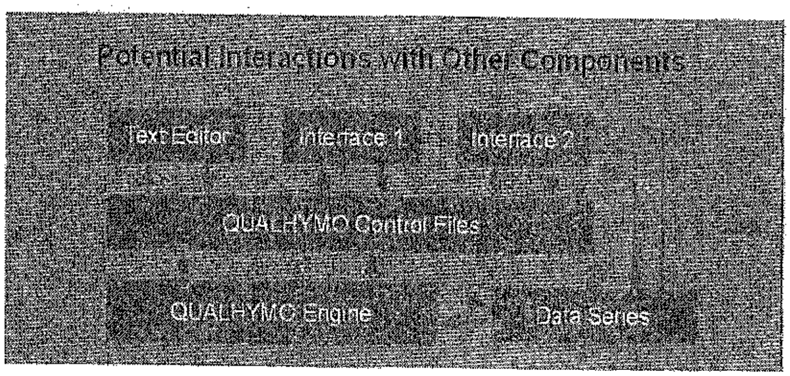
This file is how the model knows where to look to find the time series and input files that control a model run. If you have renamed any of the four files discussed above (TestInput.inp, TestPrecip.pre, TestTemp.tmp, or TestEvap.evp), you must adjust the names in the QCONTROLFILE.TXT so that it corresponds to the new file names you have chosen.

The TestOutput.out file name in this file can be changed to any valid file name, and the model will deposit its output results in a new file of that name.

More significant changes are possible by appropriate choices in the use of the QCONTROLFILE.TXT file. These are discussed in Appendix A.

3.2 Alternative Interfaces

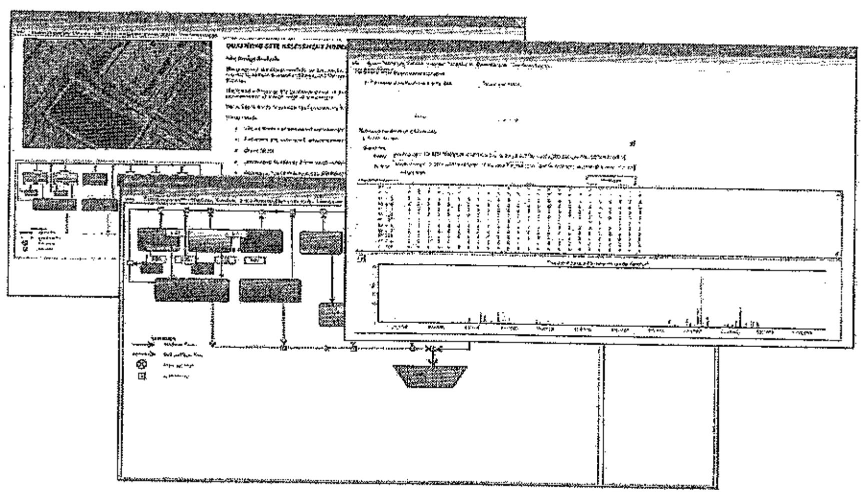
QUALHYMO is intended to function primarily as a computational engine. It is fully capable as a tool using the commands described in section 4 and input as discussed in section 3.1 above. In some communities the manipulation of text files is a preferred approach, and is held to be efficient and exact. However for many users the manipulation of text files in their raw form will seem to be awkward and a visual interface would be preferred. To support this kind of user, it is anticipated that alternative interfaces may be developed and will be available. As noted in the sketch figure below, the data set documentation makes it possible to develop interfaces that will feed off the QUALHYMO engine in several ways.



In the above example, the control files could be manipulated directly with any **text editor**, but two other possibilities also exist. In **Interface 1**, control files are edited using some preferred user interface. In **Interface 2**, the control files are manipulated, but the raw data seres themselves are also accessed. Present efforts in the development of QUALHYMO have been focused on the engine, and on making it easily possible to add new computational capabilities. In the future, there may be expanded efforts on interface. Development. In the mean time, several alternative interfaces are known to have been developed.

One, illustrated with some screen captures below, is the Water Balance Model. This is a fully developed interface made available through a web site that can be found at http://www.waterbalance.ca/waterbalance/home/wbnIndex.asp. The WBM provides a mature and capable interface that exposes many of the QUALHYMO engine capabilities. It functions much as Interface 1 in the figure above does – it writes data to and extracts data from the QUALHYMO text files, and relies on QUALHYMO to extract information from the model time series files.

Another interface that is not publicly available but that further illustrates the potential for interface development is illustrated below. This version is focused on a specific set of engine capabilities, and was developed using MIcrosoft Visual Basic as a stand alone local application. This tool not only edits the QUALHYMO control files, it operates directly on the model time series much as the **Interface 2** option described above does.



A third known interface is JAVA based, and therefore platform independent, and may be made available publicly in the near future.

Either way, the salient point is that there are numerous possibilities for interface development, and the intent that the QUALHYMO concept and documentation enable this kind of extension has been demonstrated.

4 Model Commands

4.1 An Overview of the Input File

QUALHYMO is command oriented. Commands and data are provided in the input file which is specified in the control file as discussed in section 3.0 and Appendix A. The model reads each command and its associated data and carries them out in the sequence in which they appear in the input file.

4.2 Input File Syntax

Users of earlier versions of QUALHYMO will probably be familiar with an input syntax in which the first 20 columns of every non-comment line is reserved for commands. This has changed. Following the old syntax rules will still work, but a new syntax has been implemented. The new syntax has more flexibility, and enables further future refinements. (It is noted for those familiar with old versions of code that the HONDO routine has been dropped in favor of an entirely new system.)

The input file can contain any printing character and blanks. The command parser extracts three kinds of information from the file:

- command names
- numbers
- strings

As well as this information, the user may if they wish add non-numeric text to the file to explain what the run is doing.

Command Name Rules:

Commands are entered by starting a new line, and entering the command name beginning in column 1. Following the command name are the parameters needed by that command. Continuation lines, if needed, are indicated by leaving a space in column 1.

Commands include a range of capabilities, including those listed below and some others, and can be entered in whatever number and order makes sense to the user to accomplish the model run. The model will run each command as it encounters it:

```
START
STORE
GENERATE
PRINT SPAN
PLOT SPAN
ADD SERIES
POND
REACH
CALIBRATE
POLLUTANT SERIES
SPLIT SERIES
DUMP PRINT
EXCEEDANCE
FULL POND SPAN
MAXMIN
PRINT SERIES
FINISH
CALC POND STATS
IDENTIFY SERIES
PRINT MODEL DETAILS
```

String Value Rules:

Strings must be entered in the following form:

<stringname=stringvalue>

- Values are always paired, with the first term taking the value of the name of the string, and the second the value of the string itself.
- The delimiters identifying the string name and value are '<','=' and '>'. The string name begins immediately after the '<' and ends immediately before the '='. The string value begins immediately after the '=' and ends immediately before the '>'.
- Quote marks are not required to delimit either the name or value of the string. The '<','=' and '>' characters are the only delimiters that are needed or allowed. If quote marks are added, they will be interpreted as character values and retained as part of the string.
- Blanks within a string are meaningful.
- String entries can appear one per line on any line of a command, anywhere on the line (except embedded within a command name or numeric value).

In parsing commands, QUALHYMO first reads and extract strings, and then reads numbers as noted below. The string name must be exactly as noted in the manual for the command for which it is being applied, and the string value must be meaningful for the purposes of the command. An example of a string value is:

<DIURNAL DEMAND=C:DATA/MY_PROJECT/QUALHYMO/FILE NAME.TXT>

which is one of two values used in the 'WATER REUSE' command. In this case, the string name is

'DIURNAL DEMAND'

and the string value is

'C:DATA/MY_PROJECT/QUALHYMO/FILE NAME.TXT'.

Numeric Value Rules:

Numbers must be entered in integer or floating point formats (including scientific notation in the form of #.###E+##). Numbers must be entered following a space at the end of each command. Numbers not required for a command must not be entered in the file or they will be interpreted as data and the model will attempt to use them as such.

> Hint: Adding extraneous numbers in comments is a common cause of user errors, and sometimes occurs if a user adding a comment includes a number – for example a version number for the run. If this kind of input is desired, it must occur in a comment line as noted below.

Comment Rules:

There are two kinds of comments that are allowed in the model input file:

- ***Comment lines*** can be added. They can be added between commands and are identified by an asterisk (*) in the first column of the line. Comment text, including numbers, can be entered in columns 2 though 80, and can contain any content since they are ignored by the model.
- ***Comment text*** can be added. This can consist of any non-numeric text inserted after the command name and before, between or after the numeric values provided by the user.

The first few lines of a typical input file illustrate one correct use of the syntax rules:

```
*
*
*  ******************              QUALHYMO0777          **********************
*          ====     File: RunFile22.dat               ====
*          ====     Rain File:CAL-RAIN.PRE            ====
*          ====     Snowmelt FILE:CAL-TEMP.TMP        ====
*******************************************************************************
START               START DATE OF SIMULATION          60  1  1
                    END DATE OF SIMULATION            95  5 31
                    RAINFALL WILL BE READ ON DEVICE   IRAIN  9
                    PRECIP IS IN AES HOURLY FORMAT    IPFORM 1
                    FLOW FILE WILL BE READ ON DEVICE  IFLOW 10
```

> Hint: Users often find it is useful to develop a well commented input file and then use it as a template. For different runs or projects, all that needs to be changed in each command are the numerical values.

This is well organized and makes it easy to read the file contents without reference to the user manual. It also contains comments that document what the run used as input information. To illustrate the flexibility of the input system, it is noted that the following line is exactly equivalent to the above excerpt as far as the model is concerned. It is, however, not as user friendly.

```
START 60 1 1 95 5 31 9 1 10
```

This approach to data entry has proven to be a very efficient way to run models and will be maintained in future versions of the tool.

4.3 Commands

The following sections provide the details of model commands. ***NOTE: In this manual, not all commands contained in earlier model versions are documented. Care should be used in attempting to apply commands not documented in this manual with this version of the model.***

In the tables, there are three colors used to facilitate interpretation:

- Blue sections indicate ***numeric values*** that must always be provided by the user.
- Yellow sections indicate ***numeric values*** that may or may not be required. The text explains when the yellow sections are/are not required.
- Green sections indicate ***text string values*** may be needed; string values are only used in some commands.

For convenience, the commands that are available are grouped into three categories:

- Control commands – those commands that help the user manage the run or set parameters (START a run, FINISH it, and so on)
- Simulation commands – those commands that represent physical phenomena in the watershed (WATERSHED flows, POND behavior and so on)
- Interpretation commands – those commands that provide information on the time series files that the model generates (STATISTICS and so on)

4.3.1 Control Commands

4.3.1.1 The START Command

Purpose:

This command regulates many factors that persist over the course of a model run. It identifies the span of the simulation, provides information on file numbers, and other controlling information.

Use:

The START Command ***should*** be the first command, but can be preceded by commands that don't require information contained on the START command (e.g. IDENTIFY SERIES). It may be repeated at other locations and any new values take effect from that point on.

Numerical Values:

START Command Information				
Parameter	**Value(s)**	**Units**	**Effect**	**Requirements**
IGY1	0 or a valid year	none or year	Controls run span	• If IGY1<>0, the simulation will run for a set period • If IGY1=0, the simulation will run for the whole span of available input data.
IGM1 IGD1 IGY2 IGM2 IGD2	1 through 12 1 through 31 a valid year 1 through 12 1 through 31	month day year month day	n/a	• If IGY1=0 this block must be omitted • IGY1,IGM1 and IGD1 must represent a valid date that precedes a valid date represented by IGY2,IGM2 and IGD2 • The rainfall data provided by the user must encompass the dates provided here.
IRAIN	integer	none	Identifies rainfall file	• Must match value specified in control file (see section 2 of this manual) • Provide dummy value even if data is not used
IPFORM	integer 1 or 2	none	Specifies format of rainfall file	• If IPFORM=1 AES condensed hourly format will be expected • If IPFORM=2 HEC 'STORM' hourly format will be expected
IFLOW	integer	none	Specifies input value for flow file	• Must match value specified in control file (see section 2 of this manual) • Provide dummy value even if data is not used
ITFORM	0, 1 or 2	none	Specifies format of temperature file	• If IPFORM=0 temperature will not be expected • If IPFORM=1 AES condensed hourly format will be expected • If IPFORM=2 HEC 'STORM' hourly format will be expected
IDOEVAP	0, 1 or 2	none	Specifies catchment evaporation options	• If IDOEVAP=0 evaporation will not be applied to catchment calculations • If IDOEVAP=1, evaporation will be applied to catchment calculations

				• *NOTE:* ○ *If IDOEVAP=0 CET, CETIMP and CETPER in GENERATE COMMAND MUST BE SET.* ○ *If IDOEVAP=0, CET, CETIMP and CETPER in GENERATE COMMAND MUST BE ELIMINATED.*
CPAN EVAP (12 values)	real between 0 and 1 real >=0	none mm/ month	Pan evaporation correction coefficient for catchment	• If IDOEVAP=0 this block must be omitted • If IDOEVAP=1 ○ CPAN and 12 EVAP values are required • If IDOEVAP=2 ○ CPAN is required but the 12 PEVAP values in this block must be omitted ○ the evaporation file specified in the control file will be read for GENERATE calculations
EVAPCASE	0 , 1 or 2	none	Specifies pond evaporation options	• If EVAPCASE=0 evaporation will not be applied to calculations in POND command • If EVAPCASE>0, evaporation will be applied to calculations in POND command
PPAN PEVAP (12 values)	real between 0 and 1 real >=0	none mm/ month	Pan evaporation correction coefficient for POND	• If EVAPCASE=0 this block must be omitted • If EVAPCASE=1 ○ PPAN and 12 PEVAP values are required • If EVAPCASE=2 ○ PPAN is required but the 12 PEVAP values in this block must be omitted ○ the evaporation file specified in the control file will be read for POND calculations
IFDECA	integer 0 or 1	none	Controls pollutant simulation	• If IFDECA=1, a constituent that is removed as a first order decay process will be simulated. • IF IDECA=0, a first order constituent will not be simulated
DECAYK	real >=0	/day	First order decay coefficient	• If IFDECA=0 this value must be omitted
IFSEDT	integer 0 or 1	none	Controls sediment simulation	• If IFSEDT=1, sediments will be simulated • If IFSEDT=0, sediments will not be simulated.
SEDSET (5 VALUES) SEDDIS (5 VALUES)	real >=0 real >=0	m/s none	Effective sediment settling velocity Mass fraction of total sediment	• If IFSEDT=0 this block must be omitted • SEDSET(1) must match SEDDIS(1), SEDSET(2) must match SEDDIS(2), and so on to SEDSET(5) must match SEDDIS(5),

4.3.1.2 The FINISH Command

Purpose:

This command ends a run. As soon as it is encountered, the model halts.

Use:

The FINISH Command can be entered anywhere in the input deck, and that point becomes the effective end of the file. Normally, the FINISH command will therefore be added as the last line in the input file. However, this command can also be entered earlier in the deck as a convenience if the user wants to run the model up to a certain point and then stop. This might commonly happen during watershed calibration runs, if commands later in the deck are not meaningful until the calibration is completed.

As noted below, the FINISH command has no parameters.

Numerical Values:

FINISH Command Information				
Parameter	Value(s)	Units	Effect	Requirements
n/a	n/a	n/a	n/a	This command has no parameters.

4.3.1.3 The IDENTIFY SERIES Command

Purpose:

This command allows users to access and read the metadata associated with a QUALHYMO series file.

Use:

Experience has shown that associating metadata with a series file can avoid confusion as to what the file was, how it was generated, and other key data that might be useful at some time after the work has been done. Making those data accessible can involve a huge range of technologies and options. In this case, it was decided to embed the metadata directly in the file, as discussed in section 4 below (Model Unit Files). Since the files are unformatted binary files, they cannot be readily read (although interested users can 'see' certain formatted information on the files). To make the metadata directly accessible, this command has been developed. Invoking it produces output as shown in the figure below.

```
*** SERIES HEADER INFORMATION BEGINS
SERIES INTERNAL NAME IS              :  101
SERIES TIME STEP (HOURS) IS:         :  1.00000
SERIES CREATION COMMAND WAS          : GENERATE
SERIES FILE WAS CREATED ON           : Sat Jul 14 09:25:35 2007
INPUT FILE CREATING SERIES WAS       : REGEN.INP
MODEL VERSION WAS                    : QUALHYMO0777V1AB40
COMPILER VERSION WAS                 : ABSOFT 10.00.07
*** SERIES HEADER INFORMATION ENDS
```

The content is self explanatory. It is noted that the mechanism chosen for embedding this information will support substantial long term additions with only a limited risk of losing downward compatibility.

Numerical Values:

IDENTIFY SERIES Command Information				
Parameter	Value(s)	Units	Effect	Requirements
ID	A valid series ID	none	extracts series file metadata	• a current and compatible QUALHYMO series file • NOTE: Any properly identified file that exists in the project workspace will be extracted. This need not be from a current run, it can be a legacy series left on the disc

4.3.1.4 The PRINT MODEL DETAILS Command

Purpose:

This command allows users to have the model issue a set of details that document the major facts of the current model run.

Use:

Project documentation is a key element of professional practice, since the user is responsible for maintaining accurate and effective records as to the intent and outcome of their modelling work. Users will typically have practices in place that address this. As a supplement to those practices, it was recognized that an easy way to embed basic run information in a QUALHYMO output file would be useful. This command does that. It generates some essential information for the run. A typical output might be as follows:

```
*** MODEL INFORMATION BEGINS
INPUT FILE FOR THIS RUN IS      :REGEN.INP
THIS RUN STARTED AT             :Tue Jul 17 22:48:05 2007
THIS MODEL VERSION IS           :QUALHYMO0777V1AB42
THE COMPILER USED ON THIS BUILD:ABSOFT 10.00.07
FILE ASSOCIATIONS ARE           :
   ID  9  = RAIN.PRE
   ID  8  = TEMP.TMP
   ID  7  = EVAP.TXT
*** MODEL INFORMATION ENDS
```

The content is self explanatory. It is noted that the mechanism chosen for embedding this information will support substantial long term additions with only a limited risk of losing downward compatibility.

Numerical Values:

PRINT MODEL DETAILS Command Information				
Parameter	Value(s)	Units	Effect	Requirements
n/a	none	none	extracts and prints basic model run information	• none

4.3.1.5 The FLOW IMPORT Command

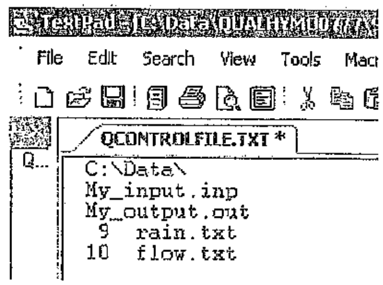
Purpose:

This command allows users to import a free format series of flow records into the internal QUALHYMO format.

Use:

Data must be entered in three places, and the source file must be provided.

1. The name of the flow file is entered in the control file. The control file is described in section 3.1 above and in Appendix A2 below. An example of a typical control file is shown to the right. In this example, the file number (10) and file name of the flow records file to be imported (flow.txt) appear on the last line of the control file.



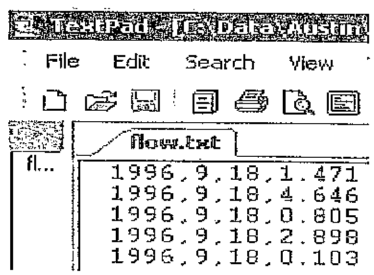
2. The START command (see section 3.2.1 above) indicates the number of the flow file; this number must match the number provided in the control file (in this example, 10).
3. Finally, to access and import data from the file, the FLOW IMPORT command is entered as described below.

Numerical Values:

FLOW IMPORT Command Information				
Parameter	Value(s)	Units	Effect	Requirements
ID	A valid series ID	none	ID for flow series to be imported	
JSER	integer > 0	non	Number of flow series to be imported	
DT	Time step of the imported series	hours	Integer divisor of 60 mins > 5	
ICONVERT	0,1	none	0 means metric data assumed; 1 means convert from	

The file to be imported must be a space delimited or comma delimited ASCII file, containing on each record the year, month, day, and flow values. A suitable example is shown to the right. Note that the file name (flow.txt) matches the name specified in the control file.

WARNING: In importing data, little data checking is done, so the user must ensure the records in the source file are as they should be.



4.3.1.6 The GET ALVI DATA Command

Purpose:

This command allows users to import data in a specific format developed in the course of a specific project carried out by a particular QUALHYMO user. It is not expected to see use in its present form other than in that project, but may be replaced in the future with a new and more generic equivalent.

Use:

When invoked, the command imports data from a user specified input flow file and converts it to an internal QUALHYMO format. The QCONTROL.TXT file specifies the name of the input flow file, which has an identifier of 10. In the input deck, the user provides information on the number of sets to be created (NUMSETS), and for each set the identifying information (ID and ISER info) plus a FACTOR for flow computation. Time step is not provided as this is calculated from the input flow file itself.

The anticipated flow import format is typified by the following records:

```
1/1/1998 1:00,0.011111e+000,0.001111e+000
1/1/1998 2:00,0.066433e+000,0.005607e+000
1/1/1998 3:00,0.091802e+000,0.009053e+000
```

These records include date (mm/dd/yyyy), time (hh:mm), flow at the top of the reach and flow laterally. The lateral flow is multiplied by the FACTOR, and added to the flow at the top of the reach. The total flow so calculated is assigned to the series that is generated. Since quality information is not provided, quality values are set to zero.

Numerical Values:

GET ALVI DATA Command Information				
Parameter	**Value(s)**	**Units**	**Effect**	**Requirements**
NUMSETS	integer	none	Number of series to be created	Must range from 1 to 10
IDOUT(i), ISER(i), FACTOR(i) where i=1 to NUMSETS	a valid series ID integer real	none none none	Series ID, ISER and FACTOR for creation	The total flow is created by adding the first flow from each record with the second flow multiplied by the FACTOR FACTOR(i) must be >=0, and will typically be <=1

4.3.2

4.3.3 Simulation Commands

4.3.3.1 The POLLUTANT SERIES Command

Purpose:

This command allows users to specify the parameters and relationships that govern pollutant generation from a particular land use. It does not actually do any simulations, but it does contain information that is used in several of the simulation commands so it is included here for convenience.

Use:

The user provides information as to the constitutent being simulated (first order constituent or sediment) and the equations being used (build-up washoff or rating curve) as well as the parameters for each. The model stores these, and uses them for simulation in several subsequent commands (examples are GENERATE, WATERSHED and POND).

Numerical Values:

POLLUTANT SERIES Command Information				
Parameter	**Value(s)**	**Units**	**Effect**	**Requirements**
JCASE	integer 1<= JRATE<=6	none	identifies series being entered	• if JCASE=1, 1st order from impervious area • if JCASE=2, 1st order from pervious area • if JCASE=3, sediment from impervious area • if JOASE=4, sediment from pervious area • if JCASE=5, 1st order in base flow • if JCASE=6, sediment in base flow
IWM	integer1 or 2	none	sets washoff method	***Omit this value if JCASE=5 or 6***
PCO	real >0	mg/l or no/dl	sets washoff coefficient	
PEX	real ≥0	none	sets washoff exponent	
IBM DAYSIN PMAX PK1	integer 1 or 2 integer>=0 real>0 real>=0	none days varies none	sets buildup method varies	***Omit this block if JCASE>4 or IWM=1*** • if IBM=1 $PBUILD = \min(PK1 \times DAYSIN^{PK2}, PMAX)$ • if IBM=2 $PBUILD = PMAX \times (1 - e^{-DAYSIN \cdot PK1})$ *WITH PBUILD AS THE AMOUNT OF BUILDUP AFTER DAYSIN DAYS, AND UNITS ARE AS APPROPRIATE IN EACH CASE*
PK2	real>0!	none		***Omit this if IBM=2 or JCASE>4 or IWM=1***

4.3.3.2 The GENERATE Command

Purpose:

This command allows users to simulate runoff from a watershed.

Use:

This provides the ability to represent long term continuous flow from a watershed. It is not intended to provide an ability to simulate detailed urban networks as might be done with the SWMM model. Rather, it is intended to enable the representation of catchments at a level of detail suitable for representation of the major factors that govern long term runoff processes. If more detailed representation is needed, this can be done by splitting the watershed into more numerous smaller catchments and aggregating the result, or by incorporating the results of an external model.

Numerical Values:

GENERATE Command Information				
Parameter	Value(s)	Units	Effect	Requirements
ID	A valid series ID	none	simulates runoff from a watershed	• None other than the ID number needs to be a valid QUALHYMO time series identifier • Any series already present and using the same ID number will be overwritten by this command
ISER	integer	none	numerical series name	• Should be unique to the catchment being run
DT	Integer fraction of 1 hour or multiples of 1 hour	hours	specifies computation time step for GENERATE	• The time step for computation of . It should be should be short enough to represent the rainfall runoff processes effectively • Typically, one hour is a useful time step for watershed level simulation
AREA	actual	Hectares	specifies watershed area	
AB	0 or 1	none	controls printing of unit hydrographs	• If AB = 1 the unit hydrographs are printed • If AB = 0, the unit hydrotraphs are not printed
FRIMP	0->1 inclusive	none	fraction of directly connected impervious area	• If FRIMP = 0 omit next block
AA	1 or 2	none	specifies unit hydrograph type	***Omit this block if FRIMP=0*** • If AA=1, a Nash hydrograph will be used • If AA=2, a Williams hydrograph will be used
XK	real>0 if AA=1 real if AA=2	none	hydrograph shape parameter	• If AA=1 XK is Nash 'n' • If AA=2 and XK>0 XK is Williams 'K' • If AA=2 and XK<0 XK is height 'H'
TP	real >0	none	hydrograph shape parameter	• If AA=1, TP is Nash parameter • If AA=1, TP is Williams parameter
ABSIMP	real >=0	mm	impervious initial abstraction	
RIMP	real 0-1	none	impervious runoff coefficient	
CETIMP	real 0-1 or <0	none	impervious area evaporation correction coefficient	• *OMIT CETIMP if IDOEVAP =0 (on START command)* • If CETIMP<0, CPAN from START command will be used

AA XK TP SMIN SMAX SK APIK API ABSPER CETPER	1 or 2 real>0 if AA=1 real<> if AA=2 real >0 real>=0 real>0 real>0 real>0, <1 real>0 real >=0 real 0-1 or <0	none none none mm mm /mm none mm mm none	specifies unit hydrograph type hydrograph shape parameter hydrograph shape parameter minimum S maximum S S change parameter initial API value pervious initial abstraction pervious area evaporation correction coef	<u>*Omit this block if FRIMP=1*</u> • If AA=1, a Nash hydrograph will be used • If AA=2, a Williams hydrograph will be used • If AA=1 XK is Nash 'n' • If AA=2 and XK>0 XK is Williams 'K' • If AA=2 and SK<0 XK is height 'H' • If AA=1, TP is the Nash parameter • If AA=1, TP is the Williams parameter • Typically, APIK is near 0.9 per day • *OMIT CETPER if IDOEVAP =0 (on START command)* • If CETPER<0, CPAN from START command will be used
NSVOL	positive integer *MUST BE 0 THIS MODEL VERSION*	none	number of soil reservoirs for baseflow simulation	• If NSVOL=0, a recession curve will be used • If NSVOL>0, a cascade of linear reservoirs is used • NSVOL=0, omit next block
SVOL(I),I=1,NSVOL SK1(I),I=1,NSVOL Sk2(I),I=1,NSVOL	positive real positive real positive real	mm /s none	starting reservoir volume reservoir constant baseflow coef	• Omit this whole group if NSVOL=0 • Provide one group for each of I=1,NSVOL
BASMIN	positive real	m3/s	minimum baseflow rate	
BFACR SVOL SWILT SFIELD SLOSKA SLOSKB	real>=1.0 positive real positive real positive real positive real positive real	mm mm mm mm /s none	baseflow coefficient starting reservoir volume minimum SVOL for baseflow soil field capacity recession const. reduction factor.	• Omit this whole group if NSVOL>0
CET	real 0-1 or <0	none	ET coefficient	• *OMIT CET if IDOEVAP =0 (on START command)* • If CET<0, CPAN from START command will be used
ISNOW BASET SNOFAC PACDEP ALPHAA XKL BCOEF XNCOEF	1 or 2 real real real real real real real	none deg C none mm none none none none	sets snowmelt method melt temperature calibration coefficient starting pack depth calibration coefficient thermal conductivity ratio, proportionality constant insulation factor	• *Omit this whole group if temperature files are not provided* • If SNOW=1 The model will use annual coefficients • If ISNOW=2 the model will use variable coefficient. • Applies to melt calculations • Applies to geothermal heat flux
KFLAG ------------------	0, 1 0R 2 ---------------	none ------------	sets removal option ------------------	• *IN THIS VERSION SET KFLAG=0* --

XN	0-1	none	fraction of snow removed	Omit XN, DEPTH AND AREAD if KFLAG=0
DEPTH	real>0	mm	depth before removal begins	
AREAD	real>0	ha	area of donor watershed	
PSTATE	real	deg C	temp. for precip. to be snow.	Omit this section if ISNOW=1
COEFD	real>0	none	calibration coefficient	If IZFLAG=1, user provides melt coefficients
COEFE	real>0	none	calibration coefficient	If IZFLAG=2, Anderson-Gray melt coefficients are used
CFACTR	real>0	none	rain gauge correction factor	If IZFLAG=3 Dorset, Ontario melt coefficients are used
CFACTS	real>0	none	snow gauge correction factor	
IZFLAG	1,2 OR 3	none	sets melt coefficient option	
CMELT(I), I=1,12)	real	none	melt coefficient	Omit this section if IZFLAG<>1

4.3.3.3 The WATERSHED Command

Purpose:

This command allows users to simulate runoff from a watershed. It is similar but not identical to the GENERATE command.

Use:

This provides the ability to represent long term continuous flow from a watershed. It is not intended to provide an ability to simulate detailed urban networks as might be done with the SWMM model. Rather, it is intended to enable the representation of catchments at a level of detail suitable for representation of the major factors that govern long term runoff processes. If more detailed representation is needed, this can be done by splitting the watershed into more numerous smaller catchments and aggregating the result, or by incorporating the results of an external model.

Numerical Values:

WATERSHED Command Information				
Parameter	Value(s)	Units	Effect	Requirements
ID	A series ID	none	simulates runoff from a watershed.	• None other than the ID number needs to be a valid QUALHYMO time series identifier. • Any series already present and using the seme ID number will be overwritten by this commaud.
ISER	integer	none	numerical series name	• Should be unique to the catchment being run.
DT	Integer fraction of hour or multiple of 1 hour	hours	specifies computation time step for GENERATE	• The time step for computation of JI should be should be short enough to represent the rainfall-runoff processes effectively • Typically, one hour is a useful time step for watershed level simulation.
AREA	real>0	hectares	specifies watershed area.	
AB	0 or 1	none	controls printing of unit hydrographs	• If AB = 1, the unit hydrographs are printed • If AB = 0, the unit hydrotraphs are not printed.
FRIMP	0 - 1 inclusive	none	fraction of directly connected impervious area.	• If FRIMP = 0, omit next block
				Omit this block if FRIMP=0
AA	1 or 2	none	specifies unit hydrograph type	• If AA=1, a Nash hydrograph will be used • If AA=2, a Williams hydrograph will be used
XK	real>0 if AA=1 real if AA=2	none	hydrograph shape parameter	• If AA=1 XK is Nash 'n' • If AA=2 and XK>0 XK is Williams 'K' • If AA=2 and XK<0 XK is height 'H'
TP	real >0	none	hydrograph shape parameter	• If AA=1, TP is Nash parameter • If AA=1, TP is Williams parameter
ABSIMP	real >=0	mm	impervious initial abstraction	
RIMP	real 0-1	none	impervious runoff coefficient	
CETIMP	real 0-1 or <0	none	impervious area evaporation correction coefficient	• *OMIT CETIMP if IDOEVAP =0 (on START command)* • If CETIMP<0, CPAN from START

				command will be used
				Omit this block if FRIMP=1
AA	1 or 2	none	specifies unit hydrograph type	• If AA=1, a Nash hydrograph will be used • If AA=2, a Williams hydrograph will be used
XK	real>0 if AA=1 real<> if AA=2	none	hydrograph shape parameter	• If AA=1 XK is Nash 'n' • If AA=2 and XK>0 XK is Williams 'K' • If AA=2 and SK<0 XK is height 'H'
TP	real >0	none	hydrograph shape parameter	• If AA=1, TP is the Nash parameter • If AA=1, TP is the Williams parameter
SMIN		mm	minimum S	
SMAX		mm	maximum S	
SK	real>=0 real>0	/mm	S change	
RKAPI	real>0	none	parameter	• Typically, APIK is near 0.9 per day
API	real>0, <1	mm	initial API value	
ABSPER	real>0	mm	pervious initial abstraction	
CETPER	real >=0 real 0-1 or <0	none	pervious area evaporation correction coef	• *OMIT CETPER if IDOEVAP=0 (on START command)* • If CETPER<0, CPAN from START command will be used
BASMIN	positive real	m3/s	minimum baseflow rate	
SVOL	positive real	mm	starting soil reservoir volume	
SLOSKA	positive real	/s	recession const.	
SLOSKB	positive real	none	reduction factor	
CET	real 0-1 or <0	none	ET coefficient	• *OMIT CET if IDOEVAP=0 (on START command)* • If CET<0, CPAN from START command will be used
ISNOW	1 or 2	none	sets snowmelt method	• *Omit this whole group if temperature files are not provided*
BASET	real	deg C	melt temperature	• If SNOW=1 The model will use annual coefficients
SNOFAC	real	none	calibration coefficient	• If ISNOW=2 the model will use variable coefficient.
PACDEP	real	mm	starting pack depth	
ALPHAA	real	none	calibration coefficient	
XKL	real	none	thermal conductivity ratio.	
BCOEF	real	none	proportionality constant	• Applies to melt calculations
XNCOEF	real	none	insulation factor	• Applies to geothermal heat flux
KFLAG	0, 1 0R 2	none	sets removal option	• *IN THIS VERSION SET KFLAG=0*
XN	0-1	none	fraction of snow removed	• Omit XN, DEPTH AND AREAD if KFLAG=0
DEPTH	real>0	mm	depth before removal begins	
AREAD	real>0	ha	area of donor watershed	
PSTATE	real	deg C	temp. for precip. to be snow.	• Omit this section if ISNOW=1
COEFD	real>0	none	calibration coefficient	• If IZFLAG=1, user provides melt coefficients
COEFE	real>0	none	calibration coefficient	• If IZFLAG=2, Anderson-Gray melt coefficients are used
CFACTR	real>0	none	rain gauge correction factor	
CFACTS	real>0	none	snow gauge correction factor	• If IZFLAG=3 Dorset, Ontario melt coefficients are used
IZFLAG	1,2 OR 3	none	sets melt coefficient option	
CMELT((I), I=1,12)	real	none	melt coefficient	• Omit this section if IZFLAG<>1

4.3.3.4 The PERVIOUS SURFACE Command

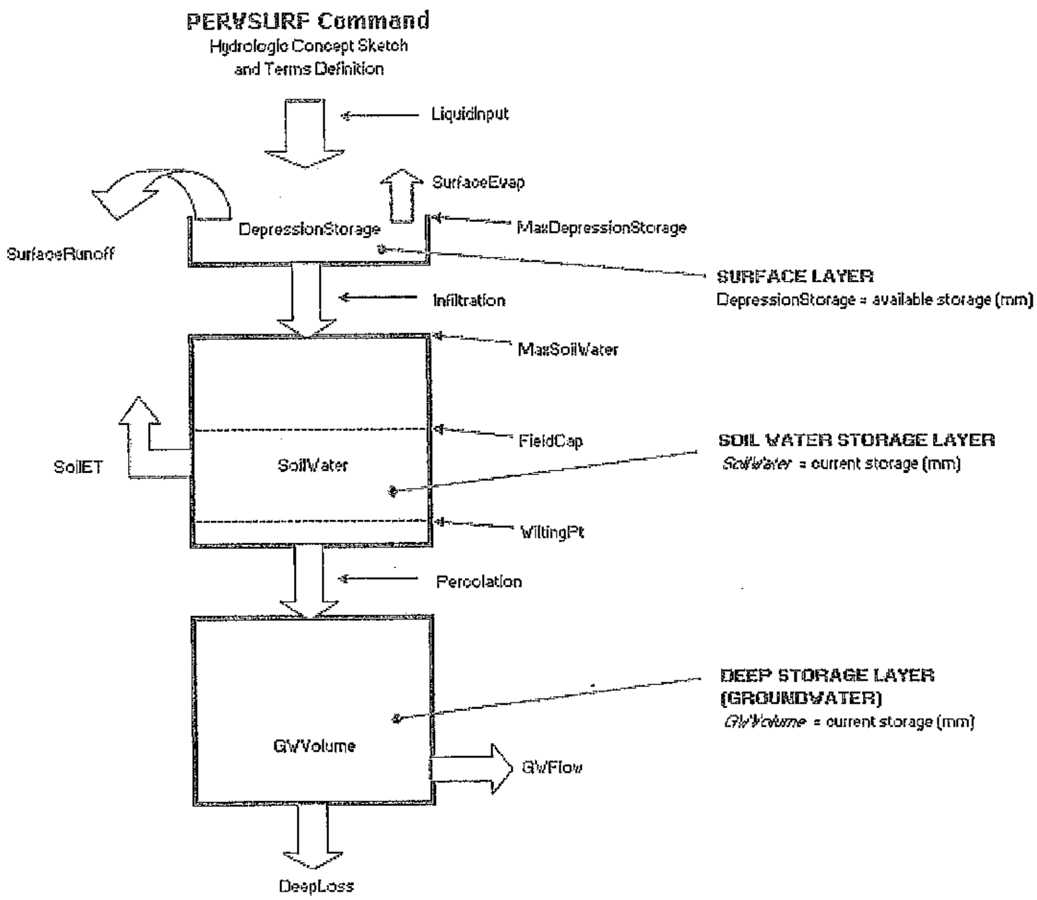
Purpose:

This command simulates hydrologic response of pervious areas (typically, vegetated or open surfaces with little development) including pollutant loads associated with surface runoff.

Use:

This command was developed specifically for the Toronto Region Conservation Authority, although it can be used elsewhere if appropriate. It can be used in place of the GENERATE command. It is one of four such commands (PERVSURF, IMPERVSURF, PERVSURFSTORAGE, IMPERVSURFSTORAGE) which were implemented to facilitate simulation of LID alternatives. As well as this section, Appendix B provides some general guidance on the use of these four commands.

The conceptual arrangement of this hydrologic element is shown below:



Outputs from the command provide several sets of information:

- Two binary outflow time series: one is surface runoff outflow (m^3/s), while the other is subsurface (groundwater) outflow (m^3/s) which conceptually could represent groundwater discharge to catchment outlet (e.g. to outlet watercourse)
- There is text output file that provides a water balance summary for each layer.
- Users can generate an optional detailed trace output: If **SurfaceID** is supplied as a negative value, then PERVSURF will generate a detailed trace output file (ASCII text format):
  - **PERVSTEPnnn.txt**: contains all water budget components (in mm), surface outflow (m^3/s) and subsurface outflow (m^3/s) for each time step (one record per time step, easy to import into spreadsheet) where **nnn = SurfaceID**

Some of the key computational factors in this command are:

- It verifies mass balance on each time step.
- Surface runoff is generated when LiquidInput exceeds current infiltration capacity, which varies with soil moisture status (see below)
- Surface runoff flow rate is computed based on the surface being represented as a sloped plane with the characteristic slope, length and surface roughness supplied as input by the modeler. The model continuously tracks the depth of water on the surface plane, and over any interval the surface outflow rate is computed using the Manning equation with hydraulic radius approximated as depth of flow.
- Soil moisture is continuously tracked. When soil moisture is above field capacity, then the excess is considered as free water that can percolate by gravity downward to the deep storage layer. The percolation rate is a constant rate supplied by the user (presumably would correspond to vertical saturated hydraulic conductivity of limiting layer).
- Soil moisture is depleted by evapotranspiration. The user supplies potential ET rates with the START command. The potential ET rates can be scaled using SoilETfactor.
- When soil moisture is at or above field capacity (wet soil condition) ET occurs at the potential rate (i.e. no limit to water supply to root systems). Actual ET will drop to zero as soil moisture drops from field capacity to wilting point.
- There is no ET from the deep storage layer. Therefore, the soil water storage layer represents the full depth of soil or overburden layers from which root systems can extract water. The input values for Field Capacity and MaxSoilWater need to be set accordingly. MaxSoilWater will generally be approximated as available porosity times the depth of the soil water layer. Similarly, field capacity as well as wilting point will in part depend on the total layer depth being represented by the soil water layer. Field capacity per unit depth will be higher in finer-textured soils (e.g. clays) than coarse-texture soils (e.g. sand).

Numerical Values:

PERVIOUS SURFACE Command Information				
Parameter	Value(s)	Units	Effect	Requirements
SurfaceID	integer > 0	none	ID for surface outflow series	
SubsurfaceID	integer > 0	none	ID for subsurface outflow series	
ExtInflowID	integer > 0	none	ID for external surface inflow	
DT	real > 0 integer fraction of 1 hour or multiples of 1 hour	hr	Time Step	DT must be an integer divisor or multiple of one hour
SurfArea	real > 0	ha	Surface Area	
SurfLength	real > 0	m	Characteristic length of catchment flow path	
SurfSlope	real > 0	m/m	Characteristic slope catchment	
SurfRoughness	real > 0	none	Characteristic catchment surface roughness	
MaxDepressionStorage	real > 0	mm	Surface depression storage	
MaxSoilWater	real > 0	mm	soil layer's water storage capacity	
FieldCap	real > 0	mm	Field capacity	
WiltingPt	real > 0	mm	Wilting point	
InfiltRate1	real > 0	mm/hr	Max surface infilt rate	
InfiltRate2	real > 0	mm/hr	Min surface infilt rate	
PercRate	real > 0	mm/day	Percolation rate from soil water layer to groundwater layer	
GWOutflowCoeff	real > 0	mm/day	Subsurface outflow coeff	
DeepLossCoeff	real > 0	mm/da	Deep loss coeff	
SoilETFactor	real > 0	none	Factor by which user-supplied potential evap rates are multiplied to get applied potential ET	
InitDepression	real > 0	mm	Initial depression storage	
InitSoilWater	real > 0	mm	Initial soil water storage level	
InitGWVolume	real > 0	mm	Initial groundwater storage level	
SNOWMELT PARAMETERS	Same as GENERATE command	none	Same as GENERATE command	

4.3.3.5 The IMPERVIOUS SURFACE Command

Purpose:

This command simulates hydrologic response of impervious (e.g. paved surface) including pollutant loads associated with surface runoff.

Use:

This command was developed specifically for the Toronto Region Conservation Authority, although it can be used elsewhere if appropriate. It can be used in place of the GENERATE command. It is one of four such commands (PERVSURF, IMPERVSURF, PERVSURFSTORAGE, IMPERVSURFSTORAGE) which were implemented to facilitate simulation of LID alternatives. As well as this section, Appendix B provides some general guidance on the use of these four commands.

Users have several output types to consider:

- There are three binary outflow time series:
  - OutflowID1= FlowFraction1 * surface runoff flow and pollutant loads
  - OutflowID2 = FlowFraction2 * surface runoff flow and pollutant loads
  - OutflowID3 = FlowFraction3 * surface runoff flow and pollutant loads
- The text output file provides water balance summary.
- Users can request an optional detailed trace output: If **OutflowID1** is supplied as a negative value, then IMPERVSURF will generate a detailed trace output file (ASCII text format). This is in the form of a file, "**IMPERVSTEPnnn.txt**" where nnn = OutflowID1 that contains all water budget components (in mm) and the total surface and subsurface outflow rates (m^3/s) for each time step. This is produced with one record per time step, so that it is easy to import into a spreadsheet for further analysis.

Numerical Values:

IMPERVIOUS SURFACE Command Information				
Parameter	Value(s)	Units	Effect	Requirements
OutflowID1	integer > 0	none	ID for surface outflow series #1	• This flow series will be comprised of FlowFraction1 of the total surface runoff from the impervious surface
OutflowID2	integer > 0	none	ID for surface outflow series #2	• Series #2 will be FlowFraction2 of the total surface runoff from the impervious surface
OutflowID3	integer > 0	none	ID for surface outflow series #3	• Series #3 will be FlowFraction3 of the total surface runoff from the impervious surface
FlowFraction1	real > 0	none	Fraction of total surface runoff and pollutant load written as series OutflowID1	
FlowFraction2	real > 0	none	Fraction of total surface runoff and pollutant load written as series OutflowID2	
FlowFraction3	real > 0	none	Fraction of total surface runoff and pollutant load written as series outflowID3	
ExtInflowID	integer > 0	none	ID for external surface inflow series	
DT	real > 0	hr	Time Step	
SurfArea	real > 0	ha	Surface Area	
SurfLength	real > 0	m	Characteristic length of catchment flow path	
SurfSlope	real > 0	m/m	Characteristic slope catchment	
SurfRoughness	real > 0	none	Characteristic catchment surface roughness	
MaxDepression Storage	real > 0	mm	Surface depression storage	
InitDepression	real > 0	mm	Initial depression storage	
SNOWMELT PARAMETERS	varies	varies	Same as GENERATE command	• Refer to GENERATE command for details on snowmelt parameters

4.3.3.6 The PERVIOUS W STORAGE Command

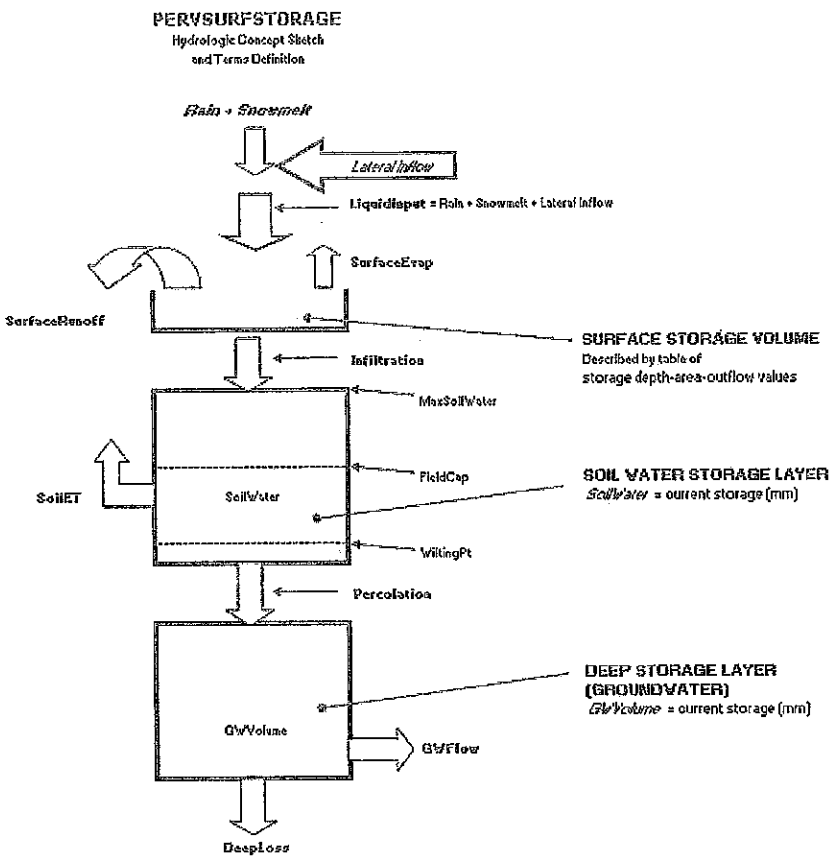
Purpose:

This command simulates hydrologic response of pervious surface that includes a surface storage volume. It is intended to allow modeling of a soakaway areas or bioretention areas that consist of vegetated area with a ponding capacity allowing both retention and infiltration into the soil profile.

Use:

This command was developed specifically for the Toronto Region Conservation Authority, although it can be used elsewhere if appropriate. It can be used in place of the GENERATE command. It is one of four such commands (PERVSURF, IMPERVSURF, PERVSURFSTORAGE, IMPERVSURFSTORAGE) which were implemented to facilitate simulation of LID alternatives. As well as this section, Appendix B provides some general guidance on the use of these four commands.

The conceptual arrangement of this hydrologic element is shown below:



The surface storage receives all surface runoff generated by the pervious surface as well as a user-specified lateral inflow series which can be any available time series. The surface storage is characterized by a table of depth-area-outflow values supplied by the user. Losses from storage include evaporation as well as exfiltration of water into the soil profile.

Outputs from the command provide several sets of information:

- There are two binary outflow time series: one is surface runoff outflow (m^3/s), the other is subsurface (groundwater) outflow (m^3/s) which conceptually can represent groundwater discharge to catchment outlet (e.g. to outlet watercourse)
- There is a text output file provides water balance summary for each layer.
- Users can specify an optional detailed trace output: If **SurfaceID** is supplied as a negative value, then PERVSURF will generate two detailed trace output files (ASCII text format):
    - **PERVSTORSTEPnnn.txt**: contains all water budget components (in mm) and the surface and subsurface outflow rates (m^3/s), for each time step (one record per time step, easy to import into spreadsheet) where **nnn = SurfaceID**
    - **PERVSURFSTORAGE.tra:** contains trace output for the surface storage volume only, including inflow, outflow, exfiltration ,evaporation and pollutant loads in and out, for each time step

Some of the computational features are:

- Soil moisture tracking and soil water storage layer simulated in same manner as described for PERVSURFACE command.
- When LiquidInput exceeds current infiltration capacity, the excess water is added to the surface storage volume.
- The surface storage volume will also receive as direct input the external inflow time series (flow and pollutant loads).
- The surface storage is defined by the user, as a table of depth-area-outflow values. The table must consist of a maximum of 20 rows, with each row containing a depth of ponding (m), a corresponding water surface area (m^2) and outflow rate (m^3/s). The values must increase from row to row. Note that the water surface area on the final row (i.e. the largest water surface area) must be less than the total surface area for the pervious surface (SurfArea)
- The surface storage volume is updated by mass balance over each time step. Water surface area is concurrently updated. Surface storage is depleted by exfiltration into the soil water storage layer. Surface storage is also depleted by surface evaporation. Exfilitration and evaporation occur only over the inundated area (i.e. water surface area). Surface outflow will occur according to the table of depth-area-outflow values.
- Pollutant routing occurs in the same manner as in the POND command. The

settling velocities and first-order time decay parameter specified with the START command are used. As with the POND command, pollutant routing is based on considering the volume to be a series of completely stirred tank reactors (nCSTRs). With nCSTRs=1, the volume is effectively a completely-mixed volume. With nCSTRs set at 5 or greater, the conditions approach those of a plug-flow reactor. With nCSTRs set between 1 and 5, the result can be considered as intermediate between completely mixed flow and plug flow.

Numerical Values:

PERVIOUS W STORAGE Command Information				
Parameter	**Value(s)**	**Units**	**Effect**	**Requirements**
SurfaceID	integer > 0	none	ID for surface outflow series	
SubsurfaceID	integer > 0	none	ID for subsurface outflow series	
ExtInflowID	integer > 0	none	ID for external surface inflow series.	• Set ExtInflowID to zero if no external inflow to be supplied
DT	integer, fraction of 1 hour, or multiples of 1 hour	hr	Time Step	
SurfArea	real > 0	ha	Total surface area	
MaxSoilWater	real > 0	mm	Soil water capacity	
FieldCap	real > 0	mm	Field capacity	
WiltingPt	real > 0	mm	Wilting point	
InfiltRate1	real > 0	mm/hr	Max surface infilt rate	
InfiltRate2	real ≥ 0	mm/hr	Min surface infilt rate	
PercRate	real > 0	mm/day	percolation rate from soil water layer to groundwater layer	
GWOutflowCoeff	real > 0	mm/day	Subsurface outflow coeff	
DeepLossCoeff	real > 0	mm/day	Deep loss coeff	
SoilETFactor	real > 0	none	Factor by which user supplied potential evap raters are multiplied to get applied potential ET	
InitDepression	real >= 0	mm	Initial depression storage	
InitSoilWater	real >= 0	mm	Initial Soil water storage level	
InitGWVolume	real >= 0	mm	Initial groundwater storage level	
nStorageTable Entries	integer >= 1, <=20	none	Number of entries (rows) in the following depth-area-outflow table	
(Depth(i), Area(i), Outflow(i)) i=1, nStorageTableEntries	all real > 0	Depth in m, Area in m², Outflow in M³/sec	Storage table depth/area/flow table	• Depth, area and outflow must increase with each data set. • Area(nStorageTableEntries) >= SurfArea
nCSTRs	integer > 0	none	the number of completely stirred tank reactors to represent mixing conditions in the storage volume, for pollutant routing.	
Snowmelt parameters	varies	varies	Same as in GENERATE command	• Refer to GENERATE command for details on snowmelt parameters.

4.3.3.7 The IMPERVIOUS W STORAGE Command

Purpose:

This command simulates hydrologic response of impervious (e.g. paved surface) that includes a surface storage volume. Intended to allow modeling of such features as flat roofs with surface storage and controlled drainage outlet; or paved parking area designed to provide surface ponding storage with controlled outlet.

Use:

This command was developed specifically for the Toronto Region Conservation Authority, although it can be used elsewhere if appropriate. It can be used in place of the GENERATE command. It is one of four such commands (PERVSURF, IMPERVSURF, PERVSURFSTORAGE, IMPERVSURFSTORAGE) which were implemented to facilitate simulation of LID alternatives. As well as this section, Appendix B provides some general guidance on the use of these four commands.

The surface storage receives all surface runoff generated by the impervious surface as well as a user-specified lateral inflow series which can be any available time series. The surface storage is characterized by a table of depth-area-outflow values supplied by the user. Losses from the storage include surface evaporation.

The command produces three binary outflow time series:

- OutflowID1= FlowFraction1 * surface runoff flow and pollutant load
- OutflowID2 = FlowFraction2 * surface runoff flow and pollutant loads
- OutflowID3 = FlowFraction3 * surface runoff flow and pollutant loads

There is a water balance summary in the text output file. There is also an optional detailed trace output. If **OutflowID1** is supplied as a negative value, then IMPERVSURF will generate a detailed trace output file (ASCII text format). This file is named **"IMPERVSTORSTEPnnn.txt",** where nnn = OutflowID1. It contains all water budget components (in mm) and the total surface and subsurface outflow rates (m^3/s) for each time step (one record per time step, easy to import into spreadsheet)

Numerical Values:

IMPERVIOUS W STORAGE Command Information

Parameter	Value(s)	Units	Effect	Requirements
OutflowID1	integer > 0	none	ID for surface outflow series #1 ID for surface outflow series #2 ID for surface outflow series #3 Fraction of total surface runoff and pollutant load written as series OutflowID1	• Flow series #1 will be comprised of FlowFraction1 of the total surface runoff from the impervious surface • Flow series #2 will be FlowFraction2 of the total surface runoff from the impervious surface • Flow series #3 will be Flowfraction3 of the total surface runoff from the impervious surface
OutflowID2	integer > 0	none	Fraction of total surface runoff and pollutant load written as series OutflowID2 Fraction of total surface runoff and pollutant load written as series OutflowID3	
OutflowID3	integer > 0	none	ID for external surface inflow series Time Step Surface Area	
FlowFraction1	real > 0	none		
FlowFraction2	real > 0	none		
FlowFraction3	real > 0	none		
ExtInflowID	integer > 0	none		
DT SurfArea	real > 0 real > 0	hr ha		
nStorageTableEntries	integer > 1, <=20	none	Number of entries (rows) in the following depth-area-outflow table	
{Depth(i), Area(i), Outflow(i)} i=1, nStorageTableEntries	all real > 0	Depth in m, Area in m2, Outflow in M3/sec		Depth, area and outflow must increase with each data set Area(nStorageTableEntries) <= SurfArea
SNOWMELT PARAMETERS			same as GENERATE command	

4.3.3.8 The CISTERN Command

Purpose:

This command simulates a simple rainwater cistern that is recharged by a specified time series, and depleted by domestic use.

Use:

This was developed specifically for the Toronto Region Conservation Authority geographic region, although it can be used anywhere. It was implemented to provide a way to simulate lot scale flow storage.

The specified cistern receives flow from a user specified inflow time series, and stores water until cistern capacity is reached. Once the cistern is full, all inflow is bypassed. Cistern storage is depleted at a user-supplied constant rate.

In the following simple example, a cistern is specified with a capacity of 1000 m^3. It is initially empty. The daily withdrawal amounts are based on cistern water being used in summer months for irrigation.

```
CISTERN        Inflow ID = 1 Outflow ID = 91
               Cistern capacity = 1000 cu m
               Initial cistern storage = 0
               Daily withdrawal volume for each calendar month
               Jan 0.0      Feb 0.0      Mar 0.0
               Apr 0.0      May 65.0     Jun 133.0
               Jul 161.0    Aug 161.0    Sep 133.0
               Oct 0.0      Nov 0.0      Dec 0.0
```

Numerical Values:

CISTERN Command Information				
Parameter	Value(s)	Units	Effect	Requirements
InflowID	integer > 0	none	ID for time series of inflow	
OutflowID	integer > 0	none	ID for outflow time series (cistern bypass flow)	
CisternCapacity	real > 0	m	Cistern storage capacity	
InitCistern Storage	real ≥ 0 <= Cistern Capacity	m	Initial volume in cistern	
DailyWithdrawal (nMonth), nMonth = 1, 12	real ≥ 0	m	DAILY withdrawal volume (one value for each month)	

4.3.3.9 The AUSTIN FILTER Command

Purpose:

This command allows users to simulate a filter type BMP.

Use:

This BMP is used when a sand filter type BMP is of interest. Flows are routed through the filter until the storage volume above is filled, and then they overflow.

Numerical Values:

AUSTIN FILTER Command Information				
Parameter	**Value(s)**	**Units**	**Effect**	**Requirements**
IDIN	A valid ID value	none	ID number for the inflow series	Must be a currently valid series ID.
IDOUT	A valid ID value	none	ID number for the outflow series	Must be a valid series ID.
ISER	Integer>0	none	Serial for the outflow series	
FILTERT	real > 0	m	Filter thickness	
FILTERK		cm/s	Filter hydraulic conductivity	
QE		m	Outflow control elevation	
NPTSV	2 through 25	none	specifies number of points on volume curve	
SV(1,i) SV(2,i) in pairs where i ranges from 1 to NPTSV	Pond stage and pond volume pairs	m and m^3	sets values for volume curve	• If NPTSV=0, then the SV pairs should be omitted
NPTSA	2 through 25	none	specifies number of points on area curve	
SA(1,i) SA(2,i) in pairs where i ranges from 1 to NPTSA	Pond stage and pond area pairs	m and m^2	sets values for area curve	• If NPTSA=0, then the SA pairs should be omitted

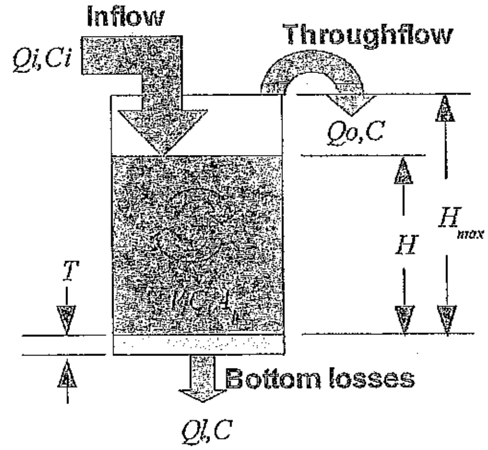
4.3.3.10 The LEAKY BMP Command

Purpose:

This command allows users to simulate a detention type BMP that has a leaky bottom.

Use:

This BMP is used to represent a typical detention pond, but in a case where there are significant exfiltration losses through the bottom. It is based on situation where a confining layer of known thickness and hydraulic conductivity is below the facility, and that it leaks continually through this layer when there is volume standing in the pond.



$$\frac{dV}{dt} = Qi - Qo - Ql$$

$$Ql = kA_h \frac{H}{T}$$

$$\frac{dVC}{dt} = QiCi - QoC - QlC - kVC$$

The figure adjacent provides a sketch of the way this BMP has been conceptualized. A known inflow and concentration are added to the pond volume. This is a wet facility, so outflow is by displacement, and occurs only if $H > Hmax$; in this version, a high capacity outflow such as a weir is assumed, so that H does not differ materially from $Hmax$ when $Hmax$ is exceeded. Outflow through the pond bottom is through a confining layer that is of known thickness and hydraulic conductivity; a D'Arcy condition defines outflow rate as a function of gradient across that unit.

In this situation, it is assumed that the land in the vicinity of the pond is of hydraulic characteristics such that the primary impediment to outflow is the layer at the bottom of the pond. This is considered to be a useful case to simulate, because in areas where flow is significantly impeded by the native material below the pond, outflow is less likely to be a factor in pond performance and bottom leakage may not be of interest. It is noted, however, that there are many cases that may occur which govern outflow through the pond bottom, that recourse to a groundwater analysis may be necessary to establish a preferred way to represent this situation.

It is further assumed that the governing head for computation of outflow, and hence the gradient, is represented by the depth of water above the bottom layer. This too should be evaluated by the user.

The equations that have been chosen to represent this case are as shown above. These are generally conservation equations, and two terms represent the key mechanisms governing flow and constituent removal. One term defines outflow as a function of head and bottom layer characteristics, in a relationship typical of groundwater behavior:

$$Ql = kA_h \frac{H}{T}$$

The other defines removal as a first order process, typical of indicator bacteria removal:

$$\frac{dC}{dt} = -kC$$

There are two discontinuities in the above system. Outflow Qo is zero if the pond is at or less than maximum depth ($H=<H_{max}$), and leakage through the bottom is zero if the pond is empty. Solution of this system in cases where $0<H<H_{max}$ is by means of a finite approximation. The basic relationship between those limits is as follows:

$$V_2 = V_1 - \frac{(Ql_1 + Ql_2)\times \Delta t}{2} + \frac{(Qi_1 + Qi_2)\times \Delta t}{2}$$

where subscripts denote conditions at the beginning (1) and end (2) of a time step. This can be rearranged to provide:

$$SIB = SIA + \frac{(Qi_1 + Qi_2)\times \Delta t}{2}$$

where

$$SIB = V(H_2) + \frac{H_2 \times k \times A_h(H_2)\times \Delta t}{2T}$$

$$SIA = V(H_1) - \frac{H_1 \times k \times A_h(H_1)\times \Delta t}{2T}$$

This is a simple variation on the classic storage indication method, and provides a robust, quick and simple solution scheme for the present problem. In practice, the model develops curves of SIB and SIA against H before the simulation of a series begins. Then, for every time step, it solves the right hand side of the equation first from known H_1, Qi_1 and Qi_2, and then solves for H_2 using the relation of SIB against H. With H_2 known, the rest of the variables of interest are solvable as well.

Where the relationship resolves to values less than zero (not a normal result) H_2 is set to zero. Where it resolves to values greater than H_{max}, H_2 is set to H_{max}. In both cases, outflow and losses are then calculated directly.

Water quality effects are solved in a comparable manner. A finite form of the conservation equation applicable to this problem is:

$$C_2V_2 = C_1V_1 + (C_1Qi_1 + C_2Qi_2)\frac{\Delta t}{2} - (kC_1V_1 + kC_2V_2)\frac{\Delta t}{2} - (C_1Ql_1 + C_2Ql_2)\frac{\Delta t}{2} - (C_1Qo_1 + C_2Qo_2)\frac{\Delta t}{2}$$

Solution of this is somewhat similar to the solution of the quantity equations, as discussed below. To do this, the quality equation can be rearranged as:

$$C_2 = \left[C_1 (V_1 - F_1)_1 + (C_1 Qi_1 + C_2 Qi_2) \frac{\Delta t}{2} \right] / (V_2 + F_2)$$

where

$$F_1 = (kV_1 + Ql_1 + Qo_1) \frac{\Delta t}{2}$$

$$F_2 = (kV_2 + Ql_2 + Qo_2) \frac{\Delta t}{2}$$

This is directly solvable for C_2, since all terms on the right hand side are known. As a matter of computational efficiency, only F_2 is calculated at any time step, since F_1 takes on the value of F_2 from the previous time step.

In practice this scheme has proven to be useful and robust. The user is cautioned, however, to note that within these relationships there are opportunities for numerical errors, as there are with any numerical methods, particularly as H moves outside the limiting values $0<H<H_{max}$. The model provides diagnostic information on flow conservation, and this is useful in detecting errors of this type. A shorter time step will generally solve this problem if it is encountered.

Numerical Values:

LEAKY BMP Command Information				
Parameter	**Value(s)**	**Units**	**Effect**	**Requirements**
IDIN	A valid ID value	none	ID number for the inflow series	Must be a currently valid series ID.
IDOUT	A valid ID value	none	ID number for the outflow series	Must be a valid series ID.
ISER	integer>0	none	Serial for the outflow series	
BOTTOMT	real > 0	m	Pond bottom thickness	
BOTTOMK	real > 0	cm/s	Pond bottom hydraulic conductivity	
STARTINGSTAGE	real >=0	m	Initial elevation of water in pond	
NPTSV	2 through 25	none	specifies number of points on volume curve	• If NPTSV=0, then the SV pairs should be omitted.
SV(1,i),SV(2,i) in pairs where i ranges from 1 to NPTSV	Pond stage and pond volume pairs	m and m³	sets values for volume curve	
NPTSA	2 through 25	none	specifies number of points on area curve.	• If NPTSA=0, then the SA pairs should be omitted.
SA(1,i),SA(2,i) in pairs where i ranges from 1 to NPTSA.	Pond stage and pond area pairs	m and m²	sets values for area curve	
FCCONC	eal>0	no/dl	Inlet concentration,	
FCLOSSK	real<=0	/s	1st order decay constant	

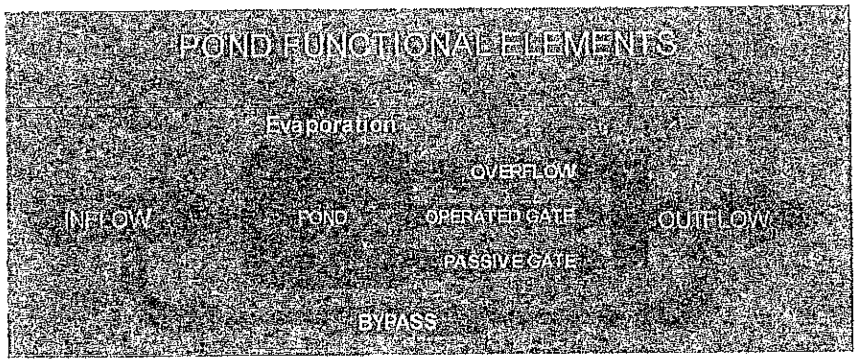
4.3.3.11 The POND Command

Purpose:

This command enables the simulation of control ponds, reservoirs or small lakes. It routes flows and, optionally, pollutants through the water body, simulating mixing and losses along the way.

Use:

The functions included in the POND command are illustrated below.



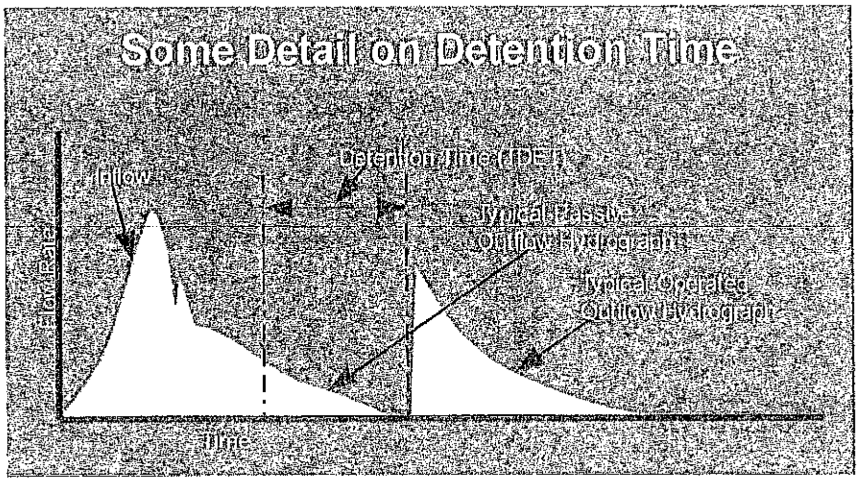
The POND command includes a substantial range of capabilities. As shown below, it can represent:

- a bypass around the whole facility, which sends a stream of inflow around the pond untreated and unrouted, to rejoin the effluent from the pond at its outlet.
- evaporation from the pond, which is a loss from the system,
- three outlet options, including
  - an overflow that only functions when the pond volume exceeds a specified minimum value,
  - a passive gate that always functions to provide an outlet as water in the pond raises and lowers and
  - an operated gate that is closed at the beginning of an inflow into the pond that
  - s a specified base flow amount and that opens after inflow ceases and a specified detention time (TDET) passes.

Experience has shown that the definition and impact of detention time as incorporated in the model is worth highlighting to avoid user misunderstanding of how this term is used.

As indicated in the figure below, the specification of a detention time not only delays the outflow, but changes the form of the outflow since the pond will tend to be fuller when release is delayed and the flows that are generated immediately shift from zero to the value that results from the full depth of water behind the opened gate. Use of outflow structures in combination can reduce this effect, since a limited outflow from a small passive structure will reduce the peak volume in the facility and therefore the rate of outflow that is developed when the operated gate finally opens.

Clearly the combination of losses, outflows and pond stage/volume relationships have a major impact on the simplistic picture just presented, but the general principles illustrate how incorporation of a detention time can affect quantity routing.



The pond volume itself can be simulated as behaving as a completely mixed reactor, a plug flow reactor, or a reactor that behaves between these extremes.

Numerical Values:

POND Command Information				
Parameter	Value(s)	Units	Effect	Requirements
IDOUT	A series ID	none	identifies output series ID	• IDOUT <> IDH
ISER	integer	none	numerical series name, and flag for detailed outputs	• If ISER<0, then detailed pond behavior will be dumped to a binary file that can be accessed using the PULL POND SPAN and CALC POND STATS commands • ISER is set to ABS(ISER) after the model is set to dump detailed diagnostic
IDH	A series ID	none	identifies input series ID	• The series referred to must have been developed in an earlier run or a command prior to the use of the POND command
TDET	real >=0	hours	specifies detention time	• TDET must be greater than the computation time step for the pond
NELS	integer 1 through 99	none	specifies number of mixing elements	• If NELS = 1, the pond is completely mixed • If NELS = 99, the pond is approximately plug flow • NELS between 1 and 99 are intermediate cases
RTING	0 < real < 1	hours	specifies computation time step for POND	• The time step for hydraulic routing (not quality routing) is set by RTING. It should be less than one hour, and should be short enough to represent the pond hydraulics effectively
QBAS	real >=0	m3/sec	specifies base flow or bypass flow	• Flows less than QBAS will not be interpreted as an inflow, so operated date will not be shut • If IFOBY<=0, approach flows < QBAS will bypass the pond rather than run into is
PPAN	real, 0 or <0	none	pond pan evaporation correction factor	• If PPAN<0, the value of PPAN specified in the START command will be used. • If PPAN>=0, the value provided here will be used
IFOBY	integer 0 or 1	none	flag specifying base flow behaviour	• If IFOBY=1, approach flows < QBAS will be diverted around the pond rather than allowed to run into it • If IFOBY=1, then any approach flow curve provided to the POND command (i.e., set if NPTQQ>0) will be ignored
NPTQQ	integer 0 or 2 through 25	none	specifies if bypass curve will be used	• If NPTQQ=0 the pond will not have a bypass curve • If NPTQQ>=2, the pond will have a bypass curve
QQ(1,i),QQ(2,i) in pairs where i ranges from 1 to NPTQQ	real >= 0	m3/sec and m3/sec	sets values for bypass curve, as approach flow and inlet flow pairs	• If NPTQQ=0 this block must be omitted • All flows must be positive • The inlet flow (QQ(1,i)) must be greater than the inlet flow (QQ(2,i)) in every pair.
NPTSQ1	integer 0, or 2 through 25	none	specifies if passive outlet will be used	• If NPTSQ1=0 the pond will not have a passive outlet • If NPTSQ1>=2, the pond will have a passive outlet

SQ1(1,i),SQ1(2,i) in pairs where i ranges from 1 to NPTSQ1	real >= 0	m and m3/sec	sets values for passive outflow curve, as (stage / outflow) pairs	• If NPTSQ1=0 this block must be omitted • All flows must be positive
ISIGA	integer 1 or 2	none	specifies how operated outlet will be input	
NPTSQ2 SQ1(1,i),SQ1(2,i) in pairs where i ranges from 1 to NPTSQ2	integer 2 through 25 real >=0	none m and m3/sec	specifies number of points on operated outlet . sets values for operated outflow curve, as (stage / outflow) pairs	• If ISIGA=2 this block must be entirely omitted, but it is otherwise required • If NPTSQ2=0, then this block must contain only NPTSQ2 • All flows must be positive
STHD BHE DIAM GRAV VISC XLENG ROUGH CD	real>0 real>0 real>0 real>0 real>0 real>0 real>0 real>0	m m m m/sec2 m none	Pipe invert Height of pond Pipe diameter Gravity Water viscosity Pipe length Roughness Discharge coefficient	• If ISIGA=1 this block must be omitted, but it is otherwise required • Consistent units are required • This group sets values for calculated operated outflow curve
ISIGB	1 or 2	none	specifies how overflow will be input	
NPTSQV SQV(1,i),SQV(2,i) in pairs where i ranges from 1 to NPTSQV	integer 2 through 25 real >=0, real >=0	none m and m3/sec	specifies number of points on overflow. sets values for overflow curve, as (stage / outflow) pairs	• If ISIGB=2 this block must be entirely omitted, but it is otherwise required • If NPTSQV=0, then this block should contain only NPTSQV • All flows must be positive
STHD BHE XLENG	real>0 real>0 real>0	m m m	Pipe invert Height of pond Weir length	• If ISIGB=1 this block must be omitted, but it is otherwise required • sets values for calculated overflow curve • Consistent units are required
ISIGC	1 or 2	none	specifies how pond volume and area will be input	
NPTSV SV(1,i),SV(2,i) in pairs where i ranges from 1 to NPTSV	2 through 25 real >=0, real >=0	none m and m^3	specifies number of points on volume curve sets values for volume curve, as (stage / volume) pairs	• If ISIGC=2 this block must be entirely omitted, but it is otherwise required. Also, NPTSA and NPTSV cannot both be 0 (i.e. at least an area or volume curve, or both, is required) • If NPTSV=0, then the SV pairs should be omitted
NPTSA SA(1,i),SA(2,i) in pairs where i ranges from 1 to NPTSA	integer 2 through 25 real >=0, real >=0	none m and m^2	specifies number of points on area curve. sets values for area curve, as (stage / area) pairs	• If NPTSA=0, then the SA pairs should be omitted
BWIDTH BSLOPE BLEN BHEIGHT	real >0 real >0 real >0 real >0	m m/m m m	sets values for calculated volume and area curves Basin width Basin slope Basin length Basin height	• If ISIGC=1 this block must be omitted, but it is otherwise required

SBEGIN	real >=0	m	Starting elevation in pond	• Must be in range of pond area and volume curves
FCMULT	real >=0	none	Multiplier for 1st order constituent concentration; adjusts concentrations in pond	• If FCMULT=1, has no effect
SEMULT	real >=0	none	Multiplier for sediment concentration; adjusts concentrations in pond	• If SEMULT=1, has no effect

4.3.3.12 The EXFILTRATION POND Command

Purpose:

This command allows users to simulate a pond that has exfiltration losses through the bottom. Outflows are via a weir, and overflows occur if pond depth exceeds a specified maximum. Basic theory is as described in the LEAKY BMP command (4.3.26 above) except for the addition of a weir. This command was originally developed at the request of EPA in support of a project exploring indicator organism treatment.

Use:

This BMP is used to represent a typical detention pond where there is a weir flow outlet and there are significant exfiltration losses through the bottom. Except for the weir, it is similar to the LEAKY BMP command. Leakage losses are based on situation where a confining layer of known thickness and hydraulic conductivity is below the facility, and that it leaks continually through this layer when there is volume standing in the pond. Rate constants (first order and sedimentation) are obtained from the immediately preceding START command.

Numerical Values:

EXFILTRATION POND Command Information				
Parameter	**Value(s)**	**Units**	**Effect**	**Requirements**
IDIN	A valid ID value	none	ID number for the inflow series	Must be a currently valid series ID.
IDOUT	A valid ID value	none	ID number for the outflow series	Must be a valid series ID.
ISER	integer>0	none	Serial for the outflow series	
BOTTOMT	real>0	m	Pond bottom thickness	
BOTTOMK	real>0	cm/s	Pond bottom hydraulic conductivity	
STARTINGSTAGE	real>=0	m	Initial elevation of water in pond	
NPTSV	2 through 25	none	specifies number of points on volume curve	
SV(1,i) SV(2,i) In pairs where i ranges from 1 to NPTSV	Pond stage and pond volume pairs	m and m³	sets values for volume curve	• If NPTSV=0, then the SV pairs should be omitted
NPTSA	2 through 25	none	specifies number of points on area curve	
SA(1,i) SA(2,i) In pairs where i ranges from 1 to NPTSA	Pond stage and pond area pairs	m and m²	sets values for area curve	• If NPTSA=0, then the SA pairs should be omitted
WEIRHEIGHT WEIRLENGTH OVERFLOWHEIGHT	real>0 real>0 real>0	m m m	weir elevation weir length overflow elevation	Elevation and overflow height are both set as elevation with the same datum as the SA and SV curves

4.3.3.13 The ALTERNATIVE FILTER Command

Purpose:

This command allows users to simulate a pond that has a sand filter at the bottom. Outflows are via a weir, and overflows occur if pond depth exceeds a specified maximum. Basic theory is as described in the LEAKY BMP command (4.3.26 above) except for the addition of a weir and the addition of flows back to the outflow stream. This command was originally developed in support of a City of Austin project exploring BMP placement and design.

Use:

This BMP is used to represent a typical detention pond where there is a weir flow outlet and there are flows through a filter at the bottom. Except for the return of filtered flows to the main stream, and the calculation of losses through the filter material, it is similar to the EXFILTRATION BMP command. Filter flows are based on situation where a filter of known thickness and hydraulic conductivity is below the facility, and that flows pass continually through this layer when there is volume standing in the pond. Rate constants (first order and sedimentation) are obtained from the immediately preceding START command.

Numerical Values:

ALTERNATIVE FILTER Command Information				
Parameter	Value(s)	Units	Effect	Requirements
IDIN	A valid ID value	none	ID number for the inflow series	Must be a currently valid series ID.
IDOUT	A valid ID value	none	D number for the outflow series	Must be a valid series ID.
ISER	integer>0	none	Serial for the outflow series	• If ISER<0, then detailed pond behavior will be dumped to a binary file that can be accessed using the PULL POND SPAN and CALC POND STATS commands. • ISER is set to ABS(ISER) after the model is set to dump detailed diagnostics.
FILTERT	real > 0	m	Filter bottom thickness	The effective filter thickness should be used, not just the physical dimension of the filter. For example, if there is a highly conductive gravel layer below a sand layer contained by filter fabric, the gravel may not be a factor in hydraulic resistance to outflow.
FILTERK	real > 0	cm/s	Filter bottom hydraulic conductivity	The effective hydraulic conductivity should be used (see note for effective thickness above).
STARTINGSTAGE	real >=0	m	Initial elevation of water in pond	

NPTSV	2 through 25	none	specifies number of points on volume curve	
SV(1,I) SV(2,I) in pairs where I ranges from 1 to NPTSV	Pond stage and pond volume pairs	m and m³	sets values for volume curve	• If NPTSV=0, then the SV pairs should be omitted.
NPTSA	2 through 25	none	specifies number of points on area curve	
SA(1,I) SA(2,I) in pairs where I ranges from 1 to NPTSA	Pond stage and pond area pairs	m and m²	sets values for area curve	• If NPTSA=0, then the SA pairs should be omitted.
WEIRHEIGHT WEIRLENGTH OVERFLOWHEIGHT	real≥0 real>0 real≥0	m m m	weir elevation weir length overflow elevation	Elevation and overflow height are both set as elevation with the same datum as the SA and SV curves.
DREMOVALFRAC SREMOVALFRAC(1) SREMOVALFRAC(2) SREMOVALFRAC(3) SREMOVALFRAC(4) SREMOVALFRAC(5)	0<=REAL<1	NONE	Removal fractions for each pollutant	

4.3.3.14 The FILTERED REMOVAL Command

Purpose:

This command allows users to represent a BMP that operates as a filter medium, as might appear in an LID or sand filter system.

Use:

The FILTERED REMOVAL command must refer to an existing time series file, and must include identification for the output series as well as the parameters required for calculation. The method used is based on Urbonas, Ben R. (Stormwater Sand Filter Sizing and Design A Unit Operations Approach) found at
http://www.udfcd.org/downloads/pdf/tech_papers/Sand-flt-paper.pdf

Numerical Values:

FILTERED REMOVAL Command Information				
Parameter	Value(s)	Units	Effect	Requirements
IDIN	a valid series ID	n/a	series to filter	• The filter throughflow is calculated as Q=FAREA*UNITFC*EXP(-DECAYC*ACCUML) Where ACOUML = accumulated filter load • The filter load increases as the sum of arriving loads with caplute = FREM*arrival rate • The filter load is reduced by the fraction PCTREM/100 once every MAINT times per year
IDOUT	A valid series ID <> IDIN	n/a	output series	
ISEROUT	integer>0	n/a	output name	
FAREA	real>0	sq m	filter area	
UNITFC	real>0	none	filter constant	
DECAYC	real>0	none	decay constant	
FREM	real>=0,<1	none	fraction removed	
TSSINIT	real>0	mg	initial TSS load	
MAINT	integer>0	/year	maintenance cycle	
PCTREM	real>0,<=100	%	percent filter load removed	
BUFVOL	real>0	cu m	buffer volume	

4.3.3.15 The REACH Command

Purpose:

This command allows users to simulate a river or channel segment.

Use:

The user provides identifiers for one or more upstream series and one or more laterally introduced series. These series represent flows introduced to the channel at its headwater or distributed along its length, respectively. The flows and constituents for these series are are routed through the channel. Hydraulically, flows are routed based on continuity and either a rating curve or Manning's equation as preferred by the user. Constituent transformations include mixing and losses. Mixing is controlled by the selected NELS parameter obtained from the immediately preceding START command. Losses are first order decay (computed based on DECAYK), and discrete settling computed (based on SEDSET values), with parameters from most recent preceding START command.

Numerical Values:

REACH Command Information				
Parameter	Value(s)	Units	Effect	Requirements
IDOUT	a valid series ID.	none	identifies output series ID	• IDOUT<>IDH
ISER	integer	none	numerical series name and flag for detailed outputs	
NIDH	integer	none	# of upstream series inputs	
IDH_i, i=1,NIDH	a valid series ID.	none	identifies input series ID.	• *Omit this block if NIDH=0* The series referred to must have been developed in an earlier run or a command prior to the use of the REAH command
NIDL	integer	none	# of lateral series inputs	
IDL_i, i=1,NIDL	a valid series ID.	none	identifies input series ID.	• *Omit this block if NIDL =0* The series referred to must have been developed in an earlier run or a command prior to the use of the REAH command
IFAORM	1 or 2	none	flag for channel flow calcs	• If IFAORM is 1, a routing curve will be calculated • If IFAORM is 2, Manning's equation will be used
NELS	1 through 99	none	specifies number of mixing elements	• If NELS = 1, the pond is completely mixed • If NELS is large in say 99, the pond is approximately plug flow • NELS between 1 and 99 are intermediate cases
DMAX	Maximum depth	m		
XLEN	reach length	m		
RTINC	Less than 1 hour	hours	computation time step for REACH	• Time step for routing. Should be less than one hour, typically
COEF EXPON			Q/S coefficient Q/S exponent	*Omit this block if IFAORM =0*

RN SF SS B	real>0 real>0 real>0 real>=0		Manning n friction slope side slope bottom width	***Omit this block if FAORM=1***

4.3.3.16 The EROSIVE Command

Purpose:

This command computes the erosive impulse (excess boundary shear stress integrated over time) applied to a user-defined stream cross-section by a specified time series of flow rates.

Use:

This command was developed specifically for the Toronto Region Conservation Authority area, and is intended to provide a way to assess the shear stresses developed in a stream as a result of long term flows.

The stream cross-section is of trapezoidal geometry; the bottom width and side slopes of the cross-section as supplied as input to this command, along with the hydraulic roughness (Manning n value) and the longitudinal bed slope.

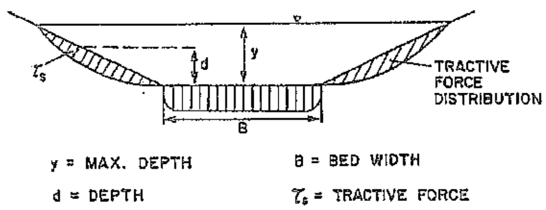
The input to this command must also include the critical tractive stress along the cross-section bed and banks. A single critical stress value must be supplied to characterize the channel bed. For the channel banks, the critical tractive stress values are supplied at equal intervals of depth above the channel bottom, per the input description below.

Generally, the critical stress values are estimated using field investigations that would include sampling and analysis of textural class of the bed and bank materials, and/or direct measurements of critical shear stress of bed and banks. Some empirical relationships between textural classification and critical stress is provided in Chow (1959).

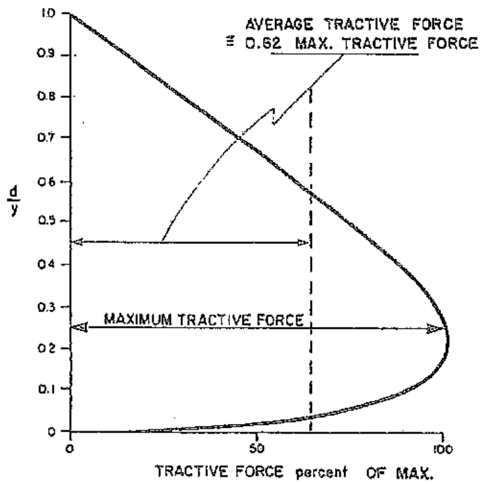
This command functions as follows:

- In each time step, the subroutine first computes the depth of flow, the hydraulic radius and the velocity of flow, using the Manning equation with the user-supplied Manning n value and assuming that energy slope equals the user-supplied bed slope.
- The resulting tractive stresses on the channel bed along the wetted portion of channel banks are computed using empirically-derived equations documented in OMNR (1982). These equations are presented below for reference.
- In each time step, the subroutine checks if the applied bed and bank stresses are greater than the user-supplied critical values. If so, then the erosive impulse value is updated. The erosive impulse is simply the time-integral of the excess tractive stress. An impulse value is computed for the bed, and an impulse value is computed for each depth interval up the banks.

The relationships used to resolve this are well known. As shown below, in a figure taken from OMNR publication "Vulnerability of natural watercourses to erosion due different flow rates", M.M. Dillon Limited, 1982, it is possible to develop an analytic solution of the distribution of tractive forces in this particular case.



RELATIVE DISTRIBUTION OF TRACTIVE FORCE ON A TRAPEZOIDAL CHANNEL BANK



Based on this case, the maximum applied tractive stress on channel banks is:

$$\tau_{Smax} = C_S \gamma R S_b$$

$$\tau_{Bmax} = C_B \gamma R S_b$$

τ_{Smax} = max tractive stress on channel banks (Pa); and

τ_{Bmax} = max tractive stress on bed (Pa); γ = unit weight of water (N/m^3)
R = hydraulic radius (m); S_b= channel bed slope (m/m)

$$C_S = (Z/2)^{0.36} \left[1.3 - 0.15 \ln (B/y)\right]$$
$$C_B = (Z/2)^{0.14} \left[1.42 - 0.019 \ln (B/y)^3\right]$$

Z = channel bank side slope (horizontal to vertical)
B = bed width (channel bottom width, m)
y = total depth of flow (m)

The distribution of applied tractive stress along the channel banks is:

$$\tau_S = \tau_{Smax} * \sin [\pi (d/y)^{0.45}]$$

where τ_S = tractive stress on channel bank at depth d above the channel bottom (m)

A sample input set for this command are below. The critical shear stress values are arbitrary, but the examples serve to illustrate the use of the command.

```
EROSIVE                   ID=-171   Start date 2005 05 28  End 2006 12 31
                          Number of depth increments = 50
                          Depth increment = 0.05 m
                          Bottom width    = 15 m
                          Sideslope       = 3
                          Slope           = 0.004
                          Manning N       = 0.05
                          Critical Bed Stress = 5
                          Critical Bank Stress Values
                            5  5  5  5  5  5  5  5  5  5
                            5  5  5  5  5  5  5  5  5  5
                            5  5  5  5  5  5  5  5  5  5
                            5  5  5  5  5  5  5  5  5  5
                            5  5  5  5  5  5  5  5  5  5
```

The text output file created by QUALHYMO will include the following output variables from the EROSIVE command:

- Total duration of analysis (hours)
- Total flow volume (hours)
- Maximum flow rate (m3/s)
- Maximum computed flow depth (m)
- Maximum computed bed stress and bank stress (Pa)
- Total bed impulse (cumulative excess shear stress on the channel bed, integrated over the duration of analysis), in Pa-hours
- Table listing the impulse on the channel banks at each depth increment (NDepth increments), in Pa-hours

If **IDin** is specified as a negative value, then there will also be generated a detailed trace output file (ASCII text) named EROSIVE.TRA, that presents results for each time step.

The result of the above input set would be as follows:

```
Results from EROSIVE POWER routine for series ID  171:
    ---------------------------------------------------------
    Total duration of analysis  =   13992.000 hours
    Flow volume                 =   38763.633 000s m3
    Maximum flow encountered    =     181.893 m3/sec
    Maximum computed flow depth =       3.312 m
    Max computed bed stress     =     127.285 Pa
    Max computed bank stress    =     111.987 Pa
    ---------------------------------------------------------
    Critical bed stress =   5.000 Pa
    Bed Impulse =       23241.355 Pa-hours
    ---------------------------------------------------------
     Depth   Critical     Bank Impulse
        bank stress
      (m)      (Pa)       (Pa-hours)
    -------  ----------  --------------
     0.000      5.0000           0.000
     0.050      5.0000        9627.908
     0.100      5.0000       10281.417
     0.150      5.0000        9120.602

(etc, every 0.05 m)

     2.300      5.0000         149.373
     2.350      5.0000         138.283
     2.400      5.0000         127.900
     2.450      5.0000         117.536
```

References Cited:

- Chow, V.T., 1959. Open Channel Hydraulics. McGraw-Hill Book Company. Library of Congress Catlog Card Number 58-13860.
- Ontario Ministry of Natural Resources (OMNR), 1982. "Vulnerability of natural watercourses to erosion due to different flow rates", report prepared by M.M. Dillon Limited, Consulting Engineers & Planners, Toronto, Ontario, dated Nov. 19, 1982, Dillon file # 9142-01, principal author F. Ivan Lorant, P.Eng.

Numerical Values:

EROSIVE Command Information				
Parameter	Value(s)	Units	Effect	Requirements
Idin	integer > 0	none	ID for time series of flow rates to be applied to the channel section	
SYR, SMO, SDAY	integer > 0 integer > 0 < 12 integer > 0 < 32	none	Starting date of analysis	
EndYR, EndMO, EndDAY	integer > 0 integer > 0 < 12 integer > 0 < 32	none	Ending date of analysis	
Ndepth	integer > 0	none	Number of depth increments at which to compute tractive stress and impulse values	Must be < 51
dDepth	real > 0	m	Depth increment	
BW	real > 0	m	Bottom width of trapezoidal cross section	
SS	real > 0	m/m	Sideslopes of channel banks (horiz:vertical)	
BedSlope	real > 0	m/m	Longitudinal channel bed slope	
MN	real > 0	none	Manning n value	
CriticalBedStress	real > 0	Pa	Critical tractive stress on channel bottom (bed)	
CriticalBankStress (n), n=1,NDepth	real > 0	Pa	Values of critical bank stress	*Enter Ndepth values of CriticalBankStress*

4.3.3.17 The GET EXCESS SHEAR Command

Purpose:

This command computes the erosive impulse (excess boundary shear stress integrated over time and area) applied to a user-defined stream cross-section by a specified time series of flow rates. It relies on non-standard data inputs, as it was developed as a special case, with flows taken from the same input file as is described in the GET ALVI DATA command. It is for test purposes only, and not for general use. It will be replaced with a standard format version at the end of 2009.

Use:

This command is intended to provide a way to assess the shear stresses developed in a stream as a result of long term flows. Where the EROSIVE command explores stresses (Pa-hours of excess shear), this command calculates excess shear (N-hours) over the areas provided. It is able to use multiple sections, where the EROSIVE command only uses one section at a time. However, it is restricted to cases in which only a single value of critical shear is applicable to the side slopes.

The stream cross-section is of trapezoidal geometry; the bottom width and side slopes of the cross-section as supplied as input to this command, along with the hydraulic roughness (Manning n value) and the longitudinal bed slope.

The input to this command must also include a single critical tractive stress for the cross-section bed and one for the banks.

Generally, the critical stress values are estimated using field investigations that would include sampling and analysis of textural class of the bed and bank materials, and/or direct measurements of critical shear stress of bed and banks. Some empirical relationships between textural classification and critical stress is provided in Chow (1959).

This command functions as follows:

- The command begins by calculating characteristic curves of excess shear for various flow rates and depths in the channel, from zero depth to the user specified maximum depth. These curves are printed for user reference, one for each section input by the user.
- Then, the command runs through each time step. It reads headwater and lateral flows from the input flow file identified in the QCONTROL.TXT file. It then calculates total flow for each section, and then calculates excess shear at each section using the curves of excess shear that are first calculated.
- Once the whole time series has been run, the summary statistics are printed for the user, including the total flow and total excess shear force calculated by the command at each section input by the user.

As with the EROSIVE command, the excess tractive stresses on the channel bed and along the wetted portion of channel banks are computed using empirically-derived equations documented in OMNR (1982). These equations are presented in the EROSIVE command. They differ only in this command in that they are converted to force rather than stress, by multiplying each stress value at each time step by the representative area.

A sample input set for this command are below. The critical shear stress values are arbitrary, but the examples serve to illustrate the use of the command.

```
GET EXCESS SHEAR          NUMBER OF SECTIONS = 5
          FLOW LENGTH  MAX   BOTTOM  SIDE  FRICTION  N  CRIT  CRIT
         FACTOR        DEPTH  WIDTH  SLOPE   SLOPE      BED   BANK
                                                        SHEAR SHEAR
                  m      m       m     m/m     m/m
           0.     100    0.1      15      3      .004   .05   2    1
           .3     100    0.1    15      3      .004  .05   2    1
           .5     100    0.1    15      3      .004  .05   2    1
           .7     100    0.1    15      3      .004  .05   2    1
           1.     100    0.1    15      3      .004  .05   2    1
```

The result of the above input set would be as follows:

```
   FLOW RECORDS WILL BE SOUGHT ON DEVICE=          10
   FLOW FILE = E:\Data\BillLucas\EROSION\TEST_RUNS\testfile.TXT
   DETECTED TIME STEP IS    1.000000     HOURS.

  CHANNEL SECTION CHARACTERISTICS, FOR SECTION       1
  J     DEPTH       V        R       FLOW       SHEAR
  2     0.005     0.038    0.005       0.00   0.1646E+00
  3     0.011     0.061    0.011       0.01   0.6490E+00
  4     0.016     0.079    0.016       0.02   0.1253E+01
```

(etc, over the depth of the channel and repeated for each section)

```
 18     0.089     0.250    0.088       0.34   0.3181E+04
 19     0.095     0.259    0.093       0.38   0.3557E+04
 20     0.100     0.269    0.098       0.41   0.3932E+04

TOTAL RUN TIME:     48.00 HOURS.

 CUMULATIVE SHEAR INDEX FOR EACH SECTION
 SECTION      TOTAL FLOW,     TOTAL IMPULSE
                (CU M)          (N-HOURS)
  1           26701.516        0.4316E+05
  2           27500.164        0.8342E+05
  3           28032.602        0.8436E+05
  4           28565.035        0.8573E+05
  5           29363.682        0.8759E+05
```

Numerical Values:

GET EXCESS SHEAR Command Information				
Parameter	**Value(s)**	**Units**	**Effect**	**Requirements**
NUMSETS	0<integer <101	none	Number of sections to be read; starting date of analysis	Must be less than 101
QFACTOR	real > 0	none	Depth increment in metres	*Note:* *You must enter NUMSETS values of these nine parameters, in order.*
SLEN	real > 0	m	Length of section	
MAXDEP	real > 0	m	Max depth	
BW	real ≥ 0	m	Bottom width	
SS	real ≥ 0	none	Sideslopes of channel banks	Side slopes expressed as horizontal to vertical ratio.
BEDSLOPE	real > 0	none	Longitudinal Channel bed slope	
MN	real > 0	none	Manning n value	
CRITICALBEDSHEAR	real > 0	Pa	Critical tractive stress on channel bottom (bed)	
CRITICALBANKSHEAR	real ≥ 0	Pa	Critical tractive stress on channel sides (bank)	

4.3.3.18 The SEDIMENT INDICATORS Command

Purpose:

This command computes the erosive impulse (excess boundary shear stress integrated over time and area), the stream power and an indicator or total sediment transport, developed for a user-defined sediment and stream cross-section influenced by a specified time series of flow rates. It relies on non-standard data inputs, as it was developed as a special case, with flows taken from the same input file as is described in the GET ALVI DATA command. It is for test purposes only, and not for general use. A standard format command with comparable functions also exists (see <u>CHANNEL SEDIMENT</u>).

Use:

This command is intended to provide a way to assess several characteristics related to stream erosion as they are affected by as a result of long term flows. Where the EROSIVE command explores stresses (Pa-hours of excess shear), this command calculates excess shear (N-hours), power (Watts) and a sediment indicator (kg) over the areas provided. It is able to use multiple sections, where the EROSIVE command only uses one section at a time. However, it is restricted to cases in which only a single value of critical shear is applicable to the side slopes.

The stream cross-section is of trapezoidal geometry; the bottom width and side slopes of the cross-section as supplied as input to this command, along with the hydraulic roughness (Manning n value) and the longitudinal bed slope.

The input to this command must also include a single critical tractive stress, critical velocity, particle size and other parameters characteristic of the sediment of interest.

The command is not intended to provide universally applicable or absolute estimates of long term erosion. Some factors and characteristics that could be relevant are not within the scope of this command, such as mobile boundary responses, are not incorporated in the command. As with other commands in QUALHYMO, the user must understand the physical problem and the nature of the command and determine a best course of action. In this case, it is necessary that the user be knowledgeable in the analysis of sediment transport and to determine how to apply this command and incorporate the computational results to problem at hand.

Generally, the critical stress values are estimated using field investigations that would include sampling and analysis of textural class of the bed and bank materials, and/or direct measurements of critical shear stress of bed and banks. Some empirical relationships between textural classification and critical stress is provided in Chow (1959).

This command functions as follows:

- The command begins by calculating characteristic curves of excess shear, power and sediment indicator for various flow rates and depths in the channel, from zero depth to the user specified maximum depth. These curves are printed for user reference, one for each section input by the user.
- Then, the command runs through each time step. It reads headwater and lateral flows from the input flow file identified in the QCONTROL.TXT file. It then

calculates total flow for each section, and then calculates excess shear at each section using the curves of excess shear that are first calculated.

- Once the whole time series has been run, the summary statistics are printed for the user, including the total flow and total excess shear force, total power and total sediment indicator calculated by the command at each section input by the user.

As with the EROSIVE command, the excess tractive stresses on the channel bed and along the wetted portion of channel banks are computed using empirically-derived equations documented in OMNR (1982). These equations are presented in the EROSIVE command. They differ only in this command in that they are converted to force rather than stress, by multiplying each stress value at each time step by the representative area.

Excess shear is calculated as noted in the EROSIVE command. Stream power is calculated as:

$$\Omega = \gamma Q S_f$$

where

γ = fluid density

S_f = friction slope

Q = flow rate (m^3/s)

The indicator of sediment transport is patterned after Brownlie (1981).

$$SED = Q7115c_b \left[\frac{V - V_c}{\sqrt{(G-1)gd_s}} \right]^{1.978} S_f^{0.6601} \left[\frac{R_h}{d_s} \right]^{-0.3301}$$

where

SED = rate of sediment transport (g/sec)

R_h = hydraulic radius (m)

d_s = characteristic sediment diameter (m)

G = specific gravity

g = gravitational constant

V = flow velocity (m)

V_c =critical flow velocity (m/s)

c_b =Brownlie coefficient

The above is provided for convenience only; the user should refer to the original documentation for particulars on this method.

A sample input set for this command are below. The critical shear stress values are arbitrary, but the examples serve to illustrate the use of the command.

```
SEDIMENT INDICATORS
          BASIC SEDIMENT CHARACTERISTICS ========
             CHARACTERISTIC PARTICLE SIZE = .00001 M
             SPECIFIC GRAVITY = 2.67
             CHARACTERISTIC CRITICAL VELOCITY = 0.01 M/S
             CRITICAL BED SHEAR = 2 N/SW M
             CRITICAL BANK SHEAR = 1 N/SQ M
             BROWNLIE COEFFICIENT = 1
          CHANNEL SEGMENT CHARACTERISTICS =======
          NUMBER OF SECTIONS = 5
          FLOW   LENGTH   MAX  BOTTOM  SIDE  FRICTION  N
         FACTOR          DEPTH  WIDTH  SLOPE   SLOPE
            -       m       m      m     m/m     m/m     -
           .3      100     0.1    1       3      .001    .05
           .3      100     0.1    1       3      .002    .05
           .3      100     0.1    1       3      .003    .05
           .3      100     0.1    1       3      .004    .05
           .3      100     0.1    1       3      .005    .05
```

The result of the above input set would be as follows:

```
 SEDIMENT INDICATORS
          BASIC SEDIMENT CHARACTERISTICS ========
             CHARACTERISTIC PARTICLE SIZE = .00001 M
             SPECIFIC GRAVITY = 2.67.
             CHARACTERISTIC CRITICAL VELOCITY = 0.01 M/S
             CRITICAL BED SHEAR = 2 N/SW M
             CRITICAL BANK SHEAR = 1 N/SQ M
             BROWNLIE COEFFICIENT = 1
          CHANNEL SEGMENT CHARACTERISTICS =======
          NUMBER OF SECTIONS = 5
          FLOW   LENGTH   MAX  BOTTOM  SIDE  FRICTION  N
         FACTOR          DEPTH  WIDTH  SLOPE   SLOPE
            -       m       m      m     m/m     m/m     -
           .3      100     0.1    1       3      .001    .05
           .3      100     0.1    1       3      .002    .05
           .3      100     0.1    1       3      .003    .05
           .3      100     0.1    1       3      .004    .05
           .3      100     0.1    1       3      .005    .05
   FLOW RECORDS WILL BE SOUGHT ON DEVICE=          10
   FLOW FILE = E:\Data\EROSION\TEST_RUNS\testfile.TXT
   DETECTED TIME STEP IS     1.000000     HOURS.

   CHANNEL SECTION CHARACTERISTICS, FOR SECTION        1
  NO.  DEPTH       V       R       FLOW       SHEAR       POWER      SEDIMENT
   -    (M)      (M/S)    (M)      (M/S)    (Pa/SQ.M.)     (WATTS)     (MG/s)
  2    0.005     0.019    0.005       0.00  0.0000E+00  0.2977E+01  0.4481E-04
  3    0.011     0.030    0.010       0.00  0.0000E+00  0.9494E+01  0.5484E-03
```

(etc, over the depth of the channel and repeated for each section)

```
 18     0.089     0.246     0.072          0.03  0.2958E+03  0.8211E+03  0.1682E+02
 19     0.095     0.254     0.076          0.03  0.3231E+03  0.9091E+03  0.1959E+02
 20     0.100     0.262     0.080          0.03  0.3503E+03  0.1001E+04  0.2263E+02

TOTAL RUN TIME:      48.00 HOURS.

 CUMULATIVE EXCESS SHEAR AND POWER INDICIES FOR EACH SECTION
 SECTION        TOTAL FLOW   TOTAL IMPULSE    TOTAL POWER   TOTAL SEDIMENT
                  (CU M)       (N-HOURS)      (WATT-HOUR)          (KG)
  1             27500.164    0.0000E+00     0.2248E+06     0.9719E+03
  2             27500.164    0.3603E+05     0.2248E+06     0.3975E+04
  3             27500.164    0.4836E+05     0.2248E+06     0.8982E+04
  4             27500.164    0.5912E+05     0.2248E+06     0.1596E+05
  5             27500.164    0.6884E+05     0.2248E+06     0.2488E+05
```

References:

Brownlie, W.R., 198, 'Prediction of flow depth and sediment discharge in open-channels.', Report no. KH-R-43A. Pasadena: California Institute of Technology, W.M. Keck Laboratory.

Numerical Values:

SEDIMENT INDICATORS Command Information				
Parameter	Value(s)	Units	Effect	Requirements
CHARSIZE SG CHARVELVEL CRITICALBEDSHEAR CRITICALBANKSHEAR BROWNLIE	real >0 real >0 real >0 real >0 real >0 real <=1	m n/a m/s Pa Pa n/a	characteristic particle size particle specific gravity characteristic critical velocity critical bank shear critical bed shear Brownlie coefficient	This block defines the basic characteristics of the particle that is taken to represent the sediment of interest.
NUMSETS	0< integer <101	none	Number of sections to be read starting date of analysis	Must be less than 101
QFACTOR SLEN MAXDEP BW SS BEDSLOPE MN	real > 0 real >= 0 real > 0 real > 0 real > 0 real > 0 real > 0	none m m m none none none	Depth increment in metres Length of section Max depth Bottom Width Sideslopes of channel banks Longitudinal Channel bed slope Manning n value	This represents the channel sections in which sediment indicators will be assessed. ***Note:*** ***You must enter NUMSETS values of these nine parameters, in order.*** Side slopes expressed as horizontal to vertical ratio.

4.3.3.19 The ADD SERIES Command

Purpose:

This command allows users to add two series together. The shortest time step of the two will be used if the time steps are not the same. Note that the larger time step must be an integer multiple of the shorter time step if the two are not equal.

Use:

The ADD SERIES command must follow at least two commands creating output series, or must be used in a situation where two output series already reside on disc, because the command needs two input series to function. Several ADD SERIES can be used in sequence.

The result of each invocation of this command is a new series that is the sum of the two input series.

Numerical Values:

ADD SERIES Command Information				
Parameter	Value(s)	Units	Effect	Requirements
IDOUT ISER IDINA IDINB	A series ID Integer>0 A series ID A series ID	none none none none	sets the output ID sets output name sets an input ID sets an input ID	• IDINA and IDINB must be existing series IDs • Time steps of IDINA and IDINB must be equal or one must be an integer multiple of the other

4.3.3.20 The SPLIT SERIES Command

Purpose:

This command allows users to split a time series into two using a defined flow split curve.

Use:

The SPLIT SERIES command must refer to an existing time series file, and must include identification for the two sub-series as well as the flow split curve. When used, the original file remains intact and the two new files are generated.

Numerical Values:

SPLIT SERIES Command Information				
Parameter	Value(s)	Units	Effect	Requirements
IDIN	A series ID	none	series to be split	• The split curve is specified in pairs where: ○ the first value is the arrival flow rate ○ the second value is the split rate for series IDOUTA ○ the series IDOUTB is calculated as the difference between the arrival flow rate and the rate for IDOUTA • The QQ curve must increase monotonically • The split values must all be less than the corresponding arrival values
IDOUTA	A series ID <> IDIN	none	1st output ID	
ISERA	integer > 0	none	1st output name	
IDOUTB	A series ID <> IDIN and <> IDOUTA	none	2nd output ID	
ISERB	Integer > 0	none	2nd output name	
NPTQQ	Integer > 0	none	# points on split curve	
{QQ(1,I),QQ(2,I)}, I=1,NPTQQ	real pairs	cu.m./sec	split curve pairs	

4.3.3.21 The WATER REUSE Command

Purpose:

This command is used to evaluate the effectiveness of water re-use based on storm flows that are captured lot by lot and then re-used locally.

Use:

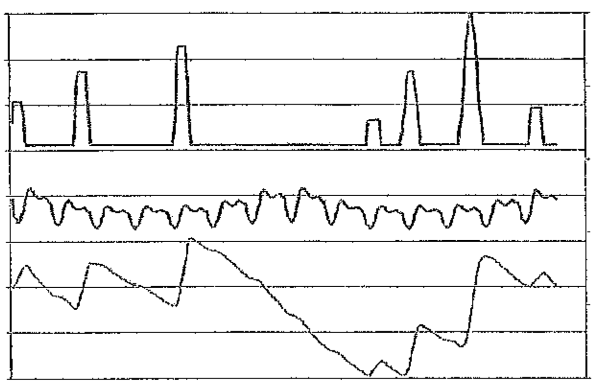
The user provides information on demand and on supply (e.g. population, lot re-use and per capita use etc.), as well as the identity of the input flow series. The user can add custom diurnal and weekly variation curves by providing two files with hourly and daily values respectively; if they do not, a constant re-use rate is used.

Technical Approach:

As implemented in this command, the typical kinds of analysis which is anticipated users will undertake would be an evaluation of the number of re-use consumers who can be serviced from a given source, or an evaluation of the size of storage volume which is needed to buffer the differences between inflow and outflow. There are at least three components needed for the simulation of water re-use in this type of problem. These are:

- the supply of water for re-use purposes,
- the storage unit that retains this water, and
- the rate of re-use.

In the figure below, which represents a typical re-use scenario, there is an inflow provided by a series of rainfall events. That inflow (shown in red) is balanced by a series of withdrawals (shown in blue), depicted by a typical diurnal demand curve superimposed on a weekly demand variation. The difference between supply and demand is made up by a storage volume (shown in green) which increases when supply exceeds demand, and reduces when demand exceeds supply.



A Typical Relationship Between Supply, Use and Storage

In this command, the three terms are represented as follows:

Supply: Available water is simulated by a standard QUALHYMO flow series that will typically represent a watershed area. In addition, there are two other factors that need to be added to the algorithm when dealing with supply at a watershed level in the urban context, which are the degree to which runoff can be captured at a lot level, and the degree to which a population will participate in a re-use program. Both are critical management parameters, and both are incorporated in the supply algorithm.

Demand: The demand for re-use will be a function of re-use targets (those parts of the non-potable system that are to be supplied with re-use product), and program compliance. A per capita unit rate and population data provide the basic rate of water consumption. The user also can provide estimates of diurnal variation and weekly variation from the unit rate[1]. As well, the estimated percent consumer adoption can be input.

Storage: The storage volume calculation is based on a standard routing algorithm. At this time it is assumed that the storage will be enclosed tanks without leakage or evaporative losses.

Specific additional data required for the domestic water reuse assessments are indicated in the tables of input values provided below.

The mathematics in this algorithm are straightforward. Continuity provides the relationship below.

$$\frac{dS}{dt} = I - O$$

where S = storage

I = rate of supply

O = rate of demand

This is solved as a finite approximation at the time step of the input series.

---

1 It is noted that data on re-use variation might not always be available. In the domestic context, diurnal and weekly variation in demand curves might be represented by typical wastewater curves, factored to account for reductions due to potable consumption elements and unsuitable (i.e. non-reuse supplied) domestic uses.

String Values:

WATER REUSE Command Information			
String Name	String Value(s)	Effect	Requirements
DIURNAL DEMAND	File name	Sets name of input file for diurnal variation	• Input file names can either be fully qualified or specified relative to the QUALHYMO executable directory. • If either of these string values is not provided, the model will attempt to use the default file provided in the QUALHYMO executable directory. • Both input files are provided as text files, with one value per record. The diurnal variation file must have 24 hourly values. The weekly variation file must have 7 daily values. In both cases, the values are provided one value per record, in free format.
WEEKLY DEMAND	File name	Sets name of input file for weekly variation	

Numerical Values:

WATER REUSE Command Information				
Parameter	Value(s)	Units	Effect	Requirements
IDIN	A series ID	none	series providing flow	• LOT_STORAGE_MAX is the upper limit of flow storage per lot • LOT_PERCENT_REUSE is the percent of lots that are engaged in re-use • FRAC_OF_FLOW is the fraction of flow from IDIN that is available for re-use by those engaged in re-use
LOT_STORAGE_MAX	real>0	cu m		
DEPTH_MAX	real>0	m		
DEPTH_STARTING	real>0	m		
POPULATION	integer>0	n/a		
POP_PER_LOT	real>0	n/a		
LOT_PERCENT_REUSE	real>0	%		
PER_CAPITA_CONSUMPTION	real>0	m3/sec per person		
FRAC_OF_FLOW	real>0	n/a		

A typical input deck for this command is as follows:

```
WATER REUSE
       <DIURNAL DEMAND=E:\Data\QUALHYMO_TESTS\BMPCal1\second\DAILY.TXT>
       <WEEKLY DEMAND=E:\Data\QUALHYMO_TESTS\BMPCal1\second\WEEKLY.TXT>
       ID=6
       MAXIMUM LOT STORAGE = 2 CU M PER LOT
       MAXIMUM DEPTH OF STORAGE ON LOT = 1 CU M
       STARTING DEPTH OF STORAGE ON LOT = 0.5 CU M
       POPULATION IN WATERSHED = 200 PEOPLE
       POPULATION PER LOT = 3 PEOPLE
       PERCENT OF LOTS PARTICIPATING IN REUSE = 70%
       PER CAPITA CONSUMPTION = 400 LITRES PER PERSON PER DAY
       FRACTION OF FLOW AVAILABLE FOR REUSE = 0.52
```

In this case, two variation curves are specified. They will be provided in two text files, one value per record. For the daily variation curve there are twenty-four hourly values, and for the weekly variation curve, seven daily values. These might look like the following few sample records:

```
      0.870616687
      0.889963724
      0.918984281
        ... (and so on)
```

A typical output of this command is as follows:

```
WATER REUSE
       <DIURNAL DEMAND=E:\Data\QUALHYMO_TESTS\BMPCal1\second\DAILY.TXT>
       <WEEKLY DEMAND=E:\Data\QUALHYMO_TESTS\BMPCal1\second\WEEKLY.TXT>
       ID=6
       MAXIMUM LOT STORAGE = 2 CU M PER LOT
       MAXIMUM DEPTH OF STORAGE ON LOT = 1 CU M
       STARTING DEPTH OF STORAGE ON LOT = 0.5 CU M
       POPULATION IN WATERSHED = 200 PEOPLE
       POPULATION PER LOT = 3 PEOPLE
       PERCENT OF LOTS PARTICIPATING IN REUSE = 70%
       PER CAPITA CONSUMPTION = 400 LITRES PER PERSON PER DAY
       FRACTION OF FLOW AVAILABLE FOR REUSE = 0.52

 DAILY VARIATION READ FROM E:\Data\QUALHYMO_TESTS\BMPCal1\second\DAILY.TXT
 CONSERVATION ERROR OF DAILY VARIATION CURVE =  0.000%

 WEEKLY VARIATION READ FROM E:\Data\QUALHYMO_TESTS\BMPCal1\second\WEEKLY.TXT
 CONSERVATION ERROR OF WEEKLY VARIATION CURVE =  0.000%

  ==== FATE OF RE-USE COMPONENTS (CUBIC METERS) ====

  STARTING VOLUME IN STORAGE          46.66666
  TOTAL FLOW TO RE-USE PROPERTIES     672.3082
  TOTAL CONSUMPTION                   217.8353
  TOTAL BYPASSES                      496.5511
  ENDING VOLUME IN STORAGE            4.588938

  CONTINUITY ERROR   0.000%
  ==================================================
```

4.3.3.22 The CHANNEL SEDIMENT Command

Purpose:

This command is used to estimate indices that reflect the tendency of flow in a channel to cause sediment transport.

Use:

The user provides information on channel section and sediment characteristics, and an input flow series. The command then routes the series through the channel, calculating shear, excess shear and power over the period of interest.

Technical Approach:

The basic relations that need to be considered are shear force and stream power. These are typically developed as follows.

Shear force is related to the slope of the stream, the hydraulic radius and the density of water:

$$\tau = \gamma R S_f$$

where

τ = unit shear stress

γ = specific weight of water

R = hydraulic radius of the channel

S_f = friction slope of the channel

Power is related to the flow rate, the slope of the stream and the density of water.

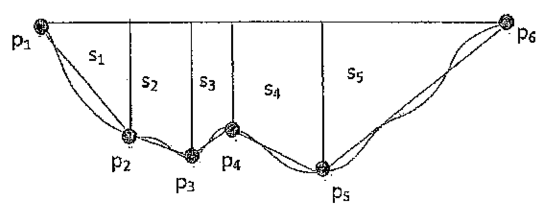
$$\Omega = \gamma Q S_f$$

where

Ω = stream power

Q = flow rate

These relationships are applied in this command. To do this, an irregular channel shape is represented by a series of points defined by lateral position and elevation.



To do this calculation efficiently, solution curves are developed for each of three cases:

- shear as a function of flow
- power as a function of flow
- excess shear as a function of flow

The model then calculates power, shear and excess shear for all values of the continuous input series. As it does this, it develops impulse and power values as the sum of incremental impulse and power states. This is done by inferring depth from flow, and power and excess shear from depth.

$$I_T(d) = \sum_0^T [\tau(d) \circ \Delta t]$$

and

$$P_T(d) = \sum_0^T [\Omega(d) \circ \Delta t]$$

where

$P_T(d) =$ time integral (finite) of power

Several points should be noted:

1. Section bifurcations are treated as single channel sections.
2. Distribution of flow is normalized across the subsections according to hydraulic radius in each section (to the 2/3 power) for shear calculation purposes.
3. The calculation of hydraulic radius uses an algorithm that is most applicable to relatively gradually varying sections typical of natural channels.

Taken together, these calculations enable an evaluation of excess shear and total power, and therefore the comparison of any particular management strategy to a base case in terms of erosive potential.

Numerical Values:

CHANNEL SEDIMENT Command Information				
Parameter	**Value(s)**	**Units**	**Effect**	**Requirements**
IDIN	A series ID	n/a	series providing flow	
CRITICAL SHEAR	real>0	Pa	critical shear stress	
SECTION LENGTH	real>0	m	channel segment length	
NUM POINTS	integer>2	n/a	channel section points	
(STATION, ELEVATION) pairs i=1, NUM POINTS	real≥0, real>0	m,m		

A typical output of this command is as follows:

```
CHANNEL SEDIMENT
          INPUT SERIES ID = 6
          CRITICAL SHEAR = 2.5 PA
          SECTION LENGTH = 2000 M AT BED SLOPE .001 M/M WITH MANNING N=.012
          SECTION DEFINED BY 7 POINTS
          STATION  ELEVATION
            (M)        (M)
             0          0
             1          1
             1.5        1.5
             2          2
             2.5        1.5
             3          1
             4          0

  CHANNEL FLOW CHARACTERISTICS
  NO.    DEPTH         FLOW         SHEAR        EXCESS SHEAR      POWER
   -      (M)        (CU.M/S)       (Pa)            (Pa)          (WATTS)
  1  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
  2  0.1000E+01  0.1318E+01  0.9810E+01  0.2739E+01  0.1293E+02
  3  0.1500E+01  0.4391E+01  0.2207E+02  0.1255E+02  0.4307E+02
  4  0.2000E+01  0.9725E+01  0.3924E+02  0.2618E+02  0.9540E+02

 CUMULATIVE EXCESS SHEAR AND POWER INDICIES
  TOTAL TIME TOTAL FLOW   TOTAL SHEAR      TOTAL EXCESS SHEAR   TOTAL ENERGY
     (HRS)      (CU M)     (N-HOURS)           (N-HOURS)        (WATT-HOUR)
     96.00 0.3591E+00    0.2674E+01           0.7465E+00        0.3523E+01
```

4.3.4 Interpretation Commands

4.3.4.1 The PULL SERIES SPAN Command

Purpose:

This command allows users to pull a detailed listing of a subset of a time series data set.

Use:

The PULL SERIES SPAN command can be used if the specified time series exists.

The result of each invocation of this command is a listing of data, prefaced by file time step and name information. A few lines of a typical output are shown as follows:

```
 FILE CHARACTERSTICS ==========
       NAME =   208
  TIME STEP =   1.00000

 YYYYMMDD      Q           D           S1          S2          S3          S4          S5
1973 215 0.1307E-03 0.0000E+00 0.1838E-09 0.7845E-10 0.7748E-10 0.3606E-09 0.2527E-08
1973 215 0.2209E-03 0.0000E+00 0.5500E-09 0.2345E-09 0.2308E-09 0.1063E-08 0.6325E-08
1973 215 0.3345E-03 0.0000E+00 0.1299E-08 0.5531E-09 0.5424E-09 0.2471E-08 0.1272E-07
1973 215 0.4686E-03 0.0000E+00 0.2608E-08 0.1109E-08 0.1083E-08 0.4881E-08 0.2202E-07
1973 215 0.6215E-03 0.0000E+00 0.4677E-08 0.1987E-08 0.1933E-08 0.8613E-08 0.3460E-07
```

Numerical Values:

PULL SERIES SPAN Command Information				
Parameter	Value(s)	Units	Effect	Requirements
ID IFY IFM IFD ITY ITM ITD	A series ID A valid year 1 through 12 1 through 31 A valid year 1 through 12 1 through 31	none year month day year month day	specifies file controls retrieval span	• IFY, IFM and IFD must represent a valid date that precedes a valid date represented by ITY, ITM and ITD. • The date span defined on the START command must encompass the dates provided here.

4.3.4.2 The PULL POND SPAN Command

Purpose:

This command allows users to pull a detailed listing of various pond characteristics out of the long time series generated in the POND command or ALTERNATIVE FILTER command.

Use:

The PULL POND SPAN command must follow a POND command or an ALTERNATIVE FILTER command, and will develop data for only the most recent preceding POND command or ALTERNATIVE FILTER command. Several PULL POND SPAN commands can be used in sequence.

NOTE: The preceding POND command or ALTERNATIVE FILTER command must have the number of the output series set to a negative value (ISER = -1 x ISER) for this command to work.

The result of each invocation of this command is a listing of data, in a few lines shown as follows:

```
      DATE       TIME        INFLOW      OUTFLOW      STAGE     VOLUME     LOSSES
                 (HRS)       (CMS)       (CMS)        (M)       (M**3)     (CMS)
1970   1   1    0.00        0.000        0.000        0.042     501.854        0.004
1970   1   1    1.00        0.000        0.000        0.041     487.089        0.004
1970   1   1    2.00        0.000        0.000        0.040     472.331        0.004
1970   1   1    3.00        0.000        0.000        0.038     457.581        0.004
1970   1   1    4.00        0.000        0.000        0.037     442.838        0.004
1970   1   1    5.00        0.000        0.000        0.036     428.102        0.004
```

Numerical Values:

PULL POND SPAN Command Information				
Parameter	Value(s)	Units	Effect	Requirements
IFY IFM IFD ITY ITM ITD ISKIP	a valid year 1 through 12 1 through 31 a valid year 1 through 12 1 through 31 integer ≥ 1	year month day year month day n/a	retrieval span skip interval	• IFY, IFM and IFD must represent a valid date that precedes a valid date represented by ITY, ITM and ITD. • The date span defined on the START command must encompass the dates provided here. • ISKIP is not needed. If not present, every record will be retrieved. If present, every ISKIPth record will be retrieved.

4.3.4.3 The CALC POND STATS Command

Purpose:

This command allows users to develop statistics of the long time series generated in the POND command or ALTERNATIVE FILTER command.

Use:

The CALC POND STATS command must follow a POND command or an ALTERNATIVE FILTER command, and will develop data for only the most recent preceding POND command or ALTERNATIVE FILTER command. Several CALC POND STATS commands can be used in sequence.

NOTE: The preceding POND command or ALTERNATIVE FILTER command must have the number of the output series set to a negative value (ISER = -1 x ISER) for this command to work.

The result is a set of four listings of monthly maximum and minimum data and annual maximum and minimum data illustrated as follows:

```
============= MONTHLY MAXIMUMS ==========
  DATE       INFLOW      OUTFLOW      STAGE       VOLUME
              (CMS)       (CMS)        (M)        (M**3)
1960   1   0.164E+00   0.994E-02   0.550E+00   0.665E+04
1960   2   0.427E-01   0.000E+00   0.141E+00   0.168E+04
1960   3   0.174E+00   0.000E+00   0.653E+00   0.815E+04

============= MONTHLY MINIMUMS ==========
  DATE       INFLOW      OUTFLOW      STAGE       VOLUME
              (CMS)       (CMS)        (M)        (M**3)
1960   1   0.000E+00   0.000E+00   0.000E+00   0.000E+00
1960   2   0.000E+00   0.000E+00   0.000E+00   0.000E+00
1960   3   0.000E+00   0.000E+00   0.000E+00   0.000E+00

============= ANNUAL MAXIMUMS ===========
  DATE       INFLOW      OUTFLOW      STAGE       VOLUME
              (CMS)       (CMS)        (M)        (M**3)
 1960      0.916E+00   0.994E-02   0.117E+01   0.178E+05
 1961      0.827E+00   0.000E+00   0.887E+00   0.121E+05
 1962      0.654E+00   0.000E+00   0.866E+00   0.117E+05

============= ANNUAL MINIMUMS ===========
  DATE       INFLOW      OUTFLOW      STAGE       VOLUME
              (CMS)       (CMS)        (M)        (M**3)
 1960      0.000E+00   0.000E+00   0.000E+00   0.000E+00
 1961      0.000E+00   0.000E+00   0.000E+00   0.000E+00
 1962      0.000E+00   0.000E+00   0.000E+00   0.000E+00
```

Numerical Values:

CALC POND STATS Command Information				
Parameter	Value(s)	Units	Effect	Requirements
IFY	a valid year or -1	year or none	controls statistics span	• If IFY<0, statistics will be calculated for entire run.
IFM IFD ITY ITM ITD	1 through 12 1 through 31 a valid year 1 through 12 1 through 31	month day year month day	provides span information	• If IFY<0 this entire block should be omitted • IFY,IFM and IFD must represent a valid date that precedes a valid date represented by ITY, ITM and ITD • The date span defined on the START command must encompass the dates provided here.

4.3.4.4 The MAXMIN Command

Purpose:

This command allows users to develop maximum and minimum monthly and annual flow rate and volume statistics from any internally generated QUALHYMO time series.

Use:

The command can be issued for any properly constituted time series that remains on the disc. Therefore, the command can be issued throughout the run or collected at the end, so long as at any point the file that is of interest exists and has not been over-written. Data are generated assuming the series contains whole months and years for the period of interest.

Output might look something like the following example, although it would typically tend to extend for many months and years:

```
============ MONTHLY MAXIMUMS ==========
         DATE      FLOW RATE
                     (CMS)
       1962  1    0.14110E-03
       1962  2    0.30217E-01
       1962  3    0.34496E-03
============ MONTHLY MINIMUMS ==========
         DATE      FLOW RATE
                     (CMS)
       1962  1    0.00000E+00
       1962  2    0.00000E+00
       1962  3    0.00000E+00
============ MONTHLY TOTALS ============
         DATE      FLOW VOLUME
                     (CU.M.)
       1962  1    0.28333E+02
       1962  2    0.65649E+04
       1962  3    0.99907E+02
============ ANNUAL MAXIMUMS ===========
         DATE      FLOW RATE
                     (CMS)
         1962     0.19767E+00
         1963     0.30116E+00
         1964     0.14915E+00
============ ANNUAL MINIMUMS ===========
         DATE      FLOW RATE
                     (CMS)
         1962     0.00000E+00
         1963     0.00000E+00
         1964     0.00000E+00
============ ANNUAL TOTALS =============
         DATE      FLOW VOLUME
                     (CU.M.)
         1962     0.74269E+05
         1963     0.15110E+06
         1964     0.10825E+06
```

Numerical Values:

MAXMIN Command Information				
Parameter	**Value(s)**	**Units**	**Effect**	**Requirements**
ID	A valid series ID	none	identifies series to be processed	• a current and compatible QUALHYMO series file • NOTE: Any properly identified file that exists in the project workspace will be processed. This need not be from a current run, it can be a legacy series left on the disc
MONTHORYEAR	+/- 1,2 or 3	none	identifies what is to be created	• If MONTHORYEAR<0 then o MONTHORYEAR is reset to positive value o The whole series will be processed • IFY and ITY should not be entered • If ABS(MONTORYEAR)=1 yearly extremes printed • If ABS(MONTORYEAR)=2 monthly extremes printed • If ABS(MONTORYEAR)=3 yearly and monthly extremes printed
IFY ITY	A valid year A valid year	years years	starting year ending year	• IFY must predate ITY • This block should not be input if MONTHORYEAR < 0

4.3.4.5 The EXCEEDANCE Command

Purpose:

This command allows users to develop exceedance curves for any time series generated by the model.

Use:

The command can be applied either with specific curves provided by the user, or with the model calculating curves based on evenly spaced points over the range of the input series.

EXCEEDANCE Command Information				
Parameter	Value(s)	Units	Effect	Requirements
ID	A series ID	none	identifies series to develop curves for	
NINQ	integer <=20	none	controls points on input flow curve	• If NINQ=0 this curve will not be calculated • If NINQ<0 the model will determine the curve • If NINQ>0 the user inputs the curve
Q(i),i=1,NINQ	real	m3/s	provides span information	• If NINQ<=0 this set of values should be omitted
NIND	integer <=20	n/a	controls points on input first order curve	• If NIND=0 this curve will not be calculated • If NIND<0 the model will determine the curve • If NIND>0 the user inputs the curve
D(i),i=1,NIND	real	conc.	provides span information	• If NIND<=0 this set of values should be omitted
NINS	integer <=20	none	controls points on input first order curve	• If NINS=0 this curve will not be calculated • If NINS<0 the model will determine the curve • If NINS>0 the user inputs the curve
S(i),i=1,NINS	real	conc.	provides span information	• If NINS<=0 this set of values should be omitted
NUMINT	integer	none	# of intervals to calculate exceedance curves for	
IFY IFM IFD ITY ITM ITD	A valid year 1 through 12 1 through 31 A valid year 1 through 12 1 through 31	year month day year month day	provides span information	• The date span defined on the START command must encompass the dates provided here • user must input NUMINT sets of intervals (all six numbers provided NUMINT times)

4.3.4.6 The CALC SERIES STATS Command

Purpose:

This command allows users to develop some basic parametric and non-parametric statistics for any time series.

Use:

The command can be applied to any series generated by the model, and can be set to ignore or account for zero values in the series.

CALC SERIES STATS Command Information				
Parameter	Value(s)	Units	Effect	Requirements
ID	a valid input id	none	identifies series to develop curves for	
IFLAG	integer = 0 or 1	none	controls inclusion of zero values	• If IFLAG=0 zero flows will be included in calcs • If IFLAG=1 zero flows will not be included in calcs

4.3.4.7 The DUMP PRINT Command

Purpose:

This command allows users to print a detailed listing of the content of a series file.

Use:

The PULL POND SPAN command must follow a POND command, and will develop data for only the most recent preceding POND command. Several PULL POND SPANS can be used in sequence.

The result of each invocation of this command is a listing of data, in a few lines shown as follows:

Numerical Values:

DUMP PRINT Command Information				
Parameter	Value(s)	Units	Effect	Requirements
ID	integer > 0	none	ID for time series to be printed	
MAXRECORDS	integer > 0	none	Maximum number of lines to be printed	

4.3.4.8 The CALIBRATE Command

Purpose:

This command allows users to develop mass and rate information about a series of rainfall events within the long term series.

Use:

One or two series may be specified. If one is specified, simple mass and rate information will be developed for each specified rainfall event. If two series are specified, then the mass and rate information for each will still be calculated, but in addition there will be some basic comparative statistics generated describing the degree to which the series of events are similar.

Numerical Values:

CALIBRATE Command Information				
Parameter	Value(s)	Units	Effect	Requirements
NUMINT	integer ≥ 1	none	Number of intervals to be evaluated.	
IDA	A valid ID value	none	ID number for one series	Must be a currently valid series ID
IDB	A valid ID value	none	ID number for the other series	Must either be a currently valid series ID or zero
(FYR,FMO,FDY,TYR, TMO,TDY) sets	NUMINT valid pairs of dates	year, month, day, year, month, day	Operates on one pair of dates for each interval (i.e. NUMINT pairs)	Two date sets, the first one must precede the second one. Date pairs should be in chronological order

4.3.4.9 The PRE POST CONTROLLED Command

Purpose:

This command allows users to develop exceedance curves directly from data sets. It creates exceedance curves for the specified IDs and optionally dumps time series in a format easily cut and pasted into a suitable graphics program.

Use:

Three series may be specified, and one parameter (flow, first order or sediment) may be viewed. Setting the parameter switch to a negative value causes the time series dump. Although as its name suggests this command was designed to be used in the context of an analysis of predeveloped, postdeveloped and controlled conditions, it can be used to evaluate series for other reasons, such as during calibration.

Numerical Values:

PRE POST CONTROLLED Command Information

Parameter	Value(s)	Units	Effect	Requirements
IDA	A valid ID value	none	ID number for one series	Must be a currently valid series ID
IDB		none	ID number for one series	Must be a currently valid series ID
IDC	A valid ID value	none	ID number for one series	Must be a currently valid series ID
IPARAMNO	A valid ID value	none	Selects parameter to be assessed and switches series dump on or off	If PARAMNO=1 flow will be evaluated If PARAMNO=2 the first order pollutant will be evaluated If PARAMNO=3 sediment will be evaluated
	-3, -2, -1, 1, 2 or 3		Selects the time interval which will be assessed	If PARAMNO= -1 flow will be evaluated If PARAMNO= -2 the first order pollutant will be evaluated If PARAMNO= -3 sediment will be evaluated If PARAMNO<0 the three series will be printed
FYR FMO FDY TYR TMO TDY	A valid pair of dates	year month day year month day		Two date sets, the first one must precede the second one. Date pairs should be in chronological order.

5 Time Series Data

5.1 An Overview of the Time Series Data Sets

QUALHYMO is continuous simulation oriented and therefore relies heavily on time series files managed on the user's hard drive. Each time series data set is contained in a unique file. There are two categories of time series data files:

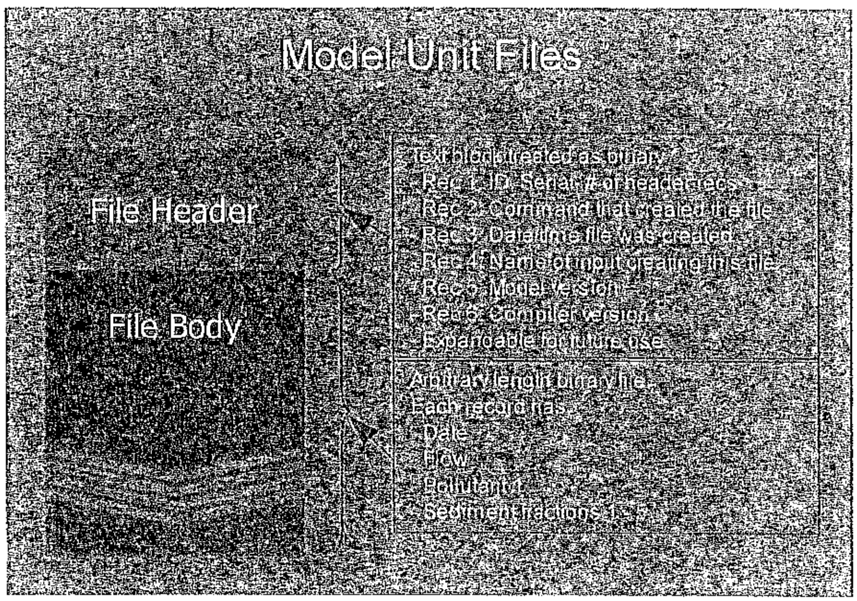
- Internal buffer files
- User input files

5.2 Internal Buffer File Structure

These are binary files that are designed to achieve high data transfer rates and small file sizes. They are structured in more than one way.

Model Unit Files

These files represent the input and output series from ADD, SPLIT, POND or REACH commands, and the output series from GENERATE commands. They are the main storage mechanism for QUALHYMO time series data. They consist of two segments, as shown below:



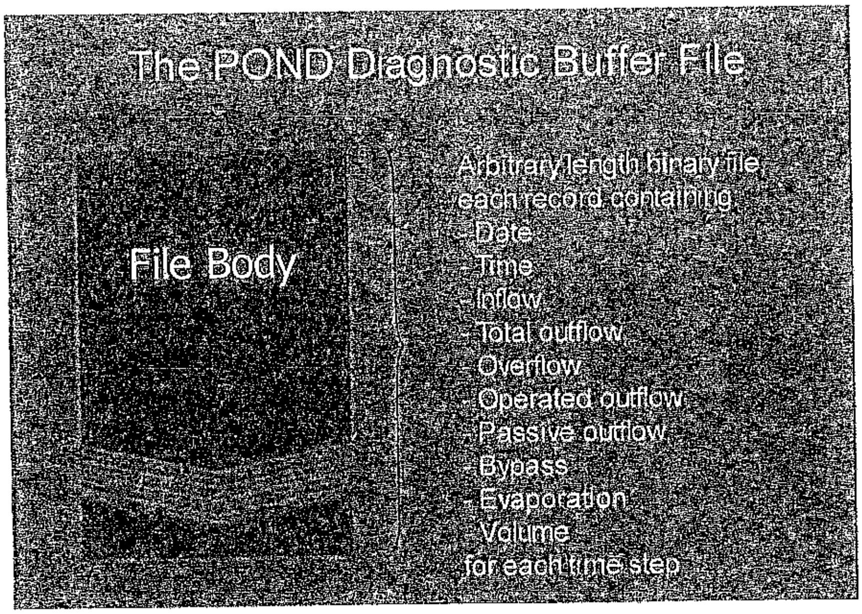
The header contains metadata that identifies file contents. The files are also named in a way that relates to the ID number associated with the file, to facilitate retrieval during a run. The body of the file contains the actual time series data, one record per time step.

> Warning: Valid ID numbers are integers from 1 to 200 inclusive. Values outside this range may give unpredictable results.

It is important to note that the model unit files remain on disc until over-written, so a user can (for example) do a GENERATE run once, and then repeatedly pass the resulting time series through a variety of POND or REACH configurations.

The POND Diagnostic Buffer File

This file is generated by the POND command if ISER<0 (see section 3.3.2), and remains in place until over-written. It is accessed by the PULL POND SPAN and CALC POND STATS commands to generate their results. It is similar to the model unit files in that it is a compact binary file, but contains no header, as shown below:



Since BMPs are a major QUALHYMO interest area, it is anticipated that this file will be accessed in a wider variety of ways in the future, but for now the PULL POND SPAN and CALC POND STATS make use of this file, and enable retrieval of data for analysis external to the QUALHYMO environment.

5.3 User Input File Structure

There are several files that fall under this category:

- rainfall
- temperature
- evaporation
- flow/pollutant series

All of these files are ASCII text files, each formatted in a common or available manner to facilitate user access.

Consistent with the intent of this draft manual, the evaporation file will be discussed further here. Other files are described in earlier manual versions, and will be described in subsequent releases of this manual.

5.3.1 Evaporation Files

These files contain evaporation information, as follows:

Year, (Evaporation(i), i=1,12)

The file is read as free formatted, so the model expects one integer followed by 12 floating point values, each separated by at least one blank (' '). An example of a few records from such a file is:

```
1911   0.00   0.00   0.00  41.50   97.70 159.00 178.00 146.50 103.60   52.00   0.00   0.00
1912   0.00   0.00   0.00  48.60  145.30 184.60 159.70 137.40   95.00   49.60   0.00   0.00
1913   0.00   0.00   0.00  56.80  117.90 128.80 175.80 140.00   93.40   46.10   0.00   0.00
1914   0.00   0.00   0.00  43.90  123.90 143.10 174.10 159.50  107.10   45.40   0.00   0.00
```

The model immediately converts this file into a time series file that is easily used by the model in subsequent calculations. For the present, this is an ASCII file that is formatted with one line per time step, as '(I4,2X,I2,2X,F8.2)', or

Year, Month, Evaporation

in a fixed format. This file is designated as a 'SCRATCH' file, and therefore only exists for the duration of a model run. Implementation of this file as a fast binary file which is persistent (exists between runs) is being considered as an extension of the model, and will be implemented if users indicate a preference for this alternative.

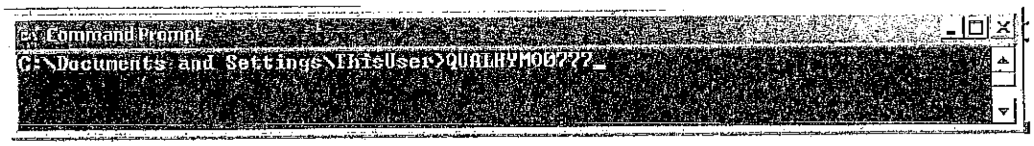
Appendix A
QUALHYMO Installation and Configuration Options

A.1 Ways to Run the Model

QUALHYMO can be run with or without command line parameters.

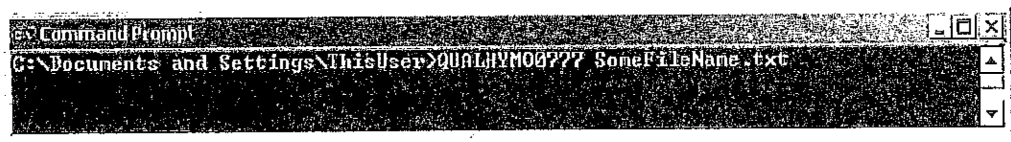
If Command line parameters are not used, then the model will run based on default control files and file locations.

- The model command is simply its name. For example, if the model is located in a user directory 'ThisUser' in the 'Documents and Settings' directory, the model would be executed as follows:



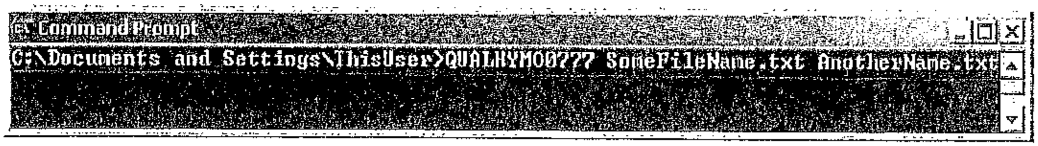
- In this case,
  - the model will expect to find the control file 'QCONTROLFILE.TXT' in the directory the model is run from
  - the model will create a log file 'QRUNLOG.TXT' in the directory the model is run from.

If command line parameters are used then either one or two file names can be provided to the model. The model command with one parameter might be as follows:



- In this example
  - the model will expect to use the user specified name (anything the user wants but in this case 'SomeFileName.txt') as the control file.
  - the model will create a log file 'QRUNLOG.TXT' in the directory the model is run from.

The model command applied with two parameters might be as follows:

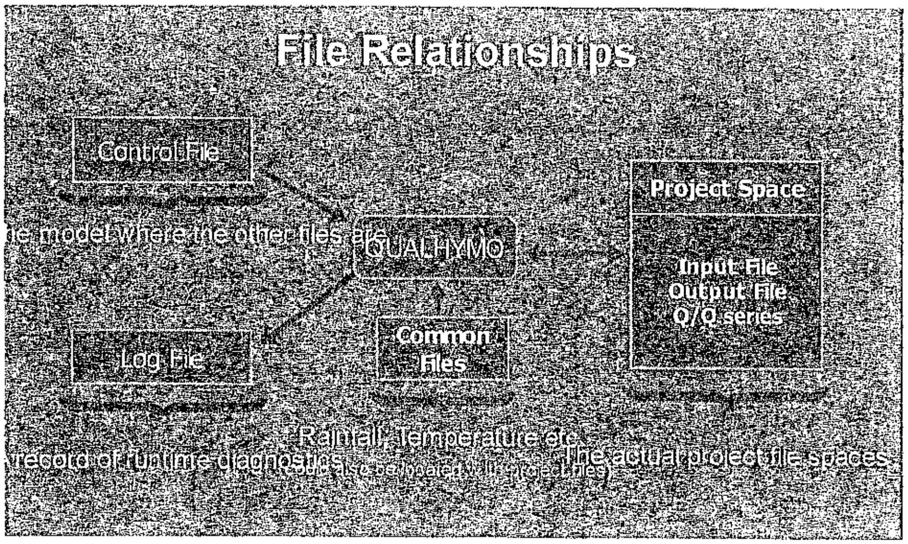


- In this example
  - the model will expect to use the first user specified name (anything the user wants but in this case 'SomeFileName.txt') as the control file.
  - the model will create a log file using the second user specified name (anything the user wants but in this case 'AnotherName.txt' in its local directory.

Note: It is not possible to specify a log file without specifying the control file.

A.2 Ways to Set up the Model Control Files

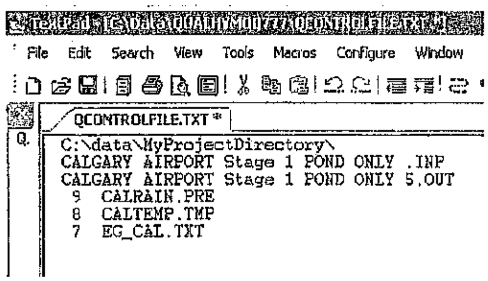
The model requires a control file which tells it where the various input and output files are located and what they are called. It also generates a log file that contains information on the events that happen during the run. The relationships between these files is illustrated below.



The Control File itself follows some basic rules:

- The file is an ASCII text file.
- The file can have any name and any extension that is legal under DOS but has a default name of 'QCONTROLFILE.TXT'.
- The content of the Control File is as follows:
  - **Path to working directory.** The working directory can be any location the user chooses. During the run, the model will look for all input files in that location, and will create its output files there as well. Two possible exceptions to this are the control file itself and the log file. The control file and log file locations are discussed in section 1.0.
  - **Name of input file.** This is the data file containing all the model commands and parameters. This name can contain embedded blanks but cannot have leading or following characters (except blanks and carriage return/line feed line terminators) that are not part of the name. This file is discussed further in section 3.0.
  - **Name of output file.** This is the file that will contain the model output generated during a run. This name can be any name legal under DOS, and can contain embedded blanks but cannot have leading or following characters (except blanks and carriage return/line feed line terminators) that are not part of the name.
  - **Up to 4 optional time series files, that can be listed in any order:**
    - **Number and name of rainfall file.** The number must always be 9 in this version of the model. The name can be anything the user wants but cannot contain embedded blanks. One or more blanks must separate the number and the name. This file is discussed further in section 3.0.
    - **Number and name of the temperature file.** The number must always be 8 in this version of the model. The name can be anything the user wants but cannot contain embedded blanks. One or more blanks must separate the number and the name. This file is discussed further in section 3.0.
    - **Number and name of the flow file.** The number must always be 10 in this version of the model. The name can be anything the user wants but cannot contain embedded blanks. One or more blanks must separate the number and the name. This file is discussed further in section 3.0.
    - **Number and name of the evaporation file.** The number must always be 7 in this version of the model. The name can be anything the user wants but cannot contain embedded blanks. One or more blanks must separate the number and the name. This file is discussed further in section 3.0.

A typical example of the control file as viewed in a popular text editor might be as follows:




```
C:\data\MyProjectDirectory\
CALGARY AIRPORT Stage 1 POND ONLY .INP
CALGARY AIRPORT Stage 1 POND ONLY 5.OUT
 9  CALRAIN.PRE
 8  CALTEMP.TMP
 7  EG_CAL.TXT
```

The Log File is not controlled by the user except possibly its name and location as noted in section 1.0. Its characteristics are:

- The file is an ASCII text file.
- The file can have any name and any extension that is legal under DOS, but has a default name of 'QRUNLOG.TXT'.
- The content is as follows:
    - The first line is the time and date at which the model was run.
    - The second line is the model version
    - The next few lines indicate successful opening of the control files and input files
    - Subsequent lines indicate events during the model run, such as commands or errors that may be encountered.
    - A final line indicates a normal run ending and the time and date at which that occurred.

An example run log might be as follows:

```
=== RUN BEGUN 28-Jun-07,02:30:35===
=== QUALHYMO VERSION 0777V1A BUILD 37 ===
=== CONTROL FILE OPENED
 - INPUT FROM: C:\data\MyProjectDirectory\CALGARY AIRPORT Stage 1 POND ONLY .INP
 - OUTPUT TO: C:\data\MyProjectDirectory\CALGARY AIRPORT Stage 1 POND ONLY 5.OUT
 - INPUT FILE OPENED
 - OUTPUT FILE OPENED
 - COMMAND TABLE GENERATED
 - READING FINAL CONTROL FILE ASSIGNMENTS
 - FILE C:\data\MyProjectDirectory\CALRAIN.PRE IDENTIFIED
 - C:\data\MyProjectDirectory\CALRAIN.PRE OPENED
 - FILE C:\data\MyProjectDirectory\CALTEMP.TMP IDENTIFIED
 - C:\data\MyProjectDirectory\CALTEMP.TMP OPENED
 - FILE C:\data\MyProjectDirectory\EG_CAL.TXT IDENTIFIED
 - C:\data\MyProjectDirectory\EG_CAL.TXT OPENED
=== CALCULATIONS BEGUN
  - RETURN FROM COMMAND INTERPRETER, NER,NCODE:  0  1
=== START COMMAND
  - RETURN FROM COMMAND INTERPRETER, NER,NCODE:  0  10
=== QUALITY PARAMETERS COMMAND
```

with further lines documenting what commands were run in what order, and finally ending as follows:

```
=== RUN ENDED NORMALLY 28-Jun-07,02:30:42 ===
```

It is not expected that most users will access the log file, since it is mainly useful in tracking input or system errors that may cause a model crash. The user specified output file will normally contain the required details of model behaviour and outputs. It is anticipated that the file will therefore be created in its default location and not routinely used. This is the reason that the optional addition of a non-default run log name and location is a command line parameter that is optional. However, users can decide for themselves if this file has material value and can manage it accordingly.

> Note: Although the internal model file handling structure is quite different from earlier versions of the model, users can still use the tools much as they have.
>
> - If they wish, users can locate all the files noted above in a single project directory, and little will have changed from earlier practices.
> - For production work, however, or to customize the model installation, users can locate files and re-use them (especially rainfall or other externally measured series) as they wish. Also, it is no longer necessary to port the executable to wherever the project files happen to be located.
>
> Flexibility has been increased, without making complexity a requirement.

A.3 A Word on Relative vs Absolute Addressing

Paths for the files used by the model can be established using standard DOS notation, which means that both relative and absolute addressing can be used. As an example, consider a case where:

- a project work space is in C:\DATA\DIR2\PROJECTLOC
- the model executable QUALHYMO0777.EXE is in C:\DATA\DIR1
- the control file is in C:\DATA\DIR1\CONTROLLOC and is called QFILE.TXT
- the user has opened a command line at C:\DATA\DIR1\RUNLOC

Since the path to the project workspace is "c:\data\dir2\projectloc\", a suitable control file might be:

```
C:\DATA\DIR2\PROJECTLOC
REGEN.INP
TESTRESULTS.OUT
 9  RAIN.PRE
 8  TEMP.TMP
 7  EVAP.TXT
```

A suitable command line to run the model with all files as described above would be as follows:

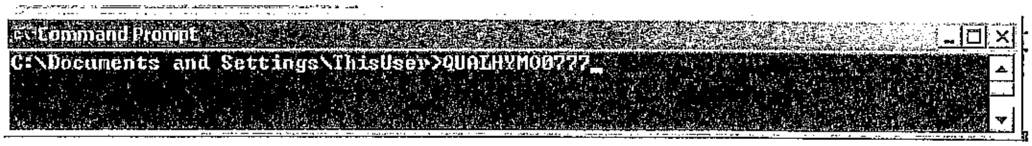
The example above uses absolute addressing. There is another option, which is to use relative addressing. In the case at hand, an equivalent form of the above command line would be:

The usefulness of relative addressing depends very much on how the user happens to have placed the various model files on their system. ***In case of doubt, absolute addressing is recommended.***

Relative addressing is not confined to the command line. Relative addressing can also be used in the path specified in the first line of the control file. If, for example, all files are located in a single directory "C:\Documents and Settings\ThisUser\ as discussed above, then the control file might be:

```
.
REGEN.INP
TESTRESULTS.OUT
 9  RAIN.PRE
 8  TEMP.TMP
 7  EVAP.TXT
```

where the path on the first line is simply a period or decimal symbol ".", and the command line becomes:



Appendix B
Representing Some Common Features with the PERVIOUS SURFACE, IMPERVIOUS SURFACE, PERVIOUS W STORAGE and IMPERVIOUS W STORAGE Commands

The QUALHYMO commands created to serve emerging requirements in the TRCA context can be employed to represent site-level measures that promote infiltration and provide physical filtration to help with pollutant load reduction. The four hydrologic commands have quite a bit in common, but differ in detail and intended use. It is up to the user to establish how to best represent a BMP in their particular case, but this section provides some insights into ways they might consider as they decide on their simulation strategy.

Command	Typical Uses
IMPERVIOUS SURFACE	Used to separately simulate different types of hard surfaces, including roadways, parking lots and roofs. These types of surface can be simulated separately by repeated use of this command so that different mean pollutant concentrations can be applied to each surface type. Changing pollutants according to land use type can be accomplished by preceding each use of IMPERVIOUS SURFACE with appropriate POLLUTANT SERIES command to apply appropriate pollutant concentrations.
PERVIOUS SURFACE	Used to simulate vegetated areas including landscaped areas. This command can be used to represent vegetated yard areas that receive roof drainage in residential areas. This command has been coded so that any existing (previously generated) flow time series can be supplied by the user as a lateral input to the surface (e.g. to roof runoff draining onto a grassed area).
IMPERVIOUS W STORAGE	Simulates impervious (e.g. paved surface) that includes a surface storage volume. Intended to allow modeling of such features as flat roofs with surface storage and controlled drainage outlet; or paved parking area designed to provide surface ponding storage with controlled outlet. The surface storage is characterized by a table of depth-area-outflow values supplied by the user. Losses from the storage include surface evaporation.
PERVIOUS W STORAGE	Used to simulate grassed swales and soakaway infiltration facilities. This command has been coded so that any existing (previously generated) flow time series can be supplied by the user as a lateral input to the surface.

These commands complement the QUALHYMO GENERATE command by providing alternate means of simulating surface runoff processes within smaller-scale situations. The GENERATE command is intended more for simulating the hydrologic response of larger watershed areas. Accordingly, GENERATE makes use of estimates of effective imperviousness over larger areas, and uses a modified SCS Curve Number approach that uses Antecedent Precipitation Index (API) to provide continuous simulation of surface runoff production at the watershed scale.

Separate representation of impervious and pervious surfaces, and allowing for surface runoff from one to be diverted onto the other, provides a more explicit means of modeling urban processes, especially when dealing within smaller-scale areas such as individual development areas or properties. This was the impetus for extending QUALHYMO's command set to include these four commands.

Notes on these commands are as follows:

1. In the case of the IMPERVIOUS SURFACE command, the command has been coded such that the surface runoff and pollutant loadings can be split into as many a three fractions. This allows, for example, one fraction to be diverted onto a pervious vegetated surface (e.g. roof drainage onto grassed area) while another fraction goes directly to storm outlet.

2. Both the PERVIOUS SURFACE and PERVIOUS W STORAGE provide continuous simulation of soil moisture status within and vertical water movement through a porous soil profile. The user must supply the following input parameters
   - Surface area in hectares
   - Maximum and minimum surface infiltration rates. The actual surface infiltration capacity at any point in time varies between these two rates depending on soil moisture status.
   - The soil moisture storage capacity, field capacity and wilting point. These are input as mm of water depth. The storage capacity is a function of the depth of the soil profile and the available porosity. Field capacity represents that amount of water that can be held against gravity drainage (*i.e.* held within the soil matrix by capillary tension). Wilting point is the amount of water held in the matrix at the point at which vegetation root systems can no longer extract moisture. Storage capacity, field capacity and wilting point will vary with soil texture. As well, when expressed as mm of water, the values will depend on the depth of the soil profile being modeled. Since all ET losses are accounted for within this layer, the depth should be at least equal to the full depth over which the vegetation's root system can extract water.
   - Percolation rate. This is the rate at which free water (*i.e.* amount of water in excess of field capacity) can move gravitationally downward through the profile and into the underlying layers, which are represented in the model as a conceptual groundwater storage reservoir. In other words, percolation is groundwater recharge. The percolation rate should be based on the limiting saturated hydraulic conductivity of the soil layers through which the water must percolate to reach the water table. The model assumes that this percolation capacity is always available.

3. In all of these commands, the total liquid input to the surface will be comprised of rain plus snowmelt, plus any lateral inflow as specified by the modeler. The lateral

inflow could, for example, be the surface runoff outflow from an IMPERVIOUS SURFACE.

4. In the PERVIOUS commands, actual evapotranspiration is computed based on potential ET rates supplied as input to the model. When soil moisture is at or above field capacity, actual ET will be equal to potential ET. Once soil moisture drops below field capacity, actual ET will be lower than the potential rate; the actual ET rate approaches zero as soil moisture approaches wilting point.
5. In the case of the PERVIOUS SURFACE command, when the total liquid input to the surface exceeds surface infiltration capacity, then surface runoff is generated. The rate of runoff (flowrate) is based on surface roughness (Manning n value), slope and characteristic length supplied by the user.
6. In the case of PERVIOUS W STORAGE, the user does not supply surface slope, length and roughness. Instead, a surface storage element is defined using a table of depth-area-outflow values that the user must compute and supply to the model. When total liquid input exceeds surface infiltration capacity, water will be stored within the surface storage element. The model continuously tracks the water depth, inundated area and volume within the surface storage element; and surface evaporation and exfiltration of stored water into the soil profile occur over only the inundated area.
7. Total outflow from the conceptual groundwater storage layer is computed as a simple linear function of storage level. The modeler can specify that a percentage of this outflow be considered as "deep losses" which do not contribute to the subsurface outflow rate.

The PERVIOUS commands do not provide any simulation of pollutant removal by filitration or other processes associated with vertical water movement downward through the soil matrix. However, the effect of this filtration process can be represented by using the POLLUTANT SERIES command to assign appropriate average pollutant concentration values to the subsurface (groundwater) outflow.

Note that in the case of the PERVIOUS W STORAGE command, pollutant removal (solids settling and first-order decay) is simulated within the volume held in the surface storage element, in the same manner as used in the POND and REACH commands. That is, the surface storage volume is represented as a number of completely-mixed tank reactors, with solids settling and first-order decay occurring based on rate parameters supplied with the START command. The PERVIOUS commands provide a conceptual representation of infiltration into, movement through and ET losses from a porous medium. These commands can therefore be used to simulate hydrologic response of vegetated areas on native soils.

As well, through appropriate values for input parameters, the PERVIOUS SURFACE and PERVIOUS W STORAGE commands can be used to represent various site-level BMPs such as infiltration trenches, vegetated swales, soakaway areas, subsurface infiltration galleries or bioretention facilities. Refer to the following table for an outline of how some commands and BMPs might be related.

Type of BMP	QUALHYMO Command	Notes on Input Parameters
Soakaway area: Designed as area for temporary surface ponding on native soils	PERVIOUS W STORAGE	• Storage depth-area-outflow table based on actual surface grading and estimate of ponding depth before spill outflow occurs. • Surface infiltration capacity and percolation capacity based on estimated saturated hydraulic conductivity of soil layers. • Lateral inflow time series is the inflow from adjacent areas
Infiltration trench or infiltration gallery: Designed using coarse granular filtration media surrounded by geotextile; allows for water to exfiltrate into surrounding native soils. May include an overflow pipe to collect water in excess of exfiltration capacity	PERVIOUS SURFACE	• Lateral inflow time series is the facility inflow • Surface area equal actual trench surface area • Surface infiltration rates set to represent high capacity for water to enter top of granular matrix. • Soil moisture holding capacity based on depth, width and effective porosity of granular matrix. • Field capacity minimal and wilting point zero (minimal water held in matrix by capillary potential). • ET factor set to zero, as no vegetative root system within granular matrix. • Percolation rate set to value representative of saturated hydraulic conductivity of surrounding native soil.
Bioretention facility: Designed to provide some surface storage ponding capacity, either on native soils or on granular fill material intended to promote infiltration	PERVIOUS W STORAGE	• Similar to soakaway area (above) • Storage depth-area-outflow table based on actual surface grading and estimate of ponding depth before spill outflow occurs. • Surface infiltration capacity based on estimated conductivity of surface soil layer or granular material • Percolation rate based on estimated conductivity of underlying soil layers
Grassed swales: Linear vegetated swales allow for infiltration of water into native soils	PERVIOUS W STORAGE	• Storage depth-area-outflow table based on average or typical swale cross-section, hydraulic roughness and bed slope to develop flow-vs-depth rating curve, which can then be used to estimate depth-area-outflow from length of swale. • Surface infiltration capacity and percolation capacity based on estimated saturated hydraulic conductivity of soil layers.

The IMPERVIOUS and PERVIOUS commands can accept lateral inflow time series as part of the total liquid water input to the surface. And, as noted above, surface outflows from IMPERVIOUS SURFACEs can be divided into three fractions. This allows for a good deal of flexibility in representing drainage connectivities that may be of significance at the urban site level.

A schematic of how this can be accomplished is shown below. This example is a model of a residential development site that includes an infiltration facility that receives all surface runoff from the site area. In this example,

Separate IMPERVIOUS SURFACEs represent roofs versus roadways and parking areas. The roof runoff is split into two equal fractions, one of which is used as lateral input to a PERVIOUS SURFACE that represents grassed yard areas that receive the roof runoff.

- A separate PERVIOUS SURFACE represents other vegetated area.
- The ADD SERIES command is then used to add up the surface runoff from the various surfaces to generate a single time series representing the total surface runoff from the area.
- This time series is then used as lateral input to a PERVIOUS WITH STORAGE that represents the infiltration facility itself. In this case, the infiltration facility is within a park area and consists of a surface ponding area over top of a granular fill matrix that allows for exfiltration into the surrounding native soils. The outflow from the surface storage element represents the net surface runoff from the site.
- The ADD SERIES command is used to add up the subsurface outflow components from each of the PERVIOUS SURFACE elements, to get the total subsurface outflow from the site.

Note that QUALHYMO generates a standard text output file that provides a water balance summary for each individual PERVIOUS or IMPERVIOUS element. These summaries include total volumes for liquid water input, surface evaporation, infiltration, ET from the soil layer and percolation to the conceptual groundwater layer, along with mass balance checks (i.e. continuity error checks). The modeler can then take the volumes from these summaries to compute the overall water balance for the site.

Appendix C
QUALHYMO License and Maintenance Agreement, General

Users are cautioned that there may be updated or different versions of the manual and/or QUALHYMO software available, and that there may be updated or different versions of the license associated with the manual and/or QUALHYMO software, so they should verify the license and version they have in hand prior to using the model.

1. LICENSE

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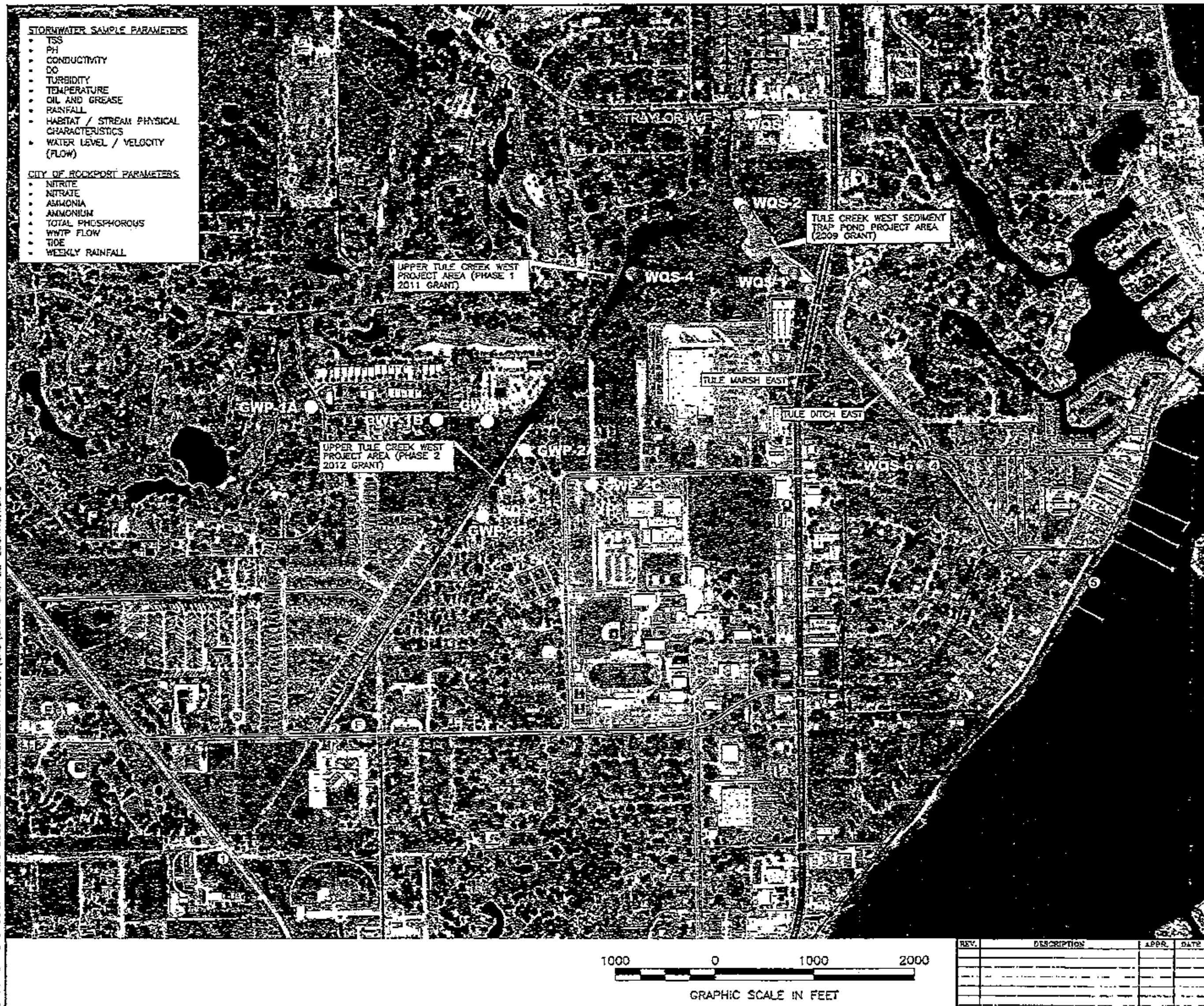
8. LIMITATION OF LIABILITY.

UNDER NO CIRCUMSTANCES AND UNDER NO LEGAL THEORY, TORT, CONTRACT, OR OTHERWISE, SHALL ACR, LLC BE LIABLE TO THE ENTERPRISE OR ANY OTHER PERSON FOR ANY INDIRECT, SPECIAL, EXEMPLARY, INCIDENTAL, OR CONSEQUENTIAL DAMAGES OF ANY CHARACTER INCLUDING, WITHOUT LIMITATION, DAMAGES FOR LOSS OF GOODWILL, WORK STOPPAGE, COMPUTER FAILURE, LOSS OF DATA OR MALFUNCTION EVEN IF ACR, LLC SHALL HAVE BEEN INFORMED OF THE POSSIBILITY OF SUCH DAMAGES. IN NO EVENT SHALL THE AGGREGATE LIABILITY OF ACR, LLC UNDER THIS AGREEMENT EXCEED THE SUM OF ONE DOLLAR (UNITED STATES CURRENCY). NOTHING IN THIS AGREEMENT SHALL EXCLUDE OR LIMIT A PARTY'S LIABILITY FOR ANY LIABILITY WHICH CANNOT BE EXCLUDED OR LIMITED BY LAW.

9. GENERAL.

This Agreement represents the complete agreement concerning this license between the parties and supersedes all prior or contemporaneous agreements and representations between them with respect to the subject matter. This Agreement may be amended only in writing executed by both parties. THE ACCEPTANCE OF ANY PURCHASE ORDER PLACED BY THE ENTERPRISE IS EXPRESSLY MADE CONDITIONAL ON THE ENTERPRISE'S ASSENT TO THE TERMS SET FORTH HEREIN, AND NOT THOSE CONTAINED IN ANY PURCHASE ORDER, AND SUCH PURCHASE ORDER TERMS SHALL HAVE NO EFFECT ON THIS LICENSE AGREEMENT. If any provision of this Agreement is held to be unenforceable for any reason, such provision shall be reformed only to the extent necessary to make it enforceable and the remainder of this Agreement shall nonetheless remain in full force and effect. This Agreement shall be governed by and construed under Florida law, except as governed by Federal law. All disputes arising under this Agreement shall be brought in the court of competent jurisdiction in Orlando, Seminole County, State of Florida in the United States, and the Enterprise consents to the personal jurisdiction of such court. The application of the United Nations Convention of Contracts for the International Sale of Goods is expressly excluded.



N W E S

LEGEND

- WATER QUALITY SAMPLE LOCATION (WQS)
- GROUNDWATER PIEZOMETER LOCATION (GWP)
- 1 CITY SAMPLE LOCATIONS
- (F) FLOW MONITORING SITE

LOCATION DESCRIPTIONS

WQS-1 – BELOW PROPOSED POND ABOVE TX BUSINESS 35.
WQS-2 – ABOVE PROPOSED POND AT CONFLUENCE.
WQS-3 – AT TRAYLOR AVE. ABOVE BRIDGE.
WQS-4 – BELOW THE UPPER TULE CREEK WEST PHASE 1.
WQS-5 – ABOVE THE UPPER TULE CREEK WEST PHASE 2.
WQS-6 – UPPER TULE CREEK DRIVE

GWP-1A – (ROCKPORT COUNTRY CLUB R.O.W.)
GWP-1B,1C – (INVERRARY DRIVE, R.O.W. ON FROST PROPERTY
GWP-2A,2B – (CITY OF ROCKPORT AQUATIC CENTER PARK)
GWP-2C – (NEAR ROCKPORT/FULTON HIGH SCHOOL)

NOTES:

1. GROUNDWATER PIEZOMETER LOCATIONS HAVE UP GRADIENT AND DOWN GRADIENT LOCATIONS.
3. INFILTROMETER TEST LOCATIONS ARE LOCATED NEAR PIEZOMETER LOCATIONS

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WATER QUALITY, STREAM FLOW GROUNDWATER PIEZOMETER SAMPLE LOCATIONS

TULE CREEK STORM WATER PROJECT

REV.	DESCRIPTION	APPR.	DATE

Drawn By	ECF	Designed By	DES	Scale	AS SHOWN	Dwg. File	8701-SAMPLE LOCATION	Sheet	1
Checked By	DES	Project No.	8701	Date	06/2012	Rev.	0	of	1

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