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Designing Coalescing Oil/Water Separators for Use at Army Washracks

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Foreword

This study was conducted for the U.S. Army Corps of Engineers under project 40162720A896, “Base Facilities Environmental Quality,” Work Unit TB0, “Oil/ Water Separator Technology.” The technical monitor was Gregory W. Hughes (CECW-EW).

The work was performed by the Environmental Processes Branch (CN-E) of the Installations Division (CN), Construction Engineering Research Laboratory (CERL). The CERL Principal Investigator was Gary L. Gerdes, CN-E. The technical editor was Linda L. Wheatley, Information Technology Laboratory. Dr. Ilker R. Adiguzel is Chief, CN-E, and Dr. John T. Bandy is Chief, CN. The associated Technical Director was Gary W. Schanche, CVT. The Acting Director of CERL is William D. Goran.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Director of ERDC is Dr. James R. Houston and the Commander is COL James S. Weller.

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1 Introduction

Background

The U.S. Army has thousands of oil/water separators to treat wastewater from tactical vehicle washracks at active Army, Army Reserve, and Army National Guard facilities. The vast majority of these separators are used as pretreatment prior to discharge of waste wash water into a sanitary or industrial sewer. Existing Army separators are typically below ground, cast-in-place concrete, simple gravity-type separators. Simple gravity separators consist of a chamber or chambers where the velocity of wastewater slows enough to allow free oil to rise to the surface. Cast-in-place concrete separators, however, are seldom constructed anymore, and designers now specify/install off-the-shelf oil/water separators. Most off-the-shelf separators being installed currently are coalescing-type gravity separators. Facility designers choose coalescing separators because they are smaller, less expensive, and require less site work than the equivalent simple gravity separators. Many manufacturers now offer aboveground separators that are significantly less expensive to install.

Oil/water separator manufacturers also incorporate coalescers in their designs to improve the performance. Because coalescing devices shorten the distance oil particles must rise, oil removal is quicker and may occur in a smaller separation chamber. Small oil particles rise to collect on the surfaces of the coalescer, combine to form larger globules (coalesce), and migrate to the water surface. The heavier soil particles sink to the lower coalescer surface, and eventually slide to the bottom of the separator. Figure 1 shows the schematic of particle movement in a simple parallel-plate coalescer.

Coalescers have many configurations, from simple arrays of parallel plates to honeycomb meshes. Recent trends in coalescer design are to cause many changes in the direction of flow as wastewater winds its way through the separator. The intent is to cause non-laminar flow, thus increasing the probability that oil droplets will collide and coalesce.

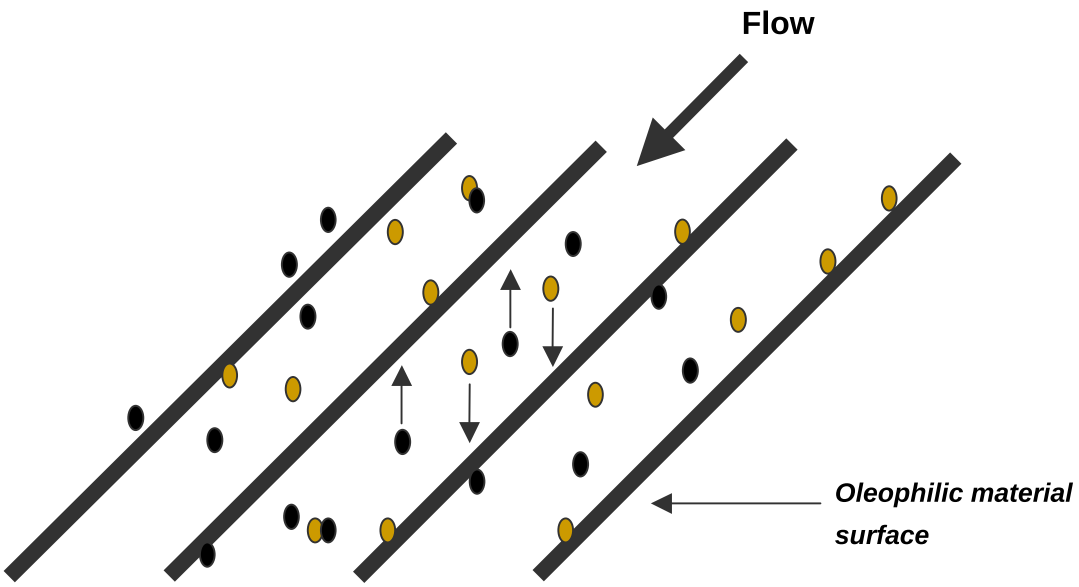


Figure 1. Oil and soil particle movement between parallel coalescer plates.

The Corps of Engineers Engineering Technical Letter (ETL) 1110-3-466, “Selection and Design of Oil Water Separators at Army Facilities,” August 1994, contains some discussion of coalescing separators, but little or no data was available to support specific design guidance. The lack of specific design guidance has led to the purchase of incorrectly sized separators at Army installations. This was reported in Public Works Technical Bulletin (PWTB) 200-1-05, “Oil/Water Separator Selection, Installation, and Maintenance: Lessons Learned,” 5 December 1997. The PWTB also discusses how vendor literature can be misleading, further reinforcing the need for design guidance.

ETL 1110-3-466 raises concerns that solids in Army wash water will collect in the gaps between coalescer surfaces and plug the separator. To minimize plugging, it recommends at least 0.75-in. gaps between surfaces. Because of the plugging problem, the ETL also raises concerns regarding the maintenance requirements for coalescing separators. These concerns are demonstrated at every Army installation by the need for periodic separator cleaning, not for the accumulation of oil but for the accumulation of sediment.

The ETL recommends that any Army oil/water separator must be easily accessible for periodic maintenance. This accessibility is especially critical for coalescing separators. The coalescer pack must be easy to remove and easy to clean. Generally, only the parallel-plate coalescers are easy to clean without completely dismantling the coalescer pack. This generalization was confirmed by CERL personnel who inspected separators with mesh or vertical mesh tube-type coalescers. These coalescers seem to easily plug with vegetation debris commonly found in Army wash water. Only coalescing separators with the flat parallel plates can be recommended for Army use; therefore, they were the primary focus of this study.

Dirt washed off Army vehicles becomes suspended solid particles in the waste wash water. These particles attach to the oil droplets, thus interfering with the oil removal capacity of the separator. This process is described in the Corps ETL on separator design (USACE 1994) and Brincks (1996). It is also supported by observations of significant amounts of oil in the sediment of Army separators. Oil-soil agglomerations have a wide range of specific gravities, but always are more dense than oil droplets. Stoke's Law is typically used to model the separation of oil and water.

Stoke's Law: $V_p = \underline{54.48}\,(\rho_p-\rho_w)d_p^2$ over μ, i.e. $$V_p = \frac{54.48}{\mu}(\rho_p-\rho_w)d_p^2$$ Velocity (V_p) is positive if particle is falling; negative if rising.

Stoke's Law generally says that the velocity of rise (or fall) of a particle in water is proportional to: the specific gravity of the particle minus 1; the diameter of the particle; and the temperature of the water. As the specific gravity of the particle approaches that of water (usually 1.0), the velocity of the particle approaches zero. Therefore, when a particle of oil attaches to a soil particle, the velocity of rise decreases. If the soil particle is large enough, the oil-soil agglomeration will sink.

For Stoke's law to be applicable when modeling the oil separation from wastewater laden with suspended solids, the distribution of oil particle and oil-soil particle diameters and specific gravities must be known. Prior to this study, this distribution was never characterized. Therefore, separator performance could not be predicted for Army wash water using Stoke's Law.

Many vendors of off-the-shelf oil/water separators use Stoke's law to predict the performance of their equipment for removing free oil. This can only be applicable for simple mixtures of free oil droplets in water. Thus, vendor literature can be misleading to persons responsible for purchasing separators for Army applications. Because Army guidance did not exist, and vendor guidance is not applicable, this study was conducted so that installation personnel, as well as washrack designers, have specific guidance for the selection of off-the-shelf coalescing oil/water separators.

Objectives

It was the objective of this study to develop design guidance that can be used by Army planners and designers when installing coalescing-type oil/water separators to pretreat vehicle maintenance wash water. It was also an objective to characterize the oil-soil agglomerations that obviously form during the washing process.

Approach

The approach for this study had two thrusts: (1) characterize Army washrack wastewater, and (2) conduct bench-scale treatability studies to match coalescer design with Army wash water. The characterization study had to be completed before initiating the treatability study. Army wash water was recreated in the laboratory based on the contaminant loading measured at actual Army washracks. It was most important to know the concentrations of suspended solids and grease/oil in the water, since it is these contaminants that are removed from the wastewater in the oil/water separator.

Wash water was sampled and analyzed from several Army washracks, representing a variety of vehicle washing scenarios. Chapter 2 of this report presents the results of this portion of the study.

The challenge to characterizing the oil-soil agglomerations that form during the washing process was that the wash water is a non-homogeneous mixture of oil droplets, soil particles, and oil-soil agglomerations. A method to differentiate these components during a particle size analysis could not be found. In particular, a method to distinguish oil-soil agglomerations of various constituent ratios seemed impossible to devise. Further, there was no guarantee that particle identification techniques would not alter the character of fragile oil-soil agglomerations during the analysis. It was concluded that characterizing the particle distribution of Army wash water was not practical, and that the characterization of the wash water would rely entirely on measuring the concentrations of oil and solids. Note: Without particle size distribution and agglomeration characterization data, Stoke’s Law cannot be used to predict oil/water separator performance for Army wash water.

An array of test cells was constructed to conduct the treatability study. The test cells were constructed so that several coalescer configurations could be evaluated at the same time, using a common source of wastewater influent. The concentrations of oil and solids in the wastewater were set according to the results of the wash water sampling study. Chapter 3 of this report discusses the experimental parameters and test results.

A performance goal of 100 ppm oil and grease (O&G) in the test cell effluent was set. This goal represents a commonly used pretreatment requirement set by many Publicly Owned Treatment Works (POTW). The success of a given testing scenario is based on this performance goal.

The presence of solids in the wash water affects performance in ways besides their becoming tied up with the oil droplets. It was also suspected that solids would accumulate on the surface of the coalescer. This accumulation would negatively affect performance by narrowing the gap between the coalescer surfaces, thus increasing the velocity of water through the coalescer and decreasing droplet removal. Solids could also negatively affect performance if they coated the oliophilic coalescer material, thus diminishing the available surface on which the oil droplets could coalesce. Evidence of these effects would have a bearing on both recommended design and maintenance requirements for coalescing separators.

Mode of Technology Transfer

Information in this technical report will be provided to the U.S. Army Engineer District at Mobile, AL, for inclusion in the new Corps of Engineers' “Guide Specification for Prefabricated Oil-Water Separators for Military Applications.” It will also be provided to the DOD Clean Water Act Services Steering Committee — Oil/Water Separator Work Group for future update to in the “Oil/Water Separator Guidance Manual,” which is currently under review prior to initial publication.

Units of Weight and Measure

U.S. standard units of measure are used in this report. A table of conversion factors for Standard International (SI) units is provided below.

SI conversion factors		
1 gal	=	3.78 L
1 ft^2	=	0.093 m^2

2 Wash Water Characterization

The information in this chapter summarizes the data obtained during studies conducted by CERL during which sampling of oil/water separator influent was necessary. Headquarters, U.S. Army Reserve Command co-sponsored a CERL study to characterize wash water at various Reserve maintenance facilities. Results from the unpublished report of that study (Gerdes 1997) are included below. Data from two studies sponsored by the U.S. Army Environmental Center are also included, as well as data from a quick-release detergent study conducted by CERL for the (former) U.S. Army Corps of Engineers Center for Public Works (1997).

U.S. Army Reserve Study

Onsite sampling efforts generated data characterizing wastewater from several Army Reserve sources. CERL sampling teams visited 11 wastewater generators during the study. An average of eight samples were taken during a typical washing event at each generator. Characteristics measured were: O&G, chemical oxygen demand (COD), total suspended solids (TSS), volatile suspended solids (VSS), and flow. Samples represented low-pressure cleaning, high-pressure cleaning, and cleaning with detergents. Sites for these studies included:

- Two Aviation Support Facilities (ASFs)
- Three Area Maintenance Support Activities (AMSAs)
- Two Equipment Concentration Sites (ECSs)
- Three Reserve Center Organizational Maintenance Shops (OMSs)

Influent Characterization: All Facilities

Table 1 summarizes the wash water analysis data from 10 sites visited. Flow at the 10 washracks summarized in the table ranged from 1.5 gpm to 19 gpm. Average flow at those washracks is about 7 gpm.

Table 1. Summary of sampling data from 10 facilities.

Parameter	Average (mg/L)	Peak (mg/L)
O&G	316	1584
TSS	1061	6502
VSS	277	1584
COD	2232	40,175

Generally, as flow increases, the concentration of contaminants decreases. Or, more accurately, when high-pressure/low-flow washers are used, contaminant concentration tends to be much higher than when low-pressure/high-flow hoses are used. Washrack wastewater would never have the maximum contaminant concentrations (listed in Table 1) throughout a washing event. Flow and contaminant levels vary significantly.

Aviation Support Facilities

CERL personnel visited two of the three ASFs remaining under the command of the Army Reserve. Table 2 summarizes the analysis data from samples obtained during those visits.

Table 2. Summary of ASF wash water characterization data.

Parameter	Average (mg/L)	Peak (mg/L)
O&G	594	1584
TSS	625	1386
VSS	408	1042
COD	8478	40,175

Helicopter washing is usually done with moderate to low-pressure washing (300 psi or less) at low flows (less than 5 gpm per hose). A variety of surface cleaning agents are used, all of which add considerable COD to the wastewater. At both locations, the surface cleaner was applied to the oily parts of the aircraft and allowed to soak. Exceptionally high COD occurs in the wash water when these parts are rinsed (see Peak COD).

About two-thirds of the suspended solids in the aircraft wash water are volatile. The sources of these volatile solids in the wash water are believed to be (1) the accumulation of vegetation particles that collect in the aircraft during takeoffs and landings, (2) the O&Gs that attach to the vegetation and inorganic soil particles, and (3) traces of concentrated surface cleaner that remain attached to the soil particles. The designer of pretreatment for aircraft washing should take into consideration the light density solids. These solids will have near neutral buoyancy and will pass over and under baffles. It is recommended that some type of screening be used to remove these solids from the waste stream. Such a screen could help protect coalescer surfaces in upstream oil/water separators from clogging. Screens would also benefit pretreatment at ground vehicle washracks where vehicle exteriors are washed.

Area Maintenance Support Activities

The AMSA shops perform a higher level of maintenance than that performed in an OMS. It is similar to that performed at Direct Support maintenance shops at large U.S. Forces Command and U.S. Army Training and Doctrine Command (FORSCOM/TRADOC) installations. Within the Reserves are several hundred AMSA shops. CERL sampling teams visited three of them. Table 3 summarizes the analysis data from samples obtained during those visits.

Table 3. Summary of AMSA wash water characterization data.

Parameter	Average (mg/L)	Peak (mg/L)
O&G	478	1419
TSS	1272	6502
VSS	416	1584
COD	1841	10316

Equipment Concentration Sites

Maintenance shops at the ECSs are used to perform maintenance similar to that performed at AMSAs and OMSs. However, the average characteristics of the wash water were more similar to that of OMS wash water. This may be because one of the ECSs visited used a low-pressure/high-flow hose for washing, which tends to lower the concentration of contaminants due to dilution. CERL sampling teams visited two ECSs. Table 4 summarizes the analysis data from samples obtained during those visits.

Table 4. Summary of ECS wash water characterization data.

Parameter	Average (mg/L)	Peak (mg/L)
O&G	183	484
TSS	1856	6015
VSS	239	1359
COD	692	3024

Organizational Maintenance Shops

Maintenance performed at the organizational level is normally routine and does not require highly specialized repair equipment. Washracks are used to clean vehicles returning from local (nontactical) usage and for cleaning vehicles before they are sent to an AMSA or Depot for more intensive repair or rebuilding. There are more than 1000 Army Reserve Centers (ARCs), most of which have an OMS. CERL sampling teams visited three OMSs. Table 5 summarizes the analysis data from samples obtained during those visits.

The vehicles washed at the OMSs visited were not very dirty, but this seems to be typical of the soiling on vehicles washed at OMSs. Soaps and surface cleaners are seldom used and should not be used.

Table 5. Summary of OMS wash water characterization data.

Parameter	Average (mg/L)	Peak (mg/L)
O&G	58	209
TSS	611	3882
VSS	77	182
COD	99	262

Other Sites

Fort Lee, VA – Transportation Motorpool. Wash water from the transportation motorpool (TMP) washrack was sampled during an evaluation of a simple gravity separator retrofitted with coalescing tubes (Gerdes 1998). The results of the analysis of the separator influent samples are as follow:

TSS -- 210 mg/L O&G -- 241 mg/L

Army National Guard – Organizational Maintenance Shops. Wash water from two OMS washracks were analyzed during a study sponsored by the Army Environmental Center (AEC) (Hudson and Gerdes 1998). The results of wash water analysis are as follow:

Total Petroleum Hydrocarbons (TPH) -- 406 mg/L peak -- 1380 mg/L

Fort Lewis – Maintenance Support Batallion. Wash water from a vehicle maintenance wash area inside a Fort Lewis motorpool was analyzed during a study to evaluate a quick-release detergent (USACE PWTB). The results of the wash water analysis are as follow:

O&G -- 250 mg/L TSS -- 700 mg/L

Summary

All of the values reported in this chapter (except peak values) are averages of the analyses of several samples taken over the course of one or more vehicle washing events. It is obvious that Army wash water contains a wide range in the concentrations of O&G and TSS. The average concentration of O&G at the different types of washracks ranged from 58 mg/L to 594 mg/L. The peak concentrations measured ranged from 209 mg/L to 1584 mg/L. Average TSS concentrations ranged from 210 mg/L to 1272 mg/L. Peak TSS concentrations ranged from 1386 mg/L to 6502 mg/L.

3 Treatability Study

Experiment Design

The overall purpose of the experiment was to determine how well various configurations of coalescers could treat fabricated Army wash water, and more specifically, to determine if buildup of solids within the coalescer structure would negatively affect performance. Such a study has numerous parameters (i.e., concentration of O&G, concentration of TSS, coalescer material, incline angle of coalescer surfaces, coalescer surface spacing, surface loading rate of the wash water, water temperature, and duration of the test runs). The resources available to the project limited the number of experimental configurations. Configurations were selected that would most efficiently achieve the goals of the project.

To conduct the experiment, pilot-scale Plexiglas test cells were constructed. Two sets of test cells were used, each with four parallel cells fed by one source of wastewater. A unique coalescer configuration was placed in each cell. The cells were constructed with overflow influent weirs set to equalize flow to all four cells. Underflow effluent baffles were used to contain the separated O&G. Wastewater was mixed in two 55-gal drums, each of which fed wastewater by gravity to one of the sets of four test cells. Figure 2 shows the test cells.

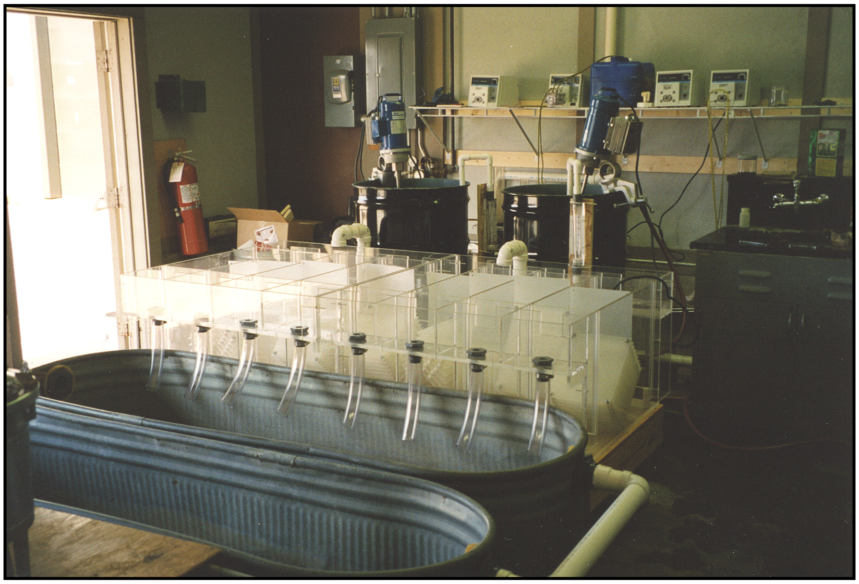


Figure 2. Eight test cells operating in parallel.

Contaminants

The concentrations of O&G and TSS were not variable parameters during the study, and were kept as constant as possible. Instead, contaminant levels were used that represented the upper range of the levels measured during the characterization study. The concentration of oil in the test cell influent was kept close to the range of 450 to 500 mg/L. No attempt was made to keep the concentration of oil in the test cell influent constant, as a variable concentration was more representative of Army washrack wastewater. Used oil from Army maintenance shops, primarily a mixture of motor oil and hydraulic oil, was used when mixing the fabricated wastewater.

The concentration of TSS was kept close to a range of 150 to 250 mg/L. That concentration is lower than what was measured during the characterization study. More than half of the solids in wash water are larger particles that tend to settle out in a grit basin or at the head end of a separator, and do not pass through the coalescer. Only fine silt and clay particles were mixed in the fabricated wastewater influent. Sediment from the effluent end of a centralized wash facility sedimentation basin was used as the source.

Clean tap water, oil, and a sediment slurry were fed into a mixing barrel to create the wastewater for the test cell experiments. As the components were fed into the barrel, they were constantly mixed with a motorized propeller. The wastewater overflowed by gravity into a trough, from which the wastewater passed over weirs into the individual test cells. Tap water flow into the mixing drum was constantly measured with a flow meter. Flow from each test cell was periodically measured manually. The oil and sediment were fed using parastallic metering pumps.

Coalescer Material

Two materials were used for the parallel plate coalescers — polypropylene and high density polyethylene. Polypropylene is the more oleophilic of the two plastics, and seems to be the most commonly used material in off-the-shelf oil/water separators. Some people in the industry believe that polypropylene is too oleophilic and does not allow oil to migrate to the water surface. Polyethylene, another commonly used material, was chosen as an alternative material for comparison.

Coalescing Plate Angle of Incline

Separator manufacturers commonly use two angles of incline to the horizontal — 45 and 60 degrees. These two angles were used for most of the test cell configurations. The 45-degree angle was used in two configurations — one with the plates at a 45-degree angle to the horizontal inlet-to-outlet axis; and the other with the plates parallel to the horizontal inlet-to-outlet axis (looking like an inverted V). During the first test period, one test cell had vertical plates parallel to the horizontal flow. During the second test period, two cells purchased for testing were configured with a waffle-shaped polyethylene coalescer, a proprietary design of Landa Water Cleaning Systems (Camas, WA).

Water Temperature

Due to resource restraints, water temperature was not used as a variable. Because of the design of the wastewater mixing apparatus, the temperature of the test cell influent was consistent for all cells. The temperature in the test cells was close to that of the cold tap water source, and was assumed to be representative of the water temperature at most outdoor Army washracks.

Configurations

Figure 3 shows the six basic configurations used during this study. The plate positioning and flow direction of the individual test cells were as follows:

Polypropylene – 45° – Downward flow

Polyethylene – 45° – Downward flow

Polypropylene – 60° – Downward flow

Polyethylene – 60° – Downward flow

Polypropylene – 45° – Horizontal flow

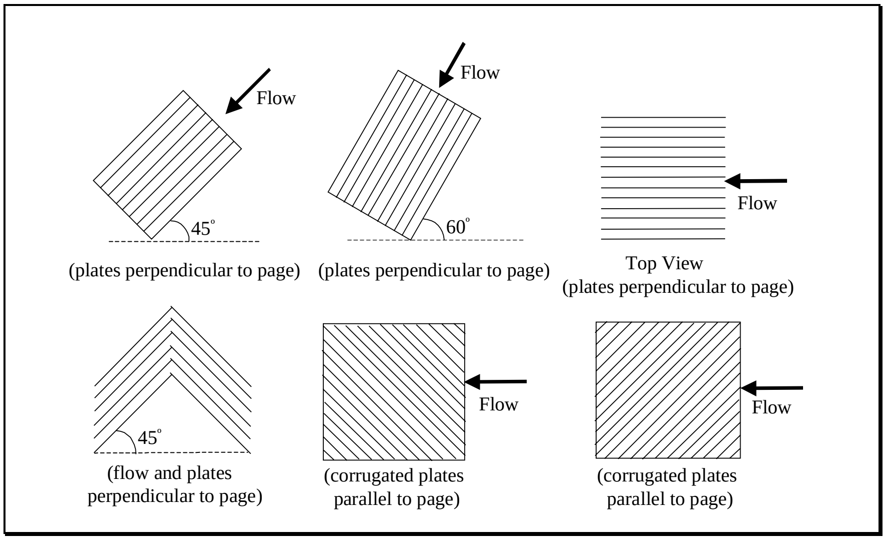
Polyethylene – 45° – Horizontal flow

Polypropylene – 90° – Horizontal flow

Polyethylene – 90° – Horizontal flow

Landa waffle – angled ribs slanted toward the horizontal flow

Landa waffle – angled ribs slanted away from the horizontal flow



(plates perpendicular to page) (plates perpendicular to page) Top View (plates perpendicular to page)

(flow and plates perpendicular to page) (corrugated plates parallel to page) (corrugated plates parallel to page)

Figure 3. Coalescer configurations.

Duration

The fabricated wash water was allowed to run through the test cells for periods of 2 hr. Researchers ran one 2-hr test per day. This schedule was to approximate a typical 1-day use at an Army washrack. Initially each test cell was operated for at total of at least 100 hr, to represent approximately 1 year's usage at an average Army washrack.

The polypropylene coalescer test cells were operated for an extended period. The intent was to determine if performance would eventually drop significantly due to an excessive buildup of oil and solids on the coalescer surfaces. Essentially the extended test was to determine if the coalescer was actually performing more as a filter and thus "breakthrough" could occur.

Surface Loading Rate

The surface loading rate for the initial test period was set according to the surface loading rate equation in API's oil/water separator design manual (API 1992, p 26) for removing 60-micron oil particles.

$$\text{Surface loading rate} = Q_m/A_H = 0.00386(S_w - S_o)/\mu$$

Q_m = design flow (ft^3/min)

A_H = projected horizontal area (ft^2) for all coalescing surfaces (one side for each plate)

S_w = specific gravity of water

S_o = specific gravity of oil

μ = wastewater viscosity in poise

Design flow was set at 1.5 gpm (0.20 cfm) for each test cell. The projected horizontal area for the coalescer material in each test cell was approximately 4.08 ft^2. The surface loading rate for the first test period was 0.37 gpm/ft^2 (0.05 cfm/ft^2). Surface loading rates of 0.25 gpm/ft^2 and 0.49 gpm/ft^2 were used for a few of the configurations in a later test period.

Sampling and Analysis

Influent and effluent composite samples were taken after every fifth 2-hr test cell operation run (i.e., after 10 hr of operation). Samples were taken more frequently at the beginning of each test cell experiment to adjust the contaminant feed pumps and establish the desired contaminant levels in the fabricated wash water. TSS analysis was done according to Standard Methods. Analysis for O&G was done according to a variation of EPA Method 1664, Revision A, developed by 3M Company and sanctioned by the U.S. Environmental Protection Agency (USEPA). An independent study has shown that this test has equivalent or greater accuracy than the original Method 1664.

Test Start-up

At the beginning of each experiment, the coalescer material in each test cell was coated with oil. The intent was to “season” the surfaces in order to eliminate the initial period of oil accumulation, and thus allow oil removal in the test cells to achieve a steady state more quickly.

Results

Graphs showing all results of the test cell sampling analysis are shown in the appendix. The following paragraphs describe CERL’s interpretation of that data.

Oil and Grease Removal

During the first 100 hr of operation, the down-flow, 45 degree, polypropylene plates provided the best effluent quality at the overflow rate of 0.37 gpm/ft^2. However, the oil concentration in the test cell influent was over 50 mg/L less than for the polyethylene test cells. During the second 100 hr of operation, the concentration of oil in the influent to the polypropylene plate cells was closer to the level going to the polyethylene plate test cells, and performance dropped below that of the down-flow, 60-degree, polyethylene.

Only the 60-degree down-flow configuration of the polyethylene plates provided consistent treatment performance in achieving the target effluent level of 100 mg/L oil at the surface loading rate of 0.37 gpm/ft^2. However, at a surface loading rate of 0.25 gpm/ft^2, both the 45- and 60-degree, down-flow, polypropylene configurations provided consistent, acceptable treatment.

Polyethylene appeared to be the better of the two coalescer materials. There are other materials that could not be tested, however, due to limited resources, and it is possible that some of those perform as well or better than polyethylene.

Sediment Accumulation

There was no visual evidence that sediment accumulation on the surface of the coalescer plates would have caused interference with the performance of the test cells. Sediment coated the top surface of each of the coalescer plates, but appeared to migrate to the bottom of the separation chamber before reaching a thickness of 0.1 in. The concentration of TSS in the effluent remained fairly constant for all configurations, and seemed to decrease slightly over time for a few of the configurations during the test period.

4 Conclusions and Recommendations

Conclusions

1. The test cell configuration with polyethylene plates installed at a 60-degree angle and having a downward flow seemed to provide the best treatment at the loading rate of 0.37 gpm/ft^2.

2. There was no evidence that, during the normal operation of an oil/water separator, a layer of sediment would collect on coalescer plates at a thickness that would interfere with flow through the coalescer, assuming the plate spacing was at least 0.75 in.

Recommendations

1. When specifying off-the-shelf, coalescing, oil/water separators, recommend the following:

   - Coalescer plate material: Polyethylene

   - Maximum surface loading rate: 0.37 gpm/ft^2

   - Coalescer plate angle: 60 degrees

   - Direction of flow: Downward at 60 degrees to the horizontal

2. Coalescing separator designs must provide storage for solids removed within the coalescer.

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Appendix: Results of Test Cell Sampling

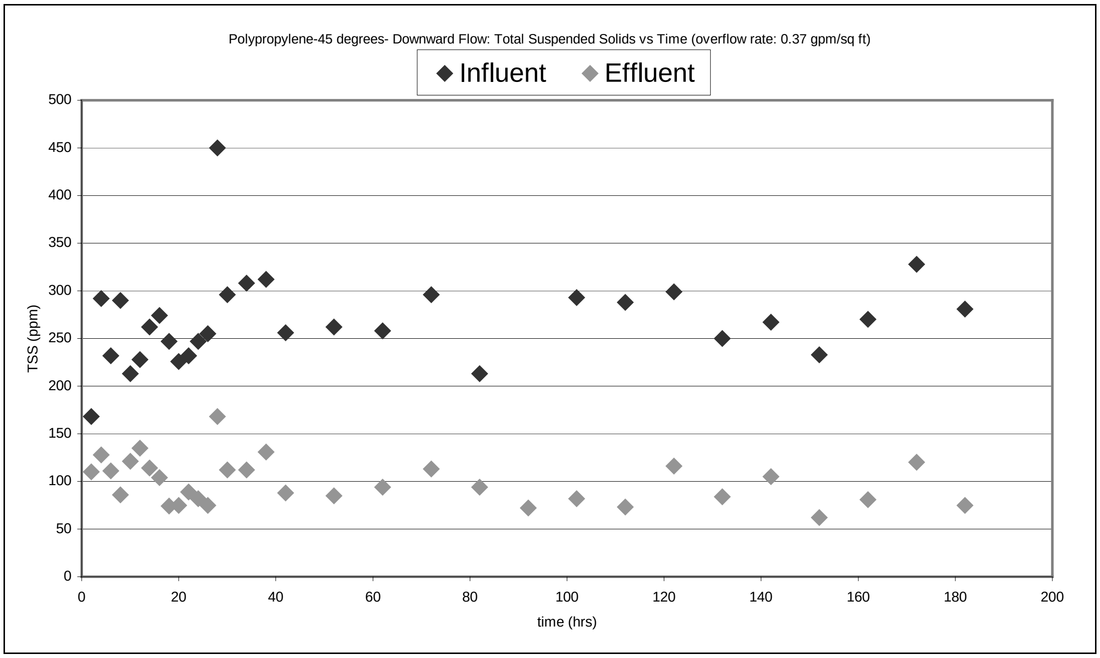


Figure A1. Polypropylene 45 degrees downward flow: TSS at surface loading rate of 0.37 gpm/ft^2.

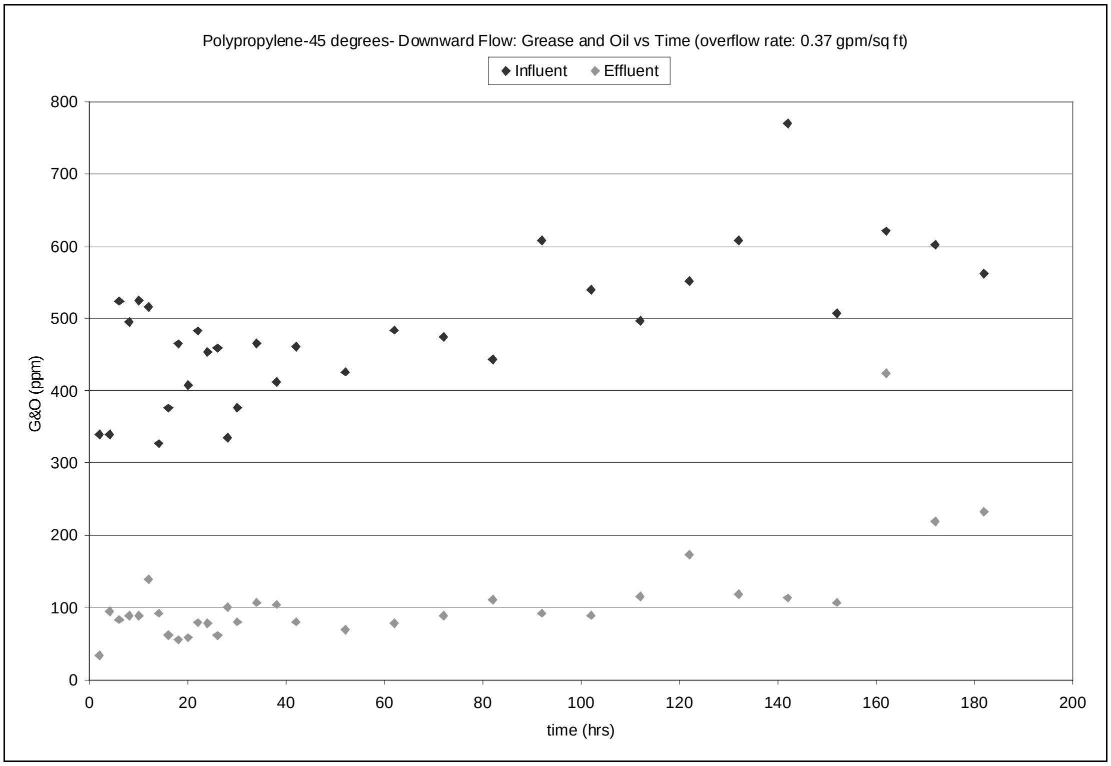


Figure A2. Polypropylene 45 degrees downward flow: O&G at surface loading rate of 0.37 gpm/ft^2.

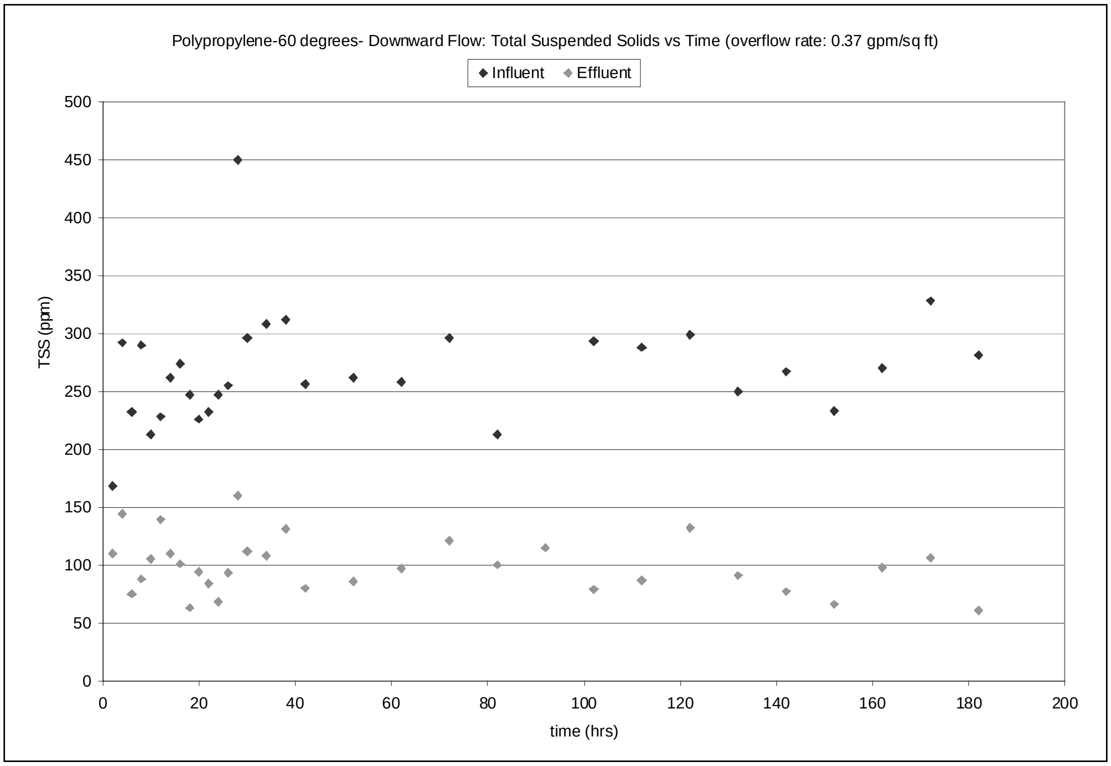


Figure A3. Polypropylene 60 degrees downward flow: TSS at surface loading rate of 0.37 gpm/ft^2.

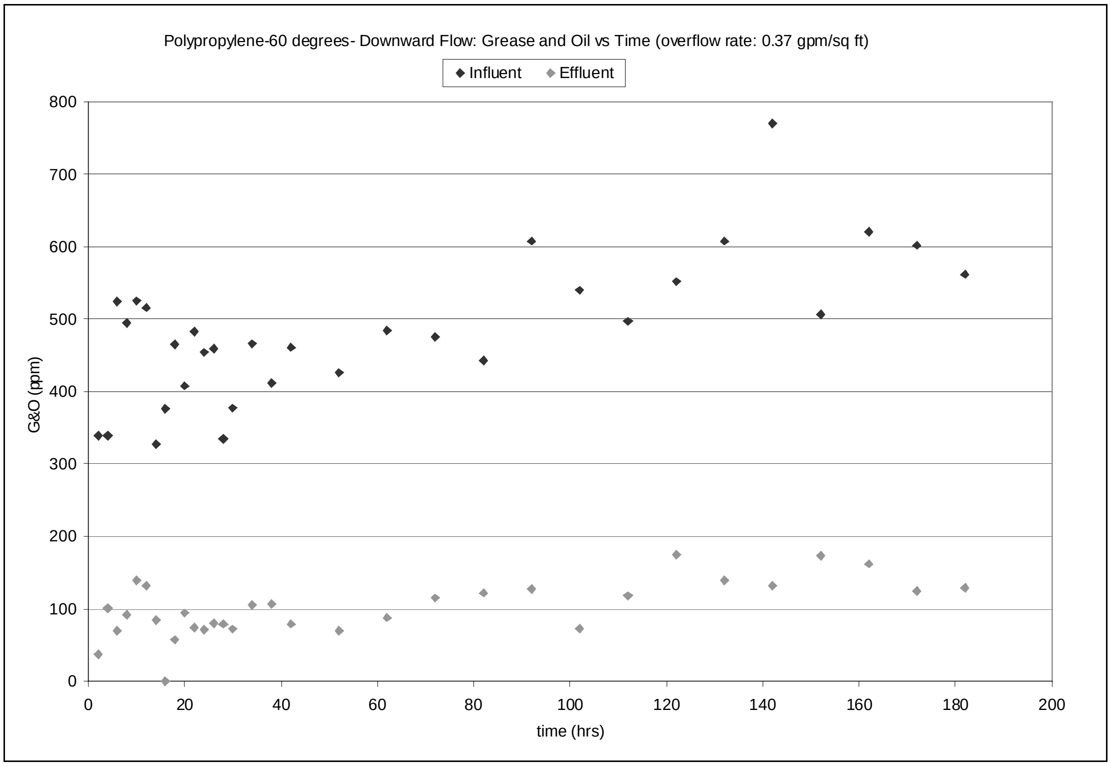


Figure A4. Polypropylene 60 degrees downward flow: O&G at surface loading rate of 0.37 gpm/ft^2.

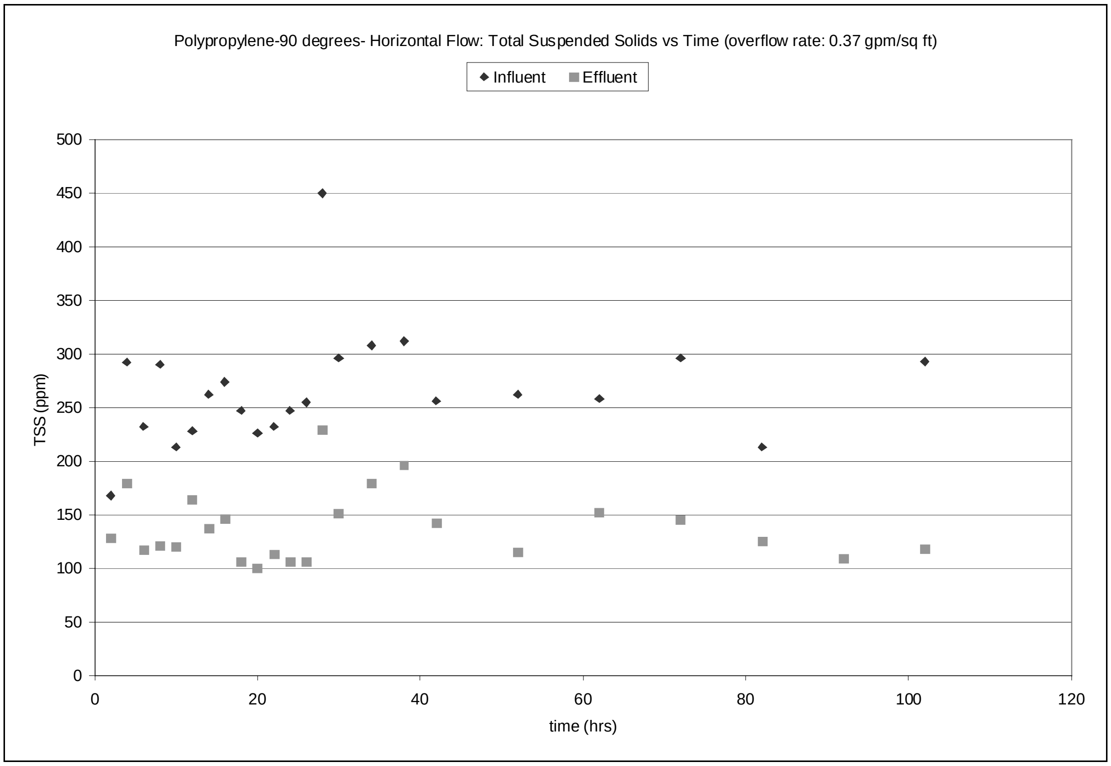


Figure A5. Polypropylene 90 degrees horizontal flow: TSS at surface loading rate of 0.37 gpm/ft^2.

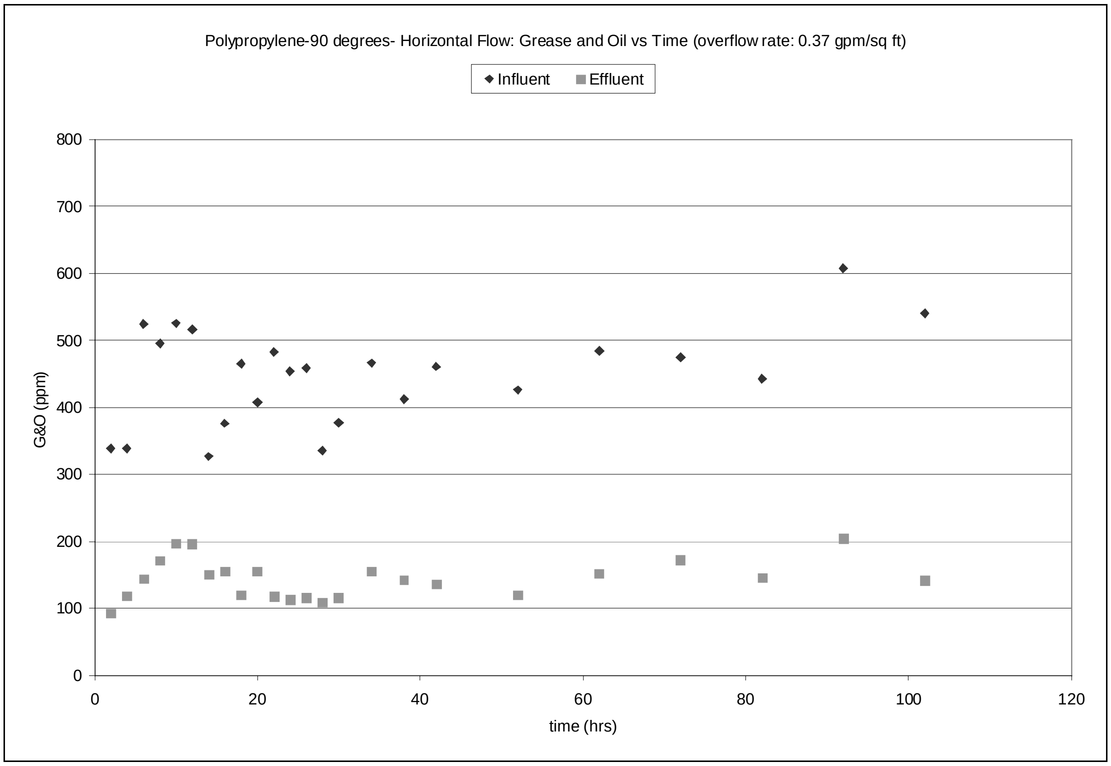


Figure A6. Polypropylene 90 degrees horizontal flow: O&G at surface loading rate of 0.37 gpm/ft^2.

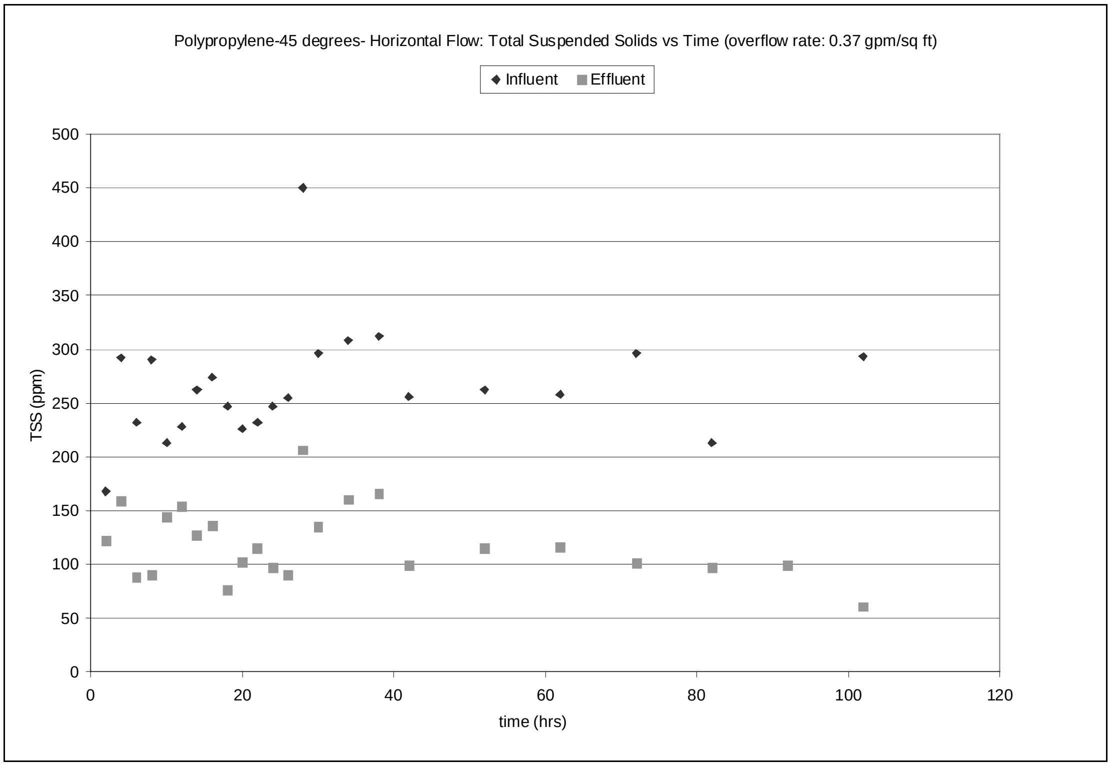


Figure A7. Polypropylene 45 degrees horizontal flow: TSS at surface loading rate of 0.37 gpm/ft^2.

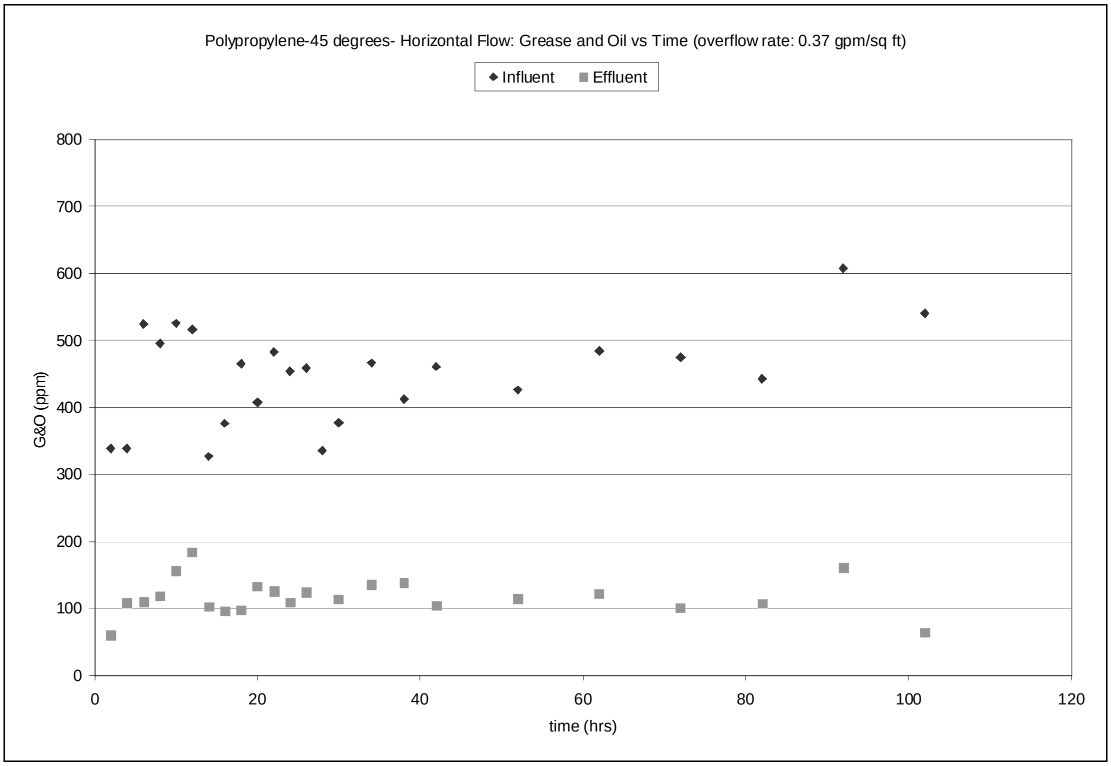


Figure A8. Polypropylene 45 degrees horizontal flow: O&G at surface loading rate of 0.37 gpm/ft^2.

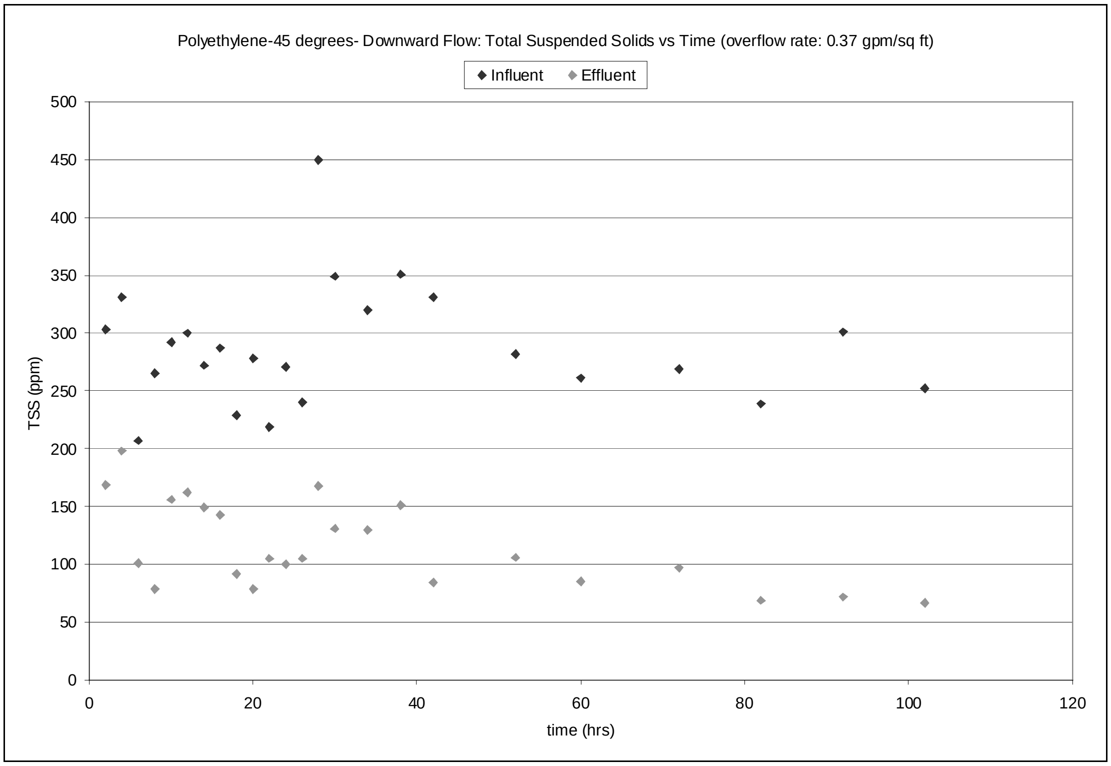


Figure A9. Polyethylene 45 degrees downward flow: TSS at surface loading rate of 0.37 gpm/ft^2.

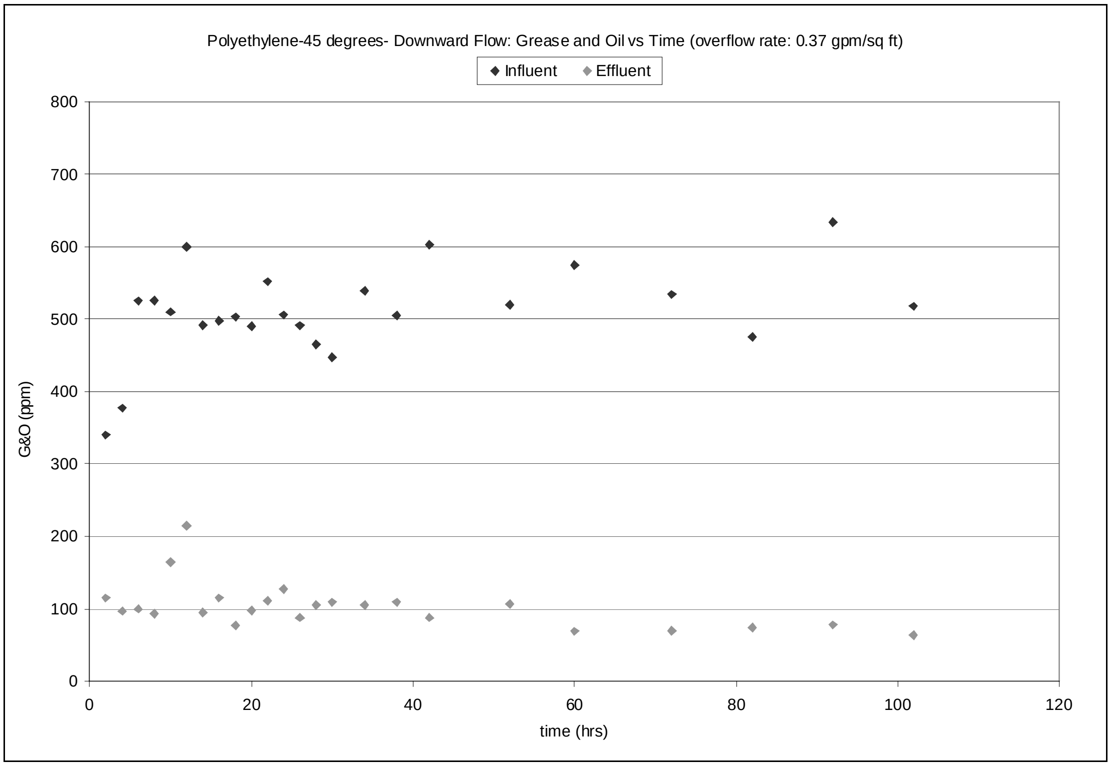


Figure A10. Polyethylene 45 degrees downward flow: O&G at surface loading rate of 0.37 gpm/ft^2.

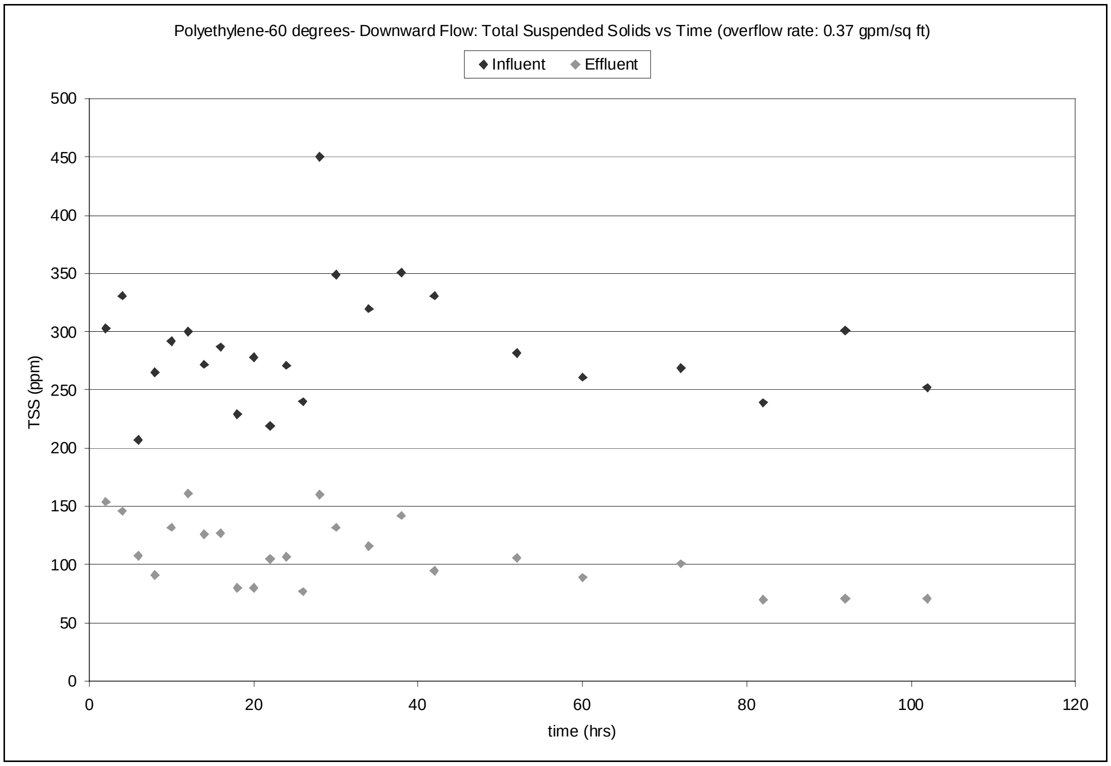


Figure A11. Polyethylene 60 degrees downward flow: TSS at surface loading rate of 0.37 gpm/ft^2.

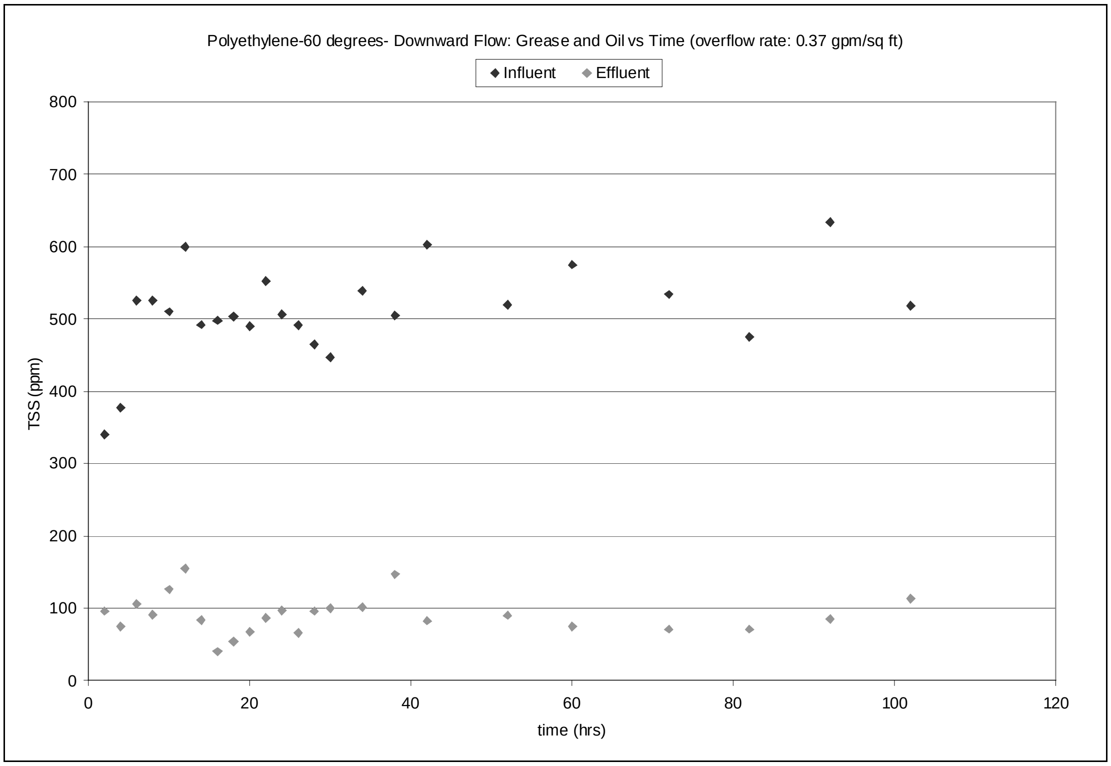


Figure A12. Polyethylene 60 degrees downward flow: O&G at surface loading rate of 0.37 gpm/ft^2.

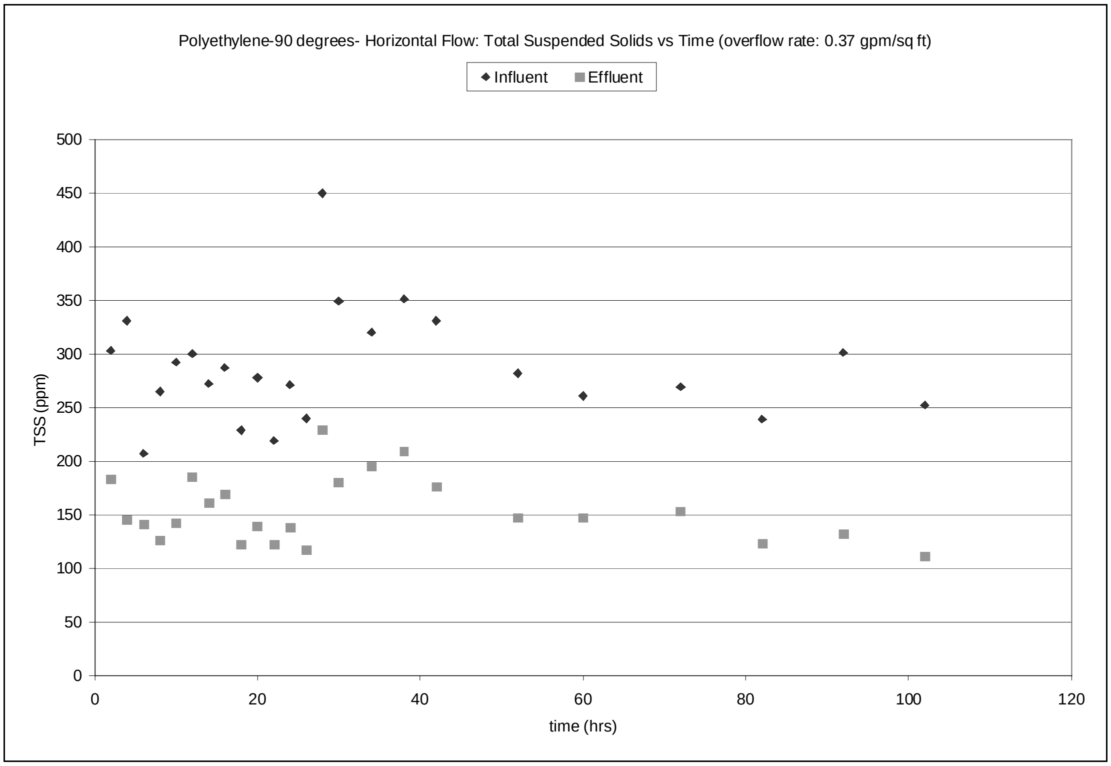


Figure A13. Polyethylene 90 degrees horizontal flow: TSS at surface loading rate of 0.37 gpm/ft^2.

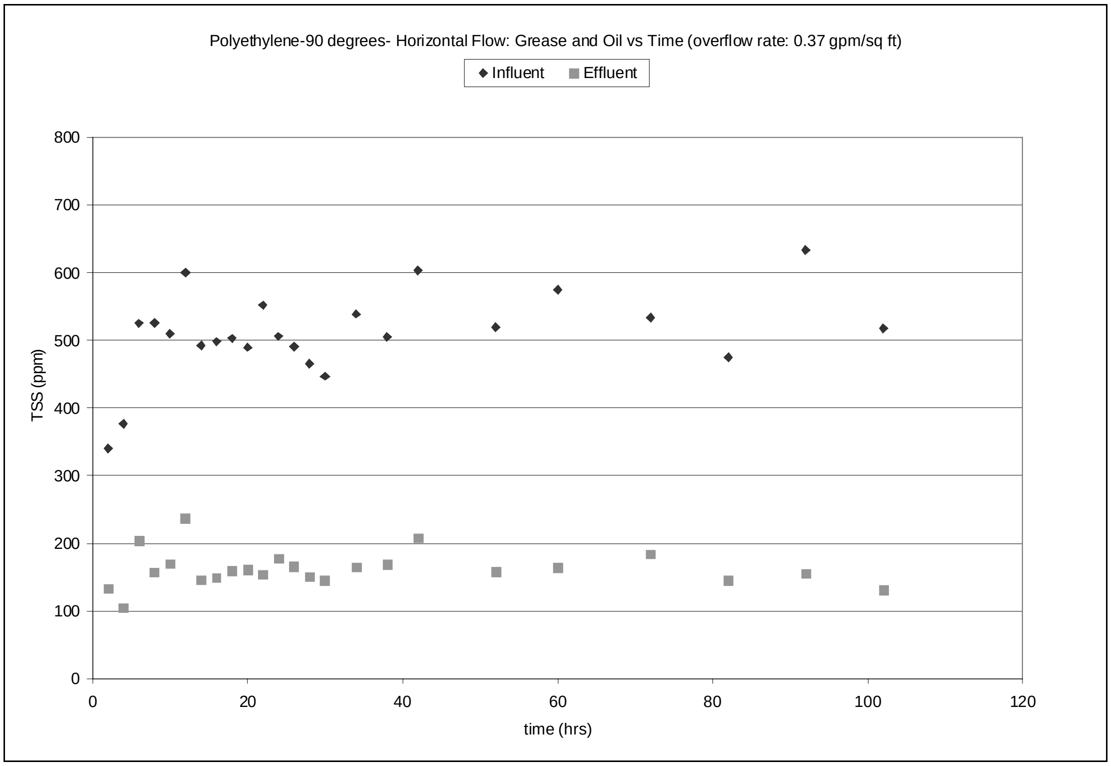


Figure A14. Polyethylene 90 degrees horizontal flow: O&G at surface loading rate of 0.37 gpm/ft^2.

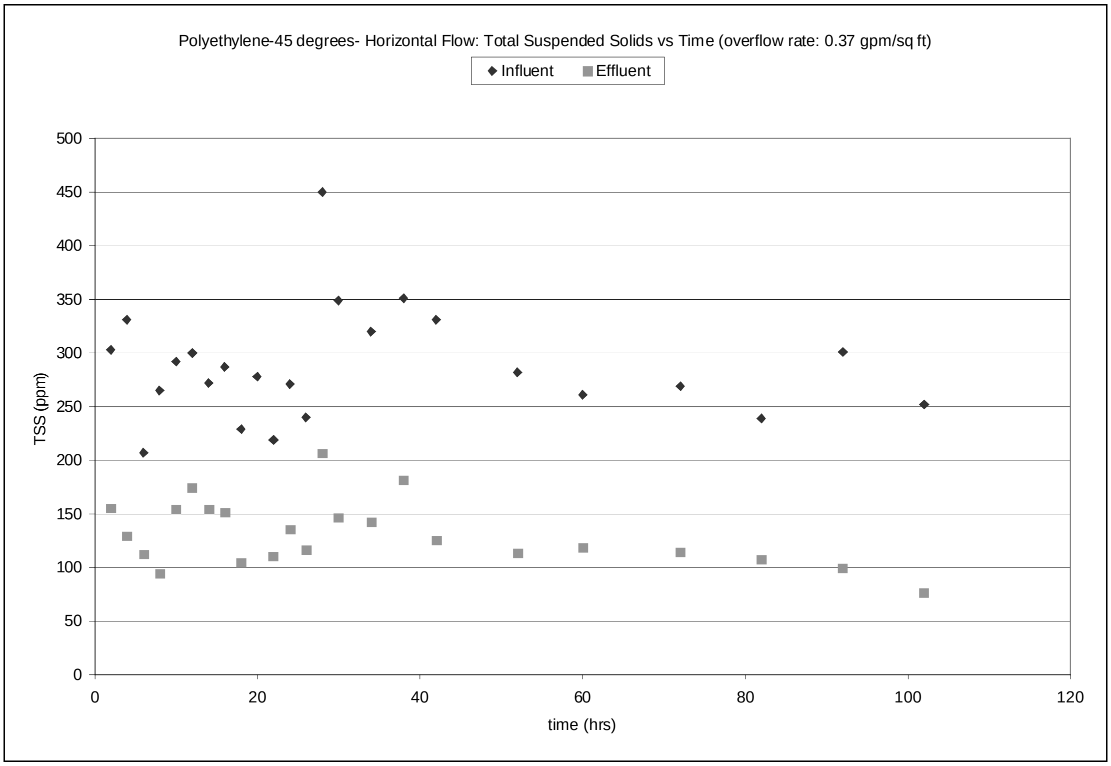


Figure A15. Polyethylene 45 degrees horizontal flow: TSS at surface loading rate of 0.37 gpm/ft^2.

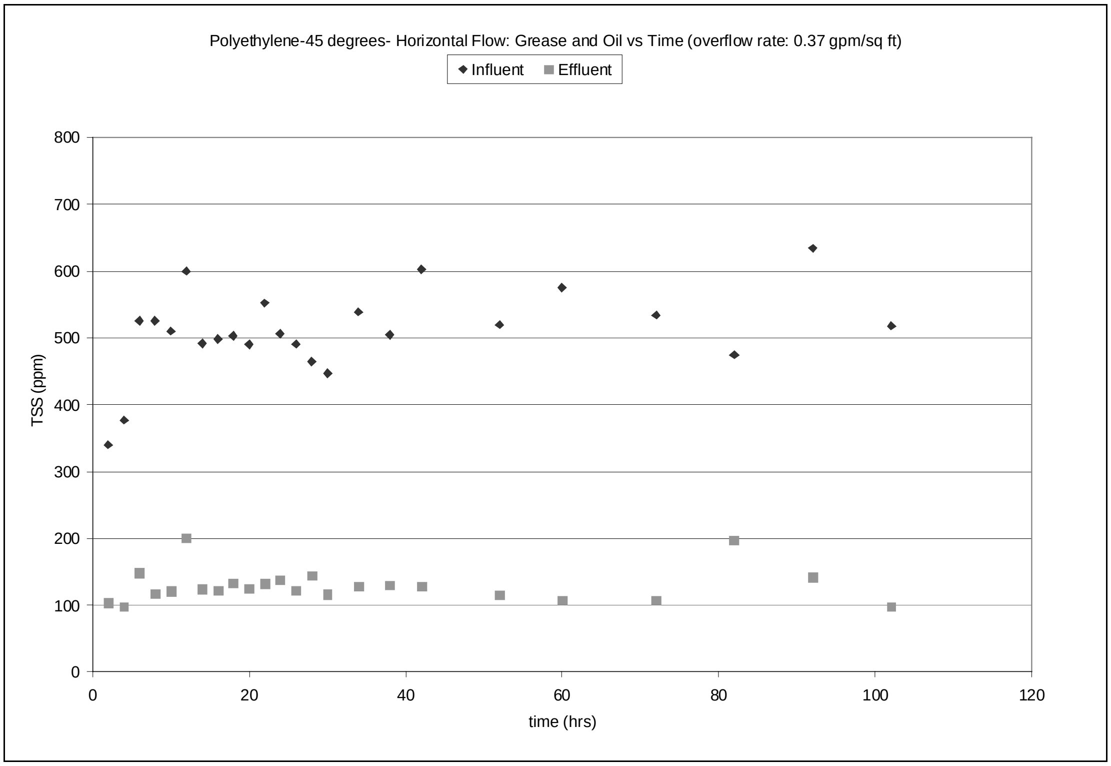


Figure A16. Polyethylene 45 degrees horizontal flow: O&G at surface loading rate of 0.37 gpm/ft^2.

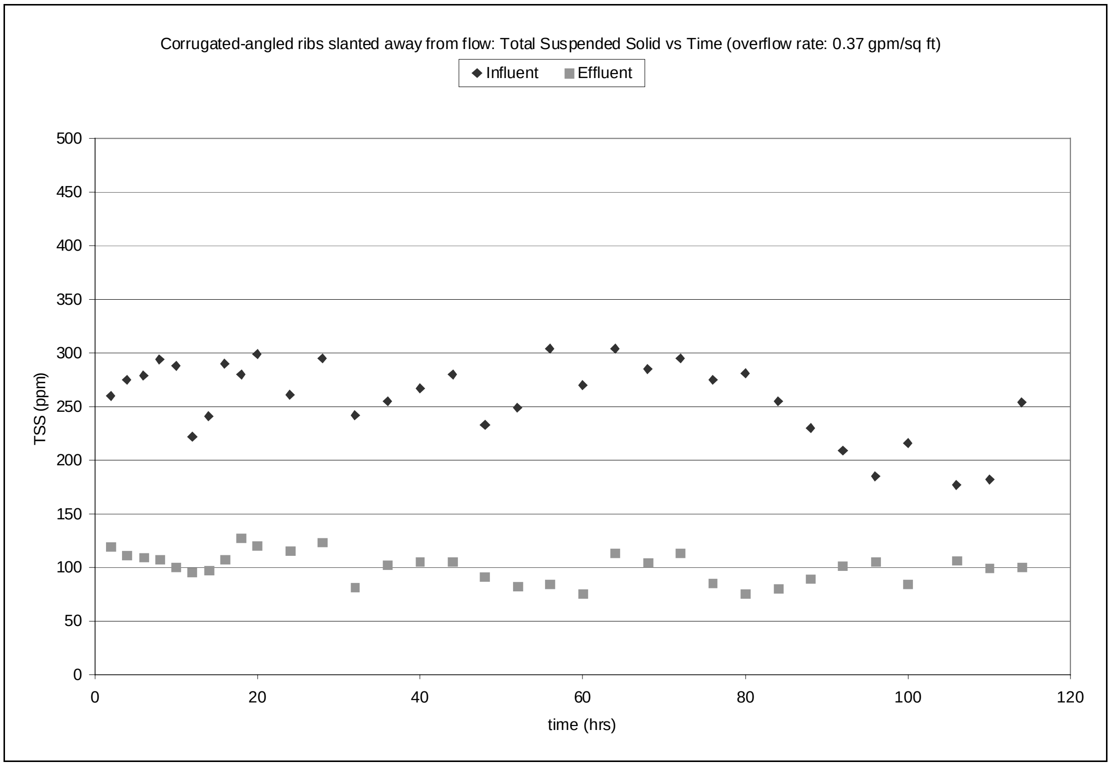
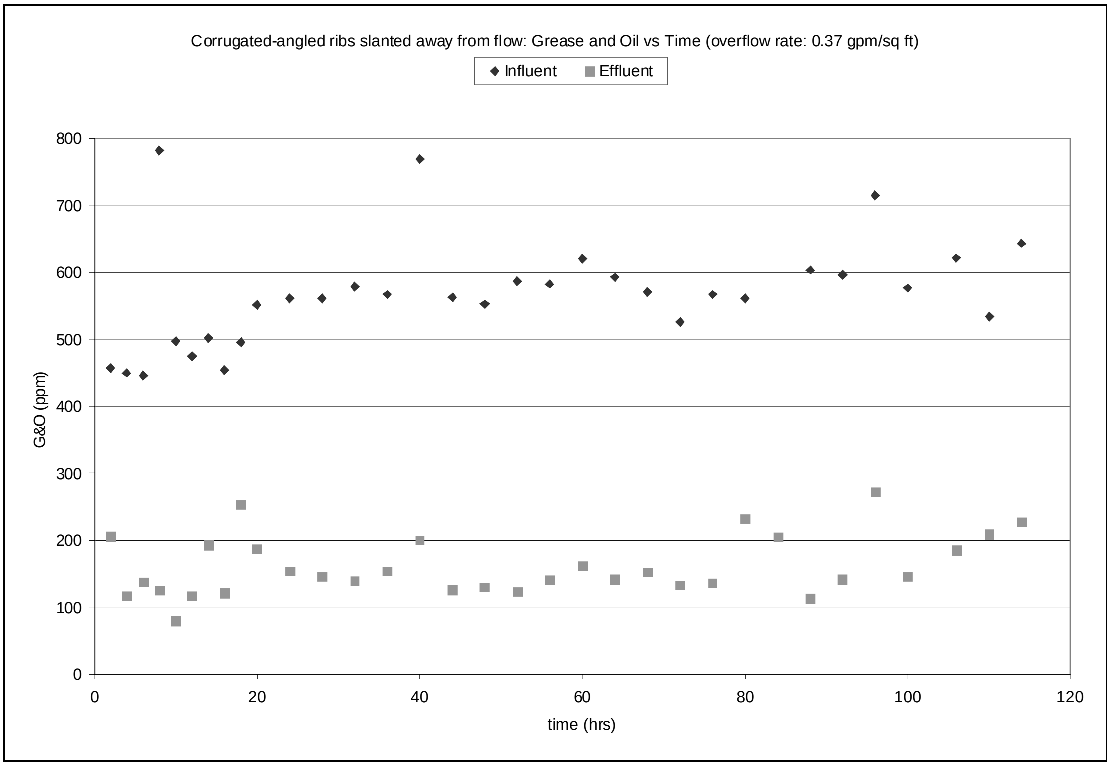


Figure A17. Corrugated angled ribs slanted away from flow: TSS at surface loading rate of 0.37 gpm/ft^2.



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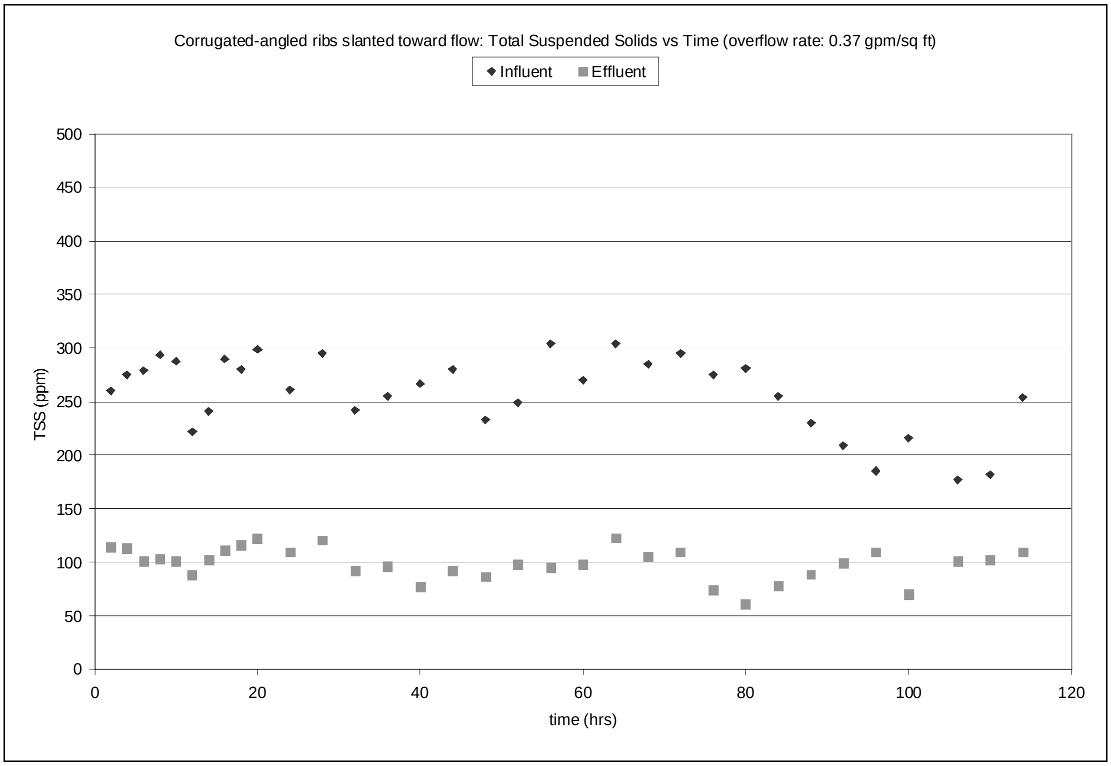

Figure A19. Corrugated angled ribs slanted toward flow: TSS at surface loading rate of 0.37 gpm/ft^2.

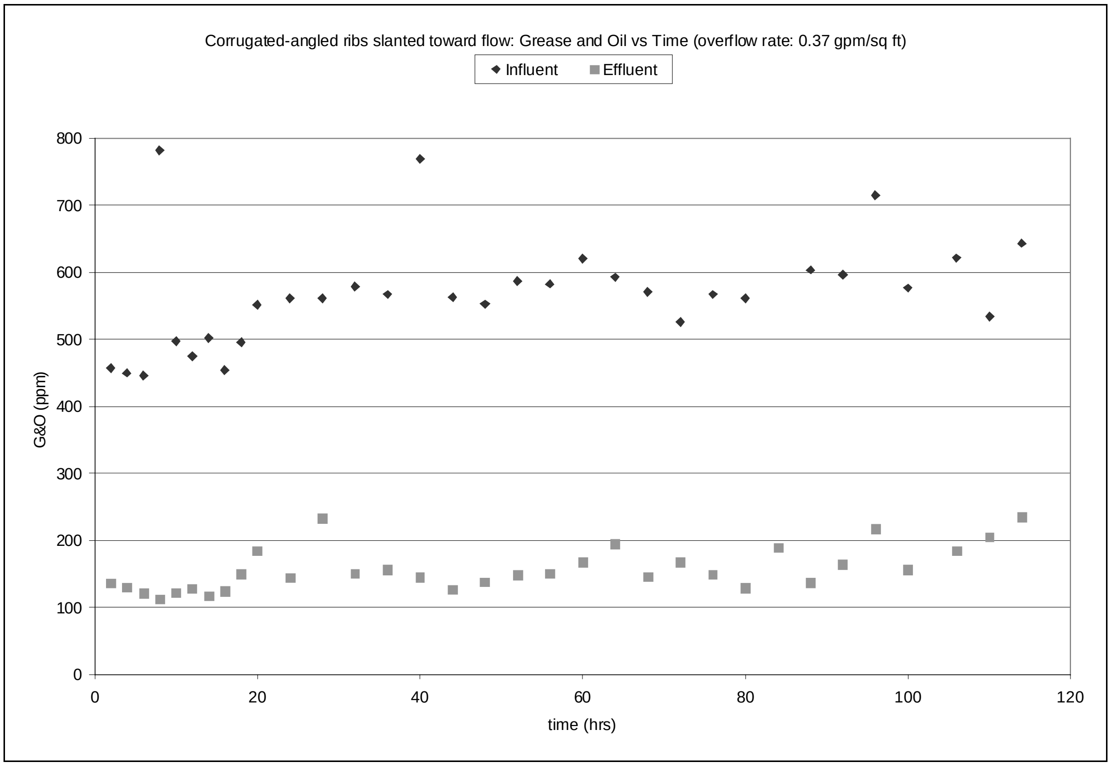

Figure A20. Corrugated angled ribs slanted toward flow: O&G at surface loading rate of 0.37 gpm/ft^2.

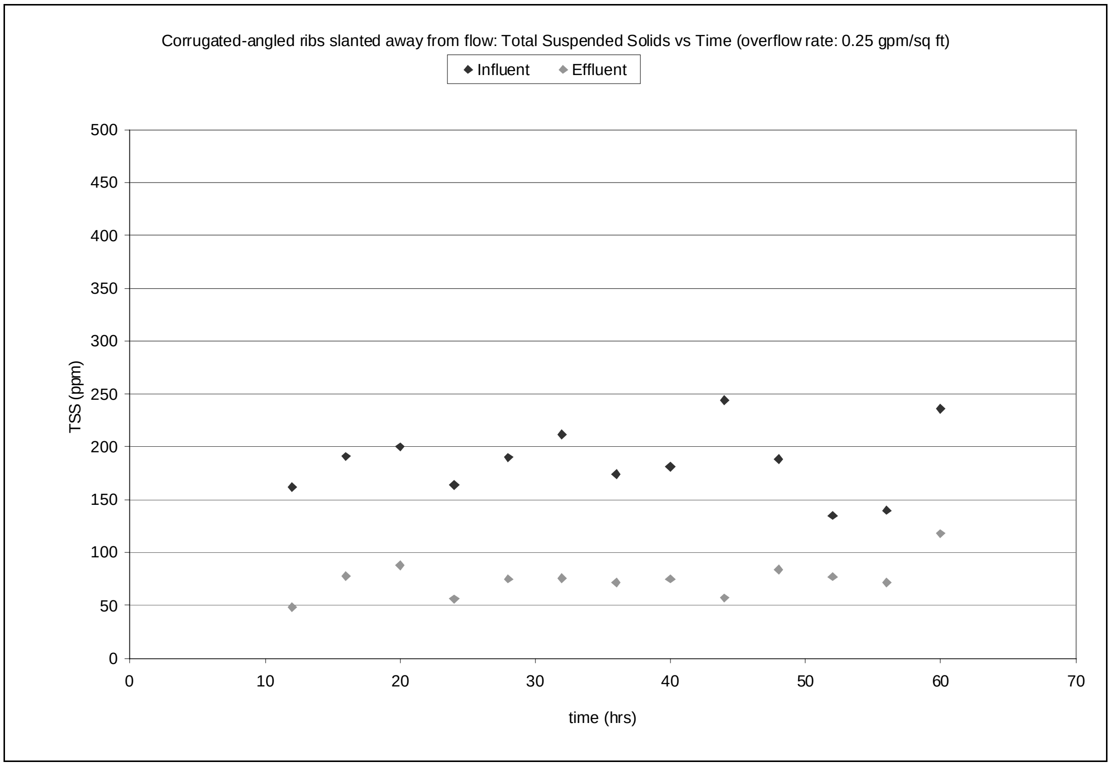

Figure A21. Corrugated angled ribs slanted away from flow: TSS at surface loading rate of 0.25 gpm/ft^2.

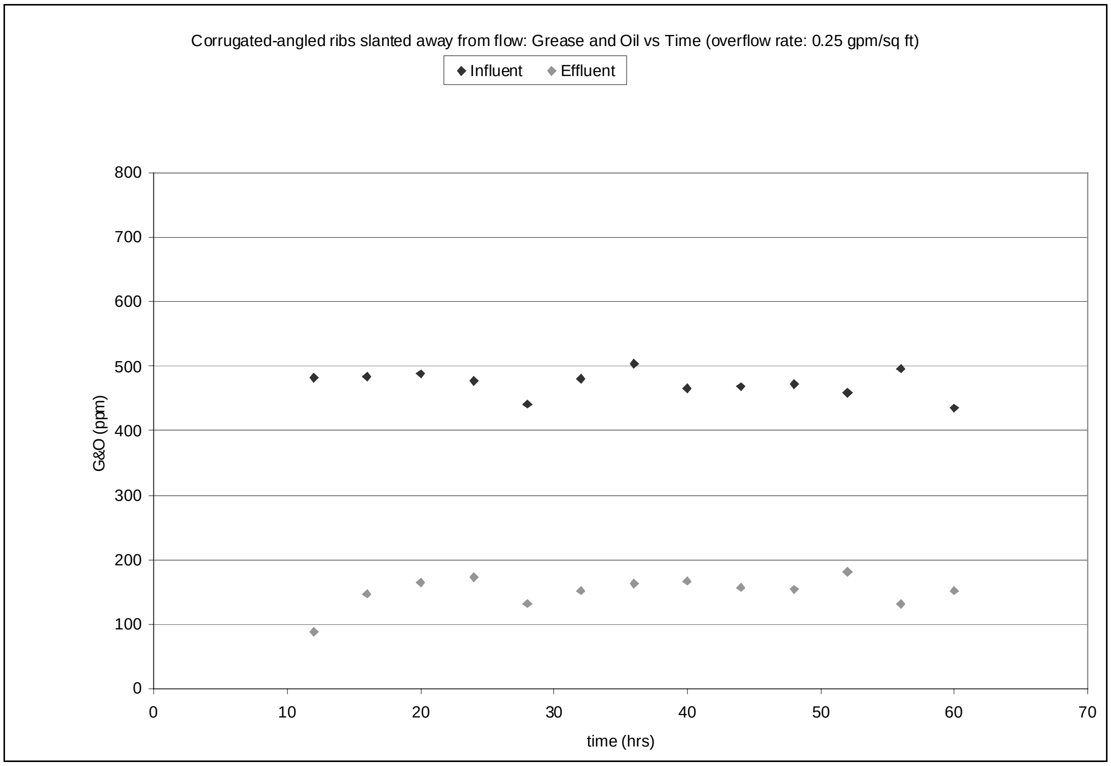

Figure A22. Corrugated angled ribs slanted away from flow: O&G at surface loading rate of 0.25 gpm/ft^2.

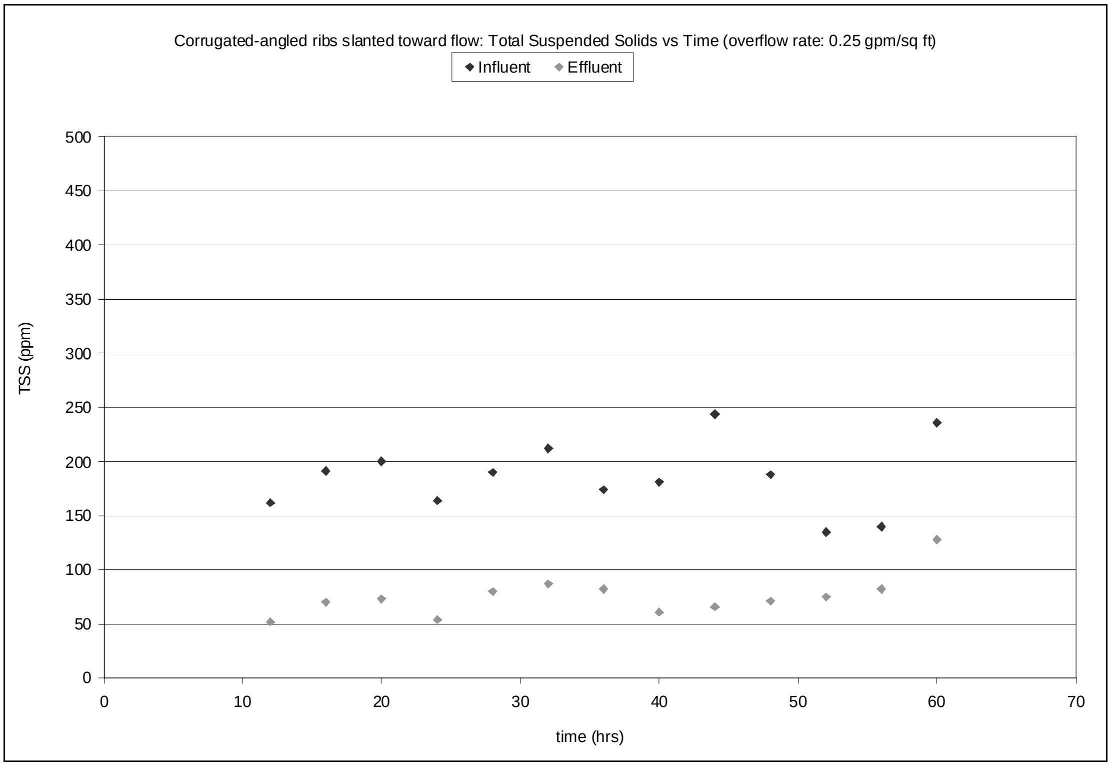

Figure A23. Corrugated angled ribs slanted toward flow: TSS at surface loading rate of 0.25 gpm/ft^2.

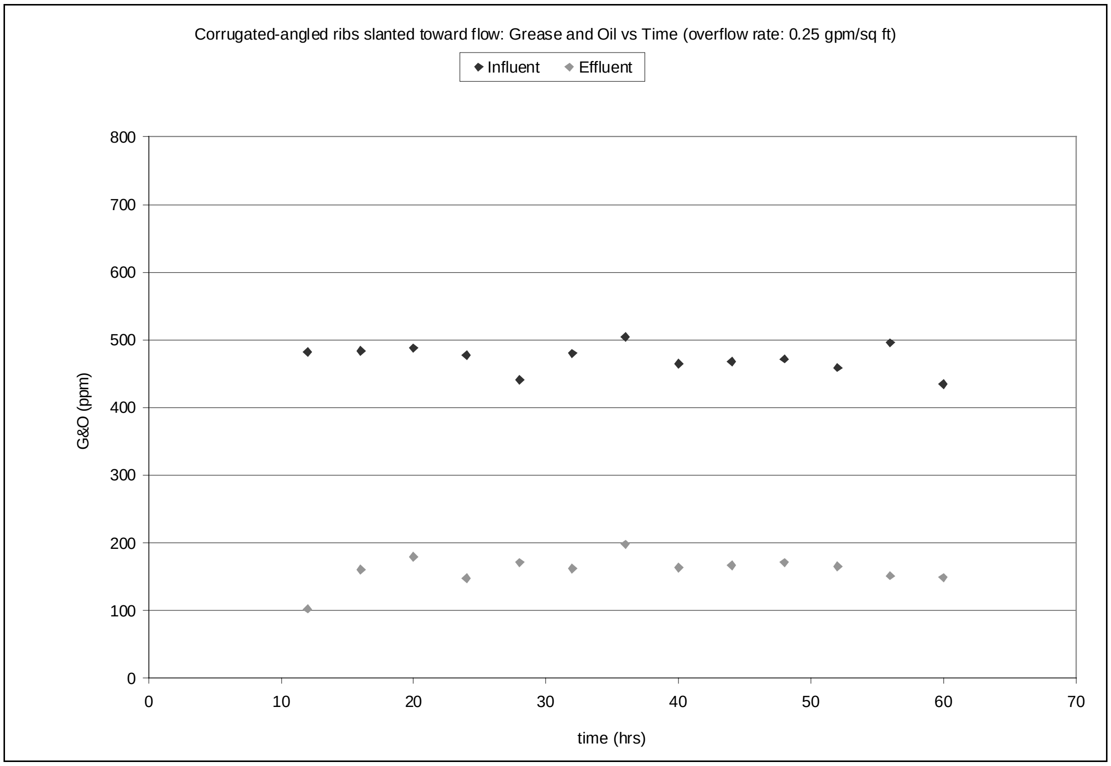

Figure A24. Corrugated angled ribs slanted toward flow: O&G at surface loading rate of 0.25 gpm/ft^2.

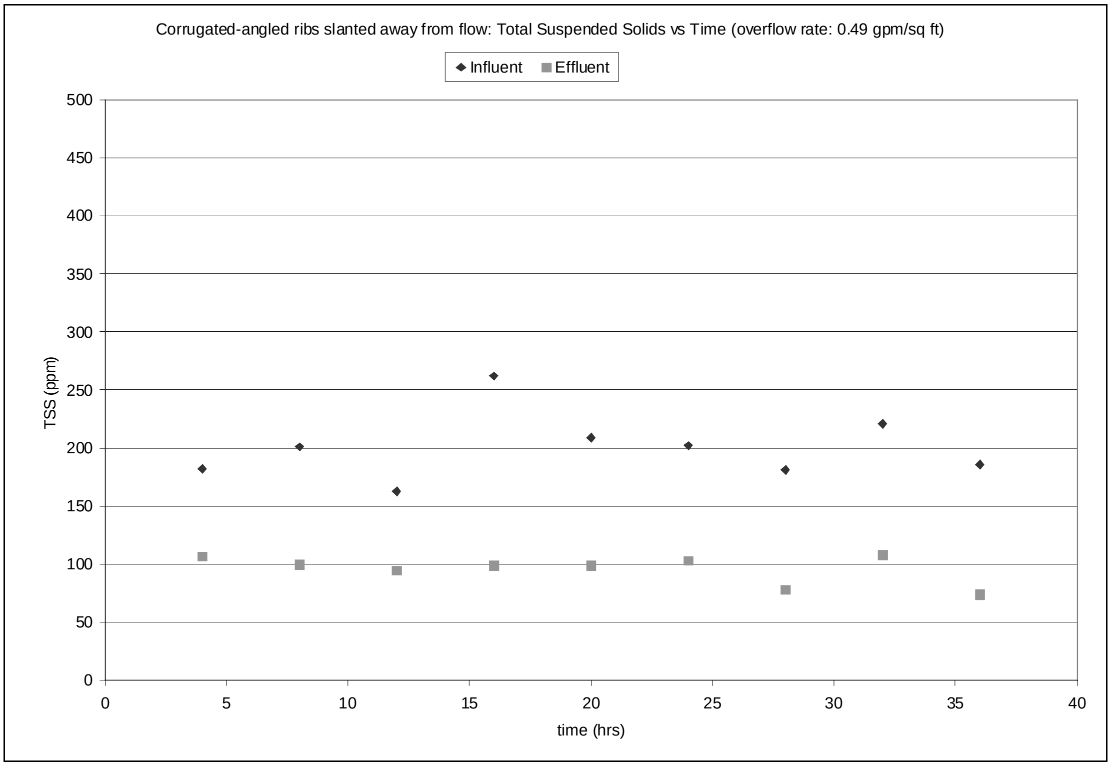

Figure A25. Corrugated angled ribs slanted away from flow: TSS at surface loading rate of 0.49 gpm/ft^2.

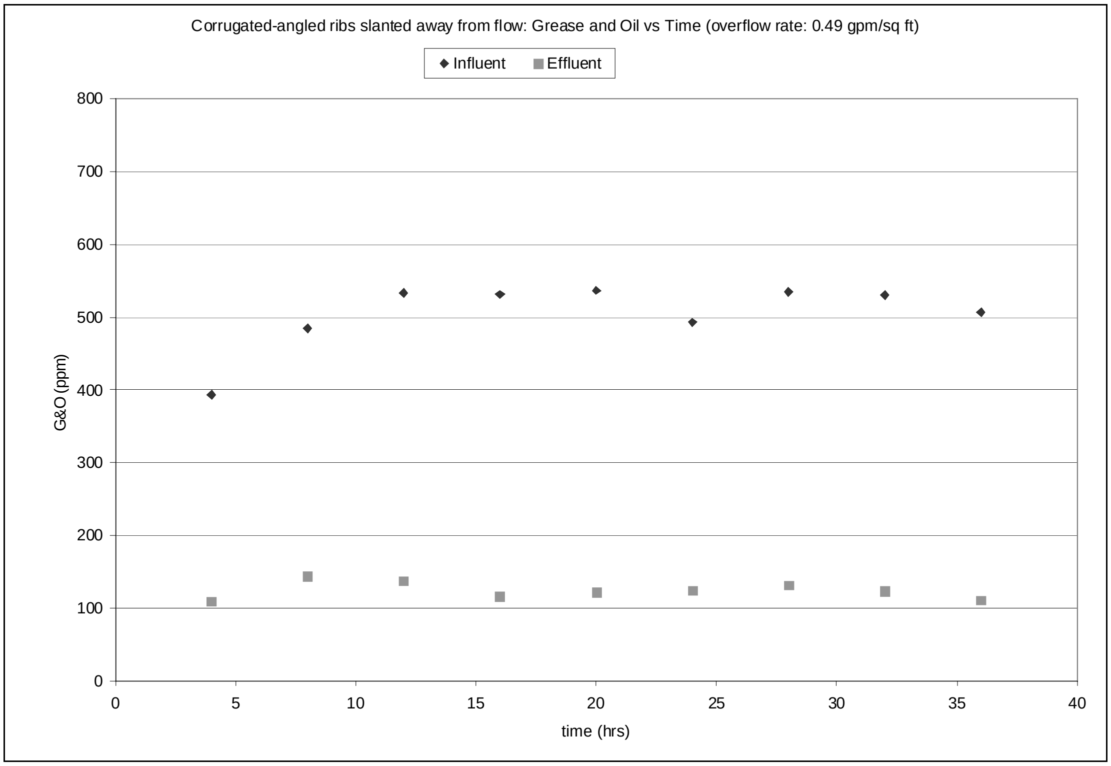

Figure A26. **Corrugated angled ribs slanted away from flow: O&G at surface loading rate of 0.49 gpm/ft^2.**

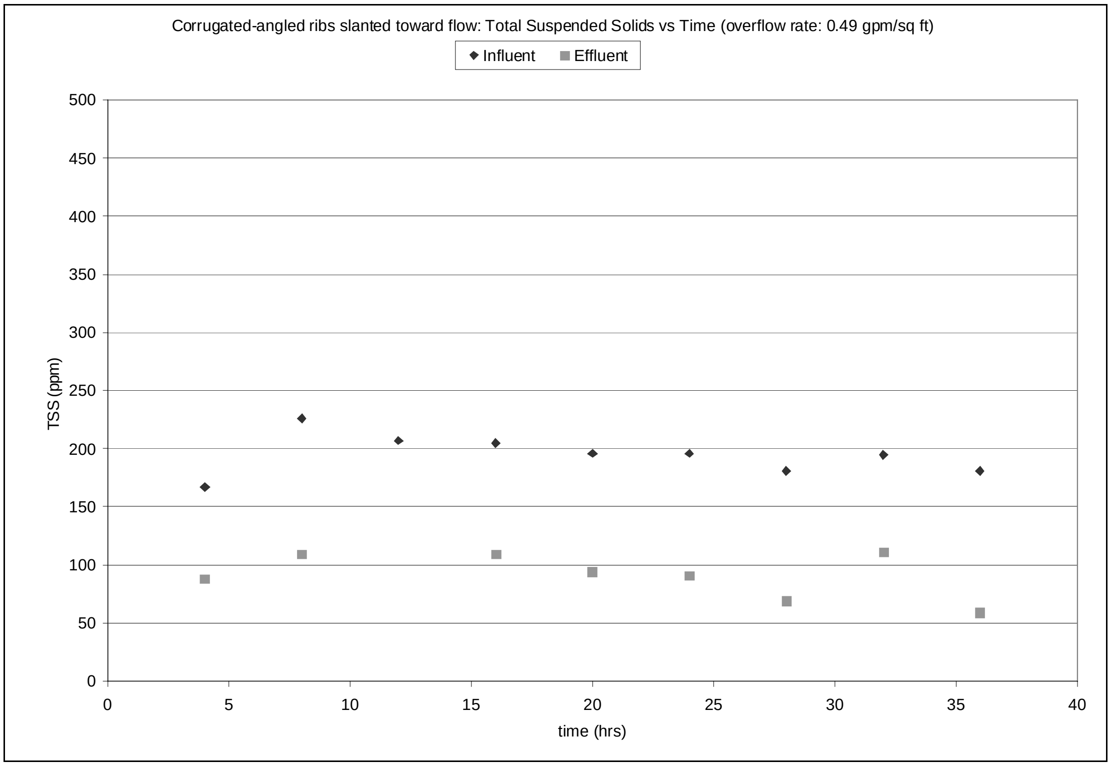

Figure A27. **Corrugated angled ribs slanted toward flow: TSS at surface loading rate of 0.49 gpm/ft^2.**

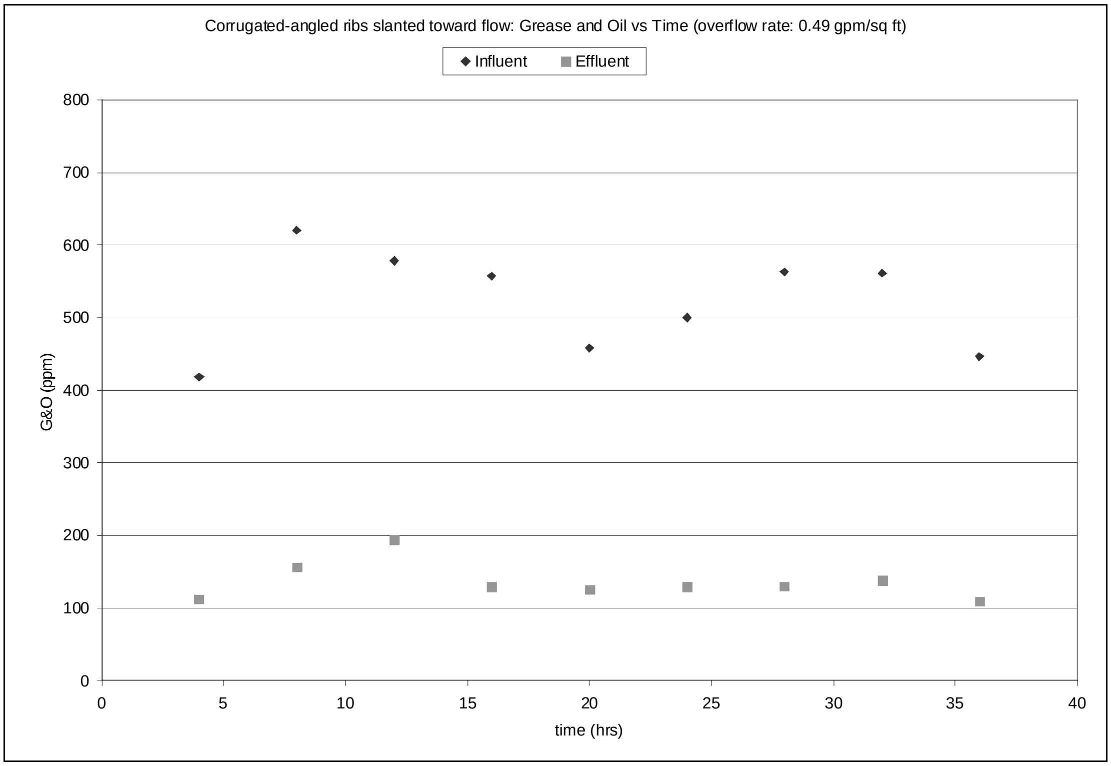

Figure A28. Corrugated angled ribs slanted toward flow: O&G at surface loading rate of 0.49 gpm/ft^2.

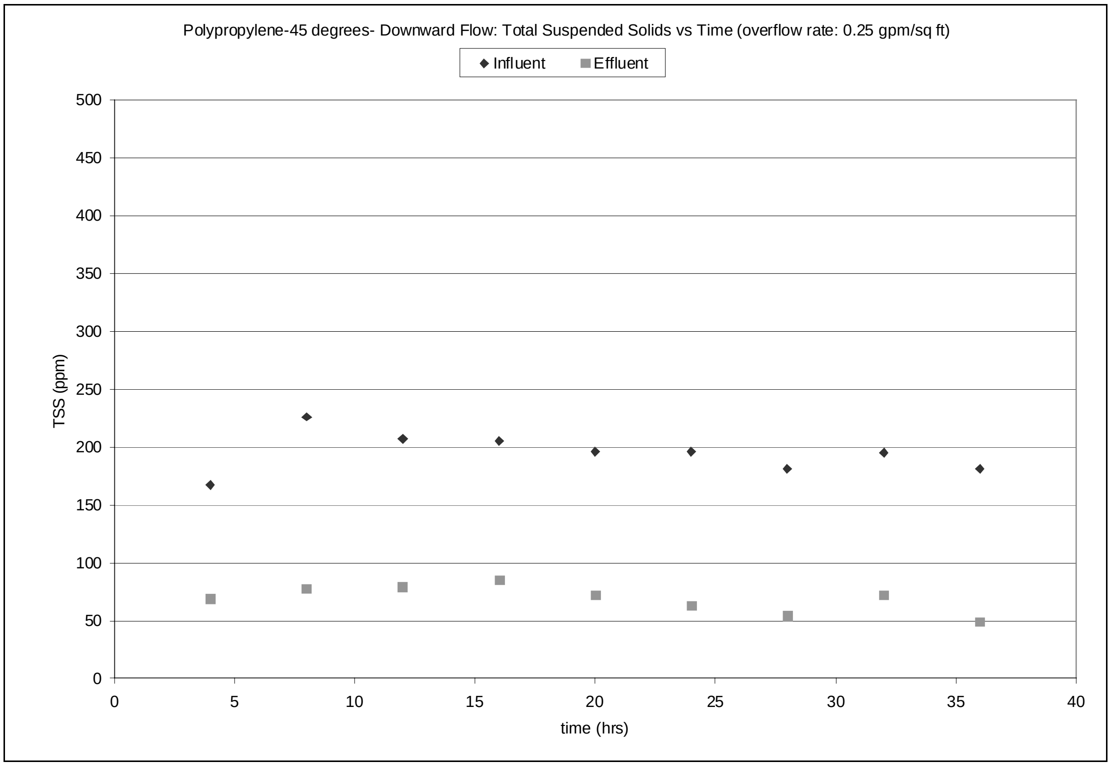

Figure A29. Polypropylene 45 degrees downward flow: TSS at surface loading rate of 0.25 gpm/ft^2.

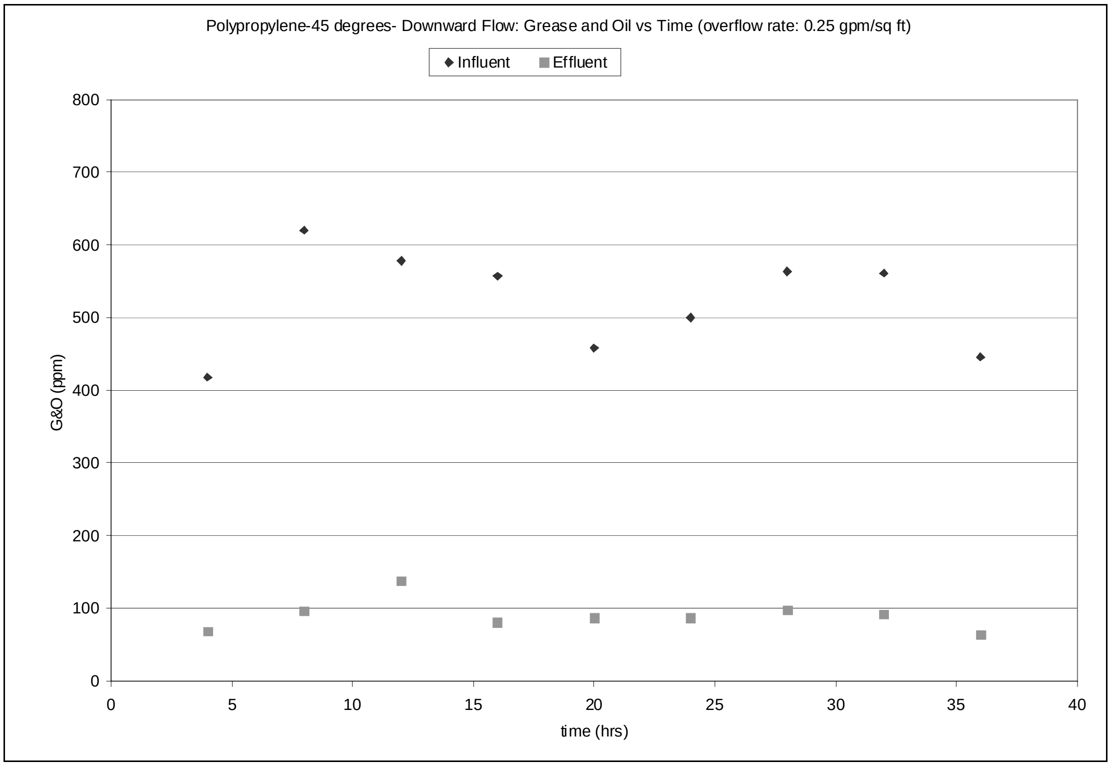

Figure A30. Polypropylene 45 degrees downward flow: O&G at surface loading rate of 0.25 gpm/ft^2.

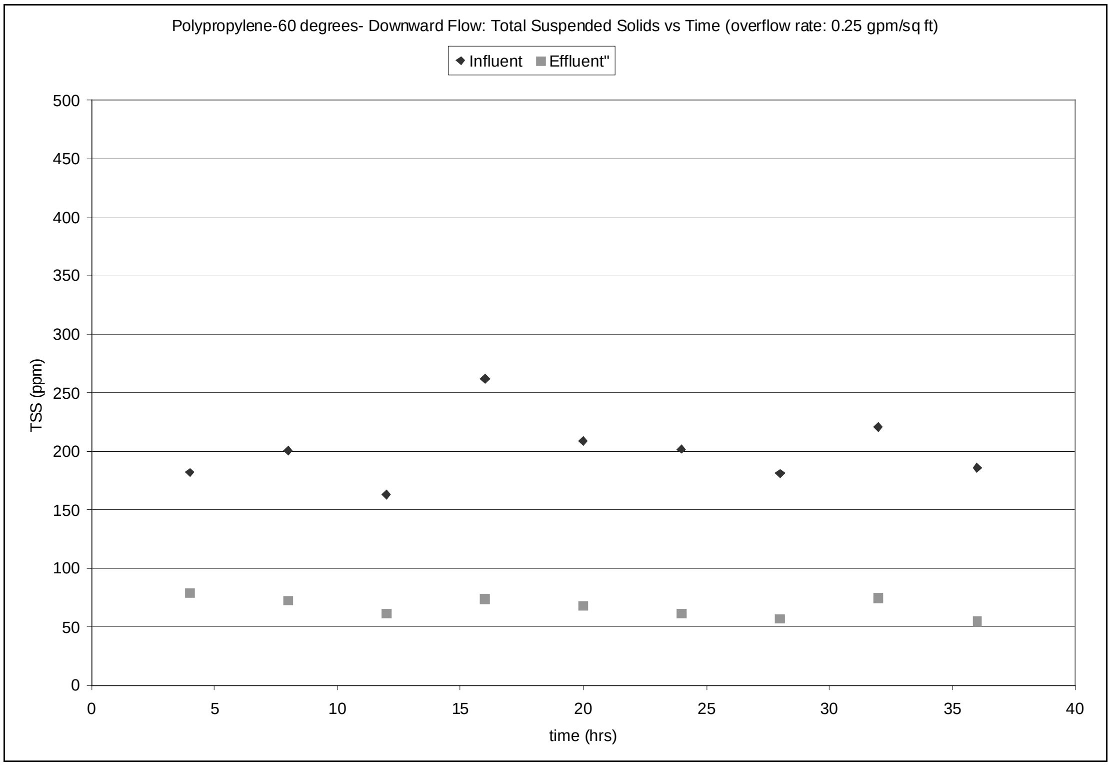

Figure A31. Polypropylene 60 degrees downward flow: TSS at surface loading rate of 0.25 gpm/ft^2.

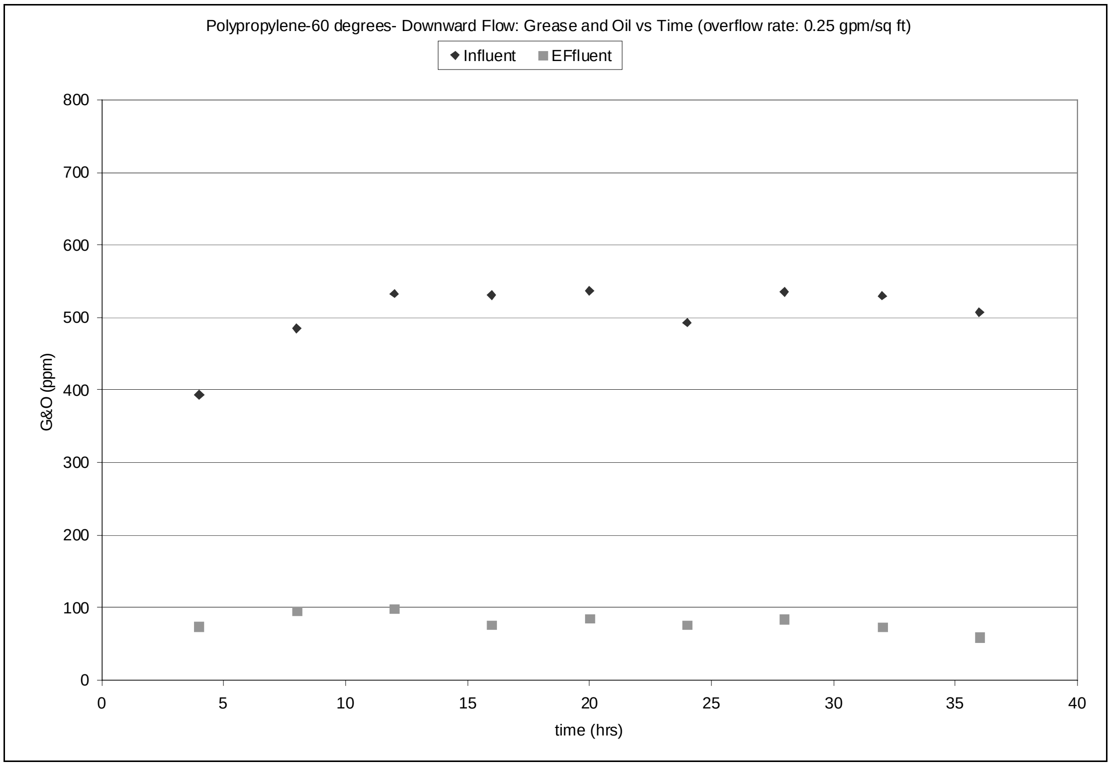

Figure A32. Polypropylene 60 degrees downward flow: O&G at surface loading rate of 0.25 gpm/ft^2.

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14. ABSTRACT

The U.S. Army has thousands of oil/water separators to treat wastewater from tactical vehicle washracks at active Army, Army Reserve, and Army National Guard facilities. The Army continues to purchase and install new separators when existing separators must be replaced, and when new vehicle maintenance facilities are being constructed. Most off-the-shelf separators being installed currently are coalescing-type gravity separators.

No Army guidance exists, however, to help environmental and Directorate of Public Works personnel purchase coalescing separators that are applicable to the high solids wash water at a typical Army washrack. Because Army guidance did not exist, and vendor guidance is not applicable, this study was conducted so that installation personnel, as well as washrack designers, have specific guidance for the selection of off-the-shelf coalescing oil/water separators.

This research concluded in the following specifications for off-the-shelf, coalescing, oil/water separators: coalescer plate material – polyethylene; maximum surface loading rate – 0.37 gpm/ft2; coalescer plate angle – 60 degrees; direction of flow – downward at 60 degrees to the horizontal.

15. SUBJECT TERMS
oil/water separators, washrack, vehicle maintenance, tactical equipment maintenance, coalescers, waste water

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