Rick Mystrom, Mayor

Meltwater Runoff from Anchorage Streets and Snow Disposal: Design Report

Document No. WMP APd99003

MUNICIPALITY OF ANCHORAGE
WATERSHED MANAGEMENT PROGRAM

JANUARY 1999

WATERSHED MANAGEMENT

Department of Public Works

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WATERSHED MANAGEMENT

Department of Public Works

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Abbreviations

ADT	average daily traffic
AKDOT/PF	Alaska Department of Transportation and Public Facilities
BMP	Best Management Practices
BOD	Biochemical Oxygen Demand
CBD	Central Business District
DHHS	Department of Health and Human Services
DOT	Department of Transportation
EPA	Environmental Protection Agency
MOA	Municipality of Anchorage
WMS	Watershed Management Section

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Introduction

The Municipality of Anchorage (MOA) and the Alaska Department of Transportation and Public Facilities (AKDOT/PF) are currently using aqueous solutions of magnesium chloride throughout the city to enhance vehicle traction during winter months. In 1998, public concerns were raised about the potential for negative environmental impacts from this use. Specifically, questions were voiced concerning the:

1. potential for increased corrosion of structures and vehicles,
2. potential for pollutant impacts to ground water resources,
3. potential toxic danger to children playing on snow disposal sites, and
4. toxic danger to wildlife and aquatic life especially from snow disposal site meltwater.

To address these concerns, the MOA Department of Public Works, Watershed Management Section (WMS) designed and implemented an exploratory assessment of deicer effects in the spring of 1998. This assessment was primarily concerned with the environmental effects of chloride. Other potential effects stemming from metals contained in the product and Biochemical Oxygen Demand (BOD) were estimated using existing data, or considered but not addressed based on low toxicity, mobility, or concentration.

The 1998 project design and data collection effort focused on deicer contained in snow disposal sites. Sampling data from three sites included in the study were used to construct a model to predict receiving water impacts from all area snow disposal sites. Additionally, the project report also considered the effects of deicer remaining on streets at the end of the winter, and the effects of solid sodium chloride contained in vehicle-traction sand. The 1998 deicer assessment design is presented in *Magnesium Chloride Deicer in Snow Disposal Sites at Anchorage, Alaska: Assessment Design,* WMS document WMP Apd98001 (Wheaton, 1998a); A summary of the data collection effort and the associated results are presented in *Magnesium Chloride Deicer in Snow Disposal Sites at Anchorage, Alaska: Data Report,* WMS document WMP APr98001 (Wheaton et.al., 1998b); Study findings and interpretations are presented in *Anchorage Street Deicer and Snow Disposal 1998 Best Management Practices Guidance,* WMS document WMP Apg98001 (Wheaton et.al., 1998c).

The general conclusion of the 1998 report was that chloride from current levels of sand and deicer use (both AKDOT/PF and MOA) do not appear to be adversely impacting area receiving waters. The report also contains recommendations for further study of chloride sources and fates, and for implementation of snow disposal site Best Management Practices (BMP). Based on the conclusions of the report, the US Environmental Protection Agency (EPA) is requiring MOA to conduct further studies on chloride impacts, including:

1. 1999 spring break-up monitoring of several snow disposal sites (including one site included in the 1998 study) to confirm 1998 modeling results.
2. 1999 spring break-up monitoring of several area creeks to confirm 1998 modeling results demonstrating the effects of chloride contained in street runoff.

The continued monitoring of snow disposal sites and creeks is not only intended to confirm modeling results but also to refine existing predictive models and assess the effectiveness of the BMPs implemented as a result of the 1998 Deicer Assessment. Data will also be used to differentiate between environmental impacts due to chloride derived from sodium chloride contained in street sand and magnesium chloride deicer.

Although not specified in directives from the EPA, municipal watershed managers also desire knowledge of the effects of deicer used as a dust palliative. During the winter of 1998-99, the State Department of Transportation (DOT) proposes exclusive use of deicer for vehicle traction enhancement on the Gambell/Ingra couplet between Fireweed Lane and 15th Avenue. This pilot study is designed to determine if substituting deicer for sand will result in improved air quality. Consequently, knowledge of chloride concentrations in street runoff from the study site, and the associated impacts to Chester Creek are important to understanding the environmental implications of expanded deicer uses.

Problem Statements

Based on the above discussion, this design document is intended to describe the steps necessary to answer the following watershed management questions:

> Do 1998 magnesium chloride and sodium chloride modeling data accurately represent chloride impacts from snow disposal sites and city streets on Anchorage area creeks?
>
> What is the effectiveness of the BMPs implemented at snow disposal sites for the winter of 1998/99?
>
> What are the relative concentrations of chloride derived from magnesium chloride (deicer) and sodium chloride (vehicle traction sand) contained in snow disposal site melt water and street runoff?
>
> What are the probable consequences to area receiving water quality if magnesium chloride deicer is widely used as a dust palliative?

Organization of Design Document

To present the project design for answering the above management questions, this document has been organized in the following manner:

Section 1 contains an introduction summarizing the context of the assessment, presents a statement of the information required by watershed managers, and describes the organization of this document.

Section 2 presents a description of the system dynamics involved in the application and mobilization of chloride applied to city streets.

Section 3 presents selection logic for the critical system parameters used to represent the application, mobilization, and fates of chloride.

Section 4 describes how selected critical parameter will be measured to represent the systems under study.

Section 5 summarizes the project approach, including when and where data will be collected, how data will be reported, data analysis methods, and project organization.

Section 6 contains cited references.

Appendix A contains pertinent information about the drainage basins included in this study. This information includes basin area and sediment wash off rates.

Tables and figures follow the section in which they are referenced.

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System Description

The following sections present a description of the content, application, and mobilization of street sand and deicer used for vehicle traction enhancement.

Magnesium Chloride Deicer

Currently the Municipality is using a magnesium chloride deicer called FreezeGard with Shield LS corrosion inhibitor. FreezeGard is an aqueous solution of magnesium chloride manufactured from a mixture of about 66% water, 32% magnesium chloride hexahydrate ($MgCl_2 \cdot 6H_2O$), 2% corrosion inhibitor and trace metals. The product may be further diluted during use to about 25% magnesium chloride. Results for a sample of the deicer product used and recently tested by WMS are shown on Table 2-1.

The magnesium chloride deicer is applied to Anchorage streets through two separate practices: 1) in a "straight" application as an anti-icing or deicing agent (magnesium chloride used as the principle means of improving vehicle traction), and 2) as a "pre-wetting" agent applied to street sand immediately before distribution of the sand onto the street surface (as a means to help embed the particles). In both cases, sanding and deicing practices are employed only in a 50 to 300-foot zone about controlled intersections (representing a relatively small fraction of total street surface).

In the anti-icing and deicing applications, the deicer is applied directly to the street surface immediately before a storm (typical anti-icing practice), or is applied to any remaining compacted snow and ice after an initial snowfall has been plowed (typical deicing practice). In either case, additional plowing events may be performed throughout the storm and additional applications of deicer may be made. Typically 1 to 3 applications are made per storm though more may be applied during larger storm events. The standard anti-icing or deicing application rate at Anchorage is about 0.75 gallons (3 liters) of approximately 25% dilute magnesium chloride per 1000 square feet (93 m^2) of street intersection surface. For reference, the Municipality applied approximately 275,000 gallons ($1.21x10^6$ liters) of deicer in anti-icing and deicing applications during the winter of 1997-98 at all controlled intersections between 3rd and 9th Avenues and L and Karluk Streets—also known as the Central Business District (CBD). Currently, anti-icing and deicing application of liquid magnesium chloride deicer is limited to the CBD and select "snow route" intersections.

The "pre-wetting" use of magnesium chloride typically uses much less deicer than anti-icing or deicing because the sand (which is wetted with deicer prior to spreading) actually provides vehicle traction. The Municipality uses from up to 3 gallons (for an average of about 2 gallons, or 8.8 liters) to pre-wet one ton (910 Kg) of sand. For reference, in a single winter the

Municipality of Anchorage currently uses about 5,000 to 7,000 tons of street sand areawide, reflecting a total annual projected use of about 12,000 gallons ($5.28x10^4$ liters) of deicer for pre-wet applications. Application of pre-wetted sand is the predominant street traction enhancement practice used for most of the Municipality's streets. Sand application is performed much the same as for deicing: sanding takes place immediately after an initial plowing and sand may be re-applied when additional plowing is required during a storm.

Vehicle Traction Sand

Street sand is purchased separately by MOA and DOT from a low-bid vendor and stored at several locations around Anchorage. Both DOT and MOA have minimum specifications for particle size distribution and other criteria, and add solid sodium chloride to the sand to keep it friable in cold temperatures (typically 3%-5% by weight). Although the salt content is presumably homogeneous when mixed, it is not known to what extent, if at all, the salt leaches during rainfall events and concentrates at the bottom of the pile.

According to MOA, sand purchase has declined over the last several years, in part due to increased reliance on deicers:

Year	Quantity of Sand Purchased (Tons)
1993	20,000
1994	10,000
1995	18,000
1996	15,000
1997	15,000

Exact DOT sand purchases are not currently known, but the amount of sand purchased is generally consistent year to year. For reference, approximately 22,000 tons of sand were placed by the DOT from Anchorage to Girdwood.

The amount of sand purchased for a winter can not be accurately correlated to the amount applied to the street, because stockpiled sand typically remains at the end of the year.

The sand is stored outside in uncovered piles at several locations. MOA stores sand at the Kloep and Klatt maintenance yards; DOT stores sand destined for use on Anchorage streets primarily at a maintenance yard near Tudor and Boniface.

Conversations with MOA Street Maintenance and Alaska Department of Transportation (DOT) indicate that sand-truck drivers apply sand to traffic lanes approaching controlled intersections based on the presence of snow or ice, traffic volume, and vehicle speed. Road types with large traffic volumes and high vehicle speeds (for example New Seward Highway) may be sanded up to 300 feet from the controlled intersection. Conversely, road types with low traffic volumes and vehicle speeds (for example residential streets) are only sanded to approximately 50 feet from a controlled intersection. Uncontrolled stretches of street and areas past controlled intersections are only incidentally sanded. Although sand is applied to streets with sharp turns or grades, the majority of Anchorage streets are straight and have little or no slope.

Chloride Transport and Mobilization

For a select fraction of Municipally-maintained streets, plowed snow is periodically windrowed, collected and hauled to snow disposal sites located throughout the Municipality. Very little data exists qualifying the quality or quantity of pollutants carried from the street with snow removal. Because of the nature of deicer practices and the properties of the deicer itself, a substantial fraction of applied deicer may remain on or near the street surface despite snow removal efforts. However limited data also suggests that some fraction of traction sand and other street pollutants (including deicers) are in fact incorporated into the hauled snow. A reasonable assumption follows that chloride content of the hauled snow will substantially vary depending upon the street source. That is, snow removed from streets with high average daily traffic (ADT) counts (e.g., arterials) will have higher chloride concentrations than snow removed from low ADT (e.g., residential) streets. Also, as a much higher amount of deicer is applied to a unit area during anti-icing or deicing than during “pre-wetted” sanding, areas treated with anti-icing or deicing practices are also anticipated to show higher concentrations of deicer in hauled snow.

Snow hauled from streets is placed and lightly compacted at snow disposal sites located throughout the city. To minimize haul costs, snow is usually taken to the nearest snow disposal site. Typically any given disposal site will accumulate snow hauled from arterial as well as residential streets. However, as anti-icing and deicing are the sole winter street treatment practices employed in the downtown Anchorage area, the Commercial Drive snow disposal site, which receives hauled snow from this area, may accumulate snow with higher deicer concentrations than that at other Municipal sites.

Substantial local and national data show a strong tendency for the rapid adsorption of metals, phosphorus compounds and petroleum hydrocarbons onto organic and inorganic particulates (mostly mineral particles and vegetable matter). Observations of the melting and runoff processes of the seasonal accumulation of hauled snow at Anchorage snow disposal sites suggest a relatively low energy environment. This quiescent environment results in substantially restricted particulate mobilization and transport and much greater opportunity for treatment and removal of particulates from meltwater. Currently most Municipal snow disposal sites include settling basins and oil/grease separators to provide some treatment of snow meltwater discharged from these sites. New snow disposal sites specifically recognize the advantage of promoting this low energy environment and incorporate design elements which will further enhance particulate removal.

However, chloride in meltwater is not readily removed by gravity treatment processes or adsorption. It is highly soluble in meltwater and, despite its relative large ionic size, is generally mobile in ground water flow through soils. The melt process in hauled snow placed at disposal sites may also increase chloride concentrations in early meltwater discharges. 1998 data indicate that chloride is apparently leached from underlying snow as meltwater from the surface of the snow pile percolates through the remainder of the snow mass (Wheaton et.al., 1998c). Consequently, chloride concentrations in meltwater are substantially elevated early in the seasonal melt period above the average concentration of chloride in the original hauled snow. Conversely, chloride concentrations are substantially reduced during the latter stages of melt.

Sodium and magnesium are also associated with street sand salt and deicer. These ions are relatively non-toxic, and under some circumstances can be used to calculate percentages of chloride derived from street sand and deicer. Sodium and magnesium are highly soluble in water, but tend to adhere to soil particles or exchange with other ions. As a result, the two metals are most representative of the relative amounts of sodium chloride and magnesium chloride in the raw water melting from the snow pack before significant exposure to soil or sediment particles.

Meltwater from Municipal snow disposal sites is typically discharged to local streams through ditched and piped drainage systems. Meltwater from the streets themselves will also transport chloride and other street pollutants to local streams and lakes. However, the relative timing of meltwaters derived from snow disposal sites differs substantially from that of urban streets and adjacent land areas, and from alpine and other large undeveloped areas. Typically, snow on urban arterial streets will melt early in the season over a relatively short period of time (approximately 1 to 2 weeks). Snow and ice on residential streets will melt later and may coincide with the first substantial meltwaters originating from municipal snow disposal sites. Alpine snowmelt and snowmelt from other large undeveloped areas occurs later still, generally coinciding with the bulk of the melt period for the city’s snow disposal sites.

Chloride loads in creeks are believed to peak early in the melt season when runoff from larger streets is discharged at basin outfalls. These peaks are probably diurnal, reflecting the diurnal character of flows coming from the storm drain system. Because the residence time of water flowing in creeks through the Anchorage bowl is typically on the order of 6 hours, peak daily chloride loads may only last for several hours, returning to near-ambient levels from late evening to mid-morning. Chloride concentrations from residential and other slower melting areas are diluted by large volumes of meltwater relative to the chloride load.

Less is know about chloride impacts to area lakes. However, effects are believed to be low due to the low hydraulic residence time in lakes (due to channeled flow) with outlets and relatively high rates of infiltration in closed basin lakes. These effects are believed to result in relatively rapid turn-over rates. Existing MOA data from MOA Solid Waste Services and Department of Health and Human Services (DHHS) Area Wide Water Quality Monitoring does not suggest chloride buildup in area lakes, but these data require further analysis.

Table 1 FreezeGard Sample Composition
September 1997

Analyte	Result	Freshwater Acute Limit	Units	Test Method
BOD_5	196		mg/L	EPA405.1
P-orthophosphate	1.2		mg/L	EPA365.1
P-total phosphate	2.3		mg/L	EPA365.1
Chloride	27.7		%	EPA300
Arsenic	1170	360	µg/L	EPA200.7
Barium	967		µg/L	EPA200.7
Cadmium	17.0	3.9*	µg/L	EPA200.7
Chromium	67.9	1700*	µg/L	EPA200.7
Copper	755	18*	µg/L	EPA200.7
Lead	U	82*	µg/L	EPA200.7
Magnesium	9.32		%	EPA200.7
Mercury	U	2.4	µg/L	SM3112B
Selenium	U	20	µg/L	EPA200.7
Zinc	1610	120*	µg/L	EPA200.7

U = not detected at or above laboratory reporting limit
* = hardness dependent criteria (values @ 100 mg/L $CaCO_3$ shown)

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Critical System Elements

To meet the goals of the project, data for the following system elements are needed to verify and refine the models used in 1998, and are therefore adopted as critical system elements:

1. Peak and average concentrations of chloride in meltwater, treated meltwater, and receiving waters (lakes and streams).
2. Meltwater and stream flow.
3. Major anions and cations (sodium, magnesium, potassium, calcium, chloride, sulfate, alkalinity).
4. Area of drainage basins associated with study sites.
5. Street area streets within each studied basin segregated by roadtype (residential, collector, minor arterial, major arterial).
6. Mass of sodium chloride and magnesium chloride applied to each basin in the study.

These critical system elements are consistent with the 1998 deicer assessment.

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Representation of Critical System Elements

The following text describes how each of the critical system elements noted above will be represented. Resolution thresholds, instrumentation, quality control practices, and calibration procedures must be consistent with those documented in the 1998 Deicer Assessment (Wheaton, 1998).

Chloride

Chloride concentrations in meltwater and stream flow will be represented primarily by field analysis of conductivity. Conductivity data will be converted to chloride based on the correlation between chloride and conductivity. To determine this correlation, no less than 30 project samples with field conductivity data representing peak and baseline conditions will be selected for chloride analysis. Regression analysis will be used to derive chloride concentrations from conductivity data. Alternatively, if 1999 data are consistent with 1998 data, relationships between conductivity and chloride derived from the 1998 data may be applied to the 1999 conductivity results.

All samples selected for chloride analysis will be analyzed using method EPA300.0. Conductivity will be continuously measured at selected outfalls and creek locations using dataloggers set to record every 30 minutes. At all sites, including those selected for datalogger installation, calibrated field meters will be used to take instantaneous conductivity measurements during site visits. The accuracy of continuous conductivity data will then be verified using instantaneous measurements.

Meltwater Flows and Stream Flows

Flow data will be collected and used for determining peak snowmelt periods and mass balance loading for various cations and anions. Creek flows will use published USGS flow data for the creek, as was performed in the 1998 deicer project. A few field measurements will still be taken, however, to verify USGS data. Sampling sites at culverts or ditches coming into the creeks will have flow measurements determined in the field. Field flow data will be collected using one of three methods: timed gravimetric, slope-hydraulic radius, or area velocity. The time gravimetric method involves collecting the entire flow in a container and measuring the length of time it takes to fill the volume. The slope-hydraulic radius method consists of using the Manning equation to relate cross-section, liquid depth, water surface slope and a roughness factor to flow. The Manning equation is:

$$Q = \frac{KAR^{2/3}S^{1/2}}{n}$$

Where Q = Flow

K = UNIT CONSTANT

A = Cross-sectional area of flow
R = Hydraulic Radius
S = Slope of the hydraulic radius
n = Manning roughness coefficient

Lastly, the area velocity method consists of determining the mean flow velocity across a channel and multiplying it by the cross-sectional area (Grant and Dawson, 1997). The type of method used will vary based on actual site conditions.

For instantaneous measurements, the area velocity method is usually considered the most accurate method of determining flow, since it involves two measurements, area and velocity. Of these three methods, the gravimetric methods may be the next most accurate, depending on flow. A timing difference of 0.1 second for 250 gpm could result in a 3% difference in flow, however, for slower flows such as 35 gpm, an error of 0.1 second may be less than 1%. For continuous measurements, relating depth measurements in culverts to flow by the Manning Equation is common practice in storm water studies and is a practical way to obtain rough estimates of flow. Difficulties determining hydraulic gradient and obtaining an estimate of the roughness coefficient, though, make flow calculation only an approximation. In the field, careful use of the Manning equation can result in accuracy to within 10 to 20%. Less careful use may result in errors of 20 to 50% (Grant and Dawson, 1997).

Major Anions and Cations

On a selected subset of samples submitted for chloride analysis, major anions and cations will be measured. These data will allow for approximate differentiation between chloride derived from sodium chloride and magnesium chloride. Samples will be selected for analysis based on representation of peak and baseline flows. The ability to differentiate between the two chloride sources will enable watershed managers to assess the relative impacts of the two chloride sources and the potential consequences of increased deicer use. Other measured ions will be used to verify the accuracy of analytical measurements via milliequivalent concentration balances of cation and anions. Samples will be analyzed using EPA methods 300.0 and 200.7.

Drainage Basin Characteristics

Predictive models constructed for the 1998 deicer assessment require knowledge of the street area within the basin by roadtype and the mass of sodium and magnesium chloride applied to those streets. For modeling chloride impacts, these characteristics are the street area within the basin and the total mass of chloride applied by street maintenance crews. This information will be acquired from previous and on-going WMS assessment projects. Data sheets from an ongoing WMS assessment of oil and grit separators that contain street area and roadtype information for the 1999 deicer study basins are included in Appendix A. **It is important to note that the information contained on the appended data sheets must be verified prior to use, particularly the area and boundaries of the drainage basins.** Information on the mass of sodium chloride and magnesium chloride applied to the study basins will be derived from an ongoing Street Sand and Deicer Inventory project.

Chloride concentrations in Area Lakes

To assess chloride loads in area lakes (both closed basin and lakes with outlets), existing data sets (e.g., MOA Solid Waste Services and DHHS) will be researched and reviewed. As a starting point, lake impacts will be assessed through chloride concentrations measured in any year between March and May. If insufficient data exist to draw reasonable conclusions (based on best professional judgement), a predictive model will be constructed.

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Project Approach

During spring breakup, samples will be collected for chloride, conductivity, major anions and cations, and flow. These samples will be collected at selected storm drain outfalls, area creeks, and snow disposal sites. The following text describes the project approach for each type of site, including:

- Study site selection and sampling location rationale
- Data Analysis
- Project Responsibilities and Data Reporting
- The Spatial and Temporal Sampling Network

Outfalls to Cook Inlet and to Streams

SITE SELECTION AND SAMPLING LOCATION RATIONALE

As noted above, the EPA is requiring that outfalls to three streams be sampled to verify 1998 deicer modeling results, and to assess the potential effects of expanded deicer use as a dust palliative. The three sites selected are an outfall at the west end of 5th Avenue that drains part of the CBD to Cook Inlet, Chester Creek at the Gambell/Ingra couplet, and Chester Creek at Tikishla Park (Figure 5-1).

While the 5th Ave outfall does not discharge to a stream, sampling this location will allow for direct measurement of chloride concentrations in street runoff that is unaffected by contributions from chloride derived from street sand. With knowledge of how much deicer was applied to the area, coupled with the fact that virtually all snow is hauled from the CBD to a snow dump, data from the site will allow for reliable calculations of how much deicer remains on the street and how much becomes entrained in the snow removed to the snow dump. If increased deicer use is proposed as a substitute for street sand or as a dust palliative, data from this site will aid in determining the environmental effects on an Anchorage-wide scale.

The Chester Creek at Gambell/Ingra was selected because of a dust palliative study being conducted by MOA Air Quality Section and AKDOT/PF. Data collected at this site will not only document chloride effects to Chester creek, but also allow assessment of environmental effects of deicer used as a dust palliative. This site differs from the 5th Avenue outfall because the area drained includes streets where sand is used for vehicle traction. As a result, chloride concentrations in the street runoff will not be exclusively from deicer.

Chester Creek at Tikishla Park was selected because of an outfall draining a relatively large residential area. Data will allow for an understanding of how meltwater flows and chloride loads differ between commercial and residential areas.

CHLORIDE, MAJOR ION, AND CONDUCTIVITY SAMPLING LOCATIONS

Storm drain outfalls will be continuously sampled via datalogger for conductivity to determine the actual mass load of chloride impacting the receiving water. Grab samples will be collected during selected peak and baseline flows for direct chloride analysis to determine correlations between conductivity and chloride. If continuous conductivity data are not collected, instantaneous data will be collected at least twice daily (10 a.m. and 3 p.m.) during the peak melt period and once daily prior and subsequent to peak flows to document baseline conditions.

At stream sampling sites (Chester Creek at Gamball/Ingra and Chester Creek at Tikishla Park), samples will be collected upstream of the outfall to document chloride concentrations in the receiving water prior to impact from the study outfall. Additionally, samples will be collected downstream of the outfall to document the actual impact of the storm water discharge on the receiving water. Stream Samples will be collected at the same time the outfall is sampled.

On a subset of samples submitted for chloride analysis, major cations and anions will be measured to assess the relative impacts of magnesium chloride and sodium chloride. These samples will be selected to represent peak and baseline conditions.

FLOW SAMPLING LOCATIONS

Flow at culverts flowing into Chester Creek at Gambell/Ingra will be measured instantaneously and can also be measured by all three methods noted in Section 4.2. These culverts are circular, allowing depth measurements or the use of a liter bottle to measure flow. Flow in the ditch outfall at Tikishla Park will be measured via the area and velocity method.

Flow will be measured at the 5th Avenue outfall both instantaneously and using a datalogger. Instantaneous flow record will use the timed gravimetric method, which consists of placing a five-gallon bucket under pipe flow as it discharges into the stilling well and timing how fast the bucket fills. A datalogger, reading in one-half hour increments, will also be placed in the stilling well to measure water depth. Instantaneous bucket measurements will be correlated to the depth readings for a continuous record of flow.

To determine if significant loads of chloride remain on the street after breakup, a section of Ingra will be spray washed with water trucks. The resulting discharge from the outfall will be measured for flow and conductivity.

DATA ANALYSIS

For each sampling site, chloride concentrations and flow hydrographs shall be prepared. Time series plots of peak and average daily chloride concentrations shall be made over the melt period for each site and associated receiving water. Analytical results shall be compared with the modeling results and threshold values documented in the 1998 Deicer Assessment Report (Wheaton et.al., 1998c).

Snow Disposal Site Sampling

CHLORIDE, MAJOR ION, AND CONDUCTIVITY SAMPLING LOCATIONS

Two snow disposal sites were selected for sampling: Mountain View and Tudor (Figure 5-1). The Mountain View Snow Disposal Site was selected because 1998 modeling results suggested that meltwater discharging to the North Fork of Chester Creek may elevate chloride concentrations in the receiving water to levels that threaten the Alaska Water Quality Standard of 250 mg/L. The Tudor Snow Disposal Site was selected because chloride data from the 1998 Deicer Assessment documented chloride concentrations above the state water quality criteria (250 mg/L) in a nearby tributary of Chester Creek.

Selected raw melt water will be sampled instantaneously at each disposal site and analyzed for major anions and cations including chloride to allow for differentiation between chloride derived from sodium chloride and magnesium chloride. As noted above, melt water after BMP treatment will be sampled for chloride, major ions and conductivity for evaluation for BMP effectiveness. To supplement these data, BMP effectiveness will be documented with site photographs and field notes.

Similar to the stream sampling regime noted above, conductivity data will be collected both up- and downstream of the receiving water outfall to elucidate chloride impacts from the snow disposal site. Additionally, groundwater seeps discharging to the receiving water will be sampled where noted by field crews (e.g., Tudor snow disposal site).

FLOW AND CONDUCTIVITY SAMPLING LOCATIONS

Continuous conductivity and flow measurements will be collected from the snow disposal site outfall discharge. This will allow for calculations of the actual mass loading of chloride, after conversion of conductivity measurements to chloride concentrations. At the Tudor site where conditions prohibit accurate measurement of meltwater flow from the disposal site (e.g., no single outfall to the receiving water), flow measurements will be collected in the receiving water. Flow estimates for meltwater from the Tudor Snow Disposal Site impacting the Chester Creek Tributary will be taken from the 1998 Deicer Data Report (Wheaton et.al., 1998b).

Flow and conductivity will be measured at the Mountain View snow site where meltwater discharges to the storm drain system using a datalogger to take depth measurements in the one-foot diameter circular outlet pipe. Depth measurements in the culvert can be transformed into flow based on the Manning equation. A few instantaneous area velocity measurements may also be taken to verify datalogger data. The outfall at 15th Avenue and Lake Otis where storm water discharges to the North Fork of Chester Creek is an open ditch with a straight, uniform cross-sectional area and a long, straight, open channel to take accurate flow measurements from. Area velocity measurements will be used to measure flow at this outfall location.

Flow will be measured at the Tudor snow site using a datalogger to take depth measurements in an arched culvert that goes under Tudor Street. Arched culverts have can have many variables that affect flow, however, a rough estimate of flow can be determined by assuming a trapezoidal channel bottom in calculating the Manning's formula. A few instantaneous area velocity flow measurements may also be taken to verify datalogger data.

DATA ANALYSIS

For each snow disposal site, gross average daily chloride concentrations and meltwater flow hydrographs shall be estimated. Time series plots of peak and average daily chloride concentrations shall be made over the melt period for each site and associated receiving water. Total daily chloride flux from the snow disposal sites and through the upstream receiving water stations shall be estimated. Analytical results shall be compared with the modeling results and threshold values documented in the 1998 Deicer Assessment Report (WMS et.al., 1998c). Additionally, BMP effectiveness will be described and illustrated with photographs.

Project Responsibilities and Data Reporting

Montgomery Watson will schedule and lead all investigation activities and will complete the project with a data report. WMS will provide technical and logistical support as needed. Street Maintenance Division, DPW will provide access to snow disposal sites and will maintain an open access to flow at the meltwater discharge points.

A data report shall be prepared summarizing the results of the assessment. The report shall summarize the history of the data collection effort documenting any deviation from this design, data completeness and quality, assessed system characteristics, and laboratory and analytical results. A digital database shall also be prepared summarizing laboratory and field results and sampling locations.

Sampling Network

Specific sampling locations and times for each study site are shown in Figures 5-2 through 5-6 and on Tables 5-1 through 5-3. The sampling regimes may be modified based on field conditions after discussions with WMS.

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MONTGOMERY WATSON

ANCHORAGE WATERSHED MANAGEMENT

FIGURE 5-1

MUNICIPALITY OF ANCHORAGE - DEPARTMENT OF PUBLIC WORKS
1999 STREET SAND AND DEICER ASSESSMENT

SITE LOCATIONS

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MONTGOMERY WATSON

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FIGURE 5-2

MUNICIPALITY OF ANCHORAGE - DEPARTMENT OF PUBLIC WORKS
1999 STREET SAND AND DEICER ASSESSMENT

5th AVENUE OUTFALL

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MONTGOMERY WATSON

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FIGURE 5-3

MUNICIPALITY OF ANCHORAGE - DEPARTMENT OF PUBLIC WORKS
1999 STREET SAND AND DEICER ASSESSMENT

CHESTER CREEK AT GAMBELL/ INGRA SAMPLING STATIONS

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MONTGOMERY WATSON

ANCHORAGE
WATERSHED
MANAGEMENT

FIGURE 5-4

MUNICIPALITY OF ANCHORAGE - DEPARTMENT OF PUBLIC WORKS
1999 STREET SAND AND DEICER ASSESSMENT

CHESTER CREEK AT TIKISHLA PARK - SAMPLING STATIONS

JOB No. 1189090.020102

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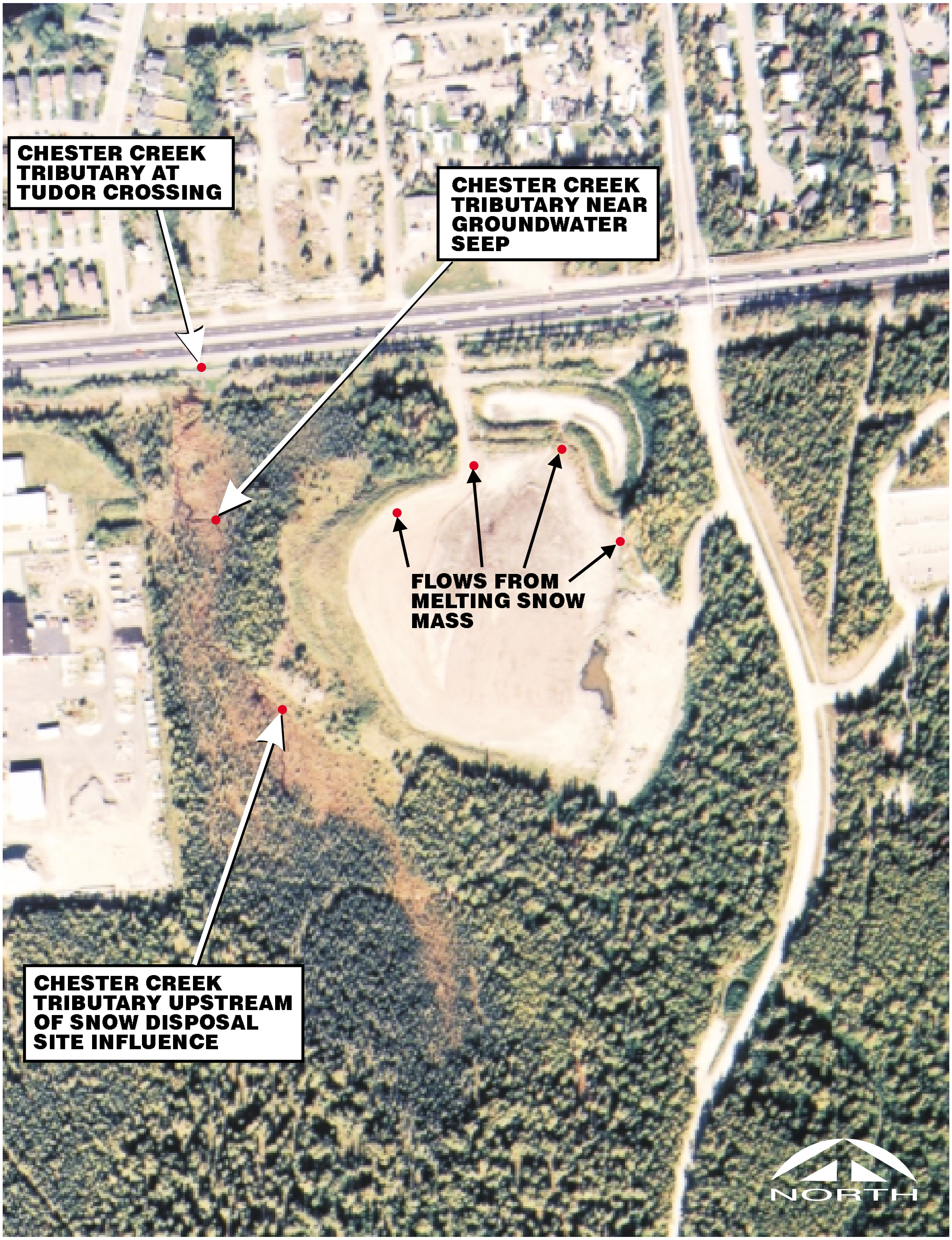
MONTGOMERY WATSON



JOB No. 1189090.020101

ANCHORAGE WATERSHED MANAGEMENT

FIGURE 5-5

MUNICIPALITY OF ANCHORAGE - DEPARTMENT OF PUBLIC WORKS
1999 STREET SAND AND DEICER ASSESSMENT

TUDOR SNOW DISPOSAL SITE - SAMPLING STATIONS

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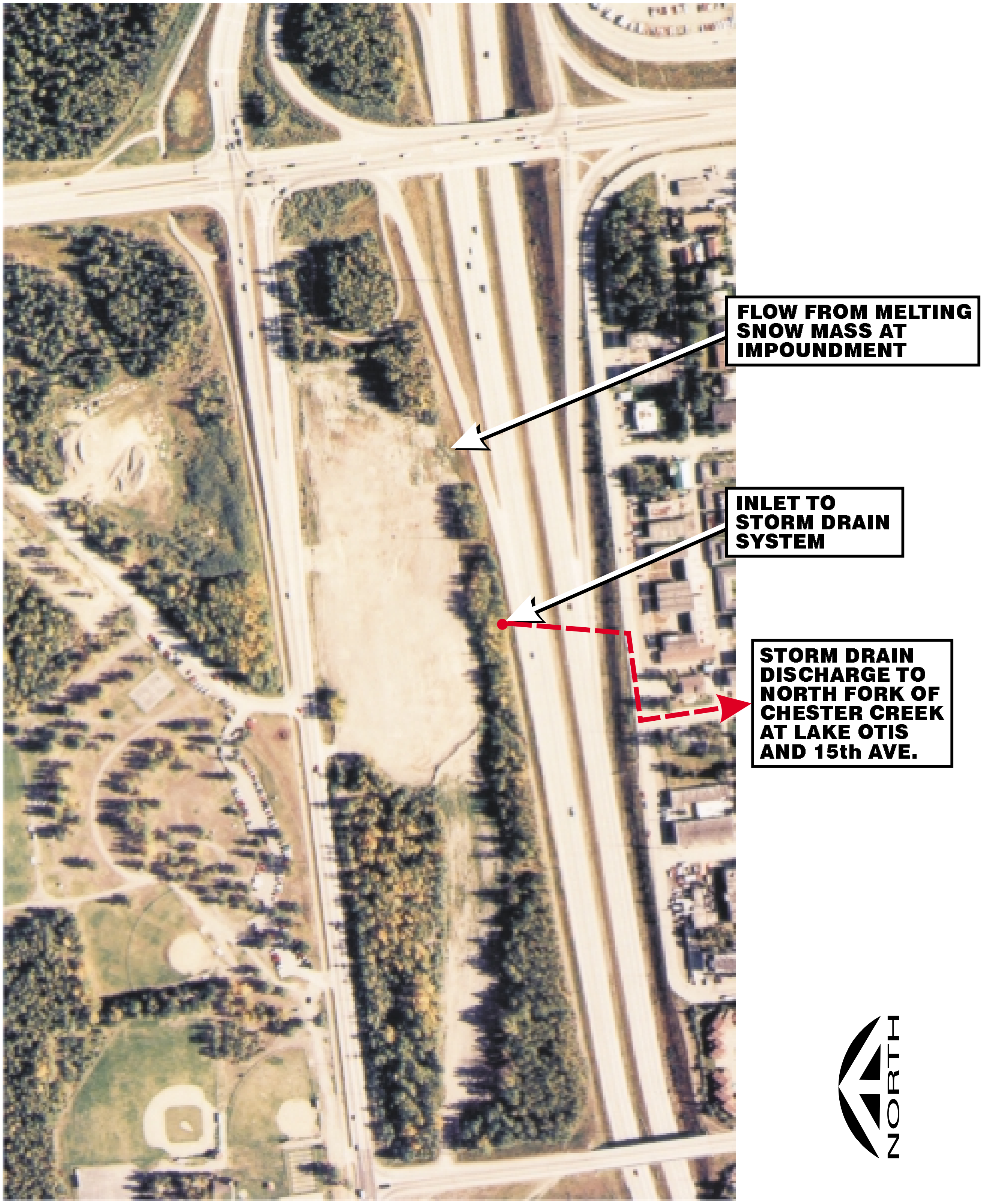
MONTGOMERY WATSON



ANCHORAGE WATERSHED MANAGEMENT

FIGURE 5-6

MUNICIPALITY OF ANCHORAGE - DEPARTMENT OF PUBLIC WORKS
1999 STREET SAND AND DEICER ASSESSMENT

MOUNTAIN VIEW SNOW DISPOSAL SITE - SAMPLING STATIONS

JOB No. 1189090.020102

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Table 2 Stream and Outfall Sampling Summary
1999 Sand and Deicer Assessment

Sampling Location	Location Rational	Flow	Conductivity	Chloride	Other Ions (1)
Storm Drain Outfall at Receiving Water	Determine peak and average discharge to the receiving water. Provide insight to receiving water data.	Continuous monitoring via datalogger or grab samples three times weekly (MWF once per day) during periods of low flow and twice daily (10am and 3pm) during periods of peak flow to characterize discharge to receiving water and allow for mass loading from calculation. Track peak melt period.	Continuous monitoring via datalogger or grab samples three times weekly (MWF, once per day) during periods of low flow and twice daily (10am and 3pm) during periods of peak flow to characterize discharge to receiving water and leverage Cl data. Also provide trigger for collecting chloride samples (see chloride).	Selected samples based on conductivity to characterize peak and base line chloride concentrations and determine correlation with conductivity data. Minimum of 5 samples.	Selected samples based on conductivity to characterize peak and base line concentrations and differentiate NaCl and MgCl2 impacts. Minimum of 3 samples.
Upstream of Outfall	Provide ambient Cl data for receiving water, prior to any impact from outfall discharge.	Not collected - USGS data will be used if necessary.	Three times weekly (MWF, once per day) during periods of low flow and twice daily (10am and 3pm) during periods of peak flow to characterize receiving water impacts and leverage Cl data. Also provide trigger for collecting chloride samples (see chloride).	Selected samples based on conductivity to characterize peak and base line chloride concentrations and determine correlation with conductivity data. Minimum of 5 samples.	Selected samples based on conductivity to characterize peak and base line concentrations and differentiate NaCl and MgCl2 impacts. Minimum of 3 samples..
Downstream of Outfall, below mixing zone	Assess actual Cl levels in receiving water due to outfall.	Not collected - USGS data will be used if necessary.	Three times weekly (MWF, once per day) during periods of low flow and twice daily (10am and 3pm) during periods of peak flow to characterize receiving water impacts and leverage Cl data. Also provide trigger for collecting chloride samples (see chloride).	Selected samples based on conductivity to characterize peak and base line chloride concentrations and determine correlation with conductivity data. Minimum of 5 samples.	Selected samples based on conductivity to characterize peak and base line concentrations and differentiate NaCl and MgCl2 impacts. Minimum of 3 samples.

(1) - calcium, sodium, magnesium, potassium, alkalinity, sulfate

Notes:
Three sites to be studied are Chester Creek at Gambell-Ingra (due to dust pallative study). Outfall to Cook Inlet at end of 5th Avenue and Chester Creek at Tikishla Park.
Sampling time frame is from the start of meltwater runoff (early March) and will run for eight weeks (early May).
Time frame will be adjusted based on site specific conditions.

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Table 3 Sampling Summary for Tudor Snow Disposal Site
1999 Sand and Deicer Assessment

Sampling Location	Location Rational	Flow	Conductivity	Chloride	Other Ions (1)
Flow From Melting Snow Mass Prior to Treatment (Four Locations)	Characterize snow melt from disposal site for comparison to post-treatment discharge. Differentiate between NaCl and MgCl2 effects.	Not Collected. Flow not representative of site because of infiltration and runoff in other areas.	Grab samples three times weekly (MWF, once per day at 3pm) to characterize discharge from snow disposal site and leverage Cl data. Also provide trigger for collecting chloride samples (see chloride).	Selected samples based on conductivity to characterize peak and base line chloride concentrations and determine correlation with conductivity data. Minimum of 5 samples.	Selected samples based on conductivity to characterize peak and base line concentrations and differentiate NaCl and MgCl2 impacts. Maximum of 4 samples.
Chester Creek Tributary at Tudor Crossing	Assess actual Cl levels in receiving water.	Continuous monitoring via datalogger <u>or</u> three times weekly (MWF, once per day at 3pm) to characterize discharge to storm drain.	Continuous monitoring via datalogger <u>or</u> three times weekly (MWF, once per day at 3pm) to characterize discharge to storm drain and leverage Cl data. Also provide trigger for collecting chloride samples (see chloride).	Selected samples based on conductivity to characterize peak and base line chloride concentrations and determine correlation with conductivity data. Minimum of 5 samples.	Selected samples based on conductivity to characterize peak and base line concentrations and differentiate NaCl and MgCl2 impacts. Maximum of 4 samples.
One Location on Tributary between Spring and Tudor Crossing	Document groundwater seep pattern and disposal site effects.	Not collected.	Three times weekly at each station to characterize groundwater seepage.	Selected samples based on conductivity to characterize peak and base line chloride concentrations and determine correlation with conductivity data. Minimum of 5 samples	Selected samples based on conductivity to characterize peak and base line concentrations and differentiate NaCl and MgCl2 impacts. Maximum of 4 samples.
Chester Creek Tributary Upstream of Disposal Site Influence	Document ambient Cl levels in receiving water.	Not collected. Difficult to accurately measure.	Three times weekly to characterize ambient receiving water.	Selected samples based on conductivity to characterize peak and base line chloride concentrations and determine correlation with conductivity data. Minimum of 5 samples	Selected samples based on conductivity to characterize peak and base line concentrations and differentiate NaCl and MgCl2 impacts. Maximum of 4 samples.

(1) - calcium, sodium, magnesium, potassium, alkalinity, sulfate.

Notes:
Site was selected for study because Cl concentrations above water quality criteria were measured in the receiving water (Station 09) in 1998.
The site also fulfills the EPA requirement to study one site in 1999 that was studied in 1998.
No samples are planned for mid-winter thaws, because snow dump must "ripen" to saturation before it will discharge.
Mid-winter thaw event of this magnatude is unlikely. However, site will be visited during mid-winter thaw events to verify assumptions.

Sampling time frame is from the start of meltwater runoff (early March) and will run for eight weeks (early May).
Based on 1998 data, this time frame is anticipated to correspond with rising, peak, and falling Cl concentrations in melt-water discharge.
Time frame will be adjusted based on site specific conditions.

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Table 4 Sampling Summary for Mountain View Snow Disposal Site 1999 Sand and Deicer Assessment

Sampling Location	Location Rational	Flow	Conductivity	Chloride	Other Ions (1)
Flow From Melting Snow Mass	Characterize snow melt from disposal site for comparison to post-treatment discharge. Differentiate between NaCl and MgCl2 effects.	Not collected	Grab samples three times weekly (MWF, once per day at 3pm) to characterize discharge from snow disposal site and leverage Cl data. Also provide trigger for collecting chloride samples (see chloride).	Selected samples based on conductivity to characterize peak and base line chloride concentrations and determine correlation with conductivity data. Minimum of 5 samples.	Selected samples based on conductivity to characterize peak and base line concentrations and differentiate NaCl and MgCl2 impacts. Maximum of 4 samples.
Storm Drain Inlet next to Snow Disposal Site	Characterize discharge from disposal site for BMP assessment. Calculate mass Cl discharge from site.	Continuous monitoring via datalogger <u>or</u> three times weekly (MWF, once per day at 3pm) to characterize discharge to storm drain.	Continuous monitoring via datalogger <u>or</u> three times weekly (MWF, once per day at 3pm) to characterize discharge to storm drain and leverage Cl data. Also provide trigger for collecting chloride samples (see chloride).	Selected samples based on conductivity to characterize peak and base line chloride concentrations and determine correlation with conductivity data. Minimum of 5 samples.	Selected samples based on conductivity to characterize peak and base line concentrations and differentiate NaCl and MgCl2 impacts. Maximum of 4 samples.
Outfall on North Fork of Chester Creek at Lake Otis and 15th Ave.	Document actual Cl load going into receiving water. Outfall drains large area, including snow dump.	Three times weekly (MWF, once per day at 3pm) to charactgerize impacts to receiving water.	Grab samples three times weekly (MWF, once per day at 3pm) to characterize discharge to receiving water and leverage Cl data. Also provide trigger for collecting chloride samples (see chloride).	Selected samples based on conductivity to characterize peak and base line chloride concentrations and determine correlation with conductivity data. Minimum of 5 samples.	Selected samples based on conductivity to characterize peak and base line concentrations and differentiate NaCl and MgCl2 impacts. Maximum of 4 samples.

(1) - calcium, sodium, magnesium, potassium, alkalinity, sulfate

Note:
Site was selected for study because modeling data indicated elevated levels of Cl in the receiving water relative to state water quality standards.
No samples are planned for mid-winter thaws, because snow dump must "ripen" to saturation before it will discharge. Mid-winter thaw event of this magnitude is unlikely. However, site will be visited during mid-winter thaw events to verify assumptions.

Sampling time frame is from the start of meltwater runoff (early March) and will run for eight weeks (early May). Based on 1998 data, this time frame is anticipated to correspond with rising, peak, and falling Cl concentrations in meltwater discharge. Time frame will be adjusted based on site specific conditions.

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References

Grant, Douglas M. and Dawson, Brian D. 1997. Isco Open Channel Flow Measurement Handbook. Fifth Edition. Isco, Inc. 501 pp.

Wheaton, S. 1998a. Magnesium Chloride Deicer in Snow Disposal Sites at Anchorage, Alaska: Assessment Design. WMS Municipality of Anchorage. Anchorage, AK, Municipality of Anchorage, Department of Public Works, Project Management and Engineering, Watershed Management Section: 19 and Appendices.

Wheaton, S. and K. Bischofberger. 1998b. Magnesium Chloride Deicer in Snow Disposal Sites at Anchorage, Alaska: Data Report. WMS Municipality of Anchorage and W. Q. Department of Health and Human Services, Anchorage, AK, Municipality of Anchorage, Department of Public Works, Project Management and Engineering, Watershed Management Section: 15 and Tables and Appendices.

Wheaton, S., B. Jokela, et.al., 1998c. Anchorage Street Deicer and Snow Disposal 1998 Best Management Practices Guidance. D. Municipality of Anchorage, Watershed Management Section, M. Watson and Woodward-Clyde, Anchorage, AK, Municipality of Anchorage, Department of Public Works, Street Maintenance Division: 41 and Attachments.

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Appendix A
Basin Data Sheets - 1999 Sand and Deicer Assessment

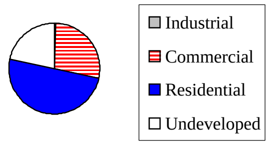
Tudor Snow Disposal Site

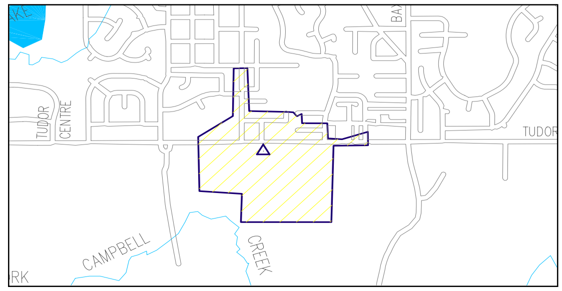
ANCHORAGE BOWL OGS PERFORMANCE MODELING

Basin: South Fork Chester Creek Non-NPDES 35

Basin Area	86	acres

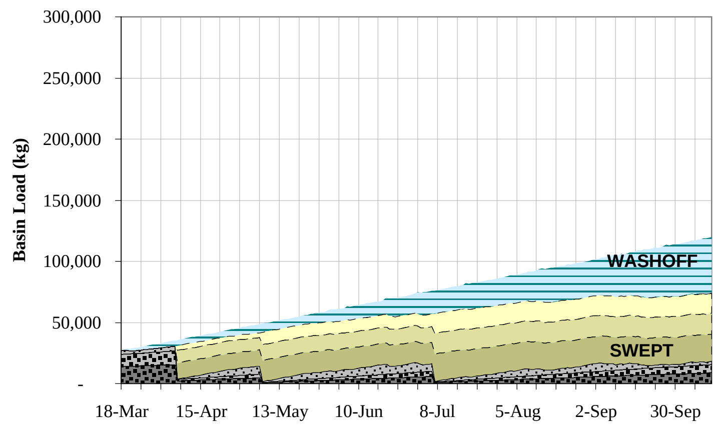
Land Use	
Industrial	1%
Commercial	28%
Residential	50%
Undeveloped	22%





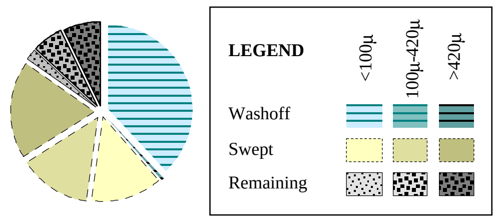
Road Areas		
Local	1.16	acres
Collector	-	acres
Minor Arterial	-	acres
Major Arterial	7.53	acres

SEDIMENT FATE

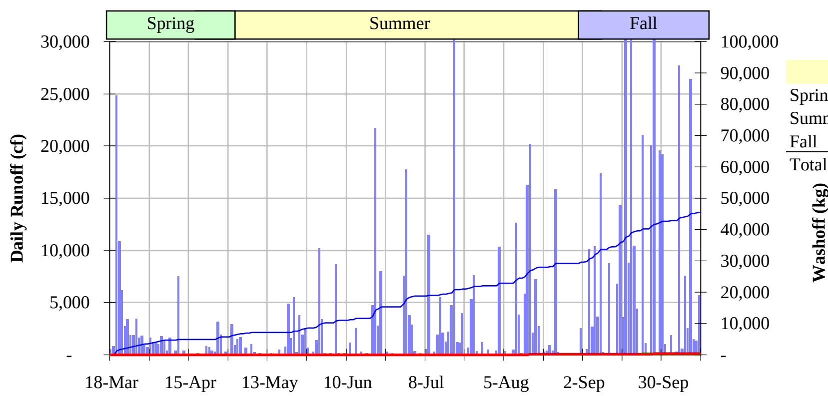


Sediment Fates (kg)

	<100µ	100µ - 420µ	>420µ	Total
Remaining	2,587	6,770	8,790	18,147
Swept	16,266	16,870	22,361	55,497
Washed Off	45,528	197	452	46,178
Total	64,381	23,837	31,603	119,821

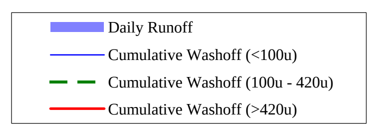


RUNOFF AND CUMULATIVE WASHOFF

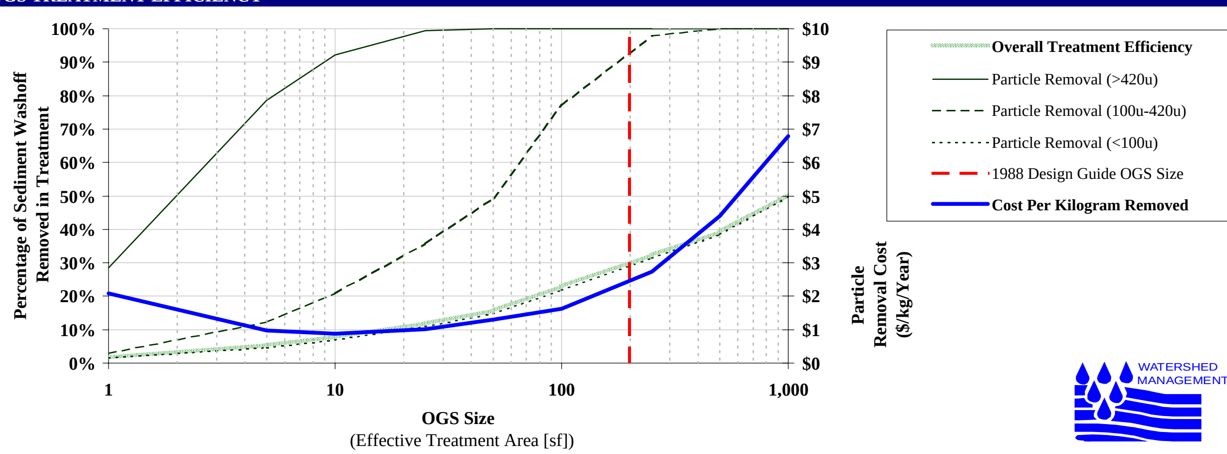


Sediment Washoff (kg)

	<100µ	100µ - 420µ	>420µ	Total
Spring	4,959	10	19	4,988
Summer	24,289	42	98	24,428
Fall	16,280	146	335	16,761
Total	45,528	197	452	46,178



OGS TREATMENT EFFICIENCY



WATERSHED MANAGEMENT

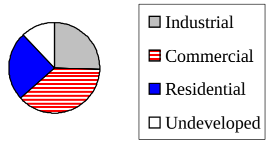
Mountain View Snow Disposal Site

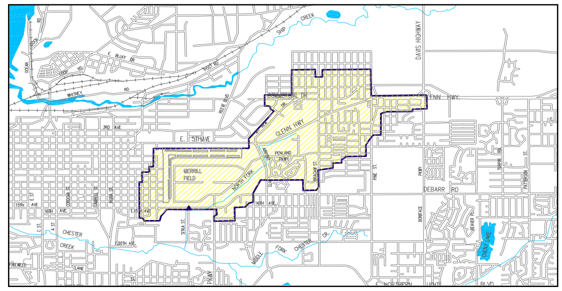
ANCHORAGE BOWL OGS PERFORMANCE MODELING

Basin: North Fork Chester Creek NPDES 84

Basin Area 1,207 acres

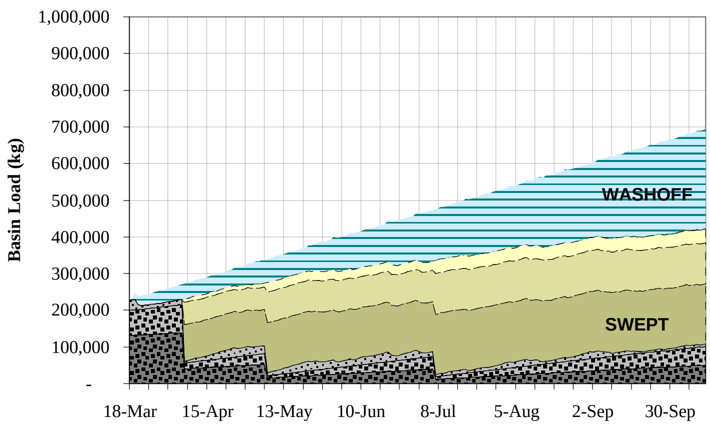
Land Use	
Industrial	26%
Commercial	38%
Residential	25%
Undeveloped	12%





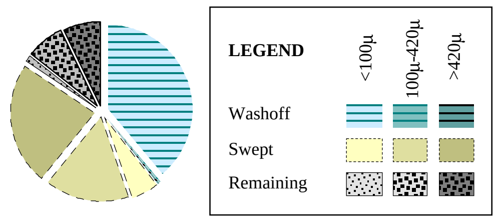
Road Areas	
Local	78.24 acres
Collector	13.09 acres
Minor Arterial	10.55 acres
Major Arterial	26.87 acres

SEDIMENT FATE

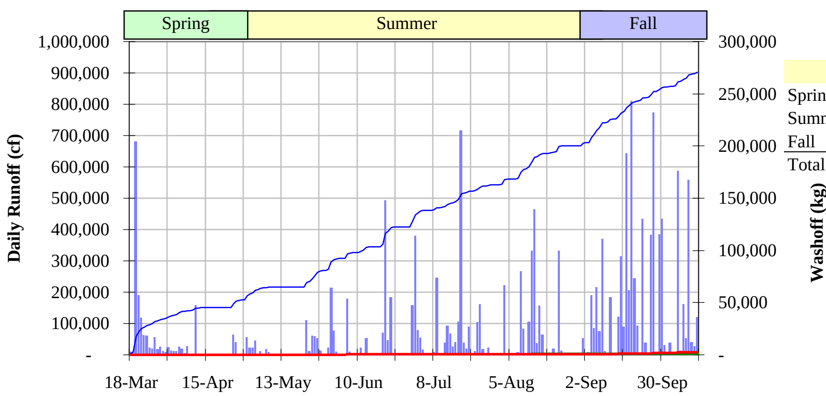


Sediment Fates (kg)

	<100µ	100µ - 420µ	>420µ	Total
Remaining	6,828	51,077	50,115	108,020
Swept	35,718	111,406	164,775	311,899
Washed Off	270,758	1,331	2,465	274,554
Total	313,304	163,815	217,355	694,473

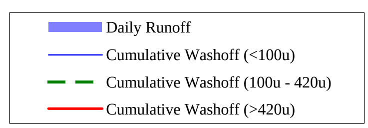


RUNOFF AND CUMULATIVE WASHOFF



Sediment Washoff (kg)

	<100µ	100µ - 420µ	>420µ	Total
Spring	45,131	99	281	45,511
Summer	155,061	281	553	155,895
Fall	70,566	952	1,631	73,148
Total	270,758	1,331	2,465	274,554



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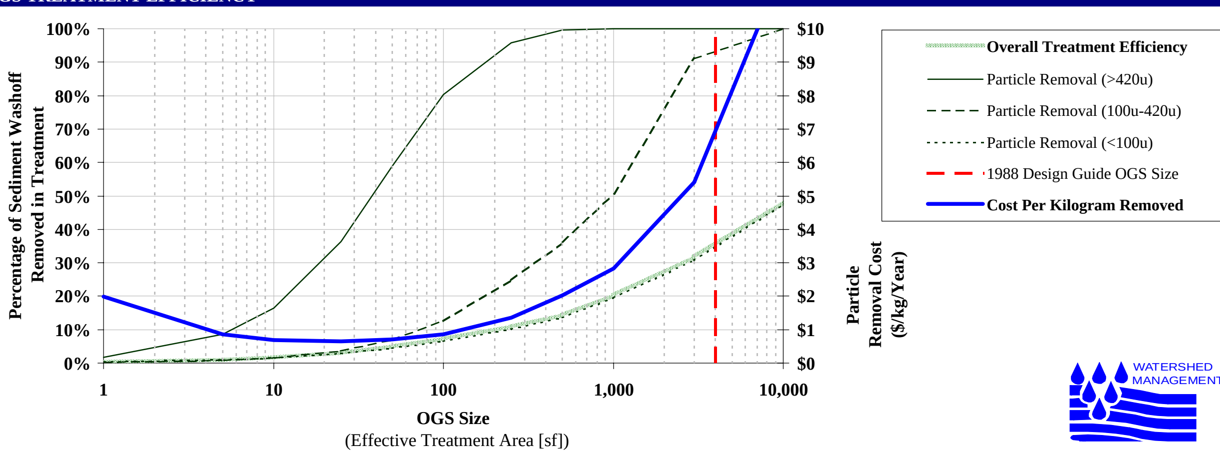


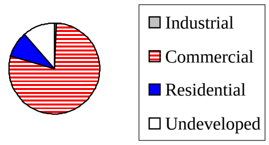
Cook Inlet Outfall at the end of Fifth Avenue

ANCHORAGE BOWL OGS PERFORMANCE MODELING

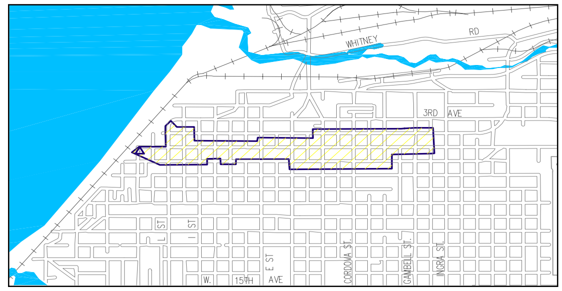
Basin: Chester Creek NPDES 41

Basin Area	117	acres

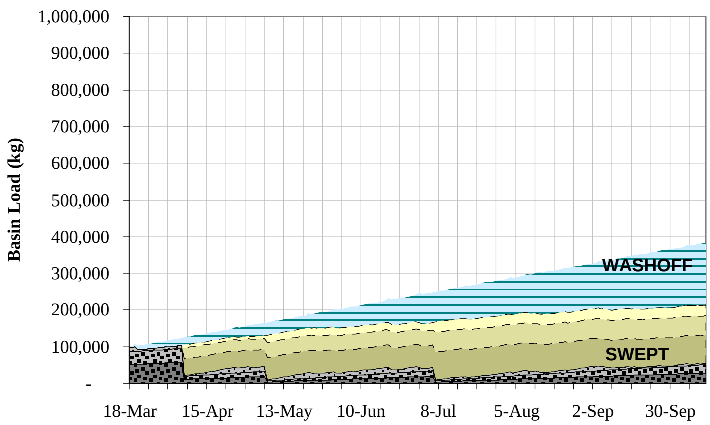
Land Use	
Industrial	1%
Commercial	79%
Residential	9%
Undeveloped	11%



Road Areas		
Local	2.18	acres
Collector	8.02	acres
Minor Arterial	5.74	acres
Major Arterial	21.13	acres

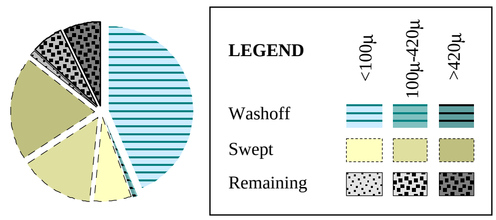


SEDIMENT FATE

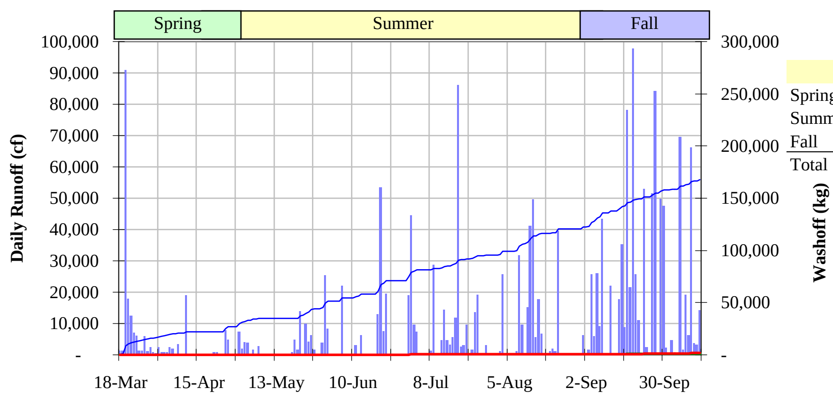


Sediment Fates (kg)

	<100µ	100µ - 420µ	>420µ	Total
Remaining	4,140	23,115	27,676	54,931
Swept	28,383	53,677	76,472	158,533
Washed Off	167,493	774	1,631	169,898
Total	200,017	77,566	105,779	383,362

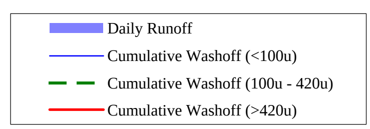


RUNOFF AND CUMULATIVE WASHOFF

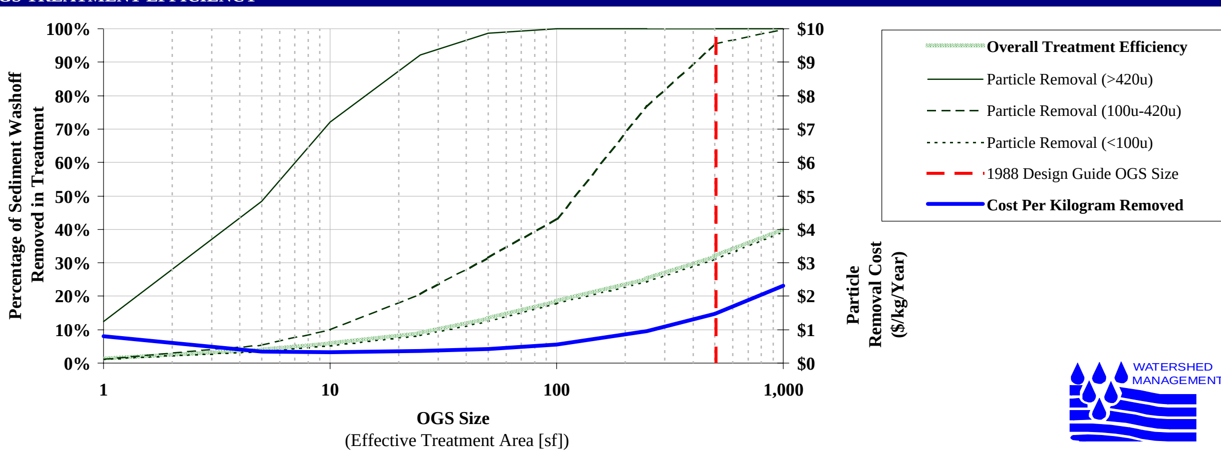


Sediment Washoff (kg)

	<100µ	100µ - 420µ	>420µ	Total
Spring	22,101	71	167	22,340
Summer	98,612	175	356	99,144
Fall	46,779	527	1,108	48,414
Total	167,493	774	1,631	169,898



OGS TREATMENT EFFICIENCY



WATERSHED MANAGEMENT

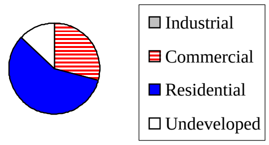
Chester Creek Outfalls at Tikishla Park

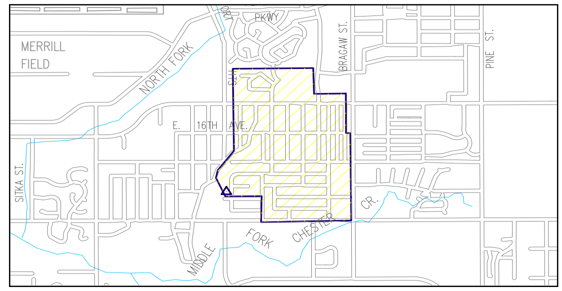
ANCHORAGE BOWL OGS PERFORMANCE MODELING

Basin: Middle Fork Chester Creek NPDES 87

Basin Area	177	acres

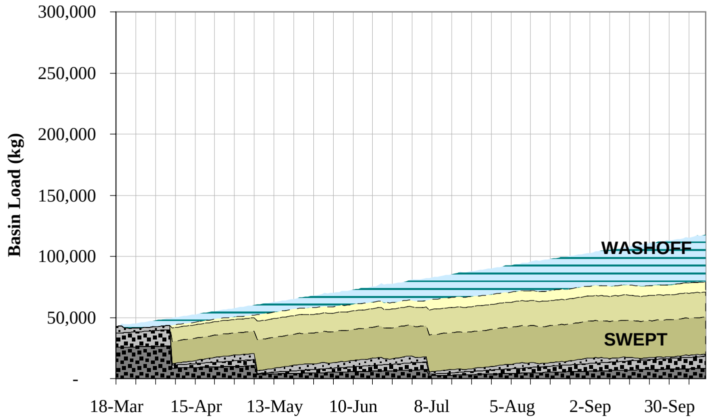
Land Use	
Industrial	0%
Commercial	29%
Residential	58%
Undeveloped	13%





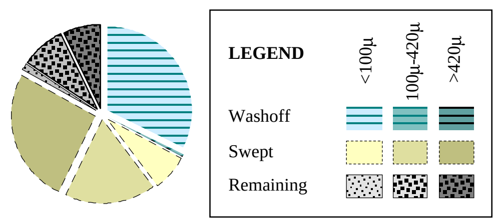
Road Areas		
Local	24.10	acres
Collector	-	acres
Minor Arterial	-	acres
Major Arterial	3.82	acres

SEDIMENT FATE

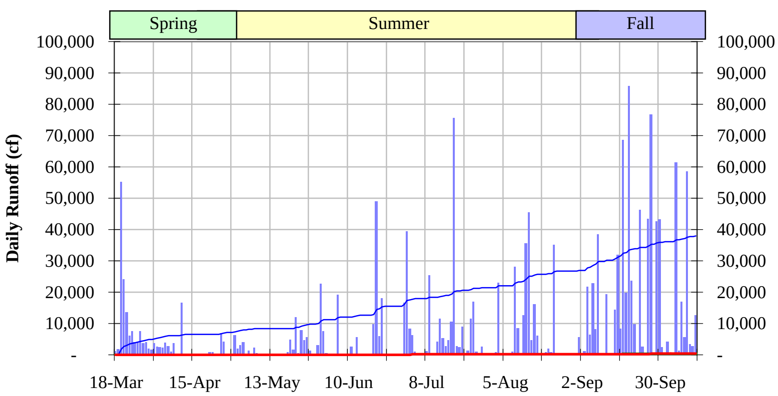


Sediment Fates (kg)

	<100µ	100µ - 420µ	>420µ	Total
Remaining	1,751	9,812	8,425	19,988
Swept	8,161	20,496	30,325	58,982
Washed Off	37,950	280	482	38,712
Total	47,862	30,588	39,232	117,682

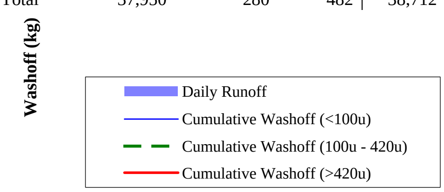


RUNOFF AND CUMULATIVE WASHOFF

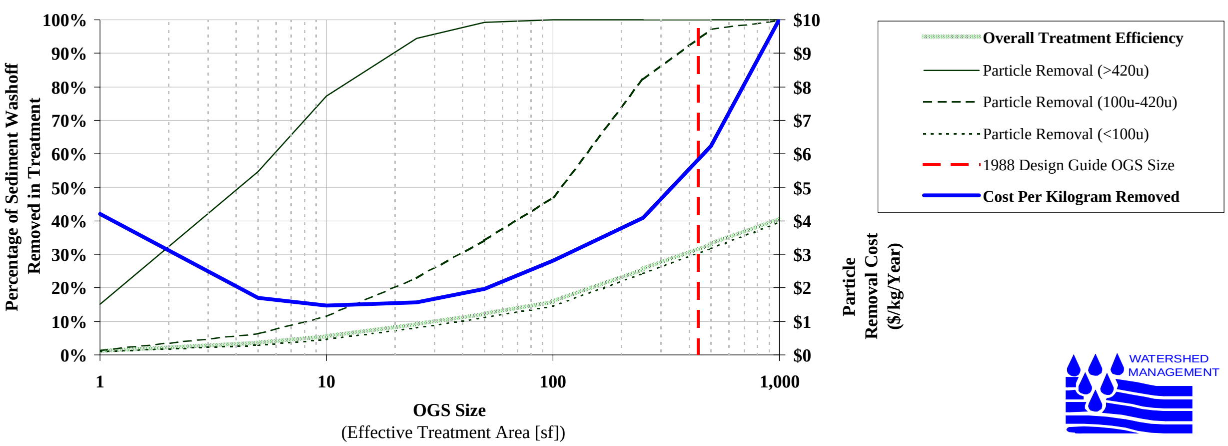


Sediment Washoff (kg)

	<100µ	100µ - 420µ	>420µ	Total
Spring	6,447	11	35	6,493
Summer	20,229	63	127	20,419
Fall	11,275	206	320	11,801
Total	37,950	280	482	38,712



OGS TREATMENT EFFICIENCY

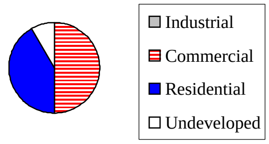


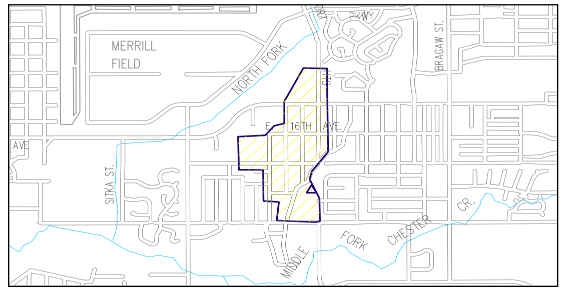
WATERSHED MANAGEMENT

ANCHORAGE BOWL OGS PERFORMANCE MODELING

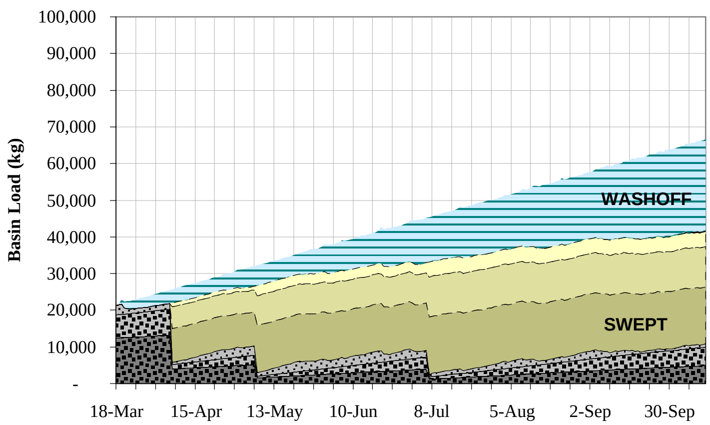
Basin: Middle Fork Chester Creek NPDES 86

Basin Area	83	acres
Land Use		
Industrial	0%	
Commercial	50%	
Residential	42%	
Undeveloped	8%	
Road Areas		
Local	9.83	acres
Collector	-	acres
Minor Arterial	-	acres
Major Arterial	2.75	acres



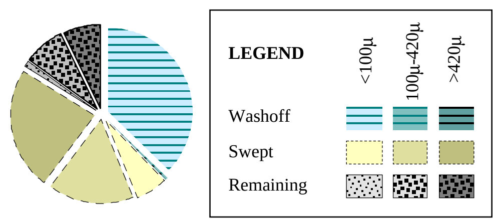


SEDIMENT FATE

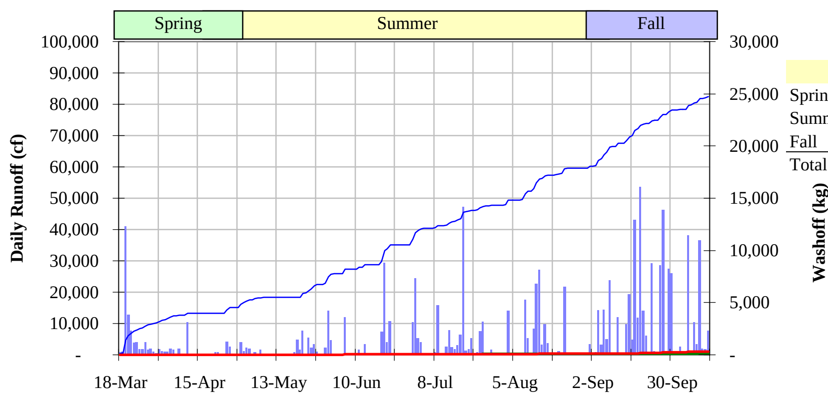


Sediment Fates (kg)

	<100µ	100µ - 420µ	>420µ	Total
Remaining	813	5,051	4,891	10,755
Swept	4,069	10,907	15,642	30,618
Washed Off	24,742	159	306	25,207
Total	29,624	16,117	20,839	66,580

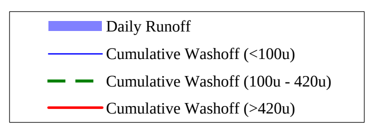


RUNOFF AND CUMULATIVE WASHOFF

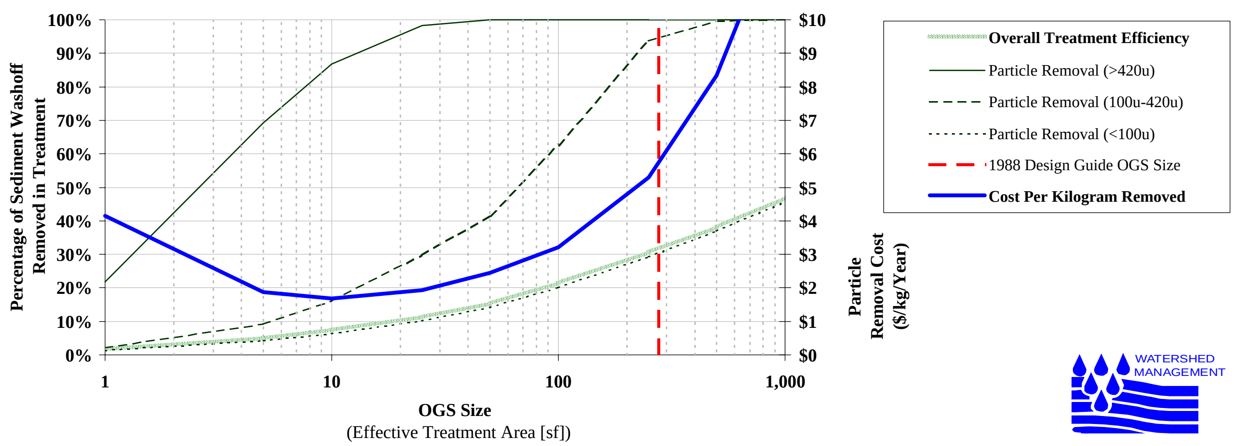


Sediment Washoff (kg)

	<100µ	100µ - 420µ	>420µ	Total
Spring	3,999	9	25	4,033
Summer	13,864	36	79	13,978
Fall	6,879	115	201	7,195
Total	24,742	159	306	25,207



OGS TREATMENT EFFICIENCY



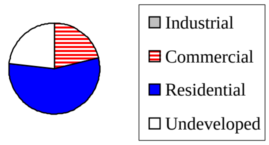
Chester Creek Outfalls at the Gambell/Ingra Couplet

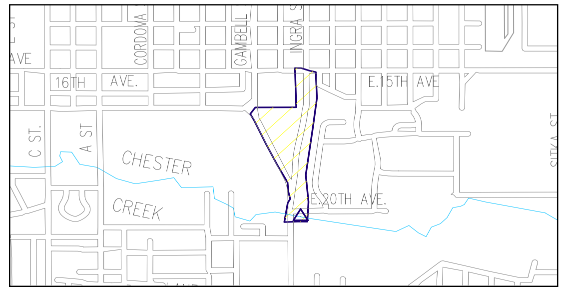
ANCHORAGE BOWL OGS PERFORMANCE MODELING

Basin: Chester Creek NPDES 69

Basin Area	24	acres

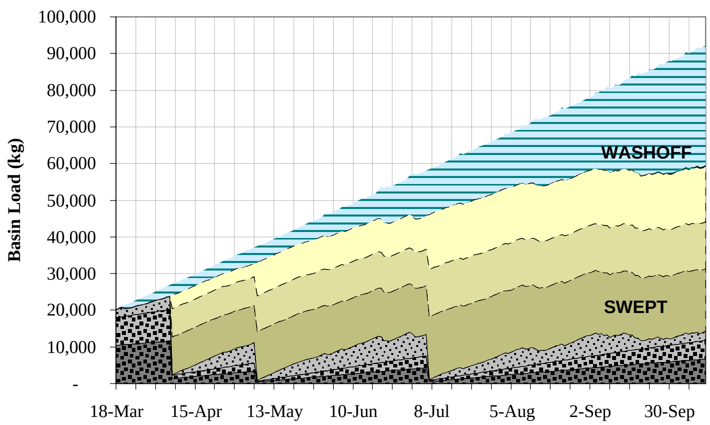
Land Use	
Industrial	0%
Commercial	21%
Residential	56%
Undeveloped	23%





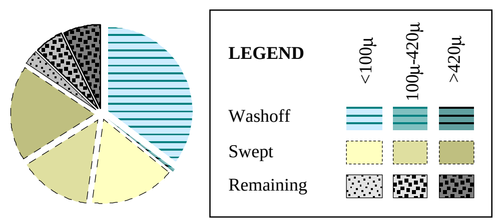
Road Areas		
Local	-	acres
Collector	0.20	acres
Minor Arterial	-	acres
Major Arterial	5.91	acres

SEDIMENT FATE

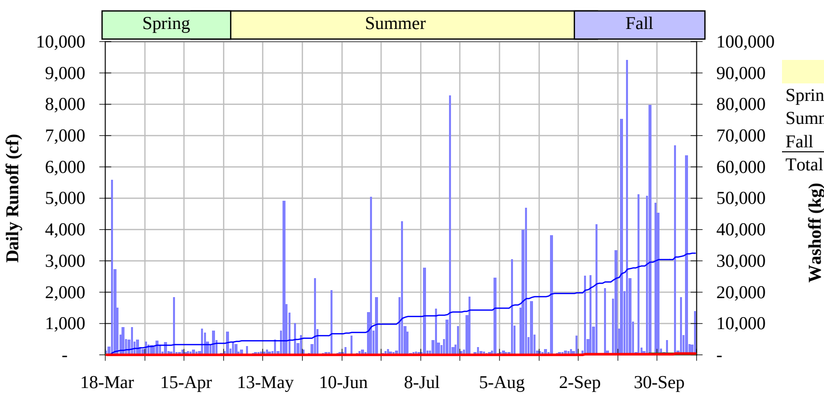


Sediment Fates (kg)

	<100µ	100µ - 420µ	>420µ	Total
Remaining	2,456	5,106	6,678	14,240
Swept	15,005	12,810	17,085	44,900
Washed Off	32,540	161	373	33,074
Total	50,001	18,077	24,136	92,214

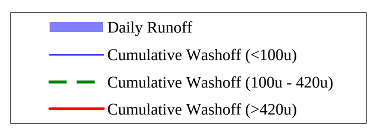


RUNOFF AND CUMULATIVE WASHOFF

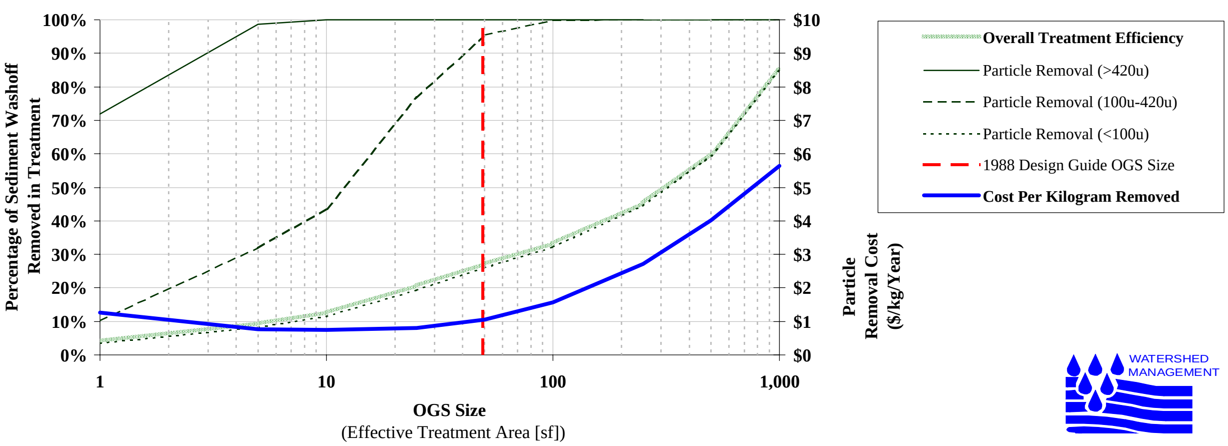


Sediment Washoff (kg)

	<100µ	100µ - 420µ	>420µ	Total
Spring	3,232	7	14	3,253
Summer	16,276	35	83	16,395
Fall	13,032	119	276	13,427
Total	32,540	161	373	33,074



OGS TREATMENT EFFICIENCY



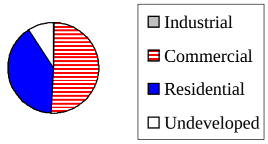
WATERSHED MANAGEMENT

ANCHORAGE BOWL OGS PERFORMANCE MODELING

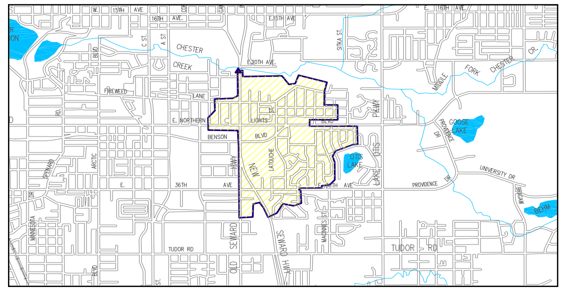
Basin: Chester Creek NPDES 68

Basin Area	450	acres

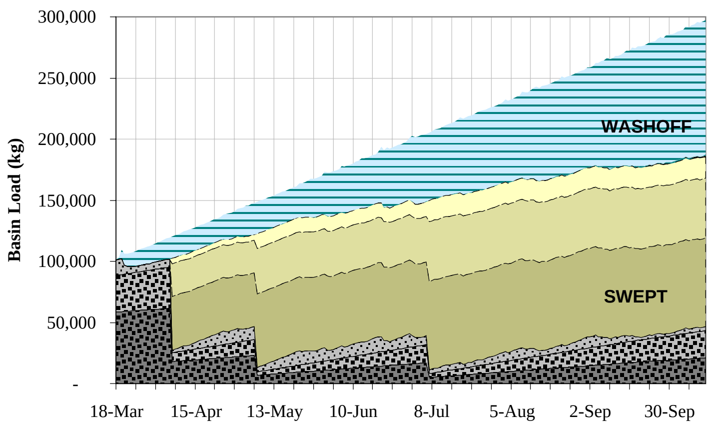
Land Use	
Industrial	0%
Commercial	51%
Residential	40%
Undeveloped	9%



Road Areas		
Local	37.31	acres
Collector	5.62	acres
Minor Arterial	6.07	acres
Major Arterial	10.38	acres

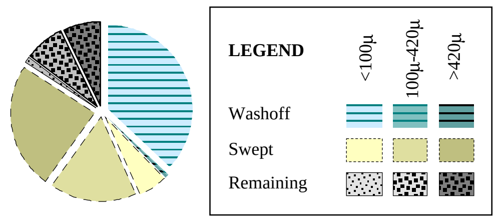


SEDIMENT FATE

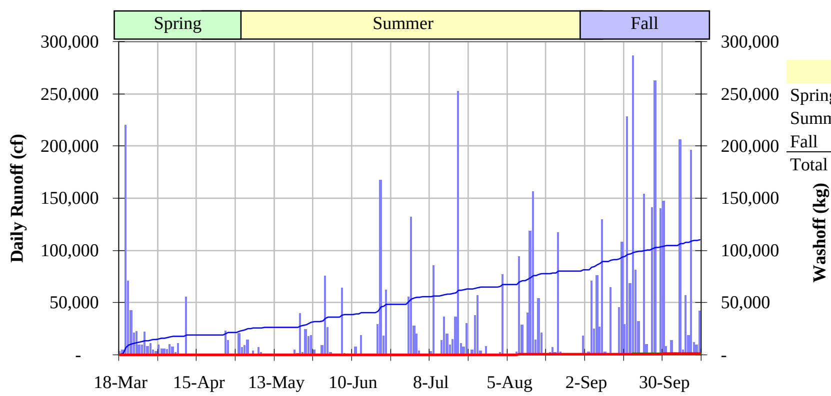


Sediment Fates (kg)

	<100µ	100µ - 420µ	>420µ	Total
Remaining	3,366	22,307	21,071	46,744
Swept	17,290	48,938	72,459	138,687
Washed Off	110,236	627	1,133	111,996
Total	130,892	71,872	94,663	297,428

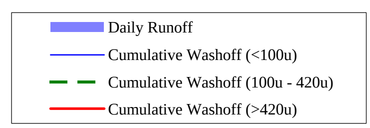


RUNOFF AND CUMULATIVE WASHOFF

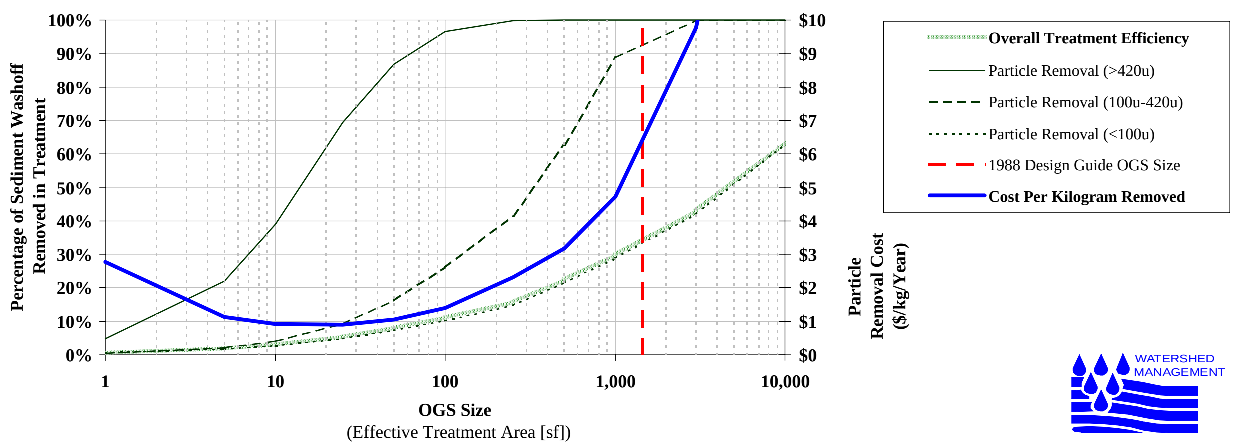


Sediment Washoff (kg)

	<100µ	100µ - 420µ	>420µ	Total
Spring	18,935	39	109	19,083
Summer	61,531	138	272	61,941
Fall	29,770	450	752	30,973
Total	110,236	627	1,133	111,996



OGS TREATMENT EFFICIENCY



WATERSHED MANAGEMENT