Anchorage Watershed Characterization

A WATERSHED SCIENCE PRIMER

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MUNICIPALITY OF ANCHORAGE
WATERSHED MANAGEMENT PROGRAM

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WATERSHED MANAGEMENT

It is difficult to talk about the basic science of watershed management until we have a common idea of what watershed management is. Watershed management is a holistic approach to water resource management. It is an application of strategies and practices designed to optimize benefits and services derived from local water resources. To work, it must be applied across whole watersheds and it must reflect community priorities for these benefits.

WATERSHED MANAGEMENT…

- **Implements Practices (BMPs)**
- **At A Large (Watershed) Scale**
- **To Optimize Water Resource Service**
- **Based On Local Conditions**
- **And Community Priorities**

Water resources are often thought of as being limited to the stream, lake and wetland features themselves. However there is a growing understanding that the functionality of these features is intimately dependent upon the character of the land areas that contribute water to them—the watershed. A ‘watershed’ approach to water resources management, then, addresses not only the receiving waters, but, just as importantly, the land near and far (‘riparian zone’ and ‘watershed’) from these waterbodies.

There is also growing recognition that natural water resources provide a range of benefits to communities much beyond just their potential to support fish. These water resource ‘services’ range from flood control to enhanced property valuation, and ultimately represent important economic value to every resident of the community (whether they fish or not). Thus development of an effective watershed management plan requires a catalogue of the full range of benefits our community can derive from local water resources and the things and activities over whole watersheds that limit the community’s ability to accrue those benefits.

Ultimately a watershed management program is a plan for action. It identifies practices that will enhance access to priority water resource benefits, weighing the value of benefits gained against costs (including the reduction in access to other water resource services). Finally, based on management plans that reflect local community priorities and desires, it applies practices (‘controls’) that are designed to minimize impacts and optimize the desired services across the whole watershed .

Watershed management requires a variety of resources, information, and public input and support in order to accomplish its mission. Watershed managers must know what water resources exist within an area, what services those resources can provide (under the best of conditions as well as existing conditions), and what those services are worth in terms of the community's economy and well being. They must have some idea of what things and activities can—and actually do—limit access to these benefits. Similarly they must know what controls can be applied to manage problems, and the general costs of applying those controls. They must communicate this technical information to the community and determine what the community desires are in the way of water resource benefits so that appropriate plans can be made that will best achieve the community's goals. Finally, they must coordinate implementation of the plans, making appropriate adjustments to the control practices as new information becomes available. These tasks can be summarized in three parts incorporating 6 major steps:

Watershed Mapping and Characterization

- Identify water resource benefits and **services** within a watershed.
- Identify potential problems and **impacts** limiting access to these benefits, and the range of practicable controls to mitigate these impacts.

Watershed Management Planning

- Identify the community's **priorities** for access to water resource benefits.
- Develop management **plans** to optimize desired benefits at a watershed scale, including planning-level estimates of the costs and time frames required for implementation.

Watershed Management Implementation

- Install practices and **controls** to implement watershed management objectives.
- Implement systems **monitoring** (at a watershed scale) to guide adjustment of controls and practices.

This document describes the basic science principles that drive the first major step in the development of a watershed management program—watershed mapping and characterization.

WATER RESOURCE SERVICES

WATER RESOURCE SERVICES…

- **Flood & Erosion Control**
- **Community Economic Value**
- **Recreational & Educational Value**
- **Fish & Wildlife Value**

Watershed management focuses on optimizing benefits or services derived from water resources. A water resource **service** is a human use or benefit that we may desire and that derives from the functions of a water resource.

It is important to note that a water resource service may occur *whether or not* that service is valued at a high or low level by the local community. The potential for provision of a service then is inherent in the functionality of the water system itself. For example, a particular wetland may attenuate peak flows in storm water runoff that enters it even though a hypothetical community ‘Northburg’ is surrounded by wetlands and therefore ‘values’ the service performed by this particular wetland at only a low level.

This leads to an important distinction between a water resource ‘service’ and a water resource ‘value’.   A water resource **value** is a *relative* measure of the economic worth of the service as viewed in the eyes of the community. The ‘value’ of a water resource service is relative to a number of factors including the specific location of the service, the local recognition of and desire for the service, the cost for replacement services, and the uniqueness or abundance of similar services within immediate and regional geographic areas. For example, as our hypothetical town of Northburg grows and environmental resources are increasingly impacted, the community, once surrounded by wetlands, may find itself placing an increasing demand on the services provided by a diminishing number of those wetlands, thus raising the ‘value’ of the remaining available services.

An estimation of community valuation of services can be logically analyzed (through quantitative and qualitative assessment of functional, service, and legal factors). However identification of relative value of services requires at its core community input and can ultimately be reached only through a public (planning) process.

Still, because availability of ‘services’ is independent of a community’s valuation or prioritization of them, water resource services can be readily inventoried through objective, quantitative analysis. Knowing something about the range of benefits, or services, that water resources can provide the community is an essential first step in development of a watershed management program. Thus a preliminary step in development and implementation of a watershed management plan is obtaining answers to the following basic questions:

- What benefits could our water resources provide us—what are the range of services that *could* be obtained from fully functioning waters?
- What is the economic value (in some standard terms) of these services to us? and

- What *required* watershed-wide conditions will bring optimum benefits, and what are the *actual* conditions?

WATER RESOURCE SERVICES

To help inventory local conditions, the MOA has grouped water resource services into the following four major categories:

Drainage, Flood, and Erosion Control Services

Services represented by this category reflect benefits derived from land characteristics across the entire watershed. Benefits include urban storm water runoff control and treatment, stream flood and icings storage and control, in-stream erosion and sedimentation control, and storm water drainage (the last including benefits provided by management of natural drainage paths as well as of streams and wetland features).

Community Economic and Aesthetic Services

This category represents benefits derived generally 'at a distance' from the receiving water. Services include many direct and indirect economic benefits including increased property valuation, tax revenues enhancement, and greenway and water resource contributions to community attractiveness to visitors, new businesses and residents alike. Benefits also include some direct consumptive benefits including water supply and wastewater disposal.

Recreation and Educational Services

This category represents those benefits obtained generally 'up close' to receiving waters (from activities within the riparian zone and along the banks of the waters) and include educational uses, and recreational benefits including trail access, swimming, skiing, fishing, and a host of other activities. These benefits also include direct and indirect economic benefits such as associated recreational retail sales and economic spinoff from national and international events hosted in part as a result of access to and the quality of local greenways.

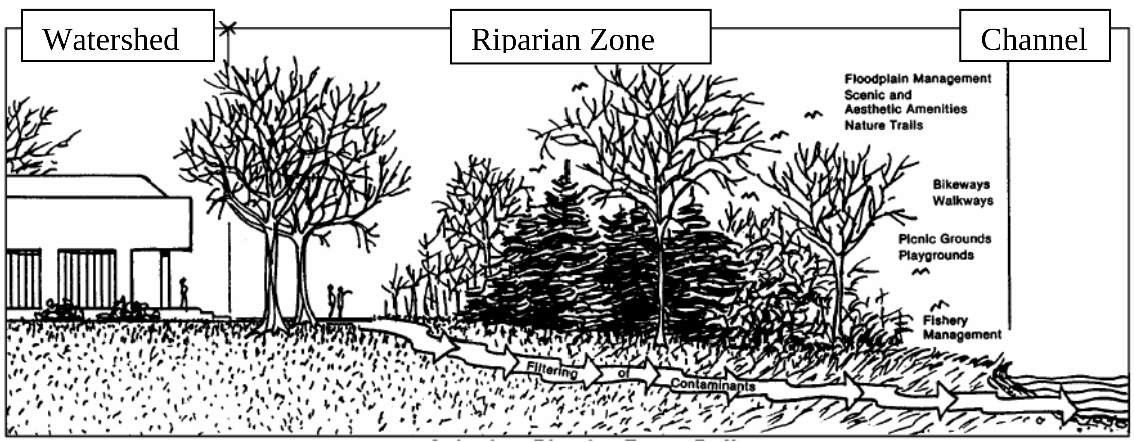
Aquatic and Terrestrial Wildlife Services

This category represents services provided as a result of water resources support of local fish and wildlife populations. Benefits accrue both directly and indirectly. Direct benefits of course may result from harvest of fish and wildlife. Indirect benefits include economic spinoff from associated retail sales, community attractiveness to visitors and new businesses, and even reduced human-wildlife conflicts and associated injury and property damage (as a result, for example, of maintenance of continuous riparian corridors—more attractive and thus more predictable paths for wild animal passage).

FUNCTIONAL WATERSHED SYSTEMS

The benefits we derive from water resources are inherent in the functionality of the receiving waters, but in turn that functionality is completely dependent upon the character of the whole watershed. Thus the degree to which receiving water benefits are available to us is dependent upon the condition of the whole watershed system, and not just of the receiving waters. It is important, then, to understand how watersheds work as whole systems if we are to optimize the benefits from our receiving waters.

Despite the fact that their watersheds make them what they are, unfortunately ‘receiving waters’ are too often managed as stand alone features. Receiving waters and the services they provide us are better thought of as the most visible, ‘downhill’ part of a watershed’s transport system for precipitation (both rainfall and snowmelt). A simplified but useful way of thinking of watershed systems is consisting of three major pieces: watershed areas (or upland runoff areas), riparian zones (or lowland areas abutting receiving waters), and the channel or basin features that actually contain the receiving waters. How these three parts work as a whole is critical to the character of the resulting receiving waters.



The **watershed area** is the ‘uphill’ side of a whole watershed system and the source of almost all the water that enters its receiving waters. Its not surprising that the character of this area more than anything else influences the character of those waters. Consider that rainwater falling on the land that makes up the watershed area must ultimately accumulate and flow across the watershed to provide the water that will make up the receiving water itself. (Important differences exist in how watershed systems work for snowmelt versus rainfall but to simplify our discussion we will focus only on rainfall here.) Only a part of the rainwater that falls will actually reach the receiving water by flowing along the land surface as storm water runoff. Some will be trapped on leaf surfaces or in shallow depressions in the ground and may be lost to evaporation. Some will infiltrate into the ground and may be used in plant evapotranspiration, or may penetrate deeper to join local ground water aquifers. Alternatively, some infiltrating precipitation may join and form shallow flows just below the ground surface (interflow).

Under natural—undeveloped—watershed conditions these losses are predominant and only a tiny fraction (a few percent) of the original rainwater arrives at local receiving waters as surface flows. However, as land development progresses, vegetation is removed and ground surfaces are smoothed and compacted (for example as lawns), or covered with impermeable surfaces (roofs, driveways, and parking lots). The amount of rainwater that is detained, evaporated or infiltrated is greatly reduced. A much larger volume enters receiving waters as storm water runoff. Timing of the receipt of these flows also can dramatically change. Infiltrated flows or flows across natural ground is delayed by the uneven ground surface and the soil, and enters a stream, lake or wetland over a prolonged period of time. Conversely storm water transported across urban impermeable surfaces runs off very rapidly. The end result of these watershed area changes is that much larger amounts of rainfall enter streams as runoff over much shorter periods of time. These faster, larger flows represent much greater amounts of erosive power available to the stream—and the character of the stream must change to accommodate them. Changes in watershed area hydraulics in fact have the most dramatic effect of any impact factor on receiving water performance, as we will see later when we discuss in more detail the factors that impact water resource benefits.

As the land area immediately adjacent to receiving waters, the **riparian zone** has the greatest potential to modify the character of storm water and shallow ground water flows before they enter the receiving waters. In fact this function as a sort of a 'shock absorber' for a stream is a major part of what defines a riparian zone in the first place. A naturally vegetated riparian zone detains storm water runoff entering from upland watershed areas. As a result it can absorb much of the hydraulic energy represented by these storm water flows, buffering the stream from extreme runoff events. It performs this same function along the stream channel too, capturing and slowing stream flood flows. As a result of its function as an energy dissipater, the riparian zone is effective at capturing nutrients as well, and so is also a critical food source for both terrestrial and aquatic fauna alike. However to function properly riparian zones must be hydraulically 'connected' to the watershed area, they must have an effective vegetative cover, and they must have sufficient size (average width) and continuity along the stream feature.

Finally, the character of the **channel** or basin itself is predictive of what benefits (or problems) we can expect from a receiving water. (The channel—or basin for lakes and wetlands—is the feature that contains the receiving waters.) For streams it is important that we view these features as dynamic and not as static elements. Over periods of time a stream channel moves back and forth across its floodplain. It shapes its channel to reflect average flow conditions within a local context of climate, slope, geology and biology. In equilibrium conditions a stream system balances its available energy against ongoing erosion and deposition occurring along its channel. Artificial changes imposed on a stream channel (whether it is removal of available riparian zone space within which it can move, local armoring of its banks, or ditching and straightening) will upset this balance and result in local increases in erosion or sedimentation. These problems are reflected in other impacts as well including increased stream icings and changes in aquatic biota.

WATER RESOURCE IMPACTS

> **WATER RESOURCE IMPACTS…**
>
> - **Watershed (Storm Water) Hydrology**
> - **Riparian Zone Changes**
> - **Channel Zone Changes**
> - **Pollutants**

Although there is some optimum level at which a specific service or benefit can be provided by a given receiving water system, services only rarely achieve this optimum. All waterway services are strongly affected by human activities taking place within the contributing watershed areas and within the streams themselves. Also optimization of any one type of service will often result in a decrease in availability of another type. For example, providing recreational access close to a stream will ultimately limit aquatic productivity of that stream, as increased human access will lead inevitably to some degradation of riparian and in-stream habitat. Although changes in level of services as a result of different management practices can be predicted through technical analyses, ultimately resolution of conflict between desired services can only be resolved through a community planning process in order to achieve the desired balance in services. These intricacies make decision-making—particularly in a real world of limited resources, cost tradeoffs and wide-ranging priorities—very difficult.

The social complexities in watershed management planning make it even more imperative that watershed managers and the public have a basic understanding of what watershed characteristics enhance or degrade water resource benefits. What watershed-wide actions or conditions increase (or decrease) benefits? What conditions or characteristics influence the availability of different services that can be provided by fully functioning receiving waters? What things or actions within the watershed reduce the availability of these benefits? What things or actions increase their availability? The answers to these questions are intrinsic to the characteristics of a properly functioning watershed system that we described earlier.

A ‘problem’ or ‘**impact factor**’ in the context of watershed management is any system characteristic that results in the prolonged reduction of an optimum level of benefits or services that can be obtained from a water resource. We have categorized impact factors according to their relation to negative changes in the critical watershed elements of: watershed (or storm water) hydrology; riparian zone quality; and channel zone quality. We have added pollutants as a separate fourth major category because pollutants can be generated and delivered to receiving waters from anywhere within the watershed, including from within the receiving water itself.

Categorizing impact factors in terms of spatial changes in watershed characteristics helps us to relate those changes to changes in access to benefits, which we have also defined in a spatial watershed context. Sorting problems and benefits in this way allows us to analyze the varying degree to which each major problem category impacts different categories of benefits (Table 1). Each of the problem categories is discussed in more detail in following sections.

TABLE 1: IMPACTS ON WATER RESOURCE SERVICES

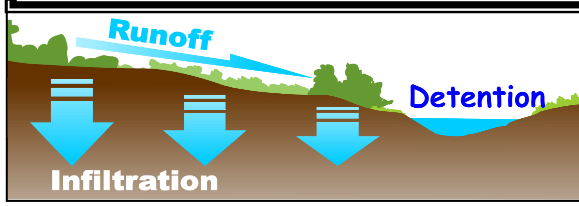
	PROBLEMS	(Factors Impacting Services)		
SERVICES	**Storm Water Hydrology** (Runoff Changes)	**Riparian Quality** (Stream Zone Changes)	**Channel Quality** (Stream Channel Changes)	**Pollutants**
Flood & Erosion Control	Very High (5)	Very High (5)	Very High (5)	Low (2)
Community Economic Value	High (4)	Very High (5)	High (4)	High (4)
Recreation & Education Value	High (4)	Very High (5)	High (4)	High (4)
Fish and Wildlife Value	Very High (5)	Very High (5)	Very High (5)	Very High (5)
Average Impact	4.5	5.0	4.5	3.75

URBAN STORM WATER HYDROLOGY

Urbanization modifies the land surface of a watershed. Parking lots, buildings, streets and lawns change the original nature of the land. These changes have a dramatic effect on the amount of precipitation that ultimately runs off to form storm water.

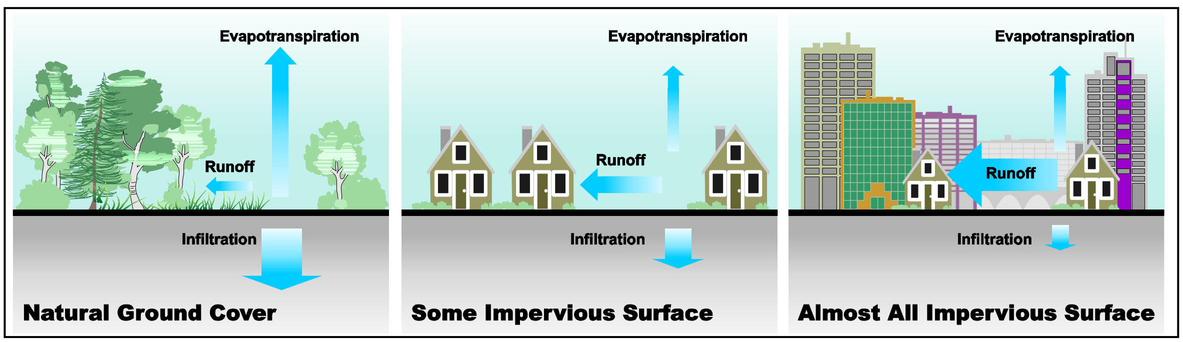
Urbanization of a Watershed…

- **Increases Impervious area which:**
- **Increases Runoff Peaks**
- **Increases Runoff Volume and**
- **Decreases Infiltration**



Once on the ground precipitation may:

- Get soaked up by soil (infiltrate)
- Be detained on leaves and other rough surfaces or in ponding on the ground surface
- Or run off the ground surface to form storm water.

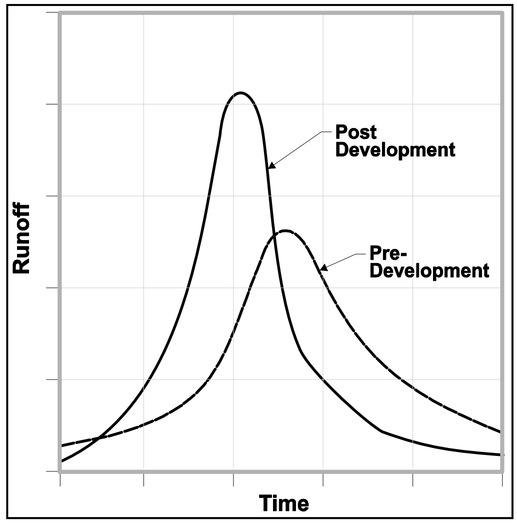


Whether water is more likely to run off, soak into the ground, or be detained depends on the type of surface onto which it falls. A highly pervious surface can soak up or detain precipitation much more readily than an impervious or compacted and graded ground surface (such as a lawn). Forests and other naturally vegetated ground surfaces have high infiltration and detention capacities, so only rarely does precipitation run off them (Table 2). However impressive changes take place when we modify these surfaces. For example when we grade and compact forest soils to make a lawn in Anchorage we reduce the ground permeability by about 10 times. Of course, constructed impervious surfaces like roofs and paved streets and parking lots are designed to have very little detention or infiltration capacity and almost all precipitation will rapidly run off these surfaces.

Table 2
Landcover and Infiltration

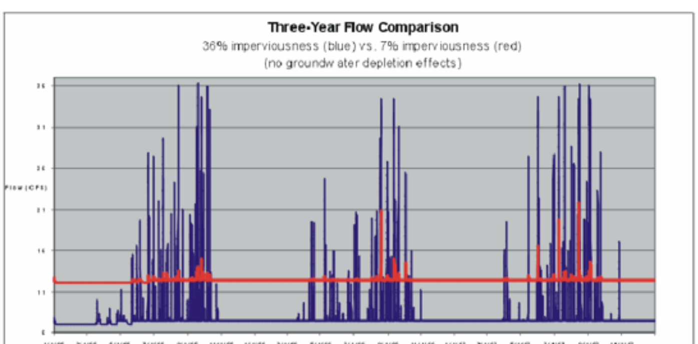
Landcover	Detention (in.)	Infiltration (in./hr.)
Forested Uplands	2.0	2.5
Wetlands	4.0	0.14
Lawns	0.3	0.25
Road Ditches	0.4	0.5
Roofs	0.15	0
Paved Parking	0.15	0
Paved Streets	0.1	0

Changes in perviousness of the landcover of a watershed area have a profound effect on the storm water runoff characteristics of the watershed. Recall that pervious surfaces detain and infiltrate most precipitation so that the *volume* of surface runoff is small. Also their rough surfaces slow runoff down so that the travel time of these flows is prolonged. Impervious surfaces have the opposite effect: almost all precipitation runs off (greatly increasing runoff volume), and the time taken to entirely drain the surface is greatly reduced. The net result is that for impervious surfaces much more runoff water is created and transported over much shorter periods of time.



These changes in watershed runoff characteristics affect the peak, volume, and timing of surface runoff delivered to a receiving water. For each precipitation event, the volume and rate of delivery of storm water to a stream is greatly increased, thereby significantly elevating the hydraulic energy that the stream must contain and pass. The change in storm water flows for combinations of highly urbanized watersheds and small stream features can be reasonably analogous to you exchanging a garden hose for a fire hose to use in washing your car.

Analysis of pre- and post-development conditions in the South Fork Chester Creek subwatershed clearly demonstrates the effects of increased watershed imperviousness. Model results suggest peak flood flows in the South Fork have increased five- to tenfold as a result of development in this watershed over the last 50 years. At the same time the model suggests that stream base flows have dropped by an order of magnitude. These watershed hydraulic changes have significance for the functionality of receiving waters in terms of flooding, icing, in-stream erosion and sedimentation, and aquatic habitat.



Chester Creek Hydrology: Pre- and Post-Development

However the hydraulic impact of watershed impervious surfaces is in part mitigated by the character of its spatial distribution. This is because storm water flowing from an impervious surface to a more pervious one will always reduce the total amount of runoff from the watershed. Given this perspective it is important to understand how impervious and pervious surfaces within a watershed are hydraulically ‘connected’ to each other.

Consider, for example, the construction of a new paved subdivision street draining to a nearby stream through piped storm drain systems, and a house, driveway and lawn on that street (that is, a system of connected impervious and semi-pervious surfaces). In one drainage scenario the roof and driveway could discharge the runoff from their surfaces directly to the street (through gutter systems). These flows would be rapidly delivered

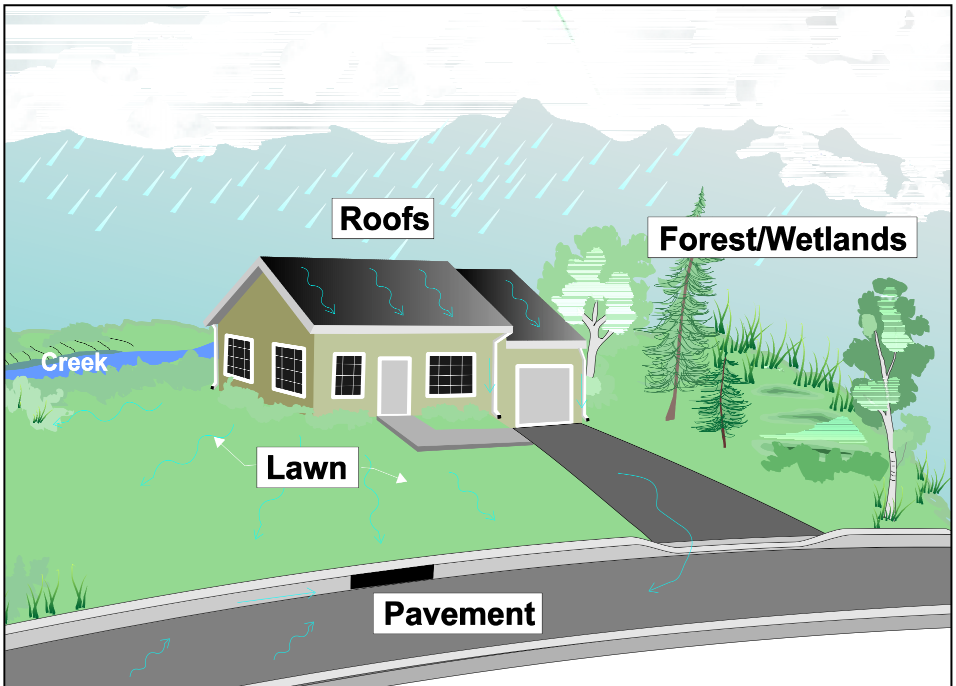
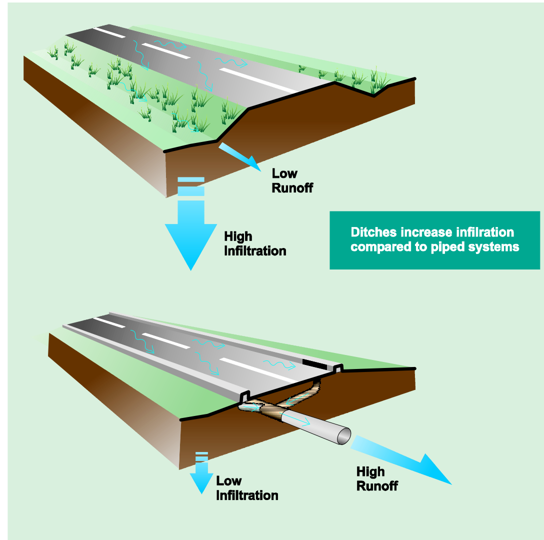


Figure 3. Connectivity Between Pervious and Impervious Surfaces

through the storm drain system to the stream. In this type of system the new driveway and house roof are said to be 'directly connected' impervious (abbreviated throughout this document as 'DCI') because their storm water flows are transported along impervious surfaces along the entire path to the receiving water. All storm water draining from these impervious surfaces is rapidly delivered to the stream and the overall watershed hydraulics would reflect maximum increases in storm water volumes and peak flows.

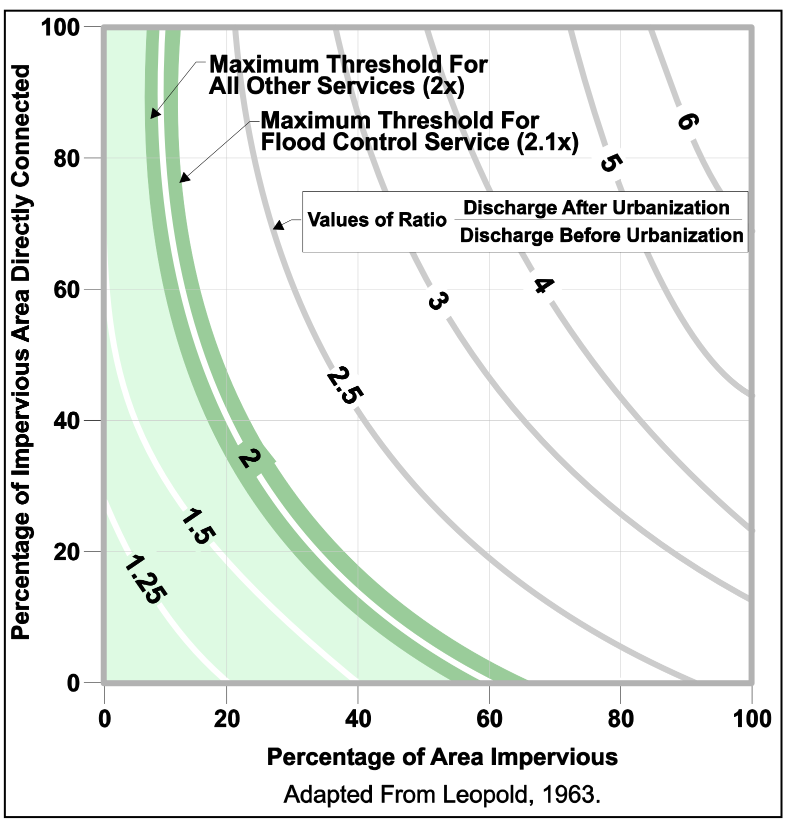
Alternatively suppose that we route the storm water from our new house through gutters that discharge onto the lawn surface instead of directly into the street. Now the storm water from our faithfully impervious rooftop will have some opportunity to be detained on, and infiltrate through, our lawn surface (though at a greatly reduced rate from that of a naturally vegetated ground surface). We say that our roof is now 'indirectly connected' impervious (abbreviated as 'IDCI'). Though the roof itself responds independently as an impervious surface (increased volume, rapid runoff), the overall impact to the watershed hydraulics would be modified slightly because the hydraulic effects (energy) of the roof



runoff has been in part absorbed through the ability of the lawn to detain and infiltrate that runoff.

From our example (and from our earlier discussion of landcover characteristics) it may also be apparent that the type of storm water conveyance in urbanized areas can be significant in terms of 'disconnecting' impervious surfaces. The piped storm drain system in our example is in effect an impervious surface itself and offers by design little or no detention or infiltration capacity. Ditches on the other hand are inevitably semi-pervious, allowing some infiltration. These differences can have a significant effect when summed over the extent of an entire watershed area.

Mapping and management of watershed impervious surfaces and their 'connectivity' is a necessary and fundamental element in any watershed management strategy. Knowledge of the nature and extent of impervious surfaces within a watershed and the degree to which they are connected or disconnected provides an immediate predictive tool for potential receiving water impact from storm water hydraulics. Based on national research significant impacts on a range of water resource benefits (including flooding, erosion, sedimentation control, and biotic support) occur as average annual stream flows increase above about 1.5 to 2.1 times those of pre-development conditions.



Knowledge of the extent and distribution of watershed pervious surfaces is also invaluable in developing watershed management plans. Storm water flows from watershed impervious surfaces can be cascaded across (connected to) these pervious lands in order to attenuate the peak storm water runoff flows. Riparian zones are particularly suited for this purpose as they are typically at the downstream end of storm water drainage systems and have ecologies well suited to wet conditions. Recent research suggests that hydraulically connecting urban storm water runoff flows to functional, substantial riparian zones can reduce the effective total watershed imperviousness by as much as 15 to 20 percentage points. We will discuss these opportunities for riparian zones in the following section.

RIPARIAN ZONE MODIFICATION

The riparian zone is an area adjacent to receiving waters that that periodically carries overbank floodflows. This zone is the stream's natural "right-of-way". A good riparian zone maintains and protect a stream's functions by performing as a "shock adsorber" against the increased flood flow peaks and volume delivered by an urbanizing watershed. Good riparian zones **minimize erosion and flooding hazards** along receiving waterbodies, serve as **conduits for wildlife**, allow a **place to recreate** and **improve stream habitat**.

Riparian Zones Support….

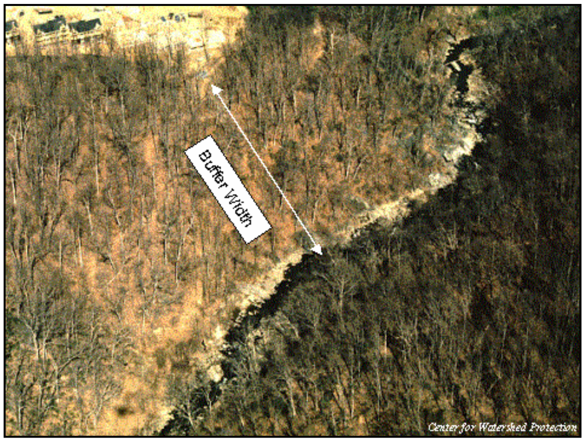
- **Storm Water Treatment**
- **Stable Stream Channels**
- **Corridor Continuity**
- **Dynamic Floodways**

A healthy riparian zone includes an adequate buffer width, or setback, along both sides of the stream and as a continuous corridor along the entire length of the stream. Such a functional riparian zone serves as an effective conduit for flood flows while at the same time decreasing flood velocities and attenuating flood peaks by detaining stream flows. It allows room for the channel to meander naturally and to create a channel geometry that will efficiently move it's natural sediment load. It buffers the effects of urban storm water. It provides for food, habitat and stability in the channel by supporting natural vegetation that helps to armor the channel bank with roots and provide for thermal stability of the channel through shading in the summer and support for insulating snow cover in the winter. Riparian buffers are even more important along smaller streams, as there are many more miles of smaller streams than of

Riparian Continuity:
- Flood 'shock absorber'
- Corridor for wildlife and recreation

Riparian Loss:
-Increased flood velocities
-Increased wildlife and human conflicts

larger streams and small streams are much more subject to erosive forces. Small streams at Anchorage often originate at ground water discharge zones and provide source flows to larger streams. Incorporating these headwaters into the riparian zone also helps maintain baseflow for larger streams throughout the year.

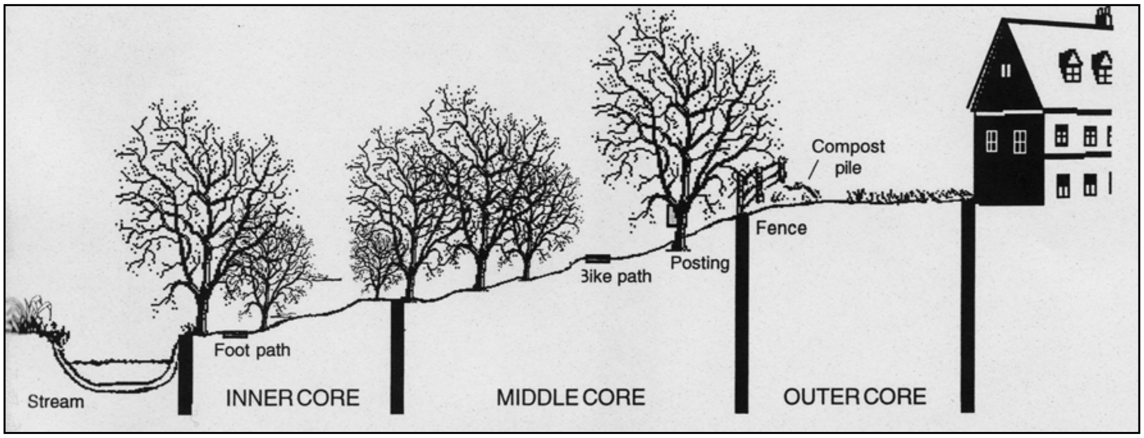


A riparian zone can be managed through use of stream setbacks—i.e., a distance perpendicular to the stream to be preserved as a riparian width. The optimum width of a riparian buffer varies based on the size of the stream. In general, setbacks should be wide enough to allow a natural meander belt for the receiving water channel, typically about 7 to 10 times the stream bankfull width for lowland streams (see Appendix A). This roughly equates to the following setbacks widths (each side of the stream):

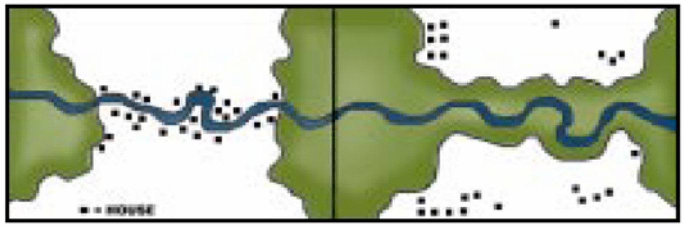
- First order (small) streams: 60 feet
- Medium size streams (e.g. Chester Creek): 125 feet
- Large streams (e.g. Campbell or Ship Creek): 150 feet

Riparian buffers should also encompass the 100-year flood hazard zone for all stream sizes. This helps ensure that there is available corridor to pass the 100-year flood through urban areas with minimal impact to the community or the receiving water. Nationally, an average riparian buffer is 100 feet. Current Municipal code provides a 25-foot buffer for Anchorage streams.

A riparian buffer is often managed as three separate zones across its width, each targeted for different management practices and landuses. The inner zone typically includes a 25 foot buffer intended to directly protect the stream channel, wetlands, vegetation, and other critical habitat immediately adjacent to stream. It is often managed as an



undisturbed, naturally vegetated area. The middle zone has a width of 25 to 75 feet, or more, and optimally includes the 100-year floodplain and wetland areas contiguous to the riparian zone. The outer zone is often dedicated as a 10- to 25-foot setback from permanent structures.



No Continuity **Continuity (Corridor)**

Riparian zones must be established not only perpendicular to a stream channel but along the length of the stream as well. Maintenance of riparian zone **continuity** along the stream ensures a critical corridor that provides an uninterrupted passage for flood flows and wildlife. A continuous corridor maintains the floodplain's natural function as a shock absorber for flood flows and a filter for urban pollutants. Without corridor continuity, the benefits of a riparian zone can become severely limited. For instance, a continuous corridor along the stream is necessary to convey storm water and flood flows smoothly downstream. Restrictions to the riparian zone by a break in the corridor can cause flood waters to backup, increasing the potential for flooding of nearby neighborhoods. Riparian corridors also provide natural seasonal migration routes and habitat for wildlife, most notably moose, bear and waterfowl for the Anchorage vicinity. Breaks in the natural corridors can promote moose or other wildlife movement out of the wildlands that exists along the stream floodplains and into our urban yards and streets, increasing the potential for property damage and injury to animals and humans alike. Incorporation of corridor 'nodes', larger tracts of land within the riparian zone such as parks are also important to optimum riparian functionality. These expanded areas in the riparian zone provide increased opportunities for flood wave detention, wildlife habitat, and recreation as well as significant community economic benefits derived from the aesthetics of large urban greenspaces.

Loss of riparian zone continuity shows how restrictions and loss of these areas can dam and impede stream flows, increasing flooding.

Channel Zone Modification

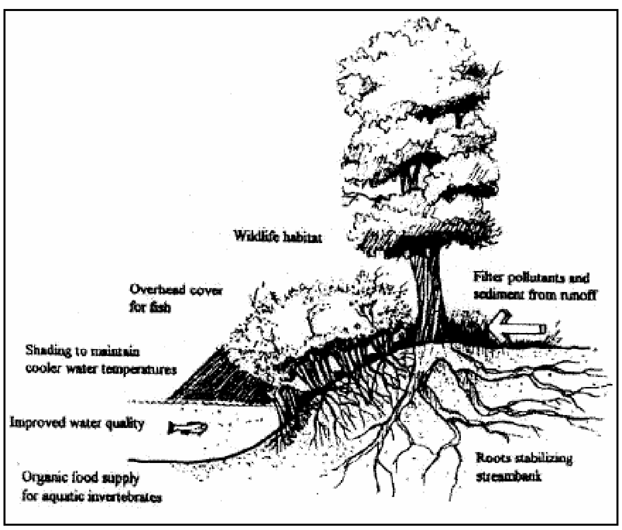
All stream channels are dynamic. They convey a range of seasonal flows, experience continual erosion and sedimentation, and tend to move across their floodplain width. In healthy natural stream regimes these processes are performed in balance with the climate, geology, and biology of the area and dramatic changes in stream character are often noticeable only as an effect of the largest flood events. A healthy channel regime, then, supports the dynamic stability of a stream's basic character. It efficiently transports sediment and flood flow in accordance to its size, minimizes sediment loss from eroding banks through self-armoring, and optimizes the amount of stable habitat available for aquatic and terrestrial wildlife.

Natural Channels Provide….

- **Flood Control**
- **Bank Stabilization**
- **Thermal Protection**
- **Sediment Management**
- **Aquatic Habitat**

Similarly, any stream system that is thrown out of balance with a change in one or more hydrologic factors will begin to move inexorably towards re-establishing a dynamic equilibrium with the new conditions, with an end result of natural establishment of the most efficient movement of water and sediment down a newly-configured stream channel. Thus any significant change in the principle factors affecting a stream's regime can dramatically change a stream's channel and flow character, often with the most immediate being greatly increased channel erosion, sedimentation, icing, and dramatic geometric reconfiguration.

Urbanization can be a primary source of change in the major factors affecting stream character, either directly or indirectly. As a watershed is developed, the infiltration and runoff patterns of snowmelt and storm water change. Urbanization results in increased flood volumes and peaks which tends to result in a short-term widening and decrease in the depth of flow in stream channels, optimizing conditions for channel erosion. The stream responds to these changes, attempting to reach a dynamic equilibrium with the new conditions. This natural response to an area-wide increase in storm water runoff can lead to increases in erosion and stream sediment load, increased flooding, loss of habitat, and other stream changes.



If there is more immediate modification of the riparian zone or the stream channel itself, such as armoring of the channel, introduction of a channel obstruction such as a bridge, or channel ditching or straightening, the stability of the channel can be even more dramatically changed, at least locally. Channel armoring can locally focus flood flows and increase flood velocities and erosion and sedimentation. Ditched and deepened stream channels can lower high velocity flood flows below the self-armoring protection of roots naturally exposed in the stream channel, dramatically increasing channel erosion. Straightened and steepened stream channels and de-vegetated stream banks can become much more subject to stream icings as well as bank erosion.

These changes in, or loss of, channel zone (in-stream) qualities affect our use of the services provided by the channel. For instance, bank erosion decreases the availability of habitat for fish, which decreases our opportunities to catch fish for recreation. Unstable channels are more prone to bank erosion and channel shifts—and ultimately property damage.

Pollutant Generation

Pollutants are any physical or chemical substances that impact functionality, especially those supporting desired services, of receiving waters. In the sense of this definition, pollutants include not only chemicals and particulates but can and does include the storm water itself, as it increases risk of flooding and erosion and other system impacts. Thus the presence of pollutants imply risks from flooding and erosion control, impacts to fish and other animals or their habitat, impacts to the aesthetics of receiving waters and to recreational and educational value, and other risks for impacts to a high functioning receiving water.

Pollutants….

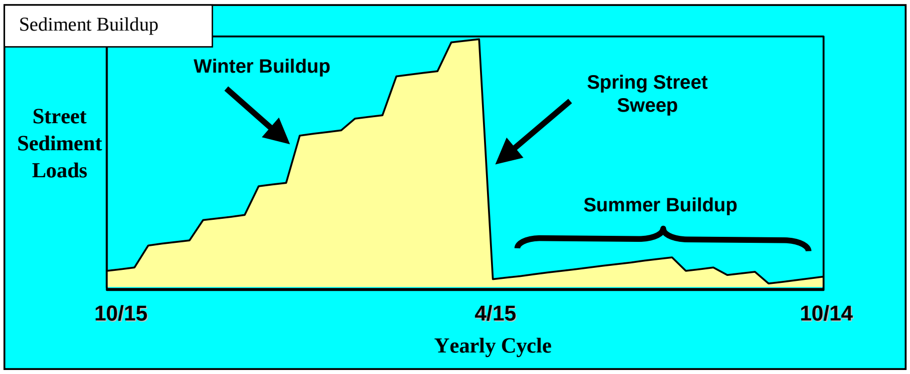
“ Controlling urban storm water, changes to the riparian zone and changes to the channel will effectively control pollutants.”

Pollutants and their sources have been studied extensively over recent years in Anchorage. Although many pollutants exist, for the Municipality the primary pollutants of concern are:

- Storm water
- Chloride
- Sediment
- Metals, POLs and Toxics
- Pathogens

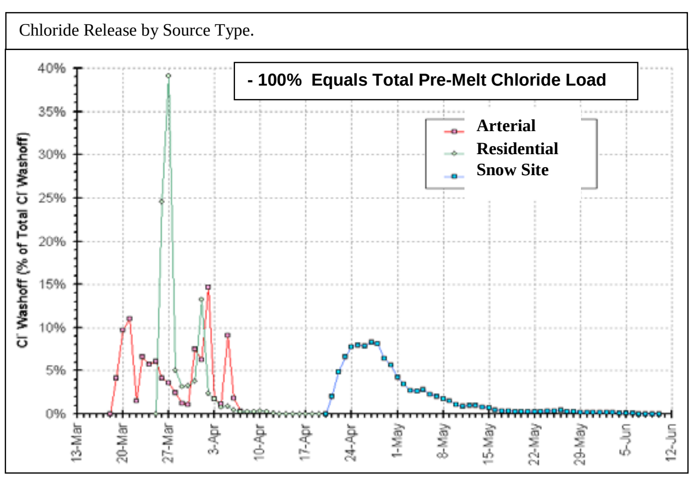
Urban **storm water** is perhaps the most significant pollutant that affects our receiving waters. From a hydraulic standpoint alone it is a primary factor in the increased channel erosion observed in many of our urban streams today. The character of our storm water runoff also controls the degree to which other pollutants are moved from the watershed surface into the receiving waters. After all, pollutants cannot impact our receiving waters if they are never transported into the receiving waters in the first place and pollutant mobilization is directly dependent upon the washoff energy of storm water. For instance, recent Municipal modeling of storm water runoff from the Chester Creek watershed showed a remarkable change in pre-development versus post-development storm water runoff volume and pollutant mobilization. As mentioned earlier, modeling of a 1950 watershed versus a 2001 watershed showed a three- to five-fold increase in post-development storm water runoff volumes and a ten-fold increase in peak stream flood flows. Even more dramatic, sediment washoff changed from almost zero for pre-development conditions to a post-development storm water particulate load of from 1,000 to 100,000 pounds per subdrainage area.

Based on a broad range of recent studies, the Municipality suspects that particulate pollutants within the Anchorage area come from two primary sources: particulates form street and land development carried by storm water washoff, and in-stream channel erosion. Sediment washed off the streets comes mainly from sand applied to street surfaces in the winter to improve vehicle traction in the winter, though sediment derived from land development and other construction activities likely contribute significantly to the annual loading as well. Sediment is applied to streets beginning in October and is continued throughout the winter. Approximately 30,000 tons of sediment are applied yearly to MOA streets. Some of this sediment is incorporated into plowed snow and hauled to snow sites. Following spring breakup approximately half of the annually applied amount is swept up. The remainder of the sediment is washed off street surfaces and sidewalks into the Muncipal storm drain systems. Municipal modeling of these sediment washoff processes suggests that about 75% of all the sediment washed off Anchorage street surfaces consists of particles less than 100 microns in size.



Still, despite the relatively large loads of sand applied to Anchorage's streets annually, urban storm water hydraulic loading alone is currently believed to be the most significant source of sediment observed in Anchorage streams. The greatly increased storm flow volumes and peaks along with common channelization of urban stream channels may be by far the primary cause of elevated sediment loading observed in Anchorage's modern urban streams. Recent Municipal analysis of Campbell Creek sediments loads suggest that less than 5% of the stream sediment load is attributable to street washoff with the rest the result of increasing in-stream erosion along channelized tributaries. Channel stability analysis of urbanized reaches of Campbell Creek indicated that approximately 35 percent of the creek channel is unstable and particularly vulnerable to the increased urban storm water runoff volumes and peaks.

The range of chemical pollutants present in storm water at Anchorage are typical of any large metropolitan community. However **chloride** may be the most important in terms of potential impact to many of Anchorage's small streams. Chloride sources at Anchorage include street applications, salt used in winter street sand (to keep it friable during application) and magnesium chloride deicer.

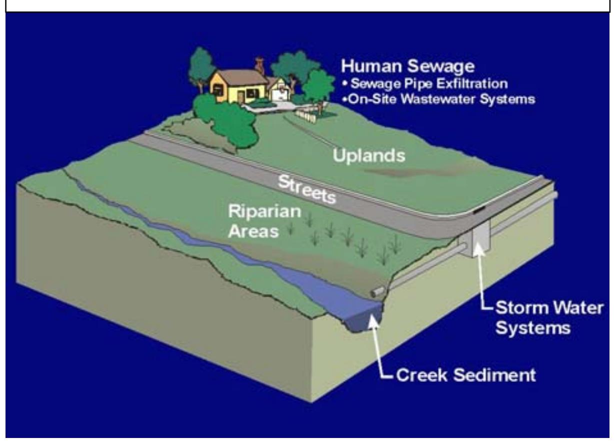


However, 80% of the total chloride loading on urban streets comes from salt applied with the sand. Because the salt is applied in the winter, the chloride accumulates on the streets surfaces until the seasonal spring breakup period. During this seasonal melt period the entire chloride load is mobilized and washed off in what under certain circumstances can be quite high concentrations. Municipality modeling of chloride washoff at Anchorage indicates that most of the chloride is washed off streets and through our stream systems within three weeks of initial spring street melt. The modeling also showed that average chloride levels do not exceed EPA criteria for vegetation and aquatics within area streams over a four-day average but that concentrations can still be dangerously elevated for brief periods of time.

Metals, POLs (petroleum products, oil and lubricants) and toxics are pollutants that are most commonly found in Anchorage adsorbed to streets sediments. Sampling for metals adsorbed to Anchorage street gutter sediments showed that typically none of the common metals (copper, chromium, lead and zinc) or PAH exceeded ADEC cleanup levels. As these pollutants are commonly associated with the street sediments, they follow the same washoff patterns to receiving waters as the sediment itself. Thus controlling the sediment and storm water runoff controls the bulk of the adsorbed-portion of pollutants as well.

In Anchorage **pathogens** are represented by the presence of fecal coliform. Fecal coliform concentrations in Anchorage streams periodically exceed State of Alaska water quality standards for this pathogen. Although there are a wide range of potential sources for pathogens in Municipal streams, the most probable source is pets and urban wildlife. However, seasonal anomalies in elevated concentrations of this pathogen in Anchorage streams may also be tied to extreme channelization of urban streams as well.

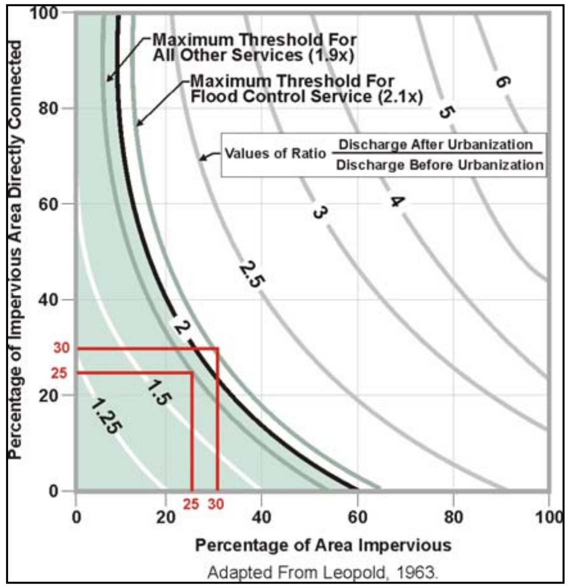
Potential Coliform Sources from Literature.



Anchorage Watershed Characterization
WATERSHED SYSTEMS THRESHOLDS

THRESHOLDS

STORM WATER THRESHOLD



Thresholds for controlling storm water are estimated at a 1.9 to 2.1 times increase in mean annual discharge. Note that higher imperviousness can be obtained if the area is not all directly connected by storm systems to the stream. Riparian quality also strongly mitigates the effects of impervious surfaces.

Impervious Surface Threshold

- Variable from 10 to 55 percent (%) depending upon impervious surface continuity (see chart at right).

RIPARIAN ZONE THRESHOLDS

Riparian zone management includes two thresholds: setback and connectivity.

Setback Threshold

A setback is a distance perpendicular to a stream at which riparian zone management practices are applied. Setbacks are typically applied in three segments: streamside, floodplain, and transition zones (as shown on Figure 1).

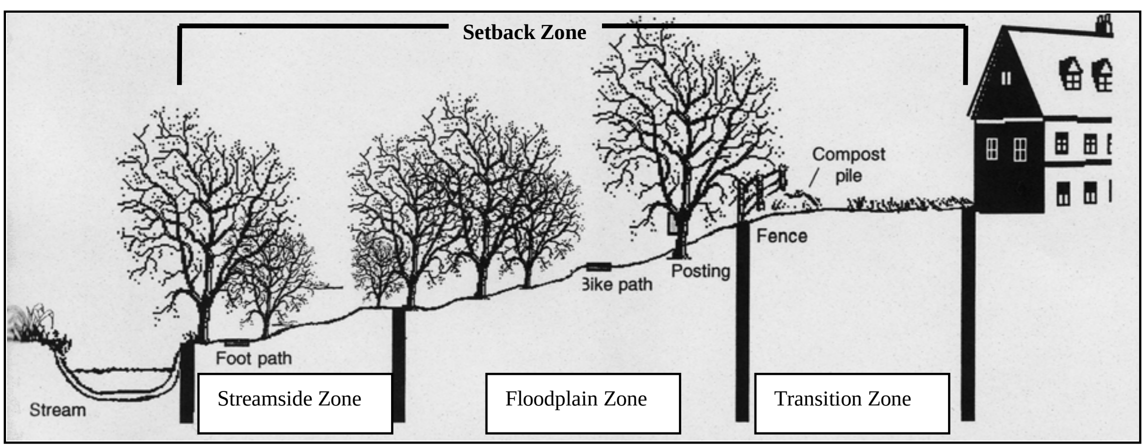


Figure 1. Three Tiered Setback Management

The characteristics of setback zones are described below:

Characteristics	**Streamside Zone**	**Floodplain Zone**	**Transition Zone**
Function	Protect physical integrity of stream	Provide corridor services	Prevent development
Vegetation	Undisturbed natural vegetation	Managed vegetation (<5% impervious surfaces)	Natural vegetation encouraged, but usually turf
Allowable Uses	**Very Restrictive**	**Restrictive** Recreational use, storm water best management practices, bike paths, etc.	**Minimally Restrictive** Lawns, gardens, etc.

Thresholds for these setbacks are provided in Table 1:

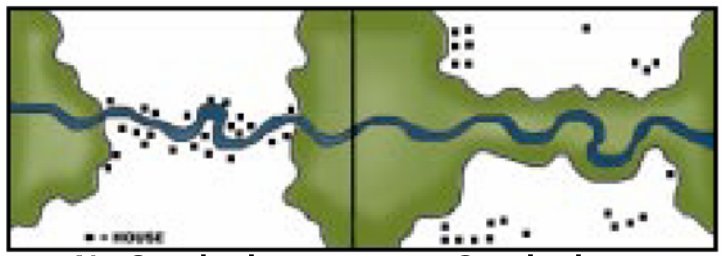
TABLE 1. STREAM SETBACK THRESHOLDS

Stream Category	Zone Category	Setback Width (feet)	Total Corridor Width (feet)
All Streams - Include 100% of the 100-year flood zone - Include all wetlands within 50 feet of bankfull streambank edge - Include all critical habitat within 50 feet of bankfull streambank edge - Extend riparian corridor 150 feet above stream headwaters			
Small Streams (<5-foot bankfull width)			
	Stream Side	25	50
	Floodplain	25	50
	Transition	10	20
TOTAL WIDTH		**60**	**120**
Medium Size Streams (5 to 25 feet bankfull width)			
	Stream Side	25	50
	Floodplain	75	150
	Transition	25	50
TOTAL WIDTH		**125**	**250**

Large Streams (>25 feet bankfull width)			
	Stream Side	25	50
	Floodplain	4x Bankfull Width	200
	Transition	25	50
TOTAL WIDTH		**150**	**300**

Note: Floodplain zone width will be dependent on the 100-year floodplain delineation for the reach in question, but should be the minimum value stated.

Continuity Threshold
Continuity is a measure of the degree a riparian zone continuously borders the stream (see illustration to right).



No Continuity (Corridor) **Continuity**

<u>Riparian Continuity Thresholds</u>

- 90% CONTINUITY OF THE 100-YEAR FLOOD ZONE
- 25-foot setback streamside zone continuity
- 10-foot setback floodplain continuity
- Total corridor width summation must still be achieved

<u>CHANNEL THRESHOLDS</u>

Channel thresholds reflect the minimum activities allowed within streams while preserving the integrity of a streams dynamic condition. These thresholds are listed in Table 2.

TABLE 2. CHANNEL THRESHOLDS

Channel Modification/Restoration
• <10% armored/piped/excavated channel length
– Modifications for critical applications only
– Restore to dynamic equilibrium conditions or for critical applications
– Extend riparian corridor 150 feet above stream headwaters
Channel Crossings
• All crossings shall be perpendicular to the stream channel
• Abutments shall be constructed outside the bankfull width

• Only one road crossing allowed per subdivision and no more than one crossing for every 1,000 feet of channel
• Bridges should be used in lieu of culverts when crossings require a 72-inch or greater diameter pipe
• Crossings shall be located along straight reaches
• Crossings should be capable of passing the 100-year flood

POLLUTANT THRESHOLDS

The Municipality of Anchorage has formed a priority list of pollutants to control, which are: storm water runoff, chloride, sediment, pathogens, and vehicular pollutants (metals, hydrocarbons, etc.). Pollutant thresholds are listed in Table 3.

TABLE 3. POLLUTANT THRESHOLDS

Pollutant	Threshold	
Storm Water Runoff	- See Impervious Surface Threshold	
Sediment	- Capture 90% of the annual sediment discharge from storm drains greater than 100-micron in size - Maximize street sweeping efficiency	
Chloride	- Total chloride applied to streets set at 2% by weight of total sediment applied - Dilute storm water discharge to comply with MOA standards for chloride concentrations:	
	<u>Fish and Invertebrates</u>	<u>Vegetation</u>
Acute (less than 1 week)	3,600 mg/L	6,400 mg/L
Acute (up to 30 days)	1,200 mg/L	3,200 mg/L
Chronic (continuous)	300 mg/L	640 mg/L
Pathogens	- Achieve 90% urban residential lot breaks - Achieve 90% pen/stable/kennel yard breaks - Achieve 90% landscaped area infiltration breaks	
Vehicular Pollutants	- Adsorbed pollutants: see sediment thresholds - Corrosion-related pollutants: see chloride thresholds - Dissolved pollutants: see storm water thresholds	

Key:
mg/L – milligrams per liter
MOA – Municipality of Anchorage

Anchorage Watershed Characterization

APPENDIX B
SETTING WATERSHED MANAGEMENT PRIORITIES

WATERSHED MANAGEMENT:

SETTING WHOLE-WATERSHED PRIORITIES

INTRODUCTION

Setting priorities for watershed management even within just a single watershed is complicated. Setting priorities for watershed management must address not only what must be done (management activity), but also where it should be done (watershed location) and when it should be done (schedule). Priorities must of course reflect political and social needs but, optimally, will also be set in context with the physical and biologic functional realities of the watershed systems themselves. It surely is obvious that because watersheds are natural systems responding to natural phenomenon (whether the body politic likes it or not), management controls and practices will be most effective if they are implemented to reflect how watersheds work. The reverse is also true: implementing controls outside this context can often result in little improvement or may even act to worsen local conditions. The following summary, then, provides recommendations to planners for incorporating a technical context into the work of prioritization of watershed management tasks.

WATERSHED MANAGEMENT PRIORITIZATION

Recommendations presented here reflect what might be an optimum approach to prioritization if money and political will were no object. As this is not likely to be the case, this guidance would be best considered a flexible, technically-based framework from which to begin the planning process.

The prioritization method summarized below reflects an implicit hierarchy of impacts on watershed functionality, listed in order from the most to least significant impact factor:

- Storm water hydraulics (watershed runoff),
- Riparian zone modification or loss,
- Channel modification and armoring, and
- Pollutant generation.

The interrelationship between these impact factors supports the prioritization approach outlined below and tends to direct the location and timing of proposed management projects as well. This prioritization approach is presented below as a series of conceptual management plan activities that are placed in a geographic and scheduling context for the whole watershed. In the following text, the management activities and their individual spatial priorities are presented in order from highest to lowest precedence for incorporation as watershed management targets.

PRIORITY 1: ACQUIRE AND ENHANCE RIPARIAN ZONES

A stream without a riparian zone can never be much more than a drainageway (a low-functioning one at that). A high-level of channel quality cannot exist without a good riparian zone. Riparian zones offer a wide range of economic opportunities for the community as well as for the proper functioning of the stream itself. Ultimately the replacement value of a riparian zone is also very high—a natural riparian zone cannot easily be restored (a wetland is not easily 'unfilled'). Given this, acquisition and management of riparian zone land is perhaps the highest technical priority in any watershed management program.

SPATIAL PRIORITIES:

- **Set Areawide Setback Controls**—all streams no matter their size provide profound and varied service to the community as a whole. The continuity and integrity of riparian zones is fundamental to a stream's capability to provide those services. As a result, establishment, implementation and enforcement of effective setbacks designed to protect the riparian zone functionality and applied across the whole watershed are paramount watershed management activities.
- **Enhance Zones Along Upstream Reaches—**riparian zones have the most effect on smaller stream features and are most critical to the control of in-stream erosion resulting from storm water runoff entering these features. Identification and control of riparian zones along these small headwater features is crucial to application of effective management practices to all downstream reaches.
- **Enhance Zone Continuity—**riparian zones provide the most functional value and opportunities when they exist as continuous corridors. At the smaller scales typical of Anchorage, connecting existing nodes will typically greatly increase functional value of the overall riparian zone as well as of the individual nodes.
- **Acquire Zones Near Major Outfalls—** a few large outfall basins often discharge most of the storm water flow and pollutants from a drainage. Riparian zones provide either natural treatment opportunities (e.g., wetlands) or space in which to construct treatment controls. Supergroup discussions in MOA watershed catalogs provide information on candidate outfalls and groups of outfalls.
- **Acquire Zones Across Wetlands and Lowlands—**wetlands and lowlands generally have high functional value and offer the most opportunities for storm water runoff control (at the least dollar acquisition cost).
- **Acquire Zones Across Public Land—**public land is generally easier to acquire or to dedicate with the least immediate dollar cost.

PRIORITY 2: APPLY SOURCE STORM WATER RUNOFF CONTROLS

The hydraulic effects of storm water runoff, magnified by urbanization, rapidly undermine the biologic functionality of a stream and increases in-stream flooding, erosion and sedimentation problems. Without hydraulic controls, the flow energy periodically flushed from urban areas will become the second most important factor in diminished services and flood problems along even the most robust of natural (or even armored) stream channels. The choice becomes one of either controlling storm water hydraulics or continuously armoring all urban streams. These hydraulic effects are best controlled at the source, and serve to control pollutants as well. Controls can be applied at the 'source' very efficiently (provide the 'most bang for the buck'), at very low cost to the overall community, and with minimal capital layout from the government. The magnitude of this problem and the economy of the solution make this the second most important element in a watershed management program.

SPATIAL PRIORITIES:

- **Control Upstream Basins—**for heavily urbanized watersheds and channelized streams, energy from, or the energetic effects of, storm water runoff is easily transmitted downstream. By and large, controlling upstream effects as a first step makes it easier (or for that matter even possible) to correct downstream problems. Starting at the upstream 'tips' of a branching stream network and working down to the main stem both in designing and implementing management practices will lead to effective and efficient systems. Practically, some placement of controls, bank erosion control for example, may be required along lower reaches but should be limited and minimized to that necessary for protection of critical areas and structures.
- **Control Larger Basins—**put out the big fires first. For any given drainage or watershed, (starting as far as possible upstream) pick the biggest problem basin (usually this means the basin with the largest area of directly connected impervious surface).
- **Control New- and Re-Development—**any land development presents opportunities to both prevent and correct watershed problems. Conversely, drainage and transportation infrastructure typically has a salvage life of 20 to 50 years so that once done it is very difficult to un-do. This is particularly a problem for drainage and flood structures where vertical elevations of structures in one development can severely limit what is possible downstream.
- **Control Public and Commercial Parking and Roofs—**these features are often connected through pipes and ditches to a single outfall and frequently add up to a big hydraulic and pollutant punch at a single point along a receiving water. However, the facilities themselves are also typically managed by organizations that may be more responsive to putting controls in place than individual homeowners and may be more easily inspected for management performance.

PRIORITY 3: APPLY SELECT POLLUTANT SOURCE CONTROLS

Studies at Anchorage and across the nation show that source controls are several orders of magnitude more effective and several orders of magnitude cheaper than controls applied at the end-of-pipe (EOP). For example, at Anchorage a pound of dirt costs 5¢ to sweep up and 10-100 to trap in an EOP grit separator (those dollar signs are *not* a typo error). These leads to a fundamental watershed management priority: control at the source first and second and third, and control at the EOP only as the (very) last resort.

SPATIAL PRIORITIES:

- **Apply Residential Landuse Controls—**these landuse types, particularly in denser urbanized areas, are likely responsible as a group for the most significant fraction of pathogens that are discharged through Municipal storm pipes. Lawns and driveways are also significant contributers to runoff volume. However control of both the hydraulic and pollutant impacts from residential features is very inexpensive when addressed on a lot by lot basis, making these features a priority target for control.
- **Apply Areawide Street and Parking Source Controls—**Streets and parking lots are a primary source of pollutants. Source control for these features includes material uses as well as material handling practices.

PRIORITY 4: APPLY SELECT EOP CONTROLS

Though source controls represent priority methodologies, occasionally opportunities exist to apply cost-effective end-of-pipe controls. At Anchorage this particularly arises where the presence of natural wetlands may allow use of these features to help manage storm water hydraulics and pollutants.

SPATIAL PRIORITIES:

- **PreTreatment at Wetland Outfalls—**use of natural wetlands dramatically reduces storm water treatment costs and generally benefits overall wetland functionality through maintenance of wetland hydration. Usually storm flows are purposefully bypassed around wetlands at Anchorage. On the occasion that they are discharged to wetlands it is often without proper pre-treatment. These instances provide relatively inexpensive opportunities to improve water quality and reduce impacts to the receiving wetland features.
- **Outfall Connection to Wetlands—**Most frequently at Anchorage storm drainage systems are purposefully disconnected from adjacent wetlands, increasing impacts to receiving streams (through erosion and hydraulicking) and to the wetlands (through dehydration). Assessment and reconnection where feasible of these storm flows will yield optimum cost/margin.
- **Detention Basins At Larger Basins—**EOP systems are expensive with very little economy of scale and so the larger the treated area, the better. Although preferably these systems are also best placed at upstream locations first, availability of suitable riparian space significantly limits opportunities.

PRIORITY 5: ENHANCE AND PROTECT NEAR-STREAM ZONES

From a technical perspective, there is a clear distinction between priorities for enhancement and acquisition of riparian zone area (a first priority) and enhancement of near-stream zones (a lower priority). An enhanced near-stream zone can't exist without a functional and appropriately sized riparian zone and it will not last as a naturally dynamic and high quality biologic feature (with or without armored banks) without some reasonable control of flood flow hydraulics. Thus priorities for successful implementation of near-stream and channel enhancements must be scheduled to match completion of a preceding foundation of storm water runoff and riparian zone objectives. Nevertheless, stream enhancement for heavily urbanized stream reaches is often an ultimate objective and useful as a much more readily recognized surrogate for success in achieving larger watershed management goals. To ensure economy and maximum stream functionality, long-term watershed management goals should prioritize near-stream restoration and enhancement projects that are designed to function at a dynamic equilibrium; i.e., a condition that designs for and accepts natural stream meander, erosion and sedimentation. Of course, given that larger watershed management effects will take many years to achieve and given the need to protect fixed urban structures, interim channel management projects used to protect critical structures will inevitably become necessary. From a standpoint of long-term economy, only in these instances should armor be used to maintain a fixed stream alignment. Careful policies and design standards should be established to identify how these projects will be identified and prioritized, how armored boundaries of channel projects must be joined (both vertically and horizontally) to more mobile up- and down-stream stream reaches , and how projects are to be designed to minimize impacts on overall stream functionality.

SPATIAL PRIORITIES:

- **Enhance Reaches With Functional Riparian Zones—**channel enhancement to achieve naturally dynamic stream function requires riparian zone enhancement—the latter *must* precede the former. Thus prioritization for channel enhancement has a simple prerequisite—look for reaches with adequate riparian zone.
- **Enhance Zones Along Upstream Reaches**—channel improvements installed at smaller headwater stream features will be less impacted in terms of design and maintenance by upstream watershed area problems than similar projects along downstream reaches. There is also the added benefit that restoration of smaller upstream reaches will represent reduced overall investments in design and construction costs and will likely be at scales that can encourage local residents' participation. Riparian zone discussions in MOA watershed catalogs identify candidate locations for these types of projects.
- **Enhance Stream Crossings—**crossings represent a bagful of problems for stream channels at Anchorage. They are often the source of increased stream icings and bank and channel erosion and sedimentation (often all at the same crossing), and, as critical impediments to passage to fish, limit biotic productivity for whole streams. Planning and prioritization for stream crossing enhancements is a difficult task because it may be approached quite differently depending upon the goals. Most important to watershed management prioritization may be establishment of channel and crossing design standards. Whereas current design criteria focus on whether a structure will convey and is resistant to a particular flood flow, watershed management may as well be interested in the degree to which the structure will have a limited impact on the functionality of the stream as a whole (and at distances other than just in the immediate vicinity of the structure). In any event prioritization of stream crossing enhancement would benefit first from establishment of an overall stream riparian zone and channel enhancement plan for whole stream features (starting up-stream).

- **Protect Critical Structures—**there are many structures critical to living in an urban environment and these require protection from flood and other stream impacts. Channel armoring may be required to protect these structures but is inevitably purchased at the price of a natural stream environment and at the cost of increased liability, maintenance, and impacts to up- and down-stream stream functionality.

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Department of Public Works
Municipality of Anchorage

Prepared by:

Scott R Wheaton, Watershed Scientist
Watershed Management Services Division