SEGMENT 15:
A UNIQUE WATERSHED

by

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INTRODUCTION

It has become very fashionable in the past few years to embrace the watershed approach to achieve goals for clean water. Scientists, engineers, environmentalists, and regulators have all looked to **watershed** management as a panacea to solving **water** management problems in the 21st Century. A new clean water act known as the Watershed Bill, or Watershed Act, went before Congress in 1994. While it did not pass, it is certain to come up before Congress again this year. Included in pending regulations are biological criteria in which the biota of one watershed are compared to another and the health of a watershed is determined by the biota it supports. It is very important to be pro-active in response to these pending regulations. We must understand how the pending regulations will affect the Metro District and how Segment 15 (***Figure 1***) of the South Platte River (South Platte) will fit into this watershed event.

A little over two years ago, I came to work for the Metro District as Water Quality Officer. I brought with me almost 30 years of work experience on watersheds and rivers in Wisconsin, Minnesota, Illinois, Indiana, and the Southeastern United States. In the past two years, it has become very apparent to me that the South Platte is unlike any other river I have worked on. This river has a very *unique* watershed--Segment 15, which extends from just above the District's discharge to a point nearly 26 miles downstream. The *uniqueness* of this watershed must not be lost in a "one-size-fits-all" watershed approach to nationwide water quality problems. Regional and local issues, unique physical and biologic characteristics, and historical use must preclude a "Made in Washington" watershed law that will have considerable effect on the District's future.

With this in mind, the following presentation was prepared along with a series of slides to point out to the regulators that Segment 15 of the South Platte is, indeed, a *unique* watershed. This *unique* watershed is a Colorado resource, and the Metro District is working with this resource to improve conditions in an attempt to make the South Platte better. Efforts to "pigeonhole" this watershed into a stereotyped watershed approach might do little to improve the water quality of the South Platte, and could indeed stifle efforts to provide innovative solutions which would improve the quality of this resource for future generations. Below is an abstract of the presentation, which follows.

Watersheds are defined as networks of channels through which water always flows from a higher to a lower elevation. The perimeter of a watershed is called a divide. In watersheds, flow always increases as you journey downstream and there is an increase in stream order. If this is the case, then there is a considerable portion of the South Platte River that does not have the attributes of a watershed and should not be treated as such. Integrated management of and in the South Platte Basin must recognize the uniqueness of the features of Segment 15. Attempts should not be made to apply models, concepts, comparisons, loads, and laws designed for "natural" systems to this segment of the river. If we wish to manage this resource as an integrated system, we first must recognize it for what it is, and not try to make it conform to a hypothetical stereotype watershed. Direction given by water management groups, Congress, urban and agricultural water owners/users, outdoor recreationists, and government agencies must be tempered with the knowledge that this watershed (?) is unique. During most of the year, a good portion of the water in Segment 15 comes from west of the Continental Divide and crosses watershed boundaries as it is transmitted through tunnels, pipes, interceptors, pump stations, and reservoirs. The South Platte River dies and is reborn again through a modern wastewater treatment facility. Stream order for this segment is not defined by the number of tributaries connecting to the main channel, rather by the size of lines connecting to main interceptors. Flow, for the most part, is not determined by precipitation, rather by urban and agricultural usage and demand. Daily tidal flows, rather than seasonal flows, regulate the nutrient load of the river. Downsteam irrigation diversions withdraw more water than is contributed by mainstem tributaries. In seeking an integrated approach to watershed management in the South Platte Basin, we must not forget it is not a natural river or watershed.

WATERSHEDS

What is a watershed? The dictionary definition of a watershed is "a ridge dividing one drainage area from another or dividing the whole region or area contributing to the supply of water in a river or lake." In other words, watersheds have a divide that surrounds them, and large watersheds are made up of several smaller watersheds. Water in a watershed flows downhill to a base level, as does the South Platte River, which joins the North Platte River to form the Platte River that flows into the Missouri River. The Missouri in turn flows into the Mississippi River, and the Mississippi flows into the Gulf of Mexico at sea level. This exemplifies how watersheds always try to achieve a base level. The South Platte watershed begins at the Continental Divide. Snowmelt and rainfall reach the ground and form tiny rivulets coalescing to form tributaries that join together as the water flows downhill. As the South Platte watershed enlarges, it eventually encompasses the Metro District.

Watersheds have certain characteristic attributes that can be compared among and between other watersheds. One specific characteristic is stream order. (***Figure 2***) The smallest watershed is called a first-order watershed and includes a first-order stream. First-order streams are young streams which have no tributaries. One first-order stream can converge with another to create a second-order stream, that second-order stream converges with another to create a third-order stream, and so forth. Each first-, second-, and third-order stream that drains a watershed can be compared with other similarly-sized streams and watersheds.

Streams and watersheds of each order can be compared for nutrient content, flow, size, fluctuation, salt content, particle size of organic constituents, and other features. Below is a review of the stream characteristics of watersheds of different orders which might be encountered on the South Platte:

First-Order Stream Characteristics (Example: a freshet coming off snowmelt)

- Might dry up (freeze up) every 24 hours
- Fluctuates widely in the amount of flow
- Dependent upon snowmelt, rainfall, or a spring
- Firm or solid base (often solid rock)
- Large particle size of organic materials in stream
- Not self-supporting; nutrients come primarily from outside the stream
- Usually has a steep gradient

Second-Order Stream Characteristics (Example: small mountain stream)

- Created from two first-order streams converging
- Gradient is still steep with firm substrate (often large rock)
- Large particle-size organic matter instream
- Not self-supporting; nutrients come primarily from outside the stream

* Biota adapted to make use of nutrients which come from outside the stream and feed on larger particles of organic matter

* Extremes in daily/seasonal fluctuation of flow

Third-Order Stream Characteristics (Example: classic brook trout stream)

* Situated in a flatter area or gentle slope

* Smaller particle sizes carried by the current

* More stable environment; daily temperature and flow fluctuations less extreme

* Increased amounts of salts and dissolved materials

* Greater drainage area

Fourth-Order Stream Characteristics (Example: Clear Creek, Golden, Colorado)

* Warmer water temperatures; flow and temperature fluctuations less extreme

* More nutrients from within the stream; more dissolved nutrients and salts present

* Smaller particle size of nutrients and organic materials in the current

* Smaller substrate size (cobble to gravel to sand)

* Larger drainage area

Fifth-Order Stream Characteristics (two fourth-order streams converging)

* Stable daily flows

* More dissolved nutrients with organic matter

* Warmer water temperatures

* Finer substrates (sand and finer soil particles)

* Most nutrients come from within the stream

Watersheds are affected by topography and have characteristic drainage patterns (***Figure 3***). They may be dendritic (branch-like), rectangular (streams converge at 90^{o} angles), radial (streams radiate away from the center), centripetal (streams converge in a low spot), trellised (ladder-like), parallel (equal distance apart), annular (ring-like), or deranged (with ponds and interconnected channels).

The drainage patterns in a watershed are usually a function of the geologic formation being drained, its age, and its hardness. Most typical watersheds are dendritic. The upper reaches of the South Platte watershed can be considered typically deranged. Along the Continental Divide is a series of alpine meadow lakes and beaver ponds connected by small streams which form the deranged drainage pattern.

Figure 3

Comparisons can be made between different watersheds by comparing the log of the number of first-order, second-order, third-order, fourth-order, and fifth-order streams in each watershed. By comparing slopes of the resulting stream bifurcation ratios (***Figure 4***), the watershed worker can numerically express how similar or different the watersheds might be.

Figure 4

As watersheds have many attributes in common, it is possible to compare watersheds by comparing their various attributes. There are 11 attributes that are typical of most watersheds:

1. All typical watersheds are surrounded by a divide.
2. In all typical watersheds, water flows downhill.
3. Watersheds have order.
4. Turbidity and color increase as you go downstream.
5. Discharge in a watershed increases as the watershed size increases and more and more streams converge.
6. The amount of water in watersheds is determined by the miles drained, the precipitation, infiltration, and runoff.
7. The water temperature increases further downstream in watersheds, as does the concentration of salts, solids, and nutrients.
8. Substrate size of the bottom materials decreases as does the amount of large particulate organic matter coming from outside the stream.
9. As higher stream order is obtained, materials carried in the water column are more likely to be either dissolved or a smaller particle size.
10. Gradient grows more gradual the farther a watershed is from its origin.
11. There is more stability, and less fluctuation of discharge in larger watersheds.

Watersheds also have biotic components and many studies have been made of the biological zonation of the plant and animal components in watersheds. In Europe, all watersheds are placed in basically four zones. These zones are distinguished by name (after characteristic fish/fauna) as follows:

Trout Zone	**A**rea of cold water and swift current
Grayling Zone	Less of a slope and warmer waters with more fish species
Barbel Zone	Includes such species as suckers and perch
Bream Zone	Warmer water and less gradient, with carp and many minnow species

I have worked for several years on a group of stream insects called caddis flies, a fairly small group of insects found in most watersheds. One particular family of these insects is known as the *Hydropsychidae*. Members of this family obtain food in streams and rivers by spinning small nets (not unlike a 1/4- to a 1/2-inch "mini" seines) perpendicular to the current. These nets entrap food particles delivered to them by the current, and the larvae clean the nets from an adjacent retreat. In the United States, there are five common genera of these insects: *Arctopsyche, Parapsysche, Hydropsyche, Cheumatopsyche,* and *Macronema.*

Each of these genera makes a net that is a little different than the others. The *Arctopsyche* make a relatively wide mesh net that looks almost like cheap gauze with rather large spaces between the silken strands, and are usually found only in first- and second-order watersheds (streamshed); the *Parapsyche* make a finer meshed net, and are in second- and third-order watersheds; the *Hydropsyche* and *Chuematopsyche* make a still finer-meshed net, and are present all the way down to very large watersheds (fifth-order and larger); and the *Macronema* make an extremely fine-meshed net, almost like a fine silk with microscopic mesh, and are generally restricted to streams and rivers with very fine particle sizes and high nutrient content (large rivers such as the Savannah, Mississippi, Missouri, and Ohio). By looking at the *Hydropsychidae*, it is possible to make judgments on and/or comparisons between watersheds.

Since the physical features, biological features, and the pollutant loadings of watersheds are so easily compared, it is only natural that the watershed management concepts are now being embraced by regulators as the next step in achieving our clean water goals. "Watershed management" and "watershed clean-up" are the latest buzz words. Everyone in the regulatory community has embraced the watershed approach (using separate acronyms). Some of the various programs/initiatives by the Environmental Protection Agency (EPA) directed at the watershed approach include:

Environmental Monitoring and Assessment Program (**EMAP**). Maps and compares water quality parameters by watershed nationwide.

Index of Biological Integrity (**IBI**). Compares the ratios of numbers and species of biological organisms in one watershed with those in a similar watershed to determine water quality.

Total Maximum Daily Loads (**TMDL**). Reflects the sum of all pollutant loadings which will not degrade a watershed below a designated use.

Use Attainability Analyses (**UAA**). Provides results in usage categories for like watersheds on different river systems.

The United States Geological Survey has also adopted the watershed approach, and its National Water Quality Assessment Program (**NAWQA**) develops comparisons between major watersheds in the United States. The U.S. Fish and Wildlife Service, Department of Agriculture, U. S. Forest Service, Soil Conservation Service, and even the Bureau of Land Management, have mandated that their personnel approach water quality issues from a comprehensive view of the watershed.

Well, you may be asking, what does this have to do with the Metro District and how we look at water quality? Let me give you some background on the watershed of the District's receiving water, which is known as Segment 15 of the South Platte River.

If you read the Water Resource Data Books, you will find that the South Platte is a major watershed in Colorado and its discharge (just above the Metro District) drains 3,884 square miles. The average discharge of the South Platte Segment 15 watershed at Henderson (a gauging station about 12 miles north of the District) is 402 cubic feet per second (cfs) (1992 data). These published data give the South Platte in Segment 15 some of the normal attributes of a typical watershed. A regulator may compare the attributes of this river segment to another one with a drainage area of about 4,000 square miles and an average discharge of about 400 cfs, and use the comparison for decision-making purposes. In doing so, the comparison would be like comparing apples to oranges. It cannot be done!

Segment 15 (***Figure 1***) originates just upstream of the Metro District and culminates 26 miles beyond, near Fort Lupton, Colorado. Unlike the waterflow in a typical watershed, which is the sum of the discharges of the various tributaries that contribute to the drainage, over 90 percent of the flow in Segment 15 for most of the year is due to the discharge from the District. Historically, the South Platte at Denver was an ephemeral stream.

Diaries of the early settlers describe how they had to dig in the sands at the confluence of Cherry Creek and the South Platte in order to obtain water for their horses. During the late summer, the South Platte watershed was nearly dry and consisted of a series of buffalo wallows. Theodore Talbot, on Freemont's second expedition, wrote of the water. . ."Here the buffalo come to drink and stand during the heat of the day, adding their own excrements to the already putrescent waters. This compound, warmed for weeks by the blazing sun, makes a drink palatable to one suffering from intense thirst." During late spring, the South Platte became a raging torrent of snowmelt.

Today, the South Platte flows 365 days a year. It is a highly regulated watershed. There is no longer a natural flow as the stream is affected by transmountain diversions, storage and flood-control reservoirs, power developments, and diversions for irrigation.

The South Platte in Segment 15 is no longer a natural watershed. During most of the year, over half of the water discharged into the South Platte does not even come from upstream within the basin. Over 51 percent of Denver's water comes from the other side of the Continental Divide. Other municipalities which contribute water to Segment 15 through the Metro District's discharge receive a considerable portion of their water from across the Continental Divide or from the Arkansas River, Clear Creek, and Sand Creek Basins. The characteristics of the water from these watersheds is different from that which naturally occurred in the South Platte basin.

The Dillon Reservoir is across the Continental Divide in the Blue River watershed. Upstream of this reservoir is the Climax Mine, the largest molybdendum mine in the world. Water from the Dillon Reservoir is diverted across the Continental Divide through the Harold Roberts Tunnel as part of Denver's water supply system. Water goes through this water supply system, and is used and then finally treated at the Metro District's plant before being discharged into the South Platte. Ironically, even though there are no major deposits of molybdenum in the South Platte basin, the Metro District's biosolids contain traces of this metal.

Some of the waters which comprise the flow in Segment 15 come through the Moffat Tunnel from the Colorado Basin, and some come from the Taylor, Roaring Fork, Eagle, and Arkansas River basins through the Homestake pipeline. Most of the water which provides the flow in Segment 15 of the South Platte is treated and used as potable water by municipalities before being discharged at the Metro District plant.

The flow in Segment 15 is not the result of topography, with a normal watershed drainage pattern and typical stream channels, but instead flows through pipes, tunnels, and pumps. Most of the flow is not determined by infiltration and precipitation in the basin. Instead, it is determined by the area served by the District, the population density, and the water used by people in the service area.

Upstream of the Metro District plant at the beginning of Segment 15, the Burlington/O'Brian Canal, a major agricultural diversion, removes most of the water from the South Platte. The exception is when there is a downstream call on water by other ditch companies with more senior rights which cannot be met by the District's discharge, downstream tributaries, and groundwater infiltration. Therefore, for most of the year there is minimal flow upstream of the District plant, which discharges into an almost dry river bed. This dry river bed becomes the South Platte River, not unlike a huge spring at the origin of a first-order stream.

Unlike the water coming from a huge spring in a first-order watershed, the water that is discharged contains dissolved nutrients, is warmed from treatment, and contains dissolved solids and finer particulate matter more typical of a large warmwater watershed. The modern wastewater treatment facilities of the Metro District plant can be compared to an enormous deranged drainage pattern. In retrospect, the discharge of Segment 15 is not due to the accession of tributaries, but due to the following:

- Size of pipes coming together
- Rate of municipal use
- Time of day

- Urban runoff
- Releases from Chatfield, Cherry Creek, and Bear Creek Reservoirs
- Downstream demand during the summer months (flows downstream decrease)

The flows of the South Platte below the Metro District are equivalent to the District's discharge (***Figures 5a and 5b***). One can even determine the time of day, as well as the day of the week, by looking closely at the flow records of the South Platte. In ***Figure 5***, the Sunday afternoon discharge (which occurred on October 4) did not have the late afternoon peak of the discharge during the other weekdays. This is due to less cleaning in the industries, less cooking (dishwashing) in the homes on Sunday evenings, and subsequently less water usage and discharge.

Figure 5(a) ***Figure 5(b)***

Streams that normally would flow into Segment 15 to provide flow to the watershed are no longer free-flowing streams, and are all highly regulated. Streams such as Clear Creek at Golden, Colorado (which discharges into the South Platte in Segment 15 and had a mean average discharge of 160 cfs during the 1992 water year) had flows of less than 5 cfs by the time it reached the South Platte during the late summer. In fact, during most of the summer months, the actual flow of the South Platte in Segment 15 decreases downstream of the Metro District. Most of the water is taken from the stream for irrigation use. Even with the irrigation withdrawals, the flow throughout Segment 15 varies with the discharge of the District.

Unlike a typical fourth-order (or greater) watershed with nearly constant daily flows, Segment 15 flows vary daily by over 200 cfs. In a normal watershed, the daily flows would be the sum of the tributary flows as the water moved downhill. In Segment 15, the flow is first pumped, filtered, and disinfected as potable water, then drained, flushed, and discharged as grey water, and finally pumped again through the District's facilities and into Segment 15.

The origin of this effluent-dominated watershed known as Segment I5 is not the mountains, but rather the skyscrapers and waterclosets of the Denver Metropolitan area. The watershed order of Segment 15 (the first-, second-, third-, fourth-, and fifth-order streams) consists of the house sewer, the lateral, the main, the interceptor, and the trunk lines which come together prior to being treated and discharged into the South Platte. Flows of the South Platte consist mainly of discharge released by the Metro District.

Western water law has a more significant effect on the watershed called Segment 15 than all of the climatic, topographic, and physiographic factors which determine discharge in a normal watershed. Upstream of the Metro District, most of the water in the South Platte has been diverted for agricultural use at the Burlington/O'Brian canal. The following senior water rights in cubic feet per second (cfs) exist downstream of Metro:

Water Right	Amount (cfs)	Year Granted
Fulton Ditch	79.70	1865
	74.25	1876
	50.23	1879
	204.18	
Brantner Ditch	29.77	1860
	5.90	1863
	12.18	1872
	63.30	1881
	111.15	

Brighton	22.22	1863
	22.58	1871
	44.80	
McCanne	40.00	1895
Lupton Short Line	72.00	1892
Lupton Bottoms	47.70	1863
	10.00	1871
	92.87	1873
	150.57	
TOTAL	**622.70 cfs**	

There were over 620 cfs of surface water rights appropriated in Segment 15 prior to 1900. Today the surface water that flows into Segment 15 during the late irrigation season is nowhere near that amount. Upstream of the Metro District, the South Platte may have a flow of about 4 cfs, and the District will discharge about 230 cfs, Clear Creek will discharge about another 4 cfs, Sand Creek about 14 cfs, and Big Dry Creek about 10 cfs, for a total of about 262 cfs. Discharge (or flow out of Segment 15) will amount to -100 cfs at the Fulton ditch, -50 cfs at the Brantner, -27 cfs at the Brighton, -75 cfs at Lupton Bottoms, and -10 cfs at the others, for a total of -262 cfs. (Remember, this is out of a total of 622.7 cfs appropriated prior to 1900, and current withdrawals could be considerably greater.) Therefore, most of the surface water discharged into Segment 15 never gets to the end of the segment. Most of the water is utilized for agricultural purposes. The nutrients it contains are applied with the water to sustain row crops growing in adjacent counties.

In a typical watershed, surface waters come together to form a growing stream. Although some discharges in Segment 15 add to the flow of the stream, the majority of the surface water is drawn away from the stream, and discharge actually decreases downstream. Water branches away from the stream through irrigation canals. The situation could become more critical in the future as downstream water rights are bought up by upstream users and less flow is allowed to reach Segment 15.

The discharge from the Metro District is the resource that sustains Segment 15. During some recent experiments, a portion of the District's discharge was diverted to the Burlington/O'Brian canal to determine what might happen if the nutrients (specifically ammonia) from the District's discharge was diverted from Segment 15 for irrigation purposes, and if this diversion of nutrients would improve the water quality of Segment 15.

By removing water quantity from Segment 15 (even though it was high in nutrients), the net effect was to decrease water quality in the segment (due in part to less flow, less natural re-aeration, increased temperatures, and less assimilative capacity). Secondary channels of the river, which provided habitat for literally hundreds of minnows in the weeks prior to the diversion, virtually dried up and became stagnant pools, with daytime temperatures too hot (over 100°F) for any native fish species.

Segment 15 is an effluent-dominated stream that does not have the characteristics of a normal watershed. H. B. N. Hynes, a prominent ecologist and pollution biologist, makes a statement in his text, *The Ecology of Running Waters,* "The more the conditions of a watershed deviate from the normal, and hence from the normal optima of most species, the smaller the number of species which occur there, and the greater the number of individuals of each species which do occur." In other words, the biota in a watershed which deviates from the normal cannot be expected to be comparable to a normal watershed in numbers of species present and/or numbers of individuals of each species present.

Yet, the present and proposed national criteria (the federal "one-size-fits-all" approach) does not consider the *uniqueness* of each watershed. Pristine reference watersheds are utilized to establish baseline (reference-reach) conditions with which comparisons are to be made. These regulations are so intent on describing and "fixing" a preconceived problem, they fail to recognize a resource and, in doing so, may ruin it. Segment 15 is a resource, a watershed that deviates far from the normal, and the biota of this resource cannot be expected to be compared to a normal watershed. It will not meet, and cannot be expected to meet, proposed watershed criteria.

Some people have described Segment 15 as watercloset watershed. Even though its flow is due to the wastewater from over one-third of Colorado's population, its *uniqueness* provides this same population of urban residents with a resource. This segment is a resource that provides unique opportunities to walk, jog, or bike along the trails which line its riparian corridor.

This treasure of the high desert also provides special opportunities for amateur ornithologists and photographers as some of the largest overwintering duck populations along the Front Range are to be found here. Over 12,000 ducks have been observed overwintering in less than a 25-block reach below the Metro District discharge, including several rare species. Segment 15 waters also support a diverse macroinvertebrate and fish community comparable to other Front Range streams.

It is a valuable resource to the urban population, as well as a source of irrigation water to the downstream agricultural communities. It is estimated that the water which leaves Segment I5 is recycled for agricultural uses in Colorado at least seven times before it reaches Nebraska. Segment 15 is truly a *unique* resource, as well as being a *unique* watershed.

If Segment 15 is such a *unique* resource, then what is the problem with trying to make it better? Nothing! The problem is trying to make it something it is not and will never be. . .a typical watershed. We can spend millions and millions of dollars on steel and concrete to try to make a high-desert, effluent-dominated, effluent-dependent stream fit our stereotype of a typical fifth-order watershed, but we cannot make it typical.

The area it drains is a combination of high-desert and the bowels of a major city. Populations, diversions (both transmountain and irrigation), precipitation, saturation, production, nutrients, irrigation, daily flows and demands, ultraviolet light, elevation, and hundreds of other factors make this watershed *unique*.

Rather than trying to make this watershed something it is not, let's recognize it for what it is--an urban resource--and look at ways to improve this resource. We must make sure that the proposed new laws regarding our nation's watersheds have the flexibility to recognize and address not only existing problems, but also the benefits of a *unique* watershed such as **Segment 15**.

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