APPENDIX A

Memorandum – Impervious Area Memo

Tables

A-1 – River Cross Section Summary

INTEROFFICE MEMORANDUM

TO: SARA MARXEN, CHRIS PITRE

FROM: STAN MILLER

SUBJECT: IMPERVIOUS AREA INFILTRATION; IRRIGATED EVAPOTRANSPIRATION AND WATER USE

DATE: FEBRUARY 12, 2004

CC:

I have done some general calculations on precipitation and runoff characteristics for Spokane to get an idea of how to deal with urban area recharge from impervious areas. The results are broken into three categories: runoff from impervious areas served by drywells, impervious areas served by infiltration swales with overflow drywells and natural recharge from precipitation minus evapotranspiration. There are two sets of numbers. The lower number represents an annual average precipitation of 16 inches; the higher number represents an annual average of 22 inches per year.

Case 1. Runoff from impervious area direct to drywell

Assumptions: Initial abstraction of precipitation is 0.03 inch. (The storm water quality study we are conducting is confirming this generally accepted number for Spokane.)

Runoff reaching drywells is injected below the root zone. ET is zero.

Increased precipitation in the region occurs as a result of orographic lifting of air masses. The number of events does not change over the region; the total precipitation in each event is proportionally increased.

The effect of snow accumulation from several storms on the amount of abstraction is insignificant.

Average annual precipitation	16.0 inch	22.0 inch
Precipitation occurring in events 0.03 inch or less.	0.55 inch	0.55 inch
Precipitation abstracted from events larger than 0.03 in.	2.45 inches	2.45 inches
Annual Recharge	13.0 inches	19.0 inches

Case 2. Infiltration swale with overflow to drywell

Assumptions: The Thornthwaite-Mather method is appropriate for use in the Spokane area.

Soil moisture in the root zone does not completely “dry out” between runoff events.

No supplemental irrigation is provided to swale vegetation.

Initial abstraction of precipitation on impervious surfaces is 0.03 inch. (The storm water quality study we are conducting is confirming this generally accepted number for Spokane.)

Increased precipitation in the region occurs as a result of orographic lifting of air masses. The number of events does not change over the region; the total precipitation in each event is proportionally increased.

The effect of snow accumulation from several storms on the amount of abstraction is insignificant.

Average annual precipitation	16.0 inches	22.0 inches
Annual Runoff to swale	144 inches	198 inches
PET / AET	24.9 inches	24.9 inches
Average annual recharge through swale	119 inches	172 inches
Average annual recharge normalized for site	13.2 inches	19.1 inches

Case 3. Natural recharge from precipitation on vegetated areas

Assumptions: The Thornthwaite-Mather method is appropriate for use in the Spokane area.

Average Annual Precipitation	16.0 inches	22.0 inches
Potential ET	24.9 inches	24.9 inches
Actual ET	12.8 inches	14.2 inches
Annual Recharge	4.6 inches	7.6 inches

A note on precipitation distribution: In the statistical data base used to generate the runoff values, the percentage of runoff associated with small events, events < 0.03 inches does not appear to vary with season. Therefore, the amount of recharge for any given time period, say month, can be scaled directly from the annual recharge value by relating to the percentage of precipitation occurring during the desired period. The recharge occurring during a period receiving 10% of the annual precipitation is 10% of the annual recharge.

Land Use, Impervious Area and Drywell number conversions.

Use the following assumptions to estimate the amount of impervious area associated with the drywell distribution in areas where there is an inventory. Where only the land use associated with a parcel is known use these relationships to derive impervious area. Combine the impervious area calculated from drywell numbers and land use relationships to arrive at a total impervious area value. Use this total to estimate recharge.

For example: In a given grid element (1 kilometer square – about 247 acres) in the model the Spokane County drywell inventory shows 65 regular drywells 10 drywells with pretreatment (located in infiltration swales) and is composed of 65 % residential and 35% commercial / business / office uses. The area receives 16 inches precip. per year.

Drywells both with and with out pretreatment recharge at the rate of about 13 inches per year. Each of the drywells drains 15,000 square feet for a total of 25.82 acres impervious. At 13 inches of runoff this yields 27.97 acre-feet of runoff per year.

As the area is in the drywell inventory area, it is assumed that all of the drywells associated with the residential use are in the streets and are accounted for by the inventory.

With 35% of the site dedicated to land uses assumed to have 85% impervious area, there is an additional 64.84 acres of impervious area. This will produce an additional 70.02 acre-feet of runoff per year.

Note the significance of the impervious area in generating aquifer recharge. If this parcel were Open Space covered with vegetation and not irrigated the recharge rate would be about 4.6 inches per year. This yields about 94.7 acre-feet of recharge per year. The impervious area, from the site, accounting for about 55% of the land, generates 92.8 acre-feet of recharge per year.

Drywell vs. Impervious Area

Spokane County type A drywells are approver to receive 0.6 cfs maximum runoff flow; type B drywells are approved for 1.0 cfs. As the installation cost of a type B drywell is effectively the same as a type A drywell and the cost of the type B unit is only slightly more than a type A drywell, most installations have type B units. Based on typical site conditions and precipitation in the Spokane area, it requires between 10 and 15 thousand square feet of impervious area to generate 1.0 cfs for the runoff management design storm.

For purposes of watershed planning it will be assumed that each drywell represents a drainage area of 15,000 square feet. Conversely, when estimating drywell numbers it will be assumed that there is one drywell for each 15,000 square feet of impervious area.

Land Use vs. Impervious Area

Residential use: A traditional rectangular street grid generally serves the urbanized Spokane area. A typical city block encompasses a 330 by 660 foot rectangle to create a 5 acre parcel. Residential streets range from 24 to 40 feet wide; the typical street is about 30 feet. About half the streets are accompanied by a 4 to 6 foot wide sidewalk. If we associate a 20foot impervious section with the street frontage around each block (one-half the street width) the 5-acre parcel is 18% impervious.

While runoff from the average 3000 square foot building and driveway coverage is to be maintained on site, typically at least some of the driveway runoff enters the street. The average effective impervious area of residential land is thus about 20%. Given the large ratio of pervious to impervious area in the off street portion of residential areas there are rarely any drywells found off the street.

Commercial / Business / Office uses: The value of land in these classifications tends to see the parcels developed to the extent allowed in the zoning code. For the last several decades, stormwater and landscaping requirements have limited total coverage to 85% to 90%. A portion of the impervious area in most parcels does not drain to drywells or infiltration swales with drywells. It runs off to “open space.” Older parcels may have all or most of the parking area developed as semi-permeable gravel parking. Air quality considerations have led to the paving of most parking spaces. Blocks containing these uses are generally large than those dedicated to residential development; the impervious area associated with streets is thus a bit smaller on a percentage basis. Assuming a nominal 10% of runoff is not connected with drywells a conservative estimate for the impervious area of a commercial / business / office uses is 75%.

Industrial uses: The diverse nature of the facilities found associated with this land use makes establishing a norm difficult. Often large areas of building are associated with moderate areas of impervious parking and roadways. However, set back requirements, noise buffers landscaping and storm water management facilities and other "open space" uses reduce the percentage of impervious area. Given the relatively small amount of industrial land in Spokane the error associated with uncertainty in this estimate should not be too great. A 50% impervious area is suitable for this land use. However, the typically large amount of vacant area in industrial parcels allows for the general dispersal of some runoff and lowers the effective impervious area to about 40%.

River Cross Section Summary

River	Cross Section Name	Distance From Mouth (river mile)	Chainage (m)	Original Source	Cross Section Measure Date
Spokane River	Modeled Length: 107488 meters, 55.36 miles. Total Length: 111.6 miles				
	SR West Boundary	44.8	107488		No Cross Section
	SR - LSR Confluence	56.4	88770		No Cross Section
	SR blw Nine Mile Dam	57.8	86653	USGS/Historical	5/30/51
	Nine Mile Dam	58.1	86035	WADOE	4/17/01
	Bobs Nine Mile Reservoir - I	58.3	85853	USGS/Historical	5/30/51
	Bobs Nine Mile Reservoir- H	58.5	85451	WADOE	4/17/01
	Bobs Nine Mile Reservoir - G	58.7	85097	WADOE	4/17/01
	Bobs Nine Mile Reservoir - F	59.2	84289	WADOE	4/17/01
	Bob's Nine Mile Reservoir - E	59.8	83412	WADOE	4/17/01
	Bobs Nine Mile Reservoir - D	60.8	81711	WADOE	4/17/01
	Bobs Nine Mile Reservoir - C	61.4	80826	WADOE	4/17/01
	SR abv Seven Mile Bridge	62.0	79890	USGS/Historical	5/31/52
	Bobs Nine Mile Reservoir- B	62.6	78933	WADOE	4/17/01
	Bobs Nine Mile Reservoir -A	63.2	77922	WADOE	4/17/01
	Downstream of Bowl and Pitcher Park Walk Br - FEMA	66.0	73436	FEMA	
	SR at Riverside State Park	66.0	73346	FEMA	
	SR FEMA15	66.1	73261	FEMA	
	SR FEMA 16	66.5	72646	FEMA	
	SR FEMA 17	66.8	72093	FEMA	
	SR downstream of Spokane WWTP	67.1	71540	FEMA	
	SR upstream of Spokane WWTP	67.6	70766	FEMA	
	SR FEMA 20	67.7	70651	FEMA	
	SR FEMA 21	68.0	70189	FEMA	
	SR at Fort Wright Br (TJ Meenach BR)	69.9	67085	FEMA	
	Hangman Creek Intersection	72.4	63160	USGS/Historical	4/5/73
	SR at Spokane, WA	72.9	62236	USGS/Historical	4/5/73
	Monroe St. Dam	74.1	60316	USGS/Historical	4/18/00
	Bobs Upper Falls Reservoi - S	74.4	59850	FEMA	
	Bobs Upper Falls Reservoir - R (Convention Center Foot Br)	74.6	59615	FEMA	
	Junction with North Channel and Upper Falls Dam	74.6	59517	FEMA	
	SR FEMA 24	74.7	59362	USGS/Historical	9/12/72
	Bobs Upper Falls Reservoir - Q (Division St. Bridge W. Side)	74.8	59193	WADOE	4/16/01
	SR downstream of Division St. Br	74.8	59186	FEMA	
	SR downstream of RR Br	75.4	58320	FEMA	
	SR downstream of Trent Rd. Br	75.5	58097	FEMA	
	SR upstream of Trent Rd. Br	75.5	58070	FEMA	
	SR downstream side of old "curved" Br (bridge repl	75.9	57431	FEMA	
	SR downstream side of 2nd Trent Rd. Bridge	76.0	57358	FEMA	
	SR downstream of 2nd RR Br	76.2	57038	FEMA	
	SR FEMA 32	76.4	56628	FEMA	
	SR downstream side of Mission St. Bridge	76.7	56168	FEMA	
	SR at Mission St.	76.7	56139	USGS/Historical	9/12/72
	SR FEMA 35	77.5	54801	FEMA	
	SR FEMA 36	77.7	54513	FEMA	
	SR at Green St. Bridge	78.1	53989	FEMA	
	SR FEMA 38	78.4	53444	FEMA	
	SR FEMA 39	79.1	52341	FEMA	
	SR FEMA 40	79.5	51660	FEMA	
	SR downstream of Upriver Dam Spillway (side channel)	80.0	50856	FEMA	
	Bobs Upriver Reservoir - P	80.1	50707	FEMA	
	Bobs Upriver Reseroir - O	80.5	50105	WADOE	4/18/01
	Bobs Upriver Reservoir - N	81.1	49056	WADOE	4/18/01

River Cross Section Summary

River	Cross Section Name	Distance From Mouth (river mile)	Chainage (m)	Original Source	Cross Section Measure Date
	Bobs Upriver Reservoir - M	81.7	48090	USGS/Historical	9/11/90
	Bobs Upriver Reservoir - L	82.4	46936	WADOE	4/18/01
	SR upstream of Argonne Rd Br and IEPC discharge	82.6	46619	USGS/Historical	9/11/90
	Bobs Upriver Reservoir - K	83.2	45776	USGS/Historical	9/11/90
	Bobs Upriver Reservoir - J (Centennial Trail Bridge)	84.0	44488	WADOE	4/18/01
	SR Island Br (Denny Ashlock Br on the Centennial T	84.3	43999	WADOE	4/18/01
	SR Trent Br	85.1	42693	USGS/Historical	2/8/73
	SR Sullivan Rd nr Trentwood (1972)	87.4	38947	USGS/Historical	2/8/73
	SR at Greenacres Waste	89.1	36245	USGS/Historical	8/16/73
	SR at Greenacres, WA Barker Rd.	90.1	34666	USGS/Historical	8/16/73
	SR abv Liberty Br nr Otis Orchard (Harvard Rd.	93.5	29136	USGS/Historical	4/21/00
	SR at State Line Br	96.0	25070	USGS/Historical	6/2/78
	SR at Post Falls, ID*	100.1	18428	USGS/Historical	6/2/78
Little Spokane River	Total Length: 79663 meters, 49.6 miles)				
	LSR nr Dartford at Painted Rocks (USGS 12431500)	3.9	73571	Spokane County	1/10/2002
	LSR btwn nr and at Dartford	7.5	67679		
	LSR at Dartford (USGS 12431000)	11.0	62138		1/10/2002
	LSR Spokane .2 miles blw Deadman (USGS 12430600)	12.3	59989	Spokane County	9/7/1977
	LSR at Buckeye (USGS 12430200)	16.6	53058	Spokane County	9/7/1977
	LSR 500ft blw Dragoon Creek (USGS12430150)	19.4	48534	Spokane County	9/6/1977
	LSR at Chattaroy	20.9	46154	Spokane County	7/24/1984
	LSR at Milan	21.1	45789		
	LSR at Deer Park Milan Rd (LS4)	27.9	34890	SCCD	9/2/1999
	LSR at Elk (USGS 12427000)	33.2	26365	Spokane County	10/17/1984
	LSR Chain Lake D.S.	36.4	17540	Lakes of Washington	
	LSR Chain Lake U.S.	38.1	15239	Lakes of Washington	
	LSR at Scotia (LS1)	42.7	11052	SCCD	1999
Dartford Creek	Total Length: 8044 meters, 5 miles				
Deadman Creek	Total Length: 34022 meters, 21.2 miles				
	Deadman Creek 30 yds below Little Deep Creek (LS6)	19.0	34094	SCCD	
	Deadman Creek (at Mead)	21.1	23461	Spokane County	2/25/1977
Dragoon Creek	Total Length: 44570 meters, 27.7 miles				
	Dragoon Creek at Crescent Road Bridge (LS5)	2.3	44214	SCCD	2001
Little Deep Creek	Total Length: 26,501 meters, 16.5 miles				

Note: River Mile is set to 0 at the mouth of the river. Chainage is set to 0 at the source of the river.