Technical Memorandum

CSO Beach Project GIS Analysis

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King County

Department of Natural Resources and Parks
Wastewater Treatment Division
King Street Center, KSC-NR-0512
201 South Jackson Street
Seattle, WA 98104

Executive Summary

King County's Wastewater Treatment Division (WTD) plans to control all its combined sewer overflow (CSO) locations to an average of no more than one overflow per year by 2030. Projects are under way to control four CSOs at Puget Sound beach locations: the Barton Pump Station, Murray Pump Station, South Magnolia Overflow Weir, and North Beach Pump Station. Construction is scheduled to be completed by 2013. In addition to storage and treatment options, demand management options, including green infrastructure techniques, are being investigated. The first step in evaluating the possibility and potential effectiveness of demand management options is to identify the sources of stormwater entering the combined sewer system (CSS).

Using King County and City of Seattle data for the CSS, municipal separate storm sewer system (MS4), and separate sanitary sewer systems, a GIS analysis was performed to calculate the acreages of impervious, pervious, and rooftop areas in parcels and impervious and pervious areas in rights of way that could contribute flow to the CSS. A series of assumptions were formulated to make up for incompleteness and inaccuracies in the GIS data; the assumptions were refined through comparisons with earlier modeling results. Field investigations helped quantify the level of confidence in the GIS data. The assumptions were applied to the GIS data to identify the probable destination of flow from identified acreages.

The basin-level results of the analysis are shown in the table below. These results will be used with flow monitoring data in a model to determine the amount of flow that needs to be controlled and the scale and location of selected CSO control techniques.

Roof Top, Impervious, and Pervious Acreage by Basin

	Barton	Murray	North Beach	South Magnolia
ROW				
Impervious	170	232	119	195
Pervious	48	48	32	48
Parcels				
Rooftop	140	184	128	144
Impervious	180	238	160	175
Pervious	324	368	193	210
Total	**863**	**1071**	**633**	**771**

Background

This paper describes the methods and results of an analysis conducted by King County to identify sources and destinations for stormwater flow in four basins in the Seattle area. The data will be used as input for the design of combined sewer overflow (CSO) control projects in the basins.

The National Pollutant Discharge Elimination System (NPDES) permit for King County's West Point Wastewater Treatment Plant includes 38 CSO locations in the Seattle area. These outfalls discharge a combination of stormwater and untreated wastewater when flows exceed the capacity of the treatment plant, usually the result of storm events.

King County's goal is to control the occurrence of CSOs at each location to once a year, on average over a five-year period, in order to meet the Washington State Department of Ecology standard. So far, 13 county CSOs are controlled to this standard. Projects are under way to control four CSOs located near Puget Sound beaches. These CSOs are at the Barton Pump Station adjacent to the Fauntleroy Ferry Terminal in West Seattle, the Murray Pump Station also in West Seattle, South Magnolia Overflow Weir on the north shore of Elliott Bay, and the North Beach Pump Station two miles north of where the Lake Washington Ship Canal discharges into Puget Sound. Construction of these projects is scheduled to be completed in 2013. These and other county CSO sites are shown in Figure 1.

As a part of project predesign, King County's Wastewater Treatment Division (WTD) will identify demand management and other in-basin alternatives to achieve control. Demand management techniques reduce the amount of wastewater in the combined sewer system (CSS). Examples include storage, inflow and infiltration (I/I) reduction, and diversion (also called separation). Other solutions may include green infrastructure (GI) techniques such as ecoroofs, bioretention, street trees, permeable paving, and roof rainwater harvesting. The four CSO contributing basins will be evaluated for GI suitability, and one will be recommended for a pilot project using one or more of the GI techniques. The GI analysis will be presented in a subsequent document.

Project Description

To help determine suitable CSO control solutions, WTD performed a GIS analysis from June through August 2008. The analysis identified sources of stormwater to the CSS and the separate municipal storm sewer system (MS4) and the characteristics of the basins as they relate to these sources. Impervious, pervious, and rooftop areas were identified, along with the destination of any flows originating from these locations, on both assessed property and the street right-of-ways (ROWs). The analysis built on flow monitoring and modeling in the CSS conducted in 2006. The results of the analysis will be used as inputs, along with rain and flow data, into a model of the basins to identify the scale and location of any CSO control solution.

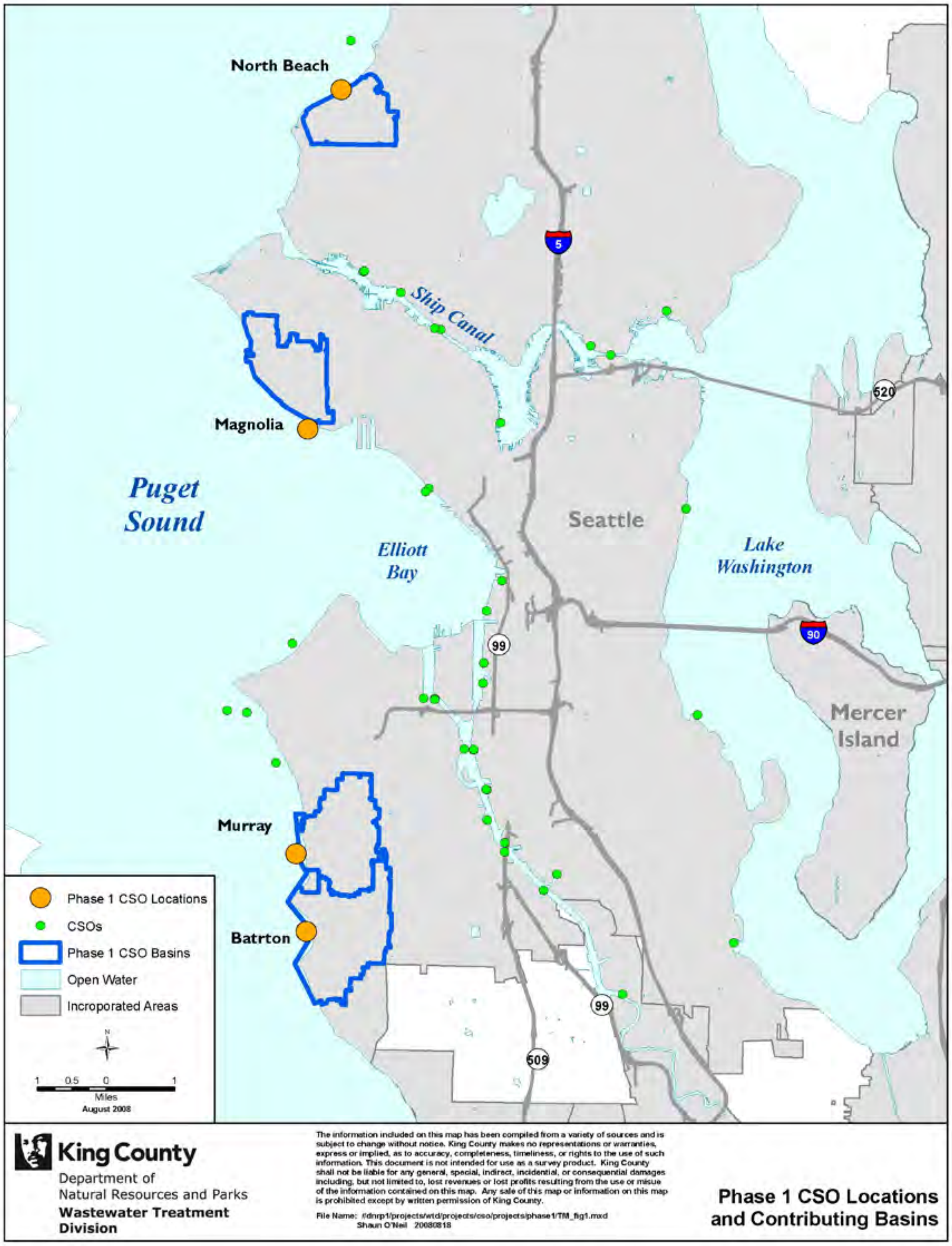


Figure 1. Location of Contributing Basins for Puget Sound Beach CSO Control Projects

Basin Descriptions

The North Beach basin is located in the northwest corner of Seattle on a northwest facing slope. The basin is 863 acres divided into three modeling subbasins: 439, 440, and 441. The South Magnolia basin is 771 acres located between the Ship Canal and Elliott Bay on the west side of the city. It is composed of four modeling subbasins: 151, 152, 153, and 154. Murray is the next basin south located in West Seattle just north of Lincoln Park. The Murray basin is 1071 acres encompassing four modeling subbasins: 419, 420, 421, and 423. Finally, the Barton basin is located just south of both Lincoln Park and the Murray basin. At 863 acres, it is smaller than the Murray basin but is made up of five modeling subbasins: 414, 415, 416, 417, and 418. Table 1 provides a description of each basin and subbasin. See appendix A for maps showing the subbasins within each CSO basin.

Table 1. Subbasin Descriptions

Subbasin	Acres	Conveyance Makeup
Barton – 863 Acres		
414	234	Partially Separated; Mostly Separate Sewer, no MS4
415	115	Partially Separated; Mostly Separate Sewer, no MS4
416	314	Partially Separated
417	200	Partially Separated
418	249	Partially Separated
Magnolia – 771 Acres		
151	174	Partially Separated
152	382	Partially Separated
153	112	Partially Separated
154	105	Partially Separated
Murray – 1071 Acres		
419	332	Partially Separated
420	397	Partially Separated
421	298	Partially Separated
423	44	Partially Separated
North Beach – 863 Acres		
439	284	Partially Separated
440	252	Separate Sewer, no MS4
441	97	Combined

Methodology

The methodology described in this section was identical for all four of the basins and was applied separately for each. It is described as one analysis regardless of location.

The steps completed in the analysis are as follows:

1. Evaluated available GIS data, selected applicable data, and developed an approach that would coincide with the selected data.

2. Input the data into a geodatabase and developed useable datasets.
3. Delineated parcels contributing to the MS4 and delineated rights-of-way by their flow destinations; CSS, MS4, or overland to the receiving water body .
4. Developed a model for extracting information from the underlying data and assigning this information to identify characteristics for each parcel and right-of-way and their contributions to the CSS and MS4.
5. Developed assumptions to account for inaccuracies in GIS data through an iterative process of data evaluation and comparison of GIS-identified impervious acres in the North Beach subbasins with 2006 modeling results.
6. Field verified basin characteristics to check assumptions.
7. Developed parcel and ROW acreages for each basin and subbasins and the destinations of flows from these acreages.

Data Used

King County maintains a GIS data warehouse consisting of vector and raster data sets developed by county departments or obtained from external sources. For this analysis, King County and City of Seattle data were used. Table 2 lists all these datasets.

Table 2 also lists for certain data sets attribute fields that were especially useful in this analysis, such as locations of catch basins, downspouts, and infiltration pits and the flow type for major pipelines and for lateral and side sewers. Different data sets were used for locating catch basins in different land use types:

- Catch basins from the City of Seattle CB_GPS data set were used for catch basins in the ROW.
- Catch basins identified in the City of Seattle DWULATPT were used for catch basins outside of the ROW.

Table 2. List of Data Sets Used in the GIS Analysis

Feature Class Name	Description	Important Features	Field of Note
	King County		
CSOBasin	CSO basin	Basin extents	
CSOBSN	Modeling subbasins	Monitored subbasins	Basin_num
Parcel	Parcels	Address	
ROW	Rights of way		
lndcov_imp	Impervious areas		
	City of Seattle		
DWUMNL	Mainline conveyance	CSS, MS4, sewer Designation	prble_flow
DWUMLAT	Lateral and side sewer conveyance	Sewer and Storm Drain designation	prble_flow
DWULATPT	Lateral line points	Catch Basins, Downspouts, Infiltration pits	ntype
CB_GPS	Catch basins in the ROW	Catch Basins	
BldgFtPt	Building footprints/roof tops		

ctr002	2-fout contours		
Ditches	Ditches	Culverts, ditches, curbs, tiled drains	Type

Data Input and Model Development

All of the data identified in Table 2 was collected into a geodatabase. Feature datasets were created for each of the four CSOs, and the data were placed into feature classes in the appropriate dataset. Because of the magnitude and complexity of the data and the processing to be done, each feature class was clipped to the individual CSO basin and modeling subbasins. The CSO basins delineated based on the City of Seattle conveyance data were used as the base and all the subbasins delineated in the 1990s before GIS data were available were either clipped or extended to match the boundaries of the CSO basin. All other feature classes were clipped to this extent.

Once the data were limited to the basin extents, the parcels and ROWs were characterized.

Parcels

The first step in parcel characterization involved investigating the entire basin area and including any parcel that was depicted as being directly connected to the MS4 in what was called the storm basin. All of these parcels were copied into the storm basin feature class and merged into a single feature to identify the areas contributing flow to the MS4.

The next step involved identifying characteristics in each parcel. A geoprocessing model was created that took the base parcel feature class, clipped to the extents of the basin, and added the fields in Table 3. The model then evaluated the existence of infiltration pits, storm drain laterals, sewer laterals, catch basins, and downspouts. The various combinations of the existence of the conveyance features and location within the storm basin, as outlined in the assumptions, provided all of the information needed to allocate the different areas of the parcel—rooftop, impervious, and pervious—to the CSS or MS4.

Table 3. List and Description of Parcel Table Fields

Field Name	Description
ADDRESS	Street Address
NUM	House Number
PREFIX	Street Prefix
NAME	Street Name
ST_TYPE	Street Type
SUFFIX	Street Suffix
ZIPCODE	Zipcode
HasDSP	Parcel contains a downspout; 1 = yes, 0 = no
HasPit	Parcel contains an infiltration pit; 1 = yes, 0 = no
HasCB	Parcel contains a catch basin; 1 = yes, 0 = no
SLateral	Parcel contains a sewer lateral; 1 = yes, 0 = no
DLateral	Parcel contains a storm drain lateral; 1 = yes, 0 = no
StormBasin	Parcel is connected directly to the MS4; 1 = yes, 0 = no
CSOBasin	Modeling subbasin in which the parcel resides
RoofSF	Rooftop square footage

ImperviousSF	Impervious area square footage
PerviousSF	Pervious area square footage
TotalParcelSF	Total parcel square footage
roof_dest_a	Roof flow destination under scenario A*
roof_dest_b	Roof flow destination under scenario B*
impper_dest_a	Impervious and Pervious flow destination under scenario A*
impper_dest_b	Impervious and Pervious flow destination under scenario B*

*C = CSS, D = MS4, O = Overland to receiving water body, RC = via ROW to CSS, RD = via ROW to MS4

The various square footages for the different area categories in each parcel were then calculated. The two feature classes—impervious areas and building footprint areas, depicting the rooftop areas—were clipped and isolated, and each was intersected with the parcel features. This process broke the impervious and building footprint features into separate features for each parcel. The two intersections, containing the Parcel Identification Number (PIN) from the parcel feature class, were joined back to the parcel feature class based on the PIN. The square footage from the impervious areas and the building footprints were captured into the appropriate fields in the parcel feature class and then the joins were removed. The impervious and rooftop square footages were then subtracted from the total area of each parcel leaving the pervious area remaining and calculated into the appropriate field.

Finally, four fields were added to identify the destination of the flow coming from the roof tops and the impervious/pervious areas for two sets of assumptions, identified as A and B in Tables 3 and 4. For each field, the options were CSS, MS4, overland to receiving water body, via the ROW to the CSS, and via the ROW to the MS4. Each code was determined by selecting those parcels that met the set of assumptions in that circumstance as described below.

ROWs

Each basin ROW was delineated based on the terrain described by the 2-foot contours, catch basins, a ditch/culvert/curb system, and the underlying CSS and MS4 systems. The ROW was split into three categories based on whether the flow from the ROW ended up in the CSS, the MS4, or the receiving water body via overland. All flow was assumed to flow downhill, conveyed by pavement, ditches, culverts, or other routes to the first downhill inlet encountered. The area contributing flow to that inlet was assumed to be bounded uphill by the location of the next inlet point. If no inlet to the MS4 or CSS was encountered, the flow from those areas of the ROW was assumed to enter the receiving water body directly.

Once the ROW was compartmentalized in this way, the impervious area feature class was intersected with the ROW feature class to populate. This resulted in the ROW feature class with impervious and pervious areas, both split based on the flow destinations and the remaining areas. Both impervious and pervious areas were assigned attributes for the destination of their flow and square footage, much like the parcel data.

Assumptions Used

Assumptions were developed because GIS data did not accurately reflect actual conditions to the degree necessary to adequately populate the model and locate CSO control solutions. The assumptions were used, primarily to help model catch basin, downspout, and conveyance locations and connectivity. Appendix B describes the process of developing the assumptions in more detail, including the earlier assumptions and the rationale for changing some of these assumptions

The final assumptions contained modifications primarily related to how it was assumed that the rooftop, impervious, and pervious areas were connected to the CSS. Because the GIS data are inconsistent in the depiction of features in different areas, two scenarios (A and B) were developed. Each scenario had its own group of assumptions. The goal was to provide a minimum and maximum value of contributing areas to each of the conveyance systems. Each scenario was developed to capture as many combinations of depicted features that would indicate the accurate characteristics for a given property. For example, parcels with storm drain laterals in a specific area of a basin indicates that these parcels contribute to the MS4. Parcels with downspouts might indicate the same. These two collections of parcels, although not mutually exclusive, should capture as many instances of parcels contributing to the MS4 as possible. Table 6 shows all the assumptions used in the process.

These revised assumptions identified parcels that had drainage conveyance onsite without an infiltration pit and that were not connected to the MS4. The flow from these parcels was allocated to the CSS. A visual evaluation of the GIS with these revised assumptions in mind suggested accuracy because very few parcel drains were identified for the areas of the North Beach CSO basin with no CSS, only dedicated sewer conveyance, and a ditch and culvert ROW drainage system, while those areas with a CSS system had a much larger number of parcel drainage systems. Finally, the results of the analysis using the new revised assumptions matched much closer to the previous model results, as shown in Table 5.

Table 4. Assumptions Used in the Analysis

Parcels		
	Directly to MS4	
Rooftop	A	Parcel shown directly connected to MS4
		A lateral identified as carrying storm drainage flow lies in the parcel
	B	Parcel shown directly connected to MS4
		A lateral identified as carrying storm drainage flow lies in the parcel
		Parcel contains a downspout
Impervious	A	Parcel shown directly connected to MS4
		A lateral identified as carrying storm drainage flow lies in the parcel
	B	Parcel shown directly connected to MS4
		A lateral identified as carrying storm drainage flow lies in the parcel
		Parcel contains no infiltration pit
		Parcel contains a catch basin

Pervious	A	Same as Impervious areas, A assumption collection
	B	Same as Impervious areas, B assumption collection
To MS4 via ROW		
Rooftop		Flow not directly to CSS or MS4
		Terrain indicates flow will enter ROW and enter MS4 conveyance for that ROW section
Impervious		Flow not directly to CSS or MS4
		Terrain indicates flow will enter ROW and enter MS4 conveyance for that ROW section
Pervious		Flow not directly to CSS or MS4
		Terrain indicates flow will enter ROW and enter MS4 conveyance for that ROW section
Directly to CSS		
Rooftop	A	Parcel not connected to MS4
		Parcel contains no infiltration pit
		A lateral identified as carrying storm drainage flow lies in the parcel
	B	Parcel not connected to MS4
		Parcel contains no infiltration pit
		Parcel contains a downspout
Impervious	A	Parcel not connected to MS4
		Parcel contains no infiltration pit
		A lateral identified as carrying storm drainage flow lies in the parcel
	B	Parcel not connected to MS4
		Parcel contains no infiltration pit
		Parcel contains a catch basin
Pervious	A	Same as Impervious areas, A assumption collection
	B	Same as Impervious areas, B assumption collection
To CSS via ROW		
Rooftop		Flow not directly to CSS or MS4
		Terrain indicates flow will enter ROW and enter CSS conveyance for that ROW section
Impervious		Flow not directly to CSS or MS4
		Terrain indicates flow will enter ROW and enter CSS conveyance for that ROW section
Pervious		Flow not directly to CSS or MS4
		Terrain indicates flow will enter ROW and enter CSS conveyance for that ROW section
Overland to Receiving Water Body		
Rooftop		Flow not directly to CSS or MS4
		Terrain indicates flow will enter ROW and not be captured by the CSS or MS4
Impervious		Flow not directly to CSS or MS4
		Terrain indicates flow will enter ROW and not be captured by the CSS or MS4
Pervious		Flow not directly to CSS or MS4

	Terrain indicates flow will enter ROW and not be captured by the CSS or MS4
ROWs	
	Flows will be collected downhill by the first inlet structure encountered
	Area contributing flow is bounded uphill by the location of the next encountered inlet point.
CSS	First Inlet structure is connected to the CSS
MS4	First Inlet structure is connected to the CSS
Overland to Receiving Water Body	No inlet structure is encountered and all flow continues to the receiving water body.

Table 5. Connected Impervious Acreages in GIS Analysis Using Revised Assumptions Compared to 2006 Modeling Acreages in the North Beach Basin

	Subbasin					
	439		440		441	
Assumption	**A**	**B**	**A**	**B**	**A**	**B**
Total % impervious and rooftop connected – GIS	8.09%	5.21%	6.05%	3.33%	12.54%	8.77%
Total % impervious connected – Model	5%	5%	8%	8%	17%	17%

Field Verification of Assumptions

Field investigations were conducted to indicate the level of confidence in the GIS data. For each of the CSO basins, two representative areas consisting of approximately two blocks each were identified. Field crews took the GIS maps for the identified areas to verify the existing downspout and catch basin locations in the GIS datasets and to identify any others not currently in the datasets. The investigations consisted solely of a survey from the ROW of visible areas of properties and ROWs. No smoke or dye testing was done.

The results exposed some interesting trends. Overall, the GIS data regarding catch basins were accurate. Catch basins were found to be connected in the manner shown in the GIS. The data representing the downspouts were, as was expected, variable in accuracy.

The data were consistent across all four basins. In areas with CSS systems, twice as many downspouts were found as were indicated in the GIS. Where the GIS showed a downspout, field inspection revealed 8 to 14 percent did not exist. These new downspouts, when taken into consideration along with the assumptions used, added 15to 30 percent of the investigated properties to those that contribute flow to the CSS.

For the two areas that were separated with no MS4 available to convey flow, in Barton and North Beach, 50 and 84 percent of the houses investigated, respectively, had downspouts that were not in the GIS and that conveyed flows from the roof or property into an underground conveyance. The existence of surface drainage, ditches and culverts, in each area implies that this flow is collected by the surface drain system and conveyed overland to the receiving water body, which is the final destination for flow from the ROW in each of these areas.

More detail on the results of the field investigations and maps showing the selected areas can be found in Appendix C.

Results – Basin Characteristics

The analysis provided total square footage for the parcel rooftop, impervious, and pervious areas and the ROW impervious and pervious areas and the final destinations of the associated flows for the two scenarios outlined in the assumptions. Total acreages for all four basins are shown in Table 6. The acreages for each basin broken down by the component areas are shown in Table 7.

Table 6. Total Acreage by Basin

	Barton	**Murray**	**North Beach**	**South Magnolia**
ROWs	218 *(25%)*	281 *(26%)*	152 *(24%)*	243 *(31%)*
Parcels	644 *(75%)*	790 *(74%)*	481 *(76%)*	529 *(69%)*
Total	**863**	**1071**	**633**	**771**

Table 7. Roof Top, Impervious, and Pervious Acreage by Basin

	Barton	**Murray**	**North Beach**	**South Magnolia**
		ROW		
Impervious	170 *(20%)*	232 *(22%)*	119 *(19%)*	195 *(25%)*
Pervious	48 *(6%)*	48 *(4%)*	32 *(5%)*	48 *(6%)*
		Parcels		
Rooftop	140 *(16%)*	184 *(17%)*	128 *(20%)*	144 *(19%)*
Impervious	180 *(21%)*	238 *(22%)*	160 *(25%)*	175 *(23%)*
Pervious	324 *(38%)*	368 *(34%)*	193 *(31%)*	210 *(27%)*
Total	**863**	**1071**	**633**	**771**

The acreages were further defined by subbasins. Table 8 shows an example of the breakdown for the North Beach basin; Table 9 shows the destination for the flow from each of the delineated areas for Subbasin 439 in the North Beach basin and the percentages of the total areas for each conveyance system. Figure 2 shows all flow destinations identified in Subbasin 439. The results by subbasin for the other basins can be found in Appendix D; maps can be found in Appendix A.

Table 8. Roof Top, Impervious, and Pervious Acreage by Subbasin—
North Beach CSO Basin

	Subbasin		
	439	**440**	**441**
	ROW		
Impervious	60 *(21%)*	43 *(17%)*	16 *(17%)*
Pervious	10 *(3%)*	19 *(7%)*	4 *(4%)*
	Parcels		
Roof	66 *(23%)*	43 *(17%)*	19 *(19%)*

Impervious	82 *(29%)*	54 *(22%)*	24 *(25%)*
Pervious	66 *(23%)*	93 *(37%)*	34 *(35%)*
Total	**284**	**252**	**97**

Table 9. Acreages by Destination for Flow from Rooftop, Impervious, and Pervious Areas and Associated Percentages of Total
North Beach Subbasin 439

		Acreage				**Percentage**			
	Assumption Scenario	**A**		**B**		**A**		**B**	
	Conveyance System	**CSS**	**MS4**	**CSS**	**MS4**	**CSS**	**MS4**	**CSS**	**MS4**
ROW	Impervious	0.0	60.0	0.0	60.0	0%	100%	0%	100%
	Pervious	0.0	9.7	0.0	9.7	0%	100%	0%	100%
Parcels	Roof	6.9	59.1	5.2	60.8	10%	90%	8%	92%
	Impervious	9.9	71.9	5.6	76.1	12%	88%	7%	93%
	Pervious	2.2	64.2	0.8	65.6	3%	97%	1%	99%
Total		**19.0**	**264.7**	**11.6**	**272.1**	**7%**	**93%**	**4%**	**96%**
		283.7		**283.7**					

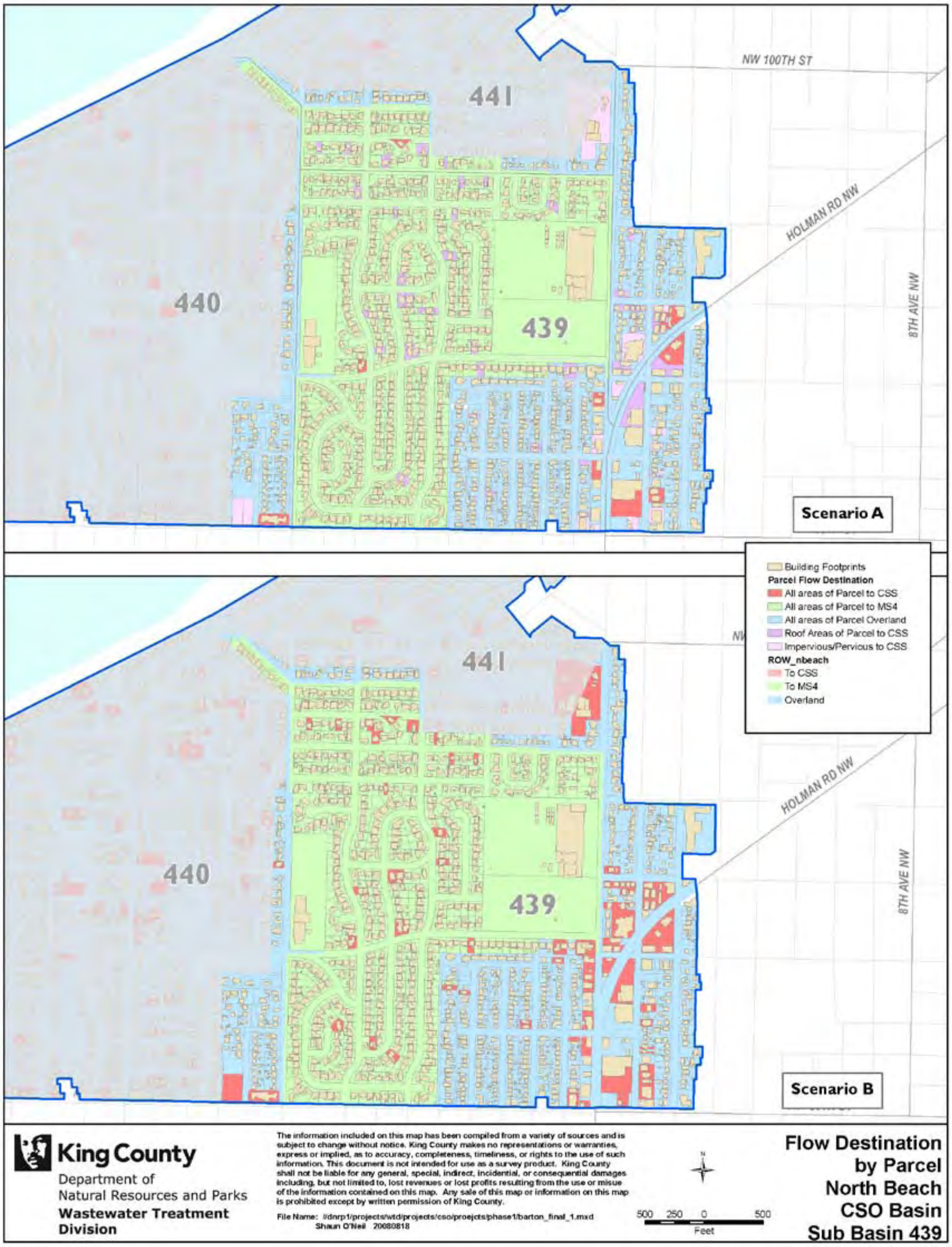


Figure 2. Characteristics of Subbasin 439

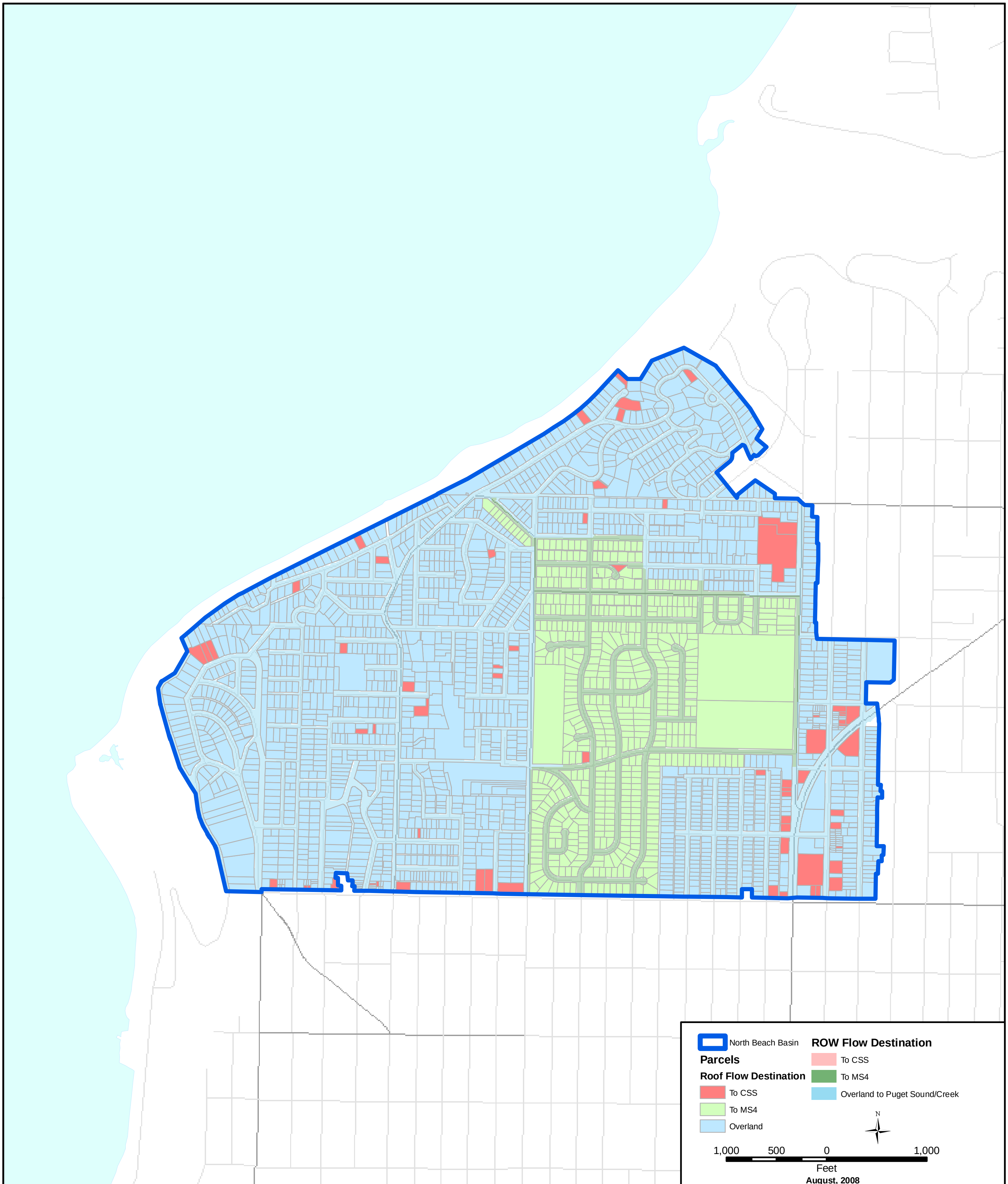
Appendices

A Basin and Subbasin Maps

B Process to Develop Assumptions

C Results of Field Verification of GIS Data

D Results of the Analysis



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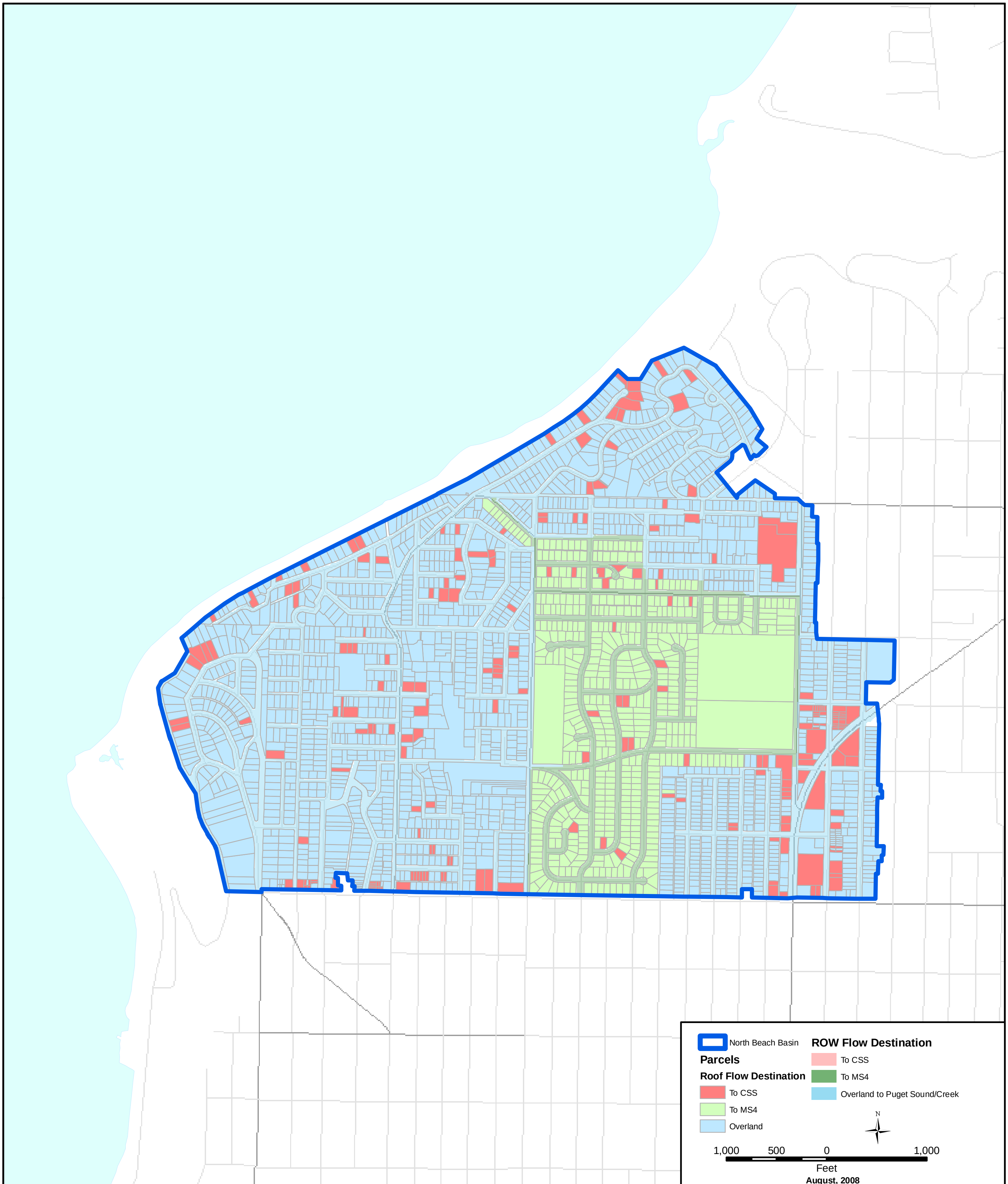
Impervious/ Pervious Flow Destinations by Parcel - Scenario A North Beach CSO Basin



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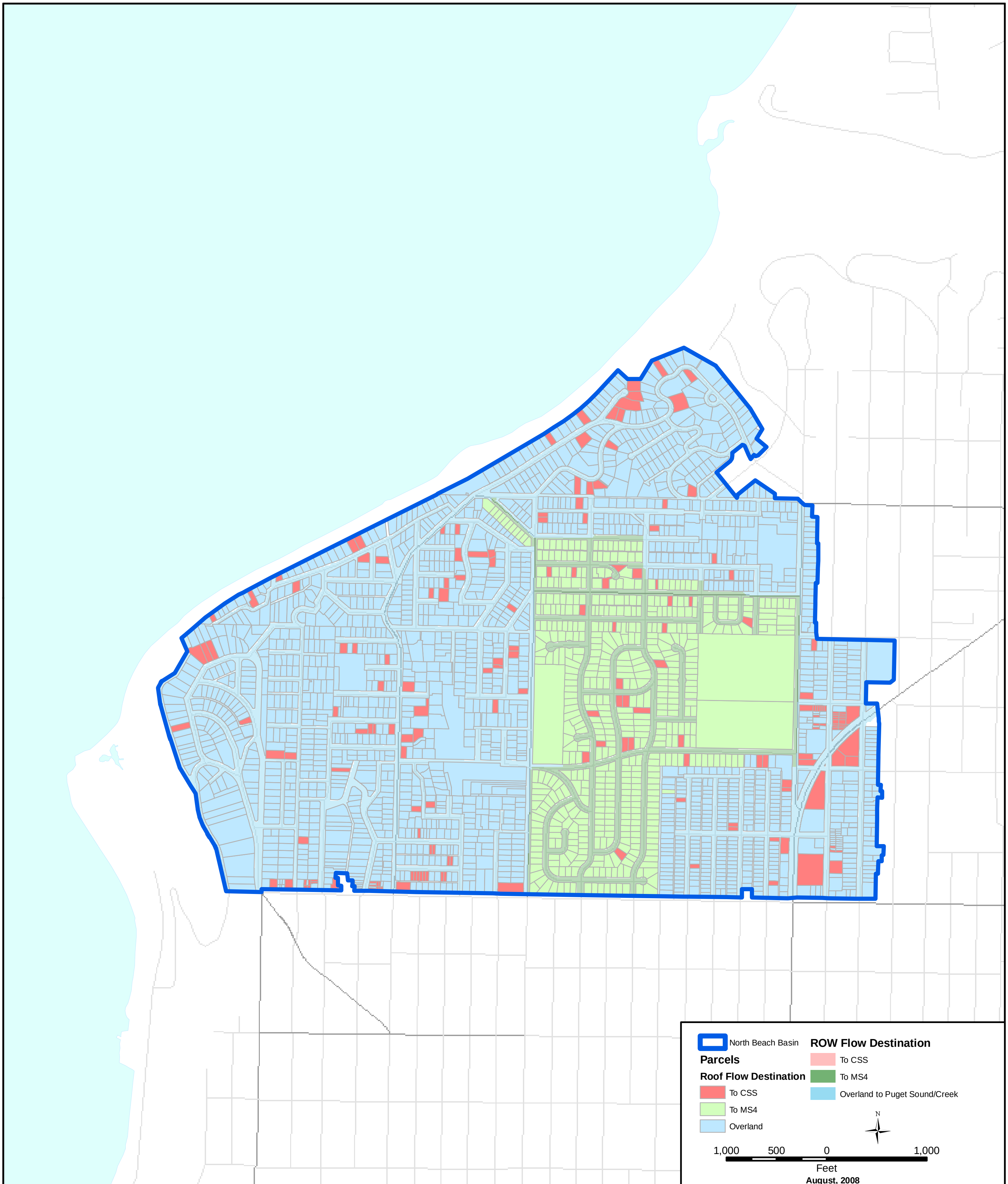
Roof Flow Destination by Parcel - Scenario B North Beach CSO Basin



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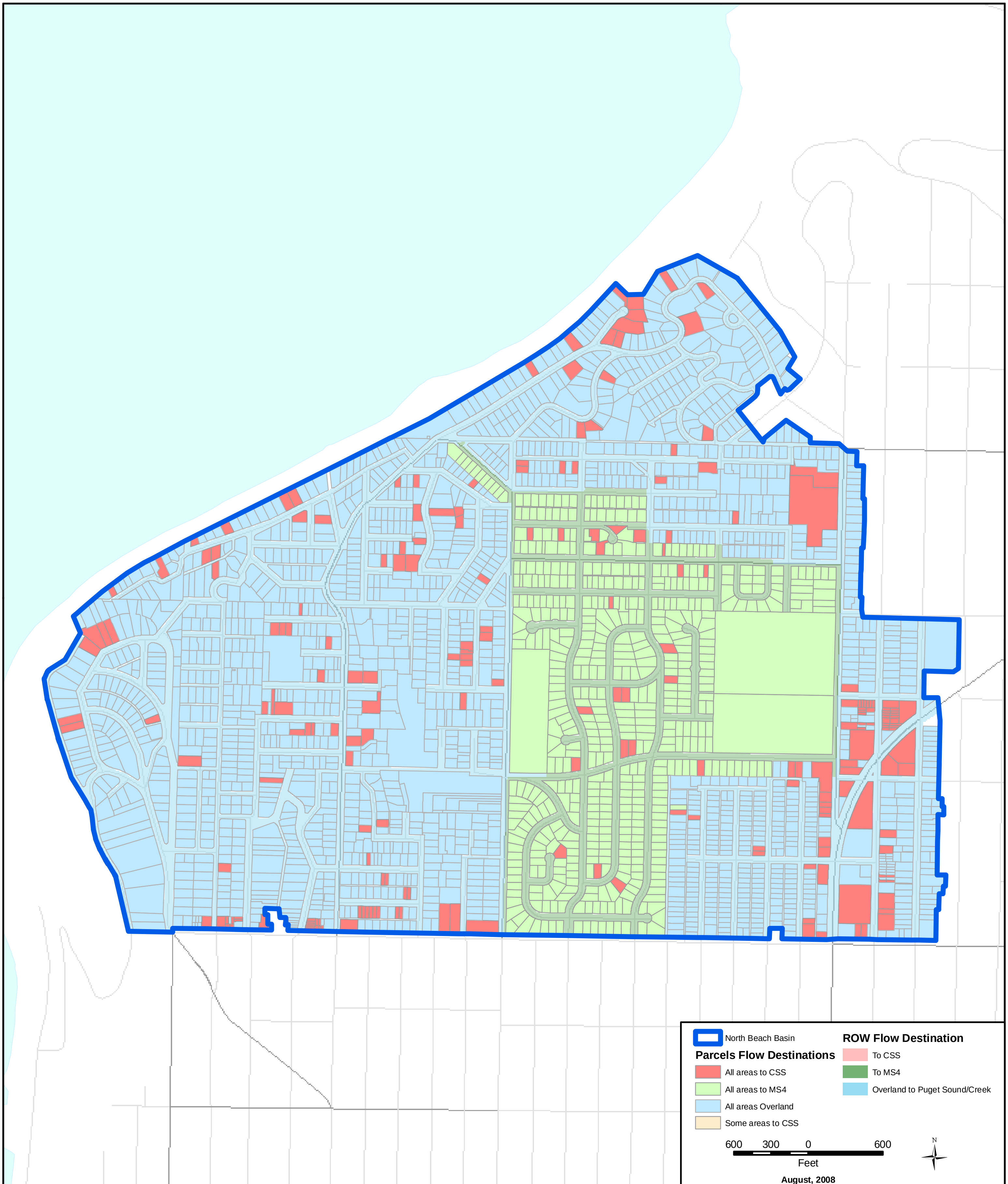
Roof Flow Destination by Parcel - Scenario A North Beach CSO Basin



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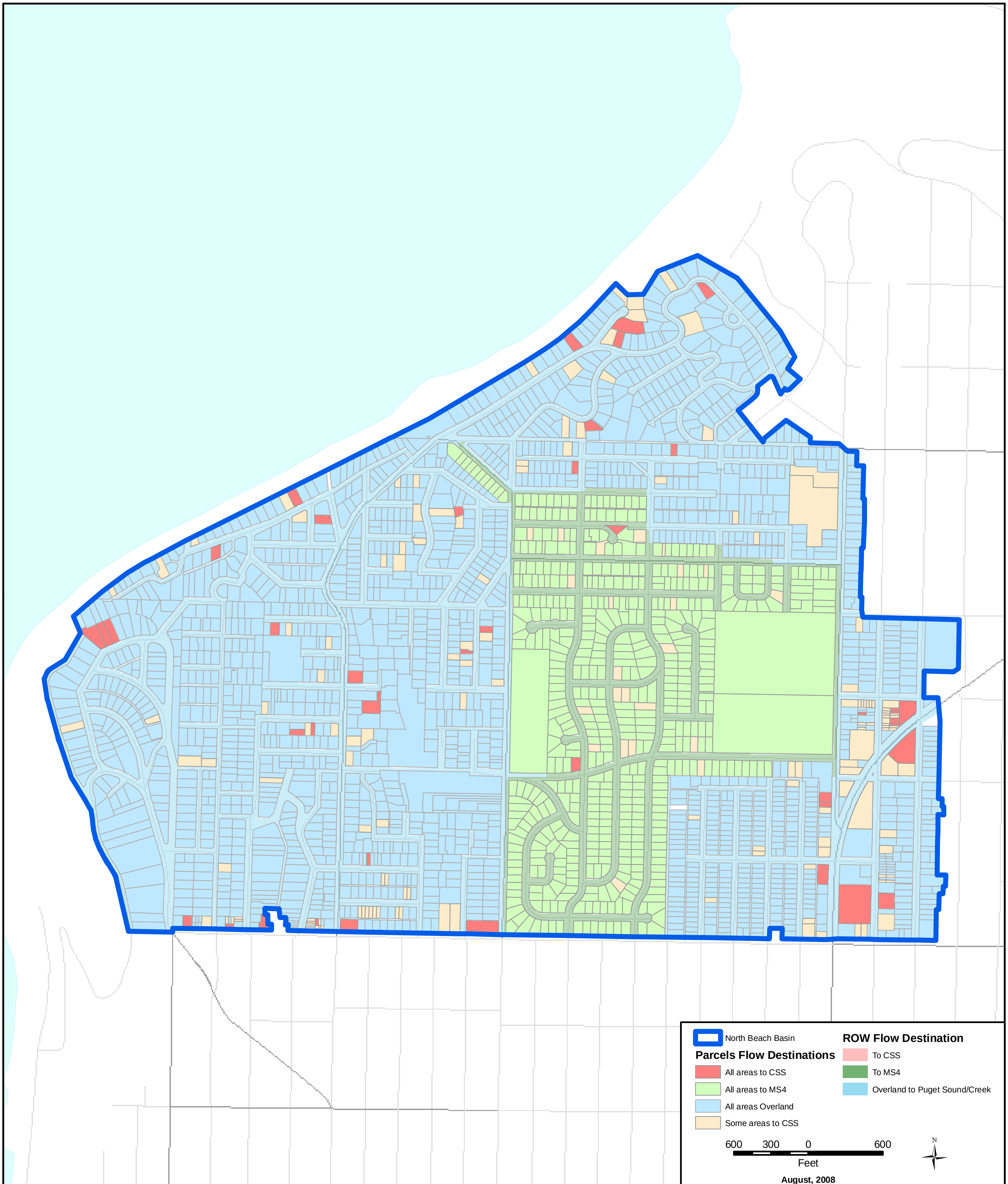
Flow Destination by Parcel Scenario B North Beach CSO Basin



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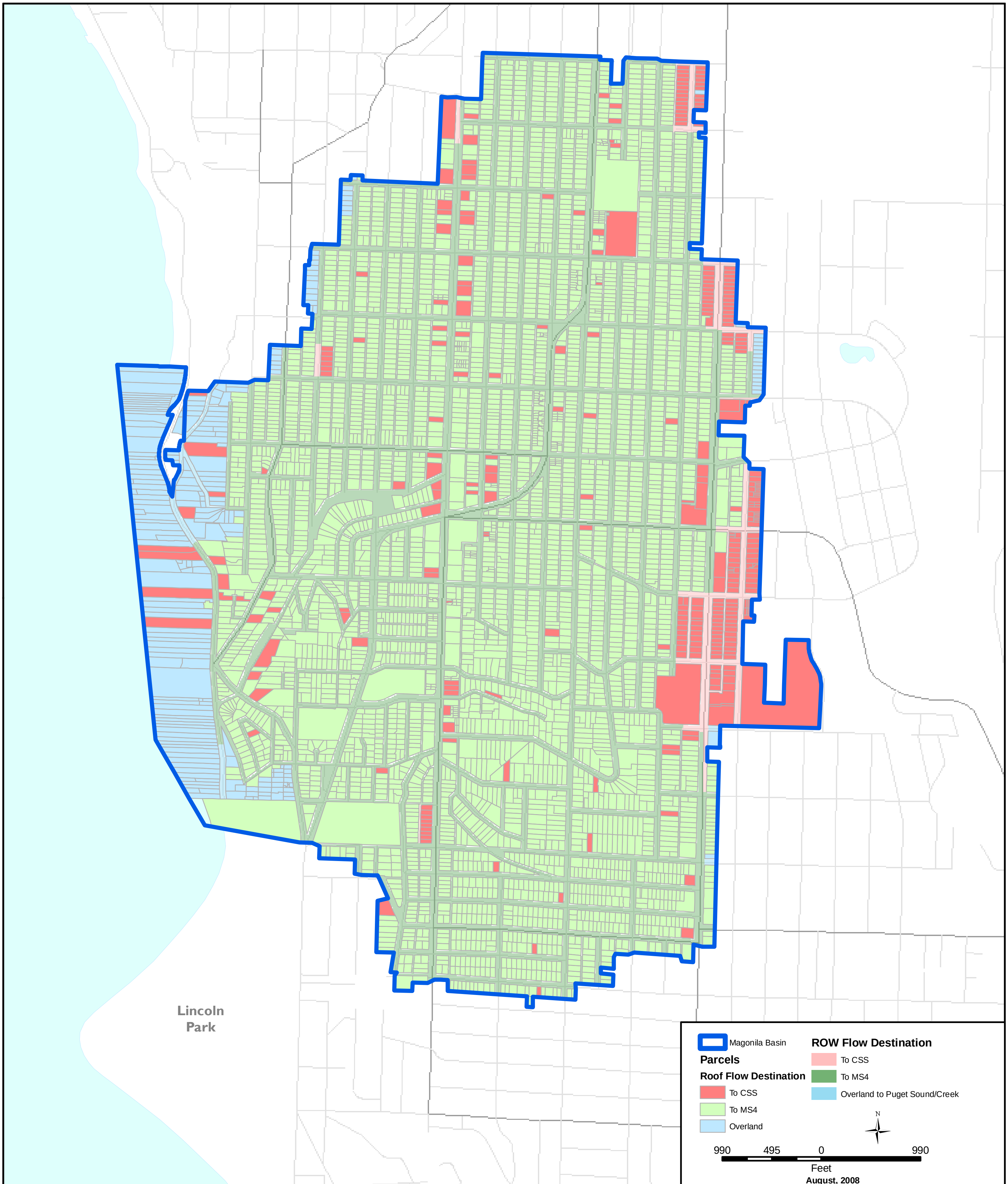
Flow Destination by Parcel Scenario A North Beach CSO Basin



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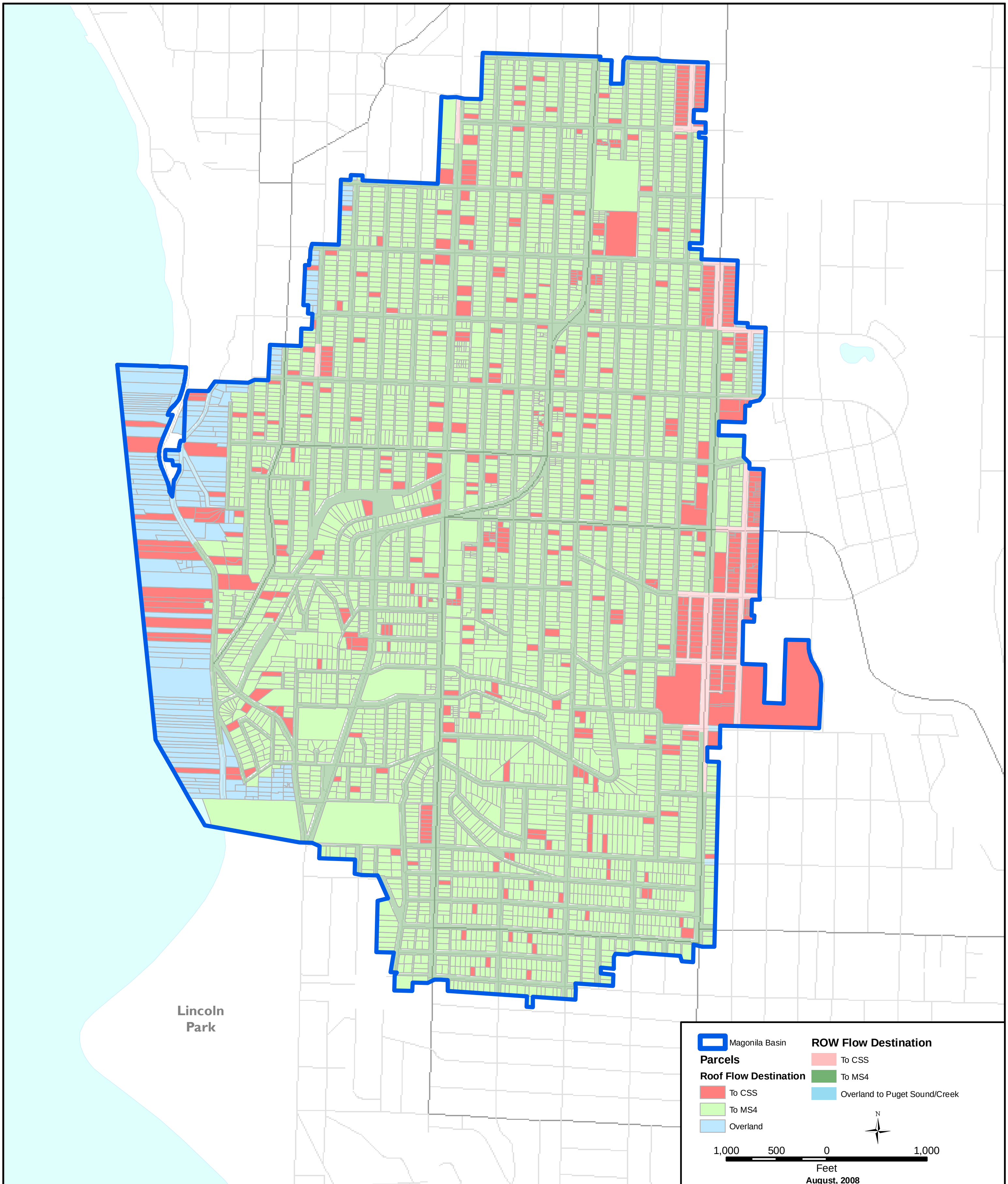
Impervious/ Pervious Flow Destination by Parcel - Scenario B Murray CSO Basin



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File Name: //dnrp1/projects/wtd/projects/cso/proejcts/phase1/Murray_final_4.mxd
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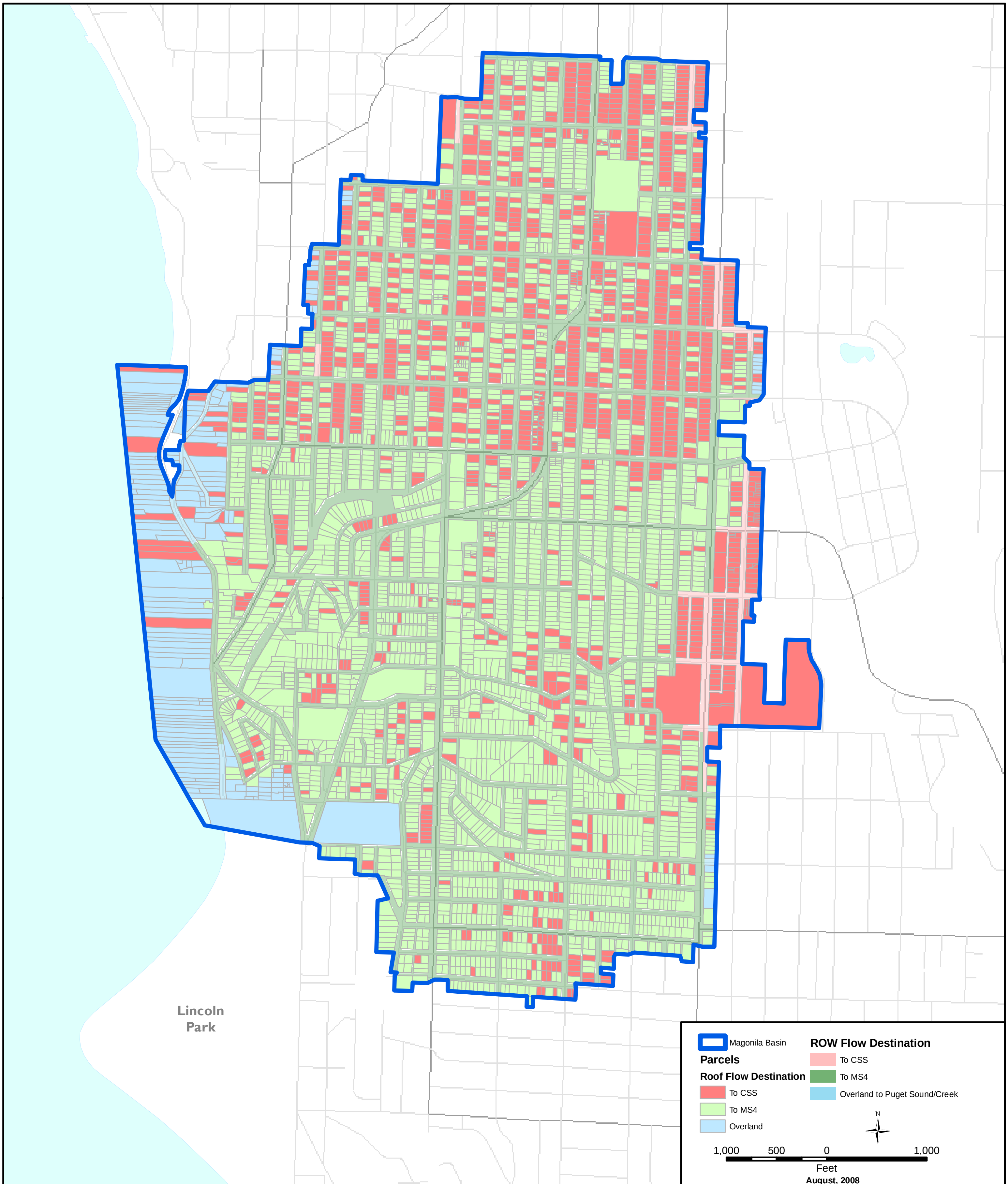
Impervious/ Pervious Flow Destination by Parcel - Scenario A Murray CSO Basin



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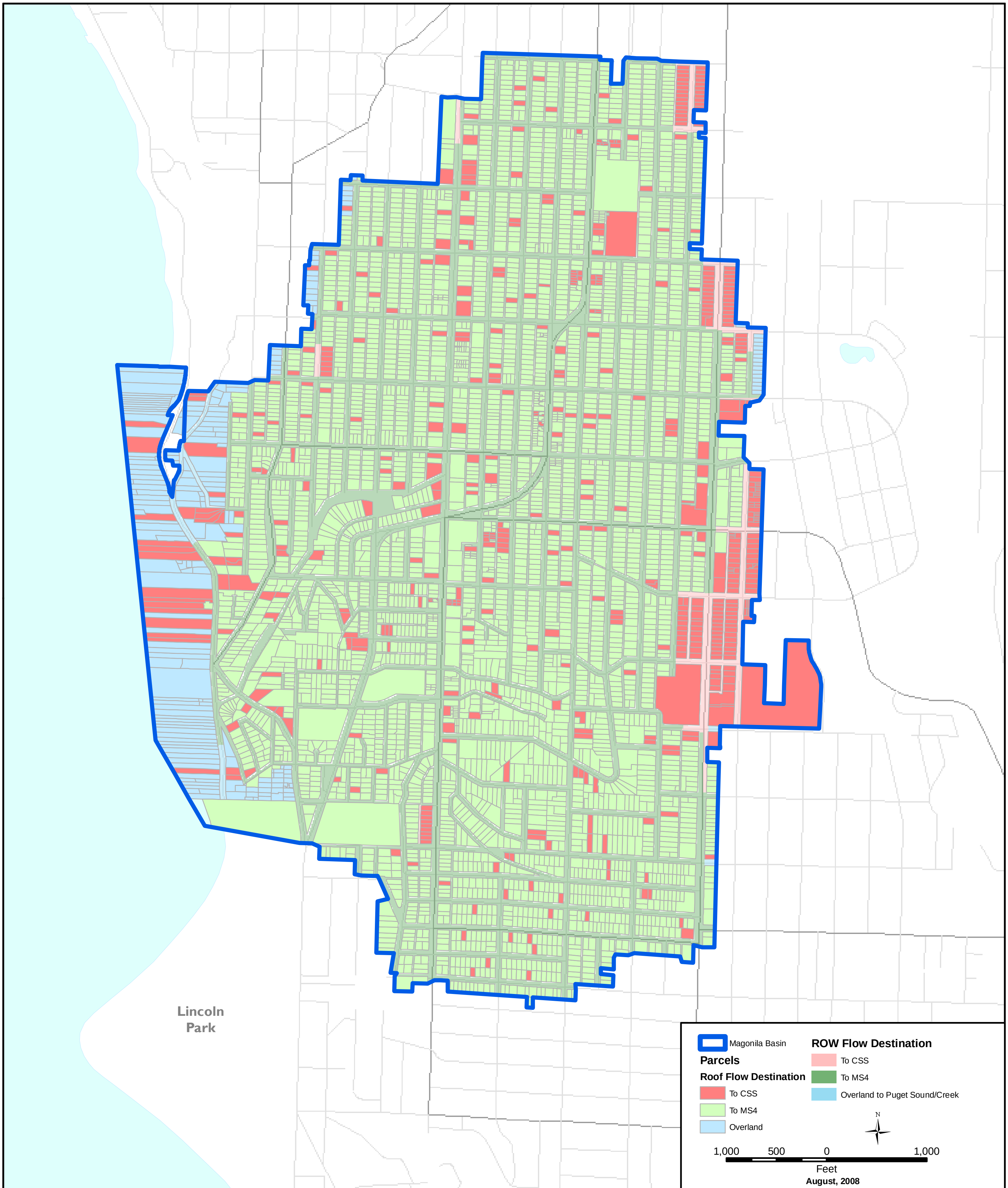
Roof Flow Destination by Parcel - Scenario B Murray CSO Basin



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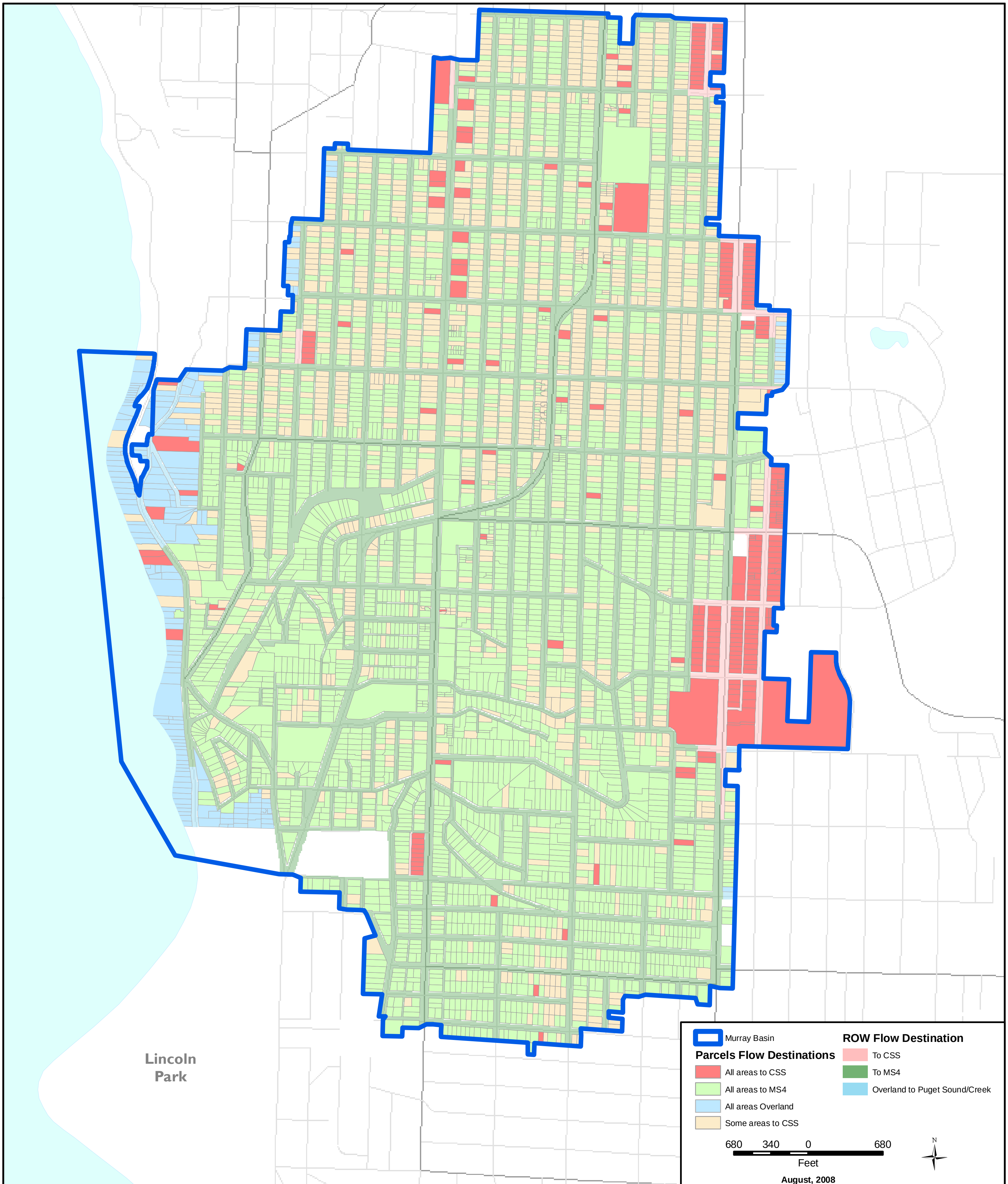
Roof Flow Destination by Parcel - Scenario A Murray CSO Basin



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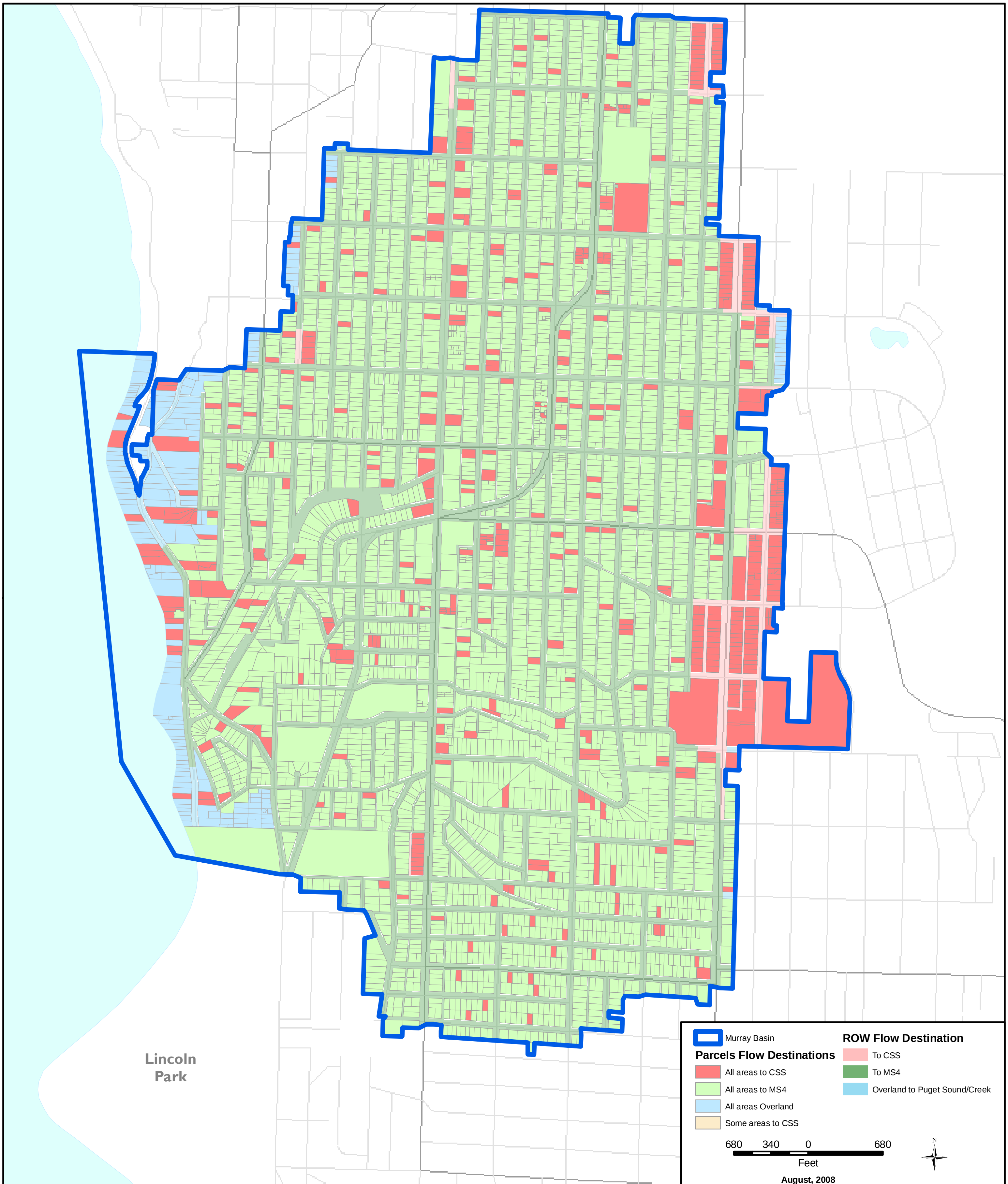
Flow Destination by Parcel Scenario B Murray CSO Basin



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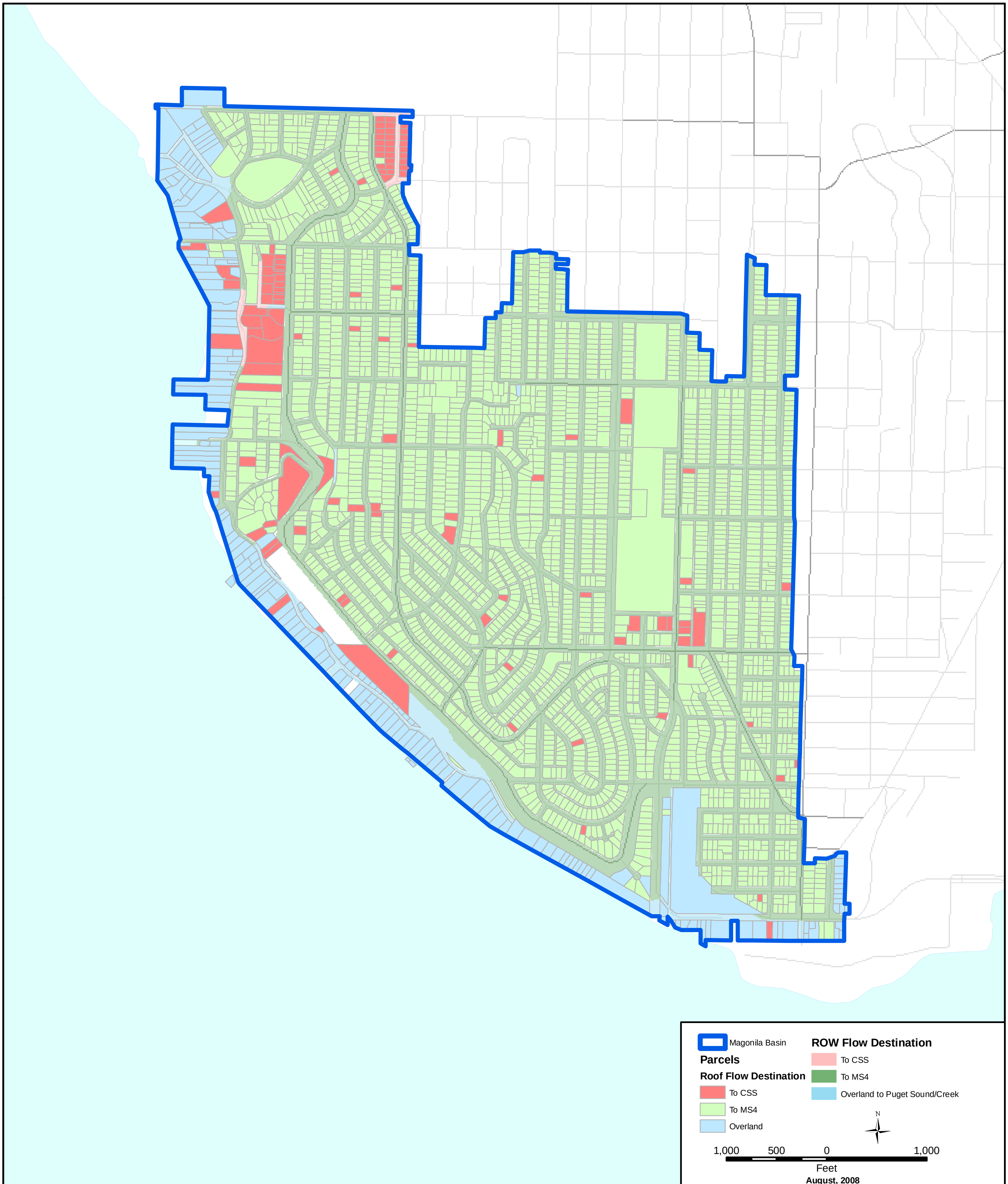
Flow Destination by Parcel Scenario A Murray CSO Basin



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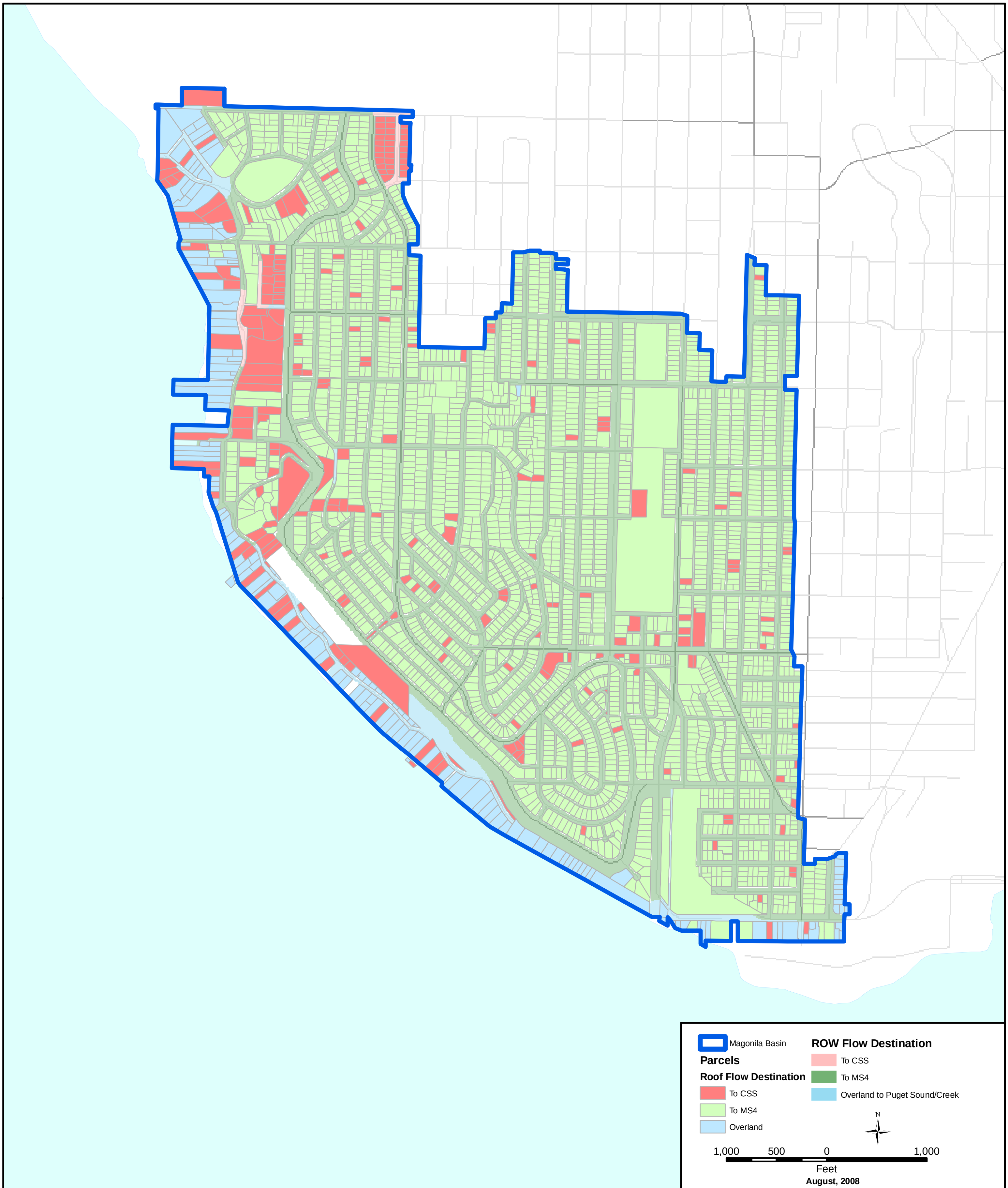
Impervious/ Pervious Flow Destinations by Parcel - Scenario B Magnolia CSO Basin



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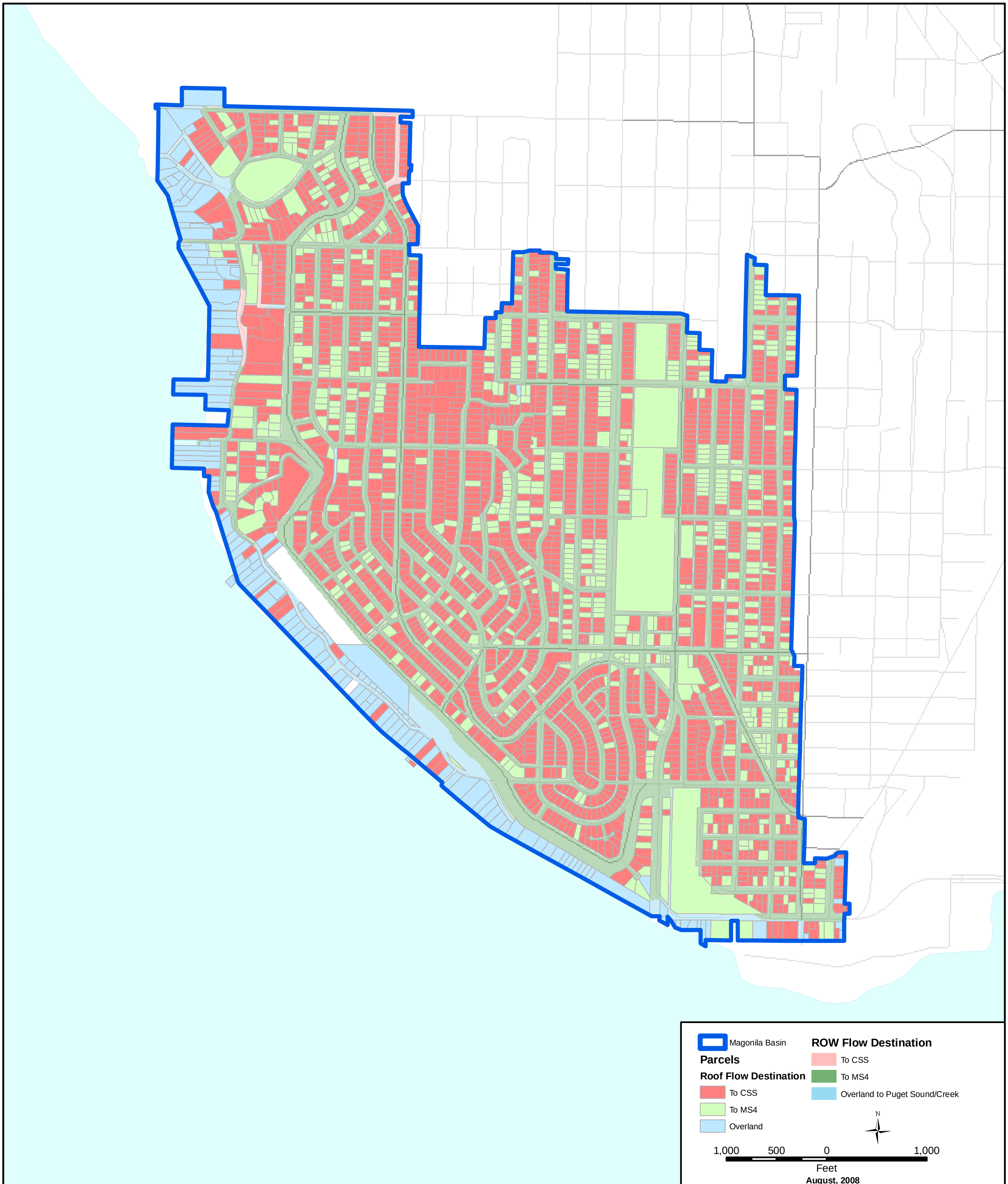
Impervious/ Pervious Flow Destinations by Parcel - Scenario A Magnolia CSO Basin



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File Name: //dnrp1/projects/wtd/projects/cso/proejcts/phase1/Magnolia_final_3.mxd
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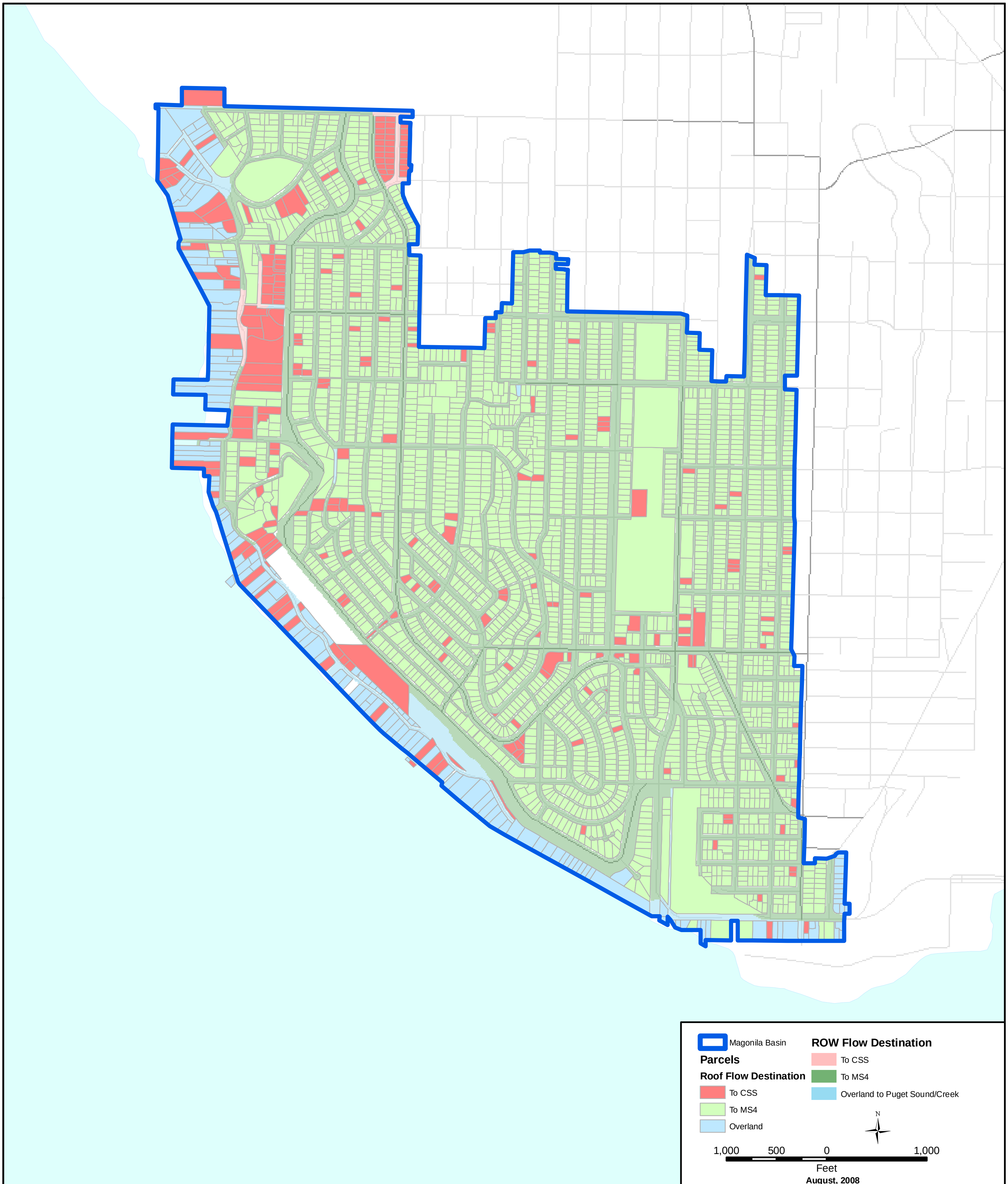
Roof Flow Destination by Parcel - Scenario B Magnolia CSO Basin



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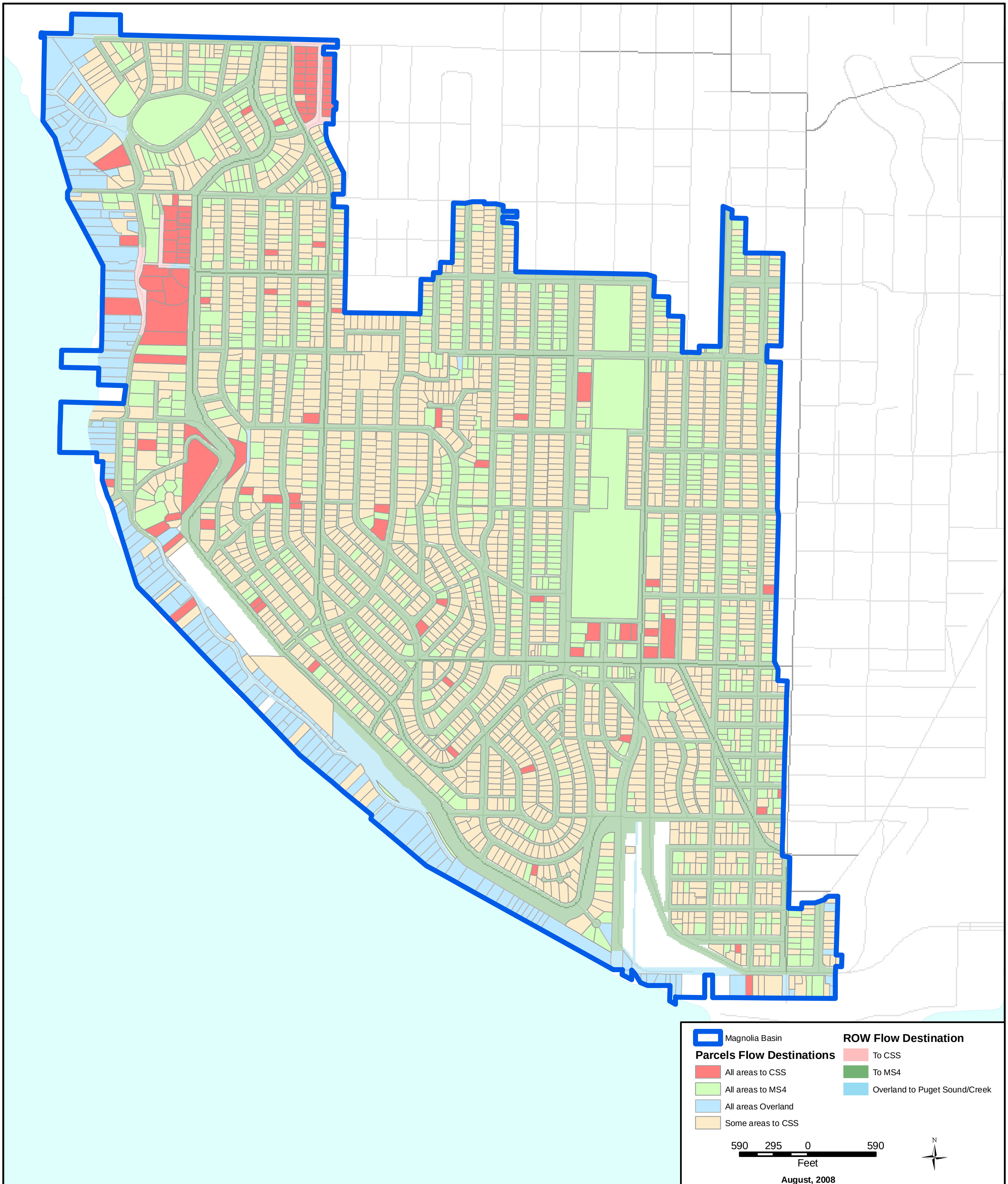
Roof Flow Destination by Parcel - Scenario A Magnolia CSO Basin



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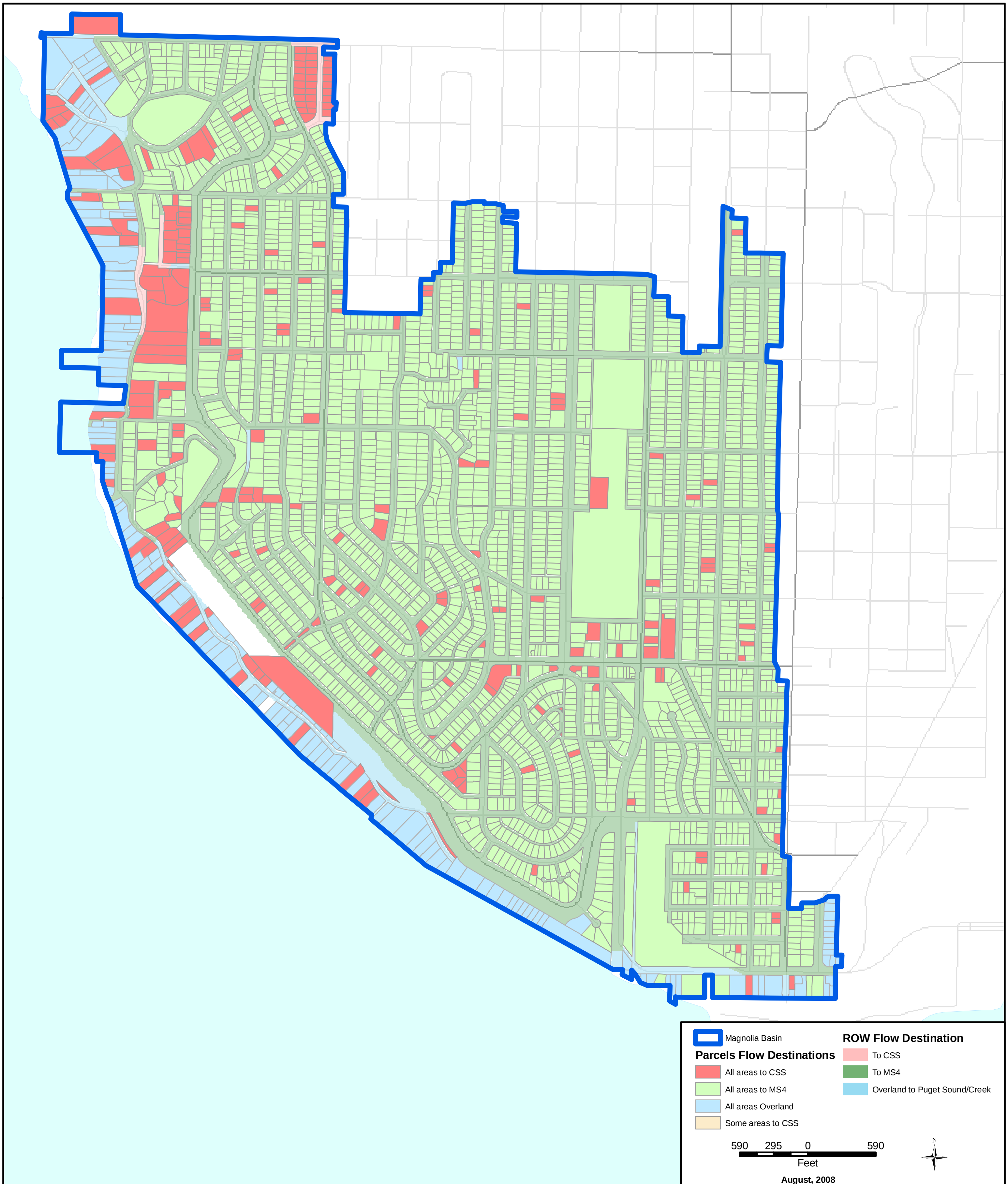
Flow Destination by Parcel Scenario B Magnolia CSO Basin



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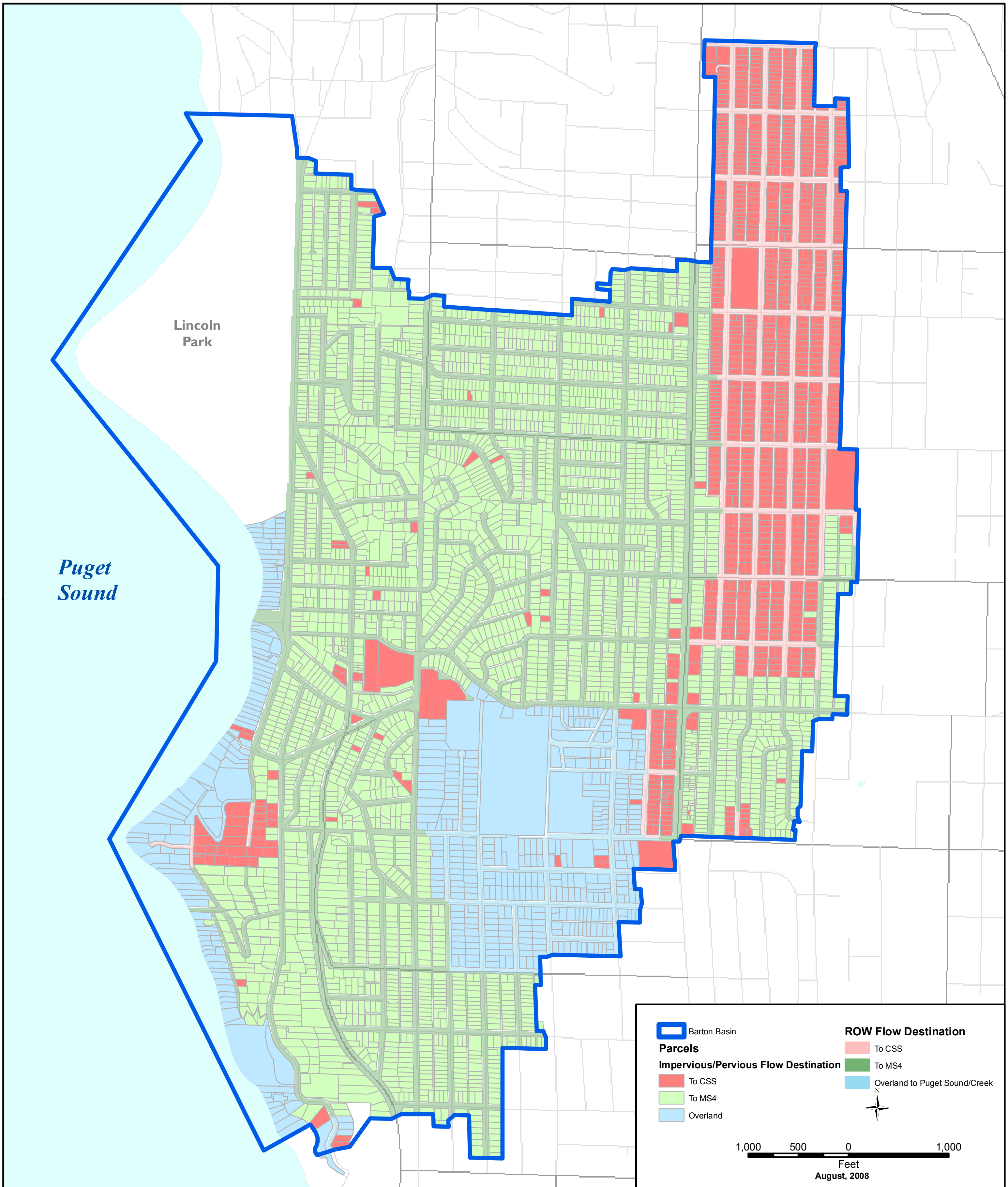
Flow Destination by Parcel Scenario A Magnolia CSO Basin



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File Name: //dnrp1/projects/wtd/projects/cso/proejcts/phase1/barton_final_5.mxd
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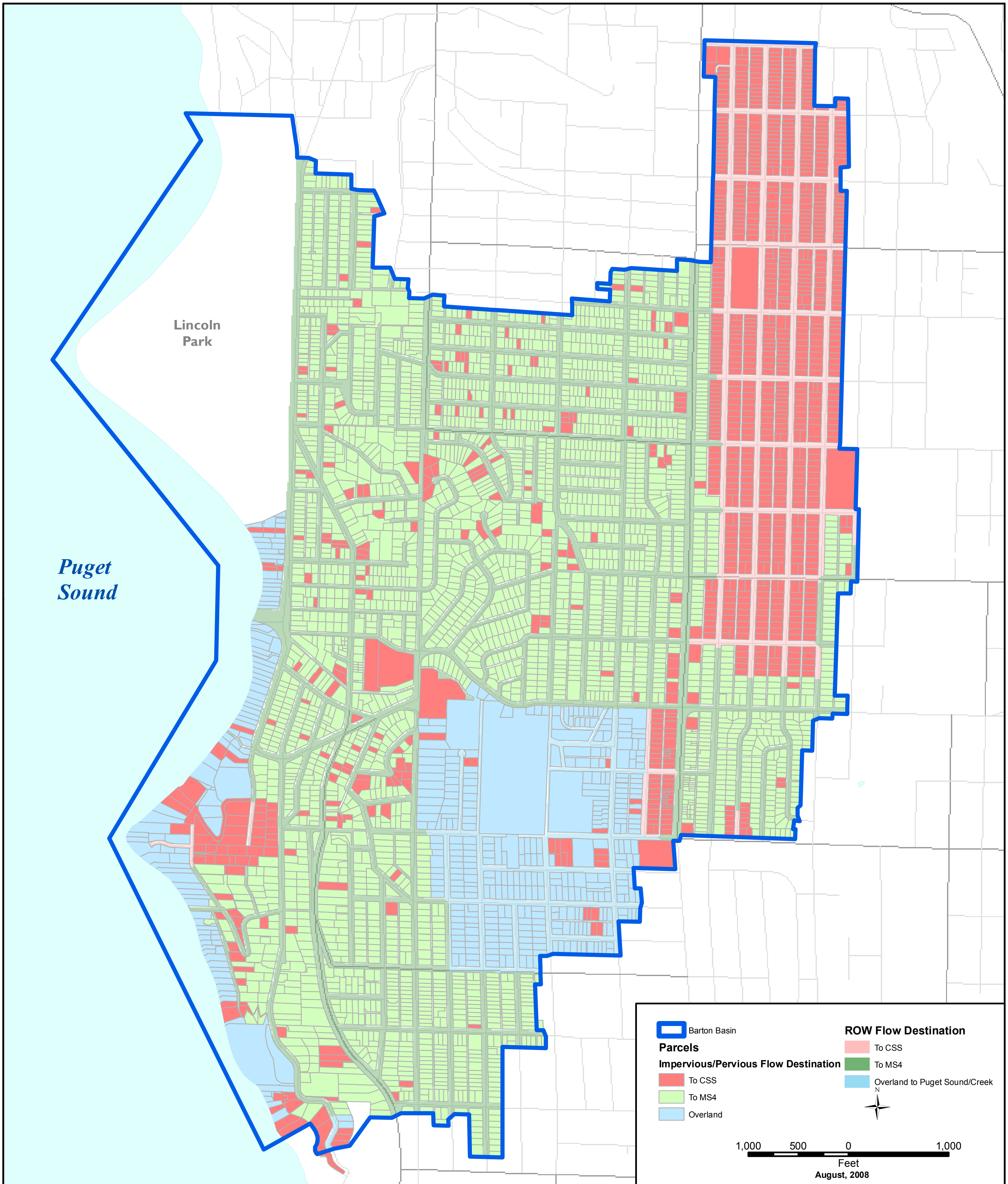
Impervious/Pervious Flow Destination by Parcel - Scenario B Barton CSO Basin



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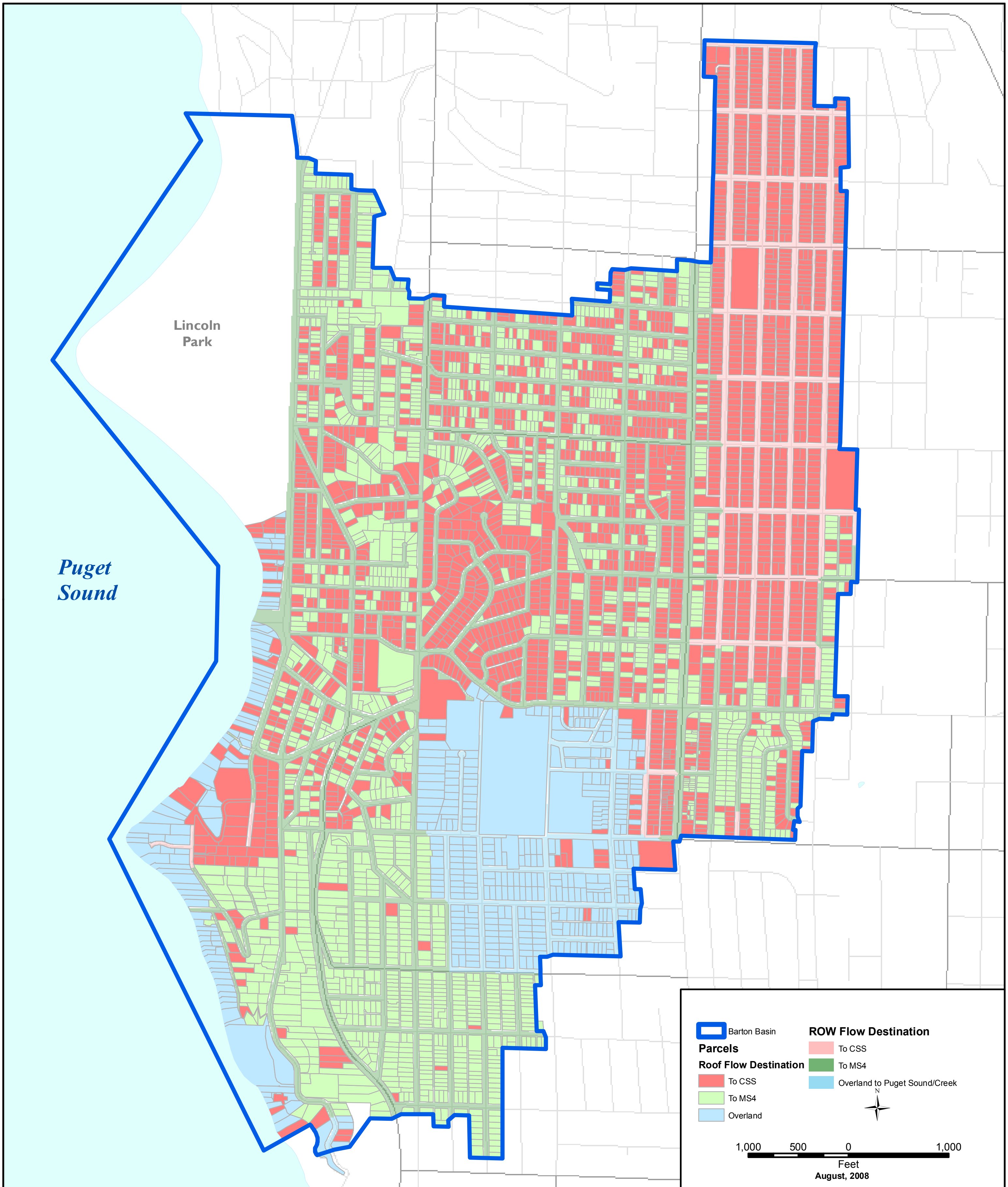
Impervious/Pervious Flow Destination by Parcel - Scenario A Barton CSO Basin



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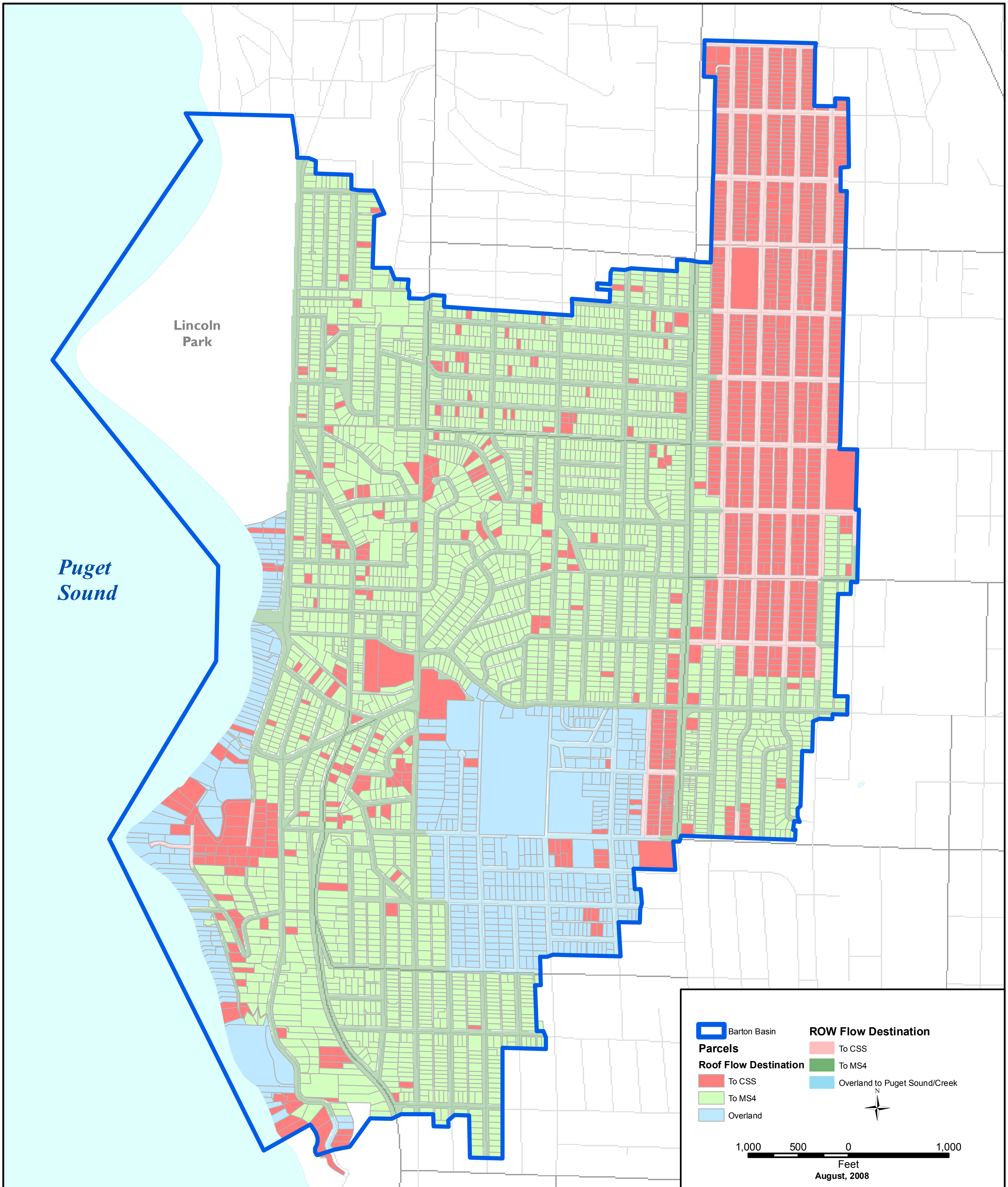
Roof Flow Destination by Parcel - Scenario B Barton CSO Basin



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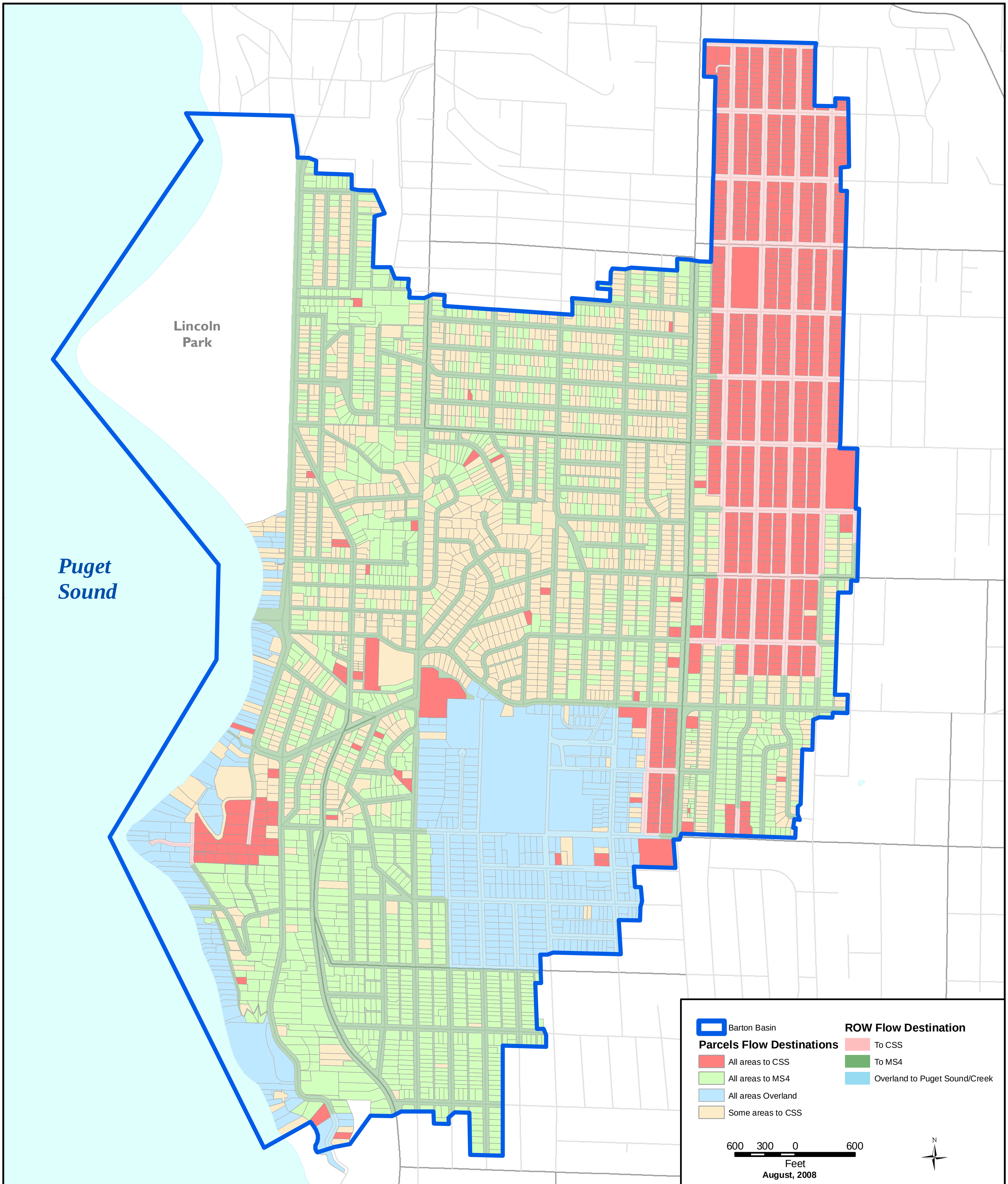
Roof Flow Destination by Parcel - Scenario A Barton CSO Basin



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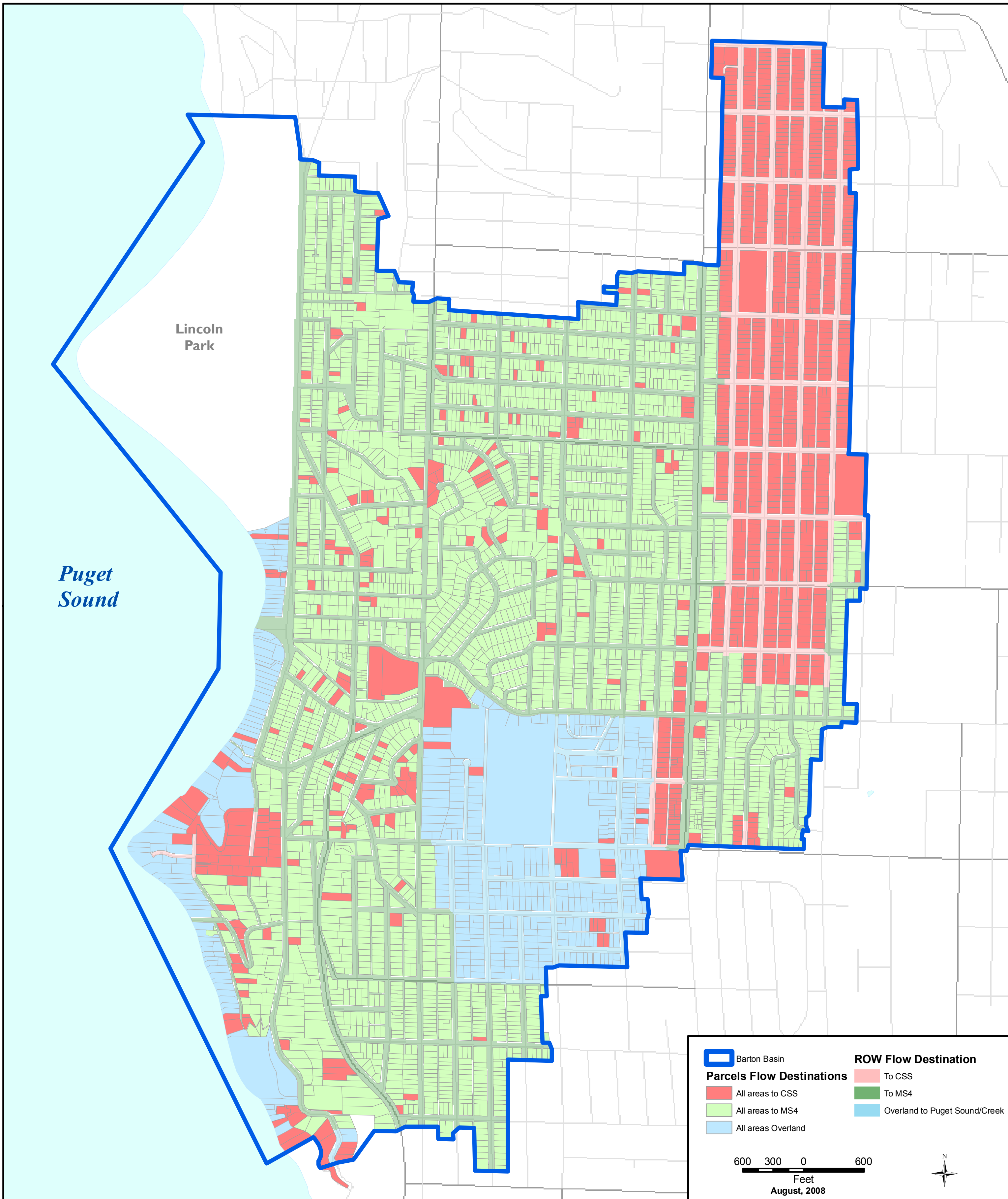
Flow Destination by Parcel Scenario B Barton CSO Basin



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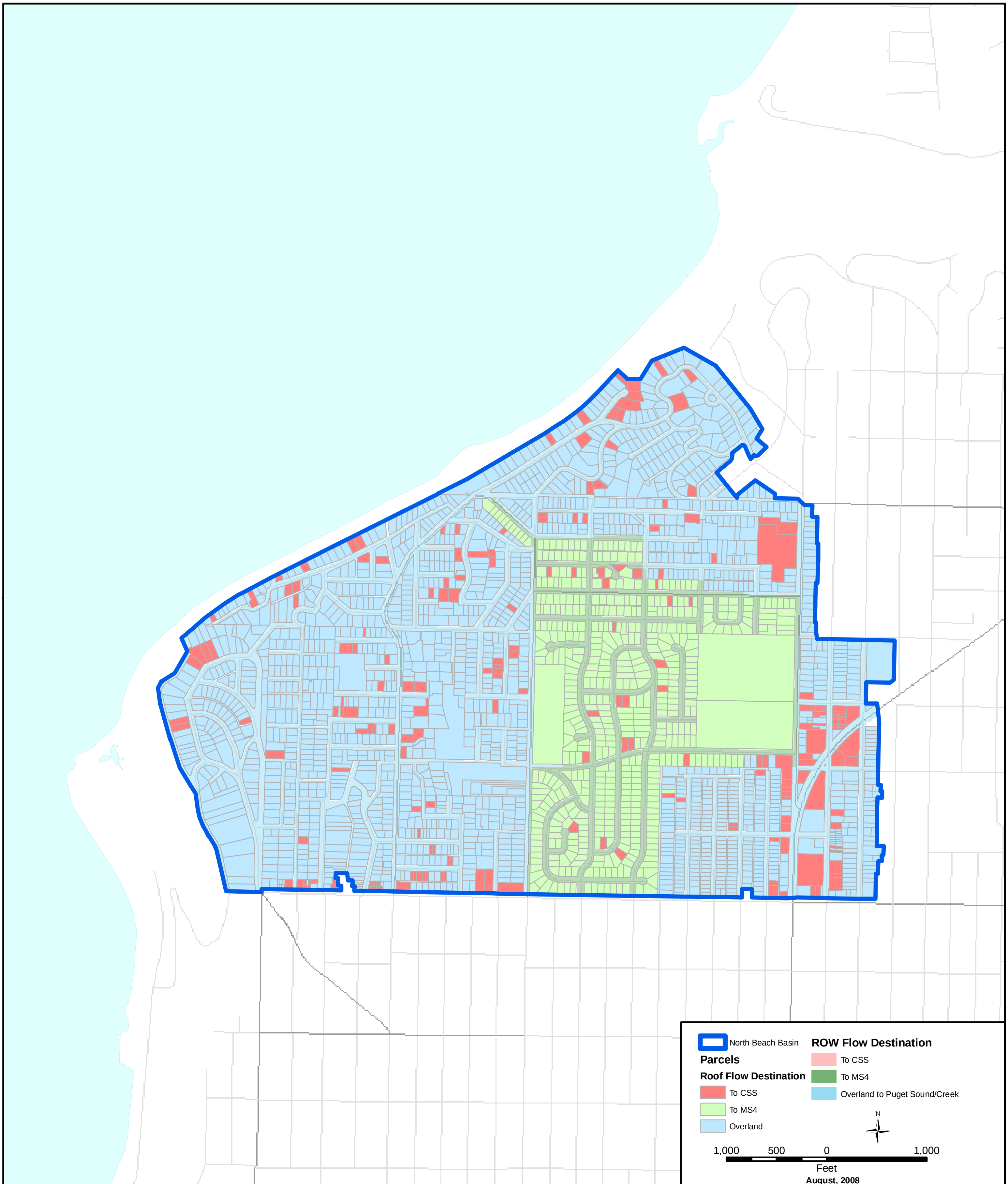
Flow Destination by Parcel Scenario A Barton CSO Basin



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File Name: //dnrp1/projects/wtd/projects/cso/proejcts/phase1/NBeach_final_5.mxd
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Impervious/ Pervious Flow Destinations by Parcel - Scenario B North Beach CSO Basin

Appendix B
Process for Developing Assumptions

Initial Assumptions

After an inventory of the available data and selection of the data most suitable for use in this analysis assumptions were developed to make use of the data. The data didn't accurately reflect reality to the degree necessary to adequately populate the model and locate control solutions requiring these assumptions. The assumptions have the greatest impact on the use of catch basin, downspout, and conveyance locations and connectivity.

The first assumption was that all GIS data was accurate and complete unless otherwise noted. Next, those areas visually connected to the MS4 were identified and assumed to be the complete collection of properties connected to the MS4 with all other flow to the MS4 coming from the ROWs. It was then assumed that all other properties uphill from a CSS pipe contributed flow to that system regardless of the presence of a lateral connecting the property to the CSS in the GIS. Properties not in the vicinity of a CSS pipe were assumed to flow overland to a receiving water body. Downspouts were assumed to be the entry point for rooftop flows and catch basins were assumed to be the entry point for the flows from the pervious and impervious areas of any property, catch basins on pervious areas for that flow and catch basin on impervious area for that flow. The presence of an infiltration pit on a property was assumed to indicate that all flow via a catch basin or downspout and not visually connected to the MS4 was captured and retained on that property. The slope and aspect of the parcels were not evaluated to determine where flow was coming from on a property. It was assumed that a catch basin would collect flow from within the parcel that contained it. Although terrain considerations define the source of flow in reality substituting the parcel that contains the catch basin for an adjacent parcel that might contribute the flow in reality was deemed reasonable given the level of the analysis.

Regarding the ROWs, all flow was assumed to flow downhill, conveyed by pavement, ditches, culverts, etc. to the first downhill inlet encountered, typically a catch basin. The area contributing flow to that inlet was assumed to be bounded uphill by the location of the next inlet point. If no inlet to the MS4 or CSS was encountered the flow from those areas of the ROW were assumed to enter the receiving water body, either the Puget Sound or a local stream.

The North Beach CSO basin was used to test the assumptions and methodology developed for all four basins. Initial comparisons of the results using these assumptions provided a relatively consistent match with previous model results conducted on the flow monitor data collected at the bottom of the basin at the North Beach pump station. The results are described in Table 1.

Table 1. Comparison of Connected Impervious in GIS Analysis to 2006 Modeling Analysis Using Initial Assumptions

	439	440	441
Total %Impervious and rooftop connected - GIS	8%	5%	15%
Total %Impervious connected - Model	5%	8%	17%

The assumptions, methodology, and initial results were presented to the project team on July 9th, 2008 to discuss and revise the assumptions and get final buyoff. The omission of the overland flow of parcel runoff into the ROW and the subsequent destination of that flow were discussed as was the assumption that any flow not entering the MS4 was entering the CSS. It was agreed to change the assumptions around the contributing parcel areas to the CSS to be dependant on the visual connection of a parcel to the CSS much like the assumptions for connection to the MS4. Also, any parcel not connected to the CSS or MS4 using these assumptions were assumed to flow overland to the ROW and be conveyed to the destination identified for that given section of ROW by the ROW assumptions above. The hydraulics of pervious and impervious flow on a parcel were also discussed and it was agreed that a catch basin on the property could be assumed to collect the flow from either area regardless of it's location on the property.

Finally, it was agreed that a range of areas contributing to the CSS and MS4 be calculated instead of a single value. The lack of confidence of the GIS data representing the existence of catch basins and downspouts on private parcels led to this adjustment. The ranges were developed based on the depiction of a property connected to the CSS alone in the GIS and then again depicted as connected to the CSS in the GIS but with the additional existence of downspouts in the case of the rooftop areas. The same assumptions were used to develop the ranges for the impervious and pervious areas but depending on the existence of catch basins or not in the GIS.

Revised Assumptions and Rational

The assumptions agreed upon were used again to calculate those areas from parcel and the ROWs contributing to the CSS and MS4. The results can be found in table 2.

Table 2. Comparison of Connected Impervious in GIS Analysis to 2006 Modeling Analysis Using July 9th Assumptions

	439		440		441	
Assumptions	A	B	A	B	A	B
Total %Impervious and rooftop connected - GIS	0.05%	0.02%	0.00%	0.00%	1.20%	0.48%
Total %Impervious connected - Model	5%	5%	8%	8%	17%	17%

As is apparent from the results, the new assumptions reduced the amount of connected impervious and rooftop areas to unrealistic levels. Upon investigation it appeared that the amount of rooftops, impervious, and pervious areas connected to the CSS under these assumptions was under-allocated. Evaluating the distribution of those areas thought to be under allocated it appeared that parcels disconnected from the CSS and connected to the MS4 during separation projects were recorded and ended up in the GIS data sets. However, parcels that remained connected to the CSS were never recorded in the GIS and were falling into the category of parcels contributing flow to the MS4 via ROW conveyance. The thinking was that changes to the system would be recorded by field staff engaging in those projects but areas not affect would not be investigated and recorded.

In addition to the realization that the above assumptions were inaccurate feedback was provided by Tetra Tech with regards to this approach in comparison to the a similar but smaller scale analysis conducted elsewhere in Seattle. Jeff Lykken confirmed that the approaches were similar and acceptable to Tetra Tech as a member of the CSO team via phone on July 25th, 2008. Similar buyoff was provided by Carollo and the King County members of the team verbally during the July 9th meeting. Lack of additional comments by these groups was assumed to further indicate acceptance of the assumptions and approach. Tetra Tech additionally communicated that field investigations indicated that catch basin depictions in the GIS were overall very accurate.

The results of the analysis with the accepted assumptions were discussed with Jeff as well as with King County members of the team and the assumptions were adjusted. The new assumptions were the same with changes only to how it was assumed that the roof top, impervious, and pervious areas were connected to the CSS. As described above, it was accepted that parcels disconnected from the CSS and reconnected to the MS4 during separation projects were depicted but parcels not affected during separation projects were not depicted as such. To determine which parcels might be connected to the CSS and which might the changes to the assumptions in Table 3 were developed.

Table 3. Changes to Assumptions

Parcel Area	Assumption Collection	New Category Assumptions
Roof Tops	A	Parcel not connected to MS4
		Parcel contains no infiltration pit
		A lateral identified as carrying storm drainage flow lies in the parcel
	B	Parcel not connected to MS4
		Parcel contains no infiltration pit
		Parcel contains a downspout
Impervious	A	Parcel not connected to MS4
		Parcel contains no infiltration pit
		A lateral identified as carrying storm drainage flow lies in the parcel
	B	Parcel not connected to MS4
		Parcel contains no infiltration pit
		Parcel contains a catch basin
Pervious	A	Same as Impervious areas, A assumption collection
	B	Same as Impervious areas, B assumption collection

These revised assumptions identified those parcels that had drainage conveyance on site without an infiltration pit and not connected to the MS4 and allocated their flow to the CSS. A visual evaluation of the GIS with these revised assumptions in mind suggested accuracy as those areas of the North Beach CSO basin with no CSS, only dedicated sewer conveyance, and a ditch and culvert ROW drainage system, as very few parcel drains identified while those areas with a CSS system had a much larger number of parcel drainage systems. Finally, the results of the analysis implementing the new revised assumptions matched much closer to the previous model results as shown in table 4.

Table 4. Comparison of Connected Impervious in GIS Analysis to 2006 Modeling Analysis Using Revised Assumptions

	439		440		441	
Assumptions	A	B	A	B	A	B
Total %Impervious and rooftop connected - GIS	8.09%	5.21%	6.05%	3.33%	12.54%	8.77%
Total %Impervious connected - Model	5%	5%	8%	8%	17%	17%

Appendix C

Results of Field Verification of GIS Data

The areas investigated for Murray were both combined. Those downspouts show in GIS but not present ran from 8%-9% of the total. An additional 112 downspouts were located within the two investigation areas 91 of which entered buried conveyance on the property. Of the 91 properties surveyed 27, or 30%, had additional connections to the CSS that were not captured within the GIS analysis.

In the Barton basin had one of the investigated areas was combined and the other had only a separated sewer system with no MS4. The combined area had similar results to the Murray basin; 7% not existing, 22 additional downspouts affecting 15% of the surveyed properties that were not captured within the assumptions. The separated system showed half of all properties, 22 of 44, that had downspouts not indicated on the GIS that entered buried conveyance. The existence of a surface drain in the street implies that flow from the properties is being conveyed in this manner overland to the receiving water body. Both of these basins, Murray and Barton, had one or two rain barrels per investigated area.

Both Magnolia areas were combined and showed 8 of 91 and 6 of 44 not existing as shown in the GIS for 9% and 14% respectively. 90 and 48 new downspouts were found in the two areas doubling the number in GIS. New properties, not included in those contributing flow to the CSS due to the GIS modeling, numbered 8 and 6, or 19% and 22% respectively. The other basin was very similar in results. Magnolia had 138 downspouts found that were not shown in the GIS which had 186. Of those 186, 14 were not found. The newly found downspouts indicated that 14 additional properties, 20% of those investigated, have the potential to contribute flow to the CSS. One of those properties did have a rain barrel on site.

North Beach was like Barton with one combined and one separated and the results were similar too. 9 out of 85 downspouts not found, 84 additional downspout were found, and 18 properties with potential influence on the CSS. The 18 properties indicated 54% more areas potentially contributing flow to the CSS. However the existence of drains emanating from the curb into the street indicates that many of these additional properties contribute flow to the ROW, as was assumed in their case in the analysis. This discovery brings the additional number of parcels potentially contributing to the CSS to 13, 39% of the total number of parcels in that area. The separated sewer area had no downspouts in GIS, 104 found, and 24 potential impacted properties. However, also like the Barton separated area, surface drainage which drains to the receiving water body, conveys storm water in this area.

Barton		
Target Block #1 - Combined	(**W**: 43rd Ave. W; **E**: Magnolia Blvd W; **N**: W Bertona; **S**: W Dravus St.)	
Downspouts in GIS		110
Downspouts in GIS not present in field		8
New Downspouts		45

Properties in addition to those identified in analysis that have potential to contribute flow to CSS		7
Target Block #2 - Separated	(**W:** 35th Ave W; **E:** 36th Ave W; **N:** W Smith St; **S:** W McGraw St.)	
Downspouts in GIS		20
Downspouts in GIS not present in field		3
New Downspouts		72
Properties in addition to those identified in analysis that have potential to contribute flow to CSS		22
Magnolia		
Target Block #1 - Combined	(**W**: 43rd Ave. W; **E**: Magnolia Blvd W; **N**: W Bertona; **S**: W Dravus St.)	
Downspouts in GIS		135
Downspouts in GIS not present in field		8
New Downspouts		90
Properties in addition to those identified in analysis that have potential to contribute flow to CSS		8
Target Block #2 - Combined	(**W:** 35th Ave W; **E:** 36th Ave W; **N:** W Smith St; **S:** W McGraw St.)	
Downspouts in GIS		51
Downspouts in GIS not present in field		6
New Downspouts		48
Properties in addition to those identified in analysis that have potential to contribute flow to CSS		6
Murray		
Target Block #1 - Combined	(**W**: 42nd Ave SW, **E**: 41st Ave SW, **N**: SW Brandon ST, **S**: SW Juneau ST)	
Downspouts in GIS		90
Downspouts in GIS not present in field		8
New Downspouts		72
Properties in addition to those identified in analysis that have potential to contribute flow to CSS		15
Target Block #2 - Combined	**(W:** 41St Ave SW, **E:** 39th Ave SW, **N:** SW Ida St, **S:** SW Portland St.	
Downspouts in GIS		63
Downspouts in GIS not present in field		5
New Downspouts		85
Properties in addition to those identified in analysis that have potential to contribute flow to CSS		12
North Beach		
Target Block #1 - Combined	1st section: (**W**: 21st Ave W; **E**: 22nd Ave W; **N**: NW 94th St; **S**: NW 90th St.) ; 2nd section: (**W**: 23rd Ave NW; **E**: 22nd Ave NW; **N**:NW 93rd St; **S**: NW 90th St)	
Downspouts in GIS		85
Downspouts in GIS not present in field		9
New Downspouts		84
Properties in addition to those identified in analysis that have potential to contribute flow to CSS		13
Target Block #2 - Separated	(**W**: 31st Ave NW; **E**: Whitney Pl NW/32nd Ave NW; **N**: NW 9th St; **S**: NW 92nd St.)	
Downspouts in GIS		0
Downspouts in GIS not present in field		0
New Downspouts		104
Properties in addition to those identified in analysis that have potential to contribute flow to CSS		24

SW ELMGROVE ST
SW SOUTHERN ST
SW ROSE ST
CALIFORNIA AVE SW
41ST AVE SW
N
70 35 0 70
Feet
SW 98TH ST
SW 100TH ST
SW 102ND ST
42ND AVE SW
41ST AVE SW
N
130 65 0 130 Feet
Downspouts from GIS
Does not Exist
Not Visible
Verified, To Pipe
Verified, To Surface
Verified, Drainage Unknown
Verified, To Rainbarrel
Found Downspouts (Not in GIS)
To Pipe
To Surface
Drainage Unknown
To Rainbarrel
Catch Basins (All verified)
Parcels - Impervious
Parcels - Pervious
CSS
MS4
Separated Sewer
Curb
Ditch/Culvert
Surface Drain
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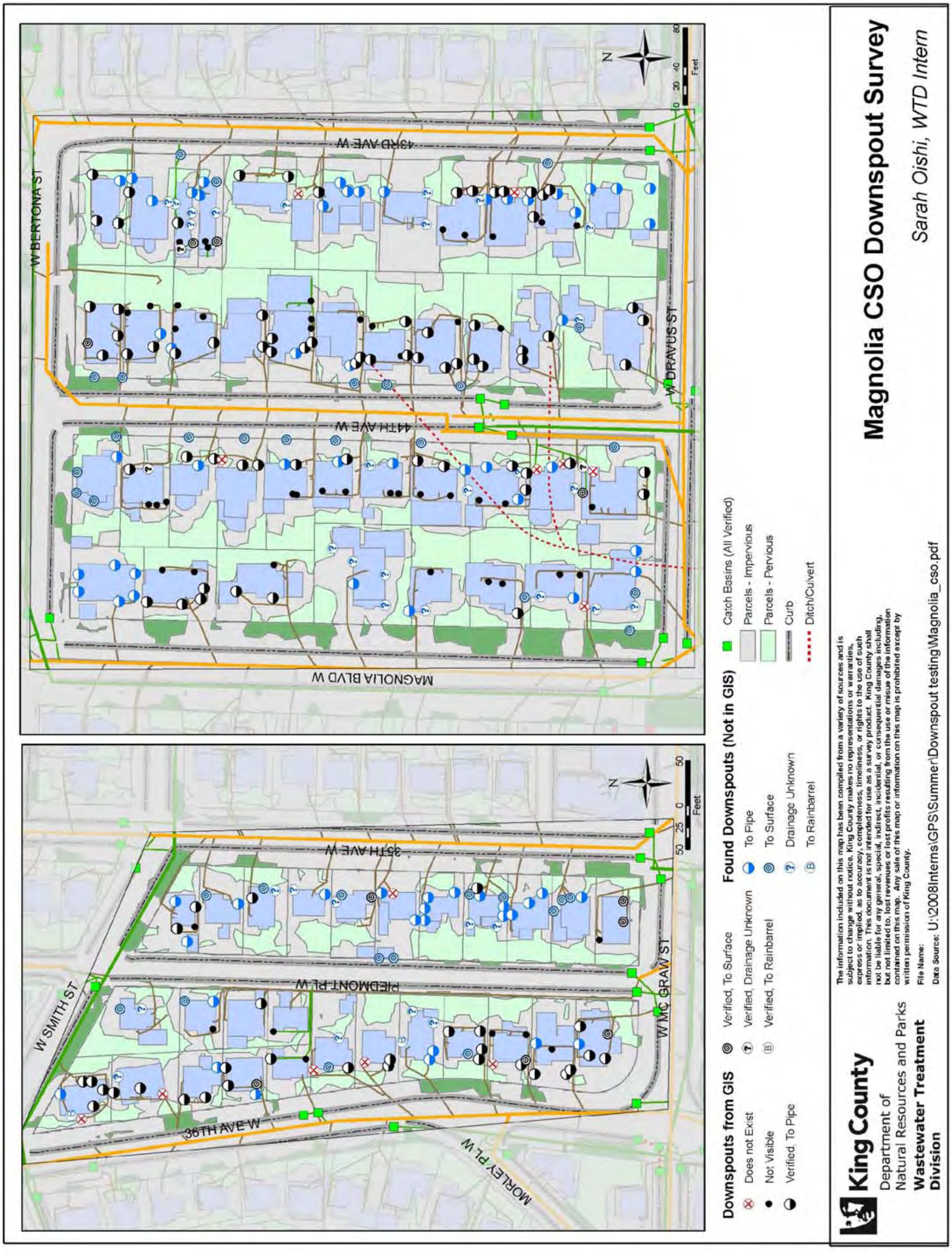
Data Source: U:\2008Interns\GPS\Summer\Downspout testing\Barton_CSO.pdf
Barton CSO Downspout Survey
Bryan Yoon, WTD Intern



Magnolia CSO Downspout Survey
Sarah Oishi, WTD Intern
W SMITH ST
36TH AVE W
MORLEY PL W
PIEDMONT PL W
35TH AVE W
W MC GRAW ST
W BERTONA ST
43RD AVE W
44TH AVE W
W DRAVUS ST
MAGNOLIA BLVD W
N
50 25 0 50 Feet
0 20 40 80 Feet
Downspouts from GIS
Does not Exist
Not Visible
Verified, To Pipe
Verified, To Surface
Verified, Drainage Unknown
Verified, To Rainbarrel
Found Downspouts (Not in GIS)
To Pipe
To Surface
Drainage Unknown
To Rainbarrel
Catch Basins (All Verified)
Parcels - Impervious
Parcels - Pervious
Curb
Ditch/Culvert
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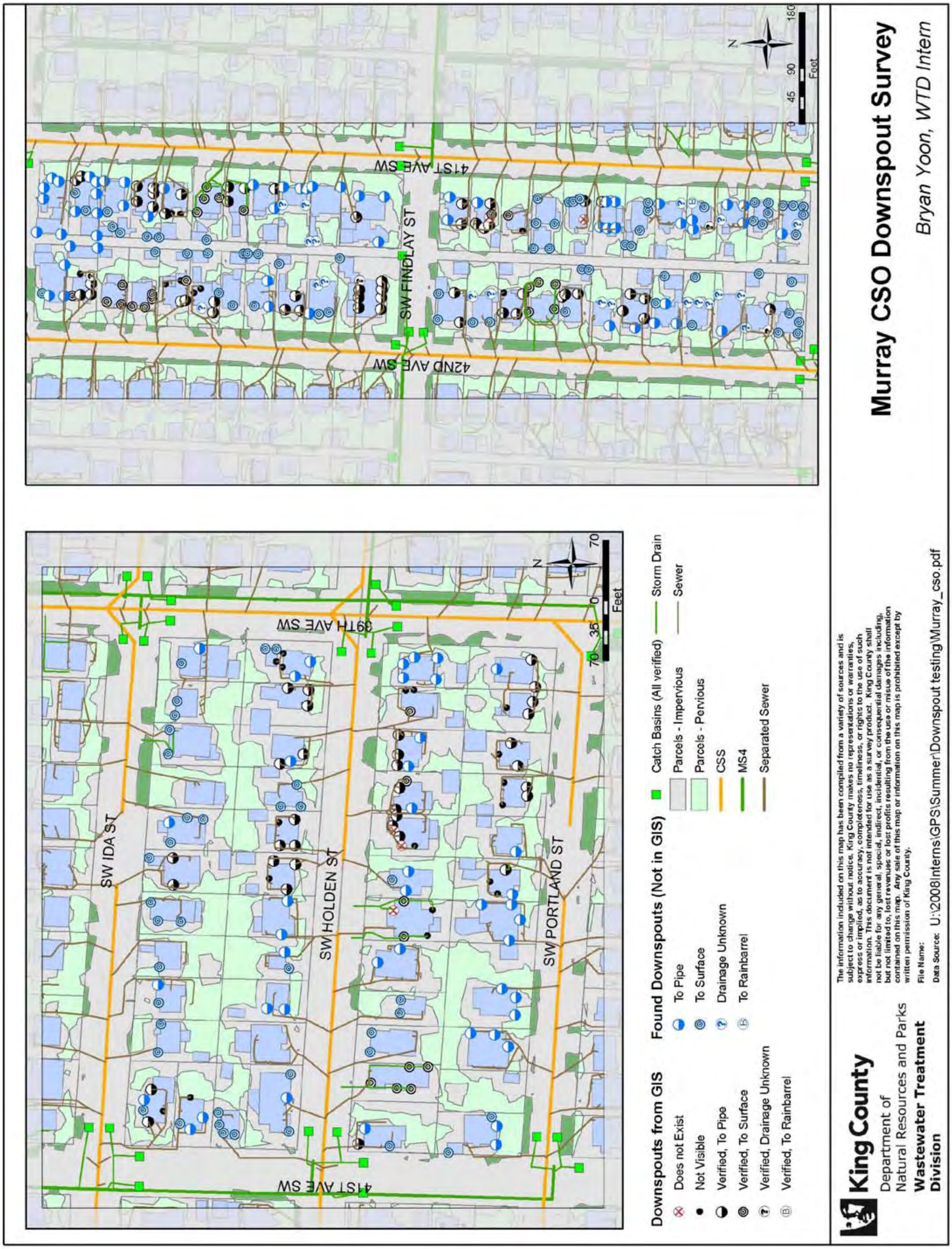
File Name:
Data Source: U:\2008Interns\GPS\Summer\Downspout testing\Magnolia_cso.pdf


Murray CSO Downspout Survey
Bryan Yoon, WTD Intern
SW IDA ST
SW HOLDEN ST
SW PORTLAND ST
39TH AVE SW
41ST AVE SW
SW FINDLAY ST
42ND AVE SW
Downspouts from GIS
Does not Exist
Not Visible
Verified, To Pipe
Verified, To Surface
Verified, Drainage Unknown
Verified, To Rainbarrel
Found Downspouts (Not in GIS)
To Pipe
To Surface
Drainage Unknown
To Rainbarrel
Catch Basins (All verified)
Parcels - Impervious
Parcels - Pervious
CSS
MS4
Separated Sewer
Storm Drain
Sewer
Feet
King County
Department of
Natural Resources and Parks
Wastewater Treatment
Division
File Name:
Data Source: U:\2008interns\GPS\Summer\Downspout testing\Murray_cso.pdf


NW 93RD ST
NW 91ST ST
23RD AVE NW
22ND AVE NW
NW 90TH ST
N
Target Block #1
NW 94TH ST
22ND AVE NW
NW 93RD ST
21ST AVE NW
N
Feet
NW 95TH ST
WHITNEY PL NW
32ND AVE NW
NW 94TH ST
NW 93RD ST
NW 92ND ST
31ST AVE NW
N
Target Block #2
Downspouts from GIS
Does not Exist
Not Visible
Verified, To Pipe
Verified, To Surface
Verified, Drainage Unknown
Verified, To Rainbarrel
Found Downspouts (Not in GIS)
To Pipe
To Surface
Drainage Unknown
Catch Basins (All verified)
CSS
MS4
Separated Sewer
Curb
Surface Drain
Tiled Drain
Percels - Impervious
Parcels - Pervious
King County
Department of
Natural Resources and Parks
Wastewater Treatment Division
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File Name:
Data Source: U:\2008Interns\GPS\Summer\Downspout testing\NorthBeach_CSO.pdf
North Beach CSO Downspout Survey
Ashley Blazina, WTD Intern

Appendix D
Results of Analysis

Table D1. Total Acreage for Each Source by Basin

	Barton		Murray		North Beach		South Magnolia	
Assumptions	A	B	A	B	A	B	A	B
ROW	287	287	281	281	152	152	243	243
Impervious	224	224	232	232	119	119	195	195
Pervious	64	64	48	48	32	32	48	48
Parcels	824	824	790	790	481	481	530	527
Roof	185	185	184	184	128	128	144	144
Impervious	234	234	238	238	160	160	175	175
Pervious	405	405	368	368	193	193	210	210
Total	**1112**	**1112**	**1071**	**1071**	**633**	**633**	**771**	**771**

Table D2. Barton - Total Acreage for Each Source by Subbasin

	414	415	416	417	418
ROW	67	8	98	46	69
Impervious	50	6	80	34	53
Pervious	17	2	18	12	16
Parcels	167	107	217	154	180
Roof	39	12	60	29	45
Impervious	46	20	77	37	54
Pervious	82	74	80	88	81
Total	**234**	**115**	**314**	**200**	**249**

Table D3. Magnolia - Total Acreage for Each Source by Subbasin

	151	152	153	154
ROW	46	128	35	33
Impervious	33	102	31	29
Pervious	12	26	4	5
Parcels	128	253	77	72
Roof	30	68	24	22
Impervious	31	92	27	25
Pervious	67	93	26	25
Total	**174**	**382**	**112**	**106**

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Table D4. Murray - Total Acreage for Each Source by Subbasin

	419	420	421	423
ROW	96	99	85	0
Impervious	79	84	69	0
Pervious	17	15	16	0
Parcels	236	297	213	44
Roof	58	67	55	3
Impervious	73	90	71	4
Pervious	105	140	87	37
Total	**332**	**397**	**298**	**44**

Table D5. North Beach - Total Acreage for Each Source by Subbasin

	439	440	441
ROW	70	62	20
Impervious	60	43	16
Pervious	10	19	4
Parcels	214	190	77
Roof	66	43	19
Impervious	82	54	24
Pervious	66	93	34
Total	**284**	**252**	**97**

Table D6. Barton 414 - Total Acreage and Percentage for Each Destination by Source and Assumption

		A Assumptions		B Assumptions		A Assumptions		B Assumptions	
		CSS	MS4	CSS	MS4	CSS	MS4	CSS	MS4
ROW	Impervious	0.4	50.1	0.4	50.1	1%	99%	1%	99%
	Pervious	0.1	16.6	0.1	16.6	0%	100%	0%	100%
Parcels	Roof	3.6	35.6	7.2	32.1	9%	91%	18%	82%
	Impervious	4.6	41.0	1.8	43.8	10%	90%	4%	96%
	Pervious	9.1	72.8	4.3	77.6	11%	89%	5%	95%
Total		**17.8**	**216.1**	**13.8**	**220.2**	**8%**	**92%**	**6%**	**94%**
		233.9		**233.9**					

Table D7. Barton 415 - Total Acreage and Percentage for Each Destination by Source and Assumption

		A Assumptions		B Assumptions		A Assumptions		B Assumptions	
		CSS	MS4	CSS	MS4	CSS	MS4	CSS	MS4
ROW	Impervious	0.7	5.6	0.7	5.6	11%	89%	11%	89%
	Pervious	0.1	1.5	0.1	1.5	3%	97%	3%	97%
Parcels	Roof	2.5	10.0	2.2	10.2	20%	80%	18%	82%
	Impervious	4.7	15.4	1.5	18.6	24%	76%	7%	93%
	Pervious	14.0	60.4	2.4	71.9	19%	81%	3%	97%
Total		**21.9**	**92.8**	**6.9**	**107.9**	**19%**	**81%**	**6%**	**94%**
		114.8		**114.8**					

Table D8. Barton 416 - Total Acreage and Percentage for Each Destination by Source and Assumption

		A Assumptions		B Assumptions		A Assumptions		B Assumptions	
		CSS	MS4	CSS	MS4	CSS	MS4	CSS	MS4
ROW	Impervious	46.3	33.6	46.3	33.6	58%	42%	58%	42%
	Pervious	10.9	6.8	10.9	6.8	62%	38%	62%	38%
Parcels	Roof	37.8	21.8	48.6	11.0	63%	37%	82%	18%
	Impervious	49.5	28.0	48.8	28.6	64%	36%	63%	37%
	Pervious	49.0	30.6	48.2	31.4	62%	38%	61%	39%
Total		**193.5**	**120.7**	**202.8**	**111.4**	**62%**	**38%**	**65%**	**35%**
		314.2		**314.2**					

Table D9. Barton 417 - Total Acreage and Percentage for Each Destination by Source and Assumption

		A Assumptions		B Assumptions		A Assumptions		B Assumptions	
		CSS	MS4	CSS	MS4	CSS	MS4	CSS	MS4
ROW	Impervious	1.9	31.6	1.9	31.6	6%	94%	6%	94%
	Pervious	0.3	11.8	0.3	11.8	3%	97%	3%	97%
Parcels	Roof	2.9	25.6	18.0	10.5	10%	90%	63%	37%
	Impervious	4.9	32.4	4.4	32.9	13%	87%	12%	88%
	Pervious	7.5	80.8	4.8	83.6	9%	91%	5%	95%
Total		**17.6**	**182.2**	**29.4**	**170.4**	**9%**	**91%**	**15%**	**85%**
		199.8		**199.8**					

Table D10. Barton 418 - Total Acreage and Percentage for Each Destination by Source and Assumption

		A Assumptions		B Assumptions		A Assumptions		B Assumptions	
		CSS	MS4	CSS	MS4	CSS	MS4	CSS	MS4
ROW	Impervious	0.0	53.4	0.0	53.4	0%	100%	0%	100%
	Pervious	0.0	15.8	0.0	15.8	0%	100%	0%	100%
Parcels	Roof	5.6	39.4	28.2	16.8	13%	87%	63%	37%
	Impervious	6.8	47.1	3.3	50.6	13%	87%	6%	94%
	Pervious	7.1	73.6	2.4	78.3	9%	91%	3%	97%
Total		**19.6**	**229.3**	**34.0**	**214.9**	**8%**	**92%**	**14%**	**86%**
		248.9		**248.9**					

Table D11. Magnolia 152- Total Acreage and Percentage for Each Destination by Source and Assumption

Magnolia 152		A Assumptions		B Assumptions		A Assumptions		B Assumptions	
		CSS	MS4	CSS	MS4	CSS	MS4	CSS	MS4
ROW	Impervious	0.0	101.9	0.0	101.9	0%	100%	0%	100%
	Pervious	0.0	26.3	0.0	26.3	0%	100%	0%	100%
Parcels	Roof	4.5	63.4	48.6	19.3	7%	93%	72%	28%
	Impervious	12.7	79.5	8.7	83.6	14%	86%	9%	91%
	Pervious	14.4	78.8	11.4	81.8	15%	85%	12%	88%
Total		**31.7**	**349.9**	**68.7**	**312.9**	**8%**	**92%**	**18%**	**82%**
		381.6		**381.6**					

Table D12. Magnolia 153 - Total Acreage and Percentage for Each Destination by Source and Assumption

Magnolia 153		A Assumptions		B Assumptions		A Assumptions		B Assumptions	
		CSS	MS4	CSS	MS4	CSS	MS4	CSS	MS4
ROW	Impervious	0.0	31.1	0.0	31.1	0%	100%	0%	100%
	Pervious	0.0	4.3	0.0	4.3	0%	100%	0%	100%
Parcels	Roof	1.1	22.9	18.2	5.8	5%	95%	76%	24%
	Impervious	1.2	25.5	0.4	26.3	5%	95%	2%	98%
	Pervious	0.8	25.0	0.3	25.5	3%	97%	1%	99%
Total		**3.2**	**108.9**	**19.0**	**93.1**	**3%**	**97%**	**17%**	**83%**
		112.1		**112.1**					

Table D13. Magnolia 154 - Total Acreage and Percentage for Each Destination by Source and Assumption

Magnolia 154		A Assumptions		B Assumptions		A Assumptions		B Assumptions	
		CSS	MS4	CSS	MS4	CSS	MS4	CSS	MS4
ROW	Impervious	0.0	28.6	0.0	28.6	0%	100%	0%	100%
	Pervious	0.0	4.7	0.0	4.7	0%	100%	0%	100%
Parcels	Roof	1.4	20.6	15.1	6.9	6%	94%	69%	31%
	Impervious	1.4	23.7	0.6	23.1	6%	94%	2%	92%
	Pervious	1.0	24.1	0.3	23.4	4%	96%	1%	93%
Total		**3.8**	**101.8**	**15.9**	**86.8**	**4%**	**96%**	**16%**	**82%**
		105.6		**102.7**					

Table D14. Murray 419 - Total Acreage and Percentage for Each Destination by Source and Assumption

		A Assumptions		B Assumptions		A Assumptions		B Assumptions	
		CSS	MS4	CSS	MS4	CSS	MS4	CSS	MS4
ROW	Impervious	13.0	66.0	13.0	66.0	16%	84%	16%	84%
	Pervious	3.2	14.1	3.2	14.1	19%	81%	19%	81%
Parcels	Roof	12.2	46.2	29.4	28.9	21%	79%	51%	49%
	Impervious	17.0	55.8	14.4	58.5	23%	77%	20%	80%
	Pervious	22.7	82.1	19.6	85.3	22%	78%	19%	81%
Total		**68.1**	**264.2**	**79.6**	**252.8**	**20%**	**80%**	**24%**	**76%**
		332.3		**332.4**					

Table D15. Murray 420 - Total Acreage and Percentage for Each Destination by Source and Assumption

		A Assumptions		B Assumptions		A Assumptions		B Assumptions	
		CSS	MS4	CSS	MS4	CSS	MS4	CSS	MS4
ROW	Impervious	0.2	84.0	0.2	84.0	0%	100%	0%	100%
	Pervious	0.0	15.1	0.0	15.1	0%	100%	0%	100%
Parcels	Roof	5.2	62.3	7.9	59.5	8%	92%	12%	88%
	Impervious	6.7	83.3	3.8	86.1	7%	93%	4%	96%
	Pervious	7.6	132.4	3.6	136.3	5%	95%	3%	97%
Total		**19.7**	**377.1**	**15.7**	**381.1**	**5%**	**95%**	**4%**	**96%**
		396.8		**396.8**					

Table D16. Murray 421 - Total Acreage and Percentage for Each Destination by Source and Assumption

		A Assumptions		B Assumptions		A Assumptions		B Assumptions	
		CSS	MS4	CSS	MS4	CSS	MS4	CSS	MS4
ROW	Impervious	0.7	68.5	0.7	68.5	1%	99%	1%	99%
	Pervious	0.1	15.7	0.1	15.7	1%	99%	1%	99%
Parcels	Roof	6.7	48.6	23.4	31.9	12%	88%	42%	58%
	Impervious	8.8	62.1	6.9	64.0	12%	88%	10%	90%
	Pervious	8.6	77.9	3.7	82.8	10%	90%	4%	96%
Total		**25.0**	**272.8**	**35.0**	**262.8**	**8%**	**92%**	**12%**	**88%**
		297.8		**297.8**					

Table D17. Murray 423 - Total Acreage and Percentage for Each Destination by Source and Assumption

		A Assumptions		B Assumptions		A Assumptions		B Assumptions	
		CSS	MS4	CSS	MS4	CSS	MS4	CSS	MS4
ROW	Impervious	0.0	0.0	0.0	0.0	0%	0%	0%	0%
	Pervious	0.0	0.0	0.0	0.0	0%	0%	0%	0%
Parcels	Roof	0.9	2.1	0.6	2.5	30%	70%	19%	81%
	Impervious	1.2	2.8	0.7	3.4	30%	70%	16%	84%
	Pervious	10.3	26.5	4.3	32.5	28%	72%	12%	88%
Total		**12.4**	**31.5**	**5.6**	**38.4**	**28%**	**72%**	**13%**	**87%**
		43.9		**43.9**					

Table D18. North Beach 439 - Total Acreage and Percentage for Each Destination by Source and Assumption

		A Assumptions		B Assumptions		A Assumptions		B Assumptions	
		CSS	MS4	CSS	MS4	CSS	MS4	CSS	MS4
ROW	Impervious	0.0	60.0	0.0	60.0	0%	100%	0%	100%
	Pervious	0.0	9.7	0.0	9.7	0%	100%	0%	100%
Parcels	Roof	6.9	59.1	5.2	60.8	10%	90%	8%	92%
	Impervious	9.9	71.9	5.6	76.1	12%	88%	7%	93%
	Pervious	2.2	64.2	0.8	65.6	3%	97%	1%	99%
Total		**19.0**	**264.7**	**11.6**	**272.1**	**7%**	**93%**	**4%**	**96%**
		283.7		**283.7**					

Table D19. North Beach 440 - Total Acreage and Percentage for Each Destination by Source and Assumption

		A Assumptions		B Assumptions		A Assumptions		B Assumptions	
		CSS	MS4	CSS	MS4	CSS	MS4	CSS	MS4
ROW	Impervious	0.0	43.3	0.0	43.3	0%	100%	0%	100%
	Pervious	0.0	18.6	0.0	18.6	0%	100%	0%	100%
Parcels	Roof	3.7	39.6	3.1	40.1	9%	91%	7%	93%
	Impervious	4.8	49.3	1.5	52.6	9%	91%	3%	97%
	Pervious	5.6	87.0	1.4	91.2	6%	94%	1%	99%
Total		**14.1**	**237.7**	**6.1**	**245.7**	**6%**	**94%**	**2%**	**98%**
		251.8		**251.8**					

Table D20. North Beach 441 - Total Acreage and Percentage for Each Destination by Source and Assumption

		A Assumptions		B Assumptions		A Assumptions		B Assumptions	
		CSS	**MS4**	**CSS**	**MS4**	**CSS**	**MS4**	**CSS**	**MS4**
ROW	Impervious	0.0	16.2	0.0	16.2	0%	100%	0%	100%
	Pervious	0.0	3.9	0.0	3.9	0%	100%	0%	100%
Parcels	Roof	2.5	16.3	1.5	17.3	13%	87%	8%	92%
	Impervious	4.9	19.2	3.7	20.5	20%	80%	15%	85%
	Pervious	3.1	31.1	1.4	32.9	9%	91%	4%	96%
Total		**10.5**	**86.8**	**6.6**	**90.8**	**11%**	**89%**	**7%**	**93%**
		97.4		**97.4**					